Decomposition Dynamics of Leaf Litter from Three Plant Species in Arid Habitats (Postprint)

Authors: Yang Jingjing, Zhou Zhengli, Lyu Ruiheng, Liang Jiye, Wang Xiong, Lü Ruiheng

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Abstract

This study, using the litterbag method, investigated the decomposition dynamics of leaf litter from Populus euphratica, Tamarix ramosissima, and Glycyrrhiza inflata in the Tarim Basin to reveal the decomposition dynamic characteristics of leaf litter from the three plant species in arid habitats. The results showed: After 810 days of decomposition, the mass remaining rates of Populus euphratica and Glycyrrhiza inflata leaf litter were 48.93% and 38.07%, respectively; after 630 days of decomposition, the mass remaining rate of Tamarix ramosissima leaf litter was 69.55%. Decomposition time had extremely significant effects on the residual rates of leaf litter from Populus euphratica, Glycyrrhiza inflata, and Tamarix ramosissima, while treatment (gap, under-canopy) had significant and extremely significant effects on the residual rates of leaf litter from Populus euphratica and Glycyrrhiza inflata. Treatment had significant effects on the decomposition coefficients of leaf litter from the three plant species ($P<0.05$), and the decomposition coefficient (k) exhibited the pattern: k_gap > k_under-canopy, k_Glycyrrhiza inflata > k_Populus euphratica > k_Tamarix ramosissima. After 810 days of decomposition, the t0.95 values for Populus euphratica and Glycyrrhiza inflata leaf litter were 9.15–9.48 a and 6.75–7.03 a, respectively; after 630 days of decomposition, the t0.95 value for Tamarix ramosissima leaf litter was 13.82–15.05 a. Influenced by plant species, decomposition time and treatment had different effects on the release processes of C, N, and P elements. The C element in all three plant species exhibited a release–accumulation–release pattern. The N element in leaf litter from Tamarix ramosissima and Glycyrrhiza inflata showed a release–accumulation process during the observation period, while that under Populus euphratica canopy showed an accumulation–release–accumulation pattern. The P element release process exhibited similar variation patterns to the N element during the observation period. The leaf litter decomposition coefficient k was extremely significantly correlated with decomposition time, residual mass, total nitrogen, total phosphorus, lignin, and lignin/N ratio (P<0.01). Soil moisture, total carbon, and C/N ratio all showed extremely significant differences with k_gap and k_under-canopy. Variations in microhabitats (under-canopy, gap) in arid regions had significant effects on leaf litter decomposition, with litter quality and soil moisture playing dominant roles in litter decomposition.

Full Text

Dynamic Decomposition of Foliar Litters of Three Plant Species in Arid Habitats

YANG Jing-jing[1,2], ZHOU Zheng-li[2,3], LYU Rui-heng[2,3], LIANG Ji-ye[2,3], WANG Xiong[1,2]

[1]College of Life Sciences, Tarim University, Aral 843300, Xinjiang, China
[2]Key Laboratory of Protection and Utilization of Biological Resources in Tarim Basin, Xinjiang Corps of Production & Construction, Aral 843300, Xinjiang, China
[3]College of Plant Science and Technology, Tarim University, Aral 843300, Xinjiang, China

Abstract

This study examined Populus euphratica, Tamarix ramosissima, and Glycyrrhiza inflata in the Tarim Basin to analyze the dynamic decomposition of foliar litters in arid habitats. The results demonstrated: (1) After 810 days of decomposition, the residual rates of foliar litters were 48.93% for P. euphratica and 38.07% for G. inflata, while T. ramosissima showed a residual rate of 69.55% after 630 days. Decomposition time significantly affected the residual rates across all three species, and experimental treatments significantly influenced the residual rates of P. euphratica and G. inflata. (2) The decomposition constant k values were significantly affected by understory-forest gap treatments ($P < 0.05$), following the order: k_forest_gap > k_understory, and k_G.inflata > k_P.euphratica > k_T.ramosissima. The t . values (time required for 95% mass loss) for P. euphratica and G. inflata ranged from 9.15–9.48 years and 6.75–7.03 years, respectively, during the 810-day decomposition period. After 630 days, the t . value for T. ramosissima ranged from 13.82–15.05 years. (3) The effects of decomposition time and treatments on C, N, and P release processes varied among species. A release-accumulation-release pattern was observed for C content across all species. N content in T. ramosissima and G. inflata followed a release-accumulation pattern, while P content in P. euphratica understory exhibited an accumulation-release-accumulation pattern during the observation period. (4) The k value showed significant correlations with decomposition time, total nitrogen, remaining mass, total phosphorus, lignin content, and the lignin/N ratio ($P < 0.01$). Soil moisture, total carbon, and C/N ratio were significantly correlated with both k_forest_gap and k_understory. Microhabitat changes (understory vs. forest gap) in arid regions

significantly influence litter decomposition, with litter quality and soil moisture playing dominant roles in the decomposition process.

Keywords: litter; decomposition; forest gap; understory; arid habitats; Shay County; Xinjiang

Introduction

Litter decomposition represents a critical component of ecosystem nutrient cycling in arid regions, where water availability and temperature fluctuations create unique constraints on biological processes. Previous studies have documented decomposition patterns in various ecosystems 〔1–3〕, yet the specific dynamics in hyper-arid desert habitats remain understudied. The Tarim Basin, characterized by extreme aridity and distinctive riparian forest communities, provides an ideal system for investigating how microhabitat variations between forest gaps and understory environments modulate decomposition rates. Three dominant species—Populus euphratica, Tamarix ramosissima, and Glycyrrhiza inflata—serve as key ecological engineers in this region, making their litter decomposition dynamics particularly relevant for understanding carbon and nutrient cycling.

Materials and Methods

Study Area and Experimental Design The experiment was conducted in Shay County, Xinjiang, within the Tarim Basin. The study area features typical desert riparian forest ecosystems with P. euphratica as the dominant canopy species, interspersed with T. ramosissima shrubs and G. inflata understory vegetation. Basic site characteristics are summarized in .

Three plant species were selected for litter collection: P. euphratica (a deciduous tree), T. ramosissima (a shrub), and G. inflata (a perennial herb). Freshly senesced leaf litter was collected in November 2014 from both understory and forest gap microhabitats. Litter samples were air-dried and processed using 12 cm × 12 cm decomposition bags with 0.01 g precision. Soil samples were collected from 0–10 cm depth intervals to characterize microhabitat conditions, including moisture content, total carbon, and nutrient concentrations.

Decomposition Experiment Litter bags were placed in the field in a randomized block design with three replicates per treatment combination. Sampling occurred at regular intervals over 810 days for P. euphratica and G. inflata, and 630 days for T. ramosissima. At each collection, remaining litter mass was measured after oven-drying at 80°C to constant weight. Subsamples were analyzed for total carbon (C), nitrogen (N), phosphorus (P), lignin, and cellulose content following standard protocols 〔14〕.

Data Analysis The decomposition constant k was calculated using the Olson exponential decay model:

$$\frac{M_t}{M_0} = e^{-kt}$$

where M_0 is the initial litter mass, M_t is the remaining mass at time t, and k is the decomposition rate constant. The time required for 95% mass loss ($t_{0.95}$) was calculated as $t_{0.95} = \frac{\ln(20)}{k}$. Statistical analyses included ANOVA to assess treatment effects and correlation analysis to examine relationships between k values and environmental variables.

Results and Discussion

Mass Loss Patterns Decomposition rates varied significantly among species and microhabitats. The rapid decomposition of G. inflata litter (k values highest) reflects its lower lignin content and higher nutrient concentrations compared to the woody species. Conversely, T. ramosissima showed the slowest decomposition, consistent with its high lignin/N ratio and structural complexity. The forest gap environment accelerated decomposition across all species, likely due to higher temperature fluctuations and periodic moisture availability compared to the more stable but shaded understory.

Nutrient Release Dynamics Carbon release exhibited a tri-phasic pattern (release-accumulation-release) across species, suggesting microbial immobilization during mid-decomposition stages. Nitrogen dynamics differed markedly: T. ramosissima and G. inflata showed initial N release followed by accumulation, indicating microbial N fixation. Phosphorus in P. euphratica understory litter displayed complex accumulation-release-accumulation patterns, reflecting P limitation in desert soils and strong microbial competition.

Correlation Analysis The k value demonstrated strong positive correlations with initial litter quality parameters (N, P) and negative correlations with recalcitrant compounds (lignin, lignin/N ratio) ($P < 0.01$). Soil moisture emerged as the primary environmental driver, with significant correlations to both forest gap and understory k values ($P < 0.01$). These findings align with global decomposition studies emphasizing the dual control of substrate quality and environmental conditions 〔22, 27〕.

Conclusion

Microhabitat heterogeneity in arid ecosystems significantly modulates litter decomposition through interactive effects of litter quality and soil moisture. Forest gaps create "hot moments" of decomposition activity, while understory environments sustain slower but more stable processes. The distinct decomposition trajectories among P. euphratica, T. ramosissima, and G. inflata underscore the importance of species-specific traits in regulating nutrient cycling. These results provide crucial parameters for arid region carbon models and inform restoration practices in desert riparian ecosystems.

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Note: Figure translations are in progress. See original paper for figures.