Postprint: Analysis of Nutrient Content in Natural Populus Forests in the Irtysh River Basin, Xinjiang

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Abstract

Analysis of biomass and organ nutrient content in five major natural poplar forests in the Irtysh River basin of Xinjiang indicates that the average leaf N content of the five poplar species is 19.36 $g \cdot kg^{-1}$, and the average P content is 2.89 $g \cdot kg^{-1}$. Leaf N content is comparable to global and domestic terrestrial plant levels, whereas leaf P content is relatively higher than the global and domestic terrestrial plant average. The average leaf N:P ratio is 6.83, which is relatively lower than the global and domestic terrestrial plant average; the leaf N:P ratio is higher than that of stems, which in turn is higher than that of roots. Leaf K content is highest in Irtysh River hybrid poplar, stem K content is highest in bitter poplar, and root K content is highest in white poplar. The biomass distribution ratio among the five natural poplar forests, i.e., bitter poplar:Irtysh River hybrid poplar:silver-gray poplar:European black poplar:white poplar, is 1:1.03:1.15:1.23:1.37, with white poplar exhibiting the highest biomass distribution and bitter poplar the lowest.

Full Text

Nutrient Content of Five Natural Poplar Forests in the Irtysh River Basin, Xinjiang

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Abstract

Our analysis of biomass and organ nutrient content in five dominant natural poplar forests in the Irtysh River Basin of Xinjiang reveals that the average leaf nitrogen content across the five species is 19.36 $g \cdot kg^{-1}$, while the average leaf phosphorus content is 2.89 $g \cdot kg^{-1}$. Leaf nitrogen content approximates levels observed in terrestrial plants globally and within China, whereas leaf phosphorus content exceeds both global and domestic averages. The mean leaf N:P ratio of 6.83 is comparatively lower than typical values for global and Chinese terrestrial flora. The N:P ratio follows the pattern: leaves > stems > roots. *Populus jrtyschensis* exhibits the highest leaf potassium content, *P. laurifolia* shows the highest stem potassium content, and *P. alba* demonstrates the highest root potassium content. The biomass distribution ratio among the five natural poplar forests—*P. lalaurifolia*, *P. jrtyschensis*, *P. canescens*, *P. nigra*, and *P. alba*—is 1:1.03:1.15:1.23:1.37. The *P. alba* forest displays the highest biomass distribution, while the *P. laurifolia* forest shows the lowest.

Keywords: Irtysh River Basin; natural poplar forest; biomass; nutrient content; Xinjiang

Introduction

Plant nutrient content is intrinsically linked to growth requirements and closely correlates with environmental nutrient availability. Nitrogen (N) represents a fundamental nutrient element for plants. Since nutrients such as N and P are often limiting in natural ecosystems, their cycling and utilization constrain most ecological processes at both individual and ecosystem scales, with plant N and P contents exhibiting strong interactions. Carbon (C), N, and P—the primary constituent elements of plant tissues—can function as "currency" for resource allocation, where interactions among different organs or tissues reflect the distribution of this currency to achieve coordinated whole-plant growth and development.

Forest biomass constitutes the foundation for studying material cycling in forest ecosystems and serves as a critical indicator for evaluating soil productivity and ecosystem structure and function. Both forest biomass and C content represent key metrics for forest carbon estimation. The extensive natural poplar forests distributed across the Irtysh River Basin in northwestern China form an important natural gene bank for Salicaceae species, featuring high species diversity and concentrated distribution. This region, acclaimed as the "gene bank of Chinese poplars," holds significant conservation value. In recent years, numerous domestic research institutions have conducted multiple germplasm resource surveys and sample collections in this area for Salicaceae species improvement and new variety breeding, yielding substantial scientific and economic benefits. This study provides fundamental scientific data for evaluating the ecological functions of natural poplar forests in the Irtysh River Basin and for the devel-

opment and utilization of superior genes through the measurement and analysis of biomass distribution and nutrient status.

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1. Study Area Overview

The Irtysh River Basin in Xinjiang is geographically located between 85°31 - 90°30 E and 46°50 -49°10 N, with an average elevation of 400–500 m. The region experiences low relative humidity, long winters, and large seasonal temperature variations. Annual precipitation is less than 200 mm, while annual evaporation exceeds 1,500 mm. The average annual temperature is 4.1 °C, with minimum temperatures reaching -28.1 °C. The $ $10 °C accumulated temperature totals 3,000 °C, annual sunshine duration averages 2,800 h, and the frost-free period lasts 120–140 days.

Natural poplar forests in the river valley typically form single- or multi-dominant mixed communities composed of multiple Salicaceae species. Dominant tree species include *Populus alba*, *P. canescens*, *P. nigra*, *P. laurifolia*, and *P. jrtyschensis* (a natural hybrid of *P. nigra* and *P. laurifolia* that represents a relatively stable multi-generational hybrid complex). This hybrid is endemic to the Irtysh River Basin and surrounding valley areas. Understory shrub species are limited, primarily comprising *Salix caspica*, *S. dasyclados*, *S. cinerea*, and *Crataegus altaica*, with peripheral scrub dominated by *Tamarix* spp., *Halimodendron halodendron*, *Rosa acicularis*, and *Haloxylon ammodendron*.

Valley soils are predominantly meadow soils with sandy loam or light loam parent material. Seasonal river flooding from spring-summer precipitation and alpine snowmelt (typically occurring in late May) inundates extensive low-riverbank terraces, making soil moisture conditions within forests notably influenced by seasonal river runoff. Overall, soil moisture characteristics along riverbanks show early spring and winter drought, summer wetness, and normal autumn moisture conditions.

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2. Methods

2.1 Sample Collection Plot Establishment: Representative study sites were selected along the Burqin-Beitun river section (86°25 –87°48 E, 47°21 - 47°41 N), where vegetation distribution typifies the broader basin forest types with consistent stand structure and minimal topographic variation, meeting criteria for experimental plot selection. Soils are primarily riverbank sandy loams with average nutrient contents of $(12.86 \pm 3.23)\ g \cdot kg^{-1}$ for N, $(1.64 \pm 0.35)\ g \cdot kg^{-1}$ for P, and $(0.37 \pm 0.08)\ g \cdot kg^{-1}$ for K.

Field surveys conducted in August measured mean tree age, DBH, height, and density for the five poplar species: *P. alba* (43.3 yr, 36.2 cm, 23.6 m, 417 trees $\cdot$ hm^{-2}), *P. canescens* (39.3 yr, 30.6 cm, 20.0 m, 456 trees $\cdot$ hm^{-2}), *P. nigra* (40.0

yr, 36.0 cm, 20.4 m, 417 trees · hm^{-2}), *P. laurifolia* (44.8 yr, 37.4 cm, 18.1 m, 370 trees · hm^{-2}), and *P. jrtyschensis* (39.5 yr, 37.9 cm, 20.5 m, 370 trees · hm^{-2}). Three representative 50 m × 50 m standard plots were established for each species, with boundaries marked using stakes and measuring ropes.

Standard Tree Selection: All poplar individuals in each plot were measured for DBH and height. Based on diameter and height distributions, one standard tree representing the mean DBH and height was selected per plot. Selected trees exhibited normal growth without stem damage. In total, 15 standard trees (3 per species) were harvested to measure leaf, stem, and root biomass.

2.2 Biomass Measurement Methods **Leaf Biomass:** After felling, total fresh leaf weight was collected and weighed. Fresh leaf samples (400–500 g each) were taken from different canopy heights, oven-dried at 70–80 °C to constant weight, and weighed to calculate dry leaf biomass.

Stem Biomass: Stems were stratified by diameter into five vertical sections. Fresh weights of trunks and branches were measured for each section, with three 400–500 g samples taken per section for oven-drying and dry weight calculation.

Root Biomass: Complete root systems were excavated, cleaned, air-dried, and weighed. Roots were stratified by diameter into five classes, with 400–500 g samples taken from each class for oven-drying and dry weight determination.

Stand-level biomass per unit area was calculated using mean standard tree biomass and stand density.

2.3 Nutrient Content Analysis Dried plant samples were ground and processed for nutrient analysis. Carbon content was determined using the potassium dichromate method, nitrogen via the Nessler colorimetric method, phosphorus by vanadium-molybdate yellow colorimetry, and potassium by atomic absorption spectrophotometry.

2.4 Statistical Analysis Data were analyzed using Excel 2003 and SPSS 13.0 software, with one-way ANOVA performed for significance testing.

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3. Results and Analysis

3.1 Organ Nutrient Content

3.1.1 Leaf Nutrient Content Significant interspecific differences were observed in leaf N content ($P < 0.05$). *P. alba* and *P. canescens* showed relatively high leaf N content, while *P. jrtyschensis* and *P. nigra* exhibited lower values (Table 1). Leaf P content also differed significantly among species ($P < 0.05$), with *P. alba* showing the highest content and *P. laurifolia* the lowest. No significant differences were detected in leaf C or K content among species.

The leaf N:P ratios were 6.83 for *P. nigra*, 8.35 for *P. laurifolia*, 6.20 for *P. jrtyschensis*, 5.97 for *P. alba*, and 6.68 for *P. canescens*, with a mean of 6.81. The ranking of N:P ratios was: *P. laurifolia* > *P. canescens* > *P. nigra* > *P. jrtyschensis* > *P. alba*.

3.1.2 Stem Nutrient Content Stem N content varied significantly among species ($P < 0.05$), with *P. laurifolia* showing the highest value and other species not differing significantly ($P > 0.05$). Stem P content was highest in *P. nigra* and lowest in *P. jrtyschensis*. No significant differences were observed in stem C or K content.

Stem N:P ratios were 4.24 for *P. nigra*, 5.19 for *P. laurifolia*, 4.56 for *P. jrtyschensis*, 3.49 for *P. alba*, and 4.33 for *P. canescens*, with a mean of 4.36. The ranking was: *P. laurifolia* > *P. jrtyschensis* > *P. canescens* > *P. nigra* > *P. alba*.

3.1.3 Root Nutrient Content Root N content differed significantly among species ($P < 0.05$), with *P. alba* showing the highest value ($7.75\ g \cdot kg^{-1}$), significantly greater than *P. nigra* and *P. canescens*. No significant differences were observed among *P. alba*, *P. laurifolia*, and *P. jrtyschensis*. Root P content was highest in *P. alba* ($3.18\ g \cdot kg^{-1}$), differing significantly from other species except *P. nigra*. No significant differences were detected in root C or K content.

Root N:P ratios were 1.29 for *P. nigra*, 0.73 for *P. laurifolia*, 2.20 for *P. jrtyschensis*, 1.39 for *P. alba*, and 1.72 for *P. canescens*, with a mean of 1.47. The ranking was: *P. jrtyschensis* > *P. canescens* > *P. alba* > *P. nigra* > *P. laurifolia*.

3.2 Biomass Distribution

3.2.1 Individual Tree Biomass Mean individual biomass ranked as: *P. jrtyschensis* (604.27 ± 30.85 kg) > *P. alba* (522.74 ± 15.11 kg) > *P. nigra* (514.21 ± 13.29 kg) > *P. canescens* (494.78 ± 21.24 kg) > *P. laurifolia* (201.36 ± 6.18 kg). Stem biomass accounted for the highest proportion of total biomass in *P. alba*, while *P. jrtyschensis* showed the lowest stem proportion. Root biomass proportion was highest in *P. canescens* and lowest in *P. laurifolia*.

3.2.2 Stand-Level Biomass Distribution The biomass distribution ratio among the five natural poplar forests was *P. laurifolia*:*P. jrtyschensis*:*P. canescens*:*P. nigra*:*P. alba* = 1.00:1.03:1.15:1.23:1.37. The *P. alba* forest exhibited the highest biomass distribution, while the *P. laurifolia* forest showed the lowest. Leaf biomass distribution was lowest in *P. laurifolia*, less than 50% of that in *P. alba*. Stem biomass distribution was lowest in *P. jrtyschensis*, approximately 50% of that in *P. alba*. Root biomass distribution was lowest in *P. alba*, about 25% of that in *P. jrtyschensis*.

The proportional distribution of root, stem, and leaf biomass was: *P. nigra* (15.47%, 82.04%, 2.48%), *P. laurifolia* (21.00%, 77.63%, 1.36%), *P. jrtyschensis* (28.92%, 68.61%, 2.46%), *P. alba* (6.80%, 90.01%, 3.18%), and *P. canescens* (17.94%, 78.53%, 3.53%). These results indicate that *P. alba* contributes substantially to timber volume in the Irtysh River Basin, while *P. jrtyschensis* possesses the highest root biomass, suggesting stronger soil and water conservation functions.

3.2.3 Stand-Level Nutrient Storage The *P. alba* forest exhibited the highest C storage (82.82 $t \cdot hm^{-2}$), indicating high carbon sequestration capacity, while *P. laurifolia* showed the lowest C storage (64.69 $t \cdot hm^{-2}$). N storage was relatively high in *P. nigra* and *P. alba*, but lowest in *P. laurifolia*. P storage was relatively high in *P. nigra* and *P. alba*, but lowest in *P. jrtyschensis*. K storage was highest in *P. alba* and lowest in *P. canescens*.

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4. Discussion

The mean carbon storage of poplar natural forests in the Irtysh River Basin is 71.35 $t \cdot hm^{-2}$, exceeding the national forest average of 35–39 $t \cdot hm^{-2}$, demonstrating substantial carbon storage and sequestration potential. As one of China' s largest remaining natural poplar forest regions with extensive distribution and rich germplasm resources, the Irtysh River Basin exerts significant influence on local ecological environments and regional climate. Conservation and research efforts for these forests are therefore crucial for national ecological civilization construction and future resource protection.

The average leaf N content of 19.36 $g \cdot kg^{-1}$ and P content of 2.89 $g \cdot kg^{-1}$ in the five poplar species indicate that N levels approximate global and domestic terrestrial plant averages, while P levels exceed them. The mean leaf N:P ratio of 6.83 is lower than global and domestic averages. Potassium, the most abundant cation in plants, influences multiple physiological processes: stem K content affects lodging resistance, root K content influences water absorption capacity, and leaf K content impacts photosynthesis and respiration.

Among the five species, *P. jrtyschensis* shows the highest leaf K content, suggesting hybrid vigor. *P. laurifolia* exhibits the highest stem K content, which may enhance lignification and siliconization, improving mechanical strength. *P. alba* shows the highest root K content, where elevated K creates greater osmotic pressure, enhancing soil water absorption.

Based on established thresholds, leaf N:P ratios >20 indicate P limitation, while ratios <10 suggest N limitation. The studied poplar forests exhibit N:P ratios of 5.97–8.35, indicating N-limited growth. Under natural conditions, valley soil moisture generally meets growth requirements, with minimal impact from winter and early spring droughts. However, intensified human disturbance could exacerbate drought conditions. Therefore, strengthening ecological protection

of natural forests in the Irtysh River Basin is essential to prevent environmental degradation.

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5. Conclusion

This study demonstrates that carbon storage in the five natural poplar forests of the Irtysh River Basin ranks as: *P. alba* > *P. nigra* > *P. canescens* > *P. jrtyschensis* > *P. laurifolia*. The *P. alba* forest exhibits the highest carbon sequestration capacity, while *P. laurifolia* shows the lowest. These findings provide important reference values for regional ecological protection and national climate change mitigation efforts, including carbon neutrality and emission peak targets.

The average leaf N content approximates global and domestic terrestrial plant levels, while leaf P content exceeds these averages. The mean leaf N:P ratio of 5.97–8.35 is lower than global and domestic averages, indicating N-limited growth. Soil N fertilization would significantly promote poplar growth. The relatively low leaf N:P ratios suggest that poplar natural forests in the basin are not experiencing severe drought stress or inhibition.

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