Relationship Between Ray Tissue Characteristics and Non-structural Carbohydrate Content in Haloxylon ammodendron Postprint

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Abstract

Currently, inconsistent conclusions remain regarding the relationship between xylem ray tissue and non-structural carbohydrate (NSC) content. This study used Haloxylon ammodendron, a dominant species in the Gurbantünggüt Desert region, as experimental material to measure characteristics of xylem ray tissue, NSC and its component contents in three ecological types of H. ammodendron. The results showed that gravel ecological type H. ammodendron had the highest values for ray density, ray proportion, NSC and its component contents, while soil ecological type showed the opposite pattern. Ray proportion was significantly positively correlated with NSC($P< 0.01$) and starch content($P< 0.05$), while ray cell wall thickness was significantly negatively correlated with NSC content($P< 0.01$). These results indicate that H. ammodendron adapts to harsh conditions by reducing ray cell wall thickness and increasing ray proportion and NSC.

Full Text

Relationship between Ray Tissue Features and Non-structural Carbohydrates in Xylem of *Haloxylon ammodendron*

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Abstract

Current research presents inconsistent conclusions regarding the relationship between ray tissue anatomical features and non-structural carbohydrate (NSC) content in xylem. In this study, *Haloxylon ammodendron*, a dominant species in the Gurbantunggut Desert, was used as experimental material to investigate this relationship. We determined ray tissue characteristics, NSC content, soluble sugar, and starch concentrations in three ecotypes distributed across different soil types: gravel soil (in Jinghe), sandy soil (in Shihezi), and loam (in Caijiahu), and analyzed the correlations between ray anatomical features and NSC as well as its components.

The results demonstrated that ray proportion in *H. ammodendron* varied from 3.69% to 7.06%, while NSC content ranged from 3.55% to 5.87% across the three ecotypes. These values were substantially lower compared to those of tropical and subtropical tree species, likely attributable to limited photosynthetic activity in *H. ammodendron* resulting from nutrient-poor soils, severe drought, and salinity stress characteristic of desert environments.

The gravel soil site, which received the lowest precipitation, exhibited the highest values of ray density, ray proportion, NSC and its components, corresponding with the lowest values of ray height and ray cell wall thickness. In contrast, the sandy soil site displayed the lowest values for ray density, ray proportion, NSC and its components. Correlation analysis revealed that ray proportion was positively correlated with NSC ($P<0.01$) and starch ($P<0.05$), while ray cell wall thickness was significantly negatively correlated with NSC ($P<0.01$).

These findings indicate that *H. ammodendron* enhances xylem nutrient status, water storage capacity, and transport efficiency to cope with severe environmental conditions by reducing ray cell wall thickness while increasing ray proportion and NSC content. These results provide significant insights into the adaptive mechanisms of this species to arid desert regions.

Keywords: *Haloxylon ammodendron*; ray proportion; wall thickness of ray cell; starch; soluble sugar; non-structural carbohydrate; Gurbantunggut Desert

2 Materials and Methods

2.1 Study Sites

This study was conducted in three representative habitats within the Gurbantunggut Desert region. The experimental sites included Jinghe (gravel soil), Shihezi (sandy soil), and Caijiahu (loam soil), representing distinct edaphic and climatic conditions.

[Figure 1: see original paper]

2.2 Sampling and Experimental Design

Sample collection and experimental protocols were established to ensure representative measurements across the three ecotypes. Standard procedures were followed for wood sample preparation and carbohydrate extraction.

2.3 Measurement Indicators

2.3.1 Ray Tissue Feature Determination Anatomical measurements included ray proportion, ray density, ray height, and ray cell wall thickness. Microscopic analysis was performed according to standard IAWA protocols.

2.3.2 Non-structural Carbohydrate Determination NSC content was quantified as the sum of soluble sugars and starch. Soluble sugars were extracted with hot ethanol, and starch was subsequently digested enzymatically. Concentrations were determined using colorimetric methods.

2.4 Statistical Analysis

Statistical analyses were performed using standard software packages. Correlation analysis examined relationships between ray tissue features and carbohydrate components. Principal component analysis (PCA) was conducted to identify key variables explaining variation among ecotypes. Significance was assessed at $P<0.05$ and $P<0.01$ levels.

3 Results

3.1 Variation in Ray Tissue Features and NSC Content

Significant variation was observed in both ray tissue anatomical features and NSC content among the three ecotypes. The gravel soil ecotype exhibited the highest ray proportion and NSC content, while the sandy soil ecotype showed the lowest values for these parameters.

3.2 Correlation Analysis

Table 2 Correlations between ray tissue features and nutrients in xylem of *H. ammodendron*

The correlation matrix revealed significant relationships between anatomical and physiological traits. Ray proportion showed strong positive correlations with NSC content ($r=0.87$, $P<0.01$) and starch ($r=0.57$, $P<0.01$). Conversely, ray cell wall thickness demonstrated significant negative correlations with NSC ($r=-0.75$, $P<0.01$) and its components.

3.3 Principal Component Analysis

PCA results indicated that ray proportion, ray height, and NSC content loaded heavily on the first principal component (PC1), explaining the majority of variation among samples. Ray cell wall thickness contributed primarily to the second principal component (PC2), accounting for 7.06% of total variance. The PCA biplot clearly separated ecotypes based on these key traits.

4 Discussion

The observed relationships between ray tissue features and NSC content in *H. ammodendron* reflect adaptive strategies to desert environments. The negative correlation between ray cell wall thickness and NSC suggests a trade-off between structural investment and carbohydrate storage. Increased ray proportion may enhance both radial transport capacity and NSC storage, providing a buffer against environmental stress.

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