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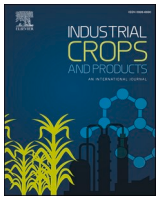

Non-structural carbohydrate (NSC) content and C:N:P stoichiometry of *Pinus yunnanensis* seedling needles in response to shade treatment

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ABSTRACT

Pinus yunnanensis is a major forest tree species in central Yunnan Province, but many stands have seedlings but no young trees, which is unfavorable for natural regeneration. The responses to *P. yunnanensis* seedlings to shade were analyzed in five treatments: 0% shade (light intensity of 14.06 $\times 10^4$ to 14.42 $\times 10^4$Lx), 20% shade (light intensity of 11.95 $\times 10^4$ to 10.55 $\times 10^4$Lx;), 55% shade (light intensity of 7.73 $\times 10^4$ to 6.33 $\times 10^4$Lx), 70% shade (light intensity of 4.22 $\times 10^4$ to 2.812 $\times 10^4$Lx), and 95% shade (light intensity of 2.11 $\times 10^4$ to 0.71 $\times 10^4$Lx). The growth indicators, needle chlorophyll content, stoichiometric characteristics, and non-structural carbohydrate (NSC) content of the seedlings were investigated under different shade treatments. The results showed that the shade treatment affected the growth and physiological indicators of the needles of *P. yunnanensis* seedlings. The growth and chlorophyll content increased and then decreased with the increasing shade level, reaching the maximum at 70% shade. The soluble sugar, starch, and non-structural carbohydrate contents were significantly lower, and the soluble sugar/starch ratio was higher in the shade treatment than in the control. The three shade treatments (20%, 55%, and 70% shade) increased the P utilization efficiency of the *P. yunnanensis* needles. A significant correlation existed between the NSC content and C:N:P stoichiometry. In summary, *P. yunnanensis* seedlings showed shade tolerant, and 70% shade is best for *P. yunnanensis* seedlings.

1. Introduction

Light is an indispensable environmental factor in plant growth and development, with profound effects on plant morphogenesis, photosynthesis, transpiration, respiration, material transport, and synthesis (Quero et al., 2006; Olsrud and Michelsen, 2009). Differences in the forest understory light environment can induce changes in plant morphological and physiological characteristics, affecting the spatial distribution and physiological-ecological characteristics of seedling regeneration. Woody plant seedling regeneration is critical in forest community succession. This stage is the most vulnerable period in plant life history because seedlings are more sensitive to environmental factors than adult individuals (Soto et al., 2017). Therefore, the adaptation strategies of seedlings to different light conditions are critical to natural forest regeneration (Zhou et al., 2017; Lee et al., 2020). Many stands for seedlings but no young trees in the forest understory. Therefore, reducing seedling mortality is essential for revegetation. A strong correlation exists in many cases between the level of seedling regeneration and the heterogeneity of the forest light environment, especially light intensity. The synergistic effect of seedling physiology and growth index pairs in response to light can help us to deeply understand the mechanism of forest seedling regeneration and elucidate the relationship between seedling mortality and environmental factors during natural regeneration. This information has theoretical and practical significance for elucidating the mechanism of natural forest regeneration and guiding the scientific management of plantation forests.

Non-structural carbohydrates (NSC) are essential components required for the growth and development of trees. They consist of

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Seasonal variation in C:N:P stoichiometry, nonstructural carbohydrates, and carbon isotopes of two coniferous pioneer tree species in subtropical China

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The characteristics of C:N:P stoichiometry, nonstructural carbohydrate (NSC) content, and C stable isotopes and their relationships affect plant responses to environmental changes and are critical to understanding the ecosystem carbon and water cycles. We investigated the water use strategies and physiological changes of two pioneer tree species (*Pinus armandii* and *Pinus yunnanensis*) in response to seasonal drought in subtropical China. The seasonal variation in needle $\delta^{13}C$ values, C:N:P stoichiometry, and NSC contents of the two tree species were studied in 25-year-old plantation in central Yunnan Province. The needle $\delta^{13}C$ values of both species were highest in summer. Soluble sugars, starch and NSC content of the two tree species decreased from spring to winter, while there was no significant difference in the seasonal variation of soluble sugars/starch in *P. armandii* needles, the maximum soluble sugars/starch in *P. yunnanensis* needles was in autumn. In addition, the C, N, and P contents of the needles and the C:N and C:P ratios of the two species showed different seasonal fluctuations, whereas the N:P ratio decreased with the season. The C:N:P stoichiometry and NSC content of the needles showed significant correlations, whereas the needle $\delta^{13}C$ was weakly correlated with C:N:P stoichiometry and NSC content. Phenotypic plasticity analysis and principal component analysis revealed that the needle nutrient characteristics (NSC and P contents and N:P ratio) and needle $\delta^{13}C$ values were critical indicators of physiological adaptation strategies of *P. armandii* and *P. yunnanensis* for coping with seasonal variation. These results increase our understanding of the water-use characteristics of the two pioneer tree species and the dynamic balance between the NSC, C, N, and P contents of the needles.

KEYWORDS

pioneer tree species, winter and spring drought, needle carbon stable isotope, stoichiometry, nonstructural carbohydrates, seasonal variation