稀土矿尾砂地氮添加对樟树幼苗根系生长、生物量分配及非结构性碳水化合物的影响

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摘　要：我国南方地区赣南、粤北、闽西等地拥有大量稀土资源，自 20 世纪 70 年代产业的大量需求，稀土资源被大量开采，由于开采方式的使周边环境遭受巨大的破坏，导致一系列的环境问题。多年来，虽然政府部门经过多年的治理，但受制于系统科学的治理技术支持，稀土尾砂生态修复较为缓慢，缺乏一定的经济效益，限制了植被恢复措施的推广和应用。樟树(Cinnamomum camphora)被证明可以在稀土尾砂上种植，而且其作为江西省的特色香料用经济树种，枝叶富含精油，目前以矮林栽培方式在我国云南、四川、湖北、湖南、贵州、广西等省广泛种植。由于樟树地上部分每年都要被平茬，枝叶的持续生长对养分的需求高，而贫瘠的稀土尾砂生境难以满足猴樟生长所需。因此，为了满足植物枝叶连续生长的需求，每年需要补充大量氮肥，但在氮肥施用过程中存在一定的盲目性，再加上稀土尾砂矿区土壤保肥能力差，多余氮肥流失会造成更为严重的水土流失和面源污染问题。基于此，本研究以樟树幼苗为研究对象，设置 3 种氮水平：对照(CK，0g/株)、低氮(N1，1.8g/株)、高氮(N2，3.6g/株)，处理 5 个月后，测定不同氮添加水平下樟树幼苗根系生长指标、生物量分配以及非结构性碳水化合物的差异，探讨樟树幼苗对氮添加的响应机制，进而为离子型稀土矿尾砂地生态修复提供有力可靠的参考。结果显示：N1 处理下樟树的叶、茎、冠层、粗根、细根、总生物量均显著高于 CK 与 N2($P<0.05$)，N2 处理下叶枝比、叶生物量占比显著高于 CK($P<0.05$)。N2 条件下茎、细根生物量占比均显著低于 CK($P<0.05$)。N1 处理下粗、细根长，粗、细根表面积显著高于 CK($P<0.05$)；N2 处理分别比 CK、N1 显著提高了比根长、比表面积($P<0.05$)；N1 处理下粗、细根直径均显著低于 CK($P<0.05$)。N1 处理下叶、茎中可溶性糖均显著高于 N2($P<0.05$)；N2 处理下茎、粗根、细根的淀粉、非结构性碳水化合物(NSC)含量均显著低于 CK($P<0.05$)。综上所述，低氮条件下樟树幼苗主要通过构建根系结构增加养分吸收，高氮条件抑制根长、根表面积的发育，导致根系养分吸收效率降低；N 添加驱动的养分缓解使更多的非结构性碳水化合物分配到地上器官，从而使地上部分 NSC 积累。

关键词：稀土尾砂；氮添加；樟树；根系性状；生物量分配；非结构性碳水化合物

Effects of nitrogen addition to rare earth tailings on root growth and biomass allocation of camphor tree seedlings and the impact of non structural carbohydrates

Abstract:【Objective】The southern regions of China, including Gannan, northern Guangdong, and western Fujian, possess a large amount of rare earth resources. Since the 1970s, due to the large demand for industry, rare earth resources have been extensively exploited. Due to the mining methods, the surrounding environment has been greatly damaged, resulting in a series of environmental problems. For many years, despite years of governance by government departments, the ecological restoration of rare earth tailings has been slow and lacks certain economic benefits due to the support of systematic scientific governance technology, which has limited the promotion and application of vegetation restoration measures. Cinnamomum camphora has been proven to be grown on rare earth tailings, and as a characteristic spice economic tree species in Jiangxi Province, its branches and leaves are rich in essential oil. Currently, it is widely planted in Yunnan, Sichuan, Hubei, Hunan, Guizhou, Guangxi and other provinces in China through dwarf cultivation. Due to the fact that the aboveground parts of camphor trees are flattened every year, the continuous growth of branches and leaves requires high nutrient requirements, and the barren rare earth tailings habitat is difficult to meet the growth needs of camphor trees. Therefore, in order to meet the continuous growth needs of plant branches and leaves, a large amount of nitrogen fertilizer needs to be supplemented every year. However, there is a certain degree of blindness in the application process of nitrogen fertilizer. In addition, the poor soil fertility in rare earth tailings mining areas can lead to more serious soil erosion and non-point source pollution problems due to the loss of excess nitrogen fertilizer.【Method】Based on this, this study takes camphor tree seedlings as the research object and sets three nitrogen levels: control (CK, 0g/plant), low nitrogen (N1, 1.8g/plant), and high nitrogen (N2, 3.6g/plant). After 5 months of treatment, the differences in root growth indicators, biomass allocation, and non structural carbohydrates of camphor tree seedlings under different nitrogen addition levels are measured to explore the response mechanism of camphor tree seedlings to nitrogen addition, Furthermore, it provides a powerful and reliable reference for the ecological restoration of ionic rare earth ore tailings.【Result】The results showed that the leaf, stem, canopy, coarse root, fine root, and total biomass of camphor tree under N1 treatment were significantly higher than CK and N2 (P<0.05), while the leaf branch ratio and leaf biomass proportion under N2 treatment were significantly higher than CK (P<0.05). The proportion of biomass of stems and fine roots under N2 conditions was significantly lower than that of CK (P<0.05). Under N1 treatment, the length and surface area of coarse and fine roots were significantly higher than those of CK (P<0.05); N2 treatment significantly increased specific root length and specific surface area compared to CK and N1 treatments (P<0.05); Under N1 treatment, the diameters of coarse and fine roots were significantly lower than those of CK (P<0.05). Under N1 treatment, the soluble sugars in leaves and stems were significantly higher than those in N2 (P<0.05); Under N2 treatment, the starch and non structural carbohydrate (NSC) content in stems, coarse roots, and fine roots were significantly lower than those in CK (P<0.05).【Conclusion】In summary, under low nitrogen conditions, camphor tree seedlings mainly increase nutrient absorption by constructing root structures, while high nitrogen conditions inhibit the development of root length and root surface area, leading to a decrease in root nutrient absorption efficiency; The nutrient relief driven by N addition allocates more non structural carbohydrates to aboveground organs, thereby accumulating NSC in the aboveground portion.

Key words: rare earth tailings; Nitrogen addition; Camphor tree; Root traits; Biomass allocation; Non structural carbohydrates