

呼伦贝尔沙地樟子松林土壤和根内真菌泛化种和特化种结构与功能特征

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摘要:【目的】为阐明樟子松 (*Pinus sylvestris* var. *mongolica*) 土壤和根内真菌泛化种和特化种群落结构与功能特征及其与土壤理化性质的相关性。【方法】以呼伦贝尔沙地樟子松天然林和人工林 (中龄林、近熟林和成熟林) 为研究对象, 利用 Illumina MiSeq 高通量测序和 FUNGuild 平台鉴定分析樟子松土壤和根内真菌泛化种和特化种群落。【结果】(1) 土壤和根内真菌泛化种保留 169 个 OTUs, 隶属于 5 门 12 纲 29 目 58 科 64 属 111 种, 其中优势属均为口蘑属 *Tricholoma*、乳牛杆菌属 *Suillus*、丝盖伞属 *Inocybe*、*Cadophora*; 土壤真菌特化种保留了 603 个 OTU, 隶属于 8 门 25 纲 58 目 107 科 165 属 315 种, 根内真菌特化种保留了 216 个 OTU, 隶属于 4 门 13 纲 35 目 59 科 69 属 110 种, 特化种优势属分别为青霉属 *Penicillium*、*Geminibasidium* 和 *Acephala*、丝盖伞属。(2) 在土壤和根内真菌中, 特化种中腐生营养型真菌相对丰度显著高于泛化种 ($P<0.05$); 除此之外, 土壤真菌特化种的腐生营养型和病理营养型真菌相对丰度显著高于根内真菌特化种 ($P<0.05$)。(3) 土壤和根内真菌泛化种中共生营养型真菌占比最高为 8.32%~51.42%, 优势生态功能群为外生菌根真菌; 土壤真菌特化种以腐生营养型真菌占比最高为 17.01%~40.01%; 根内真菌特化种共生营养型真菌占比最高为 43.87%~54.45%, 优势生态功能群为外生菌根真菌。(4) 土壤和根内真菌群落结构主要受土壤有机质、有效氮、全氮和全钾驱动, 与泛化种和特化种群落呈显著正相关关系。【结论】呼伦贝尔沙地樟子松林真菌泛化种和特化种具有不同的群落结构, 土壤和根内真菌特化种群落结构差异显著。樟子松生长过程中, 真菌泛化种共生营养型真菌大量富集占据主导地位, 有利于林木快速生长; 特化种腐生营养型真菌发挥主导作用, 有利于提高林木对外部环境抵抗能力。真菌的泛化种和特化种群落受土壤理化性质的变化的影响, 其中土壤有机质、有效氮、全氮及全钾是真菌群落结构变化的主要驱动因素。研究结果有助于深入理解呼伦贝尔沙地樟子松林土壤和根内真菌生态功能, 为樟子松林的可持续管理与保护提供科学依据, 确保其生态健康和经济效益的双重实现。

Structure and functional group characteristics of generalized and specialized species of soil and root-associated fungi with *Pinus sylvestris* var. *mongolica* forests in the Hulunbuir Desert

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Abstract: 【Objective】 To elucidate the structural and functional characteristics of the fungal community of generalized and specialized species in the soil and roots of *Pinus sylvestris* var. *mongolia* and their correlation with soil physical and chemical properties. **【Method】** This study took *Pinus sylvestris* var. *mongolia* natural and plantation forests (middle-aged, near-mature and mature forests) in Hulunbuir Desert as the research object, the Illumina MiSeq high-throughput sequencing and FUNGuild platform were used to identify and analyse the fungal generalized and specialised species communities in *Pinus sylvestris* soils and roots. **【Result】** (1) A total of 169 OTUs were retained in the soil and intra-root fungal species, belonging to 111 species belonging to 5 phyla, 12 classes, 29 orders, 58 families, 64 genera, among which the dominant genera were *Tricholoma*, *Suillus*, *Inocybe* and *Cadophora*. A total of 603 OTUs were retained, belonging to 8 phyla, 25 classes, 58 orders, 107 families, 165 genera and 315 species, and 216 OTUs were retained in the root fungal species, belonging to 4 phyla, 13 classes, 35 orders, 59 families, 69 genera and 110 species, and the dominant genera of the specialized species were *Penicillium*, *Geminibasidium* and *Acephala*, *Inocybe*, respectively. (2) Among soil and intra-root fungi, the relative abundance of saprotrophic fungi was significantly higher ($P < 0.05$) in the specialized species than in the generalized species; in addition to this, the relative abundance of saprotrophic and pathotrophic fungi was significantly ($P < 0.05$) higher ($P < 0.05$) in the soil fungi specialized species than in the intra-root fungi specialized species. (3) Soil and root fungi generalized species of symbiotic nutritive fungi accounted for the highest proportion of 8.32% to 51.42%, and the dominant ecological function group was exophytic mycorrhizal fungi; soil fungi specialization species of saprophytic nutritive fungi accounted for the highest proportion of 17.01% to 40.01%; and the specialization species of intra-root fungi accounted for the highest proportion of symbiotic nutritive fungi of 43.87% to 54.45%, and the dominant ecological function group was exophytic mycorrhizal Fungi. (4) Soil and roots fungal community structure was primarily driven by Soil Organic Matter, Active Nitrogen, Total Nitrogen and Total Potassium, and was significantly and positively correlated with generalized and specialized species communities. **【Conclusion】** Fungal generalized and specialized species in *Pinus sylvestris* Desert forests had different community structures, and the community structures of fungal specialized species in soil and roots varied significantly. During the growth process of *Pinus sylvestris* var. *mongolia*, a large number of symbiotic nutritive fungi of generalized species dominated, which was conducive to the rapid growth of forest trees; and putrefactive nutritive fungi of specialized species played a dominant role, which was conducive to the improvement of the resistance ability of forest trees to the external environment. The communities of generalized and specialized species of fungi were affected by changes in soil physical and chemical properties, in which Soil Organic Carbon, Available Nitrogen, Total Nitrogen and Total Potassium were the main driving factors for changes in the structure of fungal communities. The results of the study can help to deeply understand the ecological functions of soil and intra-root fungi in *Pinus sylvestris* var. *mongolia* forests, providing a scientific basis for the sustainable management and protection of *Pinus sylvestris* var. *mongolia* forests, and ensuring the dual realisation of their ecological health and economic benefits.