沙坡头地区生物土壤结皮的固氮活性及其对水热因子的响应

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摘要 氮是除水分之外影响干旱区生态系统生物活性的关键因子。生物土壤结皮是干旱半干旱荒漠地表景观的重要组成部分, 也是荒漠生态系统氮素的主要贡献者。通过野外调查采样, 利用开顶式生长室, 模拟不同降水梯度, 采用乙炔还原法连续测定了沙坡头地区典型生物土壤结皮(藻类结皮、地衣结皮和藓类结皮)在其主要固氮活跃期(6–10月, 湿润期)的固氮活性, 及其对水热因子的响应特征。结果表明, 试验期三类生物土壤结皮的固氮活性介于2.5×10^3–6.2×10^4 nmol $C_2H_4 \cdot m^{-2} \cdot h^{-1}$之间, 其中藻类结皮的最高(平均达$2.8 \times 10^4$ nmol $C_2H_4 \cdot m^{-2} \cdot h^{-1}$), 地衣结皮的次之($2.4 \times 10^4$ nmol $C_2H_4 \cdot m^{-2} \cdot h^{-1}$), 藓类结皮的最低($1.4 \times 10^4$ nmol $C_2H_4 \cdot m^{-2} \cdot h^{-1}$), 差异显著($p < 0.001$)。在模拟降水3 mm时, 三类结皮均可达到最大固氮速率, 当发生> 3 mm的降水事件时, 它们的固氮速率无显著增加; 不同结皮的固氮活性与温度均呈显著的负相关关系($r_{藻类结皮} = -0.711$, $r_{地衣结皮} = -0.732$, $r_{藓类结皮} = -0.755$, $p < 0.001$), 藻类和藓类结皮的固氮活性的最适温度区间为25–30 ℃, 地衣结皮为20–30 ℃。三类结皮之间的这种固氮差异主要归因于结皮组成生物体即隐花植物的差异, 藻类结皮主要成分为大量的蓝细菌和一些绿藻, 地衣结皮也由大量的固氮藻和真菌共生形成, 而藓类结皮的主要组成部分苔藓植物并不具有固氮作用, 其微弱的固氮量是结皮中混生的少量蓝细菌或地衣所致。

关键词: 乙炔还原法 生物土壤结皮 环境因子 固氮 固氮活性

Abstract: *Aims* In arid and semi-arid environments such as deserts, nitrogen is often the most limiting nutrient for biological activity. Biological soil crusts (BSCs) are an important component of vegetation in the Shapotou region in the Tengger Desert, northern China. However, their importance as contributors to soil fertility such as nitrogen fixation is relatively unknown. This study was conducted to quantify the potential nitrogenase activity (NA) of different types of BSCs in artificial vegetation areas, as well as their responses to variation in moisture and temperature.

Methods Algae crust, lichen crust and moss crust were collected from an artificial vegetation area in the Shapotou region, and were incubated under three gradients of moisture (3, 5 and 10 mm simulated rainfall) and temperature in open-top growth chambers from June to October. The NA was measured using acetylene reduction assay. One-way ANOVA and general linear models (GLM) procedure were applied to compare NA between treatments and interactions between type of BSCs, water and temperature.

Important findings NA for each type of BSC was highly variable, ranging from 2.5×10^3 to 6.2×10^4 nmol $C_2H_4 \cdot m^{-2} \cdot h^{-1}$. The NA of algae crust was higher than that of lichen crust and moss crust (2.8 vs. 2.4 and 1.4 $\times 10^4$ nmol $C_2H_4 \cdot m^{-2} \cdot h^{-1}$, respectively). The three types of BSCs under the 3 mm simulated rainfall reached the maximum rate of nitrogen fixation, but > 3 mm did not affect NA. Significant negative correlation was observed between NA of all three types of BSCs and temperature. The optimal temperature for NA in algae crust, moss crust and lichen crust were 25–30 ° C, 25–30 ° C and 20–30 ° C, respectively.

Keywords: acetylene reduction assays (ARA), biological soil crusts, environmental factors, nitrogen fixation, nitrogenase activity

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