土壤微生物膜固沙对沙生植物幼苗光合和荧光特性的影响

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摘要：为揭示土壤微生物膜固沙技术对沙生植物幼苗光合和荧光特性的影响，以沙冬青（*Ammopiptanthus mongolicus*）和沙打旺（*Astragalus laxmannii*）幼苗为研究对象，设置不同菌剂施用方式（喷施、混施）和施用量（0、1、3、5、7 和 10 g·kg^{-1}）开展盆栽试验，比较分析土壤微生物膜形成后植物气体交换和叶绿素荧光特征。研究结果表明：（1）当菌剂施用量大于 1 g·kg^{-1} 时，固结层硬度和厚度显著高于对照组（P<0.05），当施用量大于 5 g·kg^{-1} 时，土壤脲酶和蔗糖酶活性显著高于对照组（P<0.05）。（2）施用菌剂对沙冬青净光合速率无显著影响（P>0.05），3-7 g·kg^{-1} 菌剂处理组沙打旺净光合速率显著高于对照组（P<0.05），且蒸腾速率、净光合速率和胞间 CO_2 浓度均显著高于沙冬青（P<0.05）。（3）1 g·kg^{-1} 菌剂处理组沙冬青 Fv/Fm 较对照组显著降低（P<0.05），菌剂施用量大于 5 g·kg^{-1} 处理组沙打旺 Fv/Fm 显著高于对照组（P<0.05）。除 3 g·kg^{-1} 处理组之外，沙冬青 Fv/Fm 和 Q_P 均高于沙打旺。（4）土壤特性、光合气体交换和叶绿素荧光三者为部分中介模型，土壤特性直接影响叶绿素荧光特性相对效应比为 66.67%，通过影响光合气体交换进而间接影响荧光特性相对效应比为 34.23%。土壤微生物膜固沙技术提高了固结层硬度、厚度和土壤酶活性。土壤微生物膜固沙技术通过改善土壤质量、提高叶片气孔导度及气体交换中介效应增强沙冬青和沙打旺光合效率和能力，其对沙打旺光合速率和沙冬青电子传递影响更大。研究结果可为丰富完善土壤微生物膜固沙技术提供理论依据和科技支撑。

关键词：土壤微生物膜；沙生植物；光合作用；叶绿素荧光

Effects of soil microbial films sand fixation on photosynthesis and fluorescence characteristics of psammophyte seedlings

Abstract: In order to reveal the effects of soil microbial film sand fixation on photosynthetic and fluorescence characteristics of psammophyte seedlings, *Ammopiptanthus mongolicus* and *Astragalus laxmannii* seedlings were selected. Pot experiment with different application methods (spray, mix) and application amount (0, 1, 3, 5, 7 and 10 g kg $^{-1}$). The characteristics of plant gas exchange and chlorophyll fluorescence after soil microbial biofilm formation were analyzed. The results show that: (1) The hardness and thickness of the consolidated layer were significantly higher than that of the control (P<0.05), when the application amount of bacterial was greater than 1 g·kg^{-1}. When the application amount was greater than 5 g·kg^{-1}, the activities of urease and sucrase in soil were significantly higher than that of the control (P<0.05). (2) There was no significant effect on net photosynthetic rate of *Ammopiptanthus mongolicus* (P > 0.05). The net photosynthetic rate of *Astragalus laxmannii* in 3-7 g·kg^{-1} treatment was significantly higher than that of the control (P<0.05). And the transpiration rate, net photosynthetic rate and intercellular CO_2 concentration were significantly higher than those of *Ammopiptanthus mongolicus* (P<0.05). (3) Compared with the control group, Fv/Fm in 1 g·kg^{-1} treatment group was significantly decreased (P<0.05). The Fv/Fm of *Astragalus laxmannii* treated with more than 5 g kg^{-1} was significantly higher than that of the control group (P < 0.05). Except for 3 g kg^{-1} treatment, the Fv/Fm and QP of *Ammopiptanthus mongolicus* were

higher than those of *Astragalus laxmannii*. (4) Soil properties, photosynthetic gas exchange and chlorophyll fluorescence were partially mediated models. The ratio of direct effect of soil characteristics on chlorophyll fluorescence properties was 66.67%, and the ratio of indirect effect on chlorophyll fluorescence properties was 34.23% by affecting photosynthetic gas exchange. Soil microbial film sand fixation technology improves the hardness, thickness of the consolidated layer and soil enzyme activity. Soil microbial membrane sand fixation technology can improve soil quality, stomatal conductance of leaves and mediate effect to enhance the photosynthetic efficiency and capacity of *Ammopiptanthus mongolicus* and *Astragalus laxmannii*, which has a greater effect on the photosynthetic rate of *Astragalus laxmannii* and electron transport of *Ammopiptanthus mongolicus*. The research results can provide theoretical basis and scientific support for improving soil microbial films sand fixation technology.

Keywords: soil microbial films; psammophyte; photosynthesis; chlorophyll fluorescence