亚热带常绿阔叶林林下灌木光合荧光特性对长期氮磷添加的响应特征

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摘 要:【目的】探究长期氮（N）、磷（P）添加后亚热带常绿阔叶林中林下灌木的光合特性及荧光参数的变化方式及响应特征，为植物光合生理特性应对长期 N 沉降这一全球性气候变化提供基础数据。【方法】本研究基于长达 11 年的 N 及 N+P 添加野外试验，通过野外活体测定红楠（*Machilus thunbergii*）、杜茎山（*Maesa japonica*）、山矾（*Symplocos sumuntia*）、朱砂根（*Ardisia crenata*）4 种林下优势灌木的光合特性、荧光参数，通过分析不同优势树种的叶片净光合速率（P_n）、蒸腾速率（T_r）、水分利用效率（WUE）、气孔导度（G_s）、胞间二氧化碳浓度（C_i）和水蒸汽压亏缺（VPD）变化特征，利用荧光探针技术测定叶片 PSⅡ实际光量子效率（Y(Ⅱ)）、最大光化学效率（*Fv/Fm*）、潜在活性（*Fv/Fo*）、光化学淬灭系数（*qP*）、非光化学淬灭系数（NPQ）、PSⅡ非调节性能量耗散的量子产量（Y(NO)）。结合灌木叶片的光合养分利用效率，对优势灌木树种光合荧光特性对长期 N、P 添加的响应方式进行综合分析。【结果】研究发现：N 及 N+P 添加对叶片的 P_n、WUE、*qP* 及 Y(NO)有显著影响。光合特性中，朱砂根 P_n 显著高于其他树种，与 CK 相比，N 添加后山矾 C_i 显著升高，红楠 C_i 显著下降。荧光参数的种间差异较大，山矾 Y(Ⅱ)显著高于其他优势种，与 CK 相比，N 添加后山矾、红楠、杜茎山 Y(Ⅱ)均呈下降趋势，但 N+P 添加缓解了下降。与 N 添加相比，红楠和杜茎山的 *qP* 均在 N+P 添加后显著上升。杜茎山在不同处理下的 Fv/Fm 显著高于其他树种，而朱砂根 Fv/Fm 最低且显著低于其他优势种。除朱砂根外，其余优势种叶片在 N 添加后 Y(NO)显著增加。红楠和朱砂根的 PNUE 在 N+P 添加后显著提高。【结论】不同树种响应 N 及 N+P 添加的光合特征及荧光参数具有不同特点。其中，除朱砂根外，其余优势种均在 N 添加后启动光保护机制以防止 PSⅡ受到损害。而通过对林下优势树种光合和荧光特性的研究，可以较为准确的观察林下灌木为应对长期 N、P 添加的生理响应策略。

关键词: 氮磷添加；光合特性；荧光参数；林下灌木；亚热带常绿阔叶林

Effects of Nitrogen and Phosphorus Additions on Soil Organic Carbon Storage and its Components in a Subtropical Forest

Abstract:【Objective】To understand how photosynthetic properties and fluorescence parameters of understorey shrubs in subtropical broadleaved evergreen forests respond to long-term nitrogen (N) and phosphorus (P) additions, and to provide basic data on plant photosynthetic physiological properties in response to global climate change with long-term N deposition.【Method】In this study, based on an 11-year field experiment with N and N+P additions, the photosynthetic characteristics, fluorescence and fluorescence of four dominant understory shrubs, *Machilus thunbergia*, *Maesa japonica*, *Symplocos sumuntia* and *Ardisia crenata*, were measured in the field. By analyzing the changes in leaf net photosynthetic rate (P_n), transpiration rate (T_r), water use efficiency (WUE), stomatal conductance (G_s), intercellular carbon dioxide concentration (C_i) and water vapour pressure deficit (VPD) of different dominant tree species, the actual photosynthetic efficiency (Y(II)), maximum photochemical efficiency

基金项目: 国家自然科学基金项目(31770672, 31370626)

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(*Fv/Fm*), and potential activity (*Fv/Fo*), photochemical quenching coefficient (*qP*), non-photochemical quenching coefficient (NPQ), and quantum yield of PSⅡ non-regulated energy dissipation (Y(NO)) were determined using fluorescent probe technique. The photosynthetic nutrient use efficiency of shrub leaves was combined with a comprehensive analysis of the way in which photosynthetic fluorescence characteristics of dominant shrub species respond to long-term N and N+P additions.【Result】It was found that N and N+P addition had significant effects on P_n, WUE, *qP* and Y(NO) of the leaves. In photosynthetic characteristics, P_n of *Ardisia crenata* was significantly higher than other species, and compared to CK, *Ardisia crenata* C_i was significantly higher and C_i of *Machilus thunbergii* was significantly lower than it in N addition. Fluorescence parameters varied significantly between species, with Y(II) of *Symplocos sumuntia* significantly higher than other dominant species, and Y(II) of *Symplocos sumuntia*, *Machilus thunbergii* and *Maesa japonica* all showed a decreasing trend in N addition compared to CK, but the decrease was mitigated by N+P addition. The *qP* of both *Machilus thunbergii* and *Maesa japonica* was significantly higher after N+P addition compared to N addition. *Fv/Fm* was significantly higher in *Maesa japonica* than in the other species under the different treatments, while *Fv/Fm* was lowest and significantly lower in *Ardisia crenata* than in the other dominant species. Y(NO) increased significantly after N addition in leaves of all dominant species except *Ardisia crenata*. PNUE of *Machilus thunbergii* and viburnum increased significantly in N+P addition.【Conclusion】The photosynthetic characteristics and fluorescence parameters of different tree species in response to N and N+P addition have different characteristics. Among them, all dominant species, except viburnum, activated photoprotection mechanisms to prevent damage to PSII in N addition. By studying the photosynthetic and fluorescence characteristics of the dominant tree species in the understory, the physiological response strategies of understory shrubs to long-term N and P addition can be observed more accurately.

Key words: Nitrogen and phosphorus addition; photosynthetic properties; fluorescence parameters; understorey shrubs; subtropical broad-leaved evergreen forest