Effects of irradiance and temperature on photosynthesis in C3, C4 and C3/C4 Panicum species

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Abstract. Species in the Laxa and Grandia groups of the genus Panicum are adapted to low, wet areas of tropical and subtropical America. Panicum milioides is a species with C4 photosynthesis and low apparent photorespiration and has been classified as a C3/C4 intermediate. Other species in the Laxa group are C3 with normal photorespiration. Panicum prioritis is a C3 species in the Grandia group. Since P. milioides has some leaf characteristics intermediate to C3 and C4 species, its photosynthetic response to irradiance and temperature was compared to the closely related C3 species, P. laxum and P. boliviense and to P. prioritis. The response of apparent photosynthesis to irradiance and temperature was similar to that of P. laxum and P. boliviense, with saturation at a photosynthetic photo flux density of about 1 mmol m⁻² s⁻¹ at 30°C and temperature optimum near 30°C. In contrast, P. prioritis showed no light saturation up to 2 mmol m⁻² s⁻¹ and an optimum temperature near 40°C. P. milioides exhibited low CO₂ loss into CO₂-free air in the light and this loss was nearly insensitive to temperature. Loss of CO₂ in the light in the C3 species, P. laxum and P. boliviense, was several-fold higher than in P. milioides and increased 2- to 5-fold with increases in temperature from 10 to 40°C. The level of dark respiration and its response to temperature were similar in all four Panicum species examined. It is concluded that the low apparent photorespiration in P. milioides does not influence its response of apparent photosynthesis to irradiance and temperature in comparison to closely related C3 Panicum species.

Abbreviations. AP, apparent photosynthesis; r, CO₂ compensation point; gl, leaf conductance; gm, mesophyll conductance; PPFD, photosynthetic photon flux density; PR, apparent photorespiration rate; RuBPC, ribulose bisphosphate carboxylase.

Introduction

Panicum milioides Nees ex Trin. (synon. P. hians) is a tropical grass that grows naturally from southern Brazil to as far north as souther Missouri [10, 19]. Several leaf characteristics of P. milioides place it intermediate to C3 and C4 species. These characteristics include leaf anatomy, CO₂ compensation point (r), inhibition of photosynthesis by O₂, and apparent photorespiration rate (PR) [3]. The mechanism of CO₂ fixation in P. milioides is not clearly defined, although δ^{13}C ratios indicate that ribulose bisphosphate carboxylase (RuBPC) is the primary carboxylation enzyme [3, 23]. Evidence for a limited C₄ cycle in P. milioides was presented by Rathnam and Chollet.
but other researchers found almost no $^{14}$C in $C_4$ acids in $P. milioides$ under atmospheric or subatmospheric $CO_2$ levels [7, 11, 14] and little enzyme compartmentation between mesophyll cells (MC) and bundle sheath cells (BSC) [15].

Brown [2] suggested that refixation of photorespired $CO_2$, rather than a limited $C_4$ cycle, is responsible for the intermediate gas exchange characteristics of $P. milioides$ and the closely related $C_3/C_4$ species $Panicum spathellosum$ (syn. $P. schenckii$), since mesophyll conductance ($g_m$) and its reduction by $21\%$ $O_2$ were similar in these two $C_3/C_4$ intermediate species and tall fescue ($Festuca arundinacea$ Schre.) ($C_3$). It was also suggested that refixation of photorespired $CO_2$ in the $C_3/C_4$ species is more efficient at high irradiances, since $I$ and $CO_2$ loss in the light declined with increasing irradiance in $P. milioides$ and $P. spathellosum$ but not in tall fescue [4]. More efficient refixation of photorespired $CO_2$ in $P. milioides$ was also indicated by less loss of $^{14}CO_2$ from $[1-^{14}C]$ glycine and $[1-^{14}C]$ glycolate supplied to leaf discs than from similarly treated leaf discs of the $C_3$ species, $Panicum laxum$ Sw. (12). The fact that $P. milioides$ has lower apparent photorespiration rates ($PR$) and $I$ compared to $C_3$ plants, without higher $g_m$ and $C_4$ biochemical characteristics suggests the lack of a $CO_2$ concentrating mechanism and the probable existence of a $CO_2$ refixation mechanism.

The $CO_2$ concentrating mechanism of $C_4$ photosynthesis has been cited as the basis for high apparent photosynthesis ($AP$) rates, high light saturation levels and high photosynthetic temperature optima in $C_4$ compared to $C_3$ plants [9]. The lower light saturation requirements and temperature optima for $AP$ in $C_3$ plants are primarily due to lack of such a $CO_2$ concentrating mechanism. Measurement of $AP$ in $C_3$ plants under elevated $CO_2$ concentrations results in photosynthetic light and temperature responses which resemble those in $C_4$ plants [16].

Because $C_3$ and $C_4$ plants generally have distinctly different photosynthetic responses to irradiance and temperature and because these responses reflect the presence or lack of photorespiration, experiments were conducted to compare the effects of irradiance and temperature on gas exchange characteristics of $P. milioides$ and closely related $C_3$ and $C_4$ $Panicum$ species.

Materials and methods

Experiment 1

Plants of $P. boliviense$ Hack., accession 133 (synon. $P. hylaecium$) ($C_3$), $P. laxum$ Sw., accession 137 ($C_2$), $P. milioides$, USDA PI No. 285219 ($C_3/C_4$), and $P. prionitis$ Griseb., accession 126 ($C_4$) were grown in the greenhouse under an average day/night temperature regime of $32/23^\circ$C. The first three species belong to the Laxa group and $P. prionitis$ to the related Grandia group in $Panicum$. Supplemental light provided an irradiance of at least $0.38$ mmol m$^{-2}$ s$^{-1}$ photosynthetic photon flux density (PPFD) at plant height