Ecophysiology

DIFFUSIVE AND BIOCHEMICAL LIMITATIONS TO PHOTOSYNTHESIS IN ANTARCTIC PLANTS FROM TWO POPULATIONS IN ANTARCTICA

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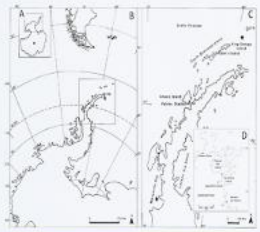
Introduction

Antarctica is the coldest, driest, and windiest continent on Earth. Only two vascular plants have naturally colonized this continent, the hair grass *Deschampsia antarctica* and the pearlwort *Colobanthus quitensis*. Considering the pronounced warming trend that the Antarctic Peninsula has experienced, it seems worth to ask how these species might be affected by climate change. In particular, we know little about the mechanism involved in the photosynthetic regulation of Antarctic plants, what are their anatomical and biochemical limitations, and if there are differences in limitations among populations exposed to different environmental conditions. In this study we evaluate *in situ* the photosynthetic performance of both Antarctic vascular species, focusing in diffusive and biochemical constraints to CO_2 assimilation. Leaf gas exchange, chlorophyll a fluorescence, leaf ultraestructure and Rubisco catalytic properties were examined in plants growing in King George (KGI) and Lagotellerie (LAG) islands.

Materials and Methods

Study area and plant material



King George Island (62°09' S, 58°28' W)
Lagotellerie Island (67° 52' S, 68° 42' W)

Leaf gas exchange and chlorophyll fluorescence

A_N-C_i curves

Relative humidity: 40 and 50%
Leaf temperature: 10 °C and 15 °C

$g_m = A_N / (C_i - (\Gamma^* (ETR + 8 (A_N + R_L)) / (ETR - 4 (A_N + R_L))))$ **(Harley et al. 1992).**

$C_c = C_i - (A_N / g_m)$ **(Manter and Kerrigan 2004).**

V_{cmax}: derived from A_N-C_i **(Farqhuard et al. 1980).**

Rubisco kinetic parameters and $S_{c/o}$ (Gago et al. 2013).

Results

Table 1. The mesophyll thickness (T_{mes}), the cell wall thickness (T_{cw}), the average distance between chloroplasts (ΔL_{cyt}), the chloroplast thickness (T_{chl}), the chloroplast length (L_{chl}), the CO_2 transfer conductances across the intercellular air space (g_{ac}), the liquid phase (g_{lc}) and the mesophyll conductance for CO_2 (g_m) calculated from leaf anatomical measurements, the mesophyll (S_m/S) and chloroplast (S_c/S) surface area facing intercellular air spaces per leaf area. Values are means ± S.E. Different letters indicate significant differences between populations for each species ($P < 0.05$).

	D. antarctica		*C. quitensis*	
	KGI	LAG	KGI	LAG
T_{mes} (µm)	101.03±5.43a	136.27±5.14b	322.29±13.42a	290.77±18.91a
T_{cw} (µm)	0.26±0.01a	0.22±0.03a	0.35±0.06b	0.21±0.02a
ΔL_{cyt} (µm)	0.68±0.18a	0.3±0.16a	0.53±0.06b	0.05±0.03a
T_{chl} (µm)	2.96±0.24a	3.58±0.52a	5.12±0.66b	1.64±0.12a
L_{chl} (µm)	4.40±0.36a	5.48±0.56a	5.32±0.28a	5.92±0.36a
g_{ac} (m s^{-1})	0.046±0.006a	0.031±0.004a	0.013±0.001a	0.019±0.001b
g_{lc} (m s^{-1})	0.0005±0.0001a	0.0005±0.0001a	0.0003±0.0000a	0.0001±0.0001b
g_m (mol m^{-2} s^{-1})	0.022±0.002a	0.023±0.004a	0.013±0.001a	0.039±0.004b
S_m/S (m^2 m^{-2})	6.40±0.75a	6.28±0.51a	4.33±0.48a	8.56±0.53b
S_c/S (m^2 m^{-2})	2.24±0.48b	1.16±0.08a	2.06±0.32a	4.42±0.63b

Table 2. The Rubisco Michaelis-Menten constant (K_c^{air}), the maximum carboxylase catalytic turnover rate (k_{cat}^c) and the specificity factor ($S_{c/o}$). Values are means ± S.E. Different letters indicate statistically significant differences among assay temperatures on each species, and an asterisk denote statistically significant differences between species for each assay temperature ($P < 0.05$).

Temp.	*D. antarctica*			*C. quitensis*		
	K_c^{air}	k_{cat}^c	$S_{c/o}$	K_c^{air}	k_{cat}^c	$S_{c/o}$
5 °C	10.9±1.2a*	0.4±0.1a*	167.5±2.9c	6.9±0.4a*	0.2±0.1a*	172.4±2.0c
15 °C	14.7±0.8a*	1.4±0.2a	151.3±4.5b*	11.1±0.6b*	1.1±0.1b	129.8±3.7b*
25 °C	23.4±1.8b	4.1±0.8b	99.5±4.8a	18.7±0.4c	3.8±0.3c	97.1±2.4a

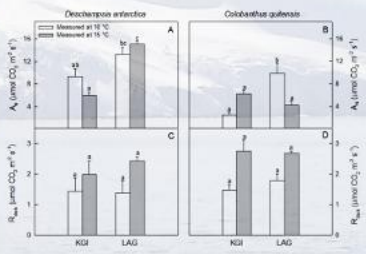


Figure 1. The net photosynthetic CO_2 assimilation rate (A_N) and dark respiration (R_{dark}) of *D. antarctica* and *C. quitensis* in King George (KGI) and Lagotellerie Island (LAG), measured at 10 °C (white bars) or 15 °C (grey bars). Values are means ± S.E. Different letters indicate statistically significant differences on each species between populations and temperatures of measurement ($P < 0.05$).

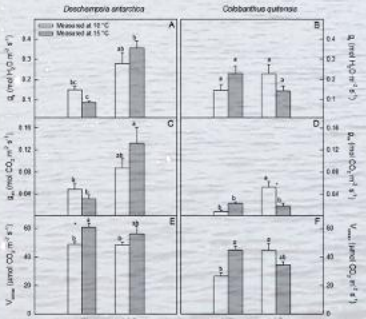


Figure 2. The stomatal and the leaf mesophyll conductances to CO_2, and the maximum rate of Rubisco carboxylation of *D. antarctica* and *C. quitensis* in King George (KGI) and Lagotellerie Island (LAG), measured at 10 °C (white bars) or 15 °C (grey bars). Values are means ± S.E. Different letters indicate statistically significant differences between populations on each species and temperatures of measurement ($P < 0.05$).

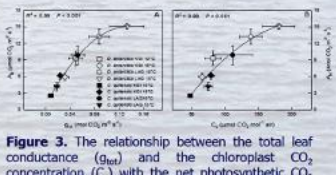


Figure 3. The relationship between the total leaf conductance (g_{tot}) and the chloroplast CO_2 concentration (C_c) with the net photosynthetic CO_2

Conclusions

In spite of the quantitative differences between populations, the diffusive and biochemical mechanism associated to the CO_2 assimilation were similar in both species. The mesophyll conductances were remarkably low, restricting the CO_2 transfer and imposing the strongest constraint to CO_2 acquisition. Rubisco presented a high specificity for CO_2 as determined *in vitro*, suggesting a tight coordination between CO_2 diffusion and leaf biochemistry that may be critical to ultimately optimize carbon balance in these species. Interestingly, both anatomical and biochemical traits resembled those described in plants from arid environments, providing a new insight into plant functional acclimation to Antarctic conditions.

Acknowledgements

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