ニー・オールスンにおける優占種 3 種の光合成の CO_2 応答特性

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Photosynthetic responses to ambient CO_2 of three dominant species in Ny-Ålesund

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The atmospheric concentration of CO_2 is exceeding 400 ppm (V/V) since last year (NOAA). The climate change and global warming affect on ecophysiological characteristics and phonological traits of land plants by changing micro-habitat conditions such as air and soil temperatures, the amount and frequency of precipitation, snow depth, timing of snow melt, and length of growth period. The High Arctic ecosystems are more sensitive to the climate change (Robinson et al. 1998, Rumbf et al. 2014, Walker et al. 2006). Our objective in this study is to clarify characteristics of the leaf photosynthetic response to increasing CO_2 of dominant vascular plant species in a High Arctic tundra ecosystem. Such basic knowledge on leaf photosynthetic performances would contribute to our further research on plant distribution and ecosystem carbon cycle on the glacier foreland. In summer of 2014, we measured the photosynthetic responses to ambient CO_2 of three plant species in the High Arctic tundra, near Ny-Ålesund, in the northwestern area of Spitsbergen, Svalbard, Norway. Three plant species, *Saxifraga oppositifolia*, *Salix polaris*, and *Dryas octopetala* are dominant and frequently occurring species in communities of heath and mesic meadow in Svalbard (Nakatsubo et al. 2005, Van der Wal, et al. 2007, Speed et al. 2010, Cooper et al. 2011, Semenchuk et al. 2013) and comparable to the studies by Muraoka et al. (2002 and 2008) in Ny-Ålesund. Our study method was based on Muraoka et al. (2002 and 2008) as follows. We sampled these plants as small blocks with the soil (about 10cm x10 cm area and 5cm depth) from relatively developed vegetation. The plant samples were put on plastic tray, watered and kept outside the field station so as to receive the ambient irradiance and air temperature until following measurements. We extracted intact plants from these small blocks, and put into the chamber and measured the gas (CO_2) exchange using a portable photosynthesis measuring system with open-gas flow line (LI-6400, LI-COR, Lincoln, Nb.), a new custom chamber made of clear acryl cylinder (inner diameter 8 cm; inner height 5 cm; Meiwafosis, Japan) and a metal halide light source (LA-180Me; Hayashi Tokei Kogyo, Japan). Conditions for CO_2 exchange measurements were the air temperature of 10 ºC for all photosynthetic curves, the reference CO_2 of 400 μmol mol^{-1} for light response curves (0-1200 μmol photons m^{-2} s^{-1}) and the light intensity of 1200 μmol photons m^{-2} s^{-1} for CO_2 response curves (0-1000 μmol CO_2 mol^{-1} air). Firstly, we measured whole plant CO_2 exchange rates under several light intensities or CO_2 concentrations. Then we removed all leaves from the shoots and measured respiration of non-photosynthetic organs, mainly stems and roots. Finally we calculated leaf gas exchange (photosynthesis and dark respiration of leaves) rates based on above results. The plant samples with leaves for *Saxifraga* and removed leaves for *Salix* and *Dryas* were taken pictures using a digital camera (Powershot SX700HS, Canon, Japan). The green area for *Saxifraga* plants and the leaf area for *Salix* and *Dryas* of each image were analyzed using ImageJ 1.48 (NIH, USA) for estimation of CO_2 exchange rates based on the leaf area and leaf mass per area (LMA). After measurements of CO_2 exchange, these samples were freeze-dried, weighed for dry plant mass, and analyzed nitrogen contents using an automatic NC analyzer (Sumigraph NCH-22F; Sumika Chemical Analysis Service, Japan).

We obtained similar results to Muraoka et al. (2008) for photosynthetic light response curves (Alw-PPFD), based on leaf dry weight "lw". The Alw-PPFD of *Sal* was the highest and one of *Sax* was the lowest (Table 1). The maximum Alw-PPFD, that is Amax (nmol CO_2 g^{-1} lw s^{-1}) for *Saxifraga*, *Salix* and *Dryas* were 15, 30 and 27, respectively. For all species, the light saturation points were more than 1000 μmol photons m^{-2} s^{-1}, and the light compensation points were less than 100 μmol photons m^{-2} s^{-1}. In photosynthetic CO_2 response curves (Alw-Ca) based on "lw", we observed that Alw-Ca for *Salix* was the highest and they for *Saxifraga* and *Dryas* were similar (Table 2). Values of the Alw-Ca (nmol CO_2 g^{-1} lw s^{-1}) at 400 and 1000 μmol CO_2 mol^{-1} air for *Saxifraga*, *Salix* and *Dryas* were 20 and 32, 34 and 45, and 24 and 34, respectively. While *Sal* was the lowest and one of *Sax* was the highest in photosynthetic CO_2 response curves (Ala-Ca) based on leaf area "la" (Table 2). Values of the Ala-Ca (μmol CO_2 m^{-2} la s^{-1}) at 400 and 1000 μmol CO_2 mol^{-1} air for *Saxifraga*, *Salix* and *Dryas* were 9 and 14, 5 and 7, and 7 and 11, respectively. We will discuss effects of some leaf traits (LMA and leaf nitrogen content) on these results and their mechanisms.

Table 1. Potosyntehtic response to light (PPFD).

Unit	Species	Amax nmol CO_2 g^{-1} s^{-1} (Mean	± SD)	Rd nmol CO_2 g^{-1} s^{-1} (Mean	± SD)	Light saturation range µmol photons m^{-2} s^{-1}	Light compensation range µmol photons m^{-2} s^{-1}
per leaf dry weight	*Saxifraga oppsitifolia*	15	7	-2	1	> 1000	0 - 100
	Salix Polaris	30	8	-5	4	> 1000	0 - 100
	Dryas octopetala	27	4	-2	0.4	> 1000	0 - 100

Table 2. Photosynthetic response to ambient CO_2.

Unit	Species	Ambient CO_2: 400 µmol mol^{-1} air				Ambient CO_2: 1000 µmol mol^{-1} air	
per leaf dry weight		A nmol CO_2 g^{-1} s^{-1} (Mean	± SD)	Rd nmol CO_2 g^{-1} s^{-1} (Mean	± SD)	A nmol CO_2 g^{-1} s^{-1} (Mean	± SD)
	Saxifraga oppsitifolia	20	2	-5	1	32	4
	Salix Polaris	34	18	-9	2	45	21
	Dryas octopetala	24	5	-42	1	34	7
per leaf area		A µmol CO_2 m^{-2} s^{-1} (Mean	± SD)	Rd µmol CO_2 m^{-2} s^{-1} (Mean	± SD)	A µmol CO_2 m^{-2} s^{-1} (Mean	± SD)
	Saxifraga oppsitifolia	9	1	-2	0.2	14	4
	Salix Polaris	5	2	-2	1	7	2
	Dryas octopetala	8	2	-1	0.3	11	2

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