Effects of soil water conditions on the morphology, phenology and photosynthesis of *Betula ermanii* in the boreal forest

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Introduction

Betula ermanii Cham (Erman's birch)

An early-successional tree species in a boreal forest

Distributed widely in subalpine forests in Japan and the Russian Far East (from 34°N to 62°N) in a various precipitation range.

* In the southern part (58°N) of Kamchatka, Russia, well-developed *B. ermanii* forests are distributed (Kojima 1994, Okitsu 1987)

	Japan	Esso in kamchatka in Russia
Annual precipitation (mm)	1690 *1	399 *2

*1 The Ministry of Land, Infrastructure and Transport fishery resource part for period 1976-2005

*2 Esso-hydrometeorological station for period 1986-2000

B. ermanii **can survive and grow even in a region with a low precipitation in the growing season.**

From the viewpoint of physiological responses of plants

Acclimation potential for various water conditions should be necessary to cope with reduction in net photosynthetic rate under water-deficit conditions.

The mid-successional species (*Acer rufinerve, Bischofia javanica* Blume)

have a higher acclimation potential in light response (Yamashita et al. 2002; Oguchi et al. 2005).

B. ermanii may have a high acclimation potential in water use efficiency (WUE) because it is distributed widely in areas with various water conditions.

Under water-deficit conditions

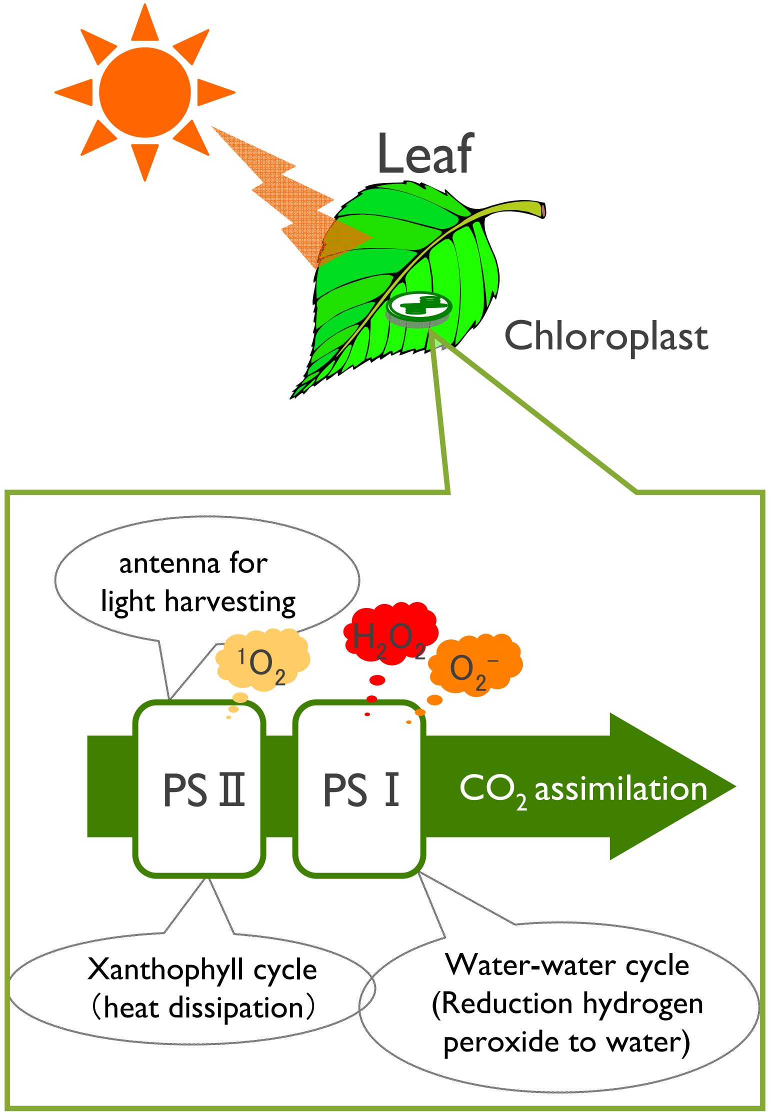
Stomatal closure

↓

Reduces CO_2 availability for chloroplasts
(Reduction photosynthetic rate)

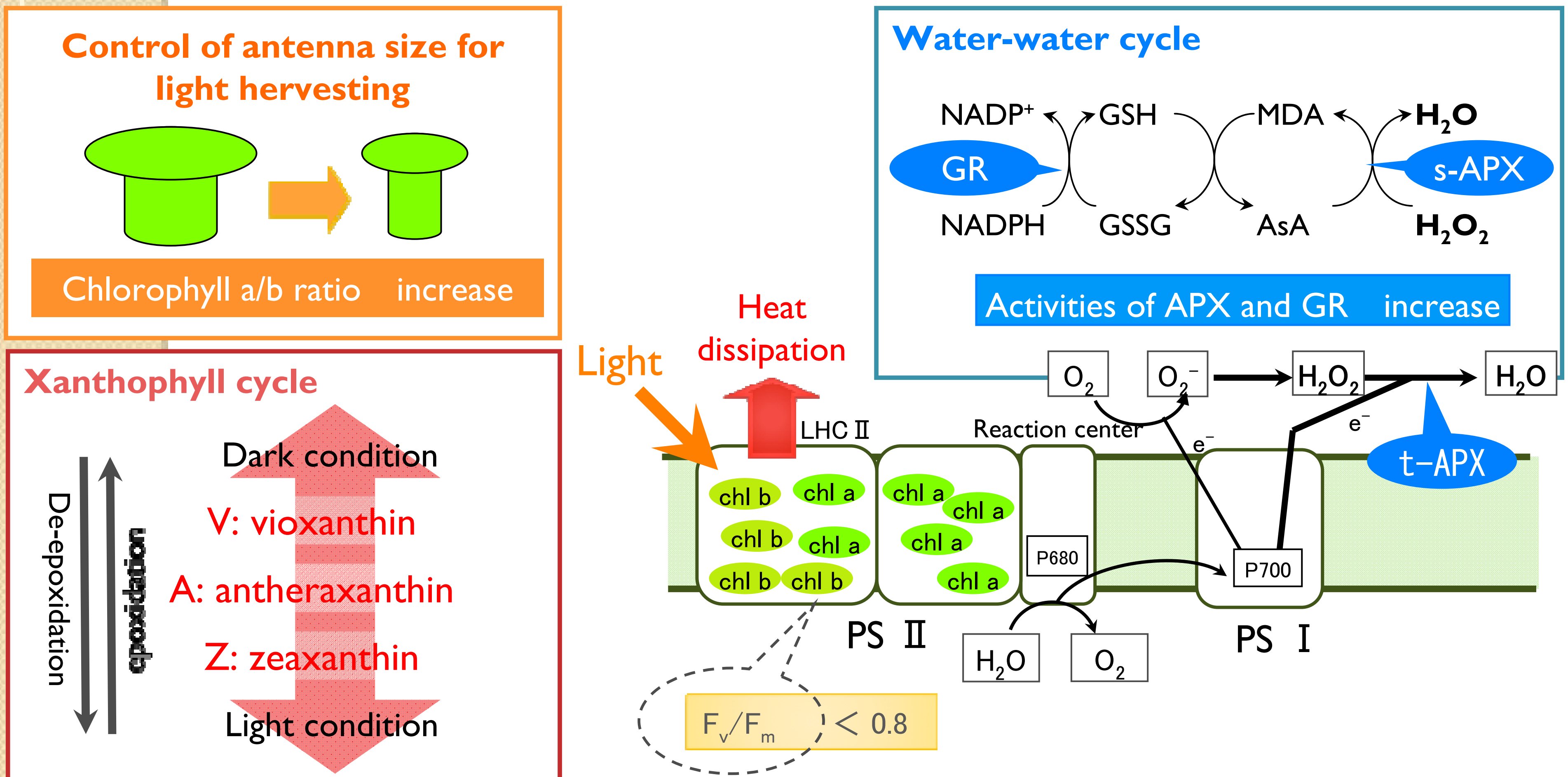
↓

Photoinhibition
by excess energy



The increase in excess energy in water deficit was reported for *B. ermanii* in a boreal forest (Kitao et al. 2003).

Various photoprotective mechanisms

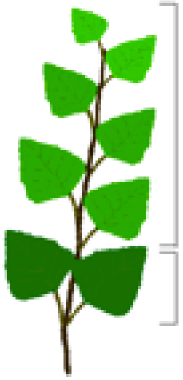


These photoprotective mechanisms are the one of the important roles to survive and maintain growth in the boreal forest.

Another way of adaptation to ambient conditions

Successive leaf emergence

(Kikuzawa 1982)



Late leaves (LLs)

Early leaves (ELs)

ELs and LLs are known to have different phenology and photosynthetic traits in a study of *Betula grossa* (Miyazawa and Kikuzawa 2004).

The formation of winter buds in *B. ermanii* is observed from late May to early July in Japan (Koike 1987).

In flush-type leaf phenology plants (such as *Fagus japonica*),
leaf number, total leaf area, and total leaf length were determined by previous-year PPFD (Kimura et al. 1998).

We can assume that *B. ermanii* also utilizes different characteristics of ELs and LLs to survive even under severe soil water-deficit conditions

Objective

In this study, we investigated how water deficit in the soil influences the morphology, phenology, and photosynthesis of *B. ermanii* seedlings to reveal the mechanisms of acclimation, survival, and growth of *B. ermanii* in the boreal forest.

We focused on the different characteristics of ELs and LLs in *B. ermanii* and effects of soil water conditions in the previous and current years on the morphological, phenological, and photosynthetic responses and individual growth of *B. ermanii* in the current year.

spring — Phenology of *B. ermanii* → summer

Early leaves — Late leaves

Plant materials and growing conditions

3-year-old seedlings of *B. ermanii* were grown in greenhouse at Hokkaido University, Sapporo, Japan (43° 08'N, 141° 34'E)

First year (2004)

Two watering regimes; a pot with 750ml of water

I : irrigated well
watering twice a week（*n*=14）
Equivalent to annual precipitation 1729mm

D : water deficit
watering every two weeks（*n*=10）
Equivalent to annual precipitation 432mm

Second year (2005)

Four 2-year watering treatments; a pot with 750ml of water

II : Irrigated well in both year (*n*=7)

ID : Well irrigated in 2004 and water deficit in 2005 (*n*=7)

DI : water deficit in 2004 and well irrigated in 2005 (*n*=5)

DD : water deficit in both year (*n*=5)

Photographs of *B. ermanii* seedlings in the growing season

I (2004)

Well irrigated → I I (2005)

Water deficit → I D (2005)

D (2004)

Well irrigated → DI (2005)

Water deficit → DD (2005)

Measurement terms

Measurement of soil water content and predown leaf potential

Measurement of morphology and phenology changes

- Leaf area, leaf thickness, leaf dry weight
- Seedling height, seedling base diameter
- Root length, dry root weight
- Leaf number, leaf longevity

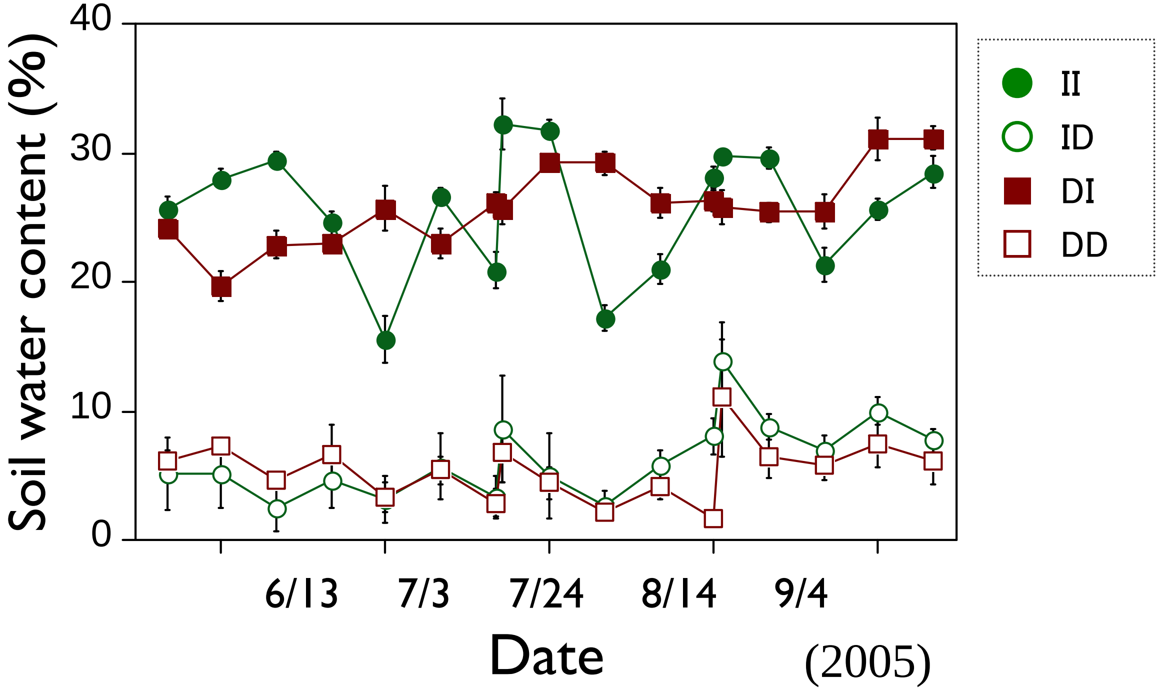
Measurement of changes in photosynthetic responses

- Photosynthetic rates
  and chlorophyll fluorescence (Li-6400, Li-Cor)
  (PAR 1200mmol m^{-2} s^{-1}, 25° C, VPD 1.22~3.08kPa)

Measurement of changes in pigments and enzyme activities

- Chlorophyll and carotenoid contents (HPLC, LC-Vp series, Shimadzu)
- APX and GR activity (spectrophotometer, DU-7400, BECKMAN)

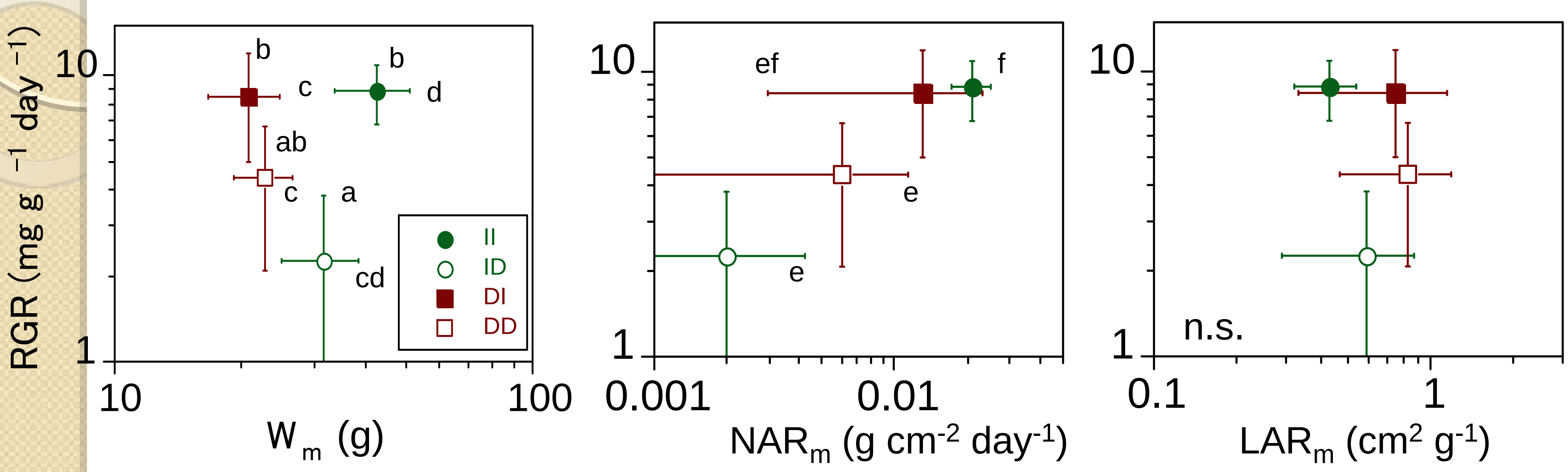
Results:
Changes of soil water content & leaf water potential



Year	Treatment	Predawn leaf water potential (MPa)
2005	II	-0.19 ± 0.02 [a]
	ID	-0.99 ± 0.26 [b]
	DI	-0.37 ± 0.06 [a]
	DD	-0.80 ± 0.17 [b]

Results:

Each of the relationships between RGR and the mean total dry weight, NAR, and LAR



Relative growth rate (RGR_m)
Total dry weight (W_m)
Net assimilation rate (NAR_m)
Leaf area ratio (LAR_m).

$RGR_m = NAR_m \times LAR_m$

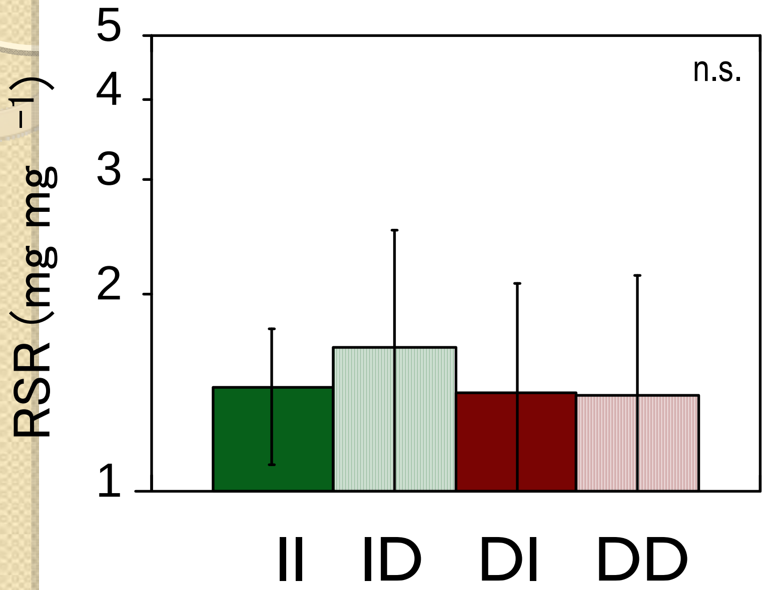
The calculation of RGR_m, NAR_m, and LAR_m were for the period between 30 May 2005 and 1 August 2005.
Values are mean ± CI (n = 3–7). Different letters denote significant differences at $p < 0.05$ (Tukey's pairwise comparison)

RGR_m was not affected by the difference in plant size and LAR_m among the four water treatments.

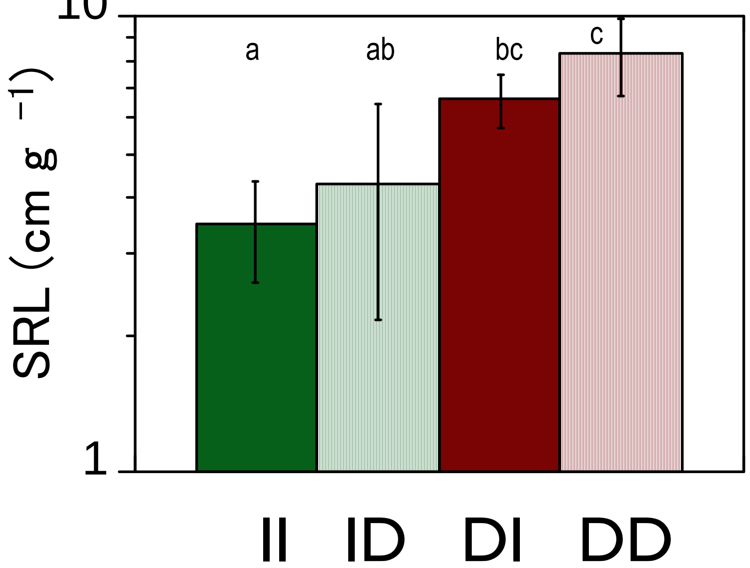
RGR_m appeared to correspond with NAR_m differing due to the watering regime of the current year, i.e., smaller NAR_m in ID and DD seedlings.

Results: Change in RSR and SRL

RSR (root / shoot ratio)



Specific root length
(SRL =total root length /root dry weight)

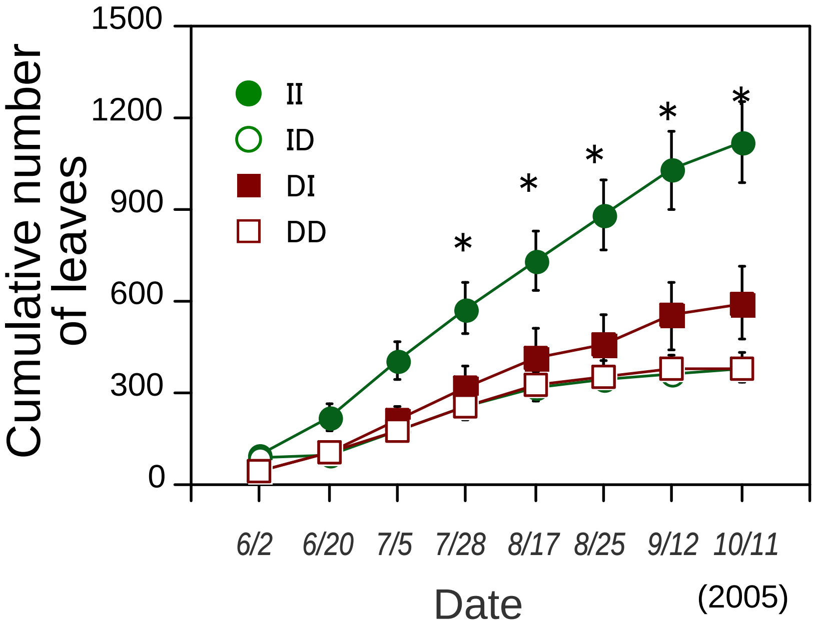


Values are mean ± CI (*n* = 5 to 7). n.s., non-significant.
Different letters denote significant differences at $P \leq 0.05$ (Tukey's test).

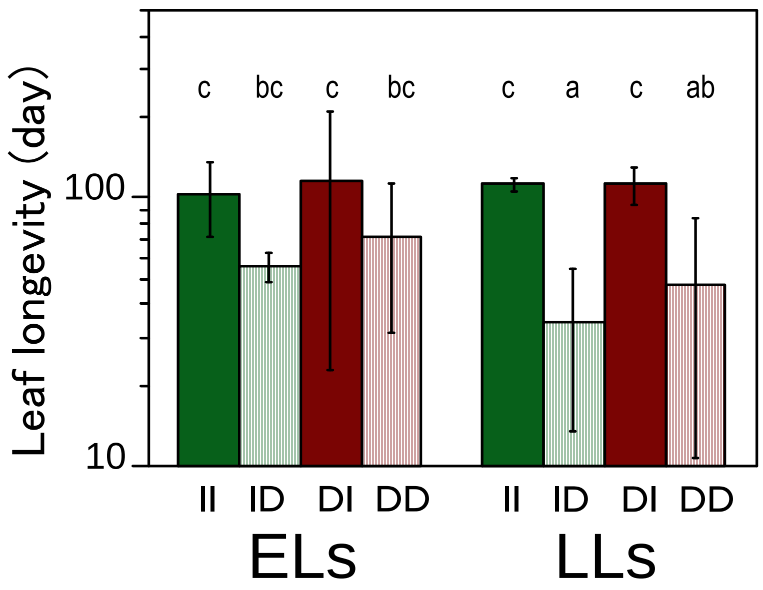
RSR suggests that the mass balance between above- and below-ground parts of *B. ermanii* is maintained constant, regardless of soil water conditions.

Increased SRL by previous-year water deficit suggests that the effect of water deficit in the previous year on the morphology of roots in the current-year is much stronger than that in the current year.

Results:
Change in leaf number (per pot) and leaf longevity



Values are mean ± SE (n = 3 to 7), Asterisk indicates a significant difference at P < 0.05 (Tukey's test)

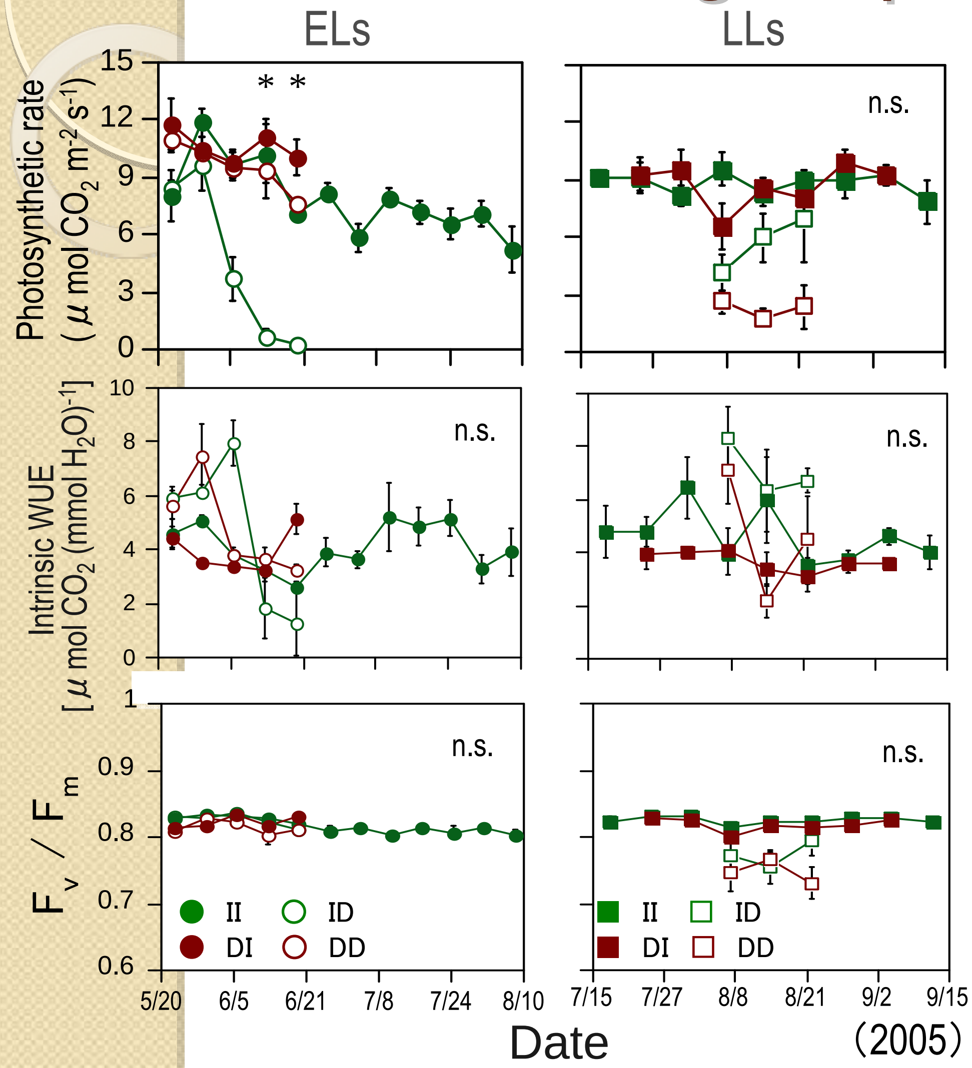


Values are mean ± CI (n = 4 to 7). Different letters denote significant differences at P ≤ 0.05 (Tukey's test).

Cumulative number of leaves that emerged in II (●) was greater than that in the other three watering treatments [ID (○), DI (■) and DD(□)] from 28 July 2005 to 11 October 2005.

ELs and LLs showed different responses of leaf longevity to drought stress

Results:
Seasonal change in photosynthetic responses



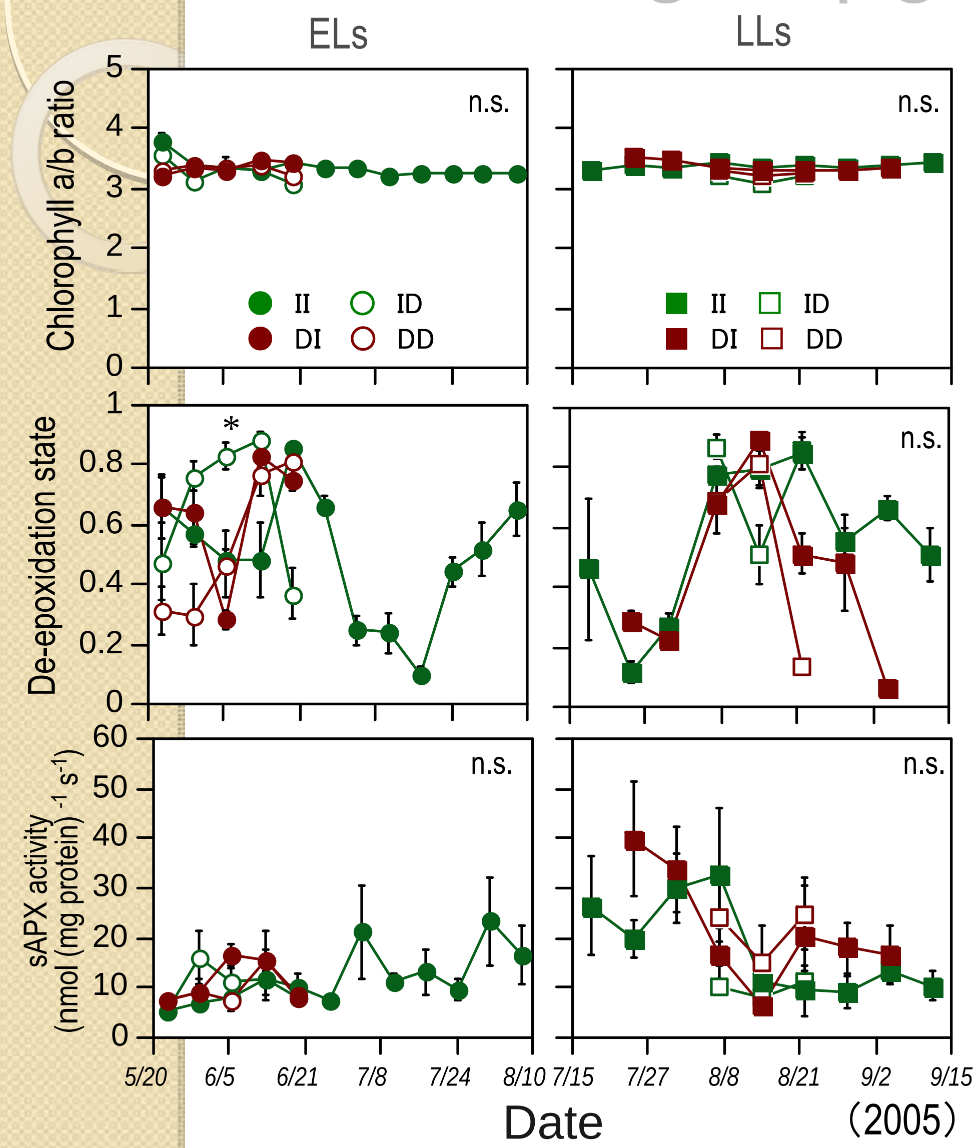
Values are mean ± SE (n = 3 to 4), n.s., non-significant at p > 0.05

Asterisk indicates a significant difference at p < 0.05 (Tukey's test)

Photosynthetic rate of ELs was not decreased significantly by current-year water deficit in the seedlings that experienced water deficit in the previous year (DD).
DD were maintained as high as the other two treatments (DI and II) where seedlings were irrigated well in the current year.

There were no significant differences in intrinsic WUE and F_v/ F_m of both ELs and LLs among the four watering treatments.

Results:
Seasonal change in pigments and enzyme activities



Values are mean ± SE (n = 3 to 4), n.s., non-significant at $p > 0.05$

Asterisk indicates a significant difference at $p < 0.05$ (Tukey's test)

There was no distinctive difference in chlorophyll a/b ratio of both ELs and LLs among the four watering treatments.

The increase in the de-epoxidation state of ELs in the seedlings under water deficit conditions in both years (DD) was delayed compared with that in ID seedlings in the early growing season.

Antioxidant enzyme activities were not affected by the four watering treatments.

Conclusion

These results suggest that

B. ermanii seedlings acclimatize to lasting water deficit largely by changing root morphology as whole-plant-level responses to water deficit, rather than using photoprotective systems of leaves.

This whole-plant-level response is likely to contribute to maintaining RGR of individuals.

Having two types of leaves, ELs and LLs, would also be important for survival and growth as leaf-level responses.

ELs can be physiologically acclimated to water deficit by experiencing previous-year water deficit.

LLs are likely to cope with water deficit by shortening leaf longevity rather than decreasing photosynthetic activities according to current soil water conditions.

These results partly explain how *B. ermanii* seedlings are able to survive and maintain growth even under varying soil water deficit conditions in the boreal forest.

END

Please refer to my paper for the details of this presentation.

Tabata, A., Ono, K., Sumida, A., and Hara, T. (2010) Effects of soil water conditions on the morphology, phenology, and photosynthesis of *Betura ermanii* in the boreal forest, *Ecol. Res.* online first

田畑あずさ「土壌水分条件がダケカンバの形態、フェノロジーと光合成機能に及ぼす影響」，光合成研究，光合成学会，20（1），pp28-32，2010