Effect of Severe Winter Cold on the Photosynthetic Potentials of Three Co-occurring Evergreen Woody Species in a Mediterranean Forest, Catalonia (Spain)

European Geosciences Union
General Assembly 2013
Vienna | Austria |
07–12 April 2013

Dominik Sperlich [1,2], Carlos Gracia [1,2], Josep Peñuelas [3], Santi Sabaté [1,2]

(1) Centre for Ecological Research and Forestry Applications (CREAF), Universitat Autonoma de Barcelona, 08193 Bellaterra, Barcelona, Spain.
(2) Departament d'Ecologia, Facultat de Biologia, Universitat de Barcelona, Diagonal 645, 08028 Barcelona, Spain,
(3) Global Ecology Unit CSIC-CEAB-CREAF, CREAF, Facultat de Ciencies, Universitat Autònoma de Barcelona. 08913 Bellaterra. Spain.

Email corresponding author:
Dominik@creaf.uab.es

INTRODUCTION

❖ Evergreen tree species in the Mediterranean region have to cope with a wide range of environmental stress conditions from summer drought to winter cold. Nonetheless, Mediterranean winter mildness can periodically lead to favourable growth conditions above the threshold for a positive carbon balance . However, there is not much known about the ecophysiological behaviour of tree communities to these highly dynamic conditions of potential growth periods and winter stress. In this work, we investigated the tree physiology in a natural and mature Mediterranean mixed forest after a period of mild winter conditions and the response to a sudden period of intense cold weather by examining the photosynthetic potentials.

Objectives

a) **Diagnose the state of the photosynthetic machinery in winter conditions.**
b) **Carry out a species inter-comparison in the two winter periods.**
c) **Examine the effect of severe winter cold on the photosynthetic machinery.**

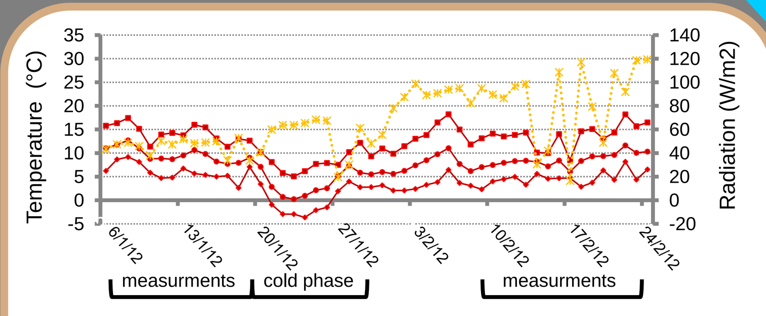

Fig. 1: Maximum, minimum and mean temperature and on secondary x-axses radiation from 06/01/12 to 24/02/12.

Methodology

Species composition:

Holm oak (*Quercus ilex*) dominated forest mixed with pubescent oak (*Quercus pubescens*), Strawberry tree (*Arbutus unedo*) & scattered shelter trees of Aleppo pine (*Pinus halepensis*).

Sampling

Twigs were cut from the sunlit & shaded crown, re-cut submerged under water, then preconditioned at 25°C & dimmed light for 1-5 d.

Gas exchange analyses

A Li-6400 portable photosynthesis system was used to generate carbon response curves to analyse the limitations to photosynthesis at light saturation. The Farquhar *et al.* (1980) photosynthesis model was applied to derive photosynthetic parameters using a nonlinear curve fitting routine following Sharkey *et al.* (2007).

Results

❖ Photosynthetic potentials of *Q. ilex* & *A. unedo* were reduced drastically by winter cold period ranging between 37 -50 %

❖ *P. halepensis* was less affected by the cold period and exhibits in total the highest photosynthetic potentials

❖ J_{max} was more sensitive to the low temperatures then V_{cmax}

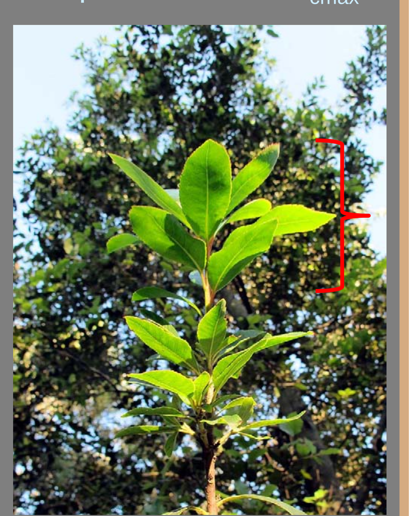

Fig. 3: New shoot growth of *A. unedo* observed during winter.

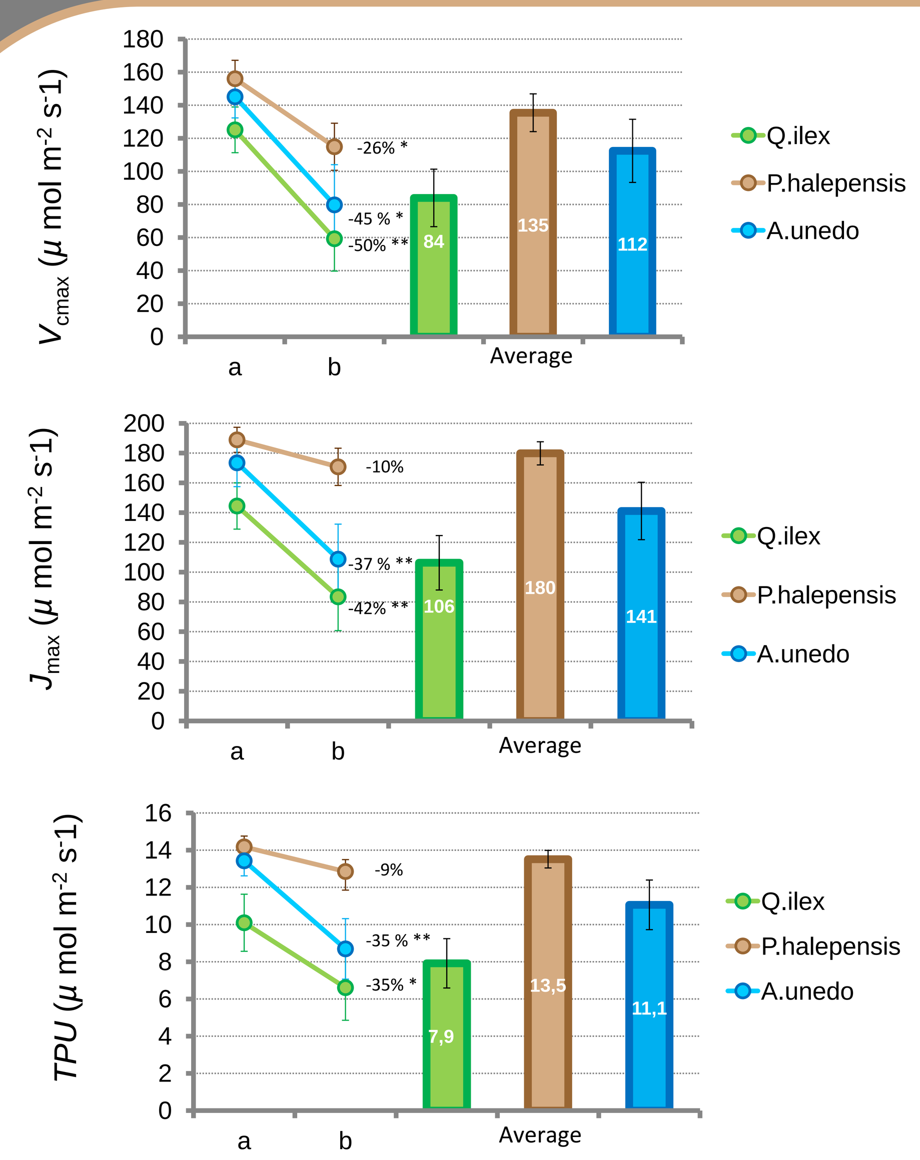

Fig. 1: Maximum rate of RuBP caboxylation (V_{cmax}), maximum rate of electron transport driving RuBP regeneration (J_{max}) and triose phosphate use limitation before the cold period (a) at the end of January (23.1.-02.2.12) and after the cold period (b) in February (14.2.-24.2.12); One asterix (*) indicates significance at p-value < 0.1, two asterix (**) indicate significance at p-value < 0.05.

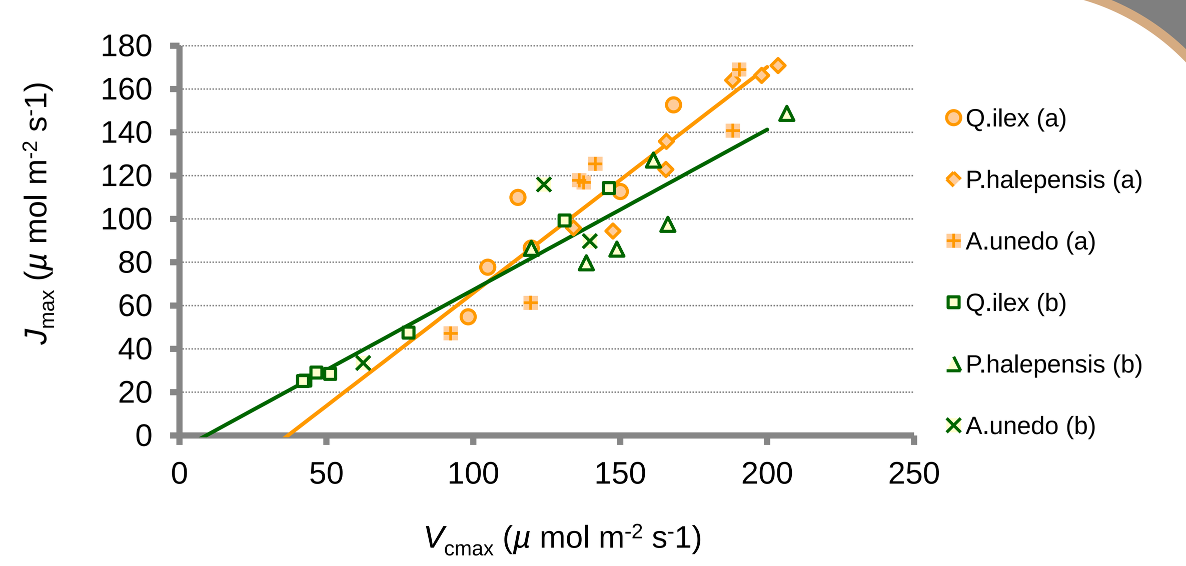

Fig. 2: Maximum rate of electron transport driving RuBP regeneration (J_{max}) over maximum rate of RuBP caboxylation (V_{cmax}), (a) before the cold period in orange at the end of January (23.1.-02.2.12) and (b) after the cold period in green in February (14.2.-24.2.12); (a) $R^2 = 0.87$, f(x) = 1,0434x - 38,5; (b) $R^2 = 0.91$, f(x) = 0,743x - 6,711; the slope decreased from 1,04 to 0,74 in the 2nd measurement period.

	Mean of all species					*Q. ilex*	*P.halepensis*	*A. unedo*
	V_{cmax}	J_{max}	*TPU*	*J/V*	Fv/Fm	Fv/Fm	Fv/Fm	Fv/Fm
Before winter cold (a)	116	148	11	0,76	0.81	0.78	0.83	0.82
After winter cold (b)	77	112	9	0.66	0.75	0.73	0.81	0.73
reducting in %	34	25	23	9	6	6	2	9
p-value	0.008	0.030	0.043	0.034	0.021	0.249	0.020	0.156

Tab. 1: Maximum rate of RuBP caboxylation (V_{cmax}), maximum rate of electron transport driving RuBP regeneration (J_{max}), triose phosphate use limitation, ratio of J_{max} to V_{cmax} (J/V) and Fv/Fm describing the fraction of absorbed photons used in photochemistry by PSII derived from chlorophyll fluorescence measurements before the cold period, at the end of January (23.1.-02.2.12), and after the cold period in February (14.2.-24.2.12).The statistical significance of the difference between them is shown by the p-value .

Fig. 4: Shoot growth of *Q.ilex* observed during winter.

❖ The ratio and the slope of J/V (Tab.1, Fig.2) were reduced significantly after cold period.

❖ The mean of all species of the photosynthetic potentials was reduced by the cold 34% (V_{cmax}), 24 % (J_{max}) and 22% (TPU).

Discussion & Conclusion

❖ Extraordinarily high photosynthetic potentials were observed after a period of mild winter conditions being **equal or higher to the values found in the spring** field campaign (data not shown). In these periods evergreen tree species compensate for the lower photosynthetic potentials during spring & summer in comparison to deciduous species. Additionally, field observation **revealed shoot growth during the winter period of all 3 tree species** (Fig. 3,4). As an early successional and photo-inhibition tolerant species (high Fv/Fm), ***P. halepensis* exhibited the highest photosynthetic potentials**, being only insignificantly affected by the sudden cold phase[3,5] in contrast to *Q. ilex* & *A. unedo.* The potentials of the latter two species instead were **strongly reduced due to the cold up to 50%**, thereby avoiding photo-inhibition stress induced by low temperatures and high irradiance by down regulating the photosynthetic machinery reflected by the lower Fv/Fm ratio. The total J/V ratio was lower after the severe cold due to stronger reductions of V_{cmax} in comparison to J_{max}, indicating a **higher sensitivity of V_{cmax} to low temperatures**[4].

Conclusion

a) The photosynthetic potentials under mild winter conditions were comparable to spring conditions
b) The response to sudden winter cold is highly species specific with max. reductions up to 50 %
***c)* V_{cmax} was more sensitive to the sudden cold phase than J_{max}**

The research leading to these results has received funding from the European Community's Seventh Framework Programme GREENCYCLESII (FP7 2007-2013) under grant agreement n° 238366 & from the projects INIA (RTA04-028-02 and RTA2005-00100-CO2)

References:

1) Ogaya, R., & Peñuelas, J. (2004). Phenological patterns of Quercus ilex, Phillyrea latifolia, and Arbutus unedo growing under a field experimental drought. *Écosicence*, *11*(3), 263–270.
2) Lin, Y.-S., Medlyn, B. E., & Ellsworth, D. S. (2012). Temperature responses of leaf net photosynthesis: the role of component processes. *Tree physiology*, *32*(2), 219–31. doi:10.1093/treephys/tpr141
3) Hikosaka, K., Ishikawa, K., Borjigidai, A., Muller, O., & Onoda, Y. (2006). Temperature acclimation of photosynthesis: mechanisms involved in the changes in temperature dependence of photosynthetic rate. *Journal of experimental botany*, *57*(2), 291–302. doi:10.1093/jxb/erj049
4) Martínez-Ferri, E., Manrique, E., Valladares, F., & Balaguer, L. (2004). Winter photoinhibition in the field involves different processes in four co-occurring Mediterranean tree species. *Tree physiology*, *24*(9), 981–90.