Geophysical Research Abstracts
Vol. 12, EGU2010-579, 2010
EGU General Assembly 2010

Short-term versus long-term responses to drought stress: coupling manipulation experiments with gradient studies

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Water availability is the main factor shaping plants form and function in Mediterranean ecosystems. Understanding the mechanisms that drive plants productivity in drought conditions is crucial in a climate change context. So far, functional relationships between drought stress and leaf physiology has mostly been studied in short term experiments unable to address the potential acclimation in leaf function and the link between short term responses and long term acclimation. Here we hypothesize that the functional relationships between drought and leaf physiology can change under the temporal scale at witch drought is applied. Hence, we measured leaf physiological parameters (gs, gm, Amax, Vcmax Jmax) implicated in the limitation of carbon assimilation on Holm Oak leaves using a design combining 2 contrasting field experiments: (1) a rainfall exclusion experiment simulating a spring extreme drought in order to study short term processes, (2) a natural rainfall gradient (650 mm to 1150 mm) made of 3 plots in order to study long term acclimation. For each experiment we related leaf physiological parameters and their respective limitation to carbon assimilation with predawn leaf water potential as a surrogate of drought stress. Results showed that functional relationships relating gs, Vcmax and Jmax to leaf water potential changed in the total rainfall exclusion, probably because of a strong effect of spring drought on phenology. In addition, trees in the wet plot of the rainfall gradient showed a stronger stomatal conductance decline relative to leaf water potential than trees in the dry plot. We interpret these changes as a result of structural modification at canopy level in the rainfall gradient related to changes in leaf area index (LAI), hydraulic adjustment or fine root/LAI ratio. As a consequence, stomatal limitation of carbon assimilation was stronger in the wet plot than in the dry plot, while total limitation was lower in the dry plot. Water conservation in the dry plot was accomplished by a decrease in leaf are index, which maintain individual leaves in an optimal condition allowing high water use efficiency. This study demonstrate how long term acclimation to drought affect leaf area index, and how this change influence leaf level functioning. We argue that this type of experimental design provide a good framework to study and test hierarchy theory.