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Extreme drought events in Mediterranean forests: phenological response as a preemptive mechanisms for water and nitrogen conservation?

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Global climate change is expected to result in more frequent and intense droughts in the Mediterranean region. To understand forest response to severe drought at different periods of the year, we used a mobile rainfall shelter to examine the impact of spring and autumn rainfall exclusion on phenology and photosynthesis in a holm oak (Quercus ilex) ecosystem. Leaf, female flower, fruit development and maturation were highly affected by the spring rainfall exclusion treatment because predawn leaf water potential started to decrease at the same time actual leaf and female flower were appearing. Half of the sampled trees did not show signs of bud burst and new leaf development. The spring exclusion treatment had much less effects on male flower, probably because they follow an earlier development than leaf and female flower and in consequence, they avoided the decrease in water potential. Spring rainfall exclusion, carried out during increasing atmospheric demand and leaf development, had a larger impact on photosynthesis than autumn exclusion, conducted at a time of mature foliage and decreasing vapour pressure deficit. The relative importance of NSL increased with drought intensity, including balanced reductions in assimilation due to mesophyll conductance (MCL) and biochemical processes (BL). Stomatal closure quickly limited net photosynthesis (An) under mild drought stress. Effects of SL and NSL were equal once total limitation (TL) reached 60%, with 15% contributions from both MCL and BL. Non-stomatal limitation greatly exceeded SL during severe drought, with 76% NSL partitioned equally between MCL and BL when TL reached 100%. Maximum carboxylation rate (Vcmax) and An decreased by more than 70% by midsummer, in response to lower predawn water potential (p). The relationship between p and NSL was steeper than for SL, and the impact of BL was strong at low p during spring exclusion. Leaf lifespan increased with spring exclusion and some trees did not produce new leaves, but the impact of leaf age on An and Vcmax was negligible at low p. Hence, the impact of extreme experimental drought was primarily caused by changes in p, rather than leaf age, which is more important at high p. The results of this study revealed functional changes in the relationship between photosynthetic parameters and water stress that are not currently included in drought parameterizations for photosynthesis modelling applications.