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# Physiological responses of Norway spruce (*Picea abies*) seedlings to drought stress

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**Summary** Four-year-old seedlings of *Picea abies* [L.] Karst (Norway spruce) were grown in semi-controlled conditions with three watering regimes. The seedlings in the control group (c) were watered to prevent any dehydration effect. The two remaining groups were subjected to mild (ms) and severe water stress (ss), respectively. The following physiological variables were monitored until ss seedlings began to die: leaf water potential ($\psi_L$), stomatal conductance ($g_s$), $CO_2$ exchange ($P_N$), free proline content (Pro), total chlorophyll ($a + b$) concentration ($Chl_t$) and the maximal photochemical efficiency of photosystem II ($F_v/F_m$). The results indicate that not all observed physiological parameters display the same degree of sensitivity to dehydration. After Day 12 of dehydration, $\psi_L$ of ss seedlings was already significantly lower than that of the two other groups. On Day 26, significant differences in $\psi_L$ were recorded among all treatments. Decreasing values of water potential were accompanied by early changes in $P_N$, $g_s$ and Pro. A significant decrease in $Chl_t$ and $F_v/F_m$ were only observed during the more advanced stages of dehydration. These results demonstrate that the drought response of *P. abies* seedlings include a number of parallel physiological and biochemical changes in concert, enhancing the capability of plants to survive and grow during drought periods, but only to a point.

*Keywords: chlorophyll, chlorophyll a fluorescence, drought, photosynthesis, proline, stomatal conductance, water potential.*

## Introduction

Water stress limits the potential range of many species by affecting plant production potential and thus establishment and competitive success. The anticipated changes in climate, including changes in precipitation patterns in certain regions on the background of increasing temperatures and atmospheric demand for water, make it imperative to understand species responses to water stress. Considering the sensitivity of *Picea abies* [L.] Karst (Norway spruce) to soil water supply (Karlsson et al. 1997, Wallin et al. 2002, Blödner et al. 2005) and its ecological and economical importance in both natural and planted stands of Europe, it is not surprising that observations of *P. abies* stands showing clear signs of drought stress cause a wide concern.

Because drought is a manifestation of a number of covarying environmental variables interacting with a large number of physiological variables, it is difficult to identify a single physiological variable as an indicator of drought stress in forest tree species. Comparing drought responses of many physiological processes based on a synthesis of available information, Hsiao (1973) proposed a generalized ranking of sensitivity of responses to water stress indexed through the reduction in tissue water potential from that of well-watered plants under mild evaporative demand. In providing the sensitivity chart, Hsiao cautioned that, for reasons of scanty data on some processes and technical difficulties measuring others, the sensitivity rank was based on considerable guesswork. Nevertheless, some of the ranking is fairly certain. For example, the effects of water stress on cell growth and wall synthesis (Hsiao et al. 1976, Nonami 1998) indeed precedes that on gas exchange. Moreover, while the exact water potential at which gas exchange and the accumulation of osmolytes, such as free proline, begin to respond to water stress remains uncertain, a conservative view is that they are affected at a similar water potential. This early work does not provide information directly bearing on chlorophyll contents, except that protochlorophyll formation is affected at about the same stress level as gas exchange and proline. Among the ranked processes, those related to gas exchange (stomatal conductance and photosynthesis) are thought to be affected over nearly the entire range of declining water potential.