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High-light acclimation in *Quercus robur* L. seedlings upon over-topping a shaded environment

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ABSTRACT

High developmental plasticity at the seedling-level during acclimation to the light environment may be an important determinant of seedling establishment and growth in temperate broadleaf forests, especially in dense understories where spatial light availability can vary greatly. Pedunculate oak (*Quercus robur* L.) seedlings were raised beneath a range of artificial light environments (high light, partial high light and low light) to examine morphological and photosynthetic acclimation to vertically stratified light availability. Acclimation observed at the seedling level included changes in proportional distribution of biomass and leaf area ratio to enhance either light gathering under low light availability or reduction of moisture stress under high light availability. Seedling-level acclimation was partially driven by plasticity at the flush level, but plasticity of traits determining flush morphology, such as leaf number, area, and mass, was largely controlled during bud formation rather than during shoot development. Therefore, flush-level acclimation was restricted when shoots elongated from a shaded environment into a high light environment. In contrast, traits influencing leaf-level acclimation, such as leaf thickness, specific leaf area, and pigment concentrations appeared to be driven primarily by the prevailing light environment during leaf development. The plastic response in leaf traits to light environments during shoot development enabled immediate acclimation of photosynthetic capacity to the prevailing light environment. In conclusion, oak seedlings displayed a large phenotypical plasticity on multiple levels that maximized whole seedling performance.

1. Introduction

Light availability near the floor of temperate forests varies greatly and has a strong impact on establishment and growth of tree seedlings (van Hees, 1997; Domke et al., 2007; Niinemets, 2007; Barbier et al., 2008). Presence of understory vegetation may further increase the complexity of the light environment experienced by subordinate seedlings (Löf, 2000). Seedlings able to over-top other understory vegetation experience a high degree of spatial light heterogeneity (Collet et al., 1998). Accordingly, a number of morphological, physiological and biochemical changes can be induced in individual leaves and seedlings to maximize and sustain photosynthetic performance in a heterogeneous light environment (Givnish, 1988; Walters, 2005).

Research on photosynthetic acclimation in herbaceous and woody species has shown a high degree of plasticity in response to gradual and abrupt change in light availability (e.g. Terashima and Evans, 1988; Naidu and DeLucia, 1997, 1998; Rosati et al., 1999; Fownes and Harrington, 2004; Niinemets, 2007). Acclimation responses may be local or involve high integration between different parts of the same plant (Novoplansky, 2002). To gain a more complete understanding of acclimation to light availability by tree seedlings will require investigations of the relevant mechanisms at different functional levels, e.g. at the levels of individual leaves, cohorts of leaves (leaves emerging at the same time), and the whole seedling.

Oak (*Quercus* spp.) seedlings growing under favorable conditions can develop several shoot flushes during a growing season (e.g. Collet et al., 1997; Welander and Ottosson, 2000). After the first flush expands and matures, terminal growth of the shoot

Abbreviations: PPFD, photosynthetic photon flux density; R/FR, red to far-red; C_a, atmospheric CO_2 concentration; C_i, internal CO_2 concentration; A/Q, photosynthetic light response; A/C_i, photosynthetic CO_2 response; A_{max}, maximum gross CO_2 assimilation rate; R_D, apparent dark respiration; I_c, light compensation point; Φ, apparent quantum efficiency; g_{smax}, maximum stomatal conductivity; $V_{c,max}$, maximum rate of carboxylation by Rubisco; J_{max}, light saturated rate of electron transport; N, nitrogen; Chl_{total}, total chlorophyll; $Chl_{a/b}$, chlorophyll a to b; SLA, specific leaf area; LMR, leaf mass ratio; R:S, root to shoot; LAR, leaf area ratio.

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