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# Improved elongation of Scots pine seedlings under blue light depletion is not dependent on resource acquisition

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**Abstract.** Removal of blue light (400–500 nm) induced shoot elongation of 2-year-old Scots pine (*Pinus sylvestris* L.) seedlings, which was not related to resource acquisition (carbohydrates, C/N ratio and soluble proteins) and frost hardening. The seedlings were grown in northern Finland (64°N) in plexiglass chambers, either orange in colour or transparent, during elongation and cold hardening periods in 2001. The orange chamber removed the blue wavelengths. The results suggest that the growth inhibiting effect of blue light on Scots pine elongation is probably a photomorphogenic regulation response; the removal of blue light did not affect the gas exchange and accumulation of growth resources. In addition, the removal of blue light also did not affect the physiological parameters (pigment composition, chlorophyll fluorescence and lipid peroxidation) measured during the preparation for winter.

**Additional keywords:** frost hardening, gas exchange, photomorphogenesis, pigments.

## Introduction

Global warming will cause vegetation to migrate towards the north (ACIA 2005), where it will experience a changed light environment (Taulavuori *et al.* 2010). Thus, vegetation will be exposed to the midnight sun northwards from the Arctic Circle (66.5°) in summer. The midnight sun is usually understood as an extended photoperiod, but also refers to a change in light quantity and quality. Because of the incremental reduction in solar angle associated with movement northward, sunlight travels a longer distance before reaching the earth's surface. Consequently, the quantity of light decreases and the quality of light changes as the scattering of shorter solar wavelengths increases. This especially increases the amount of diffuse blue light (400–500 nm) in the atmosphere, although the actual amount of direct blue light decreases as the solar angle diminishes, which also occurs during the diurnal light rhythm. However, sunset is enriched by the diffuse blue light, and, hence, its proportion in relation to longer wavelengths increases. When the solar angle further declines, the light otherwise shifted to blue turns to twilight and even darkness. Latitudes with polar summer involve a solar angle high enough to provide a blue-dominating light environment throughout summer nights. The amount of time a plant is exposed to light rich in blue wavelengths decreases with decreasing latitude.

Blue light inhibits stem elongation in plants. Fernbach and Mohr (1990) demonstrated that hypocotyl growth of Scots pine is controlled by the far-red absorbing form of phytochrome (Pfr), but requires blue light to become fully responsive to Pfr. Hypocotyl growth is reduced when plants receive both red (changes the red-absorbing form of phytochrome to Pfr) and blue light or white light. In addition to phytochrome (PHY) the control of elongation growth by blue light requires co-action with the blue light receptors cryptochromes (CRY) and phototropin (PHOT) (Parks *et al.* 2001). Stem elongation of the shade-avoiding Scots pine also increases in a shade light of a dense forest (e.g. de la Rosa *et al.* 1998), where canopy foliage efficiently absorbs blue and red wavelengths. In principle shade consists of three components: reduced PAR, reduced R/FR (red/far-red light ratio) and reduced blue light. We mimicked shade by blue light removal and also found an increase in the elongation of Scots pine seedlings (Taulavuori *et al.* 2005; Sarala *et al.* 2007).

The primary objective of the present study was to test whether blue light removal affects the resource acquisition, i.e. do responses to the given light manipulation occur in gas exchange, carbohydrate and protein accumulations as well as in N concentrations and C/N ratios. If altered resource acquisition in response to blue light removal is observed, the idea that the observed elongation response is due to the improved availability of growth resources will be supported. However, this does not exclude the possibility that also changed regulation of the metabolism, in connection with improved acquisition of


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