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Editorial

Applications of Different Light Spectra in Growing Forest Tree Seedlings

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Light intensity, duration and wavelength distribution are amongst the most important factors affecting the success of plant production in different cultivation systems. The aim of this Special Issue was to increase our understanding of the role of light quality in seedling growth and development, and in this way to promote the development of new applications for the production of healthy and vigorous seedlings of tree species.

A wealth of published information exists on the impacts of different light qualities on the growth and development of different plant species in plant production systems [1–3]. Experiments conducted mostly on crop species have shown that plant production and quality can be optimized by manipulating the spectral composition of light [4]. Although artificial light has been used in forest tree nurseries for decades for night interruption or photoperiod extension treatments to control the growth rhythm of seedlings or to increase their growth [5], the development of applications to enhance seedling quality and production efficiency in forest tree nurseries by using different light spectra has only begun recently. The development of LED (light-emitting diode) technology has enabled research into the effect of specific wavebands on the growth and development of different forest tree species [6–8].

Although some information on the responses of forest tree seedlings under nursery conditions is already available, not much is known about the mechanisms behind these seedling responses. OuYang et al. [9], investigated the impacts of different light spectra on the growth of Norway spruce (*Picea abies* (L.) Karst.) seedlings and revealed some of the mechanisms behind these responses. Supplemental light of different spectral composition was applied after sunset. They found that compared to the control treatment, including a combination of blue (B), red (R) and far-red (FR), R light promoted the growth of Norway spruce seedlings, and this response was accompanied by corresponding changes in photosynthetic physiology and the regulation of gene expression.

Camellia oleifera is an important source of *Camellia* oil that is obtained from its seeds. Song et al. [10], explored how different wavelengths of light affected the growth of *C. oleifera* at the physiological and transcriptome levels. The transcriptome profiling identified a large amount of differentially expressed genes in the leaves grown under different light conditions. These results provide insight into the molecular mechanisms by which *C. oleifera* responds to various light qualities. Interestingly, plantlets growing under B light displayed superior growth as compared to plantlets grown under R or white (mixture of B, green (G) and R) light. In the existing literature, the impact of additional B light on growth of different woody plants has been variable even within a tree species. For example, an increased proportion of B in photosynthetic light either increased, reduced, or had no effect on the growth of Norway spruce seedlings [11–13]. These different responses may have been caused by the different seed origins and the experimental setup, but may also indicate that the impact of B light varies according to the growth conditions. On the other hand, in several studies conducted in the boreal area, the growth of Scots pine (*Pinus sylvestris* L.) seedlings has been reduced by B light, regardless the experimental setup [12,14–16].

Light and temperature are important factors affecting growth rhythm of tree species growing in boreal and temperate areas. Chiang et al. [17], studied the interactive effects

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of temperature and day extension with B, red R or FR or different R:FR ratios on growth–dormancy cycles and the expression of related genes in Norway spruce seedlings. They found that the R treatment delayed or prevented bud set and advanced subsequent bud burst under elevated temperatures, while FR and B acted independently of temperature. This emphasizes the need to study the impacts of light spectra on forest tree seedlings under different growth conditions to fully understand the interactive effects of light quality and various environmental factors on the growth, physiology, and annual growth rhythm of tree seedlings.

Studies on horticultural crops have shown that light quality, intensity, and photoperiod may affect the absorption and utilization of nutrients by plants [18]. Wei et al. [19] showed that the quality of growth light has an impact not only on the growth characteristics of Korean Pine (*Pinus koraiensis*) seedlings, but it can also alter the nutrient dynamics in the shoots and roots of the seedlings.

The optimal light intensity for growth and survival differs between plant species. A plant's ability to regulate its morphological, anatomical, and physiological characteristics according to prevailing quantity and quality of radiation is an important factor determining its survival in challenging environments [20]. Wang et al. [21] investigated the plasticity of leaf traits in seedlings of *Juglans regia* f. *luodianense* in growth habitats with different light intensities in the Karst region in China. They found that the seedlings were able to regulate their morphological characters according to light intensity, which explained the survival of the species in the demanding environment.

The use of artificial lighting is obligatory in some processes in tree seedling cultivation. Unpredictable weather conditions and the requirement for stock types that are targeted for planting in different planting periods have increased the need to develop year-round pre-cultivation systems for tree seedlings. Transplant seedlings are grown in mini-containers in indoor plant growth facilities. To be able to generate optimal growth conditions in these facilities the light conditions need to be adjusted according to the needs of the seedlings. The light intensity of the LEDs used in indoor cultivation systems is usually much lower than that of sunlight. Hernandez Velasco and Mattsson [22] investigated methods that could be used to mitigate light shock stress in Norway spruce and Scots pine seedlings that are transplanted from indoor cultivation to outdoor sunlight exposure. They exposed seedlings to increased light intensity or ultraviolet A (UVA) radiation treatments at the end of the indoor cultivation or to a period under a shading cloth after the indoor cultivation. These treatments, however, did not significantly improve the adaptation of the seedlings to the changing light conditions. Although the seedlings recovered from the light shock stress later in the growing season, some of their growth potential might have been lost in their early growth phase. The authors concluded that increasing the light intensity or addition of UV radiation to the indoor lighting during the whole growth period could mitigate this problem, but these measures would substantially increase the energy consumption of the growth facilities. This emphasizes the need to develop resource-efficient growth methods, as the number and size of vertical farms producing different crops is rapidly increasing [23].

Somatic embryogenesis (SE) is being developed as a method for the vegetative propagation of conifers. The aim is to enhance the implementation of the results achieved by tree breeding by producing plants of uniform quality. Varis et al. [24] studied the effects of combinations of wavelengths in different stages of Norway spruce SE production. Although they found that low-intensity LED lights during the propagation process had little overall effect on the embryo productivity or survival, they suggest that G light during proliferation could be beneficial to embryo productivity and for the later growth of the embryos. This agrees with recent suggestions that G light makes a significant contribution to plant productivity, and that it may be beneficial to include G wavelengths in greenhouse LED lights [3]. However, the responses of the SE cultures were more affected by the genotype than by the light quality treatments. This suggests that the lighting protocol needs to be adjusted according to the genotype of the SE culture, which requires further research on the subject.

The publications included in this Special Issue provide new information on the impacts of light spectral composition on the growth, morphology, growth rhythm and nutrient dynamics of seedlings of different tree species and reveal some molecular mechanisms behind these responses. They provide broad insight into how the existing and new information could be applied to the production of tree seedlings in the future.

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References

1. Huché-Thélier, L.; Crespel, L.; Gentilhomme-Le Gourrierec, J.; Morel, P.; Sakr, S.; Leduc, N. Light signaling and plant responses to blue and UV radiations—Perspectives for applications in horticulture. *Environ. Exp. Bot.* **2016**, *121*, 22–38. [CrossRef]
2. Demotes-Mainard, S.; Péron, T.; Corot, A.; Bertheloot, J.; Le Gourrierec, J.; Pelleschi-Travier, S.; Crespel, L.; Morel, P.; Huché-Thélier, L.; Boumaza, R.; et al. Plant responses to red and far-red lights, applications in horticulture. *Environ. Exp. Bot.* **2016**, *121*, 4–21. [CrossRef]
3. Smith, H.L.; McAusland, L.; Murchie, E.H. Don't ignore the green light: Exploring diverse roles in plant processes. *J. Exp. Bot.* **2017**, *68*, 2099–2110. [CrossRef] [PubMed]
4. Paradiso, R.; Proietti, S. Light-Quality Manipulation to Control Plant Growth and Photomorphogenesis in Greenhouse Horticulture: The State of the Art and the Opportunities of Modern LED Systems. *J. Plant Growth Regul.* **2021**. [CrossRef]
5. Landis, T.D.; Tinus, R.W.; McDonald, S.E.; Barnett, J.P. The Container Tree nursery manual. In *Atmospheric Environment, Agricultural Handbook 674*; U.S. Department of Agriculture, Forest Service: Washington, DC, USA, 1990; Volume 3, 145p.
6. Mølmann, J.A.; Junttila, O.; Johnsen, Ø.; Olsen, J.E. Effects of red, far-red and blue light in maintaining growth in latitudinal populations of Norway spruce (*Picea abies*). *Plant Cell Environ.* **2006**, *29*, 166–172. [PubMed]
7. Chiang, C.; Aas, O.T.; Jetmundsen, M.R.; Lee, Y.; Torre, S.; Fløistad, I.S.; Olsen, J.E. Day Extension with Far-Red Light Enhances Growth of Subalpine Fir (*Abies lasiocarpa* (Hooker) Nuttall) Seedlings. *Forests* **2018**, *9*, 175. [CrossRef]
8. Riikonen, J. Efficiency of night interruption treatments with red and far-red light-emitting diodes (LEDs) in preventing bud set in Norway spruce seedlings. *Can. J. For. Res.* **2018**, *48*, 1001–1006. [CrossRef]
9. OuYang, F.; Ou, Y.; Zhu, T.; Ma, J.; An, S.; Zhao, J.; Wang, J.; Kong, L.; Zhang, H.; Tigabu, M. Growth and Physiological Responses of Norway Spruce (*Picea abies* (L.) H. Karst) Supplemented with Monochromatic Red, Blue and Far-Red Light. *Forests* **2021**, *12*, 164. [CrossRef]
10. Song, Q.; Chen, S.; Wu, Y.; He, Y.; Feng, J.; Yang, Z.; Lin, W.; Zheng, G.; Li, Y.; Chen, H. Comparative Transcriptome Analyses of Gene Response to Different Light Conditions of Camellia oleifera Leaf Using Illumina and Single-Molecule Real-Time-Based RNA-Sequencing. *Forests* **2020**, *11*, 91. [CrossRef]
11. OuYang, F.; Mao, J.F.; Wang, J.; Zhang, S.; Li, Y. Transcriptome Analysis Reveals that Red and Blue Light Regulate Growth and Phytohormone Metabolism in Norway Spruce [*Picea abies* (L.) Karst]. *PLoS ONE* **2015**, *10*, e0127896. [CrossRef]
12. Riikonen, J.; Kettunen, N.; Gritsevich, M.; Hakala, T.; Tahvonen, R. Growth and development of Norway spruce and Scots pine seedlings under different light spectra. *Environ. Exp. Bot.* **2016**, *121*, 112–120. [CrossRef]
13. Navidad, H.; Fløistad, I.S.; Olsen, J.E.; Torre, S. Subalpine Fir (*Abies laciocarpa*) and Norway Spruce (*Picea abies*) Seedlings Show Different Growth Responses to Blue Light. *Agronomy* **2020**, *10*, 712. [CrossRef]
14. Sarala, M.; Taulavuori, E.; Karhu, J.; Laine, K.; Taulavuori, K. Growth and pigmentation of various species under blue light depletion. *Boreal Environ. Res.* **2011**, *16*, 381–394.
15. Riikonen, J. Pre-cultivation of Scots pine and Norway spruce transplant seedlings under four different light spectra did not affect their field performance. *New For.* **2016**, *47*, 607–619. [CrossRef]
16. Alakärppä, E.; Taulavuori, E.; Valledor, L.; Marttila, T.; Jokipii-Lukkari, S.; Karppinen, K.; Nguyen, N.; Taulavuori, K.; Häggman, H. Early growth of Scots pine seedlings is affected by seed origin and light quality. *J. Plant Physiol.* **2019**, *237*, 120–128. [CrossRef]
17. Chiang, C.; Viejo, M.; Aas, O.T.; Hobrak, K.T.; Strømme, C.B.; Fløistad, I.S.; Olsen, J.E. Interactive Effects of Light Quality during Day Extension and Temperature on Bud Set, Bud Burst and PaFTL2, PaCOL1-2 and PaSOC1 Expression in Norway Spruce (*Picea abies* (L.) Karst.). *Forests* **2021**, *12*, 337. [CrossRef]
18. Xua, J.; Guo, Z.; Jiang, X.; Ahammedd, G.J.; Zhoua, Y. Light regulation of horticultural crop nutrient uptake and utilization. *Hortic. Plant J.* **2021**, *7*, 367–379.
19. Wei, H.; Hauer, R.J.; Chen, G.; Chen, X.; He, X. Growth, Nutrient Assimilation, and Carbohydrate Metabolism in Korean Pine (*Pinus koraiensis*) Seedlings in Response to Light Spectra. *Forests* **2020**, *11*, 44. [CrossRef]
20. Larcher, W. *Physiological Plant Ecology*, 4th ed.; Springer: Berlin/Heidelberg, Germany, 2003; 513p.
21. Wang, D.; Huang, X.; Chen, J.; Li, L.; Cheng, J.; Wang, S.; Liu, J. Plasticity of Leaf Traits of *Juglans regia* L. f. luodianense Liu et Xu Seedlings Under Different Light Conditions in Karst Habitats. *Forests* **2021**, *12*, 81.

22. Hernandez Velasco, M.; Mattsson, A. Light Shock Stress after Outdoor Sunlight Exposure in Seedlings of *Picea abies* (L.) Karst. and *Pinus sylvestris* L. Pre-Cultivated under LEDs—Possible Mitigation Treatments and Their Energy Consumption. *Forests* **2020**, *11*, 354. [CrossRef]
23. Butturini, M.; Marcelis, L.F.M. Vertical farming in Europe: Present status and outlook. In *Plant Factory—An Indoor Vertical Farming System for Efficient Quality Food Production*, 2nd ed.; Kozai, T., Niu, G., Takagaki, M., Eds.; Academic Press—Elsevier: Amsterdam, The Netherlands, 2020; pp. 77–91, ISBN 9780128166918.
24. Varis, S.; Tikkinen, M.; Välimäki, S.; Aronen, T. Light Spectra during Somatic Embryogenesis of Norway Spruce—Impact on Growth, Embryo Productivity, and Embling Survival. *Forests* **2021**, *12*, 301. [CrossRef]