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Basil cultivation without sunlight

Proceedings in LED technology

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Introduction

Light-emitting diode (LED) technology is irrevocably linked to great achievements in horticulture ranging from greenhouse applications to climate rooms and vertical farming (Bantis et al. 2018). To establish a high-quality as well as cost-efficient urban and greenhouse production system in Berlin and Brandenburg all year round, an LED illumination system was developed and tested which optimally reflects the sunlight spectrum in the range of the photosynthetically active (400-700 nm) radiation with elevated intensities at 450 and 660 nm *(Figure 1)*. The LED lights also include ultraviolet A and B (280-400 nm) radiation [9,1 and 0,9 W/m^2, respectively], which is suspected to alter the production of essential oils and thus increase the quality of plants.

Material and Methods

To evaluate the effectivity of the LED lights for the cultivation of basil plants, a randomized full-factorial experiment with two different light intensities (PPFD of 100 and 200 µmol/m^2/s) and four independent replications with four basil cultivars (*Ocimum basilicum* L. var. *odoratum* \`Anise\`, *O. basilicum* L. var. *cinnamomum* \`Cinnamon\`, *O. basilicum* L. var. *thyrsiflorum* \`Thai Magic\`, and *O. basilicum* L. var. *purpureum* \`Dark Opal\`) under the exclusion of natural sunlight was conducted. Weekly, plant height and developmental state of leaves, shoots and flowers of 288 individuals per cultivar and light intensity treatment were assessed. In a second experiment with identical study design, UV-A (315-400 nm) and UV-B (280-315 nm) light were added to the spectrum with the PPFD of 200 µmol/m^2/s. For GC analysis, 200 mg of air-dried basil leaves were homogenized in 1 ml isooctane containing carvacrol as internal standard. After sonification and centrifugation, the supernatants were investigated by GC (Agilent Technologies 6890N). Each sample was replicated eight times. So far, retention indices as well as standard substances were used to varify the identity of the detected substances and GC-MS measurements will follow. Statistical analyses were performed using the program R (R Core Team 2018). A mixed-effects model was used to analyze the main effect of light intensity and the measurements over time as well as the main effect of spectral range and chemotype.

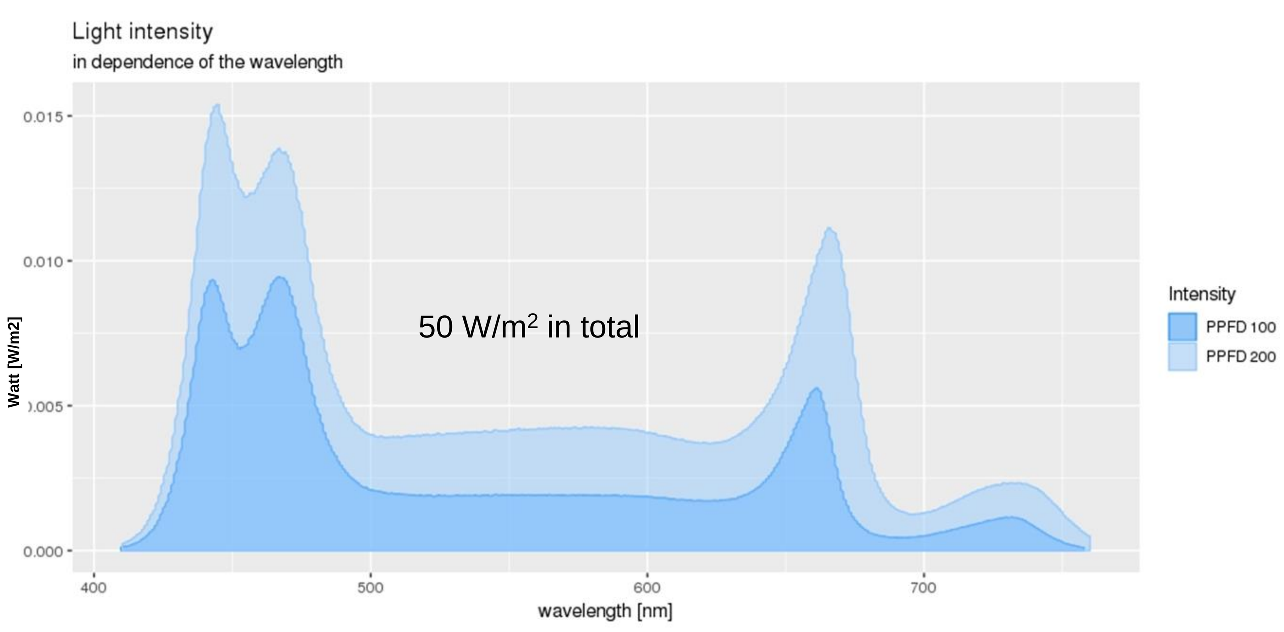

Figure 1 – Light intensity [W/m^2] per wavelength [nm] of the LED lights at canopy level. Dark blue represent the maximum light intensity with a PPFD of 200, light blue depicts the lower light intensity with a PPFD of 100 used in all experiments.

Results I – Weekly assessment of plant development

The weekly assessments of plant development demonstrate a significantly faster growth and development of *Ocimum basilicum* L. var \`cinnamomum\` *(Figure 2-3)*, *Ocimum basilicum* L. var. \`purpureum\` *(Figure 4)* and both other basil cultivars *(data not shown)* when grown under the maximal light intensity with a PPFD of 200 µmol/m^2/s in comparison to basil cultivars grown under the lower light intensity with a PPFD of 100 µmol/m^2/s. However, comparable plant growth results are achieved after not more than one and a half weeks under the lower light intensity. Growth and development of *Ocimum basilicum* L. var. \`purpureum\` *(Figure 4)* and all other basil cultivars tested (data not shown) do not differ between both UV treatments but are slowed down by up to nine days in comparison to the results found in the intensity experiment.

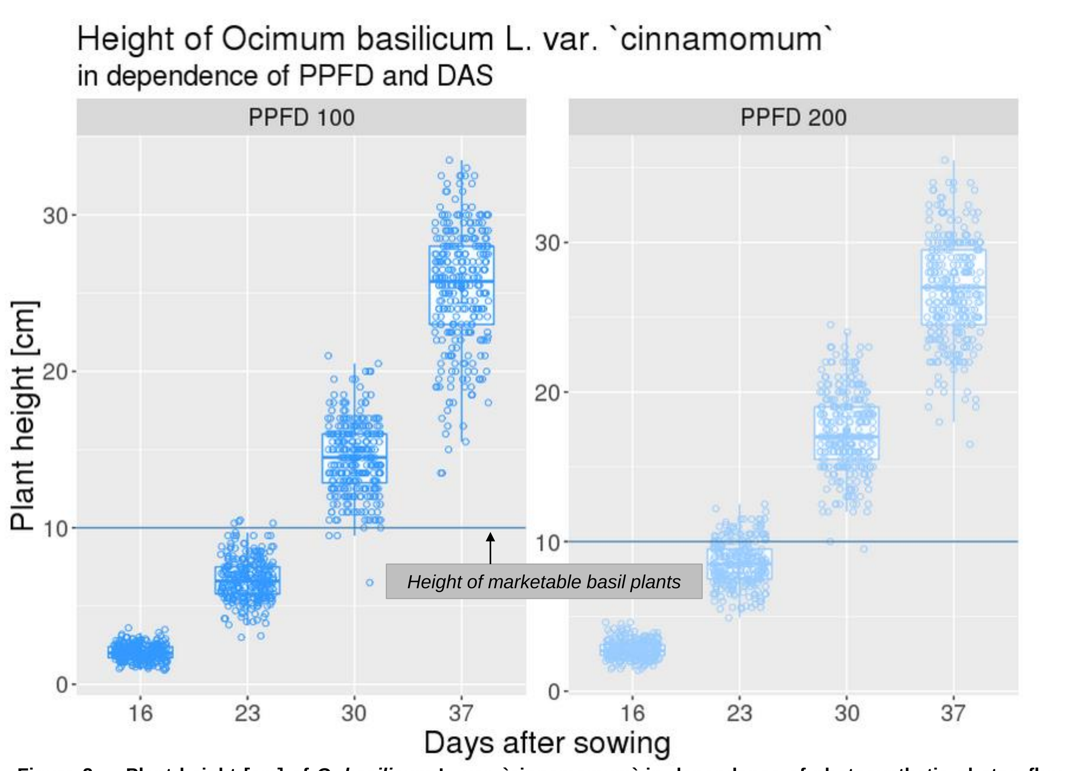

Figure 2 – Plant height [cm] of *O. basilicum* L. var. \`cinnamomum\` in dependence of photosynthetic photon flux density (PPFD) [µmol/m^2/s] and days after sowing (DAS) [n]; each black circle depicts the height of one basil plant; black horizontal line represents the common marketable height of basil plants.

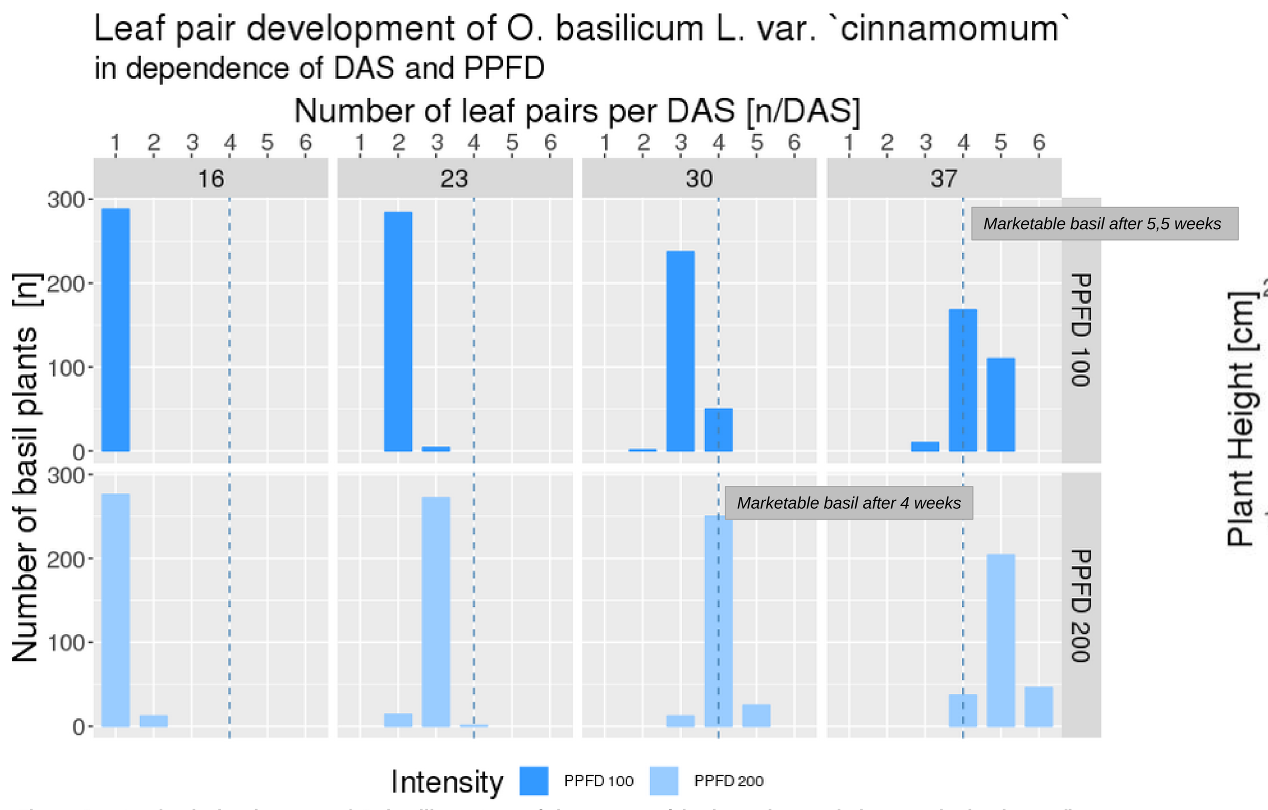

Figure 3 – Leaf pair development of O. basilicum L. var \`cinnamomum\` in dependence of photosynthetic photon flux density (PPFD) [µmol/m^2/s] and days after sowing (DAS) [n]; dashed blue lines represent the common marketable leaf pair stage of basil plants.

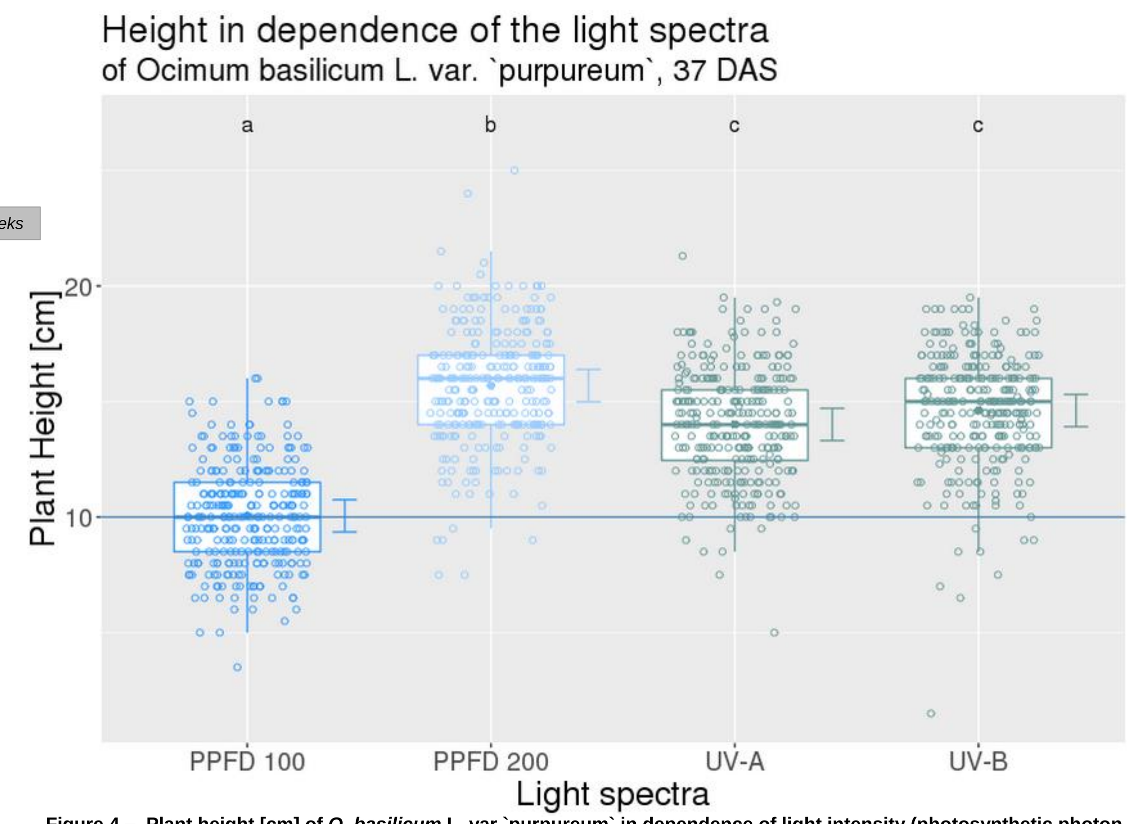

Figure 4 – Plant height [cm] of *O. basilicum* L. var \`purpureum\` in dependence of light intensity (photosynthetic photon flux density (PPFD) of 100 and 200 µmol/m^2/s) and light spectra (UV-A and UV-B radiation added to a light intensity of 200 µmol/m^2/s) 37 days after sowing (DAS); each black circle depicts the height of one basil plant; black horizontal line represents the common marketable height of basil plants; significant differences ($p \leq 0.005$) are illustrated by different letters

Results II – Content and composition of essential oil compounds

The preliminary evaluation of the GC-FID analysis reveals increasing amounts of most major essential oil compounds over time, and higher contents of such when grown under a PPFD of 200 µmol/m^2/s rather than 100 µmol/m^2/s in *O. basilicum* L. var. \`thyrsiflorum\` *(Figure 5)* and all other three basil chemotypes tested *(data not shown)*. The most prevailing essential oil compound β-elemene, which represents up to 34% of the total extract of *O. basilicum* L. var. \`thyrsiflorum\` *(Figure 5)*, increases the most, and is known for it's anti-proliferative effects on cancer cells (Zhu et al. 2011). Exceptions to the increasing trend of volatile substances represent the two aroma compounds estragole (methyl chavicol) and methyl eugenol, which demonstrated to be genotoxic carcinogens (BgVV, 2001). Their contents decrease with time, and more rapidly when grown under higher PPFD conditions. When UV radiation is added to the light spectra, the data implies reduced contents of essential oil compounds. However, no significant changes in the composition of the substances under all treatments were observed *(data not shown)*.

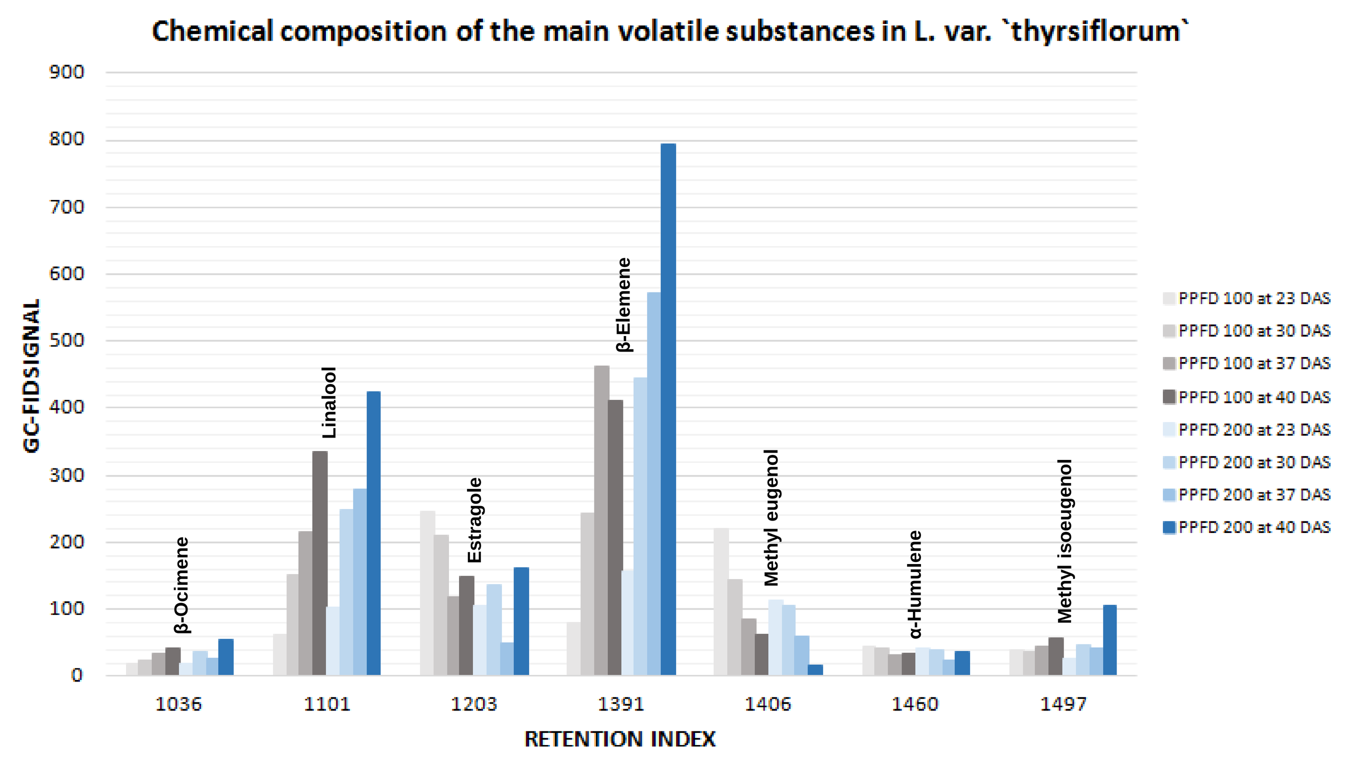

Figure 5 – Chemical composition of volatile substances in *Ocimum basilicum* L. var. \`thyrsiflorum\` in dependence of DAS (days after sowing) under a photosynthetic photon flux density (PPFD) of 100 µmol/m^2/s (see grey bars) and a PPFD of 200 µmol/m^2/s (see blue bars). Main compounds were identified by retention indices for a series of n-alkanes and standard substances

Conclusion and Perspective

Within the short cultivation period of four weeks, all basil cultivars grown under the high light intensity reached marketability, which is only met under optimal commercial greenhouse cultivation conditions of the region, and takes up to seven weeks in dependence of the season. A PPFD of 100 µmol/m^2/s as well as the addition of UV radiation delays the development of all four basil cultivars by a maximum of nine days.
Under all tested light intensities and spectral ranges, the LED system permits an accelerated, high-quality, as well as target-oriented production of top-quality basil under the absence of sunlight. Additionally, the preliminary evaluation of the GC-FID analysis substantiates the production of high-quality basil plants.
However, the final evaluation of the applied LED system will be only possible when the composition of the basil leaves has been properly determined by GC-MS and the outcome of an extensive cost-benefit analysis has been calculated in detail.

Bantis et al. (2018) Current status and recent achievements in the field of horticulture with the use of light-emitting diodes (LEDs). Scientia Horticulturae 235. 437-451.
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