THE EFFECTS OF RED, BLUE AND WHITE LIGHT ON THE GROWTH AND DEVELOPMENT OF *CANNABIS SATIVA* L.

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Abstract: The aim of this study was to investigate the effect of red (600–700 nm, peak 660), blue (400–500 nm, peak 450) and white light on the morphological and photosynthetic qualities of *Cannabis sativa* L. The two treatments were the white light (WL), and a combination of blue red lights (BR). Plants grown under WL were 23% taller than those grown under the BR light emitting diodes. The leaf area was also greater under WL than BR by 20%. The number of lateral branches and length of dominant lateral branch weren´t significantly different. It was concluded WL that emit a full spectrum of light affects plant growth and development better than BR light. The quantum efficiency ranged from 0.81 to 0.845 indicating the plants were not in stress.

Key Words: Cannabis sativa L., morphology, light quality, light emitting diode.

INTRODUCTION

Many species of medicinal and aromatic plants are cultivated for industrial uses (Lubbe and Verpoorte 2011). Herbs are used in pharmaceutical and cosmetic industry for extracting active ingredients (Roxana-Gabriela 2016). Processing of plant-derived pharmaceuticals must take place under tightly controlled conditions, using production standards (Hefferon 2010). Since 2003 medicinal grade cannabis is provided in the Netherlands on prescription through pharmacies. Domestic production of cannabis has been increasing in most European countries and export flows are dynamic and changing. Denmark appears to be a center of cannabis production, and the Czech Republic and Slovakia have become important cannabis producers and exporters to neighboring countries (Hazekamp 2006). The European market for cannabis is extremely large, and supplying cannabis, whether it is at the importation, production or distribution level, requires organization and logistics, human and other resources, and the need to generate and distribute income and profits (EMCDDA 2012). To increase the production capacity, controlled growing systems using artificial lighting have been taken into consideration (Darko et al. 2014).

A closed system for plant production with artificial light is an innovative method of plant cultivation (Schroeter-Zakrzewska et al. 2017). The majority of plants are grown in sealed rooms; these being fitted with bright lights specifically designed to emit wavelengths that maximize plant growth (EMCDDA 2012). Study conducted by Potter and Duncombe (2012), has shown that, when light intensity is increased, the Δ^9-tetrahydrocannabinol (THC) content of the cannabis is boosted because plants in brighter conditions produce proportionally more female flowers, which contain a greater concentration of THC. As an artificial light source, light-emitting diodes (LEDs) can be used to make the plants grow more quickly in closed-type plant production systems, especially in the environment of the light intensity is insufficient (Xu et al. 2016). LED lights do not consume much power, do not require ballasts and produce a fraction of the heat of High intensity discharge (HID) lamps (Thomas 2012). Their small size, durability, long operating lifetime, wavelength specificity, relatively cool emitting surfaces, and linear photon output with electrical input current make these solid-state light sources ideal for use in plant lighting designs (Massa et al. 2008).

Because light is such an important environmental parameter, plants have evolved numerous biochemical and developmental responses to light that help to optimize photosynthesis and growth

(Müller et al. 2001). Light regulates crop growth, plant development (including flowering), as well as how quickly plants use water. Managing light is obviously critical to the production of crops grown in controlled environments. When considering the different dimensions of light, we usually focus on photoperiod (day length), light quantity (intensity) and light quality (the spectral distribution) (Runkle 2017). The spectral quality of lights is the relative intensity and quantity of different wavelengths emitted by a light source and perceived by photoreceptors such as phytochromes, cryptochromes, and phototropins, and plants generate a wide range of specific physiological responses through these receptors. A specific light quality can be used to improve the nutritional quality of vegetables and yields in commercial production (Kuang-Hung et al. 2012, Takemiya et al. 2005).

The objective of this study was to examine growth and development of *Cannabis sativa* L. plants grown in controlled conditions under different light wavelengths. In this study, we used pure white LEDs (Light emitting diodes) compared to red and blue LEDs (R:B = 1:1) as a light source.

MATERIALS AND METHODS

Plant material

Plants of six female drug type varieties of *C. Sativa* (High Potency breeds acquired from CBD Botanic, Spain) were grown in a controlled indoor growing facility at the Mendel University in Brno, Czech Republic. The growing conditions were maintained at temperature of 25 ± 3 °C and relative humidity (RH) of 50 ± 5%. Indoor light was measured at ~200 ± 30 µmol m^{-2}/s (Quantum sensor SQ-500 series, USA) at plant canopy level for a photoperiod of 18 hours of day. Six cuttings were made from each plant for the study. The cuttings were dipped in an auxin solution to promote rooting and directly planted in rock wool cubes of 36x36x40 mm. The cuttings were kept in dark for 24 hours and then transferred to the Climacell (BMT Technologies, Germany) at 24 °C and 80% RH and allowed to be rooted. After proper rooting out of the 36 cuttings, 24 healthy and randomly selected female clones were used for the experiment.

Experimental set-up

The experiments were carried out in the Climacell Evo. The clones were divided into 12 clones each group and placed in two different LED light treatment groups namely Red-blue (R:B) and White light (Control). The two LED light treatments used were (1) 100% Blue and RED light and (2) 50% White. The temperature and RH in the Climacell were maintained at 24 °C and 60% (Day) and 18 °C and 70% (night) respectively. During the vegetative cycle 18h photoperiod was maintained for 2 weeks and during the flowering cycle 12h photoperiod was maintained for another 7 weeks. The wavelengths of blue and red LEDs used were in the range of 420–490 nm and 630–680 nm.

Plant growth measurements

Main measured quantities in this study were plant height, number of lateral branches, leaf area, and quantum efficiency. The leaf area was measured by the method mentioned by Pandey and Singh (2011). Using Adobe Photoshop CS 5 and Canon EOS 1100D. For quantum yield the plants were kept in dark to adapt for 15 mins. Next, randomly chosen leaves from six plants from each treatment were measured using FlourPen FP 100 (Photon Systems Instruments, Czech Republic). Statistical significance was determined by one-way ANOVA and tukeys HSD test to the treatments with significant difference. Twelve plants were used per treatment.

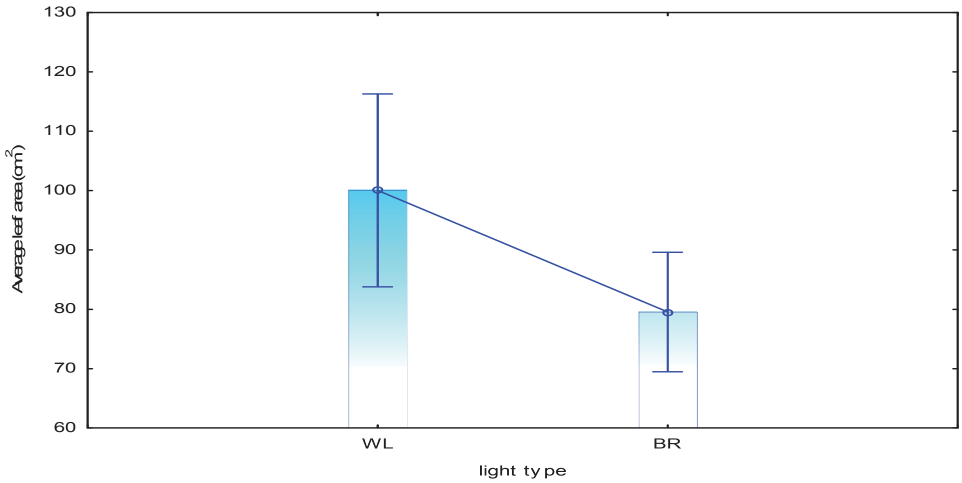
RESULTS AND DISCUSSIONS

Leaf Area

Plants grown under BR light had an average leaf area of 79.54 cm^2 which is smaller compared to plants grown in white light, where average leaf area was 100.03 cm^2 (Figure 1). Many studies show different light quality compared to white light have inhibiting effects on plants and their growth as in the case with pepper, lettuce and tobacco (Brown et al. 1995, Kim 2004, Yang et al., 2016). As Choi et al. (2016) examined effects of LED with different wavelengths on the length of petioles and width of leaflets on strawberry plants they found out that combined illumination with red and blue LED light was the most effective in increasing the length of petioles as well as the width of leaflets.

In comparison with pure red LED and pure blue LED. Arena et al. (2016) found out in an experiment with (*Solanum lycopersicum* L.) and (*Platanus orientalis* L.), growth under Red-Green-Blue (RGB) and BR reduced leaf area compared to growth under WL. Plants that were grown under BR LED lights had smaller leaf area by 20% than those grown under pure WL LED.

Figure 1 Average leaf area of WL and BR treatments.

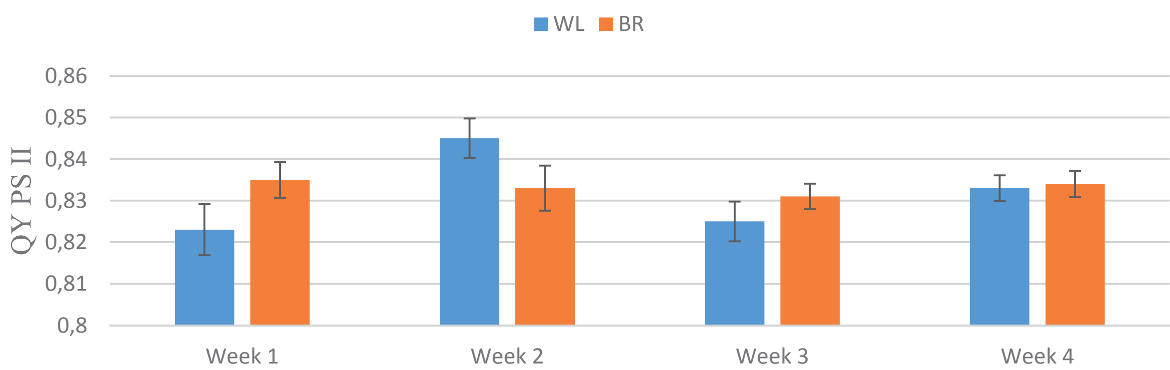


Legend: WL = white light, BR = Blue-Red. Data are mean values ± SE.

Quantum Yield of Photosystem II

The photosynthetic efficiency for both the treatments appeared to be ranging from 0.81 to 0.845. For non-stressed plants, the photosynthetic efficiency fluctuates from 0.75 to 0.85 (Bolhar–Nordenkampf et al. 1989). Which indicated that the plants were in a healthy state (Figure 2).

Figure 2 Quantum yield of photosystem II

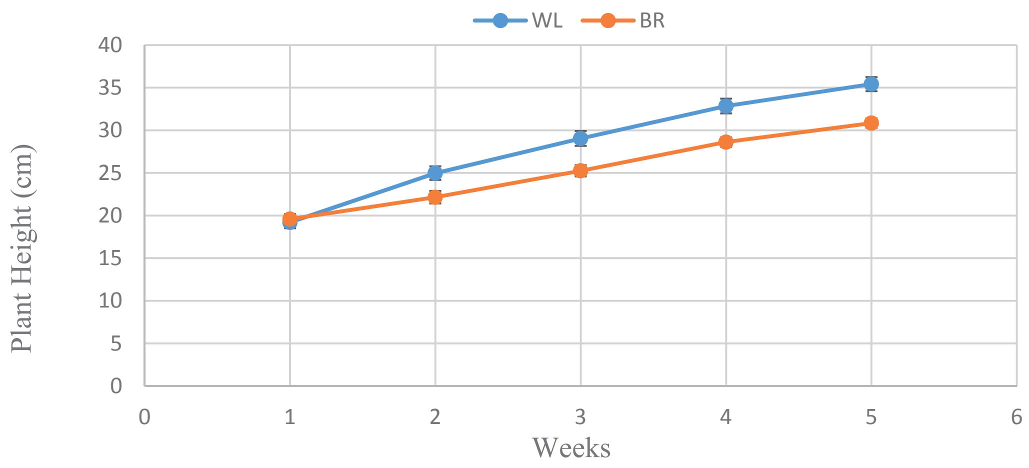


Legends: WL = White light, BR = Blue-Red. Data are mean values ± SE.

Plant Height

There was no significant difference between the two light treated variants until the fourth week of measurement. Since the fifth week, the plants growing in WL treatment started showing a considerable difference in height. The difference in the heights of plants placed under BR light was visible from the first week (Figure 3). Glowacka (2004) found tomato cultivars placed under blue light showed shorter height compared to those kept in day light. In roses and poinsettia blue light was known to reduce stem elongation (Islam et al. 2012, Terfa et al. 2013). In petunia blue light promotes stem elongation on the contrary red light suppresses plant height (Fukuda et al. 2011).

Figure 3 Plant height growth in subsequent experimental weeks.



Legends: WL = White light, BR = Blue-Red. Data are mean values ± SE.

Number of lateral branches

There were fluctuating results for lateral branches but they were not statistically significant (data not shown). Blue light is shown to stimulate bud out growth in *Triticum aestivum* (Barnes and Bugbee, 1992) and *Rosa* (Girault et al. 2008) whereas reduced it in *Solanum tubersum* (Wilson et al. 1993).

In *Lilium* (Vandenbussche et al. 2005) and *Rosa* red light inhibited lateral branching.

CONCLUSIONS

The plants grown under WL had and average leaf area of 100.03 cm^2 compared to plants grown in BR light with an average leaf area of 79.54 cm^2. The WL treatment showed an increased plant height compare to BR treatment. The Quantum yield of photosystem II indicated nonstressed plants. The number of lateral branches were not affected as they did not show any significant difference.

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