The Comparison of Supplemental Blue and Green Light Effects on Two Cucumber Hybrid Transplant Grown under HPS Lighting in Greenhouse

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Abstract

The aim of the research was to explore the influence of blue (455 nm, 470 nm) and green (505 nm 530 nm) lighting spectrum of light-emitting diodes (LEDs) for the growing and development of cucumbers transplants. Experiments were done in greenhouse of phytotron complex of Institute of Horticulture, Lithuanian Centre of Agricultural and Forestry Sciences. Four types of solid-state lamps were designed using high-power AlInGaN light-emitting diodes: 455, 470, 505 and 530 nm. The reference transplants were grown only under daylight and supplemental illumination of high-pressure sodium (SON-T Agro) lamps. Lamps were installed in a phytotron greenhouse. Transplants of cucumber hybrid 'Mirabelle' F_1 and 'Mandy' F_1 were investigated. Measurements of growth parameters and photosynthetic pigments were performed at the end of the experiment. Investigations revealed that the effect of supplementary short-wavelength blue and green light was found to be hybrid dependent. Cucumber hybrid 'Mandy' transplants better reacted to the supplemental LEDs illumination. Supplemental blue and green LEDs illumination with high pressure sodium lamps increased transplant height and leaf area of both cucumber hybrids. Meanwhile, supplemental green LEDs illumination had less positive effect on transplant growth and development. Supplemental LEDs illumination had a positive impact only on cucumber 'Mirabelle' F_1 photosynthetic pigment content.

Key words: blue light, cucumber, green light, LED, photosynthetic pigment, transplant.

Introduction

Transplants quality highly depends on various factors such as light, temperature, humidity, fertilization, substrate, cultivation methods (Weston and Zandstra, 1989; Ciardi et al., 1998; Gosselin and Ayari, 2001; Głowacka, 2002; Samuolienė et al., 2012). The light is very important indices of their quality. All the features of light have an influence for development of plants and formation of its organs. They differently work in various periods of plants ontogenesis for every species of plant. In greenhouses with insufficient natural light, transplants are lighted by lamps. Several different types of lamp such as high pressure sodium (HPS) lamp, metal-halide (MH) lamp, fluorescent lamps are being used for lighting of plants and transplants (Tennesen et al., 1995; Morrow, 2008). HPS lamps are the most commonly used type of light source in greenhouse production (Ménard et al., 2006). Supplemental lighting promotes plant development and increases leaf chlorophyll, plant biomass and early yield production. It also increases biomass allocation to fruit, fruit dry matter content and skin chlorophyll content (Blain et al., 1986; Hao and Papadopoulos, 1999). In recent years for supplemental lighting of plants in greenhouses more and more light emitting diodes (LEDs) are used (Yanagi et al., 1996; Tennesen et al., 1994; Tamulaitis et al., 2004). LED lamps consume less energy, are high-intensity, length of its using is long (Massa et al., 2008). Light emitting diodes lighting in greenhouses is used as addition for sodium lamps (SON-T Agro) or as independent source of light (Ménard et al., 2006; Massa et al., 2008). Area of using light emitting diodes is quite wide, one of the most important advantages of using diodes is the opportunity of the spectrum of LED lighting to be adjusted according to the growth of plants.

Many investigations have shown that modulation in light quality, intensity, and photoperiod can affect plant growth and development (Artificial, 1992; Gosselin and Ayari, 2001; Chen et al., 2004; Wang et al., 2007; Folta and Childers, 2008). Various parts of spectrum differently affect plants and their impact is to be discussed (Mortensen and Strømme, 1987). Blue light effects formation of chlorophyll, photomorphogenesis and moving of products of photosynthesis and their distribution in the different parts of plants (Dougher and Bugbee, 1998; Heo et al., 2002). According to Hogewoning (2010) and others' data, blue light during cucumber growth is qualitatively required for normal photosynthetic functioning. Green light plays many different roles in the biochemistry, physiology and structure of plants (Klein, 1992). Vegetable plants need varying amounts of light depending on the species (Głowacka, 2004), so it is important to know the influence of various parts of spectrum for different hybrids of cucumbers transplants growing and development.

The objective of our studies was to estimate the influence of blue (455 nm ir 470 nm) and green (505 nm ir 530 nm) lighting spectrum of light-emitting diodes (LEDs) to high pressure sodium lamps (HPS) for the quality of cucumber transplants and content of photosynthetic pigments in their leaves.

Materials and methods

Transplants of cucumber hybrid 'Mandy' and 'Mirabelle' were grown in greenhouse. Four types of solid-state lamps were designed using high-power AlInGaN light-emitting diodes: 455, 470, 505 and 530 nm. The reference transplants were grown only under daylight and supplemental illumination of high-pressure sodium (SON-T Agro) lamps. It was maintained 18 h photoperiod. The day/night temperature was 20-23/15-18 ºC and relative air humidity was 50-60 %. Ten plants (n=10) were harvested to determine height, hypocotyls diameter, number of fully expanded leaves, leaf area, shoot and root dry weight. Shoots and roots were dried in a drying oven at 105 °C for 24 h to determine dry weight. The leaf area of cucumber transplants was measured by "WinDias" leaf area meter (Delta-T Devices Ltd, UK). Plant height was measured to the tip of the youngest leaf. Photosynthetic pigments content per one gram of fresh foliage weight was measured in 100% acetone extract according to D. Wettstein method (Wettstein, 1957)

using "Genesys 6" spectrophotometer ("ThermoSpectronic", USA). Measurements were performed in four replicates (n = 4). The levels of significance for differences between various indices were analysed using one-way Anova (Anova for MS Excel, version 3.43).

Results

Lighting of cucumbers' transplants by supplemental blue and green LEDs to HPS lamps had a positive effect on transplant biometric parameters (Table 1). Supplemental blue and green lights increased height, leaf number and area, total above ground dry weight of both cucumber hybrids transplant. Cucumber hybrid 'Mandy' better reacted to supplemental LEDs lighting. Transplants were 17.9-63.6 % higher, their leaf area was 25.6-43.0 % bigger than transplants grown under HPS lamps. Meanwhile cucumber 'Mirabelle'F_1 transplants lighted by LEDs were 16.9-26.5 % higher, leaf area was 4.0-6.9 % bigger than transplants lighted only by HPS lamps. Spectrum had different impact for biometric parameters of transplants as well. Supplemental blue LEDs light had a bigger influence for biometric parameters of transplants than green LEDs light. Transplants of both hybrids lighted by LEDs were higher and had more leaves, their leaf area was larger than those transplants which were lighted by supplemental green LEDs. Supplemental blue 455 nm LEDs influenced the biometric parameters of the transplants most. These diodes increased height, leaf area and above ground dry weight of cucumber 'Mandy' F_1 transplants. Cucumber hybrid 'Mirabelle' transplants grown under supplemental blue 455 nm LEDs had the largest leaf area. The same transplants were highest when lighted by 470 nm LEDs. Total above ground dry weight of cucumber hybrid 'Mirabelle' transplants increased under supplemental green 530 nm LEDs. Both supplemental blue (455 nm and 470 nm) lights decreased hypocotyls length of cucumber hybrid 'Mandy' transplants. Cucumber hybrid 'Mirabelle' showed different results.

Table 1. **Biometric data of cucumber transplants grown under different illumination**

Indices	HPS	HPS+455 nm	HPS+470 nm	HPS+505 nm	HPS+530 nm
Cucumber 'Mandy' F_1					
Plant height (cm)	18.45±0.57	30.18±1.51	25.40±1.47	21.75±0.81	23.40±1.18
Hypocotyls length (cm)	4.37±0.21	4.07±0.26	4.15±0.25	4.26±0.25	5.10±0.18
Hypocotyls diameter (cm)	0.60±0.01	0.55±0.02	0.57±0.02	0.65±0.01	0.64±0.02
Number of leaves	3.55±0.09	4.15±0.07	4.00±0.00	3.75±0.11	3.90±0.07
Leaf area (cm^2)	575.9±23.0	823.5±23.1	766.1±26.4	742.4±30.7	723.5±26.3
Total above ground dry weight (g)	2.49±0.13	2.74±0.12	2.67±0.08	2.63±0.12	2.67±0.08
Cucumber 'Mirabelle' F_1					
Plant height (cm)	13.60±0.49	16.90±0.56	17.20±0.85	15.90±0.75	16.00±0.47
Hypocotyls length (cm)	3.60±0.08	4.20±0.26	3.80±0.27	3.70±0.15	4.10±0.19
Hypocotyls diameter (cm)	0.59±0.09	0.61±0.009	0.61±0.009	0.62±0.011	0.65±0.01
Number of leaves	3.40±0,05	3.40±0,05	3.20±0,08	3.20±0,08	3.30±0,08
Leaf area (cm^2)	711.2±20.7	760.1±18.5	755.6±31.6	739.6±26.2	744.0±29.8
Total above ground dry weight (g)	2.47±0.06	2.45±0.11	2.14±0.11	2.39±0.10	2.59±0.07

Supplementary lighting of short-wavelength solid-state lamps to high pressure sodium lamps (HPS) had a positive impact on cucumber 'Mirabelle' F_1 photosynthetic pigment content (Fig. 1). In the leaves of these transplants were 1.4 time more photosynthetic pigment than in the leaves of transplant grown under HPS lamps.

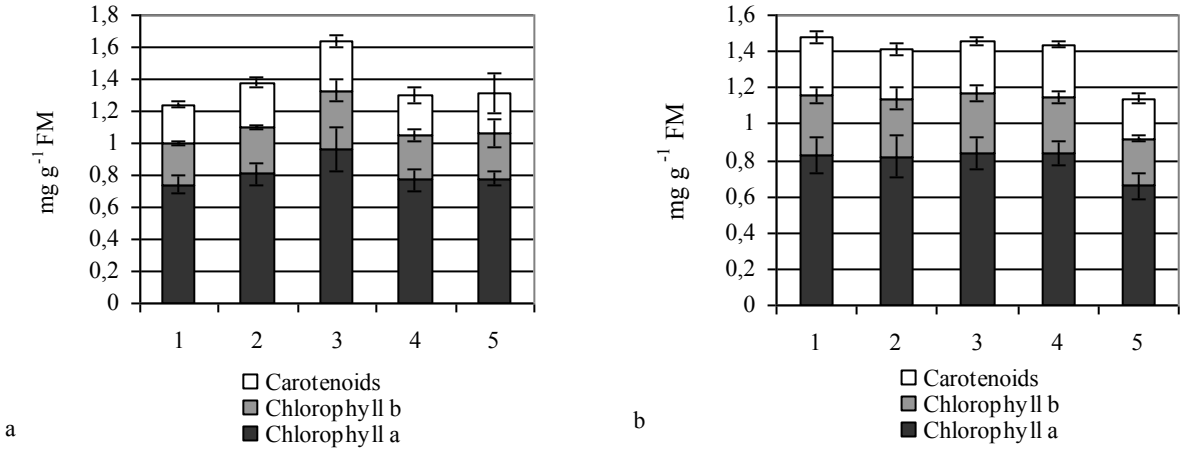

Figure 1. **The photosynthetic pigment content of cucumber transplants grown under different illumination (a - cucumber 'Mandy' F_1, b - cucumber 'Mirabelle' F_1). 1. HPS lamps, 2. HPS+455 nm, 3. HPS+470 nm, 4. HPS+505 nm, 5 - HPS+530 nm.**

The synthesis of photosynthetic pigments mostly enhanced 455, 470 and 530 nm LEDs supplemental illuminations. Supplemental green 505 nm LEDs light significantly increased content of chlorophylls a and b in leaves of cucumber 'Mirabelle' F_1 transplants. For cucumber 'Mandy' F_1 transplants supplemental LEDs lighting did not have positive impact for photosynthetic pigment content in their leaves. Supplemental green (505 and 530 nm) LEDs light slightly decreased chlorophyll a in leaves of cucumber hybrid 'Mandy'. Supplemental blue LEDs light had a bigger influence for accumulating of chlorophyll in leaves of transplants of cucumber 'Mandy' F_1. Supplemental green LEDs light increased content of chlorophyll in leaves of cucumber 'Mirabelle' F_1 transplants. LEDs illumination had no effect for carotenoids content in leaves of both cucumber hybrid transplants.

Discussion

Light quality influences plant growth and affects transplant quality (Mortensen and Strømme, 1987; Yanagi et al., 1996; Kubota et al., 1997). Supplementary lighting was shown to produce transplants with improved shoot characteristics, root systems, and shoot dry matter percentage (Masson et al., 1991). The seedlings of ones cabbage family (*Arabidopsis thaliana*) vegetable under green, red, and blue light together were taller than those grown under red and blue alone (Folta, 2004). According to Głowacka (2002) data, transplants of the tomato hybrids 'Recento F_1', 'Tukan F_1', and 'Remiz F_1' grown under fluorescent lamps emitting daylight and blue light were short, with thick stem, shortened internodes, enhanced participation of the dry mass in fresh mass. According to our researches, supplemental blue and green LEDs light influenced biometric parameters. Transplant were higher, had bigger leaf area comparing with the transplants lighted only by HPS (Table 1). Investigation showed that supplemental blue 455 nm light had the greatest positive influence on growth and development of both cucumber transplants. They formed largest leaf area, more leaves, above ground dry weight was higher. Literature data shows that blue light stimulates formation of chlorophyll, increases above-ground biomass per surface area (Dougher and Bugbee, 1998; Menard et al., 2006). Some authors reported that blue fluorescent lamps increased dry weight but decreased leaves number of cucumber transplant (Piszczek and Głowacka, 2005). Lighting with high level of blue light was useful for cucumber but not for tomato (Ménard et al., 2006). According to our researches, dry weight depends on hybrid of cucumbers. Cucumbers hybrid 'Mandy' transplants' which were grown under supplemental LEDs light above ground dry weight was bigger than transplants grown only under HPS lamps. However, above ground dry weight of cucumber hybrid 'Mirabelle' transplants lighted by supplemental green and blue LEDs, was smaller than transplants that were lighted only by HPS lamps. Liptay and others (1981) reported that stem diameter of tomato transplants is an indication of their vigor and, the accumulated reserves in tomato transplant stems enhance early fruiting. Our investigations showed that hypocotyls diameter of transplants of both cucumber hybrids grown under supplemental blue (505 nm and 530 nm) lights was the biggest. Our earlier investigations showed that supplemental green (520 nm) and orange (622 nm) light fasten the growth and development of cucumber hybrid 'Mandy' transplants (Brazaitytė et al., 2009). Our researches show transplants of both hybrids of cucumbers which were lighted by supplemental green LEDs were lower, leaf area was smaller, had less leaves than transplants which were lighted by supplemental blue LEDs. Hypocotyls diameter of cucumber 'Mandy' hybrid transplant lighted by supplemental green LEDs was bigger than lighted by supplemental blue LEDs. Hypocotyls length of cucumber hybrid 'Mandy' transplants increased under supplemental green LEDs. Hybrid 'Mirabelle' reacted in the same way under supplemental blue LEDs.

Chlorophyll is one of the photosynthetic pigments that absorb the light the plant needs. Chlorophyll biosynthesis requires light and its biosynthetic intermediates are involved in the regulation of chloroplast biogenesis (Hoober and Eggink, 1999). Li and other (2012) researchers' data show the concentrations of chlorophylls in Chinese cabbage transplant was greatest under blue LEDs. Dougher and others (1998) show us that blue light fraction had positive effect not only on dry mass, but on chlorophyll content in lettuce as well. According to our data, accumulating of photosynthesis pigments in leaves of cucumbers transplants depended on hybrid (Fig. 1). In the leaves of cucumbers hybrid 'Mandy' transplants lighted by supplemental green LEDs the content of a and b chlorophylls was smaller than those which were lighted by supplemental blue LEDs. Contrary effect was determined in cucumber hybrid 'Mirabelle'.

In our experiment comparison of cucumber hybrids growth revealed differential effect of supplemental blue (455 nm and 470 nm) and green (505 nm and 530 nm) LEDs.

Conclusions

Supplemental blue and green LEDs lighting with high pressure sodium lamps increased transplant height and leaf area of both cucumber hybrid transplant. Number of leaves, dry weight and chlorophylls content depended on hybrid of cucumber. Blue 455 nm LED illumination had the greater impact for biometric parameters of transplants. Transplants of both hybrids were highest, above ground dry weight, leaf area were the largest, had most leaves. Blue LED illumination had a bigger impact for growing and development of transplants than green LED illumination. Supplemental LED illumination had positive influence only on cucumber 'Mirabelle' F_1 photosynthetic pigment content. LED illumination had no impact for carotenoids content in leaves of both cucumber hybrid transplants.

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