# EFFECTS OF RED-AND BLUE-LIGHT EMITTING DIODES ON GROWTH AND CHLOROPHYLL CONTENT OF *Phaseolus vulgaris* L.

**Claudia BALINT, Antonia ODAGIU*, S. VÂTCĂ, I. BRAȘOVEAN, P. BURDUHOS, V. IVANCIUC**

***University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Faculty of Agriculture, Calea Mănăștur, no. 3-5, Cluj-Napoca, Romania***
*Corresponding author: antonia.odagiu@usamvcluj.ro*

***Abstract.*** *Providing basic nutritional resources has become a necessity worldwide. For this reason, in order to enhance the food supplying chain there is a real need to identify new methodologies, including unconventional ones. Artificial lighting applied to greenhouses is an innovative agricultural technology that fundamentally changes the concept of agriculture. LED lighting systems are becoming increasingly popular with researchers, engineers, biologists and manufacturers., This study aiming to test the effects of red, blue and red/blue light emitting diodes (LEDs) on Phaseolus vulgaris L., was carried out on the University of Agricultural Sciences and Veterinary Medicine Cluj – Napoca, Department of Engineering and Environmental Protection, during March-April 2021. The Phaseolus vulgaris L. plantules were grown under different light-emitting diode (LED) treatments: red (610-720 nm) light, blue (400-520 nm) light and combination of red with blue, respectively. Data were statistically processed with STATISTICA v 8.0 Office. In the end of the experiment, at 20 days after sowing, we found superior plantules height, and enhanced chlorophyll synthesis, for blue light exposure. We also found better results concerning plantules height and chlorophyll synthesis, for red light exposure, compared with those obtained in natural light. These results suggest the possibility of extending the use of blue and red LEDs light for large scale cultivation.*

***Keywords****: LED lighting, chlorophyll content, Phaseolus vulgaris L.*

## INTRODUCTION

Currently, an important challenge, at national and global level, is to provide the necessary nutritional resources to the planet, whose demographics are constantly expanding. The daily needs which increases constantly, in time, could not be met by traditional agricultural technology. If conventional approaches and production methods do not change over time, they could lead to serious social problems. New technologies are the leader and driving force for the development of modern agriculture (FAO, 2017). These include the biotechnology, information technology, water saving irrigation, modern agricultural techniques, etc. Thus, modern agriculture could register real progress, when innovative technologies are integrated in daily practice. Light is one of the most challenging environmental factor for plants as it provides not only the source of energy for photosynthesis, but also the signal for a multitude of physiological responses (ADAMS AND LANGTON, 2005). Light quality (wavelength), light quantity (intensity), photoperiod (duration) and even direction are key components of light conditions (ZHANG ET AL., 2020). Artificial lighting applied to greenhouses is an innovative agricultural technology that could influence the concept of agriculture (CHEN AND BLANKENSHIP, 2011; HOHMANN-MARRIOTT AND BLANKENSHIP, 2011). In order to obtain optimum plant productions, light traits, as spectrum, intensity, and photoperiod must meet the specific crops needs. Even though one may consider that a sustainable production needs available sunlight (HEMMING, 2009), the LED lighting systems are becoming increasingly popular with researchers, engineers, biologists and manufacturers. In recent years, LED applications became an opportunity for agricultural production, worldwide. LED is an ideal choice for protected agriculture. LED is a kind of sustainable lighting and an ideal alternative for growing plants (DEUSCHLE ET AL., 2017; JERICÓ ET AL., 2017; KIM ET AL., 2004). ACCORDING TO NARDELLY ET AL. (2017), LEDs are semiconductor diodes in solid-state, which in conditions of application of a proper amount of voltage, have capacity to release energy as photons. The massive electrical consumption destined for providing optimal light and temperature environmental conditions is a challenge for the commercial micropropagation industry (PAWŁOWSKA ET AL., 2018). The LED lighting systems could be used in order to provide sustainable technologies for plant-growing applications, because of their main traits, as: small size, durability, long lifetime and cool emitting temperature.

The energy of sunlight used in the synthesis of organic substances in plants through chlorophyll, in the process of photosynthesis. The intensity of photosynthesis is dependent on the specifics of the plant (leaf area, number and distribution of chloroplasts, enzymatic activity, etc.), light, carbon dioxide concentration, temperature, water and nutrients in the soil, etc. Chlorophyll is the main pigment for photosynthesis in plants, and by measuring the chlorophyll content of plants, we can also understand plant nutrition (MUNTEANU ET AL. 2011). Common bean (*Phaseolus vulgaris* L.) is a valuable species used for food supply in human nutrition all over the world. It is well known that common bean is one of the most sensitive àculture to environmental. It is a thermophile plant that has special temperature needs, its development being best at temperature intervals of 15 - 20ºC. It is also important to know that seed germination isighly very affected by temperature (BALINT ET AL. 2015). The objective of this study was to investigate the effects of red, blue and combination of red and blue light emitting diodes on plant (*Phaseolus vulgaris* L.) stem height and leaves chlorophyll content, during one month, on controled experimental conditions.

## MATERIAL AND METHODS

In order to conduct the experiments consisting in testing the effects of red, blue, and red and blue (50%/50%) LEDs lights on stem height and chlorophyll content of common bean (*Phaseolus vulgaris* L.) in controlled conditions, an experimental design was elaborated. The experiment was placed in the University of Agricultural Sciences and Veterinary Medicine Cluj – Napoca, Department of Engineering and Environmental Protection, during March-April 2021. In order to supply the light treatment conditions, 4 identical chambers (20cm wide and 40cm long) were used (https://www.apogeeinstruments.com/): reference glass chamber (M), red-LEDs glass chamber (I1), blàue-LEDs glass chamber (I2), red and blue-LEDs glass chamber (I3). In experimental chambers controlled environment (identical humidity and temperature) was maintained. Light is the necessary condition for photosynthesis, which is the most important process in plants' life. On our experiment the LED lamps intensity were verified in three points at the bottom and at a height of 50 cm of the experimental chambers. A special LED lighting system was designed and constructed in order to perform our study (Fig. 1). Four types of LED distribution panels are designed to achieve uniform lighting for each experimental chamber. Each panel of 20x40cm consisted of 3 rows of LED bulbs. One row was composed of 7 bulbs (arranged in series). According to the design principle, the selective absorption spectra for plants were mainly gathered between 400 nm and 720 nm, red light (610-720 nm), blue light (400-520 nm), and combination of red and blue light (400-720 nm), respectively. The typical current intensity for LEDs is 400 mA for red light and 350 mA for blue light.

The biological material used in experiment consist in common bean (*Phaseolus vulgaris* L.) variety seeds, collected from the area of Transylvania, Cluj County. The plants were maintained under 24-h photoperiod, temperature of $23^0$C and 65% relative humidity in experimental glass chambers. The soil used for bean plants growing was faeoziome on all four experimental chambers, with a pH between 5.0 and 6.5. The experimental observations (plant height, leaves chlorophyll content), were recorded after 10, 15, and 20 from seeding. The chlorophyll content of *Phaseolus vulgaris* L. leaves, at different growing stages, and in different conditions of light exposure were measured with Chlorophyll Concentration Meter – MC-100.

Fig. 1. The experimental setup

This device is used by the non-invasive method of identifying chlorophyll concentration from intact plant leaves. It is calibrated to measure chlorophyll concentration in units of µmol or chlorophyll/m$^2$ (https://www.apogee instruments.com/). The statistical data were processed with STATISTICA v.8.0 for Windows. The descriptive statistics package is used for performing: descriptive statistics, identification of significance of differences at 95% confidence interval (t-test independent, by variables) and Pearson simple correlations.

**RESULTS AND DISCUSSIONS**

The study of the mean bean stems height function of light exposure, registered at 10 days from seedling, shows that the best response, expressed in plantules height is recorded in the experimental variant placed on blue LED light (24.20 cm), while the weakest physiological development is highlighted in the absence of LED light exposure (16.60 cm). At 15 and 20 days from sowing, the biggest mean height is reported for plantules placed in blue light (41.6 cm, and 49.88 cm, respectively), but, the lowest for the plantules placed in red/blue LED light exposure (32.60 cm, and 46,58 cm, respectively). At 10, and 15 days from sowing, satistically significant differences (at 1%, and 5% thresholds, respectively) are identified between mean stem height reported for blue light exposure, and those reported for the other exposure conditions. At 20 days from sowing, even though the highest mean of plantules height is reported for those exposed at blue light, the differences between this mean an those resulted in the other experimental variants are not statistically assured at significance threshold of 5% (Table 1). These findings suggest that at 20 days of sowing, the stem growing process tendency function of LED light exposure is to uniformization.

Experiments performed by JEONG ET AL. (2014) in chrysanthemum, concerning stem elongation with blue light supplementation to red/blue light, when different photoperiods are used, led to positive results, fact that we consider as a confirmation of our results.

At 10, and 15 days of sowing, the lowes means of the leaves chlorophyll content (243.94 µmol /m$^2$, and 235 µmol /m$^2$, respectively) are reported for the experimental variant exposed to blue light, and differences from the other experimental variants are assured at statistical threshold of 5% (Table 2).

*Table 1*

The height of *Phaseolus vulgaris* L. plantules, at different growing stages, and in different conditions of light exposure

| Experimental variant | N | X (cm) | Minimum | Maximum | s | CV(%) |
|---|---|---|---|---|---|---|
| At 10 days from seeding | | | | | | |
| 1 | 5 | 16.60ac | 5.00 | 25.00 | 8.62 | 51.93 |
| 2 | 5 | 17.40ac | 10.00 | 22.00 | 4.77 | 27.44 |
| 3 | 5 | 24.20ca | 17.00 | 33.00 | 6.22 | 25.71 |
| 4 | 5 | 18.20ac | 13.00 | 22.00 | 3.96 | 21.77 |
| At 15 days from seeding | | | | | | |
| 1 | 5 | 39.20ab | 25.00 | 48.00 | 9.04 | 23.06 |
| 2 | 5 | 38.00ab | 30.00 | 44.00 | 5.83 | 15.34 |
| 3 | 5 | 41.60ab | 35.00 | 50.00 | 6.27 | 15.07 |
| 4 | 5 | 32.60b | 28.00 | 36.00 | 3.44 | 10.54 |
| At 20 days from seeding | | | | | | |
| 1 | 5 | 49.28a | 48.50 | 50.00 | 0.62 | 1.26 |
| 2 | 5 | 49.06a | 48.60 | 49.80 | 0.46 | 0.93 |
| 3 | 5 | 49.88a | 49.70 | 50.00 | 0.13 | 0.26 |
| 4 | 5 | 46.58a | 44.90 | 48.20 | 1.37 | 2.94 |

1 – control not exposed; 2 – exposed to red light; 3 – exposed to blue light; 4 - exposed to both red and blue light; N – no. of cases; X – mean; s – standard deviation; CV – coeficient of variation; a – p >0.05; b – pV0.05; c – p<0.01.

Contrarily, at 20 days from sowing, the highest mean values (634,74 µmol/m$^2$) correspond to this experimental variant, differences from the other experimental variants being assured at statistical threshold of 0.1% (Table 2).

Experiments performed by LOBIUC ET AL. (2017) on *Ocimum basilicum* L. microgreens, also led to findings similar of those obtained by us. They identify superior results concerning plant stem growth and chlorophyll synthesis under exposure to blue light.

*Table 2*

The chlorophyll content of *Phaseolus vulgaris* L. leaves, at different growing stages, and in different conditions of light exposure

| Experimental variant | N | X (µmol /m$^2$) | Minimum | Maximum | s | CV(%) |
|---|---|---|---|---|---|---|
| At 10 days from seeding | | | | | | |
| 1 | 5 | 284.54ab | 231.30 | 315.00 | 34.09 | 11.98 |
| 2 | 5 | 300.64ab | 259.90 | 333.00 | 30.18 | 10.04 |
| 3 | 5 | 243.94ab | 170.30 | 307.50 | 50.76 | 20.81 |
| 4 | 5 | 309.04ab | 280.40 | 335.70 | 19.64 | 6.36 |
| At 15 days from seeding | | | | | | |
| 1 | 5 | 298.26ab | 280.40 | 316.90 | 16.34 | 5.48 |
| 2 | 5 | 307.46ab | 258.80 | 353.60 | 35.97 | 11.70 |
| 3 | 5 | 235.28ab | 160.80 | 303.70 | 64.62 | 27.47 |
| 4 | 5 | 359.52ab | 348.70 | 377.10 | 10.76 | 2.99 |
| At 20 days from seeding | | | | | | |
| 1 | 5 | 296.64ad | 249.00 | 355.20 | 41.43 | 13.97 |
| 2 | 5 | 217.58ad | 176.00 | 264.50 | 38.45 | 17.67 |
| 3 | 5 | 634.74d | 156.60 | 2396.90 | 985.95 | 155.33 |
| 4 | 5 | 269.14ad | 235.50 | 309.40 | 32.23 | 11.98 |

1 – control not exposed; 2 – exposed to red light; 3 – exposed to blue light; 4 - exposed to both red and blue light; N – no. of cases; X – mean; s – standard deviation; CV – coeficient of variation; a – p >0.05; b – pV0.05; c – p<0.01; d – p <0,001.

Strong correlations between light exposure and leaves chlorophyll content of common bean plantules are reported when they are exposed to red (R = 0.705) and red/blue (R = 0.692) LED light exposures, with a representativeness of 49.7%, and 47.9%, respectively (Fig. 1).

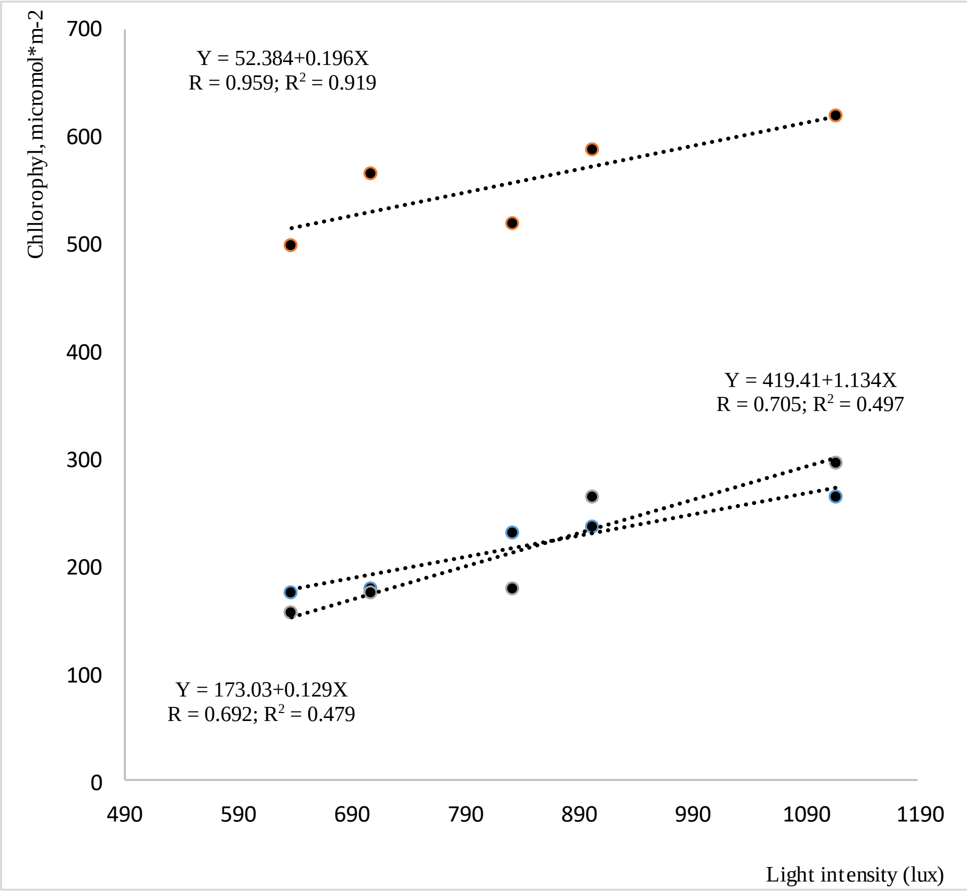


Fig. 2. The simple correlations between light intensity and *Phaseolus vulgaris* L. leaves chlorophyll content, at 20 days from seeding, in different conditions of light exposure

When plantules are exposed to blue light, a very strong correlation (R = 0.959), representative for 91.9% of plantules, is reported (Fig. 1), and this explains the highest leaves chlorophyll content of plantules (Tabel 2). This emphasize the stronger effect of blue light in stimulating chlorophyll synthesis, compared to red and red/blue lights.

## CONCLUSIONS

The different LED lights (red, blue, and red/blue) treatments have variable effect on both growth and leaves chlorophyll content of *Phaseolus vulgaris* L. plantules. The biggest means of common bean height is reported in experimental variant exposed to blue light by all three observations (24.20 cm, 41.6 cm, and 49.88 cm, respectively), but according to the results of testing the significance of differences, at 20 days of sowing, the plantules stem growing, function of LED light exposure has the tendency of o uniformization. The blue light has higher stimulat effect on chlorophyll synthesis in plantules leaves, compared to natural light, red, and red/blue lights, but it is manifested only at 20 days of sowing. These results show that blue and red light exposure could have a real potential of improving *Phaseolus vulgaris* L. growing process and chlorophyll synthesis, in early stages of development.

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