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Research Article
Quick Growth of Lettuce Plants Using Purple Led Illumination Devices

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Abstract

Background and Objective: As the world's population increases, efforts are to produce more food. The growth of vegetables requires a certain generation time that limits the amount obtained from them. The present study was initiated to evaluate the speed and capacity of lettuce plant growth in a red-blue LED sunless lighting model. **Methodology:** Lettuce seed were insert in 20 black plastic (polypropylene) seed beds 54×28 cm plates; each one with 288 alveoli (diameter 1.9 cm depth 3 cm). Plates were randomized in two groups (LED illumination or control sunlight group during 30 days)-10 plate each group-. Artificial lighting device consists of 6 LED modules (3 red and 3 blue LED modules) to form a purple color. Root length, plant height, relation height/root, number of leaves, aerial part of the plant and an index of greenery (SPAD unit) were variables included in the study. These variables were measured at the beginning of the experience and also at day 7th,15th and at day 21sth of the experience. Statistical method used was one way ANOVA using the Stat-graphics Centurion program. The mean values obtained were compared using the LSD test with a significance of $p < 0.05$ with a confidence interval of 95%. **Results:** The number of leaf and root length was similar in both groups. Root length was similar. However, leaf area, leaf/root relation, overall height of plant and SPAD units were increased in LED lighting compared with sunlight growth. **Conclusion:** The purple LED lighting model is a valid option to induce lettuce production in sunless conditions.

Key words: LED lighting, purple, LED, lettuce, plant, sunless, grow, leaves, aerial, height

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The exponential growth of the population in a finite world is at the center of many environmental and social issues, including climate change, deforestation, poverty or famine[1,2]. This fact, associated to increasing demand for valuable natural compounds and improper usage of land in utilities that competes agriculture destined for human food and current projects in order to develop human settlement in space stations, reinforce the need for artificial growing systems such as sunless systems, settlement of new communities. Most of greenhouses, soilless systems and vertical gardening growing systems require the application of additional or supplementary light sources to ensure proper plant growth. These sources usually are heat dissipaters that requires cooling systems, so new lighting technologies with different wavelength and fluence such as Light-Emitting Diodes (LEDs) are being studying to solve plants requirements like photosynthesis and light-signalling[3,4].

The pigment of photo receptors allows them to extract from the incoming natural white light the specific information related to the intensity of the environmental light constraints[5] and to initiate the photosynthesis process to produce ATP and NADPH, substances that are need in the assembly of carbon atoms for organic molecules production. The LED are considered high intensity sources of visible radiation dominantly illuminated by blue, red, red-blue, or white LED lights[6,7]. The recent decrease of both blue and red LED price together with the increase in their brightness has made LED light as an important alternative irradiation possibility[8,9], allowing better growth[10,11] and production of different plants[12,13]. The combinations of these LED allow the researchers to obtain new colorings such as purple light, which may provide new benefits in plant's development[12,14].

Several herbs (like mint or basil) and flowers are proven to grow under LED conditions[8,15]. The objective of study was to evaluate purple LED arrays in a sunless lighting model to induce growing of local food plants like lettuce.

MATERIALS AND METHODS

Type of study: This is an experimental assay based on comparison between two groups control "intervention versus" representing respectively two types of lighting methods: classic sunlight and an alternative based on purple LED lighting.

Groups of study: *Lactuca sativa* L. lettuce Takii brand seeds from La Plata, Argentina provided by Daniel Aquaroli team were placed using a semiautomatic seed planter on 20 black plastic (polypropylene) seed beds 54×28 cm plates, each one with 288 alveoli (diameter 1.9 cm depth 3 cm). Plates were randomized in two groups (LED illumination device trademark CREE type XLamp® XQ-E LED or control sunlight group) 10 plate each group. Plant growth were monitored during three weeks, which was the duration of the study. Lettuce seeds while growing were submitted either to sunlight or to purple LED light exposure according to the group to which they belonged. After 21 days (12 h of light and 12 h of darkness) each one of the plants located in cavity of every plate was harvested and carefully cleaned in order to submit them to the measurement process. The time duration up to which the study was conducted was 21 days (from November 28th to 18th December 2016.

Variables: Root length (cm), plant height (cm), relation height/root, number of leaves, aerial part of the plant (cm^2) and soil-plant analysis development -SPAD, which is an index of greenery (measured in SPAD units) were variables included in the study. Measurements included leaf area, Specific Leaf Area (SLA), shoot Fresh Mass (shoot FM) and shoot Dry Mass (shoot DM). Plant tissue samples were dried in a drying oven for 48 h at 70°C before weighing.

LED's device: The device consists of 6 LED modules (3 red and 3 blue LED modules). The modules were characterized with an Avantes spectrometer model AvaSpec ULS3648-UBS2-U25A with optical fiber FC-UVIR200-2. The arrangement thereof was such that a balance of both colors could be achieved to form a purple color. To do this, the modules insert one by one on the longer sides of a 70×40 cm rectangular aluminum bracket. On the same frame were located the drivers, one for each led module (Fig. 1, 2). It was powered with 220 V. These were suspended on the crops at an approximate height of 0.70 m generating an irradiance of close to 700 W cm^{-2} and a photopic luminance of 1000 lux.

As a mechanical protection, especially against the ingress of water during the watering, the support was covered by a plastic housing that provides insulation and robustness (Fig. 3).

Each LED module consisted of 6 power LEDs arranged in pyramidal form (1-2-3) and a driver, type switching source (Fig. 4).

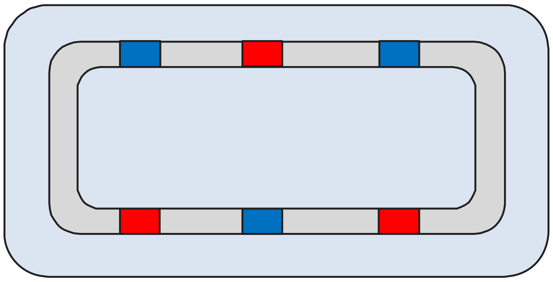

Fig. 1: Location of red and blue colors in module

Fig. 2: Module with LED and drivers

Fig. 3: Modules location

Figure 5 shows the irradiation spectrum of each module. The values of spectral irradiance were obtained at a distance of approximately 0.50 m, corresponding to the height of suspension of each source on the crops.

The position in the CIE chromatic diagram (observer 2) of the combination of both emissions, together with the characteristic values: chromatic coordinates, illuminance and irradiance on the crops can be seen in Fig. 6.

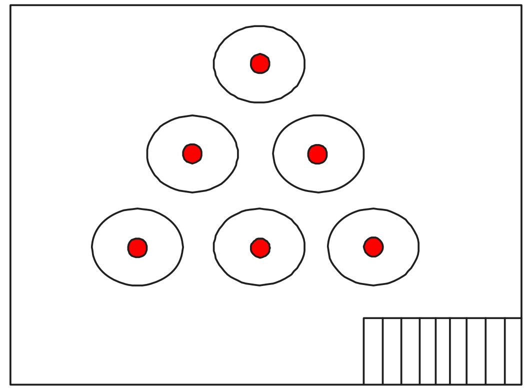

Fig. 4: LED module arrangement

The spectrum, luminance and irradiance of the luminaries were measured. To do this, it was connected to 220 V and a spectrometer was placed at 30 cm.

Statistical analysis: Comparative data of each variable between both groups were obtained by analysis of the one way ANOVA one way using the Stat-graphics Centurion program. The mean values obtained were compared using the LSD test with a significance of $p<0.05$ with a confidence interval of 95%[16].

RESULTS

Data from the present study revealed that the growth of lettuce plant located in plate's cavity, exposed to two types of lighting and harvested after 21 days of follow up was heterogeneous but also yield encouraging results. Examinations of specimens were done regularly (each 7 days) by a professional agronomist until the 3rd week of the study which allowed not only to obtain final results but also to have weekly serial data. After that period, plants were removed from each one of the plates and carefully cleaned in order to start with the measurement process.

Measures to determine the degree of growth of the plants was initiated by weighting each specimen. Data from that process provided the following information.

The average height reached by the specimens exposed to purple LED lighting was statistical greater than that obtained with sunlight p 0.02 (Fig. 7). On the other hand, the lengths of roots were longer in plants exposed to sunlight (Fig. 8).

The relation aerial vs root part was greater in LED exposition compared with control group exposed to sun lighting (Fig. 9). Although, number of leaf grown was similar in both groups (Fig. 10) and no differences were seen among them; purple LED lighting exposition had no positive effects

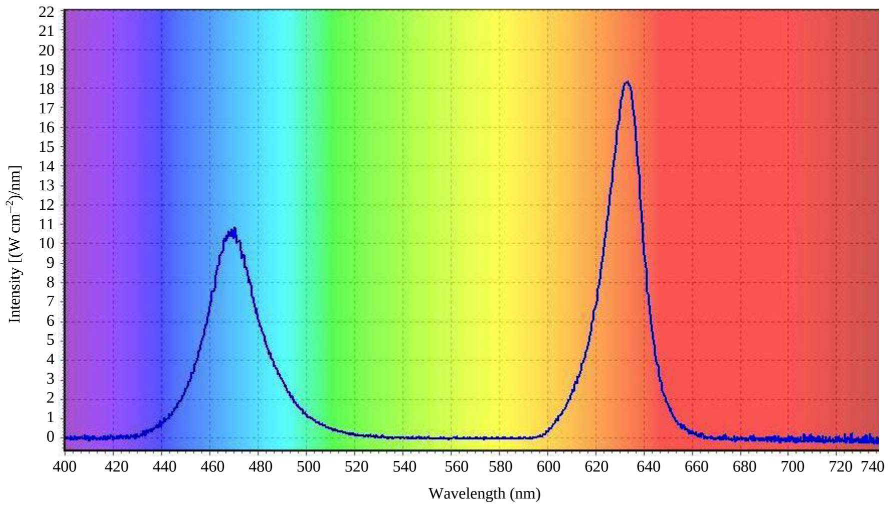

Fig. 5: Irradiation spectrum of modules

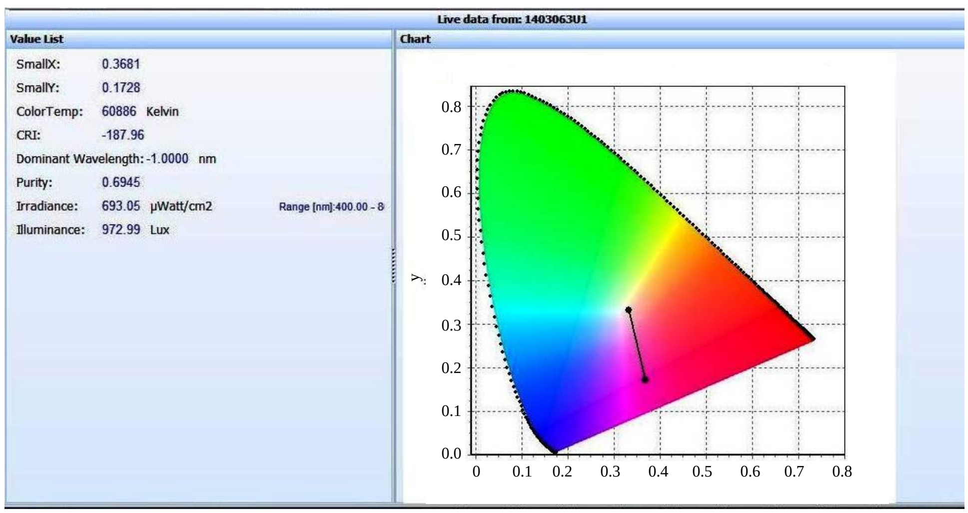

Fig. 6: Data of assay position in CIE chromatic diagram

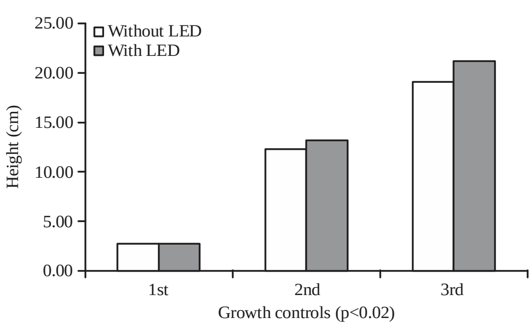

Fig. 7: Height of lettuce with and without LED lighting

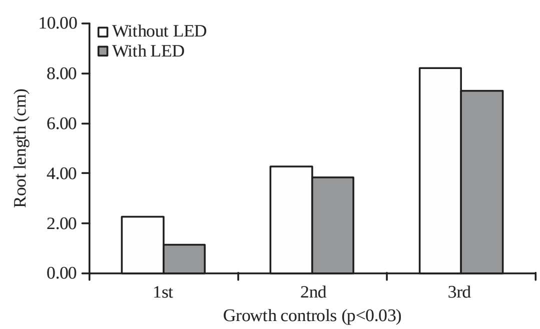

Fig. 8: Root length of lettuce with and without LED lighting

in terms of leaf area, which was higher for plants that received sun lighting (Fig. 11). The variable "overall weight" of the plants had no differences between groups.

Noteworthy, the variation of the SPAD units showed a variable and inexplicable behavior. While in the early days there was an advantage for specimens exposed

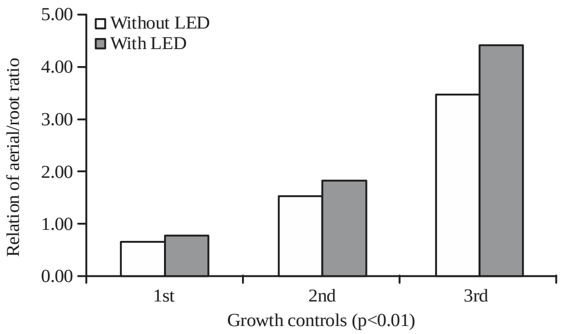

Fig. 9: Relation of aerial/root part with and without LED lighting

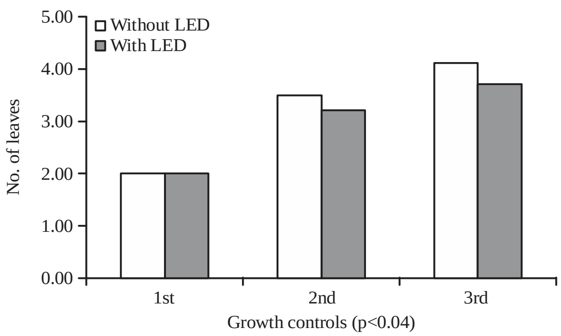

Fig. 10: No. of leaves with and without LED lighting

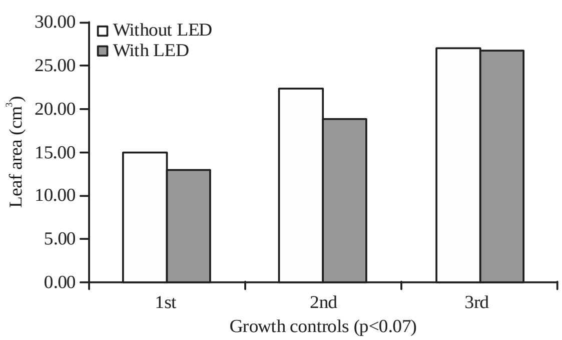

Fig. 11: Leaf area with and without LED lighting

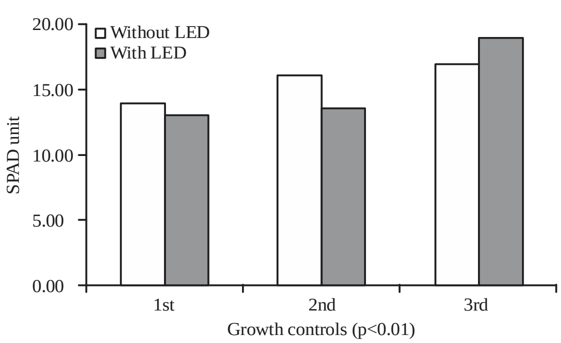

Fig. 12: SPAD with and without LED lighting

to sunlight, on 21 days, this advantage was reversed in favor of LED lighting (Fig. 12).

DISCUSSION

Although Light-Emitting Diode (LED) lighting was proven to be as effective as sunlight for inducing growth in several plant species; data is still contradictory for lettuce sativa[17-22].

Light is essential for plants since it provides energy to drive photosynthesis[23]. This process may be modified when plants grown are submitted to artificial lighting, because lamps do not usually mimic the spectrum and energy of sunlight[17]. New lighting technologies such as LEDs have the potential to cover fluency and wavelength requirements of plants for essential growth[20]. Chlorophylls are major photosynthetic pigments present in plant's kingdom[24,25]. Chlorophyll molecules absorb blue and red light in order to provide energy[26,27]. Hence, colors wave bands have different impact on plant growth because they have variations in the energy sources for photosynthetic CO^2 assimilation[28]. The addition of green light to red-blue LEDs can enhanced different plants growth including lettuce and may produced more biomass[25,26]. The ratio of blue wavelength (400-500 nm), red (600-700 nm), or purple (700-800 nm) is important for normal photo-morphogenesis of various plants[29]. Recent data demonstrated the far-red component in the light spectrum is more critical than green light in order to increase the biomass of plants exposed to LED lighting[27,28]. However, this biomass accumulation using this spectrum was insufficient when daylight was excluded[22], data that contrasts with the results obtained in the present study since the purple light was able to increase some of the lettuce's growth indicators of this assay. The biomass and metabolic products of cultivated plants can therefore be modified with the type of LED exposure[30] but evidence of LED lighting specifically for lettuce cultivation remains uncertain[18].

The present study aimed to establish the ability of LED lighting to induce growth in lettuce plant. In order to demonstrate this goal, some classic indicators that have shown efficacy in this type of measurements for other plant specimens were chosen for study variables such as plant height, number of leaves, leaves area, or root length.

Concerning these parameters, in lettuce sativa specimen, neither foliar area nor root length or number of leaves were able to increase with LED lighting like it was previously demonstrated by Li and Kubota[17], or even decreased according to the results obtained in this study.

Noteworthy, other criterion like aerial/root ratio, or greenery index measured in SPAD units demonstrated to be excellent alternatives that reflect the degree of growth[19] that a vegetable can achieve and because of that, they were also included in the protocol of the present study. Results concerning aerial/root ratio exhibited a highly significant statistical difference ($p<0.05$) in favor of LED lighting when compared with sunlight group. However, results in regard to SPAD units were unclear since during the first two weeks of the study, the SPAD index seemed to be better for solar lighting group when at the last measurement performed, that unit was better for LED lighting group.

The SPAD parameter along with the aerial/root ratio are both extremely important predictors index in order to get plants ready to be transferred to a ground stage in a production line of vegetables like lettuce.

From the present study, it is also known that purple LED lighting was able to reduced the growth generation time by increasing height and aerial/root ration of lettuce specimens.

The finding of the present study might be interesting for geographical areas where lighting is too weak that photosynthesis cannot work efficiently[20]; or in places where the excessive light exposure generates oxygen radicals that can causes photo-inhibition. Both phenomena strongly demonstrated the limits in primary productivity[21].

The results obtained in the present research should be limited to sativa lettuce and should not be overlapped or applied in other plants until further studies are done on other vegetable specimens.

CONCLUSION

This study gives evidence that purple LED lighting is capable to increase the height and the aerial/root ratio of lettuce, two critic parameters that reflect the global growth of this vegetable and determines the decision to transfer the plant to a ground stage, aspects that can shorten lettuce production time. The present approach supports LEDs capacity to mimic the effects of natural light in terms ensuring the growth and development of photosynthetic organisms. It also reinforces the idea of the potential of type of energy to manipulate the metabolism of plants in order to produce functionalized foods such as lettuce plants in regions where sunlight is not enough to induce growing in these species.

SIGNIFICANCE STATEMENTS

This study discovers the capacity of the purple LED lighting to boost vegetable growth like lettuce which can be beneficial for food production improvement based on herbaceous plants. This study will help the researcher to uncover the critical area of new agricultural techniques that many researchers were not able to explore yet. Thus, a new theory on combination of LED lighting that obtains purple color was able to reduced the plant growth cycle time.

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