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# EFFECTS OF THE USE OF LED LIGHTING IN GREENHOUSES

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**Abstract:** People are increasingly concerned about the quality of the food, showing interest in the consumption of fresh food, at affordable prices, throughout the year. Thus, a new era is envisaged for urban agriculture, where food is grown locally in limited spaces, without natural light. The implementation of LED solutions for lighting greenhouses is a new alternative, considering that productivity growth can be achieved, with reduced energy consumption, thus contributing to environmental protection. This is very important for Romania, because over 70% of the electricity consumed at national level is produced by burning fossil fuels, characterized by the well–known harmful effects. The paper presents a brief summary of current greenhouse lighting solutions using high efficiency LEDs. These offer new possibilities for intensive and efficient growth of plants, both for farmers and for specialists. The paper presents a brief summary of the current greenhouse lighting solutions using high efficiency LEDs, with the help of which different light intensities are obtained, with effects on plant growth and evolution.
**Keywords:** greenhouse, led, technology, light efficiency

## INTRODUCTION

Many urban centers around the world are facing a lack of space and light. LED systems are flexible, controllable and energy efficient, with high potential to solve this problem, many companies profiting from this opportunity. (Ganandran G.S.B. 2014)

Innovative LEDs produce light in pure colors and at spectral levels that influence the productivity and quality of greenhouse crops, compared to traditional horticultural lamps. In addition, these solutions achieve significant energy savings, over 50%, at a lower cost price, longer service life than conventional devices currently used, increased flexibility and easy maneuverability (Singh D., et al. 2014).

Manipulation of the light spectrum of the lamps could trigger potential benefits by enhancing plant growth (Carvalho and Folta, 2014), but the HPS lamps do not provide the possibility for spectral manipulation or even dimming. As a consequence, the LED technology has emerged and developed rapidly in the past decades as alternative light sources (Massa et al., 2008). LEDs are solid–state and durable light sources providing a narrow spectrum of light (Stutte et al., 2009) in the range from ultraviolet to infrared. Their lifetime could reach up to 100,000 h, in comparison with the HPS lamps with a lifetime ranging from 10,000 to 20,000 h (Bourget, 2008; Morrow, 2008). As LED use in greenhouses is developing, the prices are expected to gradually decrease and there has been a renewed interest in the use of LEDs as a tool in greenhouse research (Folta and Childers, 2008).

People are increasingly concerned about the quality of the food, showing interest in the consumption of fresh food, at affordable prices, throughout the year. Thus, a new era is envisaged for urban agriculture, where food is grown locally in limited spaces, without natural light.

The development of plants depends, among other things, on how to carry out the process of photosynthesis, which converts water and carbon dioxide into the presence of solar energy, oxygen and usable energy in the form of sugars. Photosynthesis research has been carried out in order to deduce the correlation between the illumination corresponding to the different areas of the electromagnetic radiation spectrum and the development of plants. The paper presents a brief summary of the current greenhouse lighting solutions using high efficiency LEDs, with the help of which different light intensities are obtained, with effects on plant growth and evolution.

## MATERIALS AND METHOD

Plants respond differently to light in different colors, characterized by different wavelengths of the electromagnetic radiation spectrum. Generally, the red light causes an excessive growth in the height of the plants, while the blue light causes a smaller growth, the plants having a thick waist. An adequate balance of light energy in the red and blue spectral areas determines a normal growth and shape of plants and their fruits (Munner S. et al. 2014).

Chlorophyll is a mixture of two compounds, chlorophyll a (a blue–black solid) and chlorophyll b (a dark green solid), shown in Figure 1 which provides a green color in organic solutions (Richard Willstätte – German chemist, 1912 ). In the photosynthesis reaction, chlorophyll absorbs light energy, and one electron in chlorophyll is excited, moving from a lower energy state to a higher energy state, and thus the electron is transferred to another molecule. An electron transfer step chain ends with an electron transferred to the carbon dioxide molecule. In the meantime, chlorophyll that has dropped an electron can accept an electron from another molecule (Willstätte R. 1912)

This is the end of a process that results in the removal of an electron from the water. Thus, in figure 2 is shown chlorophyll being – in the center of the oxidation reaction, a reduction, called photosynthesis between carbon dioxide and water, resulting in oxygen.

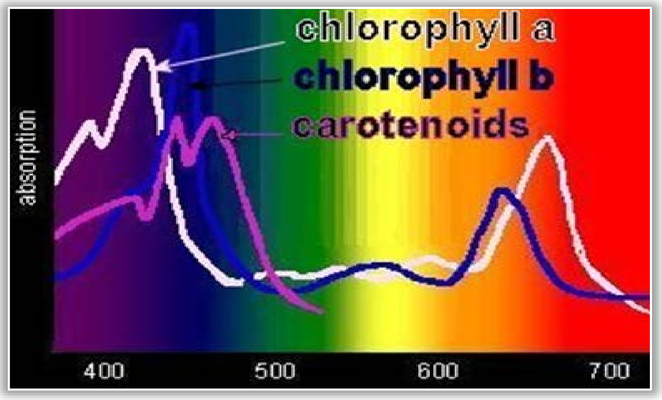


Figure 1. Absorption spectrum of chlorophyll (http://plantphys.info/)

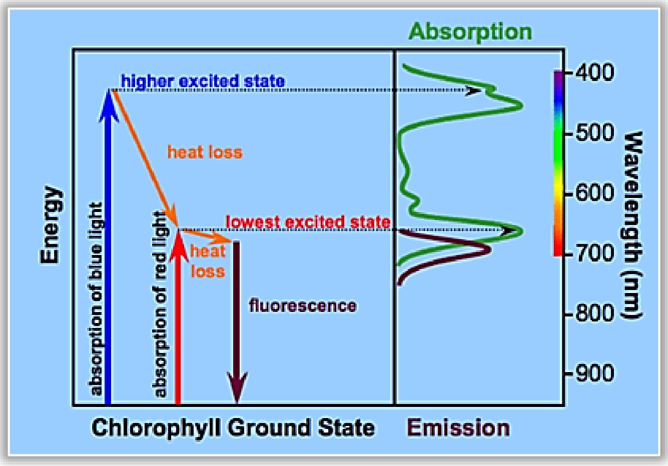


Figure 2. The stages of the electron to the degree of excitation of light absorption (http://plantphys.info/)

Studies have shown that LED lighting can stimulate plant growth by up to 40%. The lighting system is individually designed according to the application (space dimensions, plant species requirements regarding light, temperature, humidity, etc.). In order to obtain optimal results, two basic principles are essential: namely the efficiency of photosynthesis and the sufficiency of photomorphogenesis, which must be fulfilled. Photomorphogenesis represents the morphological changes induced by light in a plant, being mainly dependent on the type of photoreceptors: phytochrome, cryptochrome and phototropin. By orienting these photoreceptors to certain wavelengths, the producers are able to obtain morphological changes of the plants (e.g. flower induction and suppression, crown height, internode leaf distances, etc.), with their installations (Zielińska–Dabkowska et al. 2019). Figure 3 shows an application that uses such a lighting system for intensive plant growth in a short time.

Figure 3. LED lighting in horticulture (http://plantphys.info/plant_physiology/light.shtml)

Because the available LEDs emit light in different wavelengths depending on the manufacturing technology, the spectral complexity of the efficiency of photosynthesis must be understood and then an application developed.

Figure 4 shows Scheme Z of the photocatalysis systems, which characterize the decomposition of the water molecule.

Figure 5 shows the absorption spectrum and the action of the radiation depending on the specific wavelength of the application in figure 3. It shows that the most absorbed radiation are the orange and blue ones in this case, these having the most important contribution in the photosynthesis process.

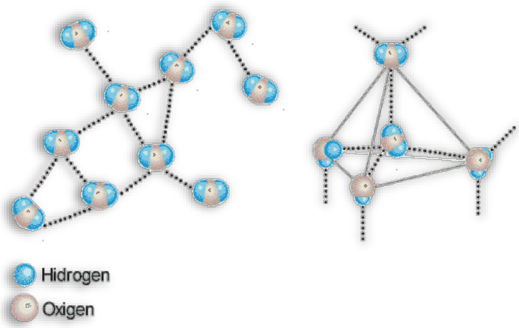


Figure 4. Water molecule decomposition (http://plantphys.info/plant_physiology/light.shtml)

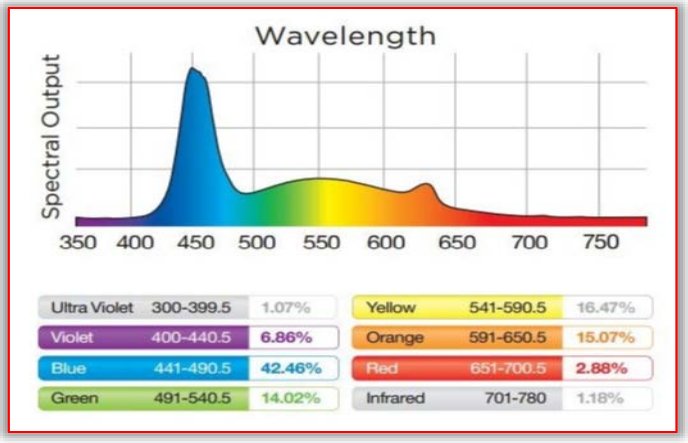


Figure 5. Electromagnetic wavelength

## RESULTS

The following figures show the influence of spectral areas obtained with LED applications on plants, during a cycle of growth and development.

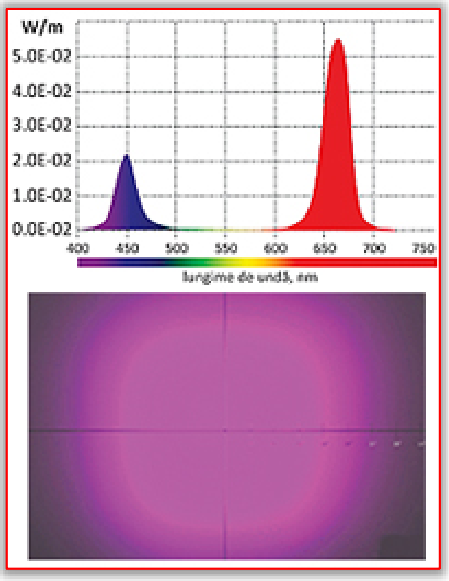


Figure 6. Lighting F1

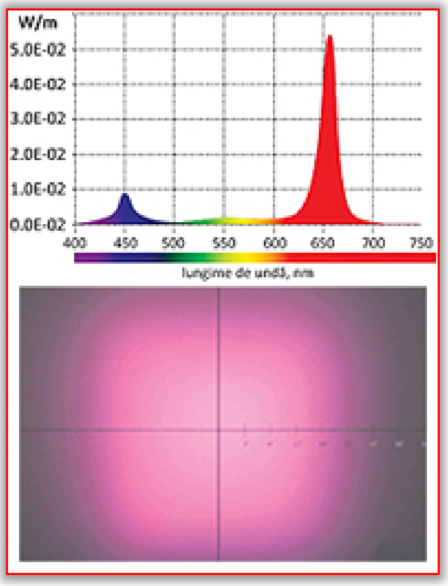


Figure 7. Lighting F3
(https://www.electronica-azi.ro/2013/11/05/iluminatul-cu-led-uri-stimuleaza-cresterea-plantelor)

Figure 6 shows the F1 (Daylight Fluorescent) illumination F1 spectrum, suitable for a wide variety of plant species during the growth cycle. The high proportion of red light, stimulates photosynthesis during the vegetative growth stage and facilitates the flowering stage.

Figure 7 shows the F3 (White Fluorescent) illumination The F3 spectrum produces the fastest germination in plant species whose germination needs light. It is recommended for use in germination chambers and for flower production.

Figure 8 shows the F6 (Lite White Fluorescent) illumination The F6 spectrum has a high blue content which reduces the height of the plant, thus improving the appearance of plants and the use of space. Recommended for the production of green leafy vegetables.

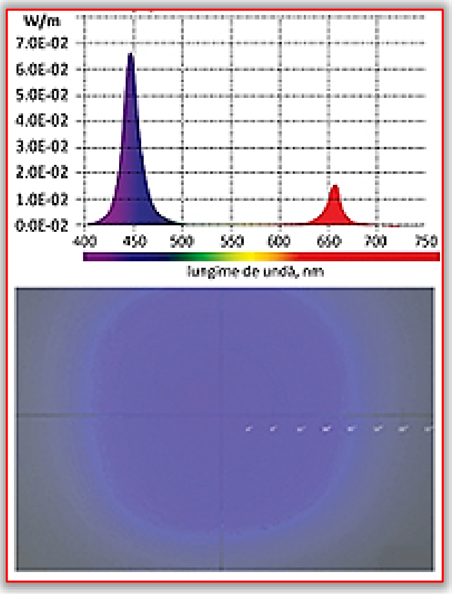


Figure 8. Lighting F6

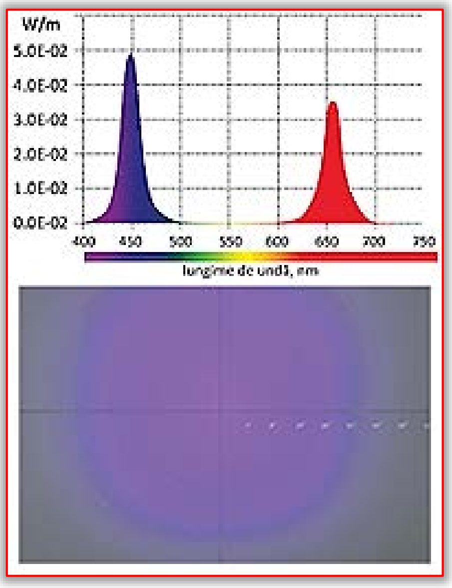


Figure 9. Lighting F7
(https://www.electronica-azi.ro/2013/11/05/iluminatul-cu-led-uri-stimuleaza-cresterea-plantelor )

Figure 9 shows the F7 illumination (Daylight simulator) The F7 spectrum has the highest blue content of all spectra and produces thick plants with short internode distances, very desirable in the seedling phase. Recommended for growing seedlings before transplanting. (http://ledlight.osram-os.com/applications/horticultural-led-lighting/ )

The benefits of cultivation with the help of growth lights cannot be ignored: there is no better way to grow large, healthy seedlings and a beautiful green. And for those who cultivate floricultural plants like orchids, African violets, citrus or hibiscus, these lights will make them flourish almost throughout the year. The same can be done by producing herbs and leafy greens during the winter.

The growth of a plant might seem like a simple and straightforward process. The plant needs to be watered, the soil needs to have certain nutrients, and it needs to be in an environment where it receives light for a certain amount of time. Yet not many know how the latter can have a big impact in the development of a plant.

In this paper, I'll explain how different color lights affect plant growth, jumping into detail on the characteristics that light possess, and the use of different colored LED grow lights to change the properties of plants and make plants grow faster.

A crucial component in the growth of a plant besides water and oxygen, is sunlight. By receiving it, a plant is able to convert sunlight into edible food that it can use. This process is called photosynthesis.

Visible light as we perceive it behaves as a wave. As such, it displays different properties depending on its wavelength. For example, a source of light with a wavelength of around 650 nm will be detected as having a red color.

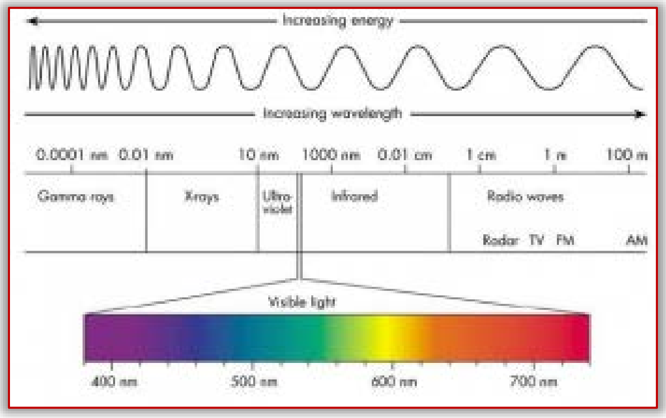


Figure 8. The increase in energy of the visible spectrum

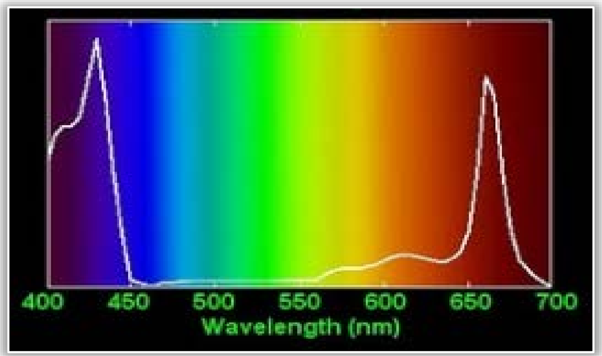


Figure 9. Chlorophyll absorption on the visible spectrum (https://www.grobo.io/blogs/growing/how-different-colors-of-light-affect-plant-growth)

Multiple studies have been conducted on how different colors of lights can have varying effects on the growth of a plant.

According to the recent developments in LED (light emitting diode) grow light technology, specific light wavelengths can now be isolated in order to control the different physical properties that a plant displays as it develops throughout its life cycle. These properties include, but are not limited to, height, weight, color, and texture, as well as the chemical composure of the plant itself.

**— The effects of each color of light**

In the following paraghraphs, I explain what each light color does, and the effects that adding or removing them will have:

- Ultraviolet – No exposure produces better growth
- Violet – Enhances the color, taste, and aroma of plants
- Blue – Increases the growth rate of plants
- Green – Enhances chlorophyll production and is used as a pigment for proper plant viewing
- Yellow – Plants exhibit less growth compared to blue and red light
- Red – When combined with blue light it yields more leaves and crops, depending on what is being grown
- Far red – Speeds up the Phytochrome conversion which reduces the time a plant takes to go into a night-time state. This allow the plant to produce a greater yield.

**— Ultraviolet (200 nm to 380 nm)**

Being exposed to UV light for a long period of time has harmful effects on human. Likewise, exposure for a long time to this type of light will damage the plants.

A study conducted demonstrated that plants raised without exposure to UV light exhibited enhanced growth.

**— Violet (380 nm to 445 nm)**

On the other hand, studies have shown that when a plant receives visible violet light, the color, taste, and aroma of the plant are enhanced.

Additionally, the plants antioxidants are able to perform their functions more efficiently, which prevents the cells in the plant from being damaged.

**— Blue (450 nm to 495 nm)**

Blue light has one of the largest effects on the development of a plant. Multiple studies have shown that exposing a plant to this color influences the formation of chlorophyll, which enables the plant to intake more energy from the sun. It also controls a plant's cellular respiration and lessens water loss through evaporation during hot and dry conditions. Blue light also has a effect on photosynthesis, and more exposure to this light can increase a plant's growth and maturity rates. This process is called photomorphogenesis.

**— Green (495 nm to 570)**

Most of the plants that we see around us possess a green color. This is due to the fact they absorb all of the colors in the light spectrum (blue, red, violet, etc.) but reflect the green one. As such, only the green light is bounced back to our eyes. Even with the relatively low amount absorbed compared to other colors, a study found that green light enhances the production of chlorophyll which helps with photosynthesis while giving the plants a greener color. Overall, adding the green color to plants does not have much effect in their life process compared to other light colors such as blue.

**— Yellow (570 nm to 590)**

Since yellow has a similar wavelength to green they both show out similar properties in plants. A source from NASA indicates that yellow light does not contribute to photosynthesis since the wavelength of the light is reflected by the plant and is not absorbed. Additionally, just like with green light, a study showed that when a plant was exposed to yellow light compared to blue and red, the growth of the plant tested was reduced.

— **Red (620 nm to 720 nm)**

Exposure to red light is another crucial factor which contributes to the optimal development of a plant. Individually, red light and far red light go hand–in–hand in regards to the effects that they have on plants. A regular plant has a phytochrome system (a light detection system) which regulates its growth, adjusting itself depending on the type of light that its exposed to. In the system, there are two predominant forms of plant protein: its biogically inactive form (Pr), and its biologically active form (Pfr). When a plant perceives that red light, Pr transforms into Pfr, and if a plant receives that far–red light, it's Pfr changes to Pr.

Pfr is important because it triggers plant growth, but it slowly reverts back to Pr over time when the plant is located in the dark. At the end of the day, a plant's flowering and vegetative growth is directly influenced by the Pr to Pfr ratio. (Chris Thiele, How Different Colors of Light Affect Plant Growth, 2019 https://www.grobo.io/blogs/growing/how–different–colors–of–light–affect–plant–growth )

An example, on how the Far Red light properties can be used to our advantage to have a higher yield is seen in cannabis growth. During the day, this plant exhibit the most flowering, and during the night it ripens. Being a short day plant, it normally requires 12 hours of exposure to light, and 12 hours of darkness. Yet thanks to far red–light, it\s phytochrome conversion is sped up, making it go into a night state quicker and requiring less time in the darkness. This way, flowering can occur under a longer daylight period, which in turn produces a greater yield. Out of all the colors mentioned above, the most crucial ones in the development of the plant are red and blue. (Zielińska–Dabkowska et al. 2019)

One source claims that for the most optimal growth of a plant, it is better to be exposed to 90 % red light, and 10 %blue light. Adding or removing the other light colors will vary the appearance and texture of the plant that are growing with the optimal characteristics.

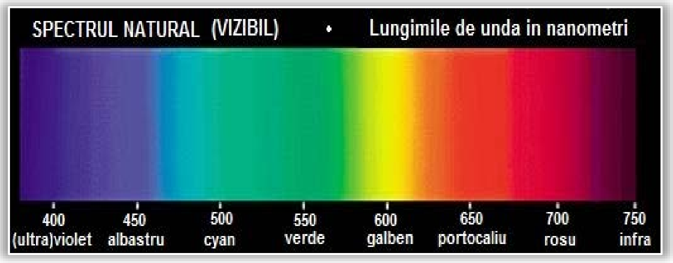


Figure 10. Wavelengths in nanometers
(Source: http://blog.seretransilvania.ro/wp–content/uploads/2015/09/Spectrul–de–lumina.jpg)

## CONCLUSION

Led lights are developed for vertical farms and greenhouses and are designed for optimal plants growth and photosynthesis that increases yield per square meter and less energy is used. Long lifetime is guarantee and is not limited of a Led light and it is easy to use, quick to install. The lights that are in their growth stage require equal distribution, as uneven light intensity over plants, are completely silent, no noise are produces by the lights as there are no active heat sinks used for cooling.

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