Influence of the photosynthetic photon flux density value on microclimate in healing and acclimatization tunnels for vegetable seedlings

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Abstract. For seedlings production, healing and acclimatization are the most important processes in obtaining healthy and vigorous plants. Influence of photosynthetic photon flux density (PPFD) on a healing tunnel environmental parameters was investigated. The experiments were carried out at HORTING institute's micro-production greenhouse using 9 alveolar trays with 104 eggplant seedlings each, placed in two sections of the specialized tunnels for healing and acclimatization of seedlings. In each section and in the research greenhouse was measured the levels of photosynthetic photon flux density, of temperature, of the relative humidity and the level of CO₂ concentration. From the meteorological station of the HORTING institute, data on the variation of outdoor temperature, relative humidity and light intensity were downloaded. The variation of the micro-climate factors in the two sections according to their external environmental conditions were compared. One of the conclusions is that seedlings that have benefited from an additional artificial source of light have a more intense photosynthetic activity. The difference on CO₂ concentration in the two sections over the same time period lead to this conclusion. This gives the certainty of obtaining healthy and vigorous plants in the sections with supplementary lighting.

1. Introduction

The newest light source used in horticulture is the light emitting diode (LED). This source has good spectral characteristics with ± 15 nm emission peak of the wavelength. So the required wavelength can be chosen accurately [1]. Also, LED have a low energy consumption and less heat emitted of the radiation. As a result, LED is widely used as a new type of light source for plant growth. It has been shown that although LEDs help regulate gene growth, photosynthesis and plant metabolism [2–4], they can also have adverse effects on plants, such as elongation, formation of auxiliary buds, on leaf anatomy [5–9].

The use of grafted vegetable in horticultural production has been expanded in order to control pathogens and to enhance the plants’ tolerance against abiotic stresses, but also in order to control exactly the time when the seedlings are ready to be transplanted in the field. Farmers, when setting up crops, are generally looking for the most cost-effective solutions for materials and manual labor. For this, they need healthy seedlings at a certain date which is usually established before.

Highly technical grafting skills and environmental controls during the healing period are required for the successful production of grafted plants. These grafted seedlings are most often obtained in specialized enclosures in order prevent the influence of the external weather conditions the micro-
climate factors inside the seedlings and ensuring optimum conditions for high percentage of seedling surviving. Usually, the grafted plants were healed under specific environmental conditions such as high relative humidity (RH) ≥ 95% and low light intensity but several recent research showed that the photosynthesis, growth, and quality of grafted plants were improved by increasing the light intensity under highly controlled conditions during the healing periods [10].

Light is an essential factor for plant growth. Both the light intensity and the light quality are important for the growth and development of plants [11], [12]. Various types of artificial light have been used in plant production but in recent years, light emitting diodes (LEDs) are a particular interest to farmers because of their features such as small size, low mass, long life, narrow spectral output, and energy conversion efficiency, LEDs enable the selection of specific wavelengths for a targeted plant response.

Among the most important factors that affect the growth and development of the grafted seedlings and can be monitored and optimized are CO$_2$ concentration and light. The seedlings grow faster in an atmosphere with high CO$_2$ concentration, an optimal value of this concentration being about 1000 ppm. A high growth rate of seedlings in a CO$_2$ enriched atmosphere can be achieved when the intensity of photosynthetic active photon flux (PPFD) is high. Also, under certain limits, insufficient PPFD could be compensate by an enrichment of CO$_2$ from the healing rooms [13]. In the countries from the northern half of Europe, the production of grafted seedlings takes place generally in spring when the conditions of natural lighting are poor. If the seedlings are grown under low light radiation, they develop the usual photosynthetic characteristics for shade plants and will no longer be able to use efficiently the relatively intense light that predominates after planting them in the large crop.

2. Materials and methods

In general, in Europe, the process of healing of vegetables grafted seedlings is carried out in the tunnels placed inside a greenhouse such as the one used at the HORTING Institute - Bucharest as shown in Figure 1. A LED lamp was mounted in one of the sections. The lamp has 6 LED modules, each module having 4 LEDs with the following characteristics: white LEDs with luminous flux at 4000 K, blue LEDs with \( \lambda = 460 \) nm and red LEDs with \( \lambda = 660 \) nm. The LED lamp dispersion angle is 90˚ and the photosynthetic photon flux (PPF) is 34 µmol/s.

![Figure 1. Healing tunnels at HORTING Institute – Bucharest](image)

Two EA80 model data loggers (Figure 2 a) were used to measure CO$_2$ concentration, temperature and relative humidity in the two sections. These data loggers can check the temperature, the relative humidity and CO$_2$ concentrations using a maintenance-free dual wave NDIR (non-dispersive infrared) CO$_2$ sensor with a range from 0 to 6.000 ppm and it can automatically data log up to 20.000 data sets. A data logger SD800 model (Figure 2 b) was used to measure CO$_2$ concentration, relative humidity and greenhouse temperature. This device has, like the other one, capability for measuring CO$_2$ concentration, a maintenance-free dual wave NDIR (non-dispersive infrared) sensor. The measurement ranges are: for CO$_2$ from 0 to 4.000 ppm; for temperature from 0 to 50°C; for relative humidity from 10 to 90%. Data logger stores readings on an SD card in Excel® format for easy transfer to a PC. For measuring the intensity of the light radiation inside the healing section, a photo radiometer model HD 2102.2
Datalogger equipped with a LP 471 PAR LP measuring probe (Figure 2 c) was used to measure the value of photosynthetic photon flux density (Photosynthetically Active Radiation) from 400nm to 700nm, with a measurement range between 0.01 μmol/(m²·s) and 104 μmol/(m²·s) ± 0.01 μmol/(m²·s). Also, temperature, relative humidity and intensity of solar radiation outside the greenhouse were measured. For these measurements, a VantagePRO2 Plus weather station was used, which can provide data on: indoor/outdoor temperature, relative indoor/outdoor humidity, barometric pressure, wind speed and direction, dew point, precipitation quantity, solar radiation, etc. In Figure 3 is shown the section equipped with additional lighting, ready for determinations.

![Figure 2](image1.png) ![Figure 3](image2.png)

**Figure 2.** Measuring devices: a) EA80; b) SD800; c) LP471  **Figure 3.** Section ready for measurements

The positioning of the tunnel in which the determinations were made in the research greenhouse is shown in Figure 4. As can be seen from this figure but also from Figure 5, around the tunnel there are a multitude of constructive elements of the greenhouse that can influence the microclimate parameters and especially the intensity of the solar radiation.

![Figure 4](image3.png) ![Figure 5](image4.png)

**Figure 4.** Position of the tunnel in the greenhouse  **Figure 5.** The two healing sections prepared for measurements

### 3. Results and discussion

The measurements were carried out between May 17 and May 22, 2019. The LED has been programmed to operate daily between 04:20 and 20:20. Throughout the measurements, the correct functioning of the measuring devices and the LEDs lamp was verified twice times per day every day. The variation of the environment parameters from May 17, 14:20 to May 18, 11:50, is shown in Figure 6.

It can be observed that the thermo-technical processes that develop in the healing rooms cause a dynamic variation of the microclimate parameters into them. These parameters interact with each other and are influenced, and also influence, the biological processes in the seedlings during this healing period.
Figure 6. Variation of the environment parameters during 24 hours between 17-18/05/2019: a) temperature variation; b) variation of CO$_2$ concentration; c) variation of light radiation intensity; d) variation of relative humidity

Obviously, as can be seen in Figure 7, the temperature increases as the intensity of the light radiation increases. Even though the heat generated of the LEDs lamp is low, an increase in the temperature in the additional illuminated section is observed. But this temperature difference between the 2 sections is influenced more by the greenhouse temperature than by the additional lamp.

Figure 7. Influence of the light radiation intensity on the temperature
In Figure 8 it can be seen that at higher values of the intensity of the light radiation, the CO$_2$ concentration decreases as a result of the increase of photosynthesis process which is an "consumer" of CO$_2$. Also, the relative humidity is influenced by the increase of the light radiation intensity as can be seen in Figure 9. Thus, the higher the value of the light intensity generate a higher intensity of the photosynthesis process. An increased photosynthesis process materializes through a high evapotranspiration process and thus an increase in relative humidity in the healing tunnel.

4. Conclusions
The environmental control strategies for controlled plant production systems depend on microclimate parameters such as air, temperature, humidity, solar radiation, etc. Understanding the plant response of the microclimate conditions and control the strategies of growing is significant for high quality and yield in production in grafted seedlings production. Automated monitoring using real-time data from the plants and from the microclimate must be able to determine the condition of the seedlings morphogenesis while imposing a minimum of physical disturbance on the plants and their environment. In order to achieve this objective, it is necessary to develop interdisciplinary research involving several scientific disciplines such as horticulture, technical engineering, computer technology, etc.

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