PRELIMINARY RESULTS OF THE ANALYSIS OF THE MAIN MICROCLIMATE FACTORS IN AN URBAN FARM MODULE

REZULTATE PRELIMINARE ALE ANALIZEI PRINCIPALILOR FACTORI DE MICROCLIMAT ÎNTR-UN MODUL DE FERMĂ URBANĂ

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ABSTRACT

As in the case of humans, in the case of plants grown in protected areas, specific microclimate conditions must be ensured for their optimal development during the growing season. The development of plants is the result of their own genetic characteristics, but this is influenced by the microclimate conditions in the environment in which they grow. In the growing areas, the specific microclimate conditions must be strictly monitored. On the other hand, in the context of climate change and urbanization, there has been a need to develop specialized modules for vegetable production. Growing vegetables on urban farms is an increasingly used concept internationally. In this sense, a team of researchers from the INMA and HORTING Institutes in Bucharest - Romania has developed a collaborative project, which aims to investigate the main microclimate parameters such as temperature, relative humidity, CO_2 concentration and light radiation intensity inside a prototype urban farm for research, in which green vegetables and microplants can be grown. Due to the complexity of the phenomena that take place in the closed spaces of culture, the amount of information necessary for the complete quantification of the variables of microclimate factors depends both on the intensity of the thermo-physical processes and on the accuracy of the measuring instruments used. This paper presents the preliminary results of the investigation of the main microclimate parameters within the experimental module.

This module is a good laboratory tool that could be used in a series of research on the influence of light radiation on certain characteristics of microplants or vegetable seedlings. Analyzing the influence of the light radiation that reaches the plants, it can be seen that they have a great influence on the way they grow.

REZUMAT

Ca și în cazul omului, în cazul plantelor crescute în spații protejate trebuie asigurate condiții specifice de microclimat pentru o dezvoltare optimă a plantelor în perioada de vegetație. Dezvoltarea plantelor este rezultatul propriilor caracteristici genetice, dar aceastea sunt influențate de condițiile de microclimat din mediul în care cresc. În ariile de cultivare, condițiile specifice de microclimat trebuie strict monitorizate. Pe de altă parte, în contextul schimbărilor climatice și al urbanizării, a apărut necesitatea dezvoltării unor module specializate pentru producția de legume. Cultivarea legumelor în așa zisele ferme urbane este un concept din ce în ce mai utilizat la nivel internațional. În acest sens, o echipă de cercetători de la Institutele INMA și HORTING din București - România a dezvoltat în colaborare un proiect, care își propune să investigheze principalii parametri de microclimat precum temperatura, umiditatea relativă, concentrația de CO_2 și intensitatea radiației luminoase în interiorul unui prototip de fermă urbană destinat cercetării, modul în care pot fi cultivate legume verzi și microplante. Datorită complexității fenomenelor care au loc în aceste spații închise de cultură, cantitatea de informații necesară cuantificării complete a variabilelor ce caracterizează microclimatul din incintă depinde atât de intensitatea proceselor termo-fizice, cât și de acuratețea măsurărilor și a instrumentelor folosite. Această lucrare prezintă rezultatele preliminare ale investigației principalilor parametri de microclimat din modul experimental dezvoltat.

Acest modul este un bun instrument de laborator care ar putea fi folosit într-o serie de cercetări privind influența radiațiilor luminoase asupra anumitor caracteristici ale microplantelor sau răsadurilor de legume. Analizand influența radiațiilor luminoase care ajung la plante, se poate observa că au o mare influență asupra modului de creștere a acestora.

INTRODUCTION

The world's population is projected to exceed 9 billion by 2050 (*United Nations 2020*). For the first time in human history, more than half of the world's population lives in cities, and by 2030, this figure will increase to more than 60% (*United Nations 2020*).

In addition to climate change and urbanization, our food production will face another mega-trend: growing demand for food amid declining productive agricultural land. Currently, 13.4 billion hectares of land worldwide are used for crop production (arable land and land with permanent crops) (FAO 2020), but intensive forms of agriculture can cause serious damage to the environment. In addition to limiting productive land, crops are now competing for land, water and other resources in many parts of the world as other types of land use (e.g. bioenergy, urbanization, nature conservation areas) emerge (FAO 2011). Large-scale urban food production could provide new opportunities for the landscape and reduce the pressure on agricultural land.

In this context, the development of integrated forms of urban food production at global level is one of the challenges facing cities today. Urban agriculture is currently considered one of the solutions to this problem. Instead of cultivating food in remote areas and spending large amounts of resources on transportation, in-city food production can offer several benefits.

Urban agriculture (UA) is becoming more widespread in urban areas of developed countries (*Dona and all 2021; Cohen et al. 2012; Mok et al. 2013*). Types of UAs are numerous and vary in location, ownership, and purpose, such as community gardens for social inclusion, private backyard gardens for self-sufficiency, and publicly owned spaces for individual small gardens.

In this regard, the specific purpose of this study was to develop an experimental demonstrator of the HI-TECH Modular Urban Farm (M.H.T.U.F.) for the production of vegetables in the urban environment, made from a modified standard transport container (Kalantari and all 2017). This experimental module is practically a laboratory tool that can be used either for research specific to vegetable production or for popularizing this concept of urban farm among the stakeholders.

MATERIALS AND METHODS

The demonstration module is a closed enclosure whose dimensions are presented in Figure 1. Figure 2 shows a general view of the module during the experimental determinations.

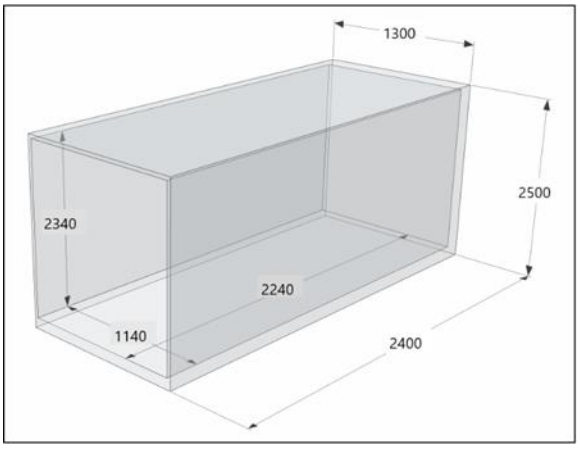


Fig. 1 - Demonstration module dimensions

Fig. 2 - General view of the module

In this module are mounted 3 shelves with trays made in galvanized metal with dimensions of 600x400mm. They have the possibility to be mounted vertically at various distances from each other, the maximum distance between 2 shelves can be a maximum of 1700 mm. Thus, for different determinations, vegetables with various sizes can be placed on the shelves, starting from microplants to various vegetable seedlings.

Above each shelf can be mounted a lighting system with LED light source. In the demonstration module presented in this paper, 6 such lighting systems with 2 lamps each are installed. One lamp emit red light radiation with λ = 660 nm and the other emit blue light radiation with λ = 450 nm. Each lighting element has the possibility to vary the spectral radiation measured in W/m², so that determinations can be made for different ratios of Red/Blue radiation that reach the foliar surface of the plants. Practically the values of Photosynthetic Photon Flux Density (PPFD) measured in µmol / (m²·s) can be varied.

In order to have a control sample with which the other samples can be compared, a lamp that emits light radiation with a wavelength λ = 4000K, a wavelength close to the solar radiation, was also installed. To prevent light radiation from the shelves from influencing each other, each plant development micro-enclosure is optically isolated from the others. Each luminaire emitting in the red and blue band has the possibility to vary the spectral radiation, measured in [W/m²], so that experiments can be made for different ratios of Red / Blue radiation reaching the foliar surface of plants, practically for different values of *Photosynthetic Photon Flux Density* (PPFD) measured in [µmol/(m²·s)] (Figure 3). For the experimental determinations presented in this article, for each enclosure was set a different characteristic of light radiation. The characteristics of the light sources for each shelf are presented in Table no.1 and the positioning of the trays on the shelves in the module premises is illustrated in Figure 4. To turn on / off the lighting system there is a programmer that can be set according to the needs of the plants (Figure 5). For the experiments made, the lighting system was started between 08:00 and 18:00 throughout the determinations.

A CO_2 concentration analyzer is also mounted in the module. Depending on the desired concentration limits, it operates a CO_2 inlet solenoid valve from a CO_2 tank mounted outside the module (Figure 6). For these experimental determinations it was established that the CO_2 concentration should be maintained between 600 ppm and 1000 ppm throughout the measurements (https://www.hortidaily.com- 7/16/2018). There is also a thermometer that controls two extractor / vacuum cleaner fans to balance the room temperature. A temperature range between 20 °C to 24 °C was chosen (*Gerrit van Straten 2013; Phillips 2018*).

Table 1

Characteristics of the light sources

Shelf no. 1	**Shelf no. 4**
red l=660 nm - blue l=450 nm	red l=660 nm - blue l=450 nm
- ratio: - red ¾ - blue 1/4	- ratio: - red ¼ - blue 3/4
- PPFD:(red + blue) 305 [µmol/(m²·s)]	- PPFD: (red + blue) 214 [µmol/(m²·s)]
- spectral radiance: - red 33 [W/m²] - blue 15 [W/m²]	- spectral radiance:- red 11 [W/m²] - blue 35 [W/m²]
- total 48 [W/m²]	- total 46 [W/m²]
Shelf no. 2	**Shelf no. 5**
red l=660 nm - blue l=450 nm	red l=660 nm - blue l=450 nm
- ratio: - red ½ - blue 1/2	- ratio: - red ½ - blue 1/1
- PPFD: (red + blue) 296 [µmol/(m²·s)]	- PPFD: (red + blue) 420 [µmol/(m²·s)]
- spectral radiance: - red 22 [W/m²] - blue 31 [W/m²]	- spectral radiance: - red 33 [W/m²] - blue 22 [W/m²]
- total 53 [W/m²]	- total 61 [W/m²]
Shelf no. 3	**Shelf no. 6**
red l=660 nm - blue l=450 nm	red l=660 nm - blue l=450 nm
- ratio: - red - blue 1/1	- ratio: - red 1/1- blue -
- PPFD: (blue) 293 [µmol/(m²·s)]	- PPFD: (red) 344 [µmol/(m²·s)]
- spectral radiance: - red -- [W/m²] - blue 75 [W/m²]	- spectral radiance: - red 44 [W/m²] - blue -[W/m²]
- total 75 [W/m²]	- total 44 [W/m²]
Shelf no. 7	**Shelf no. -**
neutral white	neutral white
PPFD: 297 [µmol/(m²·s)]	PPFD: 308 [µmol/(m²·s)]
spectral radiance: 48 [W/m²]	spectral radiance: 50 [W/m²]

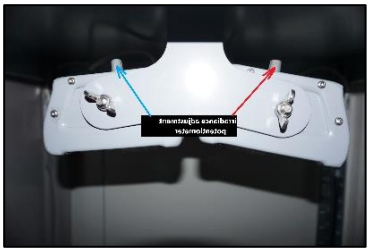
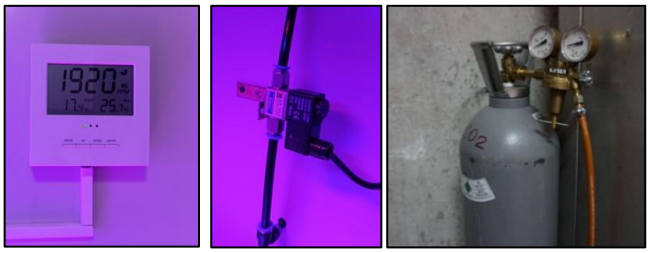


Fig. 3 - Potentiometers for spectral radiation variation

Fig. 4 - Positioning of trays during experiments

Fig. 5 - On/Off lighting programmer



CO_2 analyzer *solenoid valve* *CO_2 tank*

Fig. 6 - CO_2 analyzer and concentration controller

In the experimental module is also mounted a thermometer that controls the start/stop of two fans. These can make the air intake from the outside environment or the exhaust air from the enclosure so that the desired temperature in the enclosure can be set and maintained at a constant value.

The main factors that characterize the microclimate inside, namely temperature, relative humidity and CO_2 concentration are measured and recorded by a data logger that allows their download and subsequent analysis on a computer (workshop on vertical farming – Wageningen 2019).

For experimental determinations, *Red Amaranth* seeds were sown in 24-cell plastic pallets for seedling cultivation. After the plants come up, alveolar pallets were placed on the shelves in the module, one on each shelf as specified above (see figure 4). Figure 7 shows the 7 alveolar trays during the experiments.

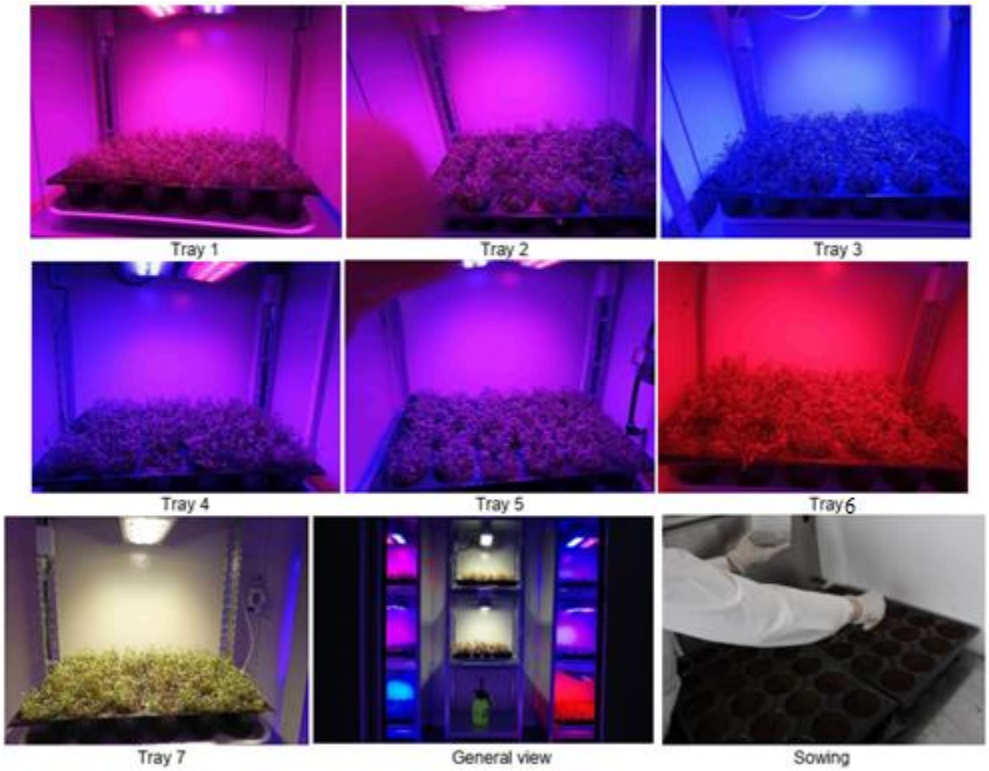
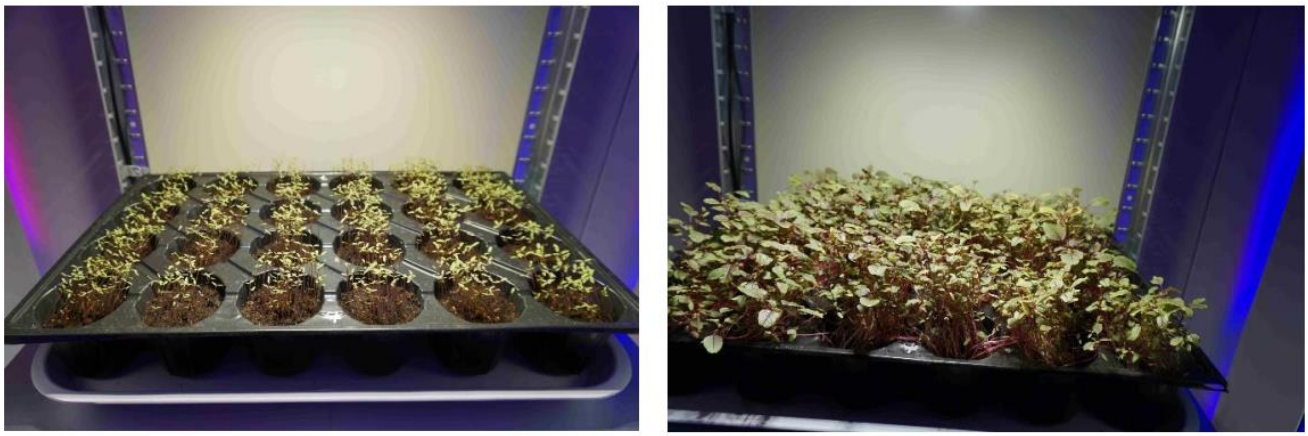


Fig. 7 - Alveolar trays during the experiments

RESULTS

The registration of the values of the microclimate factors was made using a Data logger LOG220E in the period 06.04.2022 - 04.05.2022. After downloading and processing the data, it was possible to visualize the microclimate factors variation inside the demonstration module during the experiments. In Figure 8 it can be seen how the plants in the control tray looked like in the first week and how they were at the end of the experiments. Figure 9 shows the microclimate factors variation in the first week and Figure 10 shows their variation in the last week of experimental measurements.



a) first week b) last week

Fig. 8 - Control trays during measurements -

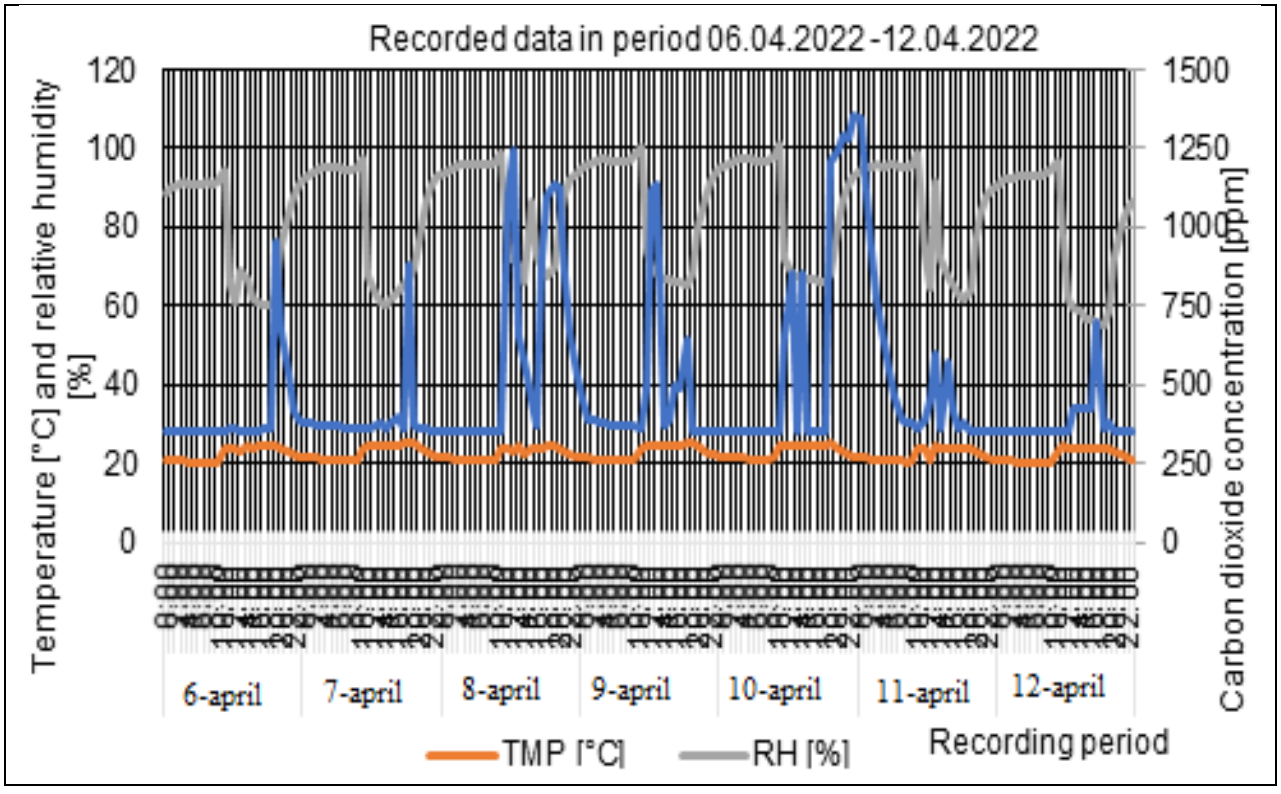


Fig. 9 - Microclimate factors variation in the first week

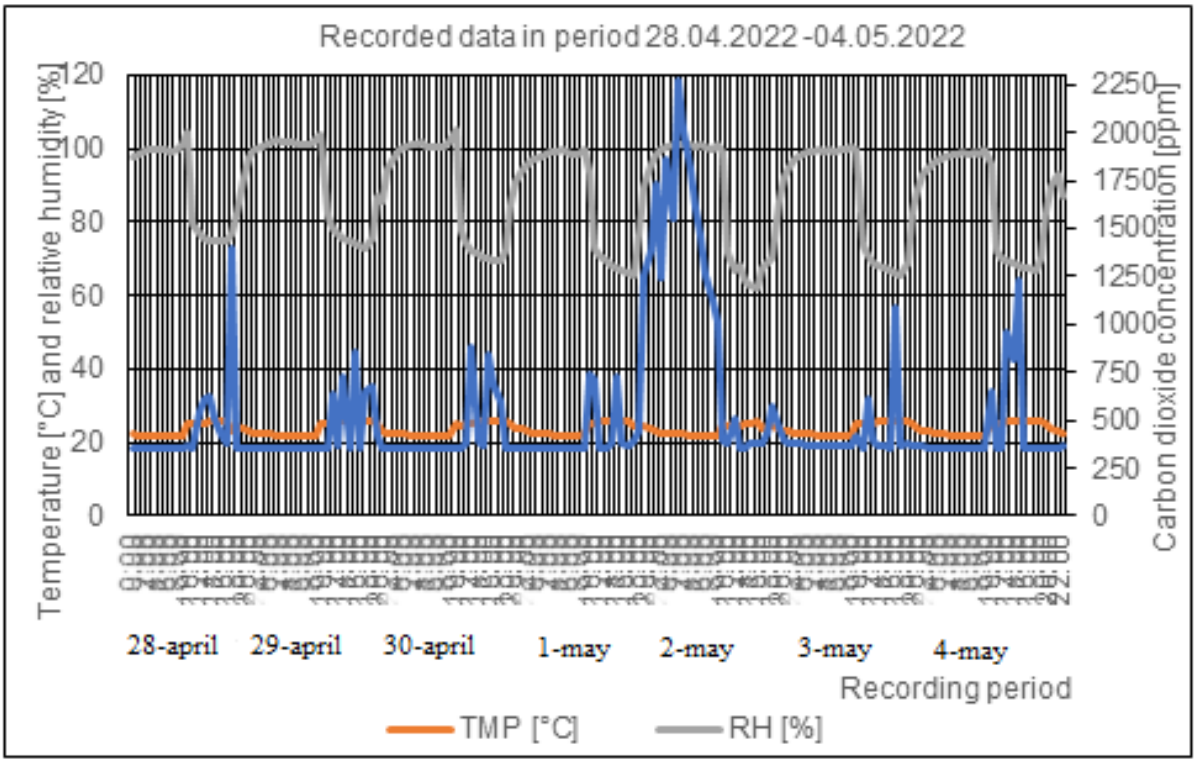


Fig. 10 - Microclimate factors variation in the last week

In Figure 11 shows the obvious differences in plant development in the 7 trays during the experiments.

**Fig. 11 - The plants, at the end of the experiment,
which were grown in the 7 different trays, under different light radiation**

CONCLUSIONS

During the experimental measurements it has been shown that (as can be seen from the graphs presented) the constructive solution chosen to maintain the relative humidity and temperature within certain chosen limits is a solution that corresponds to the purpose assumed at the start of the project. Regarding the maintaining of a CO_2 concentration within certain limits, even if the measured values are relatively near to the set values, this is a bit more difficult to obtain technically.

It can be seen that there are some values of the CO_2 concentration that are not in a normal evolution, there are certain peaks of the measured values. This is supposed to have happened for two reasons. The first would be the fact that at night the concentration of CO_2 in the enclosure increases due to the decrease of the intensity of the photosynthetic process, therefore leading to the increase of the CO_2 emission of the plants. Then there may be contamination of the air introduced from outside by the temperature control fans. The second reason could be that the injection of CO_2 into the enclosure is done through a single nozzle mounted on the top of the enclosure and therefore the homogenization of the concentration in the whole module is not done instantly but lasts a certain period. If we analyze the influence of the characteristics of light radiation that reaches the plants, we can see that this fact has a great influence on the way they grow.

In conclusion, the experimental module proved to be functional, corresponding to the purpose of the present project. Even without the improvements that should be made to eliminate the inconveniences found, this module is a good laboratory tool that could be used in a series of research on the influence of light radiation on certain characteristics of microplants or vegetable seedlings.

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