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Microclimatic Monitoring and Analysis in a Hydroponic Greenhouse

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Abstract. In the last decades, the increasing reduction of per capita arable land and the increasing demand for food requires the development of advanced solutions like soilless cultivations. Hydroponics represents an interesting and efficient response for sustainable cultivations, in particular its evolution hydroponic greenhouse that uses water instead of soil and, so, characterized by a different management. In particular, it is important to well manage not only the cultivation area, but also: structural characteristics of greenhouse, microclimate management, nutrients management. To maximize resources efficiency and quality food production, it is fundamental to characterize the microclimatic parameters and their distribution inside greenhouses.

This work provides the preliminary study to measure and analyze the main microclimatic parameters in a hydroponic greenhouse without microclimatic controlling system, located in Vinchiaturo (Italy), with a set of sensors that acquire data continuously.

After the installation of sensors to monitor the temperature, the humidity and the light intensity, a supervision system was installed to manage and historicize all the measured data.

From the data analysis, an appropriate management of the hydroponic greenhouse was identified allowing reduced expenses and improved efficiency.

Keywords: Microclimate Monitoring, Hydroponic Greenhouses, Sensors, Soilless Culture.

1 Introduction

The lack of per capita arable land and the growing demand for food of the last decades is now a serious problem [1] and greenhouse is becoming the most widespread cultivation method guaranteeing the increment of food production and the reduction of climate change damages [2].
In addition, the greenhouse can be used in places that are not suitable for cultivation thanks to its controlled environment and the sustainable management of the resources [3]. To this purpose the development of indoor cultivation environment is fundamental, especially in farming practices and technologies.

The most promising technology is the soilless cultivation inside greenhouse and hydroponics systems, in which soil is replaced by water-based mineral nutrient solutions in aqueous solvents, are now very common and efficient [4]. The management of this type of greenhouse takes into account not only the cultivation area, but it involves also other factors, for example the greenhouse structural characteristic, the microclimate and nutrients management [5, 6, 7, 8]. Thus, to optimize the management of resources efficiency and quality food production is needful the local evaluation of the main microclimatic parameters [9, 10].

Aim of this work is the preliminary study of the main microclimatic parameters in a hydroponic greenhouse, located in Vinchiaturo (Italy), comparing the case study without a microclimatic controlling system and with a ventilation system. For this purpose, a set of temperature, humidity and light intensity sensors were installed to acquire continuously data near the cultivation bed. Sensors were managed by supervision system that allowed also to historicize all measured data. From analyzed data, an appropriate management of the hydroponic greenhouse was identified to reduce expenses and improve efficiency.

2 Materials and methods

In this work microclimatic parameters were acquired in an operating hydroponic greenhouse of 500 m^2 (10 x 50m) (Width x Depth). This greenhouse (Fig. 1a, b) is located in Vinchiaturo, Molise (Italy) at 850 meters above sea-level.

a b

Fig. 1. Hydroponic greenhouse structure pictures; **a.** external environment; **b.** indoor cultivation environment.

The greenhouse structure is made of metal and polycarbonate with side openings and anti-aphid meshes. The greenhouse has two separate cultivation tanks in deep water culture hydroponic system; water inside tanks circulates in continuous. There are two entrances at opposite ends of the building and two cultivation tanks along the sides. Above these tanks a system of nozzles is mounted to moisturize canopies. This hydroponic greenhouse is not equipped with artificial lamps or LEDs to enhance crops growing. Main crops cultivated in this hydroponic greenhouse were some lettuce varieties, few aromatic herbs, and edible flowers. These crops were raised in polystyrene raft and were pushed from the bottom to the main entrance as Fig. 2 shows.

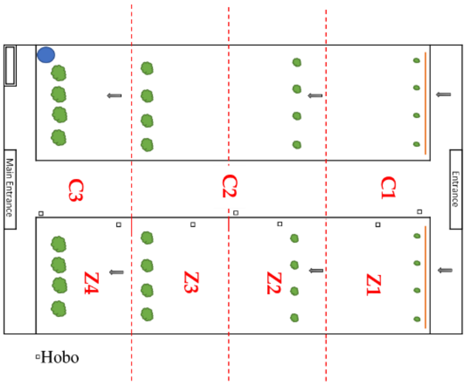

Fig. 2. Schematic view of indoor cultivation environment, where the blue circle represents the water source tank, the green shapes the crops, the arrow the direction of the path followed by the plant; Z1, Z2, Z3, and Z4 indicate the four stages of the cultivation tank; C1, C2, and C3 are the area of the central aisle close to the entrance, in the middle, and close to the other entrance.

Measurements were carried out on two productive cycles of Salanova® lettuce (28th March-27th April, 2022;14th July- 13th August, 2022), following two complete crops growth cycles and monitoring two targeted floating rafts with 4 crops each.

Tests have been made without modifying the ongoing management of the greenhouse; in fact, the first monitored cycle was characterized by the absence of a mechanical ventilation system, while the second cycle of measurements with a mechanical fan installed in May 2022 and without any automatic control for the on / off cycles.

First of all, tests were carried out dividing the inner environment in different zones both on the aisle and on the selected cultivation side tank. The cultivation tank was divided in four zones (Z1, Z2, Z3, Z4) to identify different growth stages; the central aisle in three sections (C1, C2, C3) (Fig. 2).

Seven HOBO sensors for Temperature, Relative Humidity, and Light monitoring (Tab.1) were placed close to the main openings of the greenhouse and close to the selected leafy crops for their growing phase monitoring (Fig. 3).

Tab. 1. Sensors' characteristics used for the experimental tests.

Measurements	Accuracy
Temperature	
Measurement range: -20° to 70°C (-4° to 158°F) Response time: 6 minutes (to 90% in airflow of 1 m/s)	± 0.35°C from 0° to 50°C (0.63°F from 32° to 122°F)
Relative Humidity (RH)	
Measurement range: 5 % to 95 % RH Response time: 1 minute (to 90 % in airflow of 1 m/s)	±2.5 % typical, 3.5% maximum, from 10 to 90 % RH
Light Intensity	
Range: 1 to 3000 footcandles (lumens/ft^2) typical 0-32,300 lumens/m^2 [0-3,000 footcandles (lumens/ft^2)]	
External Input	
External sensors for temperature, AC current, AC voltage, CO_2, 4-20 mA, 0-10 VDC Input range: 0 to 2.5 VDC Output power: 2.5 VDC at 2 mA, active only during measurements.	±2 mV, ±2.5% of absolute reading

a b

Fig. 3. Picture of HOBO sensors located in C3 (**a)** and near the leafy crops (b).

In particular, four of them were evenly distributed at a distance in height of 30 cm from the cultivation bed and another three sensors in the central aisle at a height of 1.80 meters.

Salanova® lettuce and Parsley (*Petroselinum crispum*) growing cycles were followed during the experimental monitoring using HOBOware Pro supervision system that measured and historicized data for 30 days (day-night cycle) with a sampling time per parameter of 6 minutes.

1 Results and Discussions

The acquired data were elaborated to evaluate the trend of the microclimatic parameters inside the hydroponic greenhouse and to identify the best optimization asset. First monitoring test of the cultivation cycle was carried out from March 28^{th} to April $27^{th,}$, characterized by unfavorable weather conditions for this cultivation system. The trend of the temperature, relative humidity, and light intensity shows no substantial differences between the different areas, both for Z and C. The results of these measurements are showed in Fig. 4a, b, c.

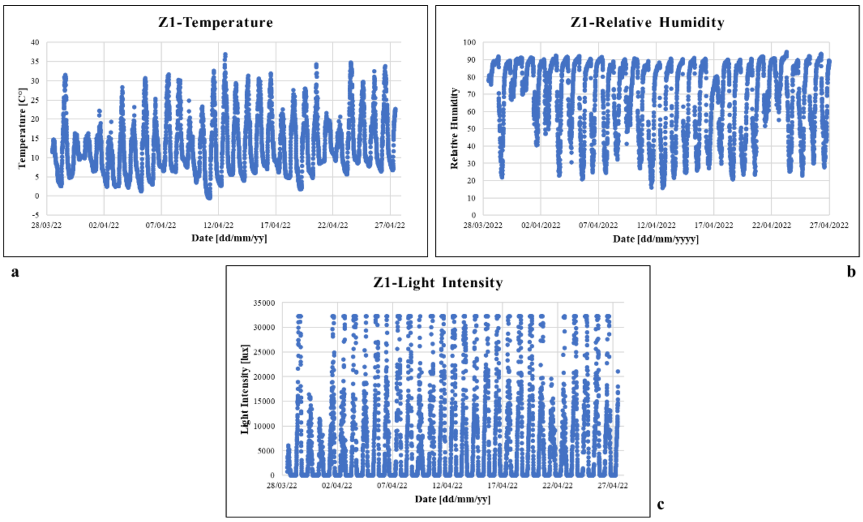

Fig. 4. Growing cycle in Z1 (March 28^{th} - April 27^{th}, 2022) temperature (**a**) , relative humidity (**b.**) and light intensity **(c.)** trend**.**

In particular, the first cycle was cold and rainy, explaining the thermal excursion of 22.33 °C with a standard deviation of 6.63 °C. This happened also because of the absence of mechanical ventilation and not proper insulation of the structure that affected the internal cultivation environment.

Also the relative humidity was strongly affected by the bad weather: the daily variation average of the relative humidity was 57.63 %, with a standard deviation of 15.91 %. The light intensity (measured in lux) was representative of the external weather conditions and was almost similar in all the zones; the average of maximum values achieved 30000 lux, optimal value for plants growing (the optimal range is 20000-50000 lux).

The strong variability of temperature and humidity can be better understood analyzing data in a short time period, showed in Fig. 5.

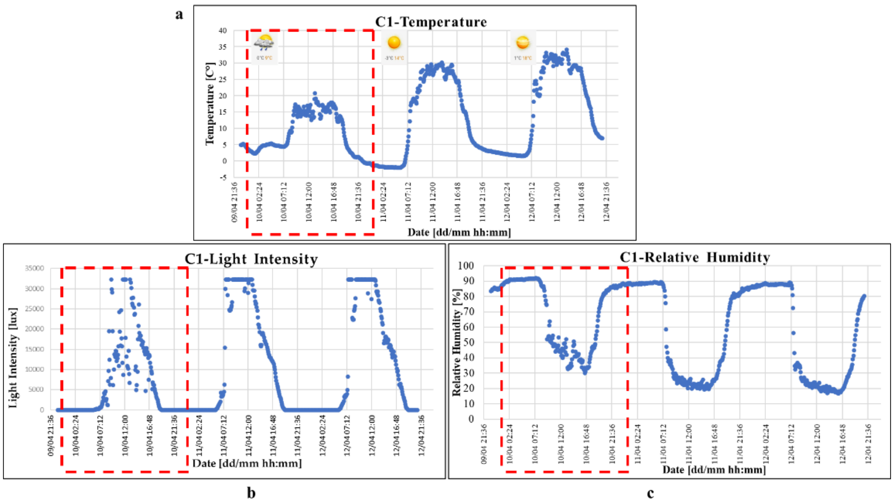

Fig. 5. Few day data (April 10th - April 12th, 2022) of total cultivation growing cycle in C1, C2, C3 (March 28th - April 27th, 2022): **a.** Temperature trend; **b.** Relative Humidity trend; **c.** Light Intensity trend.

In fact, during the raining days like the April 10th, very clear and strong fluctuations of temperature and relative humidity were evident and strictly related to the outdoor environment. For example, the indoor day temperature had an average value of 15.83 °C on April 10th, while on April 11th and 12th it was 26.95 °C and 30.11 °C. Thereby, on April 10th relative humidity increased of 20 % and the light intensity decreased of 20.49 % compared to the following days. This behavior did not slow down the crops growth, but caused physiopathies, especially rots as *Sclerotinia sclerotium*. It is evident the need of a ventilation system automatically controlled to reduce the temperature difference and of a well insulated structure.

Second monitoring test of the cultivation cycle was carried out from July 14th to August 13th, 2022. During the monitoring test a mechanical fan was daily managed. Despite maximum temperature values achieved throughout the greenhouse of 34 °C, with an average of 22°C, the average daily temperature in the side cultivation zones and in the central aisle decreased of about 15% compared the first test; in the central aisle decreased of about 6 %. In fact, the variation in average daily temperature from first test to the second decreased of about 3 °C in both cultivation and central parts (from 21.88 °C to 19.07 °C in Z areas and from 23.17 °C to 20.16 °C in C areas).

Regarding the relative humidity, it decreased of 11.86 % above the side cultivation bed (Z) and of 12.56 % in the central aisle (C) compared to the first test. The variation in average daily relative humidity decreased from 57.05 % to 51.00

% in the Z areas and from 58.54 % to 52.01 % in C areas; thus, is evident a uniformity in the decreasing of the relative humidity compared to the Z areas. Although there was a strong temperature and relative humidity range in both tests, in the last case there were no physiopathies, thanks not only to the higher temperature but also to the less amount of fluctuations through the fan.

From this analysis, it is clear that, in order to reduce the day-night excursion and increase the production efficiency, this hydroponics greenhouse management will improve consistently implementing a ventilation system controlled by a set of permanent probes. Taking into account the vegetative growth of the cultivated crops, the fan activation is recommended after a continuous period of time above a set-point of 27 °C and if the relative humidity exceed 80 %. During rainy day and in winter/ spring season, this timely action would allow not to have too low temperature (also in the case of the not well insulated structure of the greenhouse).

Conclusions

For this work two microclimatic monitoring tests were carried out in a hydroponic greenhouse placed in Vinchiaturo (Italy), at a height of 850 m. Tests were conducted on Salanova® lettuce and parsley, differentiating two areas (Z and C). In the first monitoring test, corresponding to Spring season, issues related to high humidity level were relevant, especially in rainy days. In the second monitoring test, during Summer season, the indoor humidity conditions improved not only for higher temperatures, but also for the use of the mechanical fan with a reduction of the 12% and of the 30% respectively in the cultivation side and in the central aisle. This impacted positively on the plant pathology side, avoid the onset of diseases. Regarding the temperature, even if maximum temperature values achieved about 34 °C throughout the greenhouse, the average daily temperature in the side cultivation zones and in the central aisle decreased of about 15% compared the first test. This proved that the fan was effective.
Based on the results of these two microclimatic tests is clear the need to improve the structure, because it is not completely closed and insulated (day/night temperature range), and the need of an automatic mechanical ventilation system to control temperature and humidity to reduce the fluctuations controlled by the set of sensors used for this work.

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