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THE EFFECT OF GROWING CONDITIONS ON THE YIELD AND QUALITY OF LETTUCE CULTIVATED IN THE NFT SYSTEM

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Abstract

This research investigates the effects of culture conditions on the quality of 8 lettuce varieties grown in a Nutritive Film Technique (NFT) system under LED lighting. The NFT system, an advanced hydroponic method suitable for growing cycle leafy greens, offers commercial advantages while enhancing both the nutritional and biochemical value of crops. The main aim of this study was to evaluate the growth and development of lettuce varieties in the NFT system under controlled LED lighting conditions. The study was carried out within the Faculty of Horticulture, UASMV Bucharest, under LED lighting conditions, in the research space of the Plant Factory. Vertical farms, also known as plant factories, optimize agricultural production per unit area by arranging crops on multiple stacked levels. This method is particularly advantageous in urban environments, where space availability is limited. These facilities operate year-round, being weather-independent and ensuring constant production. Although they save space and water, they consume a lot of energy for lighting and climate control, increasing costs and environmental impact.

Key words*: lettuce, LED lighting, fertilization, biochemical content.*

INTRODUCTION

Urbanization contributes to social and economic transformations, and the conversion of land from agricultural to non-agricultural activities has led to the development of new cultivation technologies (Frasetya et al., 2021).

Urban agriculture employs modern technologies in the NFT system (Chan et al., 2023) as well as perlite substrate (Micu et al., 2022) to achieve rapid and healthy yields, as well as high incomes due to reduced production costs (Micu et al., 2023). This can be accomplished through both traditional and modern methods but requires advanced technologies for high yields on limited spaces. The preference for leafy vegetables, especially pesticide-free lettuce, has accelerated the development of hydroponics in cities.

To reduce soil pollution with nitrates, one essential measure is the application of fertilizers according to the actual needs of the plants and the amount of nitrogen already present in the root zone prior to fertilization (Marinov et al., 2010).

Kowalczyk et al. (2016) emphasize the growing interest in hydroponic lettuce production, highlighting the influence of different growing media on yield and biological value. They noted that the NFT system produced the highest yield, while plants grown on coconut fiber had the lowest dry matter content.

The use of organic fertilizers in the NFT system led to the production of lettuce plants with a reduced nitrate content (Drăghici et al., 2016). Additionally, the use of structured water contributed to increased yields as well as beneficial microbiological activity (Enache et al., 2019; Matei et al., 2023).

Electrical conductivity affects the growth and quality of lettuce plants in NFT culture (Abou-Hadid et al., 1996; Nguyen et al., 2018), and Sanguandeekul (1999) notes that low electrical conductivity, particularly at night, leads to lower nitrate accumulation.

Based on conducted studies, Singe et al. (2015) concluded that cultivating lettuce in the NFT system does not affect its content (Singer 2015; William et al., 2018; Drăghici et al., 2016).

Urechescu et al. (2022) mention that the use of vermicompost for growing lettuce seedlings intended for unconventional systems led to an improvement in their quality.

Sadhana et al. (2022), in their study, concluded that the use of perlite resulted in plants with

higher average masses compared to Cocopeat, Sponges, or other substrates in NFT cultivation. Panter et al. (2014) highlighted the quantitative and qualitative differences in seedlings and lettuce production under LED lighting.
In the NFT system, a nutrient solution circulating at a specific flow rate and with a higher level of oxygenation leads to better growth and development of the root system, with beneficial effects on lettuce yield and quality (Stoica Claudia Maria et al., 2022).
The aim of the study was to highlight the effect of the NFT cultivation technology using natural light and LED lighting on both the yield and quality of the produce.

MATERIALS AND METHODS

The experiment was conducted in Faculty of Horticulture, USAMV, Bucharest, and in Plant Factory greenhouse, this being built within a joint project to create a China-Romania Demonstration Park for Science and Technology in Agriculture, partly financed by the Chinese Academy of Agricultural Sciences and partly by USAMV from Bucharest.
Eight varieties of lettuce collected in Romania were used in the research only under LED red light and in greenhouse under natural light: V1 - 'Lollo Bionda'; V2 - 'Carmesi'; V3 - 'Aleppo'; V4 - 'Lugano'; V5 - 'Presteria'; V6 - 'Tourbillom'; V7 - 'Triathlom'; and V8 - 'Sandalina'.
The temperature in the Plant Factory culture space was 20 ± 2ºC, and the nutrient solution was 19-20ºC. The duration of illumination was 18 hr/6 hr of light/dark with constant intensity of 181.7 µmol/m^2s^1. In the greenhouse, under natural conditions, the light intensity was variable, around 274.3 µmol/m^2s^1. The EC was 1.2 mS/cm in the first growth phases and of 2.2 mS/cm after two weeks from planting and the pH was kept constant at 6.
All data were recorded during the harvest period, in repetitions of 5 plants each. The following were determined: plant height, diameter, plant mass, root length and root volume. In laboratory, for the dry matter, 1 gram of fresh leaves was used by cutting the leaves into small pieces and then dried at a constant temperature of 105ºC for 24 hours.
Brix content using reflectometer, and nitrate using portable nitrate Greentest ECO. The values obtained for the basal, middle, and upper leaves of lettuce plants, for each cultivar, were recorded.
The statistical program for analysis was STATISTICA, StatSoft software (version 10) to perform ANOVA analysis at $p \leq 0.05$, 0.01, or 0.001 levels, and Tukey HSD was used to compare the significant difference of each dependent variable at $p \leq 0.05$.

RESULTS AND DISCUSSIONS

In the greenhouse, the minimum temperatures during the night showed minor fluctuations, ranging from 16.8°C at 15 days to 17.6°C at 20 days. The overall average of these minimum temperatures throughout the growing period was 17.1°C. During the day, a slight increase in the average temperature was observed in the first four intervals, reaching 21.6°C at 20 days, followed by a decrease to 19.4°C at 25 days, and then returning to 20.7°C at 30 days. The average for these intervals was 20.5°C, indicating a moderate temperature. This value suggests that the conditions in the greenhouse were relatively stable, although there were some variabilities between different time intervals.
The maximum temperature values showed a more pronounced variation compared to the minimum and average temperatures, peaking at 25.6°C at 20 days, then significantly dropping to 21.8°C at 25 days, before rising again to 24.3°C at 30 days. The overall average of the maximum temperatures was 23.8°C (Figure 1).

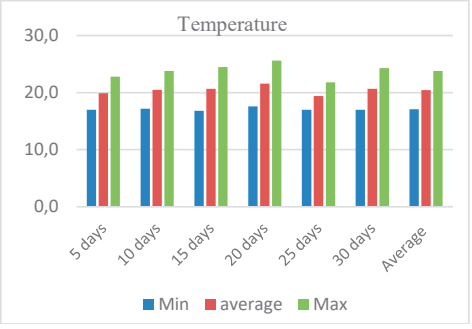

Figure 1. The temperature values recorded in the greenhouse

The minimum humidity recorded during the night was relatively stable, fluctuating between 33.0% and 36.5%. The lowest minimum value, 33.0%, was observed after 5 days, while the highest minimum value, 36.5%, was reported at 30 days. The average humidity showed an upward trend throughout the growth of the plants in the greenhouse. The atmospheric humidity was 39.5% after 5 days, reaching 47.4% at 30 days, with a value of 49.1% recorded at 25 days. Additionally, the maximum humidity values reached 62.2% at 25 days (Figure 2).

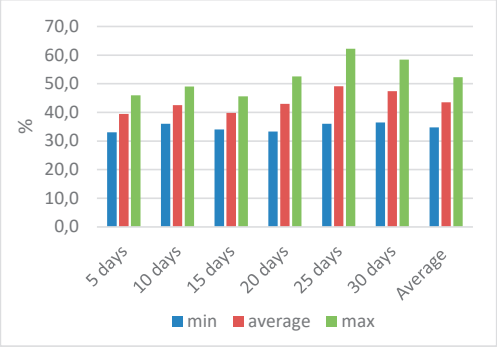

Figure 2. The values of the atmospheric humidity recorded in the greenhouse

The minimum, average, and maximum CO_2 values fluctuated significantly over the 30 days. A general upward trend was observed in the average values, rising from 529.7 ppm at the measurement taken after 5 days to 625.1 ppm after 30 days. The highest value recorded was 918.4 ppm at the measurement taken after 25 days. The minimum values varied between 387.7 ppm and 427.3 ppm (Figure 3).

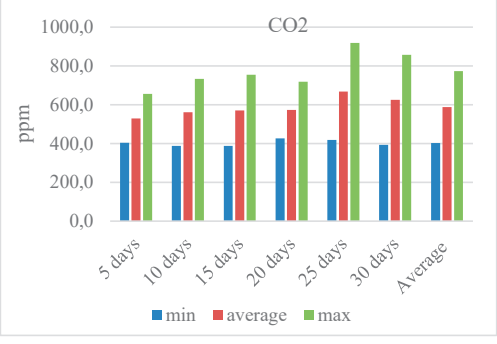

Figure 3. The carbon dioxide values recorded in the greenhouse

For the Plant Factory, the nutrient solution was kept at a constant temperature of 20ºC and exposed to light continuously for 16 hours, followed by an 8-hour break with constant intensity of 179.7 µmol/m^2s^1. Throughout the entire cycle, the concentration of carbon dioxide (CO2) was maintained at 600 (ppm).
The pH of 6 and electrical conductivity (EC) from 1.2 to 2.2 micro-Siemens/cm of the nutrient solution were continuously monitored and maintained at optimal values
On average, plants grown in the 'Plant Factory' were taller than those grown in the 'Greenhouse'. This suggests a superior efficacy of the controlled conditions in the 'Plant Factory' for growing lettuce plants. The tallest height recorded in the 'Plant Factory' was for 'Alepo', measuring 24.50 cm, while in the 'Greenhouse' the tallest height is also for 'Aleppo', with 21.45 cm. The shortest height recorded in the 'Plant Factory' is for the 'Lugano' plant, with 18.17 cm, and in the 'Greenhouse', the shortest height is for 'Presteria', with 16.33 cm. The average growth difference between the two cultivation mediums varies significantly from one variety to another, indicating that certain varieties may be more sensitive to environmental conditions than others. The variability in plant height between the two mediums is notable, suggesting that the environmental factors specific to each type of growth medium have a significant impact on plant growth (Figure 4).

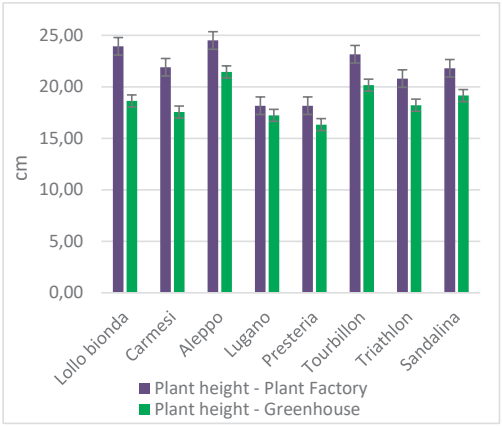

Figure 4. The height of the lettuce plants in the greenhouse and plant factory

These observations indicate that the different growth conditions in the two environments

have a variable impact on the diameter of the plants. Some varieties seem to benefit from the controlled environment of a plant factory, while others grow better in the potentially more varied conditions of a greenhouse. The 'Lollo Bionda' variety has a considerably larger diameter in the greenhouse (37.17 cm) compared to the plant factory (28.17 cm), suggesting that this variety may be more responsive to the conditions in the greenhouse to expand its diameter. The 'Carmesi' variety shows a better diameter growth in the greenhouse (32.83 cm) than in the plant factory (30.22 cm), but the difference is not as pronounced as for ''Lollo Bionda''. 'Aleppo' shows large diameters in both environments, being very close (35.55 cm in the plant factory and 37.00 cm in the greenhouse), suggesting that this variety grows well under both cultivation conditions. The 'Lugano' variety has an almost identical diameter in both locations, with a minor difference of only 0.20 cm in greenhouse conditions. For 'Presteria', there is a larger diameter difference, with greenhouse plants having almost 2.5 cm more than those from the plant factory. 'Tourbillom' has a significantly larger diameter in the greenhouse (34.00 cm) compared to the plant factory (30.22 cm), similar to observations for 'Lollo Bionda'. 'Triathlom' is one of the few varieties that has a larger diameter in the plant factory (31.17 cm) than in the greenhouse (30.55 cm). The variety 'Sandalina' has a slightly larger diameter in the plant factory (34.17 cm) compared to the greenhouse (33.18 cm) (Figure 5).

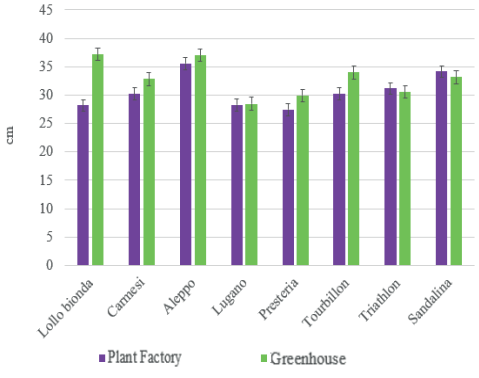

Figure 5. Diameter of lettuce plants grown in the greenhouse and plant factory

Each variety is evaluated based on two parameters: Fresh weight and percentage of dry matter. The table provides specific data on fresh weight and the percentage of dry matter for eight plant varieties grown in a plant factory and a greenhouse. For example, the variety 'Lollo Bionda' has a fresh weight of 139.87 grams in the Plant Factory, compared to 118.32 grams in the greenhouse, and a dry matter percentage of 5.65% in the plant factory versus 5.21% in the greenhouse. This indicates that 'Lollo Bionda' grew better in the controlled conditions of the plant factory. Comparatively, the 'Sandalina' variety has the highest fresh weight in the Plant factory (227.66 g), but in the greenhouse, its fresh weight significantly decreases (182.05 g), indicating that this variety might particularly benefit from the conditions in the plant factory. However, for the dry matter percentage, 'Sandalina' has a lower percentage in the plant factory (4.84%) compared to the greenhouse (5.03%), which could suggest a different composition of the plant's matter in the two environments (Figure 6).

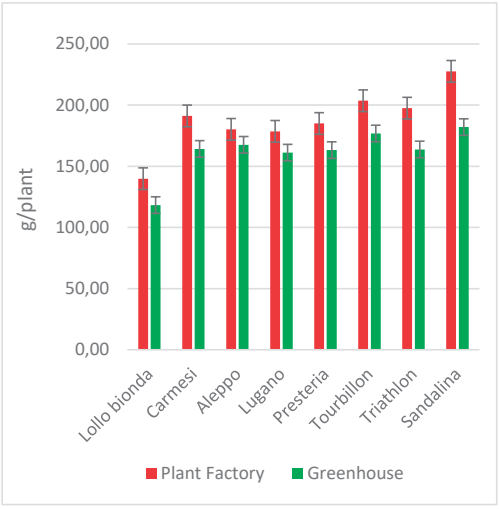

Figure 6. Average mass of lettuce plants grown in the greenhouse and Plant factory

The root length was influenced by environmental factors. With a constant temperature of the nutrient solution at 20°C, an improved root development was observed, which positively impacted the growth of the plant's mass (Figure 7).

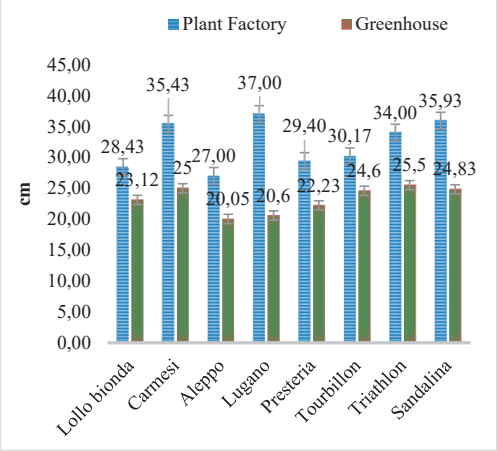

Figure 7. Results regarding the length of the roots

Based on the data presented in the figure 8, we can observe that depending on the cultivation location (Plant Factory and greenhouse), the dry matter content varied for some varieties. Thus, for the varieties 'Lollo Bionda', 'Carmesi', 'Aleppo', 'Lugano' 'Presteria', and 'Tourbillon', the determined dry matter content was higher under Plant Factory conditions compared to the greenhouse. In contrast, for the varieties Triathlon and 'Sandalina', the dry matter content was lower compared to the plants grown in the greenhouse (figure 8).

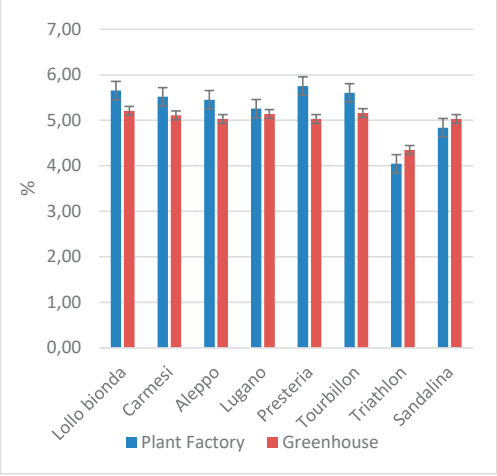

Figure 8. Dry matter content of lettuce plants

Figure 9 shows the appearance of plants in culture, in the greenhouse and in the Plant Factory.

Figure 9. Appearance of plants in culture

The nitrate content was below the maximum limit allowed by the legislation of 3000 mg/kg in the case of all the analyzed varieties. Large differences were found in the nitrate content of the leaves, thus, the basal leaves showed high values of the nitrate content compared to the middle leaves and those located at the top of the lettuce plant (Figures 10 and 11).

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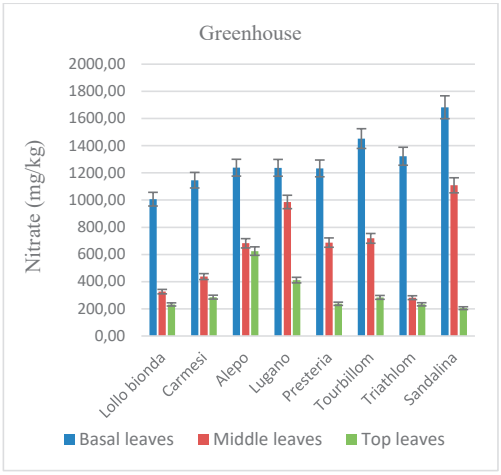

Figure 10. Nitrate content determined in greenhouse-grown lettuce plants

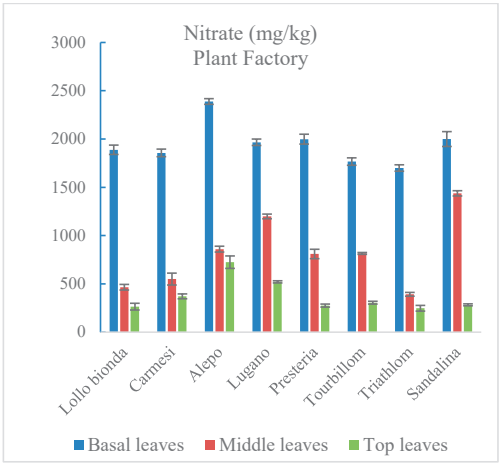

Figure 11. Nitrate content determined in Plant Factory grown lettuce plants

Regarding the carbohydrate content, in general, Brix content was high in the top and middle of the leaves, while nitrate was abundant in the basal leaves of the lettuce (Figure 4). It has been observed that the base leaves have the highest carbohydrate levels, with the 'Sandalina' variety having 6.9 g and 'Presteria' 6.4 g, which are the maximum values. The intermediate leaves exhibited greater variability, with the 'Carmesi' variety having the highest concentration of 4.3 g. Regarding the upper leaves, they have a low carbohydrate content, most of them being below 3.0 g, with the exception of the 'Sandalina' variety, which has 7.8 g (Figure 12).

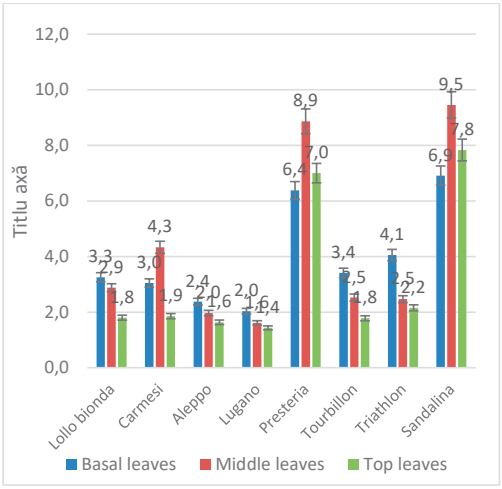

Figure 12. Carbohydrate content in greenhouse-grown lettuce plants

Compared to the carbohydrate values recorded in greenhouse plants, it was observed that under LED lighting conditions, the basal leaves had a lower carbohydrate content, while the middle and top leaves exhibited higher values, Figure 13.

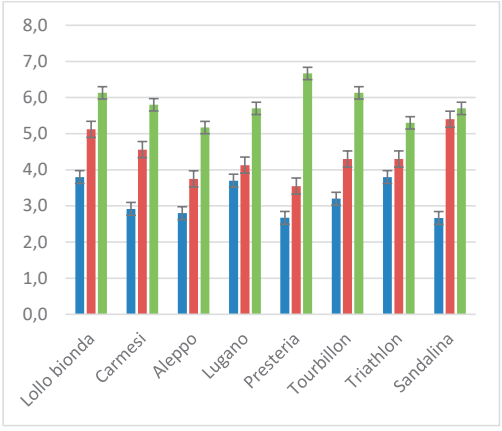

Figure 13. Carbohydrate content in Plant Factory grown lettuce plants

CONCLUSIONS

The evaluation of fresh weight and dry matter percentage reveals that the 'Lollo Bionda' variety thrives in the controlled conditions of the plant factory, while 'Sandalina' shows higher fresh weight in the plant factory, but lower dry matter percentage compared to the greenhouse. This suggests that different

environments affect not only the growth performance but also the composition of the plant matter for various lettuce varieties.

Lettuce plant diameter varies significantly between cultivation environments. The ''Lollo Bionda'' and 'Tourbillon' varieties thrive in greenhouses, while 'Triathlon' grows better in the plant factory. 'Carmesi' and 'Presteria' also show improved growth in greenhouses, whereas 'Aleppo' performs well in both settings. These results emphasize the importance of selecting appropriate environments for different lettuce varieties to maximize growth.

The cultivation location significantly influences the dry matter content of lettuce varieties, with most varieties ('Lollo Bionda', 'Carmesi', 'Aleppo', 'Lugano' 'Presteria', and 'Tourbillon') achieving higher dry matter levels in the Plant Factory compared to the greenhouse. However, the Triathlon and 'Sandalina' varieties displayed lower dry matter content in the Plant Factory, highlighting the importance of environmental conditions on plant development.

The nitrate content in all analyzed varieties was below the legislative maximum limit of 3000 mg/kg. Notable differences were observed in nitrate levels among the leaves, with basal leaves exhibiting significantly higher nitrate concentrations compared to the middle and upper leaves of the lettuce plant.

The carbohydrate content in lettuce varies by leaf position, with the highest levels found in basal leaves of the 'Sandalina' and 'Presteria' varieties, while upper leaves generally have lower carbohydrate levels, except for the 'Sandalina' variety.

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