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THE INFLUENCE OF LIGHT INTENSITY ON YIELD AND MINERAL CONTENTS OF FOUR LETTUCE SPECIES CULTIVATED IN NUTRIENT FILM TECHNIQUE (NFT)

Sovorn CHAN, Aurora DOBRIN, Elena DOBRIN, Elena Maria DRĂGHICI

University of Agronomic Sciences and Veterinary Medicine of Bucharest, 59 Mărăşti Blvd, District 1, Bucharest, Romania

Corresponding author emails: draghiciem@yahoo.com, chansovorn@gmail.com

Abstract

Lettuce cultivation in hydroponic systems using the Nutrient Film Technique (NFT) is widely practiced globally, and it can be done under either natural light or LED light conditions. LED lights are commonly employed in plant factories or as supplemental lighting during periods of insufficient natural light, such as the winter season. To achieve optimal growth and quality of vegetables grown in NFT system, various factors need to be considered, including temperature, light intensity, humidity, and others. Our study aimed to investigate the yield and mineral content of lettuce cultivars grown under natural light and LED light conditions. The experiment was conducted at a greenhouse in USAMV. We observed that lettuce cultivated under natural light conditions exhibited higher fresh weight, dry matter, phosphorus, iron, and copper content. Conversely, lettuce grown under LED light conditions showed higher nitrate, potassium, calcium, magnesium, and zinc levels.

Key words: *Lettuce, natural light, LED light, macro and micronutrients.*

INTRODUCTION

Lettuce (*Lactuca sativa* L.) is indeed one of the most extensively studied vegetables in terms of cultivation in either open field or hydroponic system (Chan et al., 2022). It is a leafy green vegetable known for its nutritional value, providing essential vitamins, minerals, and protein, Lettuce has been reported to offer various health benefits, including reducing the risk of heart disease and cancer, as well as other health-related functions (Nicolle et al., 2004; Gunes & Dogu-Baykut, 2018).

Most crops grown in modern structures with hydroponic systems are indeed influenced by a range of environmental factors. These factors include light, temperature, CO_2 concentration, humidity, and others. Each of these environmental variables plays a critical role in shaping the growth and development of crops in hydroponic systems. Among these factors, light intensity and temperature play crucial roles in regulating the growth and development of lettuce. Their interaction is known to co-regulate various physiological processes in plants. When light intensity and temperature increase simultaneously, it often leads to enhanced growth and improved nutritional values of lettuce (Fu et al., 2012; Chen et al., 2021). In regions where sunlight is limited, especially during the winter months, supplemental lighting provided by LEDs can compensate for the lack of natural sunlight. By delivering the appropriate light spectrum and intensity, LEDs ensure that plants receive the necessary light for photosynthesis, growth, and development throughout the year (Li et al., 2016). Some research suggests that red and blue light spectra can effectively promote the accumulation of biochemical compounds and yield in lettuce and other vegetable species (Mohamed et al., 2021; Rahman et al., 2021; Lin et al., 2018). Furthermore, replacing a portion of red light, blue light, or both with green light has been found to be more effective in promoting both plant growth and quality. While low light intensities have been observed to affect plant growth in several ways. For instance, light intensity led to increased plant height and specific leaf area. However, low light intensities may also result in reductions in leaf number, leaf thickness, and ultimately yield. These observations are supported by studies conducted by Dong et al. (2014), Hou et al. (2010), and Steinger et al. (2003). Moreover, harvesting at low light intensity could enhance the Ca, K, Mg (Colonna et al., 2016). All of these research studies highlight the significant impact of light intensity on plant growth parameters and mineral content, which are useful for enhancing both the quantity and quality of produce for vegetable growers.

Our study aimed to evaluate how natural light and LED red light influence the yield and mineral contents of lettuce species. By comparing the effects of these two lighting conditions on lettuce growth and nutrient composition, we sought to better understand how different light sources influence the productivity and nutritional quality of lettuce crops.

MATERIALS AND METHODS

The The research was conducted in January 2023 in the greenhouse of the USAMV of Bucharest, Faculty of Horticulture, Research Center for Quality Control of Horticultural Produce.

The lettuce varieties used in the experiment included Lollo Bionda and Lollo Rossa from Amia Seeds Company, as well as Lugano and Carmesi from Rijk Zwaan Seed Company.

At the beginning of the experiment, the seeds were sown in a plastic tray filled with a mixture of peat and perlite (75% and 25%, respectively). After approximately one week, when the seedlings had emerged and developed cotyledon leaves, they were then transferred into jiffy pots for further growth. Once the seedlings reached the age of 22-25 days and had developed four true leaves, they were transplanted into the Nutrient Film Technique (NFT) system for the duration of the experiment.

The experiment followed a Randomized Complete Block Design (RCBD) with 3 replications. Each lettuce variety had a total of 15 plants, with 5 plants per replication. EC was monitored daily and maintained at 1.2-1.4 mS/cm for the first week after seedling transfer. It was then increased to 1.8-2.1 mS/cm until harvest. pH levels were kept within the range of 5.8 to 6.2. The average temperature in natural light was 16°C, humidity, and CO_2 levels were automatically controlled at the same level for both conditions throughout the experiment. In the Nutrient Film Technique (NFT) system under natural light, light intensity varied depending on weather conditions, with a range of 300-500 µmol $m^{-2}s^{-1}$. In the vertical farm, LED red lights were installed in a closed chamber. The temperature was maintained at a constant 20°C, and the lighting schedule was set to 16 hours of light and 8 hours of darkness. The average light intensity was maintained at 220 µmol $m^{-2}s^{-1}$.

At the harvesting stage (30 days in NFT), data were recorded for five individual plants for each lettuce variety. Parameters recorded included fresh weight and dry mass. Dry mass was determined by cutting leaves into fine pieces and drying at a constant temperature of 105°C for 24 hours. For mineral determination, samples weighing 0.250 g were weighed using an analytical balance and placed in Teflon recipients. Then, 8 ml of concentrated ultrapure HNO_3 (65%) and 2 ml of H_2O_2 (30%) were added to the samples for mineralization. Mineralization was carried out using microwave digestion for 30 minutes with the ETHOS UP microwave digestion system. After mineralization, clear solutions were transferred quantitatively into volumetric flasks (50 mL) and made up with Milli-Q ultrapure water. Analysis of mineral content was conducted using the Agilent Series ICP-MS spectrometer with quadrupole analyzer 7700x and MassHunter Workstation software (Agilent Technologies). Calibration curves were performed using the ICP-MS multi-element calibration standard containing various elements in specified concentrations dissolved in 5% HNO_3 (Dobrin et al., 2018). Statistical analysis was used STATISTICA, StatSoft software (version 10) to perform the analysis.

Figure 1. Lettuces cultivated in NFT under natural light and LED red light

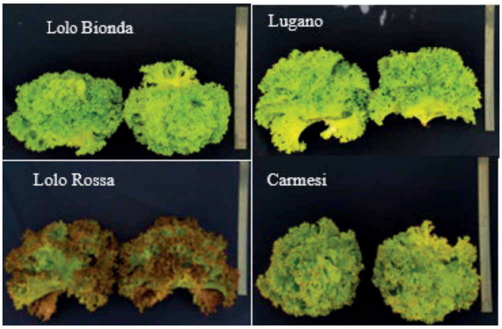

Figure 2. Lettuce varieties used in the experiment

RESULTS AND DISCUSSIONS

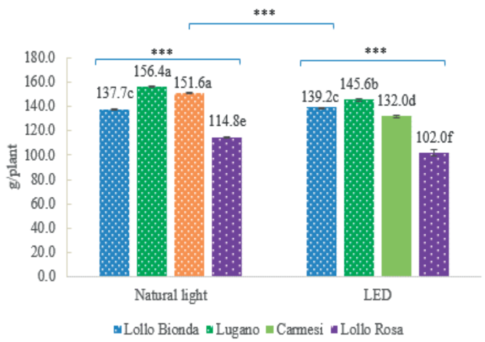

Figure 3. Fresh mass of lettuce cultivated under both light conditions. The value represents the means, standard error and significant level. The letter indicates the significant at p<0.05

Fresh mass. A strong interaction was found between lighting conditions and variety regarding fresh mass at $p \leq 0.001$ (Figure 3). Both natural light condition and LED light condition were significant at $p < 0.001$. Under natural light conditions, Lugano and Carmesi achieved the highest yields (156.4 and 151.6 g/plant, respectively), followed by Lollo Bionda and Lollo Rosa (137.7 and 114.8 g/plant, respectively). Under LED light, Lugano had the highest fresh mass (145.6 g/plant), followed by Lollo Bionda, Carmesi, and Lollo Rosa (139.2, 132.0, and 102.0 g/plant, respectively). Overall, the average fresh mass under natural light was greater than under LED light (140.1 and 129.7 g/plant, respectively). Our results are consistent with Fu et al. (2012), and Zhou et al. (2019) who reported that lettuce mass reached its highest yield when exposed to light intensity between 350-600 µmol $m^{-2}s^{-1}$. In our experiment, the light intensity under natural conditions (300-500 µmol $m^{-2}s^{-1}$) was higher than under LED conditions (220 µmol $m^{-2}s^{-1}$).

Dry matter: There was an interaction between lighting conditions and varieties regarding dry matter at $p \leq 0.05$ (Figure 4). Under natural light, the dry matter of the varieties was highly significant at $p \leq 0.001$, while under LED it was significant at $p \leq 0.01$. Lollo Rosa and Lollo Bionda exhibited the highest dry matter values under natural light (7.0% and 6.9%, respectively), followed by Carmesi and Lugano (6.6% and 5.6%, respectively). Under LED light, Lollo Rosa had the highest dry matter content (5.8%), followed by Lollo Bionda, Carmesi, and Lugano (5.7%, 5.7%, and 5.5%, respectively). On average, the dry matter content under natural light was higher than under LED light (6.5% and 5.7%, respectively). Our results are consistent with Jin et al. (2023), who conducted an experiment on gradually increasing light intensity up to 300 µmol $m^{-2}s^{-1}$ and found that dry matter increased with increasing light intensity compared to constant light intensity (220 µmol $m^{-2}s^{-1}$).

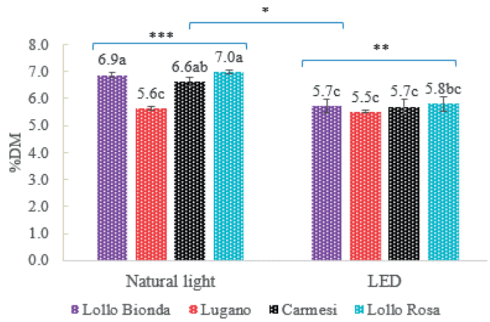

Figure 4. Dry matter of lettuce cultivated under both light conditions. The value represents the means, standard error and significant level. The letter indicates the significant at p<0.05

Nitrate. A strong interaction was found between lighting conditions and variety over nitrate content in fresh lettuce leaves at $p \leq 0.001$ (Figure 5). Both natural light condition and LED light condition were significant at $p \leq 0.001$. Under natural light, Lugano had the highest nitrate content (1567 mg/kg), followed by Lollo Rosa, Lollo Bionda, and Carmesi (1500, 1489, and 1222 mg/kg, respectively). Under LED red light, Lollo Rosa had the highest nitrate content (2078 mg/kg), followed by Carmesi, Lollo Bionda, and Lugano (1600, 1589, and 1519 mg/kg, respectively). However, this content is below the maximum level of nitrate content set by the European Union. The average nitrate content under LED light was higher than under natural light conditions (1697 and 1444 mg/kg, respectively). Lettuce grown under low light intensity usually uptakes nitrate beyond the reduction rate, leading to nitrate accumulation in the leaves, as evidenced by our experiment.

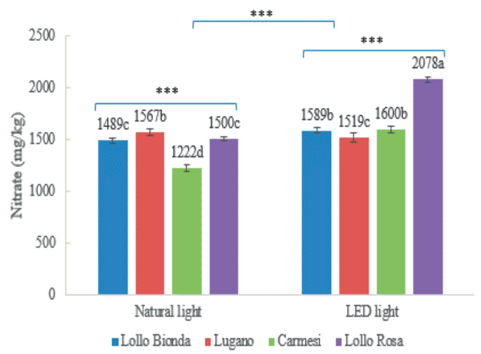

Figure 5. Nitrate of lettuce cultivated under both light conditions. The value represents the means, standard error and significant level. The letter indicates the significant at $p<0.05$

Potassium (K). Based on our results, under natural light conditions, Lollo Rosa had the highest potassium (K) content (3479 mg/kg), followed by Lollo Bionda, Carmesi, and Lugano (3346, 3255, and 3133 mg/kg, respectively) (Figure 6).

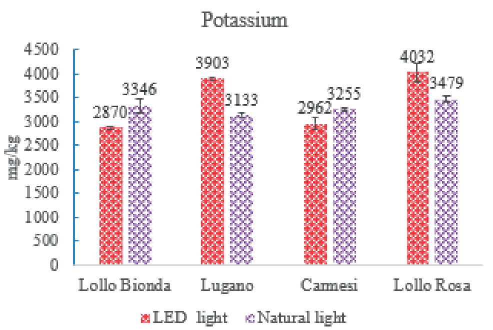

Figure 6. Potassium in lettuce's leaves cultivated under both light conditions. The value represents the means, standard deviation

Lollo Rosa maintained a high K content under LED light as well (4032 mg/kg), followed by Lugano, Carmesi, and Lollo Bionda (3903, 2962, and 2870 mg/kg). The average K content under LED light was higher than under natural conditions (3441.8 and 3303.1 mg/kg, respectively). This result consistent with Colonna et al. (2016) found that harvested at low light intensity enhanced K.

Calcium (Ca). Under natural light conditions, Lugano exhibited the highest calcium (Ca) content (1136 mg/kg), followed by Lollo Bionda, Lollo Rosa, and Carmesi (819, 756, and 566 mg/kg, respectively) (Figure 7). Under LED light, Lugano retained the highest Ca content (1474 mg/kg), followed by Lollo Rosa, Carmesi, and Lollo Bionda (1006, 824, and 739 mg/kg, respectively). The average Ca under LED light was greater than natural light condition (1010.7 and 819.1 mg/kg). Our results contrast with those of Sango (2016), who found that calcium levels in the outer leaves of headed lettuce increased with higher light intensity, ranging from 150 to 300 µmol $m^{-2}s^{-1}$.

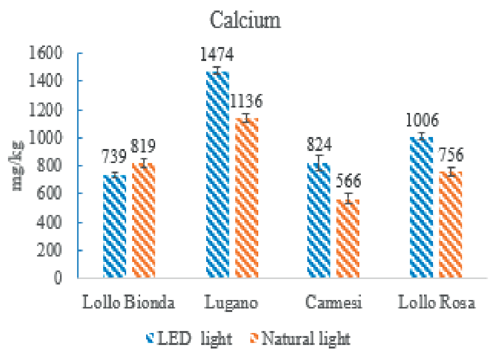

Figure 7. Calcium in lettuce's leaves cultivated under both light conditions. The value represents the means, standard deviation

Phosphorus (P). Regarding lettuce cultivated under natural light conditions, Lollo Bionda showed the highest phosphorus (P) content (469 mg/kg), followed by Carmesi, Lollo Rosa, and Lugano (422, 409, and 363 mg/kg, respectively) (Figure 8). Under LED light, Lollo Bionda maintained a high P content (430 mg/kg), followed by Lollo Rosa, Lugano, and Carmesi (374, 324, and 248 mg/kg). A significant disparity in P content between the two conditions was observed in Carmesi. Overall, all the varieties under natural light conditions demonstrated better P content compared to LED light, with average values of

415.7 and 343.8 mg/kg. Our result was similar to Chen et al. (2014), who found that phosphorus content in the shoot of white lupin plants was higher under high light intensity when the nutrient solution provided to the plants was sufficient.

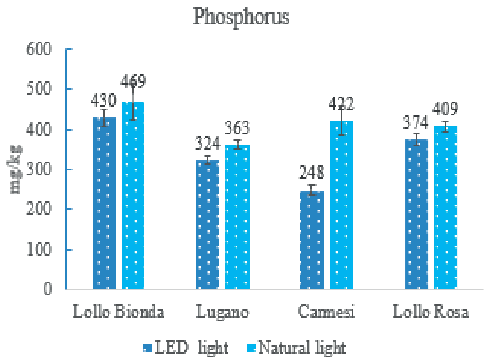

Figure 8. Phosphorus in lettuce's leaves cultivated under both light conditions. The value represents the means, standard deviation

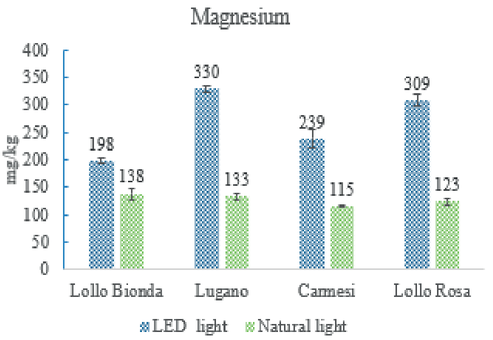

Figure 9. Magnesium in lettuce's leaves cultivated under both light conditions. The value represents the means, standard deviation

Magnesium (Mg). Under natural light conditions, Lollo Bionda exhibited a higher content of Mg at 138 mg/kg, followed by Lugano, Lollo Rosa, and Carmesi (133, 123, and 115 mg/kg) (Figure 9). However, under LED light, Lugano had the highest Mg content at 330 mg/kg, followed by Lollo Rosa, Carmesi, and Lollo Bionda (309, 239, and 198 mg/kg). The Mg content under LED light was 1.4 to 2.5 times greater than under natural light, with averages of 269 and 127.4 mg/kg. Our results are similar to those of Colonna et al. (2016), who found that magnesium levels increased under low light intensity.

Zinc (Zn). According to our results, Lollo Bionda under natural light conditions had the highest value of Zn at 5.2 mg/kg, followed by Carmesi, Lugano, and Lollo Rosa (3.9, 3.6, and 3.5 mg/kg) (Figure 10). Furthermore, Lollo Bionda maintained its lead in Zn content under LED light conditions (8.1 mg/kg), followed by Lugano, Lollo Rosa, and Carmesi (7.0, 4.3, and 2.4 mg/kg). All varieties under LED light demonstrated higher Zn content compared to those under natural light, except for Carmesi, with average values of 5.5 and 4.0 mg/kg.

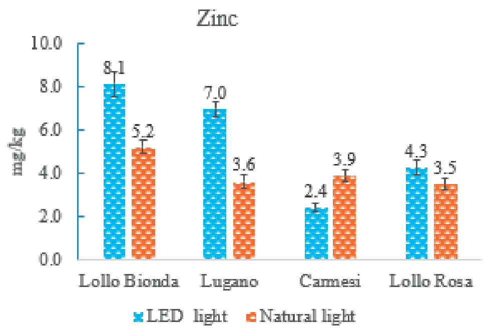

Figure 10. Zinc in lettuce's leaves cultivated under both light conditions. The value represents the means, standard deviation

Copper (Cu). Regarding the copper content in lettuce, under natural light conditions, Lollo Bionda exhibited the highest Cu content at 1.023 mg/kg, followed by Carmesi, Lugano, and Lollo Rosa (1.008, 0.965, and 0.799 mg/kg, respectively) (Figure 11).

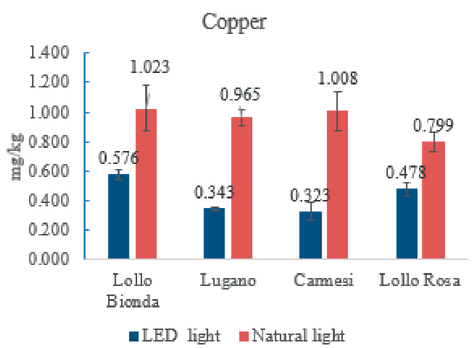

Figure 11. Copper in lettuce's leaves cultivated under both light conditions. The value represents the means, standard deviation

Furthermore, Lollo Bionda maintained a high level of Cu under LED conditions (0.576

mg/kg), followed by Lollo Rosa, Lugano, and Carmesi (0.478, 0.343, and 0.323 mg/kg). Overall, the average Cu content was higher under natural light compared to LED (0.949 and 0.430 mg/kg).

Iron (Fe). Based on the results obtained from the analysis, under natural light conditions, Lugano had the highest value of Fe (35.3 mg/kg), followed by Lollo Bionda, Lollo Rosa, and Carmesi (25.3, 22.4, and 13.6 mg/kg.fw, respectively) (Figure 12). However, under LED light conditions, Lollo Rosa had the highest value of Fe (41.9 mg/kg), followed by Carmesi, Lugano, and Lollo Bionda (20.8, 5.3, and 4.5 mg/kg). It is noteworthy that Lollo Bionda and Lugano had higher Fe values under natural light, while Carmesi and Lollo Rosa had higher Fe values under LED light. The average Fe content was higher under natural light compared to LED (24.2 and 18.1 mg/kg).

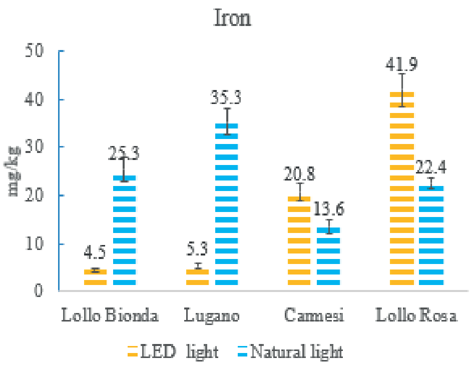

Figure 12. Iron in lettuce's leaves cultivated under both light conditions. The value represents the means, standard deviation

CONCLUSIONS

Based on our experiment's results, we conclude that cultivating lettuces species in NFT under both natural light and LED light conditions influenced various parameters, including fresh mass, dry matter, nitrate content in leaves, and macro and micronutrient levels.

Under natural light conditions, lettuce exhibited higher fresh weight, dry matter, phosphorus, iron, and copper content.

On the other hand, lettuce cultivated under LED light conditions showed higher nitrate content, potassium, calcium, magnesium, and zinc levels.

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