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THE INFLUENCE OF ARTIFICIAL ILLUMINATION AND TILLAGE TREATMENTS ON ENHANCING LETTUCE GROWTH AND QUALITY

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Abstract: Lettuce (*Lactuca sativa* L.) indoor cultivation during the winter is mainly influenced by low light intensities. Also, its production is significantly affected by tillage techniques. Therefore, our research aimed to investigate the impact of applied light treatments during the seedling stage and applied tillage treatments after plant transplanting on the Viola lettuce genotype. Applied light and tillage treatments significantly influenced shoot weight, while the root weight and the total chlorophyll content varied depending on the light treatment. Tillage treatment did not affect shoot weight and the total chlorophyll content, but significantly influenced soluble sugar content.

Keywords: *Lactuca sativa* L., Viola genotype, light-emitting diodes, soluble sugar, total chlorophyll.

Introduction

In intensive greenhouse vegetable production, lettuce (*Lactuca sativa* L.) production during the winter without heating occupies a significant place. However, one of the major factors affecting lettuce cultivation is light. In low-light greenhouse conditions, such as those found in the Balkans during winter, lettuce growth can be slow (Hamdani et al., 2019). Therefore, establishing appropriate light intensities is one of the major challenges in winter lettuce production (Hasan et al., 2017; Landi et al., 2020). Additionally, tillage plays an important role in lettuce production (Jackson et al., 2002). It is known that cultivated lettuce has a shallow root system with a short taproot and prolific lateral branches in the upper layers of the soil (Jackson, 1995). Such root architecture results in its rapid growth and shoot uniformity, but also potentially high losses of nutrients below the root zone (Jackson, 1995).

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This research aimed to investigate the effects of different light treatments applied during the lettuce seedling stage, as well as the impact of tillage treatments on the lettuce growth and development after its transplantation into the greenhouse.

Materials and methods

The research was conducted at the Institute for Vegetable Crops Smederevska Palanka. Lettuce (*Lactuca sativa* L.) seeds of the Viola genotype were sown in nine styrofoam containers filled with commercial substrate (Pindstrup Mosebrug A/S, Denmark). At the phenophase of three permanent leaves, six containers were transferred to plant growth chambers where the plants were grown for 25 days under white (W) and blue (B) LEDs, with a photoperiod of 9/15h and 10/14h (light/dark). Additionally, three containers with plants were grown in a greenhouse under daily light (DL) conditions, serving as a control group.

The experiment in the greenhouse followed a random block system with three repetitions in the irrigation system and two types of cultivation: deep tillage (50 cm) and shallow tillage (15 cm). Lettuce was planted at a spacing of 20×25 cm. At the full maturity stage, root and shoot weight, total chlorophyll content, and soluble sugar content were measured. The total chlorophyll content was determined spectrophotometrically following the method described by Lichtenthaler (1987), while soluble sugar content was measured using Refractometer HI 96801.

A two-factor ANOVA analysis model was used to examine the influence of the type of light and length of lighting on lettuce morphological and chemical properties. Duncan's test was performed to determine the significance of mean differences ($p < 0.05$) between the genotype, light and tillage treatments using SPSS software version 22.0 (IBM Corporation, New York, NY, USA).

Results and discussion

The results obtained in these studies indicated that tillage (T) and applied light treatments (L) have a statistically significant effect on the shoot weight (Table 1). Root weight and the total chlorophyll content varied depending on the applied light treatment (L), while tillage (T) did not affect the analyzed traits (Tables 1 and 2). On the other hand, tillage (T) showed a statistically significant effect on sugar content (Table 2). The T×L interaction did not show statistical significance in any of the studied traits (Tables 1 and 2).

Table 1. The analysis of variance for shoot and root weight

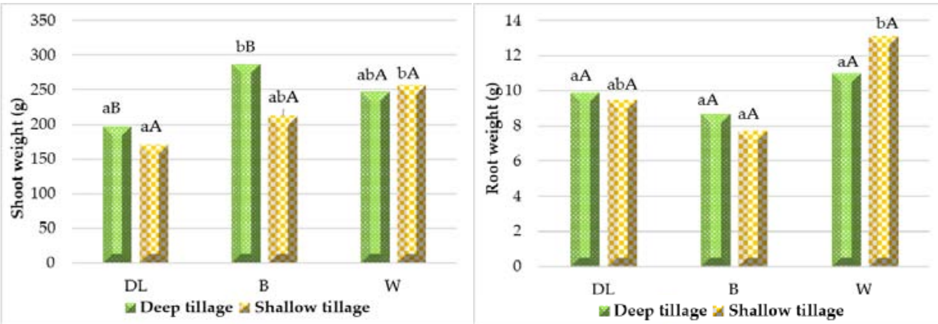
Source of variation	df	Shoot weight (g)		Root weight (g)	
		MS	F	MS	F
Tillage (T)	1	4363.337	5.894*	0.517	0.093^{ns}
Light treatment (L)	2	8868.472	11.980**	22.528	4.065*
Repetition	2	681.196	0.920^{ns}	2.024	0.365^{ns}
T × L	2	2731.012	3.689^{ns}	3.899	0.704^{ns}
Error	10	740.263	-	5.542	-
Total	17	-	-	-	-

Table 2. The analysis of variance for the total chlorophyll content and soluble sugar content

Source of variation	df	Total chlorophyll content (mg g^{-1})		Soluble sugar content (°Bx)	
		MS	F	MS	F
Tillage (T)	1	0.199	4.028^{ns}	2.880	9.763**
Light treatment (L)	2	0.234	4.731*	0.222	0.751^{ns}
Repetition	2	0.002	0.031^{ns}	0.102	0.345^{ns}
T × L	2	0.02	0.411^{ns}	0.412	1.395^{ns}
Error	10	0.049	-	0.295	-
Total	17	-	-	-	-

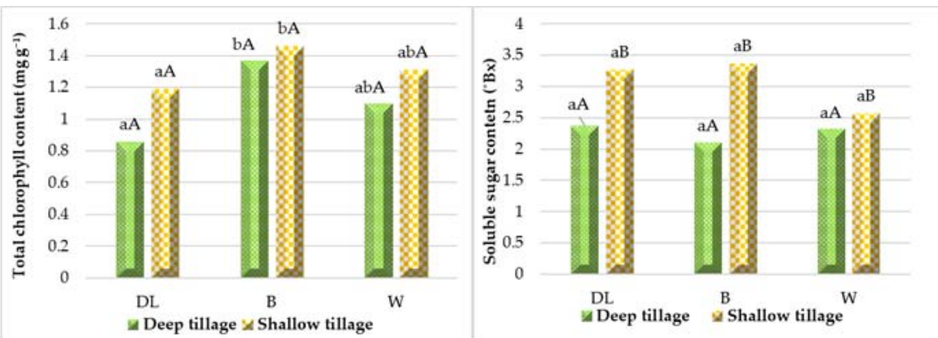
Plants' exposure to LEDs during the seedling stage positively affected the shoot weight. Additionally, plants grown on deeply tilled soil had a significantly higher shoot weight compared to the shallowly tilled soil (Graph 1). Similar results were obtained by Jackson et al. (2002). In our research, plants cultivated on deeply tilled soil with prior exposure to B LEDs had significantly higher shoot weight (288.09 g). Johkan et al. (2010) also observed the shoot weight increase in plants grown under B LEDs. However, tillage treatment did not affect shoot weight in plants grown under W LEDs during the seedling stage. However, plants exposed to W LEDs throughout the seedling stage achieved significantly higher shoot weight (247.31 g - deep tillage; 256.5 g - shallow tillage) compared to plants grown under DL (197.87 g - deep tillage; 171.01 g - shallow tillage). The lowest shoot weight was obtained in plants cultivated under DL during the seedling stage.

The tillage treatment did not significantly affect root weight and the total chlorophyll content in the studied lettuce genotype. The highest root weight was achieved in plants exposed to W LEDs during the seedling stage (11.0 g - shallow tillage; 13.15 g - deep tillage), and the lowest in plants exposed to B LEDs (8.69 g - shallow tillage; 7.74 g - deep tillage) (Graph 1).



Graph 1. Effects of different light and tillage treatments on root and shoot weight

The highest total chlorophyll content was obtained in plants exposed to B LEDs during the seedling stage (1.37 mg g - 1 deep tillage; 1.46 mg g - 1 shallow tillage) (Graph 2), which could be attributed to the strong absorption capacity of chlorophyll for blue light (Yu et al. 2018; Huang et al. 2023). No difference between the total chlorophyll content was observed between the plants grown under DL and W LEDs during the seedling stage.



Graph 2. Effects of different light and tillage treatments on the total chlorophyll content and soluble sugar content

Despite the fact that the content of soluble sugar in lettuce increases with increasing light intensity (Zhou et al. 2011), in our research, plants' exposure to LEDs during the seedling stage did not affect the soluble sugar content in lettuce leaves, while the tillage treatment significantly influenced this trait.

Plants grown on shallow-tilled soil achieved significantly higher soluble sugar content (3.37 DL, 3.37 B LEDs, 2.57 W LEDs) compared to plants grown on deeply tilled soil (2.27 DL, 2.1 B LEDs, 2.33 W LEDs) (Graph 2).

Although plants grown under B LEDs generally achieved higher shoot and root weight and total chlorophyll content than plants grown under DL, these plants started to elongate 10 days after the light treatment application in the seedling stage (Luković et al., 2024). Consequently, this significantly affected the mature plants' aesthetics. In our research, the plants exposed to B LEDs during the seedling phase resulted in an elongated stem, that made them unsuitable for commercial sale.

Conclusion

Deep tillage positively affected Viola genotype shoot weight. However, because lettuce has a shallow root system, deep tillage did not significantly affect its overall quality.

Artificial lighting during the seedling stage contributed to significantly healthy growth and quality of plants.

Results of our research indicate that plant exposure to B LEDs during the seedling stage positively affected shoot weight and the total chlorophyll content in plants after their transplantation. However, considering that plants grown under B LEDs were elongated and had a marketable unacceptable appearance, special attention must be paid to defining the optimal length of exposure of plants to artificial lighting.

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