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Original scientific paper

The growing profile of Diplotaxis tenuifolia (L.) DC. under different LED lighting

Abstract

*The growth of rocket Diplotaxis tenuifolia (L.) DC. profiles was studied during 30 days of growing in the chamber under different lighting regimes; T5_ peak at 630 nm, LED1_ peak at 545 nm and LED2_ peak at 599 nm. There were no significant differences in dry weight after 15 days, however, from day 15 to 30, the increase in dry weight was significantly biggest under LED2. This agrees well with estimated average leaf area (LA) per plant (43.83 cm^2), the increase of LA (39.70 cm^2) and total fresh weight (7.898 g per plant). The regression analysis revealed the strongest correlation between the dry weight and PPFD_R light intensity (0.792**), showing the positive effect of additional LED lighting in comparison with standard T5 light.*

Keywords: *fresh weight, dry weight, leaf area, LED, wild rocket*

Introduction

Vegetables from the *Brassicaceae* family are widely cultivated and valued as a healthy food source. So they have frequently been widely studied as a potential source of health-promoting compounds, and epidemiological studies indicate that their consumption may reduce the risk of several types of cancer (Neugart et al., 2018).

Diplotaxis tenuifolia (L.) DC. also known also as wild rocket (arugula, rucola, roquette), is a vegetable considered to be increasingly important in the salad vegetable market in the areas surrounding the Mediterranean Sea (Pasini et al., 2012). Wild rocket contains many health-promoting compounds, including vitamins, carotenoids, polyphenols and diverse group of glucosinolates. (Tan et al., 2020).

During the various growth stages of plants, light is the primary source of energy for photosynthesis and one of the most critical environmental factors required for growth (Muneer et al., 2014). It has been established that plants respond to photosynthetically active radiation (PAR) with a waveband of 400–700 nm, and the role of light is vital for photosynthetic biosynthesis and productivity (Ghasemzadeh et al., 2010). Low light results in etiolated plants, while excessive light generates oxygen radicals, triggering photoinhibition, both of which strongly limit primary productivity (Darko et al., 2014).

Among the PAR, blue (400–500 nm) and red (600–700 nm) light wavelengths have the greatest impact on plant growth and development, because they are absorbed by chlorophyll pigments or other secondary pigments involved in carbon fixation and basic metabolism (Metallo et al., 2018).

For instance, Kopsell et al. (2015) reported that different RB LED light treatments of 5% blue (470 nm)/95% red (630 nm), 5% blue/85% red/10% green (530 nm), and 20% blue/80% red at an intensity of 250 ± 10 µmol m^{-2} s^{-1} cause significantly higher individual and total aliphatic and total indole glucosinolates in broccoli (*Brassica oleracea* var. *italica*) grown under a fluorescent light treatment.

Tan et al. (2020) showed that the growth of pak choi (*Brassica rapa* subsp. *chinensis* var. *parachinensis*) under 160 µmol m^{-2} s^{-1} red-blue (160RB) LED light produced the highest shoot

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fresh weight and dry weight for all three growth stages tested (i.e., one-leafed seedlings, three-leafed seedlings and adult plants).

The main purpose of this study was to investigate the yield potential of *Diplotaxis tenuifolia* (L.) DC. at different growth stages under different LED light types.

Materials and methods

Plant materials and growing conditions

Seeds of wild rocket were sown in germination trays (54 cm×27 cm×6 cm) filled with BIO Potgrond mix (Klasmann-Deilmann GmbH, Geeste, Germany). Approximately 1.4 g of seeds were sown in each germination tray before 3 L of tap water was added. Subsequently, each tray was watered every two days with 1 L of tap water by sub-irrigation. All plants were grown indoors at 25 ± 2°C/22 ± 2°C (light/dark) and 65 ± 5% relative humidity under three different light regimes; T5 (LUMii, 60 cm, 87 W supplied by EnviroGro), LED 1 (TXVSO 600W LED Grow Light, unknown supplier) and LED 2 (SAMSUNG LM301B, 80-W supplied by EasyGrow S600). Each light was applied in three repetitions for 15 and 30 days.

Biomass and growth parameter analyses

For growth evaluation the total fresh (FW) and dry weight (DW) of individual plants were measured 15 and 30 days after sowing. Twenty-five plants (n=25) per treatment were randomly selected at both intervals and destructively sampled for biomass analysis. The FW and DW of individual plants were recorded using a three-decimal-point electronic balance (Mettler Toledo ML303 Precision Balance; Greifensee, Switzerland). Biomass partitioning was determined by measuring the FW and DW of the various plant parts (e.g., leaves, petiole, stem and roots). Samples were dried in the oven at 60°C till the weight stabilized.

Total leaf area (LA) of each plant was determined by photographing laminas for each plant using a camera (Canon EOS 2000D; Tokyo, Japan), followed by leaf area determination using Image J v. 1.51 (National Institute of Health; Bethesda, MD, USA).

Light characterization

The spectral characteristics expressed as PPFD-UV, PPFD-B, PFD-G, PPFD-R and PPFD-FR magnitude per (μmol m^{-2} s^{-1}) were determined using a light spectrometer (Uprtek AI-MK350D). The spectral output of all lights is shown in Fig. 1, where it can be seen that most energy packets arrive in different wavelength bands with peaks at 545 nm (T5), 599 nm (LED 2) and 630 nm (LED 1). Secondly, a broad wavelength photosynthetically active radiation (PAR) expressed as PPFD_B, PPFD_G and PPFD_R (Table 1), showed differences in distribution between the lights in the area 0.2 m directly below and adjacent to the light source.

Table 1: The difference in PAR spectrum between different lights (μmol m^{-2} s^{-1})
Tablica 1: Razlika u PAR spektru između različitih svjetala (μmol m^{-2} s^{-1})

PAR	T5 (80 W)	LED1 (80 W)	LED2 (80 W)
PPFD-UV	0.863	0.133	0.195
PPFD-B	36.015	35.380	21.077
PPFD-G	51.847	24.358	63.305
PPFD-R	30.534	66.126	65.669
PPFD-FR	3.100	1.399	4.631

The T5 has the biggest PAR output in PPFD_G band (51.847 μmol m^{-2} s^{-1}), while LED1 has it in the PPFD_R band (66.126 μmol m^{-2} s^{-1}). In contrast, LED2 shows practically the same PPFD_R, as well as the PPFD_G band (65.669 μmol m^{-2} s^{-1} and 63.305 μmol m^{-2} s^{-1}).

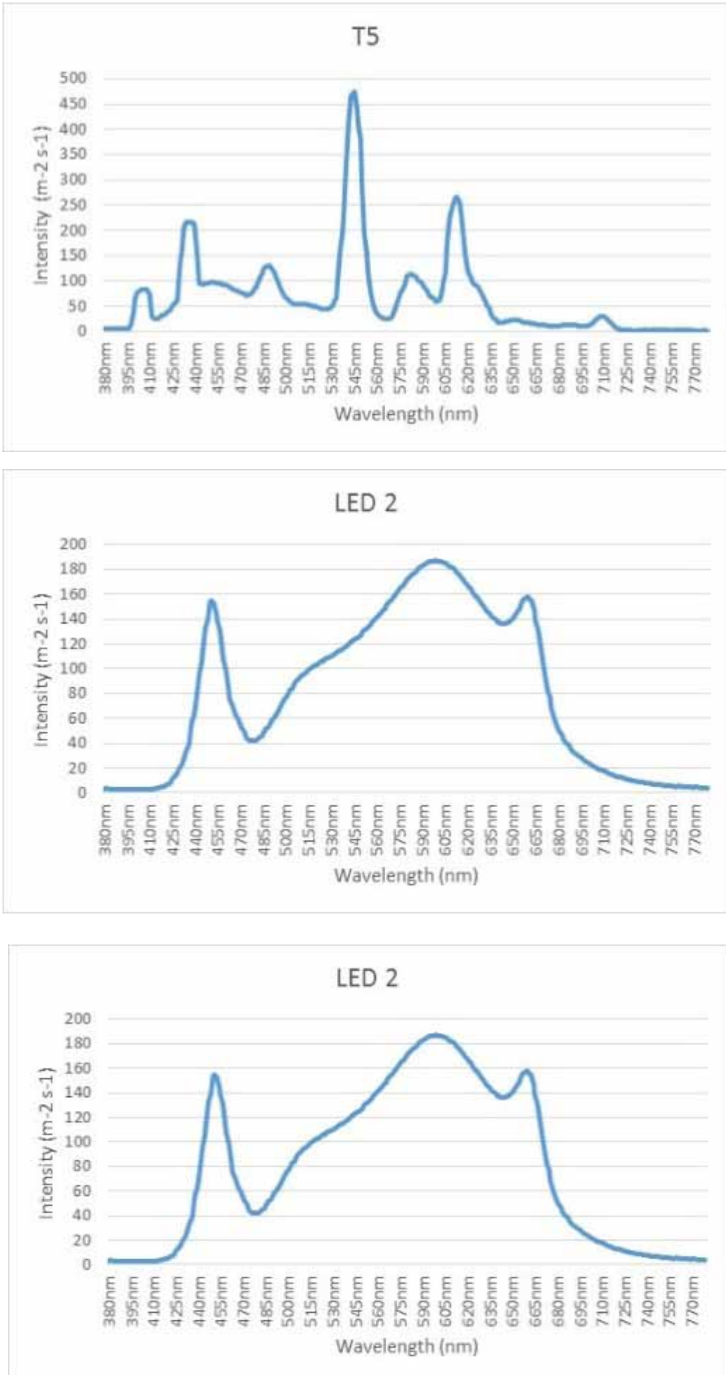


Figure 1: Spectral output of T5 (a), LED 1 (b) and LED 2 (c) lights installed in the grow-cell.
Slika 1.: Spektralni izlaz T5 (a), LED 1 (b) i LED 2 (c) svjetala instaliranih u rastućoj stanici

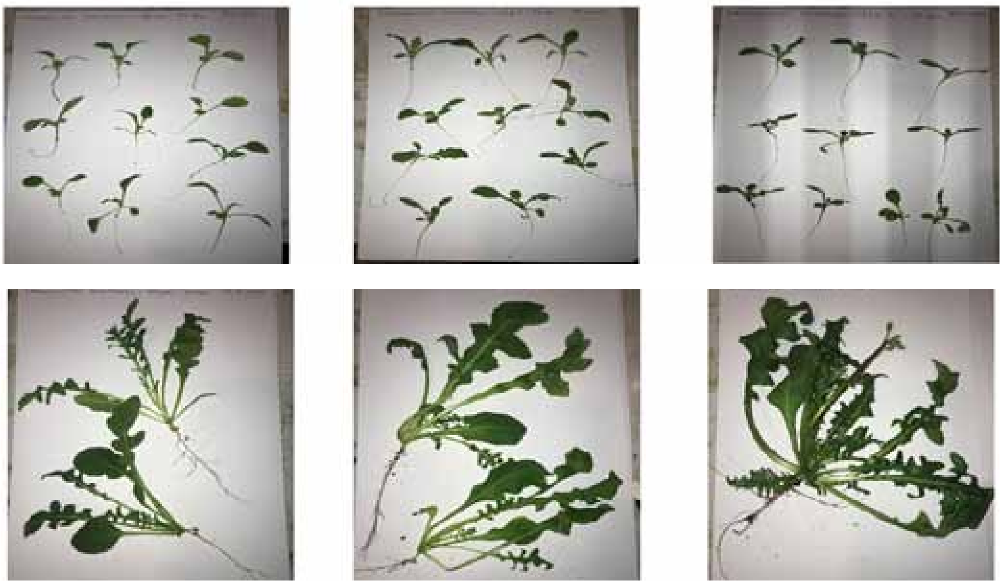
Statistical analyses

All statistical analyses were performed using IBM SPSS Statistics 25 (IBM, 2020), whereby a two-way analysis of variance (ANOVA) was applied for estimating the interaction effects of factors on the dependent parameter. When an interaction effect was not confirmed, one-way ANOVA was used for interpreting the effects of each tested factor. The differences in the content levels were estimated by Duncan's test. P-values of less than 0.05 were considered statistically significant.

Results

Growth assessment of wild rocket in response to different light

Unfortunately, the weight of leaves and stems after 15 days of growth was too low for separate estimation (Fig. 2), so only the data for the whole plants are presented. As shown in Table 2, there was no difference in dry weight after 15 days, probably due to the very short initial sampling period. However, after 30 days of growing the significantly highest total dry weight (0.930 g) was measured under LED2, while there was no difference between T5 and LED1 lights.



a) b) c)

Figure 2: Wild rocket plants after 15 days (top images) and 30 days of growing (bottom images) under T5 (a), LED1 (b) and LED2 (c) light

Slika 2.: Biljke uskolisnog dvoredca nakon 15 dana (gornje slike) i 30 dana rasta (donje slike) pod T5 (a), LED1 (b) i LED2 (c) svjetlima

Table 2: Effects of different LED light types on shoot DW

Tablica 2.: Efekti različitih vrsta LED svjetala na suhu masu stabljike

Treatment	Total DW 15 days (g)	Total DW 30 days (g)	Root DW 30 days (g)	Leaves DW 30 days (g)	Steam DW 30 days (g)
T5	0.016 b	0.260 bc	0.008 c	0.243 b	0.006 c
LED1	0.017 ab	0.357 b	0.046 a	0,292 b	0.036 b
LED2	0.018 a	0.671 a	0.050 ab	0,557 a	0,069 a

[a,b,c]...significant at p<0,05 (Duncan)

When comparing the plant parts that are of commercial interest (leaves and stems), the highest fresh yield of leaves and stem (7.321 g) was measured under LED2 light, which was significantly higher than under LED1 and T5 (Table 3).

Table 3: Effects of different LED light types on shoot FW
Tablica 3.: Efekti različitih vrsta LED svjetala na svježu masu stabljike

Treatment	Total FW 15 days (g)	Total FW 30 days (g)	Root FW 30 days (g)	Leaves FW 30 days (g)	Steam FW 30 days (g)
T5	0.163 b	2.413 c	0.046 b	2.320 c	0.047 c
LED1	0.268 a	5.842 b	0.672 a	4.643 b	0.527 b
LED2	0.192 b	7.898 a	0.577 ab	6.528 a	0.793 a

[a,b,c]…significant at p<0,05 (Duncan)

The regression analysis between different light intensities and the sum of plants parts (Table 4) revealed that the increase in total dry matter is correlated with the PPFD_R light intensity (r=0.796***) at most. The same was estimated for the leaves and roots, while there was no correlation for the stem. Contrary, there was weaker correlation with PPFD_B and PPFD_G intensity and leaves and roots, respectively. Again there was no correlation with the roots.

Table 4: Correlation coefficients between different PPFD light intensity and DW after 30 days
Tablica 4.: Koeficijent korelacije između različitog intenziteta PPFD svjetla i suhe mase nakon 30 dana

	Leaves	Stem	Roots	Total
PPFD_R	0.792***	0.158 n.s.	0.785***	0.796***
PPFD_G	0.526**	0.005 n.s.	0.506**	0.521**
PPFD_B	0.478**	0.189 n.s.	0.487**	0.488**

*significant at p<0.05, ***significant at p<0.01, ****significant at p<0.001

Leaf area assessment of wild rocket in response to different light

The leaves represent most important market value of the wild rocket plant, so their development was separately estimated by measuring a LA (leaf area) incensement. As can be seen from Table 5, the highest leaf area per plant was measured under LED1 light (43.83 cm^2/plant) and significantly differ from T5, while there was no difference to LED2. The same was measured for the increase of LA from day 15 to day 30, which was again the biggest under LED1 (39.70 cm^2).

Table 5: Effects of different LED lights types on LA development
Tablica 5.: Efekti različitih vrsta LED svjetala na razvoj površine lista

Treatment	LAI 15 days (cm^2/ plant)	LAI 30 days (cm^2/ plant)	Increase (cm^2/ plant)
T5	4.33 a	15.06 b	10.73 b
LED1	4.23 a	41.40 a	37.17 a
LED2	4.13 a	43.83 a	39.70 a

[a,b,c]…significant at p<0.05 (Duncan)

The regression analysis between different light intensity and LA development showed that the strongest correlation was estimated between the PPFD_R light intensity after 30 days of growing (r=0.930***) and the PPFD_G light intensity and the increase of LA (r=0.843***), respectively (Table 6). In contrary, there was very weak correlation between the PPFD_B light intensity and LA. These findings correspond only partly with those of Tan et al. (2020), who reported a significant effect of RB LED light on shoot growth in choy sum; on the other hand, Kopsell et al. (2015) found no positive effect for blue light on mustard (*Brassica juncea* L.) microgreens.

Table 6: Correlation coefficients between different PPFD light intensity and LA
Tablica 6. Koeficijent korelacije između različitih intenziteta PPFD svjetla i površine lista

Treatment	LAI 15 days	LAI 30 days	LAI Increase
PPFD_R	0.404*	0.931***	0.930***
PPFD_G	0.567**	0.840***	0.843***
PPFD_B	0.129	0.262*	0.257

*significant at p<0.05, **significant at p<0.01, ***significant at p<0.001

Conclusions and discussion

In this study we highlighted differences in growing potential of wild rocket under controlled indoor conditions in the growing chamber with three different light types. The results of this experiment were in contrast with field conditions, which often stress plants and create phytochemical profiles reflective of fluctuating environmental stresses such as light intensity, temperature, pests and disease.

The use of LED lighting with higher PPFD_R and PPFD_B intensity is favorable to high yield in commercial categories of wild rocket (leaves). As seen from regression analysis, FW and DW production was more influenced by PPFD_R (r=0.792**) than by PPFD_G (r=0.521**) and PPFD_B (r=0.488**), respectively. The same was found out for a leaf area development, which was mostly affected by PPFD_R.

To overcome the lack of understanding of the interaction among different wavelengths and growing profile of the wild rocket, future research should investigate monochromatic LED light, which could be used to optimize photosynthesis effectiveness more precisely. With such approach one could investigate the expression of genes necessary for the biosynthesis of both phytohormones and their effect of growing more precisely.

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Izvorni znanstveni rad

Potencijal rasta rukole Diplotaxis tenuifolia (L.) DC. pod različitim LED osvjetljenjem

Sažetak

*Potencijali rasta rukole Diplotaxis tenuifolia (L.) DC. proučavani su tijekom 30 dana uzgoja u komori pri različitim režimima osvjetljenja; T5_ max 630 nm, LED1_ max 545 nm i LED2_max 599 nm. Nije bilo značajnih razlika u suhoj težini nakon 15 dana, međutim, od 15. do 30. dana, povećanje suhe težine bilo je značajno najveće pod LED2. Dobro se slaže s procijenjenom prosječnom površinom lista (LA) po biljci (43,83 cm^2), te povećanjem LA (39,70 cm^2) i ukupnom svježom masom (7,898 g po biljci). Regresijskom analizom utvrđena je najjača korelacija između suhe težine i intenziteta svjetla PPFD_R (0,792**), što pokazuje pozitivan učinak dodatne LED rasvjete u usporedbi sa standardnim T5 svjetlom.*

Ključne riječi: *svježa masa, suha masa, lisna površina, LED, divlja rukola*