Agr. Nat. Resour. 59 (2025) 590307

AGRICULTURE AND NATURAL RESOURCES

Journal homepage: http://anres.kasetsart.org

Research article

Optimum blue light proportions enhance growth and phytochemicals in Ivy-Gourd (*Coccinia grandis* L. Voigt) microgreens

K G Sachini W. Gnanathilaka[a,†], Det Wattanachaiyingchareon[a,†], Wandee Wattanachaiyingchareon[b,†], Thammasak Thongket[a,*]

[a] *Department of Agricultural Science, Faculty of Agriculture, Natural Resources and Environment, Naresuan University, 99 Moo 9, Thapho Sub District, Mueang Phitsanulok District, Phitsanulok Province 65000, Thailand.*

[b] *Department of Biology and Center of Excellence for Biodiversity, Faculty of Science, Naresuan University, 99 Moo 9, Thapho Sub District, Mueang Phitsanulok District, Phitsanulok Province 65000, Thailand.*

Article Info

Article history:
Received 25 September 2024
Revised 5 December 2024
Accepted 19 December 2024
Available online 30 May 2025

Keywords:
Accessions,
2,2-diphenyl-1-picrylhydrazyl (DPPH) antioxidants,
Light spectrum,
Plant factory,
Vitamin C

Abstract

Importance of the work: Ivy-gourd is a nutrient-rich but underutilized microgreen. Light spectrum, especially blue and red light ratios, influences plant growth and phytochemicals. This study explored optimal light combinations to enhance growth and quality in ivy-gourd microgreens.

Objectives: To produce ivy-gourd microgreens in a plant factory under different ratios of blue (B) and red (R) light combinations and to investigate its growth and phytochemical properties.

Materials and Methods: A 3 ×6 factorial in a randomized complete block design was used. Factor A was three ivy-gourd accessions from Thailand and factor B was six different light combinations using white (W), monochromatic red (R) and monochromatic blue (B) and three combinations of varying B-to-R ratios (B75:R25, B50:R50, B25:R75).

Results: There were significant differences in growth and carotenoid content among the accessions ($p < 0.05$), while there was no significant difference in the phytochemical content. However, all parameters were significantly different under the B and R light combinations. Monochromatic R light promoted the growth and demoted the phytochemicals. Contrarily, increasing the B light percentage caused decreased growth and increased phytochemical levels. The non-linear regression analysis revealed a strong correlation (coefficient of determination > 0.8) between increasing the B light amount and each of fresh weight, hypocotyl length, vitamin C, 2,2-diphenyl-1-picrylhydrazyl (DPPH) antioxidant activity, phenolic compounds and total soluble solids, while pigments and dry weight did not show such a correlation.

Main finding: There was a specific optimum level of the B light ratio to maximize each phytochemical. The growth parameters were maximized under monochromatic R light. In contrast, phenolic compounds and the DPPH antioxidants peaked close to 100% B light, while the total soluble solids and vitamin C content maximized in the range 50−75% B light.

† Equal contributions.

* Corresponding Author
E-mail address: thammasakt@nu.ac.th (T. Thongket)

https://doi.org/10.34044/j.anres.2025.59.3.07

Introduction

In modern agriculture, innovation is key to achieving global food security, with Control Environment Agriculture and artificial lighting being the leading approaches. The Plant Factory with Artificial Lighting approach is a promising system with light-emitting diodes (LEDs) providing photosynthetically active radiation (PAR) (Alrifai et al., 2019) and less energy consumption (Gupta and Agarwal, 2017; Morrow, 2008). In leafy greens and microgreens, certain light spectra are crucial for plant growth and phytochemical synthesis (Olle and Virsile, 2013; Samuolienė et al., 2013).

Microgreens, produced using various types of edible seeds (Huang et al., 2016; Treadwell et al., 2010) are rich in vitamins, minerals and phytochemicals (Brazaityte et al., 2019; Verlinden, 2019), with over 100 species currently used for production (Ebert, 2022; Treadwell et al., 2010).

While the Cucurbitaceae family includes many edible species, it is not commonly used for microgreen production (Fapohunda et al., 2018), likely due to limited published research and its low profile among producers and consumers. Results from growing cucumber, pumpkin, and bottle gourd microgreens under greenhouse conditions indicated vitamin C levels of less than 25mg/100g fresh weight (FW) and 2,2-diphenylpicrylhydrazyl (DPPH) antioxidant activity of less than 4.31 µmol Trolox equivalent/100g FW, while total phenolic compounds were in the range 67-89 mg gallic acid equivalent/100 g FW (Yadev et al., 2018).

However, ivy-gourd (*Coccinia grandis* L. Voigt), a nutrient-rich member of this family, is an underutilized vegetable often used in Indian (Soundarya et al., 2022) and Thai cuisines (FAO, 1999). It is rich in vitamins and minerals (FAO, 1999) and phytochemicals (Sutar et al., 2010), especially antioxidants and phenolics (Nanasombat and Teckchuen, 2009; Sakharkar and Chauhan, 2017). Ivy-gourd leaves contain carbohydrates, alkaloids, glucosides, flavonoids, tannins and saponins (Pathania and Chawla, 2023). In addition, the plant has anti-hyperlipidemic (Bunkrongcheap et al., 2015), anti-diabetic (Akhtar et al., 2007), obesity-controlling compounds (Tak et al., 2021) and antimicrobial properties (Khatun et al., 2012).

The enticing nutritional profile of ivy-gourd has raised interest in its production as a microgreen. Therefore, the current research was planned to study the effects of genetic variation and the light spectrum, specifically different combinations of blue and red spectra on the growth and phytochemical synthesis of ivy-gourd microgreens.

Materials and Methods

Planting material

Three accessions of ivy-gourd seeds were obtained from the Gene Bank of the Tropical Vegetable Research Center, Kasetsart University, Nakhon Pathom Province, Thailand. Their accession codes were CGR 001, CGR 009 and CGR 016, being collected from Pattani, Ratchaburi and Phetchabun Provinces, respectively located in the South, Central and Northern Thailand, respectively. A germination test was performed to assess the germination capacity of each accession to determine the optimal seeding rate.

Experimental design and light treatments

A 3 × 6 factorial experiment in a randomized complete block design was conducted with three replicates in which replications (blocks) were repeated over time. Factor A consisted of the three ivy-gourd accessions, while factor B consisted of six different light spectra using white (W), monochromatic red (R) and monochromatic blue (B) and three combinations of varying B-to-R ratios (B75:R25, B50:R50, B25:R75), as shown in Fig. 2.

The light setups were arranged using sets of vertical growing tires, each with two growing chambers (0.06 m ×0.06 m ×0.05 m) equipped with adjustable 50 cm long, 20 W monochromatic batten Plug and Grow LED lights (Civic Agrotech Co. Ltd; Thailand). The light intensity was set at 150 µmol/m^2/s using a spectrometer (PAR meter; UPRtek, Model PG200N; United Power Research Technology Co-operation; the Netherlands). The photoperiod was 16 hr/8 hr light/darkness cycle, with an equal DLI of 8.64 mol/m^2/d. The growth room temperature was maintained at 25 ± 2°C, with 50% relative humidity (RH) and the CO_2 levels were in the range 350–380 parts per million.

Seed treatments and seed sowing

The seeds were hydro-primed, sterilized and sown in containers 10 cm ×10 cm ×7 cm in size (150 seeds per container with 100 cm^2 growing area) with a peat moss substrate (pH 6.0; Potgrond H; Klasmann-Deilmann GmbH; Germany). After germination, the containers were placed randomly under one of the six specific lighting combinations and kept for 6 d until harvesting. On the 11th day after seed sowing, the microgreens were harvested. The study period was from November 2022 to February 2023.

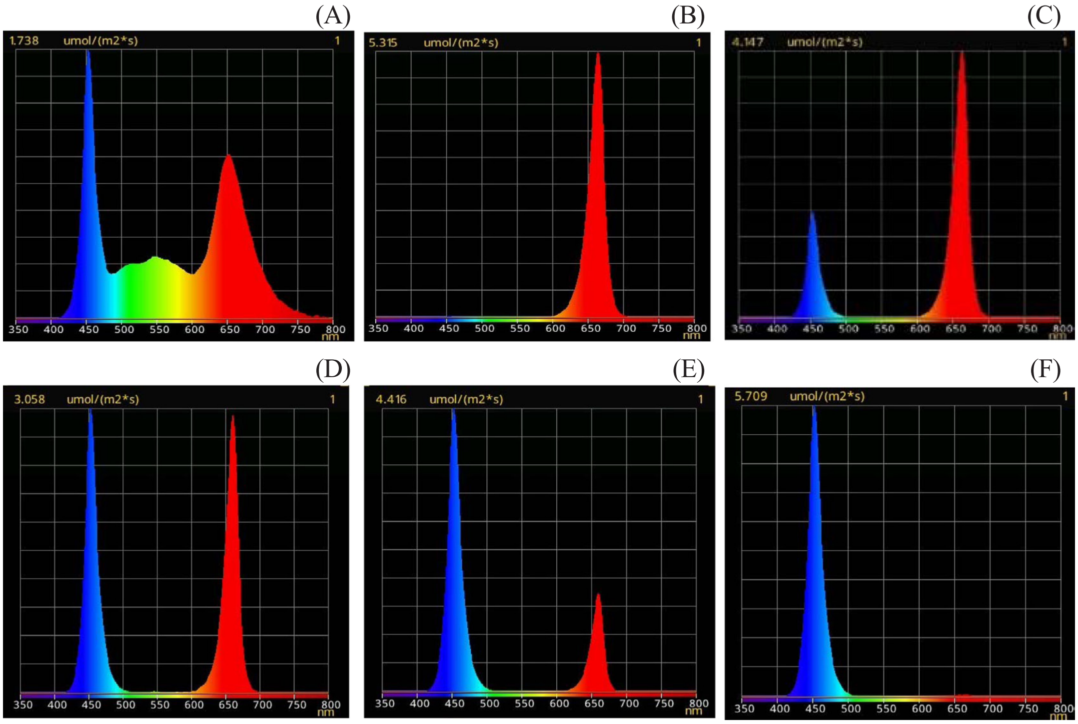

Fig. 1 Light spectrum combinations of six treatments: A) white light; B) monochromatic red (R); C) B25:R75; D) B50:R50; E) B75:R25; F) monochromatic blue (B)

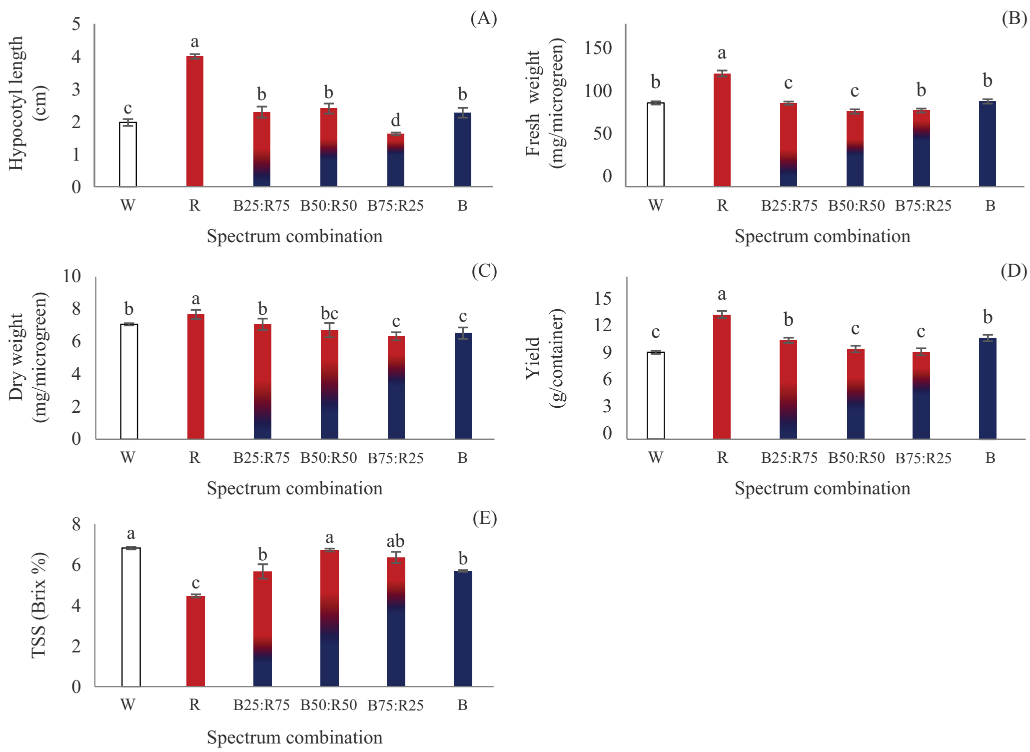

Fig. 2 Growth performance and total soluble solids (TSS) of ivy-gourd microgreens grown under different spectrum combinations at 6 d after germination: (A) hypocotyl length; (B) fresh weight; (C) dry weight; (D) yield per container; and (E) total soluble solids (TSS)
W = white light, R = red light, B = blue light; Different lowercase letters above bars are significantly different ($p < 0.05$) according to Duncan's multiple range test (n = 3). Error bars indicate ± SD.

Growth and total soluble sugar determination

Growth

Yield (grams per container), fresh weight (grams) and dry weight (DW; grams) were measured using an analytical balance (ES 600HA; Zepper; Thailand). The yield was determined just after harvesting all the microgreens in a container with 100 cm^2 area. Then, 10 fresh microgreens were measured for FW. The same samples were dried in an oven (1375FX; Sheldon Manufacturing; USA) at 60°C until a constant weight (DW) was obtained (Li et al., 2021). The hypocotyl length (HL) was measured in centimeters.

Total soluble solids

The total soluble solids (TSS) were determined using a refractometer (PALI; Atago; Japan), according to (Dalal et al., 2019).

Phytochemical analysis

Chlorophyll a, b, total chlorophyll and carotenoids were measured as pigments using the spectrophotometric method (Dere et al., 1998), and the total phenolic (TP) content was measured using the Folin-Ciocalteu colorimetric method (Pintatum et al., 2014). DPPH radical scavenging assay was applied (Oueslati et al., 2012) to measure DPPH antioxidant levels. The vitamin C was analyzed using the 2,4- dinitrophenyl hydrazine method (Roe et al., 1948).

Statistical analysis

Two-way analysis of variance was conducted. The mean difference was determined using Duncan's multiple range test to compare multiple group means. The confidence interval was set at 95%. Furthermore, a regression analysis was performed based on the B light proportion versus the growth and the phytochemical contents to identify any correlations.

Results

Based on the results, the accession factor significantly affected all growth parameters, the yield and the carotenoid content of the ivy gourd microgreens. At the same time, there were no significant differences among the accessions for the TSS and phytochemicals. In contrast, the light spectrum factor significantly affected the growth, TSS and phytochemicals. Additionally, there was insignificant interaction between accession and light spectrum treatments (Table 1).

Accession effect on growth, yield and carotenoids

The CGR 001 and CGR 009 accessions produced higher yields than CGR 016, whereas CGR 009 had the highest FW, DW and HL values among the three accessions. However, CGR 016 had the highest carotenoid content (Table 2).

Table 1 Statistical significance of main and interaction effects of accession and light spectrum on growth and phytochemical parameters of ivy-gourd microgreens at 6 d after germination.

Factors	Accession (A)	Light spectrum (LS)	A × LS
Yield	**	**	ns
Fresh weight	**	**	ns
Dry weight	**	**	ns
Hypocotyl length	**	**	ns
Total soluble solids	ns	**	ns
Chlorophyll a	ns	**	ns
Chlorophyll b	ns	**	ns
Total chlorophyll	ns	**	ns
Carotenoid content	**	**	ns
Vitamin C	ns	**	ns
Phenolic compounds	ns	**	ns
DPPH antioxidant	ns	**	ns

DPPH = 2,2-diphenyl-1-picrylhydrazyl;
** = highly significant ($p < 0.01$); ns = non-significant ($p \geq 0.05$)

Table 2 Growth parameters (hypocotyl length, fresh weight, and dry weight yield) and carotenoid content of three ivy-gourd accessions grown under LED light at 6 d after germination, averaged across light spectrum treatments.

Accession	Hypocotyl length (cm)	Fresh weight (mg/microgreen)	Dry weight (mg/microgreen)	Yield (g/container)	Carotenoid content (mg/100g FW)
CGR 001	2.28 ± 0.84^{b}	98.49 ± 16.52^{b}	6.40 ± 0.57^{b}	11.40 ± 1.67^{a}	7.56 ± 0.28^{b}
CGR 009	2.62 ± 0.84^{a}	104.25 ± 17.71^{a}	7.31 ± 0.45^{a}	10.89 ± 1.77^{ab}	7.63 ± 0.21^{b}
CGR 016	2.38 ± 0.81^{b}	99.09 ± 14.95^{b}	7.01 ± 0.57^{a}	10.47 ± 1.41^{b}	7.90 ± 0.32^{a}

Values represent means ± SD ($n = 6$); Means within the same column superscripted with different lowercase letters are significantly different ($p < 0.05$), according to Duncan's multiple range test.

Light spectrum effect

Effect on growth, yield and total soluble solids

The light spectrum treatments significantly affected the HL, FW, DW and yield of the ivy-gourd microgreens, with their effects following similar trends. R produced the significantly highest values while the combination of B and R light produced a significant decrease in all growth parameters-the higher the B proportion, the lower the growth and yield. Unexpectedly, when the B light proportion was maximized, all other growth parameter values (except for DW) increased, though not to the same highest value as R light. Notably, W light produced intermediate values for all growth parameters, except for yield (Figs. 2A–2D). Furthermore, W light and the B50:R50 light spectrum significantly dominated TSS accumulation in the ivy-gourd microgreens, while the R light produced the lowest value (Fig. 2E).

Effect on phytochemicals

Pigments

There were significant differences among all pigments of ivy-gourd microgreens due to the effects of the light spectrum treatments. Notably, the highest pigment content was produced under the B75:R25 light treatment, while the B50:R50 treatment had the lowest values for all pigments. Furthermore, the W light produced Chl a and carotenoid contents in amounts comparable to B75:R25 (Figs. 3A–3D).

Total phenolic compounds

The TP compounds differed significantly with the various spectrum combinations. The B light produced the highest results, whereas the R and B25:R75 combinations produced the lowest. The results for the W, B50:R50 and B75:R25 light treatments were substantially identical to the maximum value (Fig. 3E).

Vitamin C

The vitamin C content was significantly different among the light treatments and followed a rising trend with the proportion of B light, with the maximum produced by the B75:R25 and B50:R50 treatments. In contrast, the R treatment produced the lowest level (Fig. 3F).

DPPH antioxidant activity

The DPPH antioxidant activity displayed the same rising trend with the B light proportion, reaching its highest value with the B light. The lowest level was observed in R light. The B25:R75 and B50:R50 treatments produced comparatively lower amounts of antioxidants than the W light treatment (Fig. 3G).

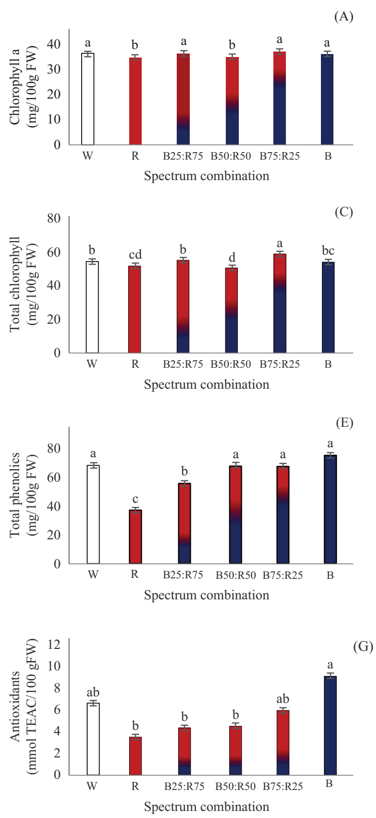

Fig. 3 Total chlorophyll content of ivy-gourd microgreens grown under different light spectrum combinations at 6 d after germination: (A) chlorophyll a; (B) chlorophyll b; (C) total chlorophyll; (D) carotenoid content; (E) phenolic compounds; (F) vitamin C; (G) 2,2-diphenyl-1-picrylhydrazyl antioxidant activity; W = white light, R = red light, B = blue light, FW = fresh weight. Different lowercase letters above bars are significantly different ($p < 0.05$) according to Duncan's multiple range test (n = 3). Error bars indicate ± SD. TEAC = Trolox equivalent antioxidant capacity aaa

Correlation between blue light proportion with growth and phytochemicals

Based on the regression analysis results, there was a significant non-linear relationship between the blue light percentage (BLP) and the growth, yield and some phytochemicals of the ivy-gourd microgreens. The BLP was strongly correlated (coefficient of determination, $R^2 > 0.8$) with the HL, FW and yield of ivy-gourd microgreens, which decreased as the BLP increased from 0% to 50–75%, then rose again as the BLP approached 100% (Figs. 4A–4D). In contrast, the TSS increased with a higher BLP, peaking at 50–75%, before declining ($R^2 > 0.8$), as shown in Fig. 4E. The effect of BLP on pigments such as chlorophyll was minimal ($R^2 < 0.3$), as shown in Figs. 4F–4I. However, BLP had a strong positive correlation ($R^2 > 0.8$) with TP, vitamin C and DPPH antioxidants, with peak values occurring at 75–100% for TP, 50–75% for vitamin C, and 100% for DPPH antioxidants (Figs. 4J–4L).

Discussion

Effects of accessions on growth, total soluble solids and phytochemicals

Genetic markup plays a crucial role in determining the quantity and quality of microgreens. Other studies have shown substantial differences in growth and phytochemical content among accessions and cultivars of microgreens such as amaranth (Di Bella et al., 2020; Ebert et al., 2015), hemp (Corrado et al., 2022), radish (Tilahun et al., 2023)

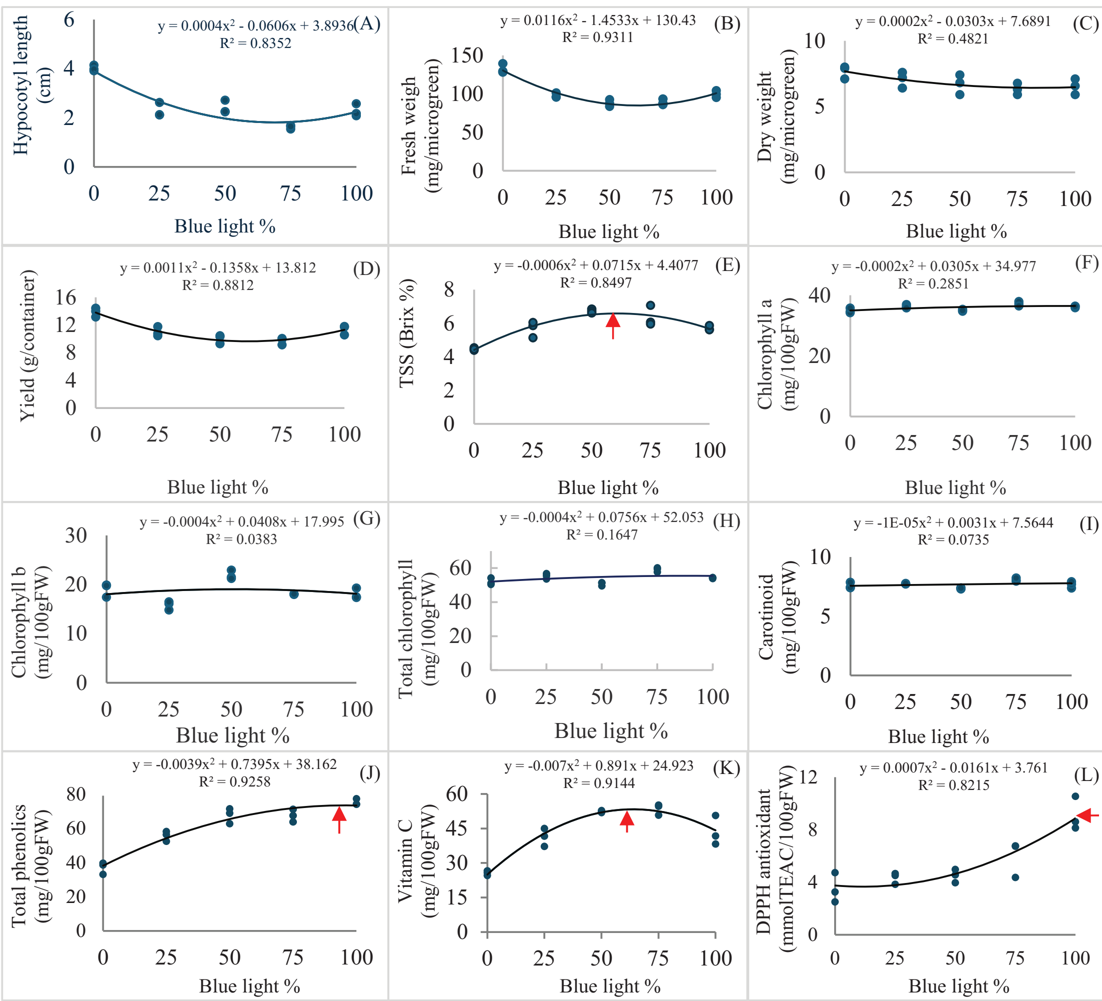

Fig. 4 Non-linear relationship between blue light percentage versus: (A) hypocotyl length; (B) fresh weight (FW); (C) dry weight; (D) yield per container; (E) total soluble solids (TSS); (F) chlorophyll a; (G) chlorophyll b; (H) total chlorophyll; (I) carotenoid content; (J) phenolic compounds; (K) vitamin C; (L) 2,2-diphenyl-1-picrylhydrazyl (DPPH) antioxidant activity, where regression equation accepted at coefficient of determination (R^2) > 0.5

and broccoli (Di Bella et al., 2020). The current study hypothesized that the genetic differences would similarly affect the growth and phytochemical content of ivy-gourd microgreens.

The results revealed significant differences in growth parameters and yield among the three accessions, with CGR 009 having superior growth and yield, while CGR 016 had the highest carotenoid content. Notably, there were no significant differences in the other phytochemicals, such as chlorophyll a, b, and total chlorophyll, and TP, vitamin C and DPPH antioxidant activity. This suggested a close genetic relationship among the three accessions, consistent with other findings on ivy-gourd genetics in Thailand (Kittiwongwattana, 2022). Additionally, there was no interaction between accessions and light spectrum treatments.

Effect of light spectrum on growth and total soluble solids

Based on the results, the light spectrum significantly impacted the growth, yield and secondary metabolite synthesis in the ivy-gourd microgreens. the R light produced higher growth and yield values than the B light and the R and B combinations. Growth and yield metrics, such as HL, FW, DW and yield of ivy-gourd microgreen, were highest under the R light and decreased with increasing B light mixtures. Notably, the growth under the B light increased up to 100%; however, it was still not as effective as R light alone.

R light led to a 2.03-fold increase in HL compared to W light. R and B lights worked together to regulate microgreen hypocotyl elongation through phytochrome (Phy) and cryptochrome (Cry) pathways (Tsuchida-Mayama et al., 2010). These pathways activate COP1 (CONSTITUTIVE PHOTOTMORPHOGENIC 1) and stabilize HY5 (LONGHYPOCOTYL 5) and HYH (LING HYPOCOTYL 5 HOMOLOG) promoting photomorphogenesis and hypocotyl elongation (Brazaityte et al., 2021). The R light effect on elongation was consistent with findings in mustard and kale (Brazaityte et al., 2021), amaranth and turnip green microgreens (Toscano et al., 2021). In addition, Kong et al. (2019b) reported that under 100% B light, a low phytochrome equilibrium triggered hypocotyl elongation, resembling a shade avoidance response to low light intensity.

For growth and yield, monochromatic R light reportedly provided a higher quantum yield (measured in moles of CO_2 assimilated per mole of photons) than the blue and green light spectra (Liu and van Iersel, 2021; Zha et al., 2020). Hence, this would explain how the R light increased the FW, DW and yield by 1.5-fold, 1.8-fold and 1.43-fold, respectively, compared to W light. Notably, B light accumulated higher levels of FW and DW than W light and the R and B combinations in the current study. Similarly mustard microgreens had the highest DW and FW at 100% B and the lowest at 50% B, while kale microgreens recorded the highest FW and DW at 10% B and 100% B, respectively (Brazaityte et al., 2021). R and B light combinations induces stomatal opening, while B light alone induces stomatal conductance and rubisco enzyme activity (Li et al., 2023). Furthermore, B light produced an increment in the transcriptional rates of genes encoding the Calvin cycle enzymes (Wang et al., 2009). In addition, B light controls the relocation of chloroplasts and influences light capture; consequently, the maximum light amount is harvested under the low intensity of B light and this improves the photosynthesis rate (Jones-Baumgardt et al., 2020).

The TSS is the key parameter for determining the taste and quality of fruits and vegetables, representing the percentage of dissolved solids (primarily sugars) in a solution (Chen et al., 2019). The main sugars in microgreens such as mizuna, kohlrabi and broccoli are sucrose, fructose and glucose (Samuoliene et al., 2019), with the TSS having the strongest correlation with sucrose (Wei et al., 2020). The light spectrum significantly influences the sugar contents in plants (Choi et al., 2015; Fan et al., 2013). In the current study, the ivy-gourd microgreens had the highest TSS under W light and the lowest under monochromatic R light. A combination of R and B light yielded higher TSS values from the monochromatic spectrum, with the peak observed in between the B50:R50 and B75:R25 ratios (Fig. 4E). This combination proved effective in promoting sugar accumulation, consistent with findings by Ohashi-Kaneko et al. (2007) and Li et al. (2017).

Effect of light spectrum on phytochemicals

Pigments

The combination of B and R light has been shown to promote chlorophyll and carotenoid concentrations (Fan et al., 2013). In the current study, the B75:R25 combination produced the highest levels of Chl a, b, total chlorophyll and carotenoid, while the B50:R50 combination produced the lowest. This higher B light dosage significantly stimulated chlorophyll and carotenoid synthesis, consistent with findings in basil (Lobiuc et al., 2017) and amaranth microgreens (Toscano et al., 2021). Chlorophyll biosynthesis depends on the interaction of Cry and active Phy (Hernández and Kubota, 2016). However, R light suppresses chlorophyll biosynthesis gene expression such as MgCH, GluTR, and FeCH (Wang et al., 2009) and reduces the tetrapyrrole precursor (5-aminolevulinic acid), leading to decreased chlorophyll formation (Sood et al., 2005), with the downregulation of chlorophyll precursors such as AIA, Pro IX, Mg-Proto IX and Pchilide (Fan et al., 2013).

In the current study, the carotenoid content varied significantly among treatments, with the B75R25 light combination producing the highest levels, while B50R50 produced the lowest. However, the statistical analysis revealed only a weak relationship between carotenoid and BLP (Fig. 4I) indicating that the increasing BLP did not affect the carotenoid content of the ivy-gourd microgreens. Carotenoid biosynthesis is regulated by R, B and W light photoreceptors (Gupta and Pradhan, 2017). Similar studies on mustard, kale, arugula and red cabbage (Ying et al., 2020), green and red basil (Lobiuc et al., 2017) and red amaranth (Meas et al., 2020) microgreens also showed no significant differences in carotenoids due to spectrum effects. However, Samuoliene et al. (2017) found that 33% B light led to the highest carotenoid levels in beet microgreens, suggesting that the effect of the light spectrum on carotenoid synthesis is species-specific; for ivy-gourd microgreens, a specific B and R combination is required to maximize this pigment synthesis.

Total phenolic compounds, vitamin C and 2,2-diphenyl-1-picrylhydrazyl antioxidant activity

Based on the current results, BLP had a significant effect on the TP compounds in ivy-gourd microgreens, with a strong positive correlation (R^2 = 0.93), as shown in Figs. 3E and 4J. However, there was a positive relationship with B light up to a specific point (Fig. 4J), with the TP compounds increasing with BLP up to 50% after which it plateaued. Similar findings were reported in other studies, where higher phenolic levels were observed in green and red basil microgreens under a higher B light combination (1R:2B), according to (Lobiuc et al., 2017) and in turnip greens and amaranth under monochromatic B (Toscano et al., 2021). Additionally, kale and mustard microgreens had a positive linear relationship with 5–30% B (Ying et al., 2020).

B light stimulates cry-mediated protective mechanisms against reactive oxygen species and enhances phenolic compound biosynthesis through isoprenoid/phenylpropanoid pathways (Iwai et al., 2010) . Enzymes such as phenylalanine ammonia-lyase (PAL) and flavonoid 3’ hydroxylase (F3H) are more active under B light and W light than under R light (Kim et al., 2015). PAL plays a role in initiating phenylpropanoid biosynthesis (Chang et al., 2009). Monochromatic B light also promotes higher transcription rates, enhancing phenylpropanoid biosynthesis and gene expression patterns (Brazaityte et al., 2021). While W light boosts kaempferol synthesis and reduces hydroxybenzoic acid and quercetin, B light influences the synthesis of various phenolic compounds (Kim et al., 2015), leading to an increase in the overall phenolic content.

The DPPH antioxidant activity in the ivy-gourd microgreens had a non-linear, positive relationship with BLP, peaking at 100% B (Fig. 4L). This was consistent with Vaštakaitė et al. (2015) and Lobiuc et al. (2017), indicating the major role of B light in enhancing plant antioxidant activity. B light, with its shorter wavelength, induces stress and activates Cry that triggers the production of reactive oxygen species in plant cells. In response, Cry upregulates the genes responsible for synthesizing antioxidant compounds such as anthocyanin, phenolic compounds, flavonoids and vitamin C (Larsen et al., 2022; Roeber et al., 2021).

Conclusion

The growth and phytochemical contents were investigated of ivy-gourd microgreens of three accessions grown under different light spectra, especially B and R light combinations. Based on the findings, monochromatic R light notably enhanced the growth and yield of the ivy-gourd microgreens. W light significantly increased the TSS level compared to the other light spectra tested, while B light enhanced the phytochemicals, namely vitamin C, total phenolic compounds and DPPH antioxidants. Nevertheless, the optimum B light proportion that maximized phytochemicals varied with the type of phytochemical. All three ivy-gourd accessions differed in their physical traits that can affect the growth and yield of microgreens; however, they did not differ in their TSS and phytochemical contents (except for carotenoid) and had similar responses to the tested light spectrum treatments.

Conflict of Interest

The authors declare that there are no conflicts of interest.

Acknowledgements

The Thailand International Corporation Agency, Royal Government of Thailand provided funds for conducting this research. The Tropical Vegetable Research Center, Kasetsart University, Nakhon Pathom province, Thailand provided the ivy-gourd seeds used in this research.

References

Akhtar, M. A., Rashid, M., Wahed, M. I. I., Islam, M. R., Shaheen, S. M., Islam, M. A., Amran, M. S., Ahmed, M. 2007. Comparison of long-term antihyperglycemic and hypolipidemic effects between Coccinia cordifolia (Linn.) and Catharanthus roseus (Linn.) in alloxan-induced diabetic rats. Res J Medicine Med Sci 2: 29-34.

Alrifai, O., Hao, X., Marcone, M. F., Tsao, R. 2019. Current Review of the Modulatory Effects of LED Lights on Photosynthesis of Secondary Metabolites and Future Perspectives of Microgreen Vegetables. J Agric Food Chem 67: 6075-6090. doi.org/10.1021/acs.jafc.9b00819

Brazaityte, A., Miliauskiene, J., Vastakaite-Kairiene, V., Sutuliene, R., Lauzike, K., Duchovskis, P., Malek, S. 2021. Effect of Different Ratios of Blue and Red LED Light on Brassicaceae Microgreens under a Controlled Environment. Plants (Basel) 10. doi.org/10.3390/plants10040801

Brazaityte, A., Virsile, A., Samuoliene, G., Vastakaite-Kairiene, V., Jankauskiene, J., Miliauskiene, J., Novickovas, A., Duchovskis, P. 2019. Response of Mustard Microgreens to Different Wavelengths and Durations of UV-A LEDs. Front Plant Sci 10: 1153. doi.org/10.3389/fpls.2019.01153

Bunkrongcheap, R., Inafuku, M., Oku, H., Hutadilok-Towantana, N., Wattanapiromsakul, C., Sermwittayawong, D. 2015. Lipid-lowering effects of hexane fraction of Ivy gourd (*Coccinia grandis* L. Voigt) root in mice fed a high-fat diet. Walailak Journal 13(10): 815-825.

Chang, J., Luo, J., He, G. 2009. Regulation of polyphenols accumulation by combined overexpression/silencing key enzymes of the phenylpropanoid pathway. Acta Biochim Biophys Sin 41: 123–130. doi.org/10.1093/1bbs/gmn014.source.pubmed

Chen, X.-l., Wang, L.-c., Li, T., Yang, Q.-c., Guo, W.-z. 2019. Sugar accumulation and growth of lettuce exposed to different lighting modes of red and blue LED light. Sci Rep 9: 6926.

Choi, H. G., Moon, B. Y., Kang, N. J. 2015. Effects of LED light on the production of strawberry during cultivation in a plastic greenhouse and in a growth chamber. Sci Hortic 189: 22-31.

Corrado, G., Pannico, A., Zarrelli, A., Kyriacou, M. C., De Pascale, S., Rouphael, Y. 2022. Macro and trace element mineral composition of six hemp varieties grown as microgreens. J Food Compos Anal 114: 104750.

Dalal, N., Siddiqui, S., Neeraj. 2019. Effect of chemicala treatment, storage and packaging on physio-chemical properties of sunflower microgreens. Int J Chem Stud 7(5): 1046-1050.

Dere, Ş., Gunes, T., Sivaci, R. 1998. Spectrophotometric determination of chlorophyll-a, b and total carotenoid contents of some algae species using different solvents. J Bot 22: 13-17.

Di Bella, M. C., Niklas, A., Toscano, S., Picchi, V., Romano, D., Lo Scalzo, R., Branca, F. 2020. Morphometric characteristics, polyphenols and ascorbic acid variation in *Brassica oleracea* L. novel Foods: sprouts, microgreens and baby leaves. Agronomy 10: 782. doi.org/10.3390/agronomy10060782

Ebert, A., Wu, D., Yang, R.-Y. 2015, 25-27 February 2014. Amaranth sprouts and microgreens - a homestad vegetable production option to enhance food and nutrition security in the rural-urban continuum. SEAVEG2014: Families, Farms, Food, Bangkok, Thailand.

Ebert, A. W. 2022. Sprouts and Microgreens-Novel Food Sources for Healthy Diets. Plants (Basel) 11. doi.org/10.3390/plants11040571

Fan, X., Zang, J., Xu, Z., Guo, S., Jiao, X., Liu, X., Gao, Y. 2013. Effects of different light quality on growth, chlorophyll concentration and chlorophyll biosynthesis precursors of non-heading Chinese cabbage (Brassica campestris L.). Acta Physiol Plant 35: 2721-2726. doi.org/10.1007/s11738-013-1304-z

FAO. 1999. The vegetable sector in Thailand - A review. F.-R. O. f. A. t. Pacific.

Fapohunda, S. O., Adewumi, A. A., Jegede, D. O., . 2018. Cucurbitaceae - The family that nourishes and heals. MicroMedicine 6(2): 85-93. doi.org/10.5281/zenodo.1436798

Gupta, S. D.,Agarwal, A. 2017. Artificial Lighting System for Plant Growth and Development: Chronological Advancement, Working Principles, and Comparative Assessment. In Light Emitting Diodes for Agriculture pp. 1-25. doi.org/10.1007/978-981-10-5807-3_1

Gupta, S. D.,Pradhan, S. 2017. Regulation of Gene Expression by LED Lighting. In Light Emitting Diodes for Agriculture pp. 237-258. doi.org/10.1007/978-981-10-5807-3_10

Hernández, R.,Kubota, C. 2016. Physiological responses of cucumber seedlings under different blue and red photon flux ratios using LEDs. Environ Exp Bot 121: 66-74. doi.org/10.1016/j.envexpbot.2015.04.001

Huang, H., Jiang, X., Xiao, Z., Yu, L., Pham, Q., Sun, J., Chen, P., Yokoyama, W., Yu, L. L., Luo, Y. S., Wang, T. T. 2016. Red cabbage microgreens lower circulating low-density lipoprotein (LDL), liver cholesterol, and inflammatory cytokines in mice fed a high-fat diet. J Agric Food Chem 64: 9161–9171. doi.org/10.1021/acs.jafc.6b03805

Iwai, M., Ohta, M., Tsuchiya, H., Suzuki, T. 2010. Enhanced accumulation of caffeic acid, rosmarinic acid and luteolin-glucoside in red perilla cultivated under red diode laser and blue LED illumination followed by UV-A irradiation. J funct foods 2: 66-70.

Jones-Baumgardt, C., Llewellyn, D., Zheng, Y. 2020. Different Microgreen Genotypes Have Unique Growth and Yield Responses to Intensity of Supplemental PAR from Light-emitting Diodes during Winter Greenhouse Production in Southern Ontario, Canada. HortScience 55: 156-163. doi.org/10.21273/hortsci14478-19

Khatun, S., Pervin, F., Karim, M. R., Ashraduzzaman, M., Rosma, A. 2012. Phytochemical screening and antimicrobial activity of *Coccinia cordifolia* L. plant. Pak J Pharm Sci 25: 757-761.

Kim, Y. J., Kim, Y. B., Li, X., Choi, S. R., Park, S., Park, J. S., Lim, Y. P., Park, S. U. 2015. Accumulation of phenylpropanoids by white, blue, and red light irradiation and their organ-specific distribution in Chinese cabbage (Brassica rapa ssp. pekinensis). J Agric Food Chem 63: 6772-6778.

Kittiwongwattana, C. 2022. Genetic relationship of Coccinia grandis (L.) Voigt accessions, based on RAPD and ISSR markers. Sci Eng Health Stud22030005-22030005.

Kong, Y., Schiestel, K., Zheng, Y. 2019b. Maximum elongation growth promoted as a shade-avoidance response by blue light is related to deactivated phytochrome: A comparison with red light in four microgreen species. Can J Plant Sci 100: 314-326.

Larsen, D. H., Li, H., Shrestha, S., Verdonk, J. C., Nicole, C. C., Marcelis, L. F., Woltering, E. J. 2022. Lack of blue light regulation of antioxidants and chilling tolerance in Basil. Front Plant Sci 13: 852654.

Li, T., Lalk, G., Bi, G. 2021. Fertilization and pre-sowing seed soaking affect the yield and mineral nutrients of ten microgreen species Horticulturae 7: 14. doi.org/https://doi.org/10.3390/horticulturae702001

Li, X., Zhao, S., Lin, A., Yang, Y., Zhang, G., Xu, P., Wu, Y., Yang, Z. 2023. Effect of different ratios of red and blue light on maximum stomatal conductance and response rate of cucumber seedling leaves. Agronomy 13: 1941.

Li, Y., Xin, G., Wei, M., Shi, Q., Yang, F., Wang, X. 2017. Carbohydrate accumulation and sucrose metabolism responses in tomato seedling leaves when subjected to different light qualities. Sci Hortic 225: 490-497.

Liu, J.,van Iersel, M. W. 2021. Photosynthetic Physiology of Blue, Green, and Red Light: Light Intensity Effects and Underlying Mechanisms. Front Plant Sci 12: 619987. doi.org/10.3389/fpls.2021.619987

Lobiuc, A., Vacilache, V., Pintilie, O., Stoleru, T., Burducea, M., Oroian, M., Zamfirache, M.-M. 2017. Blue & red LED illumination improves growth & bioactive compounds contents in acynic & cynic *Ocimum basilicum* L. microgreens. Molecules 22(12): 1-14. doi.org/10.3390/molecules22122111

Meas, S., Luengwilai, K., Thongket, T. 2020. Enhancing growth and phytochemicals of two amaranth microgreens by LEDs light irradiation. Sci Hortic 265: 1-10. doi.org/10.1016/j.scienta.2020.109204

Morrow, R. C. 2008. LED Lighting in Horticulture. HortScience 43(7): 1947-1950.

Nanasombat, S.,Teckchuen, N. 2009. Antimicrobial, antioxidant and anticancer activities of Thai local vegetables. J Med Plants Res 3: 443–449.

Ohashi-Kaneko, K., Takase, M., Kon, N., Fujiwara, K., Kurata, K. 2007. Effect of light quality on growth and vegetable quality in leaf lettuce, spinach and komatsuna. Environ Control Biol 45: 189-198.

Olle, M.,Virsile, A. 2013. The effects of light-emitting diode lighting on greenhouse plant growth and quality. Agric Food Sci 22: 223-234.

Oueslati, S., Trabelsi, N., Boulaabaa, M., Legault, J., Abdelly, C., Ksouri, R. 2012. Evaluation of antioxidant activities of the edible and medicinal Suaeda species and related phenolic compounds. 36: 513-518. doi.org/10.1016/j.indcrop.2011.10.006

Pathania, R.,Chawla, R. 2023. Ivy Gourd. In A. D. Ranga & J. Singh (Eds.), Underutilized vegetable crops Importance and cultivation Jaya Publishing Housse. Delhi, India. pp. 92–99.

Pintatum, A., Suteerapataranon, S., Watla-iad, K. 2014. Antioxidant capacity of tea seed (*Camelia oleifera*) oil planted in the Northern of Thailand The 26th Annual Meeting of the Thai Society for Biotechnology and International Conferance,

Roe, J. H., Mills, M. B., Oesterling, M. J., Damron, C. M. 1948. The determination of diketo-l-gulonic acid, dehydro-l-ascorbic acid, and l-ascorbic acid in the same tissue extract by the 2,4-dinitrophenylhydrazine method. 201-208.

Roeber, V. M., Bajaj, I., Rohde, M., Schmülling, T., Cortleven, A. 2021. Light acts as a stressor and influences abiotic and biotic stress responses in plants. Plant Cell Environ 44: 645–664. doi.org/10.1111/pce.13948

Sakharkar, P.,Chauhan, B. 2017. Antibacterial, antioxidant and cell proliferative properties of Coccinia grandis fruits. Avicenna J Phytomed 7: 295–307.

Samuolienė, G., Brazaitytė, A., Jankauskienė, J., Viršilė, A., Sirtautas, R., Novičkovas, A., Sakalauskienė, S., Sakalauskaitė, J., Duchovskis, P. 2013. LED irradiance level affects growth and nutritional quality of Brassica microgreens. Cent Eur J Biol 8: 1241-1249.

Samuoliene, G., Brazaityte, A., Virsile, A., Miliauskiene, J., Vastakaite-Kairiene, V., Duchovskis, P. 2019. Nutrient Levels in Brassicaceae Microgreens Increase Under Tailored Light-Emitting Diode Spectra. Front Plant Sci 10: 1475. doi.org/10.3389/fpls.2019.01475

Samuoliene,G.,Virsile,A.,Brazaityte,A.,Jankauskiene,J.,Sakalauskiene,S., Vastakaite, V., Novickovas, A., Viskeliene, A., Sasnauskas, A., Duchovskis, P. 2017. Blue light dosage affects carotenoids and tocopherols in microgreens. Food Chem 228: 50-56. doi.org/10.1016/j.foodchem.2017.01.144

Sood, S., Gupta, V., Tripathy, B. C. 2005. Photoregulation of the greening process of wheat seedlings grown in red light. Plant Mol. Biol. 59: 269-287.

Soundarya, C., Kumari, K. U., Rao, A. D., Patro, T. K., Umakrishna, K. 2022. Evaluation of Ivy gourd (*Coccinia grandis* L.) genotypes for growth, yield and yield attributing traits. The Pharma Innovation Journal 11(7): 3042-3045.

Sutar, N., Garai, R., Sharma, U., Singh, N., Roy, S. 2010. Pharmacognostical studies of Coccinia indica Wight & Arn leaves. Int J Pharm Res Dev 2: 15-24.

Tak, J. K., Pilania, S., Dashora, A., Lakhawat, S., Dadheech, S. 2021. Genetic Divergence Analysis in Ivy Gourd (*Coccinia grandis*). Int J Curr Microbiol App Sci 10: 1336-1341.

Tilahun, S., Baek, M. W., An, K.-S., Choi, H. R., Lee, J. H., Hong, J. S., Jeong, C. S. 2023. Radish microgreens produced without substrate in a vertical multi-layered growing unit are rich in nutritional metabolites. Front Plant Sci 14: 1236055.

Toscano, S., Cavallaro, V., Ferrante, A., Romano, D., Patane, C. 2021. Effects of Different Light Spectra on Final Biomass Production and Nutritional Quality of Two Microgreens. Plants (Basel) 10. doi.org/10.3390/plants10081584

Treadwell, D. D., Hochmuth, R., Landrum, L., Laughlin, W. 2010. Microgreens: A new specialty crop.

Tsuchida-Mayama, T., Sakai, T., Hanada, A., Uehara, Y., Asami, T., Yamaguchi, S. 2010. Role of the phytochrome and cryptochrome signaling pathways in hypocotyl phototropism. The Plant Journal 62: 653-662.

Vaštakaitė, V., Viršilė, A., Brazaitytė, A., Samuolienė, G., Jankauskienė, J., Sirtautas, R., Novičkovas, A., Dabašinskas, L., Sakalauskienė, S., Miliauskienė, J., Duchovskis, P. 2015. The effect of blue light dosage on growth and antioxidant properties of microgreens. Scientific Work of Institute of Horticulture, Lithunia Research Center for Agriculture and Forestry and Aleksandras Stulginskis University, Sodininkyste Ir Darzininkyste. pp. 25-35.

Verlinden, S. 2019. Microgreens - Definitions, product types, and production practices. In I. Warrington (Ed.), Horticultural Reviews Vol. 37. John Willey And Sons, Inc. doi.org/10.1002/9781119625407

Wang, H., Gu, M., Cui, J., Shi, K., Zhou, Y., Yu, J. 2009. Effects of light quality on CO2 assimilation, chlorophyll-fluorescence quenching, expression of Calvin cycle genes and carbohydrate accumulation in Cucumis sativus. J. Photochem. Photobiol. B: Biol. 96: 30-37.

Wei, K., Ma, C., Sun, K., Liu, Q., Zhao, N., Sun, Y., Tu, K., Pan, L. 2020. Relationship between optical properties and soluble sugar contents of apple flesh during storage. Postharvest Biol. Technol. 159: 111021.

Yadev, L. P., Koley, T. K., Tripathi, A., Singh, S. 2018. Antioxident potentiality and mineral content of summer season leafy greens: Comparison at mature and microgreen stages using chemometric. Agric Res. doi.org/10.1007/s40003-018-0378-7

Ying, Q., Kong, Y., Jones-Baumgardt, C., Zheng, Y. 2020. Responses of yield and appearance quality of four Brassicaceae microgreens to varied blue light proportion in red and blue light-emitting diodes lighting. Sci Hortic 259. doi.org/10.1016/j.scienta.2019.108857

Zha, L., Liu, W., Yang, Q., Zhang, Y., Zhou, C., Shao, M. 2020. Regulation of ascorbate accumulation and metabolism in lettuce by the red: blue ratio of continuous light using LEDs. Front Plant Sci 11: 704.