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Evaluation of growth and nutritional profile of microgreens of different crops under various LEDs light spectrums

Swarna Mahajan[1], Minhazul Kashem Chowdhury[1], Sohel Rana Mazumder[1], Abul Hasnat M. Solaiman[1], Zerin Tasnim[1], S.M. Anamul Arefin[2] and Jasim Uddain*

[1]*Department of Horticulture, Faculty of Agriculture, Sher-E-Bangla Agricultural University, Dhaka-1207, Bangladesh.* [2]*Department of Genetics and Plant breeding, Faculty of Agriculture, Sher-E-Bangla Agricultural University, Dhaka-1207, Bangladesh. *E-mail: jasimhort@sau.edu.bd*

Abstract

Carefully selecting the appropriate lighting is vital for indoor farming systems to ensure sustainable agriculture and the production of microgreens rich in health-beneficial phytochemicals. This study aimed to investigate the impact of various light spectrums on the growth and nutritional composition of microgreens. The experiment focused on a single factor: five different concentrations of LED lights, specifically White light (L1) at 100%, Red light (L2) at 100%, Blue light (L3) at 100%, Red and Blue light (L4) at a 70:30 ratio, and Red, Green, and Blue light (L5) at a 70:10:20 ratio. Four microgreen crops were used: Mustard (C1), Lettuce (C2), Radish (C3), and Broccoli (C4). The results showed that the hypocotyl lengths of C1, C2, C3, and C4 were higher under the L4 light treatment (70:30 Red and Blue), measuring 10.53 cm, 8.47 cm, 15.23 cm, and 11.43 cm, respectively. The shorter hypocotyl lengths of 7.67, 5.53, 11.2 and 7.73 cm were observed under the L1 (White light) condition. The greater fresh weights for C1, C2, C3, and C4 (0.1 kg each) and yields (0.115 kg, 0.110 kg, 0.135 kg, and 0.125 kg, respectively) were also obtained under the L4 light condition. The higher SPAD values for C1 (38.2 nm), C2 (16.9 nm), C3 (55.3 nm), and C4 (49.9 nm) were recorded with the L4 light treatment. Additional findings included potassium content for C1 (0.19%), C2 (0.19%), C3 (0.22%), and C4 (0.16%), and antioxidant capacity for C1 (0.22%), C2 (0.23%), C3 (0.19%), and C4 (0.18%). The higher gross income was achieved with the L4C1, L4C2, L4C3, and L4C4 treatments, while the lower was with the L1C1, L1C2, L1C3, and L1C4 treatments. The benefit-cost ratios were higher (4.1, 3.9, 4.9, and 4.5) for the L4C1, L4C2, L4C3, and L4C4 treatments, respectively. Therefore, a 70:30 Red and Blue light combination (L4) can be used profitably in indoor farming to maximize growth, yield, and nutritional content of microgreens.

Key words: Microgreens, LED, light spectrums, control farming

Introduction

A class of consumable salad crops known as microgreens are increasingly available in premium markets and restaurants. These are ingested seedlings of herbs and vegetables that have soft cotyledons and roughly developed first pairs of leaves. During the harvest period, the height of the plants ranges from 2.5 to 8 cm, with variations according on the specific species. The harvest takes place at the base of the hypocotyl once the first genuine leaves begin to appear (Xiao *et al*., 2012). The popularity of microgreens has risen due to their high concentration of essential nutrients, including vitamins, minerals, and antioxidants, compared to fully grown greens. These nutrient-dense crops assist address nutritional deficiencies (Burlingame, 2014). Microgreens from the Brassicaceae, Asteraceae, and Fabaceae families have gained popularity because to their simple germination process, rapid growth, and diverse range of flavors and colors.

LEDs are a novel light source technology employed in greenhouses and compact plant growth chambers. In recent research, numerous studies have shown the significant impact of LED lighting, namely blue and red light, on various vegetative parameters of plants. Brazaitytė *et al.* (2016) investigate the effects of different ratios of LED illumination (Red, Blue, and Green) on the growth and nutritional profile of microgreens, specifically focusing on ascorbic acid and antioxidant levels. Light plays a crucial role in controlling plant growth, development, and photosynthesis, making it one of the most significant environmental elements (Claypool and Lieth, 2020). LEDs are considered the most efficient light source with great potential. They are being developed to produce strong and effective emission spectra that cover the entire range of photo synthetically active radiation (Avercheva *et al.,* 2016).

The addition of green LEDs to the lighting system improved the growth and physical characteristics of the plants, whilst the inclusion of blue LEDs resulted in higher levels of minerals and vitamins (Kamal *et al*., 2020). Red-blue (RB) LED lighting systems are commonly employed in plant cultivation due to the efficient absorption of red and blue light by photosynthetic pigments (Phansurin *et al*., 2017). The utilization of LED illumination to augment efficiency in the cultivation of indigenous vegetable microgreens has been studied (Harakotr *et al*., 2019). The red light has the largest quantum yield of CO_2 fixation compared to other wavelengths in the photosynthetically active spectrum, as demonstrated by Hogewoning *et al.* (2010). Blue-light signaling has been found to initiate various processes, including photomorphogenesis, stomatal opening and phototropism. These processes have a significant impact on the rate of photosynthesis (Horrer *et al*., 2016; HucheThelier *et al*., 2016).

Several research have confirmed the significance of utilizing a combination of red and blue light to enhance plant growth and nutritional value in crops such lettuce, cucumber, soybean seedlings, and pakchoi (Chen *et.al*., 2017). Plants exhibit diverse physical and functional reactions to specific light wavelengths, and the present progress in LED technology allows for customization of the light spectrum to achieve desired plant growth or nutritional benefits (Mickens *et al*., 2019).

The present research aims to cultivate microgreens in a regulated grow-house using LEDs light spectrum, based on the scheme mentioned above. The objective is to examine the development and productivity of microgreen crops, as well as determine the nutritional composition of microgreens from various crops exposed to different LED light spectrums.

Materials and methods

Experimental design and layout: The experiment was conducted in the FAB LAB of Sher-e-Bangla Agricultural University in Dhaka, Bangladesh, from November to December 2020. The studies were conducted in growth chambers with controlled environments. The day and night temperatures were maintained at 23±1°C, with a 16-hour photoperiod and a relative humidity of 60-64%. The experiment was designed as a single-factor study using a Randomized Complete Block Design (RCBD). It consisted of three replications with a total of 20 treatment combinations, each replicated three times. The experiment consisted of five treatments: L1, which involved 100% white light; L2, which involved 100% red light; L3, which involved 100% blue light; L4, which involved a mixture of 70% red light and 30% blue light; and L5, which involved a mixture of 70% red light, 10% green light, and 20% blue light. Four distinct crops are cultivated at this light intensity: C1 = mustard, C2 = lettuce, C3 = radish, and C4 = broccoli. The experiment was conducted on the five tiers of the iron rack. Four boxes were positioned in each stratum. The distance between the boxes was 8 centimeters, and the size of each box was 24×22 cm^2.

Preparation of different concentration of LEDs light: Each module had a primary array of high-power LEDs with varying PPFD levels. The primary source of photosynthetic photon flux consisted of a combination of white, red, blue, red and blue, and red, green and blue light, with intensities of 150, 81, 224, 248, and 89 $\mu mol.m^{-2}.s^{-1}$. Each module provided lighting for an area of 0.22 m^2, which was enough space for plants to develop simultaneously and produce sufficient data for statistical analysis. The measurement and regulation of PPFD at the crop level was performed using a photometer-radiometer. The light was programmed to be on for 16 hours each day, from 6:00 am to 10:00 pm, using a timer.

Plant production: Seeds of four varieties of microgreens, namely mustard (*Brassica juncea*), lettuce (*Lactuca scariola* var. *sativa*), radish (*Raphanus raphanistrum* subsp. *sativas*), and broccoli (*Brassica oleracea* var. *capitata*), were obtained from a nearby seed market for use as plant materials. In order to facilitate the germination process, all the chosen seeds were immersed in water for a duration of 4 hours. Additionally, preparations were made for the germination media (namely rock wool) and the indoor area by regulating temperature and humidity.

The seeds were planted in Rockwool, which is made from Basalt rock and Recycled Slag. The seeds were let to grow for a period of 9-10 days, from germination to harvest. Each vessel was seeded with 10 grams of seeds for each crop. Approximately, 125mL hydroponic solution (KNO_3-25.28mL/L, $Ca(NO_3)_2$-70.85mL/L, $MgSO_4$-36. 97mL/L, KH_2PO_4-13.61mL/L, NH_4CL-53.50g/L, H_3BO_3 -3.092mL/L, MnCl -1.98mL/L and $ZnSO_4$ -0.567mL/L) was providedto each of the growing boxes so that, the rock wool did not get dry.

A plastic cover was used to envelop the box, generating heat to facilitate germination. The box was then positioned in an indoor environment. After five days of seeding, when the cotyledons are completely bent backwards, a daily addition of 300 mL of a hydroponic solution with a concentration of 25% was made to each tray until harvest. Microgreens are typically harvested 12 days after they were sown. The plants from each treatment combination were taken from every box and utilized for data observation and recording of yield performance.

Growth and morphology measurements: The length of the hypocotyl was measured beneath the cotyledons. The length of ten randomly selected plants were measured using a meter scale at 3-day intervals, starting from 3 days after sowing (DAS) and continuing until harvest. The measurements were denoted in centimeters.

At harvest, yield characteristics were measured, including fresh weight and yield per box. For the purpose of determining the fresh weight (FW) and dry weight (DW), a total of ten samples were collected. Each sample consisted of ten seedlings randomly picked from each species. Following the collection of FW data, each sample was divided into segments and subjected to a 72-hours period of sun drying, followed by an additional 72-hours period of drying in an oven at a temperature of 70°C. The data was quantified in grams (g) using an electric balance.

SPAD value: The chlorophyll content of the cotyledons was quantified using a SPAD meter. (SPAD-502; Konica Minolta Sensing, Inc., Osaka, Japan).

Nitrogen content (%): The salicylic sulphuric acid technique was used to quantify the nitrogen concentration. 10 milligrams of samples that had been dried in an oven at 80°C for 48 hours were placed in ten milliliters of distilled water and stirred for 2 hours. Subsequently, 20 L of the sample were combined with 80 L of a solution containing 5% salicylic acid in H_2SO_4, as well as 3 milliliters of a 1.5 N NaOH solution. The samples were chilled to the temperature of the surrounding environment and the spectrophotometer measurements were taken at a wavelength of 410 nm. The nitrogen content was determined by referencing a calibration curve using a KNO_3 reference. The data were presented based on the fresh weight (FW) and taking into account the ratio of fresh weight to dry weight.

Brix% (°Brix): The measurement of Brix% was conducted using a refractometer (ERMA, Tokyo, Japan) at the ambient temperature. Initially, the microgreens were gathered and placed in a mortar, where they were mixed using a pestle to extract the juice. Next, the extract was placed on the refractometer and the % brix was recorded.

Potassium content (%): The samples were dried in an oven at 80°C for 48 hours, pulverized, and then treated with nitric acid for digestion. The elements were quantified using inductively coupled plasma mass spectrometry (ICP-MS). The data were expressed on a fresh weight basis, taking into account the ratio of fresh weight to dry weight.

Antioxidant (%): The ethanolic extracts were evaluated for their antioxidant activity by measuring their ability to scavenge the stable 1,1-diphenyl-2-picryl hydrazyl (DPPH) free radical. One milliliter of each solution with varying concentrations (ranging from 1 to 500 micrograms per milliliter) of the extracts was combined with 3 milliliters of a solution containing 0.004% ethanolic DPPH free radicals. The absorbance of the preparations was measured at 517 nm using a UV spectrophotometer after a 30-min. interval. This measurement was then compared to the absorbance of standard ascorbic acid doses ranging from 1 to 500 µg/mL. Subsequently, the percentage of inhibition was determined using the following mathematical equation:

$$\text{Radical (\%)} = \frac{A_B - A_S}{A_B} \times 100$$

Where, A_B= Absorbance of blank. A_S= Absorbance of scavenging activity sample

From calibration curves, obtained from different concentrations of the extracts, the IC_{50} (Inhibitory concentration 50%) was determined. IC_{50} value denotes the concentration of sample required to scavenge 50% of the DPPH free radicles.

Statistical analysis: The average values of all the recorded characters were assessed and analysis of variance was conducted. The significance of the variation among the treatment combinations of means was assessed using the Least Significant Difference (LSD) value at a 5% threshold of significance.

Economic analysis: The economic study was conducted by computing the production cost and price of the produce. The cost of production was calculated by incorporating all input costs and interest expenses on working capital. The interests were computed at a basic interest rate of 13%. The market value of microgreens crops was utilized to calculate the gross and net revenue. The economic evaluations were conducted following the methodology outlined by Kumbhare *et al.* (2014). The calculation of the benefit cost ratio (BCR) was performed in the following manner:

$$\text{Benefit Cost Ratio (BCR)} = \frac{\text{Gross return (tk)}}{\text{Total cost of production (tk)}}$$

Results and discussion

Hypocotyl length: Different LED-light spectral ratios had a notable impact on the hypocotyl length of mustard, lettuce, broccoli, and radish at various growth phases, as demonstrated in Table 1. The hypocotyl length of four different crops at 3, 6, 9, and 12 days after sowing (DAS) exhibited statistically significant variation as a result of varied combinations of LED light treatment. The higher hypocotyl lengths for mustard, lettuce, broccoli, and radish were found at 3, 6, 9, and 12 DAS under Red: Blue -70:30 light spectrum. For mustard, the lengths were 4.57, 7.83, 9.63, and 10.53 cm, respectively. For lettuce, the lengths were 2.97, 5.23, 6.9, and 8.47 cm. For broccoli, the lengths were 6.47, 11, 13.93, and 15.23 cm and for radish, the lengths were 3.57, 7.47, 9.83, and 11.43 cm. The lower hypocotyl lengths were found in the control treatment (White - Full), which was statistically identical to Red – 100%.

The present study yielded results consistent with the findings of Brazaityte *et al.* (2016). They discovered that supplementing light in greenhouses can enhance crop yield by stimulating photosynthesis and plant growth. Additionally, they observed that microgreens exhibited longer hypocotyls when exposed to a higher percentage of red-blue LED light. A comparable outcome was also shown by Craver *et al.* (2017).

Table 1. Hypocotyl length of selected crops at different growth stages (3, 6, 9 and 12 DAS) influenced by different LED light spectral ratios

Treatment	Hypocotyl length (cm)			
	3 DAS	6 DAS	9 DAS	12 DAS
L1C1	3.13ef	5.57d	7e	7.67f
L2C1	3.45cde	5.8cd	7.2e	7.96f
L3C1	4.12bc	6.9bc	8.54d	9.67de
L4C1	4.57b	7.83b	9.63bcd	10.53bcd
L5C1	3.97bcd	7b	8.67cd	9.77cde
L1C2	1.83i	3.7f	4.83g	5.63g
L2C2	1.98i	4ef	5.1fg	5.87g
L3C2	2.51fghi	5.12d	6.2ef	8.21f
L4C2	2.97efg	5.23d	6.9e	8.47ef
L5C2	2.83efgh	4.85de	6.33ef	8.11ef
L1C3	4.63b	7.87b	10.2b	11.2b
L2C3	4.78b	8b	10.53b	11.43b
L3C3	6.1a	10.46a	12.93a	14.92a
L4C3	6.47a	11a	13.93a	15.23a
L5C3	5.96a	10.33a	12.88a	14.82a
L1C4	2.03hi	5.07de	6.73e	7.73f
L2C4	2.22ghi	5.5d	6.92e	8.0f
L3C4	3efg	7.23b	9.35bcd	11.1bc
L4C4	3.57cde	7.47b	9.83bc	11.43b
L5C4	3.22def	7b	9.56bcd	11.2b
SE (±)	0.41	0.55	0.63	0.69
LSD (0.05)	0.82	1.12	1.27	1.39
CV (%)	13.4	7.36	5.77	5.03

In a column means having similar letter(s) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability. Here, 1. L_1= White Light -100%, 2. L_2= Red Light- 100%, 3. L_3= Blue Light – 100%, 4. L_4= Red & Blue Light -70:30, 5. L_5= Red, Green &Blue Light- 70: 10: 20, A. C_1= Mustard, B. C_2= Lettuce, C. C_3= Radish and D. C_4= Broccoli

Fresh weight (g)/box and dry weight (g): The fresh weight of four crops showed notable fluctuation when exposed to varied LED-light spectral ratios, as indicated in Table 2. The results indicated that the greater fresh weight of these crops were obtained in the treatment with a ratio of Red to Blue light of 70:30, which was significantly different from the other treatments.

The dry weight exhibited a comparable pattern to that of the fresh weight. The greater dry weight observed in broccoli (5.6) under the treatment Red: Blue -70:30. The experiment showed that the treatment Red: Blue -70:30 resulted in the higher dry weight for all microgreens.

Brazaityte *et al.* (2016) also reported comparable findings to the present study, demonstrating that the use of Red and blue LEDs resulted in an increase in the fresh biomass of Brassicaceae microgreens. In Bian *et al.* (2018) study, the maximum fresh and dry weight and leaf area were observed under blue LED light, specifically with a red and blue light ratio of 70:30. This finding is consistent with the results of the current investigation, which also reported similar outcomes compared to fluorescent lamps (FL).

Total yield (kg): Significant statistical differences were seen in the overall yield of selected microgreens in the experimental area for each treatment, which was influenced by changing the ratios of LED-light spectra (Fig. 1). The findings indicated that the Red: Blue -70:30 treatment resulted in greater overall crop yields for mustard (47.44%), lettuce (22.22%), radish (37.75%),

Table 2. Fresh and dry weight of selected crops at harvest influenced by different LED-light spectral ratios

Light	Fresh weight (gm)				Dry weight (gm)			
	C1	C2	C3	C4	C1	C2	C3	C3
L1	72.0c	92.3a	93.3a	91.0ab	1.4g	1.3g	3.6c	2.6e
L2	76.7bc	95.0a	98.7a	91.3ab	1.5g	1.5g	2.6e	2.6e
L3	88.3ab	96.7a	99.3a	97.7c	2.1f	1.2g	4.3b	3.4cd
L4	100.0a	100.0a	100.0a	100.0a	4.3b	3.5c	4.6b	5.6a
L5	93.3a	99.3a	100.0a	98.3a	2.43ef	3.03d	4.2b	3.8c
SE (±)	7.4				0.2			
LSD (0.05)	15.1				0.4			
CV (%)	9.8				7.6			

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability. Here, 1. L_1= White Light -100%, 2. L_2= Red Light- 100%, 3. L_3= Blue Light – 100%, 4. L_4= Red & Blue Light -70:30, 5. L_5= Red, Green &Blue Light- 70: 10: 20, A. C_1= Mustard, B. C_2= Lettuce, C. C_3= Radish and D. C_4= Broccoli

and broccoli (25%) in comparison to the control treatment (White - Full), which exhibited lower total yield.

According to Specht *et al.* (2014), vertical farming enables the cultivation of high value crops with greater productivity compared to traditional agricultural methods. LED lights are superior to traditional light sources in terms of energy efficiency and longevity. However, another study by Snowden *et al.* (2016) showed that an increase of up to 30% green light from LED sources did not have any effect on the dry mass of the same lettuce cultivar. Piovene *et al*. (2015) discovered that plants exhibited enhanced biomass and fruit production in basil and strawberry when exposed to LED lighting. Furthermore, a red to blue light ratio of 0.7 was found to be crucial for optimal plant growth and improved nutraceutical properties. According to Wong *et al*. (2020) report, manipulating the quality and quantity of lighting can enhance the yield and phytonutrient levels of leafy greens.

SPAD value: The SPAD value of mustard, lettuce, broccoli, and radish exhibited statistically significant fluctuation when exposed to varied LED-light spectral ratios (Fig. 2). The results showed that higher SPAD values for mustard, lettuce, broccoli, and radish were obtained under Red: Blue -70:30 light, with values of 38.2nm, 16.9nm, 55.3nm, and 49.9nm, respectively. These values were significantly different from those obtained under other treatments. On the other hand, lower SPAD values for mustard, lettuce, broccoli, and radish were recorded under the control treatment (White Light – Full), with values of 29.5nm, 12nm, 41.4nm, and 40.6nm, respectively. These values were statistically identical to those obtained under Red – 100% light. This finding suggests that the presence of red and blue light is accountable for the increased chlorophyll concentration. Blue light (BL) increases the number of stomata and the thickness of leaves (Hogewoning *et al*., 2010; Wang *et al*., 2016). BL has been found to enhance the chlorophyll content, as demonstrated by studies conducted by Hogewoning *et al*. (2010) and Johkan *et al*. (2010). A larger proportion of blue light (BL) is linked to the formation of sun-type leaves, which are characterized by their thick leaves and strong photosynthetic capability (Hogewoning *et al.,* 2010).

Nitrogen and potassium content (%): The nitrogen levels of mustard, lettuce, radish, and broccoli were significantly affected by different ratios of LED-light spectra (Table 3). The Red: Blue -70: 30 treatment exhibited higher nitrogen concentration in the plants. The treatment exhibited a marked divergence from the other treatments and led to a notable elevation in nitrogen content when compared to the control treatment (White Light - Full). The nitrogen concentration in mustard, lettuce, radish, and broccoli experienced a respective rise of 29.5%, 41%, 33.4%, and 131.35% in the Red: Blue -70: 30 treatment compared to the control treatment. The control treatment exhibited less nitrogen content. The present study's findings align with those of Brazaityte *et al*. (2016), indicating that the increased proportion of blue light mostly caused variations in the amount of different mineral elements.

A similar trend to the one discovered for nitrogen (N) was seen in the buildup of potassium (K) in the plant tissue. Exposure to Red: Blue -70:30 light resulted in a 111.11% rise in potassium content in mustard, a 72.72% increase in lettuce, a 57.14% increase in radish, and a 60% increase in broccoli, compared to the control condition (White Light - Full) where the potassium level was recorded less among all the levels mentioned in Table 3. The results were consistent with the findings reported by YanqiZhan *et al.* in 2021.

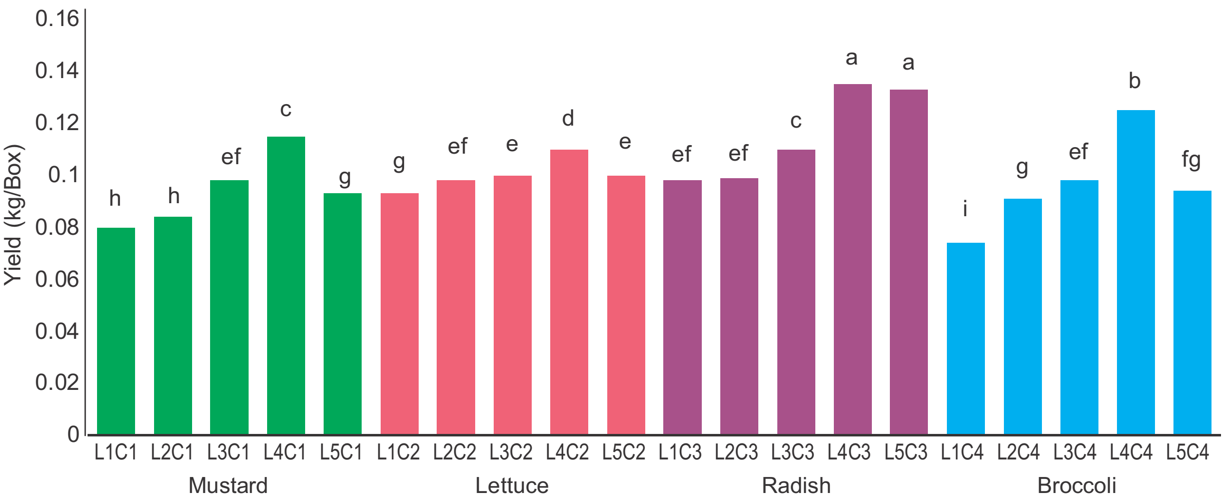

Fig. 1. Graphical view of yield (kg/box) of selected crops influenced by different LED-light spectral ratios. (Here, 1. L_1= White Light -100%, 2. L_2= Red Light- 100%, 3. L_3= Blue Light – 100%, 4. L_4= Red & Blue Light -70:30, 5. L_5= Red, Green &Blue Light- 70: 10: 20, A. C_1= Mustard, B. C_2= Lettuce, C. C_3= Radish and D. C_4= Broccoli)

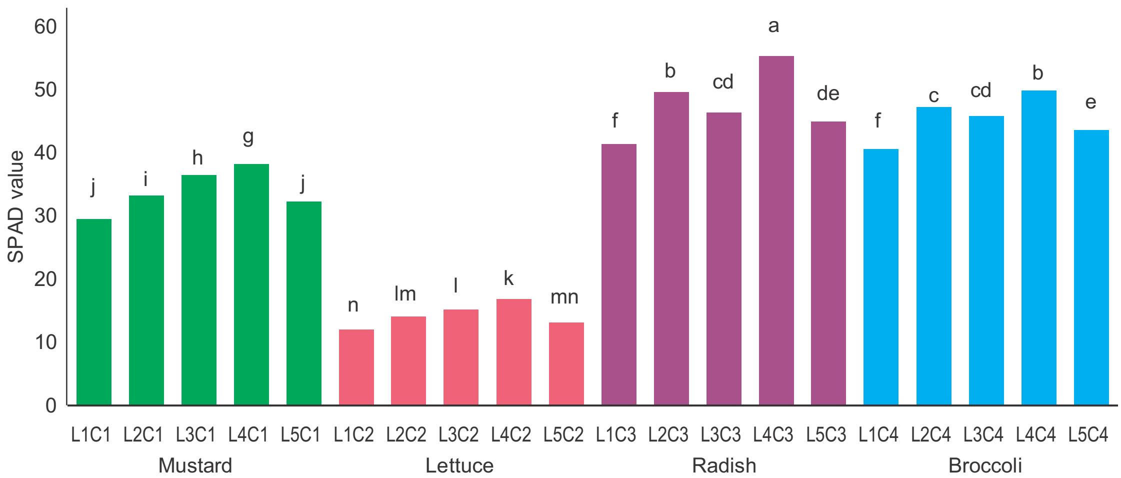

Fig. 2. Graphical view of SPAD value (nm) in different treatments for the selected crops. (Here, 1. L_1= White Light -100%, 2. L_2= Red Light- 100%, 3. L_3= Blue Light – 100%, 4. L_4= Red & Blue Light -70:30, 5. L_5= Red, Green & Blue Light- 70: 10: 20, A. C_1= Mustard, B. C_2= Lettuce, C. C_3= Radish and D. C_4= Broccoli)

Antioxidant capacity (%) and TSS (°Brix): The lettuce microgreen accumulated higher percentage (0.23%) of antioxidants when exposed to Red: Blue - 70:30 light, surpassing other microgreens. In contrast, broccoli accumulated a lower amount of antioxidants. In addition, the mustard, lettuce, radish, and broccoli plants had the greatest antioxidant capacity when subjected to Red: Blue - 70:30 light. Conversely, the control treatment (White Light - Full) exhibited less antioxidant capacity. This was statistically indistinguishable from the Red - 100% treatment.

Zhang *et al*. (2019) demonstrated that blue LEDs illumination caused notable enhancements in the antioxidant capacity of microgreens. Shibaeva *et al.* (2022) also observed a comparable outcome to the current investigation, indicating that the use of continuous LEDs lighting enables producers to enhance the antioxidant capacity of Brassicaceae microgreens.

In case of °Brix level, higher result was observed in radish (6.17%) under the Red: Blue - 70: 30 treatment. Besides the Red: Blue - 70: 30 treatment found higher °Brix level compared to other treatments. Conversely, lower °Brix levels were recorded under the control treatment (White Light - Full). The current study was consistent with the findings of Mickens *et al.* (2019).

Economic analysis: The economic study entailed the computation of the cost benefit ratio, specifically within the framework of Bangladesh, using the Bangladeshi currency (BDT) as the unit of measurement. The net returns were calculated by deducting the production costs from the gross revenue for different combinations of LEDs light and selected microgreens crops (Table 4). The Red: Blue - 70: 30 treatment resulted in higher net returns. Mustard, lettuce, radish, and broccoli had net returns per hectare that were more than 70.67, 29.56, 50.80 and 32.75% more, respectively, compared to the control treatment which had lower net returns. Radish exhibited higher benefit-cost ratio of 4.86. Among all treatments, the Red: Blue - 70: 30 treatment exhibited higher benefit-cost ratio for all crops.

Based on the aforementioned findings, it can be inferred that the treatments L4C1, L4C2, L4C3, and L4C4 (Red: Blue – 70:30) in vertical farming, which involve two different LED-light spectrums, had the most notable and positive impact on the growth, yield-contributing parameters, as well as the quality parameters of mustard, lettuce, radish, and broccoli microgreens. The treatment L4C1, L4C2, L4C3, and L4C4 (Red: Blue – 70:30) can be regarded as the most optimal treatment out of all the treatments.

Undoubtedly, further research is necessary to assess the impact of various combinations of red and blue light on the characteristics of microgreens, such as other nutritional value, color, texture, and taste. Additionally, these studies should also focus on determining the most effective LED management protocol and identifying the optimal cultivation conditions. Furthermore, the results of our study indicate that the selection of various LED light spectrums had a substantial impact on the growth, yield, quality, and economic returns of microgreens.

Table 3. Quality parameters of selected crops at harvest influenced by different LED- light spectral ratios

Treatment	Quality Parameters			
	Nitrate (%)	Potassium (%)	Antioxidant (%)	Brix (%)
L1C1	29.5k	0.09h	0.14d	2.97k
L2C1	32.33jk	0.14d	0.18b	4.07d
L3C1	33.33ijk	0.13b	0.18b	3.63fg
L4C1	38.23ghi	0.19de	0.22a	4.6b
L5C1	36.13hij	0.12ef	0.15cd	3.4hi
L1C2	12.0l	12.0l	0.14d	2.67l
L2C2	13.1l	0.14d	0.19b	3.47gh
L3C2	14.07l	0.14b	0.18b	3.2ij
L4C2	16.93l	0.19d	0.23a	4.4bc
L5C2	15.2l	0.13de	0.15cd	3.17jk
L1C3	41.43efg	0.14d	0.11ef	3.1jk
L2C3	44.9cdef	0.17c	0.15cd	4.33c
L3C3	46.4a	0.17a	0.19b	3.97de
L4C3	55.27bcde	0.22c	0.16c	6.17a
L5C3	49.7bc	0.14d	0.11ef	3.13jk
L1C4	40.6fgh	0.1gh	0.09g	3.27hij
L2C4	43.73def	0.14d	0.14d	3.63fg
L3C4	45.8b	0.12c	0.12ef	3.63fg
L4C4	49.93bcde	0.16ef	0.18b	3.83ef
L5C4	47.33bcd	0.12ef	0.1fg	3.4hi
SE (±)	2.45	7.96	8.83	0.11
LSD (0.05)	4.97	0.02	0.018	0.23
CV (%)	0.56	6.82	6.95	3.7

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability. Here, 1. L_1= White Light -100%, 2. L_2= Red Light- 100%, 3. L_3= Blue Light – 100%, 4. L_4= Red & Blue Light -70:30, 5. L_5= Red, Green &Blue Light- 70: 10: 20, A. C_1= Mustard, B. C_2= Lettuce, C. C_3= Radish and D. C_4= Broccoli

Table 4. Cost and return of selected microgreens under different LEDs lights in indoor condition

Treatment	Cost of Production (tk/ha)	Yield of micro greens (t/ha)	Gross return (tk/ha)	Net return (tk/ha)	Benefit cost ratio (BCR)
L1C1	1944325	26.9	5649000	3704675	2.91
L1C2	1944325	31.03	6516300	4571975	3.35
L1C3	1944325	33.8	7098000	5153675	3.65
L1C4	1944325	34.5	7245000	5300675	3.73
L2C1	1902000	29.3	6153000	4251000	3.24
L2C2	1902000	32.8	6888000	4986000	3.62
L2C3	1902000	35.5	7455000	5553000	3.92
L2C4	1902000	36.6	7686000	5784000	4.04
L3C1	1998800	37.9	6528900	4530100	3.27
L3C2	1998800	32.8	6888000	4889200	3.45
L3C3	1998800	39.7	7959000	5960200	3.98
L3C4	1998800	34.5	7245000	5246200	3.62
L4C1	2014350	39.7	8337000	6322650	4.14
L4C2	2014350	37.9	7938000	5923650	3.94
L4C3	2014350	46.6	9786000	7771650	4.86
L4C4	2014350	43.1	9051000	7036650	4.49
L5C1	3119499.65	31.03	7959000	4839500.35	2.55
L5C2	3119499.65	35.2	7392000	4272500.35	2.37
L5C3	3119499.65	37.9	8337000	5217500.35	2.67
L5C4	3119499.65	39.7	7959000	4839500.35	2.55

Here, 1. L_1= White Light -100%, 2. L_2= Red Light- 100%, 3. L_3= Blue Light – 100%, 4. L_4= Red & Blue Light -70:30, 5. L_5= Red, Green &Blue Light- 70: 10: 20, A. C_1= Mustard, B. C_2= Lettuce, C. C_3= Radish and D. C_4= Broccoli

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