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Growth Behavior of Coleus (*Plectranthus scutellarioides* L.) Cuttings In Relation To Light Emitting Diodes (LED) Intensities

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Abstract

Background: Coleus is a perennial herbaceous foliage plant belongs to the family Lamiaceae with long history of medicinal and food uses. Coleus plant have reputed medicinal uses, which includes anti-aggregate, anticancer, antidepressant, antidiuretic, antiglaucomic, antimetastatic, antispasmodic, bronchodilator, bronchospasmolytic, cardiotonic.

Hypothesis: Harsh environmental conditions including irregular temperature, unexpected rains and natural calamities have made the production of ornamental plants difficult. Therefore, coleus plants were cultivated under LED intensities to make its availability possible under harsh environmental conditions.

Study site and dates: The study was carried out during Feb-May (summer) 2017 at Horticulture Garden, Sindh Agriculture University Tandojam, Sindh, Pakistan.

Methods: Vegetative as well as chlorophyll contents were measured using different plant observations in plants grown under different light intensities. Some parameters of economic importance were studied which included: Sprouts cutting-1, sprouting index (SI), plant height (cm), branches per plant, leaves per plant, leaf length (cm), leaf width (cm), leaf area (cm^2), single leaf weight (g), chlorophyll content (SPAD) and root length (cm).

Results: Growth of coleus varieties were significantly ($P<0.05$) affected by various LED intensities. The two coleus varieties treated with 1204 µmol. m^{-2} S^{-1} produced maximum 3.08 sprouts cutting-1, 0.30 sprouting index, 14.60 cm plant height, 5.05 branches plant-1, 10.23 leaves plant-1, 11.39 cm leaf length, 8.88 cm leaf width, 101.20 cm^2 leaf area, 1.75 g single leaf weight, 27.51 chlorophyll content (SPAD) and 9.37 cm root length. However, minimum coleus varietal performance was observed under low light intensity (LI1= 301 µmol m^{-2} s^{-1}) having 1.08 sprouts, 0.10 sprouting index, 6.58 cm plant height, 1.05 branches, 2.27 leaves, 2.99 cm leaf length, 1.83 cm leaf width, 5.55 cm^2 leaf area, 0.28 g single leaf weight, 10.41 chlorophyll content (SPAD) and 4.66 cm root length.

Conclusions: Growth of coleus plant increased simultaneously with increasing LED light intensities. 1204 µmol m^{-2} s^{-1} resulted in maximum growth of coleus. In case of varieties, "Coleus Brown" resulted in significantly maximum vegetative and flowering traits as compared to variety "Coleus Fairway Rose".

Keywords: Coleus; Ecology; Greenhouse; Illumines; Chlorophyll; Leaves traits

Introduction

Coleus is a perennial herbaceous foliage plant belongs to the family Lamiaceae with long history of medicinal and food uses [1]. It is available in variety of bright colors that are adapted to different amounts of light from shade to full sun. It is used as an ornamental plant and planted as a pot or bed plant in many gardens and herbaria around the world [2]. Coleus has long been prized for their colorful foliage which may combine shades of green, yellow, pink, red and maroon. New introductions of this popular annual have been selected for increased sun and heat tolerance, turning coleus into a "plant for all locations" in the annual garden. World Health Organization (2003) estimates that 80% of the world's population depends on traditional medicine for their health needs. Coleus plant have reputed medicinal uses, which includes anti-aggregate, anticancer, antidepressant, antidiuretic, antiglaucomic, antimetastatic, antispasmodic, bronchodilator, bronchospasmolytic, cardiotonic, pancreatostimulant, positive inotropic, secretagogue, sialagogue, thyrotropic and vasodilator [1]. The first ornamental coleus was introduced into Europe from Java by Dutch horticulturist M.J.A. Willink in 1851 and due to its rapid growth rate and superior performance in the landscape, coleus quickly gained popularity as a bedding plant [1]. In Papua New Guinea, it is used as a Food additive, while in Southeast Asia it is considered a medicinal plant and used to treat a variety of ailments including dyspepsia, ophthalmia, and wound infections [1,3].

Harsh environmental conditions including irregular temperature, unexpected rains and natural calamities have made the production of ornamental plants difficult. Under intensive horticultural cultivation natural light levels often limit crop production during several periods. For an optimum plant production and product quality light intensity, spectrum and photoperiod have to be adapted to the needs of the crops at every moment. Light has to be optimized together with all other growth factors like temperature, humidity and CO_2 [4]. When sunlight is optimized it can still be necessary to add artificial light to ensure a year-round supply of horticultural products. There is still room for improving the crop energy efficiency under artificial lighting by changing duration and intensity of lighting, different growing systems

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and plant densities. Since artificial lighting requires a high amount of energy, new artificial lighting systems have been developed, such as inter lighting and light emitting diodes (LED). LED gives the possibility for true light spectrum control in the future [4]. These possibilities can contribute to respond to the increasing demand for high-quality horticultural products by the consumers and to the conservation of global natural environment and resources. Therefore, present study has been designed to evaluate the growth behavior of coleus cuttings in relation to LED intensities.

Materials and methods

Setting out of an experiment

Present study was conducted during summer, 2017 at Horticulture Garden, Department of Horticulture, Sindh Agriculture University, Tandojam. Cuttings of two coleus varieties was obtained from a commercial nursery in Hyderabad and was planted in 20 cm diameter earthen pots in late February 2017 using a silt FYM-based medium in a 1:1 ratio based on volume. Potted plants was grown in a shaded greenhouse under four LED treatments resulted from the installation of black shade cloth. Shade cloth was positioned at a height of 100 cm from the ground and centered across the row with a width of 100 cm so that it hung down on either side of the row. Such a design has been used to exclude any direct illumination and to obviate any microclimate alterations due to the presence of the shade cloth. 5W LED bulbs were hanged in each treatment then converted into lumens on the basis of following formula. Watts= lumens per watt. 1W= 60.2 lumens and 60.2 x 5=301 lumens per 5W LED bulb.

During the entire experiment cultural practices like weeding, hoeing and watering were carried out as per plant requirement. 0.5% urea was applied per pot after 20 days of sprouting. No disease or pathogen was found during the entire experiment. A two factor Completely Randomized Design (CRD) was set out with three replications where each replication was contain three pots. Temperatures and relative humidity in the shaded greenhouse was recorded on daily basis.

Treatments. Two factors (A and B)

Factor-A. Varieties (V) = 02 (V_1 = Coleus Fairway Rose, V_2 = Coleus Brown)

Factor-B. LED Intensities (LI) = 04 (LI_1= 301 µmol $m^{-2} s^{-1}$, LI_2= 602 µmol $m^{-2} s^{-1}$, LI_3= 903 µmol $m^{-2} s^{-1}$, LI_4= 1204 µmol $m^{-2} s^{-1}$)

Observations recorded. Sprouts per cutting, sprouting index (SI), plant height (cm), branches per plant, leaves per plant, leaf length (cm), leaf width (cm), leaf area (cm^2), single leaf weight (g), chlorophyll content (SPAD), root length (cm).

Sprouts per cutting. Sprouts were observed visually and counted daily after plantation for up to ten days after planting of cuttings.

Sprouting Index (SI). This parameter was calculated on the basis of number of sprouts as per following formula

$$SI = \frac{\text{no of sprouts}}{\text{Days of final count}}$$

Plant height (cm). Plant height was measured at the appearance of first flower bud stage with measuring tape from base to the top of the plant then average was done as per treatment.

Branches per plant. Average number of branches per plant was counted from six randomly selected plants of each variety from different LED treatments at the time of plant height measurement.

Leaves per plant. Average number of leaves per plant was counted visually from six randomly selected plants of each variety under different LED treatments.

Leaf length (cm). This was measured vertically from lamina base to the tip of lamina through central part of the leaf. Average was done as per treatment.

Leaf width (cm). It was measured horizontally from top, mid and base of leaf lamina as three readings there of average was calculated as per single leaf width.

Leaf Area (cm^2). Calculated by multiply leaf length with average leaf width.

A = L x W

Single leaf weight (g). Weight of single leaf was measured through randomly picking of leaves from top, mid and lowered part of the plant then weighted through digital weighing balance in (g).

Chlorophyll content (SPAD). Was measured by Chlorophyll meter (SPAD – 500 plus) in arbitrary units as relative greenness (RG). Chlorophyll was noted from central part of three randomly selected leaves of each six plant of each treatment then average was done as per treatment.

Root Length (cm). Measured by foot scale after the plant has been fully grow and other parameters have been noted.

Statistical analysis**.** The data was statistically analyzed using Statistix-8.1 computer software (Statistix, 2006). The LSD test was applied to compare treatments superiority in case results are significant at $P \leq 0.05$ probability level.

Results

Effect of LED intensities on sprouts

The results regarding the average sprouts of two coleus varieties as affected by LED intensities are presented in (Table 1). The sprouts of coleus varieties were maximum (3.08) when grown under 1204 µmol $m^{-2} s^{-1}$, followed by 903 µmol $m^{-2} s^{-1}$ with 2.58 average sprout $cutting^{-1}$, respectively. The coleus varieties plant grown under with 602 and 301 µmol $m^{-2} s^{-1}$ produced average sprouts per cutting of 1.25 and 1.08. The results for varieties and their interaction was non- significant.

Effect of LED intensities on sprouting index (SI)

The results regarding the average sprouting index of two coleus varieties as affected by LED bulb applications are presented in (Table 2). The sprouting index of coleus varieties was highest (0.30) at 1204 µmol $m^{-2} s^{-1}$, followed by 903 µmol $m^{-2} s^{-1}$ with 5.19 average sprouting

LED Intensities	Varieties		Mean
	Coleus Fairway Rose	Coleus Brown	
301 µmol $m^{-2} \cdot s^{-1}$	0.83	1.33	**1.08 B**
602 µmol $m^{-2} \cdot s^{-1}$	1.50	1.00	**1.25 B**
903 µmol $m^{-2} \cdot s^{-1}$	2.83	2.33	**2.58 AB**
1204 µmol $m^{-2} \cdot s^{-1}$	2.83	3.33	**3.08 A**
Mean	**2.00**	**2.00**	
	Treatment	**Varieties**	**T x V**
SE ±	0.81	0.57	1.14
LSD 0.05	1.64	NS	NS

Table 1: Sprouts of coleus varieties under LED intensities.

index. The coleus varieties plant treated with 602 µmol m^{-2} s^{-1} produced average sprouting index of 0.12; while the minimum sprouting index of 0.10 was noted in plants grown under 301 µmol m^{-2} s^{-1}. The results further showed that the sprouting index of coleus varieties was non-significant (0.20).

Effect of LED intensities on plant height (cm)

Plant height (cm) is one of the important growth trait associated with the growth habit of a particular variety being used and use of inputs. The results regarding the average plant height of two coleus varieties as affected by LED bulb intensities are presented in (Table 3). The plant height of coleus varieties was found to be highest (14.60 cm) when grown under 1204 µmol m^{-2} s^{-1}, followed by 903 µmol m^{-2} s^{-1} with 12.36 cm average plant height, respectively. The coleus varieties grown under 602 µmol. m^{-2} S^{-1} produced average plant height of 9.08 cm, respectively; while the minimum plant height of 6.58 cm was noted under 301 µmol m^{-2} s^{-1}. The results further showed that the plant height of coleus variety "Coleus Brown" was highest (11.02 cm) than variety "Coleus Fairway Rose" (10.29 cm). The interactive effect of LED bulb level of 1204 µmol m^{-2} s^{-1} × variety "Coleus Brown" resulted in maximum plant height (15.60 cm); and the lowest plant height (6.46 cm) was found in the interaction of 301 µmol m^{-2} s^{-1}× variety "Coleus Fairway Rose".

Effect of LED intensities on branches per plant

The results in regards to branches per plant of two coleus varieties as affected by LED bulbs are given in (Table 4). The branches of coleus varieties were noted maximum (5.05) in plants grown under 1204 µmol m^{-2} s^{-1} followed by 903 µmol m^{-2} s^{-1} with 3.78 average branches per plant. The coleus varieties treated with 602 µmol m^{-2} s^{-1} produced average branches in plant of 2.60, while minimum branches 1.05 of plant was noted under 301 µmol m^{-2} s^{-1}. The results further showed that the branches per plant of coleus variety "Coleus Brown" was maximum (3.33) followed by variety "Coleus Fairway Rose" (2.90). The interactive effect of LED bulb level of 1204 µmol m^{-2} s^{-1} × variety "Coleus Brown" resulted in maximum branches $plant^{-1}$ (5.33); and the lowest average branches (0.90) was found in the interaction of LI_1= 301 µmol m^{-2} s^{-1} × variety "Coleus Fairway Rose". The LSD test suggested that the differences in branches $plant^{-1}$ of coleus between LED bulb levels was significant (P<0.05) and also significant (P<0.05) between rest of the LED bulb levels and varieties.

Effect of LED intensities on plant leaves

The leaves of coleus varieties plant (Table 5) were counted at maximum (10.23) while grown under 1204 µmol m^{-2} s^{-1}, followed by 903 µmol m^{-2} s^{-1} with 7.02 average plant leaves. The coleus varieties treated with 602 µmol m^{-2} s^{-1} produced average plant leaves of 3.98, while the minimum plant leaves of 2.27 were noted under LI_1= 301 µmol m^{-2} s^{-1}. The results further showed that plant leaves of coleus variety "Coleus Brown" was maximum (6.22) than variety "Coleus Fairway Rose" (5.53). The interactive effect of LED bulb intensities of 1204 µmol m^{-2} s^{-1} × variety "Coleus Brown" resulted in maximum plant leaves (10.26); and the minimum plant leaves (2.05) were found in the interaction of 301 µmol m^{-2} s^{-1} × variety "Coleus Fairway Rose" (Figures 1-3).

Effect of LED intensities on leaf length (cm)

Leaf length (cm) is generally a major growth character but it is also associated with the growth habit of a particular variety being used and use of inputs. The results regarding the average leaf length of two coleus varieties as affected by LED bulb applications are presented in (Table 6). The leaf length of coleus varieties was highest (11.39 cm) at 1204 µmol.m^{-2} S^{-1}, followed by 903 µmol.m^{-2} s^{-1} with 8.50 cm average leaf length, respectively. The coleus varieties plant treated with 602 µmol.m^{-2} S^{-1} produced average leaf length of 4.84 cm, respectively; while the minimum leaf length of 2.99 cm was noted under LI_1= 301 µmol. m^{-2} S^{-1}. The results further showed that the leaf length of coleus variety "Coleus Brown" was greatest (7.23 cm) than variety "Coleus

LED Intensities	Varieties		Mean
	Coleus Fairway Rose	Coleus Brown	
301 µmol m^{-2}·s^{-1}	0.08	0.10	**0.10 B**
602 µmol m^{-2}·s^{-1}	0.13	0.15	**0.12 B**
903 µmol m^{-2}·s^{-1}	0.23	0.28	**0.25 AB**
1204 µmol m^{-2}·s^{-1}	0.28	0.33	**0.30 A**
Mean	**0.20**	**0.20**	
	Treatment	**Varieties**	**T x V**
SE ±	0.0811	0.0573	0.1146
LSD 0.05	0.1646	NS	NS

Table 2: Sprouting Index (SI) of coleus varieties under LED intensities.

LED Intensities	Varieties		Mean
	Coleus Fairway Rose	Coleus Brown	
301 µmol m^{-2}·s^{-1}	6.46 f	6.70 f	**6.58 D**
602 µmol m^{-2}·s^{-1}	8.50 e	9.66 d	**9.08 C**
903 µmol m^{-2}·s^{-1}	12.35 c	12.38 c	**12.36 B**
1204 µmol m^{-2}·s^{-1}	13.61 b	15.60 a	**14.60 A**
Mean	**10.29 B**	**11.02 A**	
	Treatment	**Varieties**	**T x V**
SE ±	0.1068	0.0756	0.1511
LSD 0.05	0.2169	0.1534	0.3068
Prob.	0.0000	0.0000	0.0000

Table 3: Plant height (cm)of coleus varieties under LED intensities.

LED Intensities	Varieties		Mean
	Coleus Fairway Rose	Coleus Brown	
301 µmol m^{-2}·s^{-1}	0.90 g	1.20 g	**1.05 D**
602 µmol m^{-2}·s^{-1}	2.16 f	3.03 e	**2.60 C**
903 µmol m^{-2}·s^{-1}	3.50 d	4.06 c	**3.78 B**
1204 µmol m^{-2}·s^{-1}	4.76 b	5.33 a	**5.05 A**
Mean	**2.90 B**	**3.33 A**	
	Treatment	**Varieties**	**T x V**
SE ±	0.1482	0.1048	0.2096
LSD 0.05	0.3009	0.2127	0.4255
Prob.	0.0000	0.0003	0.0026

Table 4: Branches of coleus varieties under LED intensities.

LED Intensities	Varieties		Mean
	Coleus Fairway Rose	Coleus Brown	
301 µmol m^{-2}·s^{-1}	2.05 f	2.50 f	**2.27 D**
602 µmol m^{-2}·s^{-1}	3.56 e	4.40 d	**3.98 C**
903 µmol m^{-2}·s^{-1}	6.31 c	7.73 b	**7.02 B**
1204 µmol m^{-2}·s^{-1}	10.20 a	10.26 a	**10.23 A**
Mean	**5.53 B**	**6.22 A**	
	Treatment	**Varieties**	**T x V**
SE ±	0.1937	0.1369	0.2739
LSD 0.05	0.3932	0.2780	0.5560
Prob.	0.0000	0.0000	0.0098

Table 5: Plant leaves of coleus varieties under LED intensities.

Figure 1: Leaves of Coleus Brown taken from plants grown at 1204 µmol $m^{-2}·s^{-1}$.

Figure 2: Leaves of Coleus Fairway Rose taken from plants grown at 1204 µmol $m^{-2}·s^{-1}$ LED intensity.

Figure 3: Coleus growing under light intensity 1204 µmol $m^{-2}·s^{-1}$.

Fairway Rose" (6.63 cm). The interactive effect of LED bulb level of 1204 µmol. $m^{-2}S^{-1}$ × variety "Coleus Brown" resulted in maximum leaf length (11.41 cm); and the lowest leaf length (2.76 cm) was found in the interaction of 301 µmol. $m^{-2}S^{-1}$ × variety "Coleus Fairway Rose".

Effect of LED intensities on leaf width (cm)

Leaf width (cm) data showed that results regarding the average plant leaves of two coleus varieties as affected by LED bulb intensities are presented in (Table 7) which indicated that plant leaves were significantly ($P<0.01$) influenced by LED bulb intensities, varieties as well as by their interaction. The leaf width of coleus varieties was at highest (8.88) in plants grown under 1204 µmol m^{-2} s^{-1}, followed by 903 µmol m^{-2} s^{-1} with 4.82 average leaf width. The coleus varieties plant treated with 602 µmol m^{-2} s^{-1} produced average leaf width of 3.15, while the minimum leaf width of 1.83 was noted in coleus grown under 301 µmol m^{-2} s^{-1}. The results further elaborated that the leaf width of coleus variety "Coleus Brown" was maximum (5.09) than variety "Coleus Fairway Rose" (4.25). The interactive effect of LED bulb intensities of 1204 µmol m^{-2} s^{-1} × variety "Coleus brown" resulted in maximum leaf width (9.60) and the lowest leaf width (2.1) was found in the interaction of LI_1= 301 µmol. m^{-2} S^{-1}×variety "Coleus brown".

Effect of LED intensities on leaf area (cm^2)

Leaf area (cm^2) is generally a major growth character considered especially for ornamental plants grown as foliage, as all its beauty lies in leaves. The results regarding the average leaf area of two coleus varieties grown under LED bulb intensities are presented in (Table 8). The leaf area of coleus varieties was noted maximum (101.20 cm^2) at 1204 µmol m^{-2} s^{-1}, followed by 903 µmol m^{-2} s^{-1} with 41.26 cm^2 average leaf area. The coleus varieties grown under 602 µmol m^{-2} s^{-1} produced average leaf area of 15.45 cm^2, while the minimum leaf area of 5.55 cm^2 was noted under light intensity of 301 µmol m^{-2} s^{-1}. The results further showed that the leaf area of coleus variety "Coleus Brown" was greatest (45.26 cm^2) than variety "Coleus Fairway Rose" (36.47 cm^2). The interactive effect of LED intensity 1204 µmol m^{-2} s^{-1} × variety "Coleus Brown" resulted in maximum leaf area (109.10 cm^2); and the lowest leaf area (4.20 cm^2) was found in the interaction of 301 µmol m^{-2} s^{-1} × variety "Coleus Fairway Rose" (Figures 4 and 5).

Effect of LED intensities on single leaf weight (g)

Results pertaining to single leaf weight (Table 9) were observed to be maximum (1.75 g) at light intensity of 1204 µmol m^{-2} s^{-1}, followed by 903 µmol m^{-2} s^{-1} with 1.07 g of average single leaf weight. The coleus varieties grown under 602 µmol m^{-2} s^{-1} produced average single leaf weight of 0.68 g, while the minimum single leaf weight of 0.28 g was noted under LI_1= 301 µmol m^{-2} s^{-1}. The results further showed that the single leaf weight of coleus variety "Coleus Brown" was greatest (1.06 g) than variety "Coleus Fairway Rose" (0.83 g). The interactive effect of LED intensity of 1204 µmol m^{-2} s^{-1} × variety "Coleus Brown" resulted in maximum single leaf weight (1.86 g) and the lowest single leaf weight (0.21 g) was found in the interaction of 301 µmol m^{-2} s^{-1} × variety "Coleus Fairway Rose".

Effect of LED intensities on chlorophyll content (SPAD)

More green color of leaf is due to the presence of chlorophyll molecule which in turn is associated with the presence of light intensity. Chlorophyll content (SPAD) of coleus varieties (Table 10) was highest (27.51 SPAD) at 1204 µmol m^{-2} s^{-1}, followed by 903 µmol m^{-2} s^{-1} with 18.92 average chlorophyll content (SPAD). The coleus varieties

LED Intensities	Varieties		
	Coleus Fairway Rose	Coleus Brown	Mean
301 µmol.$m^{-2}·s^{-1}$	2.76 g	3.21 f	2.99 D
602 µmol.$m^{-2}·s^{-1}$	4.38 e	5.30 d	4.84 C
903 µmol $m^{-2}·s^{-1}$	7.96 c	9.05 b	8.50 B
1204 µmol $m^{-2}·s^{-1}$	11.36 a	11.41 a	11.39 A
Mean	6.63 B	7.23 A	
	Treatment	Varieties	T x V
SE ±	0.1184	0.0837	0.1674
LSD 0.05	0.2403	0.1699	0.3399
Prob.	0	0	0.0001

Table 6: Leaf length (cm) of coleus varieties under LED intensities.

LED Intensities	Varieties		
	Coleus Fairway Rose	Coleus Brown	Mean
301 µmol $m^{-2}·s^{-1}$	1.5 b	2.1 g	1.83 D
602 µmol $m^{-2}·s^{-1}$	2.8 f	3.5 e	3.15 C
903 µmol $m^{-2}·s^{-1}$	4.5 d	5.1 c	4.82 B
1204 µmol $m^{-2}·s^{-1}$	8.1 b	9.60 a	8.88 A
Mean	4.25 B	5.09 A	
	Treatment	**Varieties**	**T x V**
SE±	0.1552	0.1098	0.2195
LSD 0.05	0.3151	0.2228	0.4456
Prob.	0	0	0.0334

Table 7: Leaf width of coleus varieties under LED intensities.

LED Intensities	Varieties		
	Coleus Fairway Rose	Coleus Brown	Mean
301 µmol $m^{-2}·s^{-1}$	4.20 g	6.90 g	5.55 D
602 µmol $m^{-2}·s^{-1}$	12.38 f	18.53 e	15.45 C
903 µmol $m^{-2}·s^{-1}$	36.00 d	46.52 c	41.26 B
1204 µmol $m^{-2}·s^{-1}$	93.30 b	109.10 a	101.20 A
Mean	36.47 B	45.26 A	
	Treatment	Varieties	T x V
SE ±	1.87	1.32	2.65
LSD 0.05	3.8	2.69	5.38
Prob.	0	0	0.0085

Table 8: Leaf area (cm^2) of coleus varieties under LED intensities.

Figure 4: Coleus growing under light intensity 301 µmol $m^{-2}·s^{-1}$.

grown under 602 µmol m^{-2} s^{-1} produced average chlorophyll content of 13.75 SPAD, while the minimum chlorophyll content of 10.41 was noted under LI_1= 301 µmol m^{-2} s^{-1}. The results further showed that the chlorophyll content of coleus variety "Coleus Brown" was greatest (17.95 SPAD) than variety "Coleus Fairway Rose" (17.35 SPAD). The interactive effect of LED intensity of 1204 µmol m^{-2} s^{-1} × variety "Coleus Brown" resulted in maximum chlorophyll content (27.76 SPAD) and the lowest chlorophyll content (10.36 SPAD) was found in the interaction of LI_1= 301 µmol m^{-2} s^{-1} × variety "Coleus Fairway Rose" (Figure 6).

Effect of LED intensities on root length (cm)

Root length of coleus varieties was highest (9.37 cm) at LED intensity of 1204 µmol m^{-2} s^{-1}, followed by 903 µmol $m^{-2}·s^{-1}$ with 8.40 cm (Table 11). Coleus varieties plant grown under 602 µmol m^{-2} s^{-1} produced average root length of 5.82 cm, while the minimum root

Figure 5: Measuring chlorophyll content and showing root length of Colues Brown grown at 1204 µmol $m^{-2}·s^{-1}$ of light intensity.

LED Intensities	Varieties		
	Coleus Fairway Rose	Coleus Brown	Mean
301 µmol $m^{-2}·s^{-1}$	0.21 h	0.36 g	0.28 D
602 µmol $m^{-2}·s^{-1}$	0.61 f	0.75 e	0.68 C
903 µmol $m^{-2}·s^{-1}$	0.88 d	1.26 c	1.07 B
1204 µmol $m^{-2}·s^{-1}$	1.63 b	1.86 a	1.75 A
Mean	0.83 B	1.06 A	
	Treatment	Varieties	T x V
SE ±	0.036	0.02	0.05
LSD 0.05	0.007	0.05	0.1
Prob.	0	0	0.0064

Table 9: Single leaf weight (g) of coleus varieties under LED intensities.

length of 4.66 cm was noted under LI_1=301 µmol m^{-2} s^{-1}. The results further explored that the root length of coleus variety "Coleus Brown" was at maximum (7.28 cm) than variety "Coleus Fairway Rose" (6.85 cm). The interactive effect of LED intensity of 1204 µmol m^{-2} s^{-1} × variety "Coleus Brown" resulted in maximum root length (9.71 cm) and the lowest root length (4.66 cm) was found in the interaction of 301 µmol m^{-2} s^{-1} × variety "Coleus Fairway Rose".

Discussion

Light-emitting diodes emit a wide range of wavelengths, including those within the photo synthetically active wavelength (Hemming 2011). Continues light cause negative effect on plants growth like chlorosis, stunted plant growth (Hemming 2011). The findings of the

LED Intensities	Varieties		
	Coleus Fairway Rose	Coleus Brown	Mean
301 µmol $m^{-2}·s^{-1}$	10.36 g	10.46 g	10.41 D
602 µmol $m^{-2}·s^{-1}$	13.26 f	14.23 e	13.75 C
903 µmol $m^{-2}·s^{-1}$	18.50 d	19.35 c	18.92 B
1204 µmol $m^{-2}·s^{-1}$	27.26 b	27.76 a	27.51 A
Mean	17.35 B	17.95 A	
	Treatment	**Varieties**	**T x V**
SE ±	0.1137	0.0804	0.1608
LSD 0.05	0.2309	0.1633	0.3265
Prob.	0	0	0.0023

Table 10: Chlorophyll content (SPAD) of coleus varieties under LED intensities.

LED Intensities	Varieties		
	Coleus Fairway Rose	Coleus Brown	Mean
301 µmol $m^{-2}·s^{-1}$	4.66 f	4.66 f	4.66 D
602 µmol $m^{-2}·s^{-1}$	5.41 e	6.23 d	5.82 C
903 µmol $m^{-2}·s^{-1}$	8.28 c	8.53 c	8.40 B
1204 µmol $m^{-2}·s^{-1}$	9.03 b	9.71 a	9.37 A
Mean	6.85 B	7.28 A	
	Treatment	**Varieties**	**T x V**
SE ±	0.098	0.069	0.139
LSD 0.05	0.199	0.141	0.282
Prob.	0	0	0.006

Table 11: Root length (cm) of coleus varieties under LED intensities.

Figure 6: Coleus varieties grown under 1204 µmol $m^{-2}·s^{-1}$ light intensity.

present research indicated that the growth of coleus cuttings increased simultaneously with increasing light emitting diodes. 1204 µmol m^{-2} s^{-1} resulted in maximum growth of coleus cuttings. In case of varieties, "Coleus Brown" resulted in significantly maximum vegetative traits as compared to variety "coleus fairway rose". These results are in agreement with those of Giorgioni (2010) determined the effect of light intensities (approximately 4, 7, 11 and 20 µmol m^{-2} s^{-1}) on growth, foliar micromorphology, essential oil content, yield and chemical composition of *Ocimum gratissimum* L., their study confirmed that biomass production of different organs, root: shoot ratio and leaf mass per area were linearly increased with increased light availability [5]. Assessed that plants grown at the highest light intensities produced the greatest numbers of flower stalks, and these were heavier than those produced in the shade [6]. found that light intensity had remarkable effects on plant growth, total gypenosides accumulation and photosynthesis, white light had increased in biomass, stem diameter and newly sprouted leaves than homogeneous light did, compared with blue and green light, white light presented a higher content of total gypenosides which was closest to that of red light, suggesting the effect of white light on gypenosides accumulation was involved in red light. The net photosynthetic rate under red light was higher than those under blue or green lights, but obviously lower than that under white light.

Alam et al. [7] conducted a glasshouse experiment to evaluate the regeneration and yield potential in purslane using both seeds and stem cuttings of 20 collected accessions from different locations in Western Peninsular Malaysia, results revealed significant variations ($P<0.05$) for morphological traits viz., plant height, number of main branches, number of nodes, inter nodal distance, stem diameter, number of leaves, leaf area, number of flowers, root length, fresh and dry weight but no significant difference were observed for physiological traits viz. [8] grew seedlings under two light intensities (low, 125 µmol m^{-2} s^{-1} and high, 250 µmol m^{-2} s^{-1}) consisting of 10% Blue and 10% Green light and the following percentages of R–HR: 0–80, 40–40, 80–0, further, they found that shoot fresh weight was similar in all light intensities, whereas shoot dry weight was often greater under the higher light intensity, especially under the 40–40 treatments. Leaf chlorophyll concentration under 40–40 low, 80–0, or both was often greater than that in plants under the high light treatments, indicating that plants acclimated to the lower light intensity to better use photons available for photosynthesis.

Adams & Langton [9] observed that antirrhiumn cultivars under long days produced early flowering (41.9 days) with a minimum number of leaves below the inflorescence (8.2) as compared to short days, which triggered late flowering (57.3 days) and produced the maximum number of leaves (18.2). Proctor & Reicher [10] reported that in the tropics and warmer regions, a complete life cycle may be two to three and a half months, and up to four months in cooler regions. Rapid vegetative growth begins at 15 days and flowering begins after one month or 10 to 12 leaf stage, they indicated that both the plant dry mass (leaf, shoot, root and whole plant) and the number of the leaves responded similarly to light intensity. They were the highest at FAL and decreased as much as the plants were shaded [11]. The decrement was 30-50% for the plants which were grown under 25% of FAL. Further, they indicated that high-light intensities grown *S. officinalis* plants yielded greater productivity than low-light grown ones just like was shown for several other plants [12,13]. However, it has been reported that the intermediate light conditions (about 50% of FAL) were more adequate for some species to reach higher levels of biomass productivity [14]. On the other hand, the height of *S. officinalis* plants was increased as the light intensity decreased. In particular, the plants which were grown under 25% of FAL became about 70% taller than the plants grown under full sunlight [15].

The synthesis and degradation of the photosynthetic pigments are associated with the plants adaptability to different environments [11]. The chlorophylls are usually synthesized and photo-oxidized in the presence of light. Nonetheless, the excess of light can cause greater degradation and consequently, a reduction in the levels of total chlorophyll [14]. This response fulfils the function of the photosynthetic antennae absorbing the required light energy [14] considering that the highly pigmented leaves show higher light absorption efficiency per unit of leaf biomass, which may allow the plant to achieve a better carbon balance under light limitation [16-18]. In environments with high solar radiation, the increase of photo-oxidation of chlorophylls depends upon the concentration of carotenoids, which can prevent chlorophylls photo-destruction [14], while in low light environments carotenoids may play a more important role in light absorption and

its transfer to chlorophyll. From present results, there appear to be two alternative explanations for the observed effects of light intensity. First, it is possible that leaves developed in weaker light could have lower activity of the carboxylating enzyme, carboxydismutase, than those from stronger light.

Conclusion

Global warming and harsh environment conditions restrict plant growth under such cases use of LED intensities is opening a new era for continuous plant production. From the present research it is concluded that the growth of coleus plant increased simultaneously with increasing LED bulb intensities. 1204 μmol $m^{-2} s^{-1}$ resulted in maximum growth of both coleus varieties. In case of varieties, "Coleus Brown" resulted in significantly maximum vegetative plant growth as well as chlorophyll content as compared to variety "Coleus Fairway Rose".

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