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Effects of artificial light in indoor vertical garden on growth of Philodendron Lemon Lime and Philodendron Brasil

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Abstract The effects in two types of light-emitting-diode (LED) lighting in a vertical garden on the growth of Philodendron Lemon Lime and Philodendron Brasil were investigatded. Result showed that the dependent variables of plant height, stem fresh weight, leaf area, leaf area index number leaf, total dry weight, chlorophyll a, chlorophyll b, chlorophyll a+b, carotenoids, spad, and shoot/root ratio. The most fundamental results revealed to be able to verify or reject prior agricultural theories for the full spectrum LEDs which better light sources than fluorescence LEDs. At 120 days after planting, full-spectrum LED lamps provided 94.56% which higher growth of Philodendron Lemon Lime, Philodendron Brasil than fluorescent LED lamps. It is proved that a vertical garden and the beauty of the vertical garden showing the best growth on the leaf shapes and colorful leaf of Philodendron Lemon Lime under full-spectrum lamps. Other specific findings may benefit for future investigation of philodendrons and other plants.

Keywords: Vertical garden, Philodendron Lemon Lime, Philodendron Brasil, LED fluorescence, LED full spectrum

Introduction

Philodendron Lemon lime and Philodendron Brasil belong to the genus *Philodendron* and the family Araceae. They are common indoor plants, easily grown houseplants that can extend their stems into a cascaded network, covering a large area in a vertical garden. The scientific name of Philodendron Lemon Lime is *Philodendron erubescens* K. Koch & Augustin 'Lemon Lime' (Supananthananon, 2018). Baanlaesuan (2016), however, investigated this plant in a local name of Heart-leaved Philodendron. It had green-colored leaves. It grew fast even under low light and small amounts of fertilizer and water (Gardeningbrain, 2020). The scientific name of Philodendron Brasil (common name) is *Philodendron hederaceum* 'Brasil' (Supananthananon, 2018). It s a colorful foliage, indoor plant that grow well under low light and small amounts

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of fertilizer and water. It is most suitable for low-maintenance garden (Baanlaesuan, 2016). Philodendron Brasil leaves has shaped like a heart. Their colors range from green to yellow to lime green and deep green (Raffaele, 2021).

Artificial light emitting diodes (LEDs) (red, R, blue, B, red per blue R:B) and fluorescent lamps have been used as light sources for growing indoor plants for 30 years. An LED emits light from a semiconductor diode when electric current flows through it (Singh *et al*, 2015). It was used as direct light sources in greenhouse plants (Olle and Viršile, 2013). Photosynthesis and all of its products vary with the wavelength of light, especially in the 400-700 nm range (Macedo *et al*, 2011). Red and blue LEDs provided significantly different growth, development, photosynthetic rate, and physiology of plants (Kim *et al*, 2005 and Chen *et al*, 2014). Nguyen *et al*. (2019) found that light with an intensity of 190 µmol m^2 s of red (80 lamps) and blue (20 lamps) LEDs (R660/B450) provided high growth values (plant height, leaf number, leaf area (LA), NGR, NAR) and yield quality (Chla, Chl (a+b) and carotenoid contents). Hernández *et al*. (2016) found that the biomass accumulation and yield of tomatoes as well as the plant's leaf area and chlorophyll content were greater under LED red plus blue lamp than under LED monochrome (red or blue) lamps. Morning glory grown under red LEDs had the longest stem and the largest fresh weight relative to those grown under LEDs of other colors, at two weeks after planting. It can be concluded that a combination of red and blue LEDs at 1:1 or 2:1 would be a good light source for vertical indoor garden (Lapjit, 2017).

Growing plants on the exterior or interior surfaces of a building is called vertical garden (Green walls, green facades, and vertical garden systems). They are increasingly becoming popular. The authors held an opinion that philodendrons would be good, natural air purifiers, in the sense that plants purify the air in the outdoor, and it should be able to purify air in the indoor. As the first step toward achieving solid experimental outcomes to support that claim, we investigated quantitatively the light and amounts of nutrition and water required for growing philodendrons in an indoor vertical garden. A comparative experiment between two types of light source, fluorescence LEDs and full spectrum LEDs, for indoor philodendron growth was conducted.

To know more about the influence of light sources, we investigated the effects of light-emitting diode (LED) sources of two types (fluorescence and full spectrum lamp) on the growth and chlorophyll content of Philodendron Lemon Lime and Philodendron Brasil in an indoor vertical garden.

Materials and methods

Experimental design

The experiment was conducted indoor in a building of the Faculty of Agricultural Technology, King's Mongkut Institute of Technology Ladkrabang, Bangkok, Thailand, from August to December 2020. The experiment was performed using a split-plot in randomized, complete block design (RCBD) with three replications. The main plot was foliage plants (Philodendron Lemon Lime and Philodendron Brasil), and the sub-plots were two kinds of light source (fluorescence and full spectrum LEDs). The specifications of the full-spectrum LEDs were as follows: energy, 60W; Bulb Base, E27; Lamp color and number, red (40), blue (14), infrared (2), ultraviolet (2), and white (2); finally, voltage, AC 265V. The specifications of the fluorescence LEDs were as follows: energy, 60W; bulb base, E27; Lamp color and number: white (60); and voltage, AC265V.

Crop husbandry

The vertical gardening system in this experiment was a ready-made, D.I.Y., vertical gardening system, called 'SCG Modular Green Hive model' in Thailand. The loamy soil in the planting pots was analyzed of its chemical properties and composition (pH = 6.3, EC=2.6 µS/cm, OM=1.95%, P=46.59 ppm, K=335.40 ppm, Fe=142.60 ppm, Mn=308.00 ppm, Zn=2.95 ppm, and Cu=2.01 ppm). The vertical garden was furrow-irrigated every three days. The preparation of the plants was as follows. Three-to-five-node-long (10-15 cm long) stems were cut from Philodendron Lemon Lime and Philodendron Brasil stock plants. Pull your foliage plants gently out of the propagation soil after 4 weeks to SCG Modular Green Hive model D.I.Y.

Data collection

Growth and chlorophyll content data from three randomly selected plants from each pot of SCG Modular Green Hive model (D.I.Y.) were collected and recorded at 120 days after planting.

Determination of growth paramrters

Plant height was measured from the ground to the top leaf (the highest fully expanded leaf) of the plant. Stem fresh weight and number of leaves were

determined after the leaves and the root were removed from the specimen. Leaf area (LA) was another growth parameter that could be conveniently deteceted by a leaf area meter (Li-Cor model: Li 3100c, USA). Total dry weight was defined as the sum of the dry weights (DW) of stem, leaf, and root, which were dried in a hot air oven (2-3 days) set to high heat (80 ℃). Shoot per root ratio was an indicator of nitrogen availability, which was essential to plant growth.

Going back to leaf area index (LAI), it could be calculated by an equation presented by Hunt (1978),

$$\text{Leaf area index (LAI)} = \frac{\text{Total leaf area}}{\text{Ground area}}$$

where the ground area of a plant could be determined by a method reported by Watson (1947).

Determination of chlorophyll content

Chlorophyll content of leaves (greenness) was determined in the laboratory and in the field (but causing no damage to the plants).

In the laboratory, chlorophyll absorbances at 663nm, 645, nm and 480 nm were scanned with a spectrophotometer (Thermo Scientific™ GENESYS™ 10S UV-Vis Spectrophotometer). Fifty milligrams of crushed fresh leaves were extracted for chlorphyll with 10 ml of Dimethyl sulfoxide (DMSO) in a glass tube (25 ml) at 65 ℃, with regular interval shaking until the color of the crushed leaves became white, following a method reported by Arnon (1949). They also provided formulas for calculating various types of chlorophyll content below,

Chlorophyll a = 12.7(A663) – 2.69(A645)
Chlorophyll b = 22.9(A645) – 4.68(A663)
Chlorophyll a+b = Chlorophyll a + Chlorophyll b
Carotenoid = [A480 + (0.114(A663) - (0.638 - A645)].

In the field, an Spad unit (Spad-502, Konica Minolta) was used to non-invasively measure the total chlorophyll content of a plant. It should be randomly selected sampled leaf (3-5 nodes down from the apical bud) on each plant.

Determination of lighting paramrter and soil moisture

Light sensor logger (Li-cor model: LI-1500, USA) measures Photosynthetically active radiation (PAR, in μmol of photons m^{-2} s^{-1}) at 3 times (8.00, 12.00 am and 16.00 pm). Lux meter; Lux meters can be used to measure light by lux meter model: 840006 which is a measure 3 time (8.00, 12.00 and

16.00 am). Soil moisture; The soil moisture content is the quantity of water content or moisture content in the soil which is a measure 3 time (8.00, 12.00 am and 16.00 pm) by Extech MO750 soil moisture meter.

Statistical analysis

Statistical analyses were conducted with Excel-software and Sas software 9.2 for windows. The experimental design was a split-plot in RCBD. Data were analyzed by analysis of variance (ANOVA), and differences between the means were tested using the Least Significant Difference (LSD) test ($P < 0.05$).

Results

Lighting paramrter and soil moisture

Lux meters are used to measure light intensity in experiment. The full-spectrum lamp was the highest averaged value in the experiment at 8.00 (12,938.90 lux), 12.00 (11,831.00 lux), and 16.00 (7,592.00 lux) pm.

The LED fluorescence lamp was lowest averaged value in the experiment at 8.00 am (12,868.00 lux), 12.00 am (11,831.00 lux) and 16.00 pm (7,592.00 lux). Photosynthetically Active Radiation (PAR, W per M^{-2}) is the light spectrum in the 400 to 700-nanometer wavelength range by plants for photosynthesis. The full spectrum lamp was the highest value in the experiment at 8.00 am (12494.2500 W per M^{-2}) and followed by 12.00 am (12013.000 W per M^{-2}) and 16.00 pm (8048.000 W per M^{-2}). LED fluorescence lamps were the minimum averaged value in the experiment at 8.00 am (198.550 W per M^{-2}) and followed by 12.00 am (177.406 W per M^{-2}) and 16.00 pm (135.725 W per M^{-2}). The soil moisture content is the water stored in the soil. SCG Modular Green Hive model D.I.Y. measures soil moisture at 30, 60, 90, and 120 days after the plant. The moisture content of a soil experiment is 71% (Figure 1).

Plant height and stem fresh weight

Plant height ($P \leq 0.01$) and stem fresh weight ($P \leq 0.05$) of two foliage plants were significantly affected by LED Lamp. Philodendron Lemon Lime was the highest on plant height (38.278 cm) and stem fresh weight (51.833 g per plant) and the lowest on plant height (13.828 cm) and stem fresh weight (28.473 g per plant) in Philodendron Brasil (Table 1 and 2).

There was a significant difference ($P \leq 0.05$) in the two LED lamps between full spectrum and fluorescence (Table 1 and Figure 2). Foliage plants grown under LED Full Spectrum lamps were maximum value on plant height

(27.070 cm) and stem fresh weight (43.890 g per plant) treatment and LED fluorescent lamps were minimum value on plant height (25.037 cm) and stem fresh weight (36.417 g per plant) in Table 2 and Figure 2. Furthermore, there was a non-significant linear correlation between foliage plants and LED lamps.

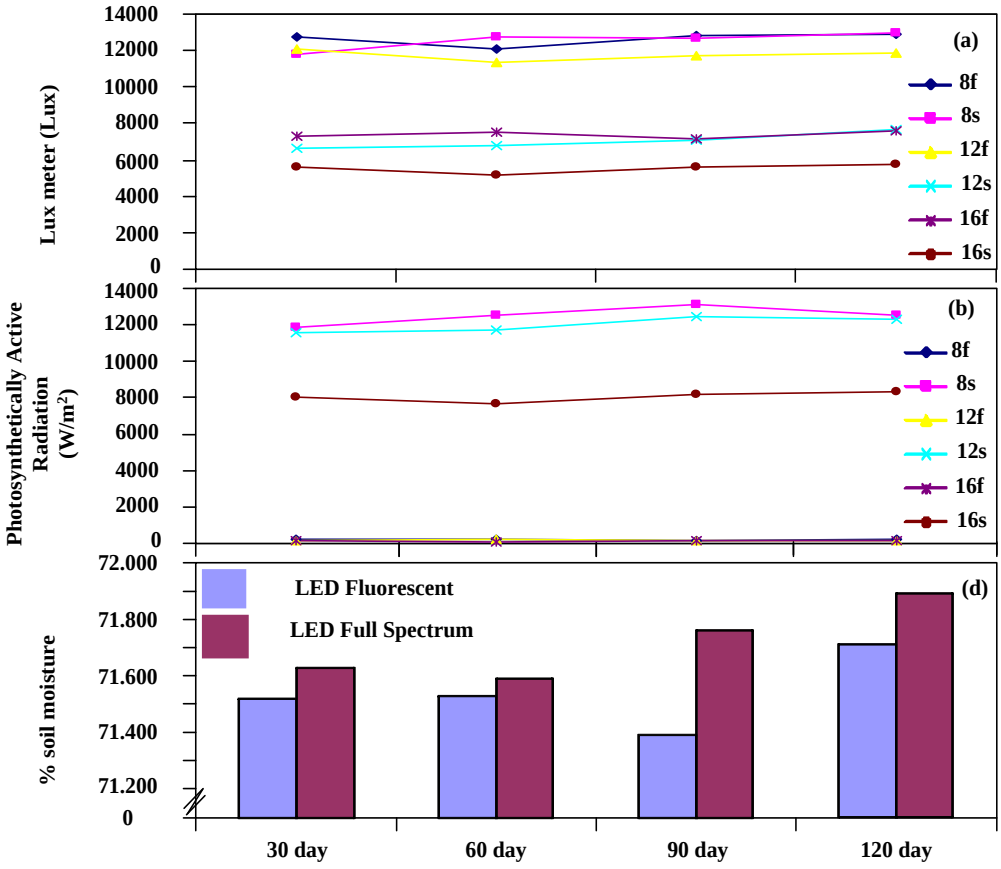

Figure 1. Lighting parameters of lux meter (Lux) (a), Photosynthetically active radiation (PAR, W per M^{-2}) (b), and Soil moisture (%) (c) of Philodendron Lemon Lime and Philodendron Brasil in the vertical garden at 120 days after plants under affected two types LED lamp (LED fluorescence and full spectrum lamp), 8f = 8.00 am of full spectrum lamp, 8s = 8.00 am of fluorescence lamp, 12f = 12.00 am of full spectrum lamp, 12s = 12.00 am of fluorescence lamp, 16f = 16.00 pm of full spectrum lamp, and 16s = 16.00 pm of fluorescence lamp

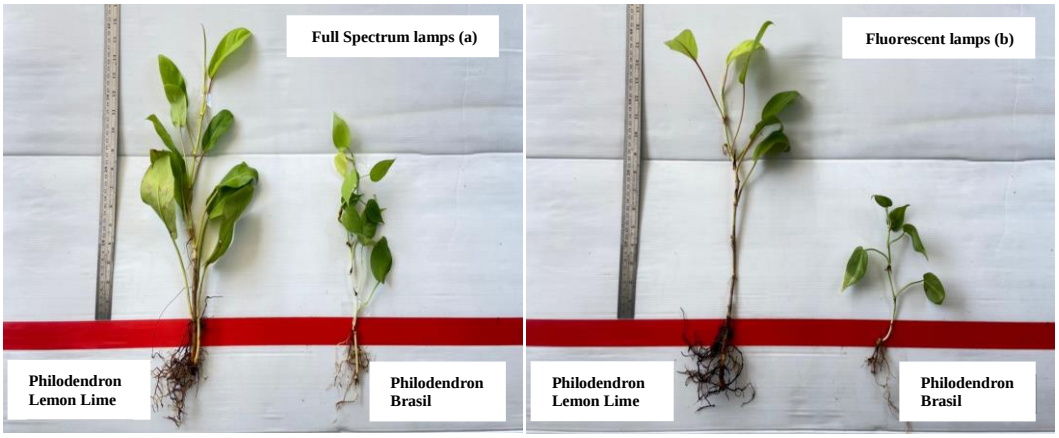

Figure 2. Plant height (cm) on the growth of Philodendron Lemon Lime and Philodendron Brasil in the indoor vertical garden at 120 days after plants under LED full spectrum lamps (a) and fluorescent lamps (b)

Table 1. Data Mean square values from analysis of variance (ANOVA) for plant height, stem fresh weight, leaf area, leaf area index, number leaf, and total dry weight on the growth of Philodendron Lemon Lime and Philodendron Brasil in the indoor vertical garden under artificial light

Source of variation	d.f.	PH	SFD	LA	LAI	No. Leaf	Total DW
Block	2	1.940^{ns}	34.115^{ns}	11,009.524^{ns}	0.754^{ns}	11.083^{ns}	7.061^{ns}
foliage plants (A)	1	503.107**	1,637.059*	168,232.201**	11.505**	660.083**	31.687*
Error (A)	2	2.138	18.918	1,358.003	0.093	1.583	0.782
LED lamp (B)	1	77.724*	167.552*	55,629.537*	3.797*	234.083*	38.521**
(A)x(B)	1	37.453^{ns}	5.824^{ns}	25,428.814^{ns}	1.740^{ns}	0.083^{ns}	0.367^{ns}
Error (B)	4	4.986	13.050	4,292.047	0.291	11.333	0.277
Total	11	58.762	178.974	26,472.163	1.809	87.720	7.943

PH=plant height; SFD=stem fresh weight; No. Leaf=number leaf; LA=leaf area; LAI=leaf area index; total DW=total dry weight

ns = non-singnificant, * = significant at 0.05, and ** = significant at 0.01, respectively.

Leaf growth parameters

Leaf growth parameters (leaf area (LA), leaf area index (LAI)) of Philodendron Lemon Lime and Philodendron Brasil were significantly ($P \leq 0.01$) affected by LED Lamp. Philodendron Brasil was the lowest values in leaf area (236.733 m m^{-2}) and leaf area index (1.955) and Philodendron Lemon Lime was the highest increase in leaf area (473.580 m m^{-2}) and leaf area index (3.913).

LED full spectrum and fluorescence lamps were significantly different in leaf growth parameters leaf area, leaf area index (Table 1). Foliage plants grown under LED full spectrum lamps were maximum value on leaf area (423.263 m m^{-2}) and leaf area index (3.497) treatment and LED fluorescent

lamps were minimum value on leaf area (287.090 m m^{-2}) and leaf area index (2372) in Table 2. Furthermore, there was a non-significant linear correlation between foliage plants and LED lamps (Table 1, 2 and Figure 2).

Table 2. Plant height (cm), stem fresh weight (g per plant), leaf area (mm^{-2}), leaf area Index, number leaf (leaf per plant), and total dry weight (g per plant) on the growth of Philodendron Lemon Lime and Philodendron Brasil in the indoor vertical garden under artificial light

Treament		PH (cm)	SFD (g plant)	LA (mm^{-2})	LAI	No. Leaf (l plant)	Total DW (g plant)
Foliage plants (A)	P Lemon Lime	38.278^{A}	51.833^{A}	473.580^{A}	3.913^{A}	22.333^{B}	15.700^{A}
	P Brasil	13.828^{B}	28.473^{B}	236.733^{B}	1.955^{B}	31.000^{A}	12.467^{B}
LED lamp (B)	Fluorescence	25.037^{b}	36.417^{b}	287.090^{b}	2.372^{b}	37.000^{b}	8.867^{b}
	Full spectrum	27.070^{a}	43.890^{a}	423.263^{a}	3.497^{a}	46.000^{a}	12.800^{a}
mean		26.053	40.153	355.177	2.934	34.083	12.458
LSD(0.05)(%)(A)		4.433	10.805	91.543	0.758	3.126	2.197
LSD(0.05)(%)(B)		1.767	5.791	105.020	0.865	5.396	0.843
LSD(0.05)(%)(A)x(B)		ns	ns	ns	ns	ns	ns
CV(A) (%)		6.850	10.832	10.375	10.397	3.692	7.100
CV(B) (%)		4.209	8.997	18.445	18.385	9.877	4.222

P = Philodendron, PH = plant height; SFD = stem fresh weight; No. Leaf = number leaf; LA = leaf area; LAI = leaf area index; total DW = total dry weight

Means followed by different letters are statistically different according to Least Significant Difference (LSD)

Number leaf and total dry weight

Number leaf ($P \leq 0.01$) and total dry weight ($P \leq 0.05$) of Philodendron Lemon Lime and Philodendron Brasil were significantly affected by LED Lamp. Philodendron Lemon Lime was the highest increase in number leaf (22.333 leaf per plant) and total dry weight (15.700 g per plant) and Philodendron Brasil was the lowest values in Number leaf (31.000 leaf per plant) and total dry weight (12.467 g per plant).

The number of leaves and total dry weight of foliage plants grown under LED lamps were significantly different (Table 1). Foliage plants grown under LED full spectrum lamps treatment were maximum value on number leaf (46.000 leaf per plant) and total dry weight (12.800 g per plant) and LED fluorescent lamps were minimum value on number leaf (37.000 leaf per plant) and total dry weight (8.867 g per plant). Furthermore, there was a non-significant linear correlation between foliage plants and LED lamps (Table 1 and 2).

Chlorophyll content

Chlorophyll a, chlorophyll b and chlorophyll a+b of Philodendron Lemon Lime and Philodendron Brasil were significantly ($P \leq 0.01$) affected by LED

lamp in Tables 3. Chlorophyll a (1.450 mg per g), chlorophyll b (0.343 mg per g) and chlorophyll a+b (1.793 mg per g) of Philodendron Brasil was the highest values in chlorophyll content and Philodendron Lemon Lime was the lowest values decrease in Chlorophyll a (1.148 mg per g), chlorophyll b (0.285 mg per g) and chlorophyll a+b (1.433 mg per g) in Table 3.

There was a significant difference in the two LED lamps between full-spectrum and fluorescence of chlorophyll a ($P \leq 0.05$), chlorophyll b, and chlorophyll a+b ($P \leq 0.05$). Foliage plants grown under LED full spectrum lamps were maximum value on chlorophyll a (1.461 mg per g), chlorophyll b (0.352 mg per g) and chlorophyll a+b (1.813 mg per g) and LED fluorescent lamps were minimum value on chlorophyll a (1.137 mg per g), chlorophyll b (0.277 mg per g) and chlorophyll a+b (1.413 mg per g) (Table 4). Furthermore, there was a non-significant linear correlation between foliage plants and LED lamps.

Carotenoids and spad

Carotenoids ($P \leq 0.01$) and Spad unit ($P \leq 0.05$) of two foliage plants (Philodendron Lemon Lime and Philodendron Brasil) were significantly affected by LED lamp. Philodendron Brasil was the highest values in carotenoids (0.075 mg per g) and Spad (34.517 Spad unit) and Philodendron Lemon Lime was the lowest values in carotenoids (0.055 mg per g) and Spad (30.050 Spad unit).

LED full spectrum and fluorescence lamps were significantly different ($P \leq 0.05$). Foliage plants grown under LED full spectrum lamps were maximum value on carotenoids (0.075 mg per g) and Spad (33.917 Spad unit) treatment and LED fluorescent lamps were minimum value on carotenoids (0.056 mg per g) and Spad (30.650 Spad unit). Furthermore, there was a non-significant linear correlation between foliage plants and LED lamps (Table 3 and 4).

Table 3. Data Mean square values from analysis of variance (ANOVA) for chlorophyll a, chlorophyll b, chlorophyll a+b, Carotenoids, Spad and Shoot/Root ratio on the growth of Philodendron Lemon Lime and Philodendron Brasil in the indoor vertical garden under artificial light

Source of variation	d.f.	Chl a	Chl b	Chl a+b	Chl c	SPAD	S R ratio
Block	2	0.0004^{NS}	0.0004^{NS}	0.0013^{NS}	0.0000^{NS}	0.106^{NS}	0.1698^{NS}
Foliage plants (A)	1	0.2745*	0.0102*	0.3906*	0.0013**	59.853*	108.486**
Error (A)	2	0.0088	0.0004	0.0111	0.0000	2.061	0.088*
LED lamp (B)	1	0.3159**	0.0169**	0.4788**	0.0011**	32.013*	8.249
(A)x(B)	1	0.0103^{NS}	0.0019^{NS}	0.0209^{NS}	0.0003^{NS}	4.083^{NS}	3.483^{NS}
Error (B)	4	0.0079	0.0003	0.0103	0.0000	1.963	0.458
Total	11	0.0592	0.0029	0.0869	0.0003	9.831	11.142

Chl a = chlorophyll a, chl b = chlorophyll b, chl a+b = chlorophyll a+b, Chl c = Carotenoids, S R ratio = Shoot Root ratio

ns = non-singnificant, * = significant at 0.05, and ** = significant at 0.01, respectively.

Table 4. Chlorophyll a (mg g), chlorophyll b (mg g), chlorophyll a+b (mg g), Carotenoids (mg g), Spad (Spad unit) and Shoot/Root ratio on the growth of Philodendron Lemon Lime and Philodendron Brasil in the indoor vertical garden under artificial light at 120 days after plants

Treament		Chl a (mg g)	Chl b (mg g)	Chl a+b (mg g)	Chl c (mg g)	Spad	S R ratio
Foliage plants (A)	P Lemon Lime	1.148^{B}	0.285^{B}	1.433^{B}	0.055^{B}	30.050^{B}	9.456^{A}
	P Brasil	1.450^{A}	0.343^{A}	1.793^{A}	0.075^{A}	34.517^{A}	3.443
LED lamp (B)	Fluorescence	1.137^{b}	0.277^{b}	1.413^{b}	0.056^{b}	30.650^{b}	5.621^{b}
	Full spectrum	1.461^{a}	0.352^{a}	1.813^{a}	0.075^{a}	33.917^{a}	7.279^{a}
mean		1.299	0.314	1.613	0.066	32.283	64.450
LSD(0.05)(%)(A)		0.232	0.050	0.2621	5.414E-03	3.567	0.738
LSD(0.05)(%)(B)		0.142	0.029	0.1628	9.794E-03	2.246	1.085
LSD(0.05)(%)(A)x(B)		ns	ns	ns	ns	ns	ns
CV(A) (%)		7.211	6.432	6.538	3.323	4.447	6.450
CV(B) (%)		6.861	5.738	6.295	9.316	4.340	10.497

P = Philodendron, Chl a = chlorophyll a, chl b = chlorophyll b, chl a+b = chlorophyll a+b, Chl c = Carotenoids, S R ratio = Shoot/Root ratio

Means followed by different letters are statistically different according to Least Significant Difference (LSD)

Shoot / Root ratio

Shoot/Root ratio of Philodendron Lemon Lime and Philodendron Brasil were significantly ($P \leq 0.01$) affected by LED lamp. Philodendron Lemon Lime was the highest values in Shoot/Root ratio (9.456) and Philodendron Brasil was the lowest decrease in Shoot/Root ratio (3.443).

LED full spectrum and fluorescence lamps on Shoot/Root ratio were significantly different ($P \leq 0.05$). Foliage plants grown under LED full spectrum lamps were maximum value on Shoot/Root ratio treatment (7.279) and LED fluorescent lamps were minimum value on Shoot/Root ratio (5.621) (Table 3 and 4). Furthermore, there was a non-significant linear correlation between foliage plants and LED lamps.

Discussion

Foliage plants for the vertical garden are grown primarily for bringing beauty. It has adapted to a low-oxygen, low-water, and low-light environment and fastest-growing (Gardeningbrain, 2020). Plant growth of foliage plants is affected by water, nutrition, soil moisture, light, temperature, and humidity (MasterClass, 2020 and Gardeningbrain, 2020). Foliage plants have the leaf in many different shapes and colorful Leaf sus as ovate, lanceolate leaf, linear leaf, oblanceolate leaf, acicular leaf, orbicular leaf, sagittate leaf, falcate leaf, peltate leaf, hastate leaf, and lobed leaf, respectively (Supananthananon, 2018).

Growth in plants occurs as the plant height, roots lengthen, increase in leaf, leaf area, and stem diameter, increase in fresh weight and dry weight of stem, leaf, and root, etc (Pandey *et al.,* 2017). Growth and development of foliage plants are influenced by genetic and environmental factors (light, temperature, water, humidity, and nutrition) (Tardieu, 2013). Philodendron Lemon Lime is one of the Foliage plants that grow best in the experiment. Parameter growth in plant height, number leaf, leaf area, leaf area index, fresh weight, and dry weight, stem fresh weight, and chlorophyll content (chlorophyll a, chlorophyll b, chlorophyll a+b, Carotenoids and SPAD unit) was significantly different in table 1, 2, 3, 4 and Figure 2. In our research, Philodendron Brasil was the lowest on growth and chlorophyll content. There are many different species of Philodendrons and it is different shapes, and sizes of the leaf and colorful Leaf (VanZile, 2021).

Photosynthesis generally occurs in plant leaves within the chloroplast. Full-spectrum light (natural daylight) is the best option for growing plants because photosynthesis has been used electromagnetic radiation from infrared to near-ultraviolet or all wavelengths that are useful to plant. LED fluorescent lamps are very popular because of their lower upfront cost, less efficiency, higher energy costs, non-contains toxic mercury, and their daily use. Plants need to take in light (light energy into chemical energy), carbon dioxide (carbon dioxide into oxygen), and water (water from the ground into the air). Light-emitting diodes (LED) lighting has great potential for the plant with a wavelength between 400-700 nm. LED full spectrum and fluorescence lamps on parameter growth (plant height, number leaf, leaf area, leaf area index, fresh weight, and dry weight, stem fresh weight) and chlorophyll content (chlorophyll a, chlorophyll b, chlorophyll a+b, carotenoids, and Spad unit) were different significantly. In this study, the parameter growth of foliage plants was the maximum value under Full Spectrum lamps (a combination of blue and red wavelengths). i.e. plant height, number leaf, leaf area, and leaf area index. In this study, the parameter growth of foliage plants was the maximum value under Full Spectrum lamps (a combination of blue and red wavelengths), i.e.: plant height, number leaf, leaf area, and leaf area index. Besides, Chlorophyll content was the maximum value under Full Spectrum lamps in Tables 3 and 4. According to Bian *et al.* (2018) and Hernández *et al.* (2016) also reported that the effects of red and blue LED light on plant growth under the 23% light spectral treatment was highest plant height, leaf area, and fresh and dry weight and spectral drastically affects the growth and development of plants (Kim *et al.,* 2005 and Chen *et al.,* 2014). Red: Blue ratio, The light red per blue rated at 3:1, 4:1, 5:1 are good to accelerate the growth of leaf for a plant (Pennisi *et al.,* 2019). A similar result was also observed in our study when foliage plants were

grown under LED full spectrum. Red LED light (660-690 nm) was increased the biomass yield, leaf length, and antioxidant of lettuce (Goins *et al.*, 20001 and Mizuno *et al*., 2011). Effect on plant physiology under red LED light (640 nm) was increased chlorophyll a, b, and a+b (Lefsrud *et al.*, 2008, Buschmann *et al*., 1978, Leong and Anderson, 1984). Suggestions for a vertical garden, The beauty of the vertical garden is the best growth on the leaf shapes and colorful leaf of Philodendron Lemon Lime under full-spectrum lamps.

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