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# GROWTH RESPONSE OF INDOOR ORNAMENTAL PLANT SPECIES TO VARIOUS ARTIFICIAL LIGHT INTENSITIES (LED) IN AN INDOOR VERTICAL GARDEN

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**ABSTRACT**

Urban population spends most of their time indoors leading to multiple problems. Making an indoor vertical garden and associating people to this new concept will help build the indoor environment with improved energy efficiency, indoor air quality, their improved health and well-being. Of all of the factors affecting plant growth in interiors, adequate light is by far the most important. LED is an efficient, energy-saving light source widely used in artificial light plant production systems. Lack of scientific information regarding the light intensity requirement for optimum growth of the indoor ornamental plant species under Indian conditions makes the study of utmost importance. Five indoor ornamental plant species namely, *Schefflera arboricola, Dracaena godseffiana, Philodendron salloum, Syngonium podophyllum* and *Scindapsis aureus* were planted in pots (5”) with soil less media arranged as vertical structures (6′11”x4′3”) aligned to interiors walls of a room. Four such structures/frames were fabricated, fertigated with 100 % of the Hoagland solution and artificially illuminated using LED lighting system (PWM controlled) with different light intensities i.e. 700-1100 lux (LI I), 1100-1500 lux (LI II), 1500-1900 lux (LI III) and LI IV had no artificial light illumination (control). From the most effective positive response of plant species under study on the basis of their growth response towards different light intensities, it was concluded that *Philodendron salloum* responded best to LI I (700-1100 lux), *Scindapsis aureus* to LI II (1100-1500 lux), *Dracaena godseffiana, Schefflera arboricola* and *Syngonium podophyllum* to LI III (1500-1900 lux).

***Keywords:*** Artificial LED light intensities, growth response, Hoagland’s solution, indoor ornamental plant species, indoor vertical garden.

## INTRODUCTION

Rapid expansion of cities has restricted ways of increasing greenery in urban environmental since it is hard to find available surfaces. In the 21$^{st}$century, urban landscaping is attaining great popularity as people are gradually realizing the necessity and importance of green architecture where new aspects and technologies are emerging in terms of green buildings. Bringing land to life and life to land is the prerequisite of the era and the conversion from grey to green walls is only possible by landscaping, possibly through the concept of vertical gardens. This is a distinctive method of gardening by expanding the possibility of growing ornamental plants in a vertical space wherever space is a constraint. Majority of the urban population spends 80-90 % of their time indoors where air pollutants can be several times higher than outdoors causing major health concern. As indicated by a couple of reports, ‘Indoor’ potted-plants can evacuate air-borne contaminants such as volatile organic compounds (VOCs), more than 300 of which have been recognized in indoor air (Abbritti and Muzi, 1995; Krzyanowski, 1999; Carpenter, 1998; American Lung Association, 2001). Furthermore, these plants can also help in cooling the indoor environment through the natural process of evapotranspiration thereby, making plants become perfect insulators. Indoor air pollutants have also led to health issues like ‘sick building syndrome’ (Brasche *et al*., 1999; Carrer *et al*., 1999) with symptoms of headache, dizziness, nausea, sore eyes and throat, or loss of concentration. Therefore, associating people to the new concept of indoor vertical gardening will assist in developing the indoor environment with improved energy efficiency, air quality, building structure protection, expanded biodiversity, improved health and well-being of the people.

Multiple factors are vital for growth and development of plant species, of which light source plays key role in obtaining improved quality and plant yield. Usually, light sources like fluorescent, high-pressure sodium, metal halide and incandescent lamps have been used for plant cultivation. However, they contain unnecessary wavelengths which are placed outside the photosynthetically active radiation spectrum and thus are of low efficiency for promoting growth (Kim *et al*., 2004). In comparison to these traditional artificial light sources, the light-emitting diode (LED) is becoming an important research field as an encouraging irradiation source for plant production systems due to its smaller volume and mass, prolonged functional life, single wavelength and higher electric efficiency (Bula *et al*.,1991; Brown *et al*., 1995; Lin *et al*., 2013). For this reason, LED lighting system was chosen for our study. Light intensity requirement is highly species dependent and its requirement for indoor plants is comparatively lower than outdoor plants. However, there is some minimum and optimum light requirement required for their proper growth and development. As natural light available indoors may not fulfil their optimum light requirement necessary for photosynthesis, it is important to optimize suitable light intensities by using artificial light source essential for proper growth and development of indoor ornamental plants in an indoor vertical garden. Moreover, little information and scientific data related to this aspect under Indian conditions makes the study of utmost significance. Furthermore, light source would inevitably affect plant absorption and utilization of mineral nutrients. This experiment therefore aims to select an optimal LED light intensity range suitable for healthy growth of the indoor ornamental plants under indoor vertical gardening.

## MATERIAL AND METHODS

The present study was conducted at Landscape Nursery, Department of Floriculture and Landscaping, Punjab Agricultural University, Ludhiana using five indoor ornamental plant species namely *Schefflera arboricola, Dracaena godseffiana, Philodendron salloum, Syngonium podophyllum* and *Scindapsis aureus*; planted in pots (5”) filled with media containing cocopeat: perlite: vermiculite in the ratio 3: 1: 1 arranged as vertical structures (6′11” x 4′3”) aligned to interior walls of a room. Four such structures were fabricated consisting of 45 pots each. Every frame was artificially illuminated with different light intensities i.e. the first frame with the light intensity between 700-1100 lux, second between 1100-1500 lux, the third frame between 1500-1900 lux and the fourth frame with 150-250 lux (no artificial light illumination; this was the natural measured light intensity of the room) and served as control. These light intensities were PWM (pulse width modulation) controlled. Fertigation of the plant was done with 100 % of the Hoagland solution. Optimum light intensity suitable for indoor plant species was observed on the basis of their response towards different light intensities w.r.t. various growth parameters under study. The observations on survival percentage, plant height, plant spread, leaf area, number of leaves/ plants, leaf length and leaf thickness were recorded at 90 days interval from date of transplanting (DAT) whereas fresh and dry canopy and root weight, root density, number of roots/plant and root density were recorded at the end of experiment. Experimental design was factorial completely randomized block design keeping three replications in each treatment.

## RESULTS AND DISCUSSION

### Survival percentage (%)

Maximum mean survival percentage was recorded in *Scindapsis aureus* (93.51 %) whereas minimum in *Philodendron salloum* (83.33 %).100 % survival was observed in all the indoor plant species irrespective of the treatments provided, whereas minimum mean survival percentage was evident in the plants lacking supplemental light i.e. LI IV (control). The results indicate that poor light intensity hinders photosynthetic activity of the plants resulting in plant mortality. Every plant species has some minimum light requirement to carry out various physiological and metabolic activities and if not provided with this minimum light requirement, it will not be able to perform photosynthesis and synthesize food material and show poor growth, ultimately resulting in plant mortality.

### Plant morphological parameters

A significant increase in the mean plant height, spread, number of leaves, leaf length, area and thickness were observed in *Schefflera arboricola* with increasing light intensities with maximum length recorded under LI III. *Dracaena godseffiana* also showed maximum plant height when treated with LI III. At par results in terms of plant height, spread and leaf thickness were achieved in *Syngonium podophyllum* under LI II and LI III. Reverse effect was evident for *Philodendron salloum* which had maximum plant spread under LI I. *Scindapsis aureus* showed maximum plant height, spread, leaf area and leaf

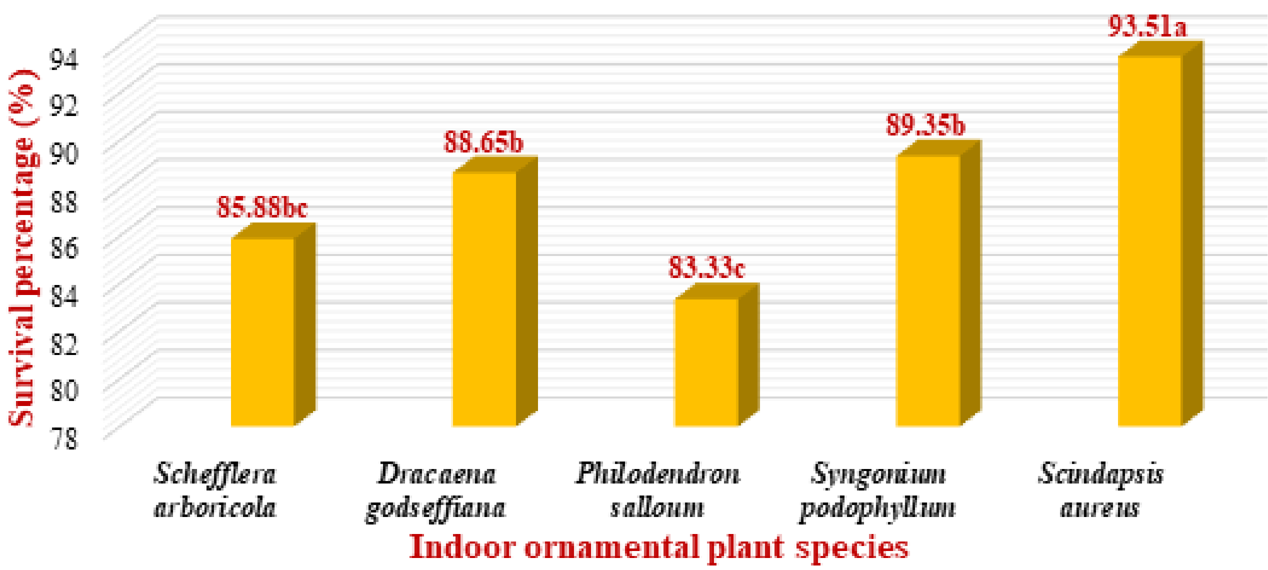


**Figure 1:** Effect of different light intensities on the mean survival percentage of indoor ornamental plant species

**Table 1:** Response of various plant species under study to different light intensities in terms of growth characteristics in an indoor vertical garden

| Growth parameters | Indoor ornamental plant species | LI I 700-1100 lux | LI II 1100-1500 lux | LI III 1500-1900 lux | LI IV 150-250 lux (control) |
|---|---|---|---|---|---|
| Plant height (cm) | *Schefflera arboricola* | 12.70c | 15.40b | 17.89a | 5.10d |
| | *Dracaena godseffiana* | 16.90b | 17.88b | 22.37a | 9.62c |
| | *Philodendron salloum* | 18.41b | 18.48b | 5.22c | 19.33a |
| | *Syngonium podophyllum* | 19.80b | 23.51ab | 26.82a | 10.90c |
| | *Scindapsis aureus* | 20.20b | 39.04a | 21.83b | 11.95c |
| Plant spread (cm) | *Schefflera arboricola* | 19.58c | 20.99b | 22.56a | 7.33d |
| | *Dracaena godseffiana* | 13.70b | 22.04a | 21.41a | 7.82c |
| | *Philodendron salloum* | 15.57a | 14.59b | 14.38c | 5.63d |
| | *Syngonium podophyllum* | 15.72b | 19.16a | 20.05a | 20.05a |
| | *Scindapsis aureus* | 15.93c | 23.35a | 19.40b | 19.40b |
| Leaf area ($cm^2$/ plant) | *Schefflera arboricola* | 242.58c | 288.00b | 330.83a | 66.66d |
| | *Dracaena godseffiana* | 232.83a | 248.46a | 260.33a | 113.17b |
| | *Philodendron salloum* | 151.91a | 146.00a | 159.41a | 65.83b |
| | *Syngonium podophyllum* | 265.83b | 457.75a | 270.83b | 143.00c |
| | *Scindapsis aureus* | 191.04c | 526.67a | 282.75b | 140.60d |
| Number of leaves | *Schefflera arboricola* | 5.00c | 6.00b | 7.41a | 1.66b |
| | *Dracaena godseffiana* | 4.75a | 5.83a | 5.50a | 2.16b |
| | *Philodendron salloum* | 2.41a | 2.33a | 2.33a | 1.00d |
| | *Syngonium podophyllum* | 3.66a | 4.08a | 4.83a | 2.00b |
| | *Scindapsis aureus* | 5.33c | 10.16a | 7.66b | 4.50c |
| Leaf length (cm) | *Schefflera arboricola* | 8.48c | 9.24b | 9.95a | 3.64d |
| | *Dracaena godseffiana* | 13.34b | 16.66ab | 19.40a | 8.38c |
| | *Philodendron salloum* | 9.85b | 12.02a | 12.01a | 4.02c |
| | *Syngonium podophyllum* | 12.20a | 13.04a | 13.22a | 7.16b |
| | *Scindapsis aureus* | 7.80a | 7.91a | 7.98a | 7.03b |
| Leaf thickness (mm) | *Schefflera arboricola* | 0.42c | 0.48b | 0.51a | 0.17b |
| | *Dracaena godseffiana* | 0.40a | 0.40a | 0.46a | 0.20b |
| | *Philodendron salloum* | 0.28b | 0.44a | 0.44a | 0.10c |
| | *Syngonium podophyllum* | 0.36b | 0.60a | 0.65a | 0.15c |
| | *Scindapsis aureus* | 0.25b | 0.37a | 0.35a | 0.24b |

The different letters in each column are significantly different at $P \leq 0.05$ by Duncan's Multiple Range Test (DMRT)

number when treated with LI II. There was statistically non-significant difference in the mean leaf area as well as number of leaves/ plants between different treatments given in *Dracaena godseffiana and Philodendron salloum.* Statistically non-significant difference in the mean leaf length between different light intensity treatments was recorded in *Dracaena godseffiana, Syngonium podophyllum* and *Scindapsis aureus.* Mean leaf thickness remained insignificant in case of *Dracaena godseffiana* irrespective of different light treatments given. Maximum leaf thickness was recorded in LI III which was at par with LI II in *Philodendron salloum* and *Scindapsis aureus.*

**Table 2:** Effect of different light intensities on number of roots/plant and root density of indoor ornamental plant species in an indoor vertical garden in an indoor vertical garden

| Growth parameters | Indoor ornamental plant species | LI I 700-1100 lux | LI II 1100-1500 lux | LI III 1500-1900 lux | LI IV 150-250 lux (control) |
|---|---|---|---|---|---|
| Number of roots/ plants | *Schefflera arboricola* | 5.00c | 7.00b | 12.00a | 0.00d |
| | *Dracaena godseffiana* | 3.67b | 6.33a | 7.67a | 1.33c |
| | *Philodendron salloum* | 9.33a | 8.67b | 7.33c | 0.00d |
| | *Syngonium podophyllum* | 6.67b | 7.67b | 9.33a | 1.67dc |
| | *Scindapsis aureus* | 4.00b | 6.33a | 5.67a | 2.33c |
| Root density | *Schefflera arboricola* | 0.31b | 0.44b | 0.75a | 0.00c |
| | *Dracaena godseffiana* | 0.23b | 0.40a | 0.48a | 0.08c |
| | *Philodendron salloum* | 0.58a | 0.54b | 0.46c | 0.00d |
| | *Syngonium podophyllum* | 0.42c | 0.48b | 0.58a | 0.10d |
| | *Scindapsis aureus* | 0.25b | 0.40a | 0.35a | 0.15c |

The different letters in each column are significantly different at P≤0.05 by Duncan's Multiple Range Test (DMRT)

**Table 3:** Response of various plant species under study to different light intensities in terms of fresh and dry canopy and root weight and number of roots/plant in an indoor vertical garden

| Growth parameters | Indoor ornamental plant species | LI I 700-1100 lux | LI II 1100-1500 lux | LI III 1500-1900 lux | LI IV 150-250 lux (control) |
|---|---|---|---|---|---|
| Fresh canopy weight (g) | *Schefflera arboricola* | 16.07c | 20.10b | 26.50a | 0.00 |
| | *Dracaena godseffiana* | 3.10b | 3.77b | 7.67a | 0.00 |
| | *Philodendron salloum* | 15.67a | 13.57b | 8.45c | 0.00 |
| | *Syngonium podophyllum* | 11.58c | 22.82b | 26.20a | 0.00 |
| | *Scindapsis aureus* | 12.13b | 27.68a | 14.76b | 0.00 |
| Dry canopy weight (g) | *Schefflera arboricola* | 3.92c | 5.83b | 8.33a | 0.00 |
| | *Dracaena godseffiana* | 0.68b | 0.84b | 1.62a | 0.00 |
| | *Philodendron salloum* | 1.13a | 0.87b | 0.70b | 0.00 |
| | *Syngonium podophyllum* | 4.23b | 5.91b | 8.21a | 0.00 |
| | *Scindapsis aureus* | 3.51b | 7.36a | 3.31b | 0.00 |
| Fresh root weight (g) | *Schefflera arboricola* | 4.80c | 8.67b | 10.00a | 0.00 |
| | *Dracaena godseffiana* | 2.76c | 3.99b | 6.33a | 0.00 |
| | *Philodendron salloum* | 30.67a | 27.33b | 20.67c | 0.00 |
| | *Syngonium podophyllum* | 3.53c | 7.60b | 10.16a | 0.00 |
| | *Scindapsis aureus* | 3.28c | 3.82a | 3.46b | 0.00 |
| Dry root weight (g) | *Schefflera arboricola* | 0.71b | 0.94b | 1.21a | 0.00 |
| | *Dracaena godseffiana* | 1.28b | 1.49b | 2.61a | 0.00 |
| | *Philodendron salloum* | 8.39a | 8.27a | 3.08b | 0.00 |
| | *Syngonium podophyllum* | 1.74b | 2.49a | 2.90a | 0.00 |
| | *Scindapsis aureus* | 0.81a | 0.86a | 0.70b | 0.00 |

The different letters in each column are significantly different at P≤0.05 by Duncan's Multiple Range Test (DMRT)

Photosynthesis is the most important process triggered by light in plants used by them to produce food so as to build plant material. Photosynthetic rate is directly proportionate to the growth of the plants. Different plant species have dissimilar light intensity requirements to grow at their optimum rate and reach their maximum potential. If sufficient light is not received by the plants, they will not grow at their maximum rate or reach their maximum potential, regardless of how much of any other variable i.e. water, growth medium or fertilizer they receive. From the results of our research, it is clear that the species responded differently to different light intensities. Physiological studies have demonstrated that leaves are the sight of light perception (Zeevart, 1984) and phytochromes present in it perceives the light signal which releases chemical signal that is transported to the apical meristem where it changes the fate of the cells produced (Kendrick and Weller, 2003). This might be the reason that the increase in number of leaves and leaf area resulted in higher light perception which led to positive impact on plant height, plant spread and leaf length and leaf thickness that increased significantly.

Reports of Bantis *et al.,* (2016) in *Ocimum* plants concludes that plant height was significantly affected with different LED light intensities. Zervoudakis *et al.,* (2012) reported an increase in leaf number and other growth parameters with increasing light intensity in Salvia. In our study, *Schefflera arboricola* and *Syngonium podophyllum* also responded similarly to increasing light intensities i.e. to LI III (1500-1900 lux). Increase in leaf area with increasing light intensities was reported earlier by Baligar *et al.,* (2001) in sunhemp, cowpea and lablab. With higher leaf areas, these crops might have higher photosynthetic rates than other plant species. Moss (1984) reported that plants having large leaf areas have a potential for greater growth than those with smaller ones. On the other hand, Sesbania produced larger leaf areas under low intensities of light. This indicated that this species might have a higher photosynthetic rate even at lower light intensities than the other plant species tested. The plants generally perform efficiently and give the best positive response only under optimum light conditions required to carry out its various physiological functions. These results clearly indicate that optimum rate of photosynthesis varies at different light intensities for different species and is the reason why plants responded differently to different light intensities.

**Number of roots/plant and Root density (number of roots/16sq. inch.)**

Light treatments significantly affected number of roots/plant as well as root density with maximum values observed in case of *Schefflera arboricola* and *Syngonium podophyllum* under LI III whereas reverse was true for *Philodendron salloum*. On the other hand, *Dracaena godseffiana* and *Scindapsis aureus* showed similar effect in both the parameters under LI II and LI III. Higher root density and more number of roots/plant are the characteristics of ideal root growth. Studies conducted by Bantis *et al.,* (2016) in *Ocimum spp.* showed difference in root number under different light intensities. Higher number of roots contributes to an efficient and higher absorption of water and nutrients from the media and transporting to the plant body. Congenial light conditions enhance root growth which might have led to better absorption of nutrients and ultimately resulted in better plant growth. Active roots can improve shoot growth by providing plants with water and mineral nutrition.

**Fresh and dry weight of plant canopy and roots**

An increase in plant fresh and dry canopy as well as root weight with increasing light intensities was witnessed in case of *Schefflera arboricola, Dracaena godseffiana* and *Syngonium podophyllum.* Conversely, *Philodendron salloum* and *Scindapsis aureus* showed maximum weight of all the above-mentioned parameters under LI I and LI II, respectively. Also, non- significant results in terms of dry root weight of *Syngonium podophyllum* under LI II and LI III as well as LI I and LI II in case of *Philodendron salloum* and *Scindapsis aureus* was observed.

Light intensity has a direct impact on plant biomass production. Ideal light intensity range triggers photosynthetic activity resulting in higher accumulation of photosynthates leading to elevated fresh and dry biomass production. Our results are in agreement with former studies which indicate that the plant responses to LED lighting are species and/or cultivar dependent (Bantis *et al*., 2016). The fresh and dry biomass production of the plants under our research was directly associated with the plant growth, i.e. number of leaves, leaf area, leaf length, etc. which can be justified by the studies conducted by Zervoudakis (2012) who showed that both the plant dry biomass (leaf, shoot, root and whole plant) and leaf number responded similarly to light intensity. Also, Baligar *et al*., (2001) observed that increase in leaf area, increased the shoot and root weight with increasing light intensities in sunhemp, cowpea and lablab. These crops might have higher photosynthetic rate with higher leaf areas which may have resulted in higher accumulation of photosynthates and higher biomass. Moss (1984) reported that plants having large leaf areas have a possibility for greater growth than those with smaller leaf areas. On the other hand, *Sesbania* produced larger leaf areas under low light intensities. This specified that this species might have a higher photosynthetic rate even at lower intensities than the other plant species tested. However, some reports also suggest adequacy of intermediate light conditions for some species to reach higher levels of biomass productivity (De Carvalho Gonçalves *et al*.,2005). This justifies the fact that optimum rate of photosynthesis varies at different light intensities for different species.

Similar reports were made by Bantis *et al.,* (2016) in *Ocimum spp.* who reported a difference in the fresh and dry shoot and root weight at different light intensities.

A variable response of root fresh and dry weight w.r.t. different LED light intensities was also observed. This could be the result of higher carbohydrates and primary metabolite accumulation suggesting that LED light affects photosynthetic activity. The significant differences between Hoagland's solution formulation along with artificial LED lights on root growth and root vitality exemplify that different composition of ions affect the uptake of nutrient and then lead to distinct performance on root biomass.

## CONCLUSION

From the most effective positive response of plant species on the basis of various parameters under study towards different light intensities, it can be concluded that *Philodendron salloum* responded best to LI I (700-1100 lux), *Scindapsis aureus* to LI II (1100-1500 lux), *Dracaena godseffiana, Schefflera arboricola* and *Syngonium podophyllum* to LI III (1500-1900 lux).

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