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Use of LED Light To Produce Superior Quality Ornamental Plants

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ARTICLE ID: 49

Abstract

The ornamental industry has an advantage over conventional production methods due to the adaptability of LED technology, which offers interesting potential in terms of energy efficiency, robustness, compactness, long lifespan, and low heat emission. It can be used as a sole source or supplemental lighting system. A vital component of the environment, light serves as a signal and regulates the complex processes involved in the growth and development of plants. It also gives plants energy through photosynthesis. The ability to precisely control the light growing environment has been highlighted as a useful tool to produce modified plants in response to market demand, since variations in light quality affect specific plant traits like flowering, plant architecture and pigmentation. Growers can benefit from a number of productive advantages when lighting technology is used, including planned production (early flowering, continuous production, and expected yield), improved plant habitus (rooting and height), controlled leaf and flower color as well as improved commodity quality attributes. The potential advantages of LED technology for the floriculture sector extend beyond the increased aesthetic and commercial value of the final product. It is a sound, sustainable way of reducing the use of energy inputs (electrical energy) and agrochemicals (pesticides and plant growth regulators).

Keywords: light-emitting diodes, ornamental plants, flowering regulation, plant architecture, photoperiod

Introduction

The ornamental industry develops a very broad variety of plants, such as floriculture crops, ornamental grasses, turf grasses, and ornamental trees and shrubs, for their aesthetic value. The significance of floriculture's economic influence is remarkable. The flower and ornamental plant market size has grown strongly in recent years. It will grow from $43.09

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billion in 2023 to $46.68 billion in 2024 at a compound annual growth rate (CAGR) of 8.3% (Global flower and ornamental plant market report, 2024). As per National Horticulture Database published by National Horticulture Board, during 2023-24 the area under floriculture production in India was 285 thousand hectares with a production of 2284 thousand tonnes loose flowers and 947 thousand tonnes cut flowers (Source: Ministry of Agriculture and Farmers Welfares, 2nd Advance estimates, 2023-24). India's total export of floriculture was Rs. 717.83 Crores/USD 86.63 million in 2023-24. The ornamental industry also faces a number of difficulties, including as the globalization of the market, the unpredictability of climate change, competition from other land uses and human demands (Ferrante *et al*., 2015 and Hill *et al*., 2018).The agricultural production sectors in this scenario require more sustainable solutions that allow for advances in product quality and output while lowering production costs, environmental pressures and the depletion of natural resources.The application of artificial light in controlled environment systems (greenhouses, soilless systems, and indoor farming) presents one opportunity or possibility for the optimization of ornamental production in terms of both economics and sustainability. Overall, this approach allows for an accurate handling of environmental parameters through the use of technology (Van *et al*., 2021).

Light is the essential environmental factor coordinating plant growth, development and function since it represents the driving force for photosynthetic CO2 assimilation. Additionally, it is the signal that initiates a variety of response pathways known as photo morphogenesis, which are all involved in many developmental aspects of growth (Xu *et al*., 2019). Artificial lighting has emerged as a viable option for plant cultivation in the last few decades. It can be used as a primary light source or as an alternative when solar radiation is scarce. Artificial lighting can power photosynthesis, control crop morphogenesis and control the flowering process (Massa *et al*., 2008 and Marondedze *et al*., 2018). By adjusting/modulating the light components/properties, such as quantity (intensity), duration (photoperiod), and quality (spectral composition), it is possible to attain important ornamental production targets to induce flowering, control leaf shape and plant architecture, extend the production season, fine-tune leaf and flower color, improve longevity, and enhance resilience to pathogens (Xu *et al*., 2019).

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Until recently, the viable and widely used options for artificial lighting systems were high-intensity discharge (high-pressure sodium, HPS, metal halide, MZ) and fluorescent lamps due to their relatively high fluence and economical affordability (Zheng *et al*., 2019). However, these conventional lighting systems show some disadvantages, including the generation of excessive heat, high energy needs, and inability to modulate the light spectrum, generally emitting light over a limited broad spectrum (orange-red region, 550–650 nm, with less in the blue region, 400–500 nm) (Paradiso *et al*., 2021). The recently emerged light-emitting diode (LED) technology has great potential for protected ornamental production (Singh *et al*., 2015). As the most ecologically friendly and energy-efficient lighting technology on the market today, LEDs provide a number of distinct advantages over previous lighting systems (Bantis *et al*., 2018). With their increased energy efficiency and other performance attributes like robustness, compactness, durability and long lifespan, LEDs are a cost-effective solution that is highly valued in commercial settings. This allows for reductions in electricity costs (Singh *et al*., 2015). Low heat emission allows the light source to be placed close to the canopy, ensuring a uniform spectral distribution while preventing tissue damage from photostress (Morrow, 2008). Furthermore, LEDs remarkably fulfill the unique requirements of leaf optical properties, including dynamic photosynthetic activity and biochemical processes to control plant growth and development, because of the benefits of high-light-intensity selection and spectral modulation (Karabourniotis *et al*., 2021 and Trivellini *et al*., 2023).

This review is innovative in that it explains how farmers can use LED lighting to stimulate innovation in the ornamental industry and offers guidelines or recommendations for enhancing the quality and productivity of their production methods. Thus, the regulation of flowering, plant architecture, postharvest/postproduction longevity, flower and leaf color and pathogen and disease management are some of the ornamental plant properties that are modulated by LEDs.

1. Flowering Regulation:

Flower induction and initiation are intricate procedures that are influenced by both internal and environmental elements that affect the change from the vegetative phase to the reproductive competence stage (Srikanth *et al*., 2011 and Cho *et al*., 2017). Numerous plant species, including ornamental crops, detect variations in the light environment, such as photoperiod, light intensity, spectral composition, and direction, to synchronize their growth

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and development. In terms of photoperiodic requirements, most ornamental plants can be classified as long-day (LD) plants, short-day (SD) plants and day-neutral plants (ND). Flowering of LD plants is induced when the night length is less than a certain threshold (critical duration). In contrast to ND plants, which can flower at any time of day, SD plants are encouraged to flower during long nights (short days) (Erwin *et al*., 2007). A complex gene regulation network involved in light sensing, which is stimulated by photoreceptor action, enables leaves to respond in a coordinated way to the relative lengths of the light and dark periods during flowering (Weller *et a*l., 2015 and Proietti *et al*., 2022). Based on molecular evidence, the flowering transition occurs by the inhibition of antiflorigenic FT (AFT)/Terminal Flower 1 (TFL1) and the upregulation of blooming LOCUS T (FT), also referred to as florigen (Higuchi *et al*., 2018). In some ornamental crops, low-temperature exposure is required to regulate the transition from vegetative to reproductive growth (vernalization) (Meng *et al*., 2017). he key integrated method for harvesting schedules and making use of greenhouse space is the link between temperature and photoperiod, which has been demonstrated to control the flowering transition in many species. The second most important ornamental crop is chrysanthemum, which can be produced as potted or cut flowers. Artificial lighting is used as a day-length extension to promote vegetative growth or as a night break to prevent premature flowering in order to ensure year-round availability for the market demand for short-day plants like chrysanthemums and to assure the programmed flowering on predetermined market can be traced (Park *et al*., 2020).

For both long-day and short-day plants, the spectral composition affects flowering in addition to photoperiod (Cerdan and Chory, 2003). The flower transition is triggered by a certain type of light, and this triggers transcriptional regulation of the genes encoding photoreceptors, or activators of flowering. A variety of photoreceptors are involved in the perception and absorption of various wavelengths: phototropins (PHOT), ZTL/FKF1/LKP2, and UVR8, which primarily absorb UV-B light, phytochromes, which preferentially absorb in the red (660 nm)/far-red (730 nm) spectral regions and cryptochromes, which preferentially absorb in the blue/UV-A wavelengths (Casal, 2000). In this regard, LEDs are just as effective as conventional light sources but have a lower overall cost of operation (Meng *et al*., 2014). Long hours of illumination with a red/white/far-red lamp and a high daily light integral (DLI) significantly assisted in the production and development of flowers in petunias (*Petunia* *hybrida* E. Vilm.) and snapdragons (*Antirrhinum majus* L.) (Garrett-Owen *et al.*, 2018). In the same way, day-neutral *Cyclamen persicum* Mill. found that flowering and subsequent development might be aided by combining high light intensity with both blue and red wavelengths. Similarly, day-neutral *Cyclamen persicum* Mill. found that flowering and subsequent development might be aided by combining high light intensity with both blue and red wavelengths (Heo *et al.*, 2003).

2. Plant Architecture:

Customized light recipes can be created for the purpose of manipulating plant design thanks to LED technology's capacity to choose particular wavelengths. Plant quality, or the distribution of energy across various wavelengths, is frequently a combination of particular plant characteristics, which are heavily impacted by the spectral makeup of LED light. These characteristics include branching, compactness, roots, and leaf growth (Paradiso *et al.*, 2021). Since the absorption spectra of photosynthetic pigments mostly focus on blue (400–500 nm) and red (600–700 nm) light (Li *et al.*, 2020), the combination of red and blue wavelengths is a reasonable choice for commercial plant production employing LED systems. The physiological and morphological characteristics of plants, including stomatal openings, height, chlorophyll biosynthesis, stem elongation, branching, leaf expansion, and reproduction, are generally impacted by red and blue LED lighting (Paradiso *et al.*, 2021). When compared to growth under ambient light supplemented with an HPS lamp or cool white fluorescence, both supplemental and sole sources of LED lighting, with blue radiation in a red background, limit the extension growth and leaf expansion. This is an efficient nonchemical method of controlling the height of several bedding plant species. For example, it has been demonstrated that Impatiens hybrida hort. responds better to conditions that are high in red light and low in blue light. Trichomes are anatomical structures that are associated with preventing water loss by transpiration (Kobori *et al.*, 2022). This light formula also increased cutting survivability and plug compactness, allowing for a trade-off between cutting quality and dehydration. *Lavandula angustifolia* Mill., *Rhododendron simsii Planch*. hybrids, and *Chrysanthemum* × *morifolium* (Ramat.) Hemsl. were among the species in which treatment with red light alone (100) proved to be particularly effective in promoting rooting performance (Christiaens *et al.*, 2015).

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3. Postharvest Longevity:

The ability to maintain the exterior properties of ornamental plants, such as size, shape, color, and flower and leaf turnover, is just as important as their ability to maintain those qualities (Ferrante *et al*., 2015). In actuality, following harvest or production, they are still highly perishable and metabolically active as fresh commodities, making them exceedingly susceptible to significant postharvest losses. Therefore, the primary objective of ornamental plants' commercial success is to maintain their value. However, inferior postharvest conditions, which frequently arise during storage and shipping, have a detrimental impact on the overall quality and hasten the degenerative processes. For cut flowers and potted plants, a variety of commercial compounds are available, such as sugars, ethylene inhibitors, antibacterial agents, and synthetic growth regulators are used to reduce the postharvest loss of fresh commodities. Ethylene is widely known as an aging hormone, as it promotes and accelerates senescence-related processes. Gaseous 1-methylcyclopropene (1-MCP) was found to be an excellent ethylene perception blocker, preventing leaf and blossom abscission and extending the life (keeping the freshness) of many ethylene-sensitive potted plants and cut flowers (Iqbal *et al*., 2017). Recently, the processes underlying the vase life response under different light environments were explored in several ornamental plants. Prolonged exposure to a low storage temperature reduced the lifespan of the cut stems in anthuriums, a tropical cold-sensitive species. While red light reduced the amount of ROS in the cells, applying a single source of blue light during cold storage resulted in the highest rate of water loss and electrolyte leakage from the spathes (Aliniaeifard *et al*., 2020). In cut roses, red light has been demonstrated to affect floral opening and water balance (Horibe, 2020).

4. Flower and Leaf Color:

The color of the leaves and flowers is another important indicator for the ornamental plant sector, beside plant architecture and longevity. This factor influences consumer preferences and consequently, profits. Chlorophylls, carotenoids, anthocyanins, flavonoids and betalains are the major classes of plant pigments that control the color of leaves and flowers (Zhao *et al*., 2015). The formation and control of pigmentation patterns are primarily driven by genetic determinants and environmental factors, such as temperature, light intensity, and light spectrum. Plants can be classified as having high, medium and low light requirements. *Hibiscus syriacus* L. flowers, for instance, developed a bright red color in their petals as a result of exposure to red light (Young *et al*., 1997). Anthocyanins and carotenoids have been found to

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accumulate more when LED supplementary illumination enriched with red and blue wavelengths is used. This leads to in vibrant foliage color and an overall enhancement in the decorative value of plants (De Keyser *et al*., 2019).

5. Pathogens and Disease Control:

Light quality, in addition to causing differential metabolic rearrangements, can directly or indirectly impact pathogens and pests, as well as their natural antagonists. When cultivating crops in controlled environments (such as growth chambers and greenhouses), limited exposure to a UV-B light fluorescent lamp is frequently employed to prevent disease incidence. By increasing secondary bioactive chemicals, low doses of UV-B radiation applied for 6 hours fully decreased powdery mildew infection in high-density greenhouse-grown roses (Kobayashi *et al*., 2013). Several horticultural crops are affected by the common and destructive plant disease, *Botrytis cinerea*, which causes gray mold. Numerous ornamental crops that are susceptible to gray mold can benefit from the application of blue light and UV radiation, as evidenced by their demonstrated ability to inhibit the pathogenic growth of *B. cinerea* (Horibe, 2020 and Meyer *et al*., 2021).

Conclusion

Using LED lighting technology to carefully select light spectrum components can significantly improve the quality-related characteristics of ornamental plants by influencing various physiological and metabolic processes, including rooting, flowering, branching, and vase life. The control of flowering can generate a consistent yield, shape the habitus of the plant and highlight attractive features all while reducing costs and production time. Moreover, artificial lighting offers an alternative for chemical pitching's growth retardants and a fascinating method for managing some plant diseases in growth chambers or greenhouses. With studies focusing on species/cultivar specific light requirements, the use of LED light in controlled environment can result in the production of ornamental plants with superior characteristics, representing a new frontier in applied science. Additionally, its application can help in reducing the use of agricultural resources likely energy and soil in a sustainable way.

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