



Plant Archives

Journal homepage: <http://www.plantarchives.org>

DOI Url : <https://doi.org/10.51470/PLANTARCHIVES.2025.v25.no.2.069>

ARTIFICIAL LIGHT: SUSTAINABLE LIGHTING CONDITIONS FOR ORNAMENTAL PLANTS

K. Johitha*, M. Raja Naik, T. Sumathi and N. Vinod Kumar

Department of Floriculture and Landscaping, College of Horticulture, Anantharajupeta - 516 105 (Dr. Y.S.R. Horticultural University), Andhra Pradesh, India.

*Corresponding author E-mail : kjohitha@gmail.com

(Date of Receiving-26-05-2025; Date of Acceptance-05-08-2025)

ABSTRACT

In the realm of ornamental horticulture, artificial lighting plays a crucial role in managing blooming, plant growth and overall sustainability. When it comes to indoor gardening, LED technology truly stands out because it promotes plant growth and does so in an energy-efficient way. While vertical farms and greenhouses provide controlled environment for growing plants, the lack of natural sunlight can result in the occurrence of various diseases. In horticulture, artificial lighting techniques typically offer a range of applications in the area of controlled lighting to provide daylight or natural growing conditions. Artificial lights can be used for photoperiod as a replacement or as supplemental light. Conventional lighting options that affect plant growth include incandescent, fluorescent and high-pressure sodium (HPS) lights. HPS lights are effective, but they typically don't provide enough blue light for plants to grow to their full potential. LEDs are efficient and long-lasting with low heat loss and adjustable spectrum. By tweaking photoperiods, growers can steer flowering cycles, which is particularly crucial for popular plants like chrysanthemum, Poinsettia and Petunia etc. The quality of the light is crucial for blossoming and different wavelengths are absorbed by photoreceptors like Phytochromes and cryptochromes. Red, far-red and blue lights are critical to the morpho-physiological growth of the plant. Use of LED lighting, which emits light in different wavelengths that can be used to economically track the growth of plants such as snapdragons and petunias.

Key words : Artificial light, Cryptochromes, Phytochromes, ROS, Photoreceptors.

Introduction

Artificial lighting, such as LED lights, has become a crucial component of indoor gardening, which includes both decorative and flowering plant species. Greenhouses and vertical farms provide regulated conditions for plant growth. Many plant diseases brought on by a lack of natural light are one of the main industrial concerns. Controlling these diseases is necessary because they reduce the ornamental plants economic worth. For getting quality of produce energy and consumption of water plays a major role. As a result, using LEDs significantly reduces expenses. Unfortunately, the adoption of new technology is frequently impeded by societal concerns and a lack of consideration for the effects on the environment. Garden horticulture is encouraged by microclimatic devices, but qualitative plant traits like flowering and colour intensity

are frequently overlooked. Modification of these characteristics improves product quality and market competitiveness. Even achieving the desired flowering time is aided by various forms of illumination. Strong stem structures are achieved on post-harvestable stems with the aid of LED lighting systems, extending their shelf life. Improved skeletal structure can lead to optimal levels of productivity. Increasing set schedules helps raise the bar for meeting rising expectations. The horticultural landscaping is impacted by problems like globalisation, climate change, competition for land use and human pressures. Achieving affordable sustainable solutions, minimising resource depletion and environmental effects and enhancing product quality and yield all require striking a balance. Using artificial lighting in controlled settings (such as greenhouses, soilless systems or indoor

gardening) is one of the method to increase the sustainability and economic feasibility of ornamental production. It is crucial to meet all of a plant's needs for growth and photosynthesis (Trivellini *et al.*, 2023).

One of the most important aspects of managing light is the precise control of environmental parameters. Artificial lighting, either primary or supplemental, can be used to affect crop growth and flowering. Controlling light intensity, duration and quality can help to achieve many important ornamental production goals, including bloom induction, plant shape control, extending the production season, improving pathogen resistance and controlling plant shape (Trivellini *et al.*, 2023). The spectral makeup of the light source is referred to as its quality. By adhering to particular standards for leaf optical characteristics which include dynamic photosynthetic activity and biochemical processes. LEDs can improve the regulation of plant growth and development (Karabourniotis *et al.*, 2021).

This review offers a thorough overview of the application of LED lighting technology in the production and cultivation of ornamental crops. The LED lighting can be utilised to encourage innovation in the ornamental market while simultaneously providing guidance to the growers with suggestions to raise the standard yield of their systems and production techniques (Fig. 1).

Types of artificial lighting

Replacement lighting : The complete replacement of indoor growth rooms and growth chambers with solar radiation.

Supplemental lighting (SL) : In greenhouses, it is used to make up for times when there isn't enough natural light. SL is one of the cheapest ways to grow plants when there are a lot of them at once.

Photoperiod lighting : Photoperiod-dependent plant responses, such as flowering or vegetative development, are stimulated or influenced by it.

Systems for artificial lighting

Commercially available artificial light sources come in a variety of forms, including high-pressure sodium (HPS), fluorescent, incandescent and more recently, light-emitting diodes (LED), each of which has a unique light quality and are as follows.

Incandescent lamps (IL) : Incandescent lamps rely on heating a filament until it glows, producing visible light. While they're the most affordable option, their inefficiency has greatly limited their application in areas like horticultural lighting. Since they emit only a small fraction of their electricity as photo-synthetically active radiation

(PAR), they're not ideal for plant growth (Islam *et al.*, 2012).

Fluorescence lamps (FL) : A low-pressure mercury electric discharge lamp is made out of a glass tube that holds a low-pressure mixture of argon gas and mercury vapor. When the current flows through the ionized gas between the electrodes, the mercury arc emits ultraviolet light, which is then converted into visible light by the phosphorus coating on the inner glass of the tube. Their lifespan is similar to that of metal halide lamps (MHL), and their luminous efficiency falls in between that of high-intensity discharge (HID) and incandescent (IL) lights. Fluorescence lamps are available with a range of spectrum properties. Reasonably cost cool white bulbs and full-spectrum lights are options for additional lighting applications and replacement illumination, respectively (Kumari *et al.*, 2014).

Light-emitting diodes (LED) : Semiconductors are the building blocks of LEDs. Since this substance is solid by nature, LEDs are marginally more resilient. When the semiconductor material's electrons start to whirl when electricity is applied, they release energy in the form of visible light.

Because of their long lifespan, low radiant heat production, controllable spectrum composition (such as red and blue wavelengths) and adjustable light intensity, LED lamps offer a lot of promise. For red LEDs, 40% of the energy is transformed into light, while for blue LEDs, it's 38% (Islam *et al.*, 2012). From an economic perspective, it is becoming more and more possible to use light-emitting diode (LED) technology for horticultural lighting. The market is always seeing cheaper and more effective equipment due to the rapid advancement of technology. In several research studies, the potential application of monochromatic LED light for growth regulation and assimilation support in decorative pot plants was investigated. Various wavelengths, such as polychromatic white light, were used in greenhouse settings either as the only light source or in conjunction with natural light. Plant development and growth were significantly impacted by the various treatments. For plant growth, white and blue light were shown to be the most effective. Blue light, however, significantly increased stem elongation under specific conditions (Bergstrand and Schussler, 2012).

High-pressure sodium (HPS) lamps : High-pressure sodium (HPS) lamps were generated light using an arc-induced discharge in a combination of mercury and sodium vapor. The yellow-orange-red (500–650 nm) region of the emission spectrum has a high concentration.

Thirty percent of the electricity can be converted to PAR lights (Islam *et al.*, 2012). Their extended lifespan, high PAR emission, electricity efficiency, and reasonably priced installation make them popular in greenhouse production.

Flowering Regulation

Flower induction and initiation are the intricately regulated processes controlled by environmental and inherent factors that affect the transition from the vegetative stage to reproductive competence. An endogenous signal integrated in reaction to extrinsic stimuli is strictly moderated by a complicated series of genetic pathways to guarantee the progeny's success (Wang, 2014).

Many ornamental crops and other plant species sense variations in the light environment, including photoperiod, light intensity, spectral composition and directions, to synchronize their growth and development. The majority of ornamental plants fall into one of three categories based on their photoperiodic needs: long-day (LD), short-day (SD), or day-neutral (ND). When the duration of the night drops below a certain value (critical duration), LD plants start to flower. Unlike ND plants that can flower at any time of day, SD plants are more likely to flower during long nights (short days) (Erwin, 2007).

By a complicated gene regulatory network vital to light detection and influenced by photoreceptor activity, leaves exhibit coordinated internal responses to changing light and dark lengths during the flowering stage. It is the up-regulation of FLOWERING LOCUS T (FT), or florigen, and repression of anti-florigenic FT (AFT) / TERMINAL FLOWER 1 (TFL1) that pushes the flower towards flowering, as suggested by molecular studies. The first integrated technique for harvesting schedules and utilization of greenhouse space is the temperature-photoperiod relationship, which has been shown to regulate the flowering transition in numerous species. This allows one to design a controlled growth environment and generate high yields constantly over pre-specified periods of time. To promote flowering and minimize their crop production period, LD plants are typically subjected to low light intensity during nights, as opposed to SD plants, which are prevented from flowering and stimulated to grow vegetative (Dixon *et al.*, 2019).

Chrysanthemums rank as the second most significant ornamental crop, cultivated either as traditional flowers and potted plants. To guarantee a continuous supply that meets market demand for short-day species like chrysanthemums and to ensure that flowering occurs on specific market dates, artificial lighting is utilized to extend day length for vegetative growth or to provide a night

break that prevents early flowering. Beyond photoperiod, the spectral composition also plays a crucial role in the flowering process of both short-day and long-day plants. The quality of light specifically influences the transition to flowering, which subsequently regulates the transcription of genes responsible for producing flowering activators, namely the photoreceptors. Various photoreceptors are involved in detecting and absorbing different wavelengths: phytochromes that primarily absorb in the red (660 nm) and far-red (730 nm) regions; cryptochromes that mainly absorb blue and UV-A wavelengths. Red and far-red light are generally effective in promoting flowering in long-day plants (Figs. 1 and 2). The effectiveness of LEDs was assessed in comparison to traditional lamps (HPS) by examining their regulatory impact on the flowering of photoperiodic plants. LEDs offer comparable performance to traditional light sources but with lower operating expenses (Meng *et al.*, 2014). Long-duration lighting with high day light integration and red/white/far-red lamps enhances flower development in petunias and snapdragons (Owen *et al.*, 2018).

Pot plant production

When it comes to interiorscaping, the way potted plants are produced plays a crucial role in their visual charm and market value. To cultivate high-quality dwarf and compact potted plants, growers often rely on artificial

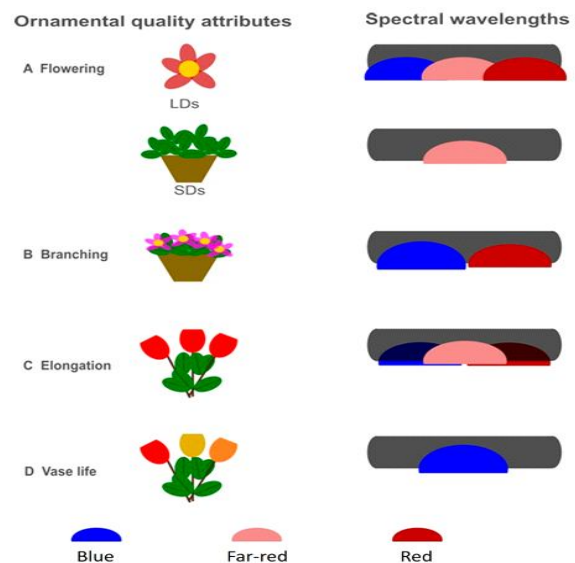


Fig. 1 : Spectral wavelengths affect ornamental plant traits. (A) Blue, far-red, and red lights promote flowering in long-day (LD) plants, while far-red light at day's end aids growth in short-day (SD) plants. (B) Blue light on a red background limits growth and promotes branching. (C) Stem elongation is controlled by adjusting the shade avoidance response with a lower R/Fr ratio or higher red light in a blue-light setting. (D) Cut flower longevity improves in cold conditions with only blue light exposure.

Table 1 : Main effects of LEDs on different ornamental plants (Trivellini *et al.*, 2023).

Species	Light Typologies	Effect of LEDs on Plants	References
<i>Ficus benjamina</i> L., <i>Cordyline australis</i> (G. Forst.) Endl. and <i>Sinningia speciosa</i> Hiern	B (100% blue, 460 nm), R (100% red, 660 nm), and W (white, 7% blue (400–500 nm), 16% green (500–600 nm), 75% red (600–700 nm) and 2% far-red (700–800 nm)) and RB (75% R and 25% B, peaks at 460 and 660 nm).	B and RB increased fy/ Fm and PSII; R decreased biomass. B increased stomatal conductance, leaf thickness and palisade parenchyma in <i>F. benjamina</i> . B and RB increased palisade parenchyma in <i>S. speciosa</i>	Zheng <i>et al.</i> (2017)
<i>Petunia hybrida</i> E. Vilm., <i>Geranium (Pelargonium hortorum</i> L.H. Bailey) and <i>Coleus (Solenostemon scutellarioides</i> (L.) Codd)	R: FR (1:0, 2:1 and 1:1) at two PPFs (96 and 288 mol m ⁻² s ⁻¹), all with a B photon flux density of 32 mol m ⁻² s ⁻¹ .	As R: FR decreased, stem length in all species increased. Decreasing R: FR increased the leaf area in petunias, and increased shoot dry weight in petunias and coleus. Decreasing R: FR promoted subsequent flowering in petunias at both PPFs. In geraniums, the addition of FR did not affect flowering, irrespective of PPF	Park and Runkle (2018)
<i>Tradescantia zebrina</i> Bosse <i>Chlorophytum comosum</i> (Thunb.) Jacques	Different light treatments: TO Tube luminescent Dunn (TLD) lamps or control, TB (TLD lamps + blue light-emitting diodes (LEDs)), TR (TLD lamps + red LEDs) and TBR (TLD lamps + blue and red LEDs).	Both species had increased root, shoot, and total dry weights under blue LED conditions. The chlorophyll concentration showed a specific response in each species under monochromatic or mixed red-blue LEDs. The highest photosynthetic rate was measured under the addition of mixed red-blue LEDs with TLD lamps. The addition of blue LEDs increased the production of ornamental foliage species.	Garcia <i>et al.</i> (2020)
<i>Chrysanthemum morifolium</i> 'Orlando'	Blue, red, far-red; daily light integral: 4.1 mol m ⁻² d ⁻¹ in interaction with auxin treatments.	Lowering the R: FR ratio improved rooting significantly. In contrast, adding blue light to solely red light decreased rooting. Phytochrome plays a role in adventitious root formation through the action of auxin, but the blue light receptors also interact in this process.	Christiaens <i>et al.</i> (2019)
<i>Petunia hybrida</i> E. Vilm., <i>Geranium (Pelargonium hortorum</i> L.H. Bailey) and <i>Coleus (Solenostemon scutellarioides</i> (L.) Codd)	R: FR (1:0, 2:1, and 1:1) at two PPFs (96 and 288 mol m ⁻² s ⁻¹), all with a B photon flux density of 32 mol m ⁻² s ⁻¹	As R: FR decreased, stem length in all species increased. Decreasing R: FR increased the leaf area in petunias and increased shoot dry weight in petunias and coleus. Decreasing R: FR promoted subsequent flowering in petunias at both PPFs. In geraniums, the addition of FR did not affect flowering, irrespective of PPF.	Park and Runkle (2018)
<i>Crocus sativus</i> L.	(i) R L = 660 nm (62%) and B L = 450 nm (38%) (RB); and (ii) R L = 660 nm (50%), GL = 500–600 nm (12%), and B L = 450 nm (38%) (RGB) and a photosynthetic photon flux density of 120 mol m ⁻² s ⁻¹	The two LED treatments increased the antioxidant compounds. RGB enhanced the total flavonoid content and reduced corolla fresh weight. RB and RGB increased DPPH.	Orlando <i>et al.</i> (2022)
<i>Dianthus caryophyllus</i> L.	W (400–730 nm), R (660 nm), and B (460 nm).	B determined the lowest relative membrane permeability (RMP) in flowers and the longest vase life. The R and W lights accelerated flower senescence and increased expression of DcACS and DcACO. B inhibited the expression of ethylene biosynthetic genes	Aalifar <i>et al.</i> (2020)

Abbreviation: B = blue; R-R = far-red; G = green; R = red; W = white LED color; D = darkness.

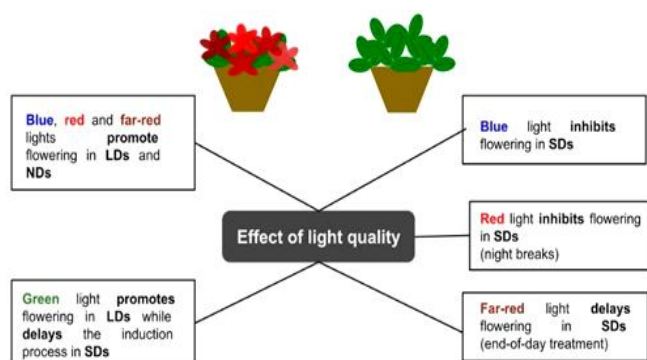


Fig. 2 : Diagrammatic illustration of how light quality affects ornamental plants' flowering processes (Trivellini *et al.*, 2023).

lighting systems while using FR-absorbing plastic films to keep stem lengths in check. For instance, when comparing the Solatrol 1 film to standard polyethylene film, the ratio of red to far-red light jumped from 1.0 to over 3.8. This change led to a 30% reduction in the height of *Petunia × hybrida* and a 19% decrease in *Impatiens walleriana*. Interestingly, *Petunia × hybrida* took an extra day or two to bloom under these conditions (Fletcher *et al.*, 2005). Similar height reductions were observed in *Euphorbia pulcherrima* with a more FR-absorbing film (R:FR ratio = 5.7) (Matta and Botto, 2009). Though branching remained unchanged. A different FR-absorbing film (R:FR ratio = 1.74) resulted in a 25.8% increase in axillary stems in *Euphorbia pulcherrima*. Under natural greenhouses, red and blue LED lighting efficiently suppresses stem elongation with a reduction of 34% in *Euphorbia pulcherrima* when exposed to R (80%) and B (20%) LED light for 10 hours a day in comparison to high-pressure sodium lamps (Islam *et al.*, 2012).

Tissue culture

White fluorescent lamps are widely applied in micropropagation but are responsible for patchy illumination. LEDs that emit band-like light are more effective in propagating woody and herbaceous ornamentals, but their high price restricts their application in tissue culture. Different types of LEDs emit blue, red, or far-red light at a lower price, thus serving as a lower-cost alternative compared to conventional lighting (Soontornchainaksaeng *et al.*, 2001). Investigation on *Chrysanthemum in vitro* nodal cuttings cultured on MS medium for 35 days under varying light conditions exhibited maximum net photosynthesis by red and blue LEDs, maximum leaf area, fresh weight and dry weight by fluorescent and red plus blue LEDs, minimum growth by blue and far-red LEDs and maximum stem elongation by red and red plus far-red LEDs (Kim *et al.*, 2004).

Production of secondary metabolites

The generation of secondary metabolites is significantly impacted by light quality. Secondary metabolites protect against UV rays and fight off infections and reactive oxygen species (ROS). They prepare the plant for changes in its surroundings so that it can handle stress better. Increasing the blue light fraction may help to the plants become more resilient to stress because it activates their biological defences (Ouzounis *et al.*, 2014). Few research findings proved that additional illumination affected the secondary metabolites in roses, chrysanthemums, and campanula by increasing levels of all phenolic acids and flavonoids with a larger blue light ratio (Kumari *et al.*, 2014).

Disease management

The host's light environment either before or during infection can have an impact on plant infection and its dissemination. Both pathogen infection and the severity of plant diseases are often increased by low light intensity and dense plantings. Another non-chemical method for managing this debilitating illness is to employ UV-B light and adjust day length and light quality to lessen powdery mildew in roses. Roses were sufficiently protected against powdery mildew by exposed to a short daily nighttime UV-B interruption (1 W m⁻² for 5 min) Suthaparan *et al.*, 2010). Plants exposed to red light decreased conidia germination when the effects of light quality on powdery mildew were examined, suggesting new avenues for managing the disease in roses (Suthaparan *et al.*, 2012).

Pest control

Even in low light levels, *Orius insidiosus* effectively preyed successfully in complex arenas and microcosms under all artificial lighting conditions tested. In microcosms, the predator quickly came into contact with prey and showed a high probability of attack in all spectral bands. However, the predation activities were significantly influenced by the spectrum composition, particularly the percentage of red light. Surprisingly, *Orius insidiosus* could feed on thrips in more complex settings even in the absence of natural light (Canovas *et al.*, 2024).

Conclusion

Artificial lighting enhances the potential for year-round cultivation of ornamental plants, which in turn will boost the income of growers involved in the flower industry. Light-emitting diodes facilitate a deeper understanding of the interactions among light, pests, diseases, natural enemies and plants, as they enable the use of very specific wavelengths. LEDs are a practical way to increase the quality of ornamental plant products while reducing the need for growth retardants. The higher

the blue light ratio, the more secondary metabolites are produced. These secondary metabolites protect plants from UV rays and fight against pathogens and reactive oxygen species (ROS). They also help plants adapt to changes in their surroundings and better to handle stress. Utilizing the new opportunities presented by LED light quality can help to improve the growth and yield of crops. Understanding how various light spectra impact on production of ornamental plants, flowers, postharvest physiology and the genes that regulate flowering in these plants requires further research.

References

- Aalifar, M., Aliniaiefard S., Arab M., Mehrjerdi M.Z. and Serek M. (2020). Blue light postpones senescence of carnation flowers through regulation of ethylene and abscisic acid pathway-related genes. *Plant Physiol. Biochem.*, **151**, 103-112.
- Canovas, M.L., Abram P.K., Cormier J.F., Galstian T. and Dorais M. (2024). Artificial lighting affects the predation performance of the predatory bug *Orius insidiosus* (Say) against the Western flower thrips *Frankliniella occidentalis* (Pergande). *bioRxiv*: 2024-10.
- Christiaens, A., Gobin B., Van Huylenbroeck J. and Van Labeke M.C. (2019). Adventitious rooting of Chrysanthemum is stimulated by a low red: far-red ratio. *J. Plant Physiol.*, **236**, 117-123.
- Dixon, L.E., Karsai I., Kiss T., Adamski N.M., Liu Z., Ding Y., Allard V., Boden S.A. and Griffiths S. (2019). Vernalization controls developmental responses of winter wheat under high ambient temperatures. *Development*, **146**(3), 172684.
- Erwin, J. (2007, June). Looking for new ornamentals: flowering studies. In: *VI International Symposium on New Floricultural Crops*, **813**, 61-66.
- Fletcher, J.M., Tatsiopoulou A., Mpezamihigo M., Carew J.G., Henbest R.G.C. and Hadley P. (2005). Far-red light filtering by plastic film, greenhouse-cladding materials: effects on growth and flowering in Petunia and Impatiens. *The J. Horticult. Sci. Biotechnol.*, **80**(3), 303-306.
- García-Caparrós, P., Martínez-Ramírez G., Almansa E.M., Javier Barbero F., Chica R.M. and Teresa Lao M. (2020). Growth, photosynthesis, and physiological responses of ornamental plants to complementation with monochromatic or mixed red-blue LEDs for use in indoor environments. *Agronomy*, **10**(2), 4.
- Heo, J.W., Lee C.W., Murthy H.N. and Paek K.Y. (2003). Influence of light quality and photoperiod on flowering of *Cyclamen persicum* Mill. cv. 'Dixie White'. *Plant Growth Regulation*, **40**, 7-10.
- Islam, M.A., Kuwar G., Clarke J.L., Blystad D.R., Gislerød H.R., Olsen J.E. and Torre S. (2012). Artificial light from light emitting diodes (LEDs) with a high portion of blue light results in shorter poinsettias compared to high pressure sodium (HPS) lamps. *Scientia Horticulturae*, **147**, 136-143.
- Kim, S.J., Hahn E.J., Heo J.W. and Paek K.Y. (2004). Effects of LEDs on net photosynthetic rate, growth and leaf stomata of chrysanthemum plantlets *in vitro*. *Scientia Horticulturae*, **101**(1-2), 143-151.
- Kumari, P., Panwar S., Singh K.P., Raju D.V.S. and Kumar P. (2014). Artificial lighting systems for ornamental plants-A review. *J. Ornament. Horticult.*, **17**(1 and 2), 1-11.
- Kong, Y., Schiestel K. and Zheng Y. (2019, June). Blue light associated with low phytochrome activity can promote flowering: A comparison with red light in four bedding plant species. In International Symposium on Advanced Technologies and Management for Innovative Greenhouses. *GreenSys2019*, **1296**, 433-440.
- Mata, D.A. and Botto J.F. (2009). Manipulation of light environment to produce high-quality poinsettia plants. *HortScience*, **44**(3), 702-706.
- Meng, Q. and Runkle E.S. (2014). Controlling Flowering of Photoperiodic Ornamental crops with Light-emitting Diode Lamps: A Coordinated Grower Trial. *HortTechnology*, **24**(6), 702-711.
- Ouzounis, T., Fretté X., Rosenqvist E. and Ottosen C.O. (2014). Spectral effects of supplementary lighting on the secondary metabolites in roses, chrysanthemums and campanulas. *J. Plant Physiol.*, **171**(16), 1491-1499.
- Orlando, M., Trivellini A., Puccinelli M., Ferrante A., Incrocci L. and Mensuali-Sodi A. (2022). Increasing the functional quality of *Crocus sativus* L. by-product (tepals) by controlling spectral composition. *Horticult., Environ. Biotechnol.*, **63**(3), 363-373.
- Owen, W.G., Meng Q. and Lopez R.G. (2018). Promotion of Flowering from Far-red Radiation depends on the Photosynthetic Daily Light Integral. *HortSci.*, **53**(4), 465-471.
- Park, Y. and Runkle E.S. (2018). Far-red radiation and photosynthetic photon flux density independently regulate seedling growth but interactively regulate flowering. *Environ. Exp. Bot.*, **155**, 206-216.
- Suthaparan, A., Torre S., Stensvand A., Herrero M.L., Pettersen R.I., Gadoury D.M. and Gislerød H.R. (2010). Specific light-emitting diodes can suppress sporulation of *Podosphaera pannosa* on greenhouse roses. *Plant Disease*, **94**(9), 1105-1110.
- Suthaparan, A., Stensvand A., Solhaug K.A., Torre S., Mortensen L.M., Gadoury D.M., Seem R.C. and Gislerød H.R. (2012). Suppression of powdery mildew (*Podosphaera pannosa*) in greenhouse roses by brief exposure to supplemental UV-B radiation. *Plant Disease*, **96**(11), 1653-1660.
- Soontornchainaksaeng, P., Chaicharoen S., Sirijuntarut M. and Kruatrachue M. (2001). *In vitro* studies on the effect of light intensity on plant growth of *Phaius tankervilliae* (Banks ex L'Herit.) Bl. and *Vanda coerulea* Griff. *Science Asia*, **27**(4), 233-237.
- Trivellini, A., Toscano S., Romano D. and Ferrante A. (2023). LED lighting to produce high-quality ornamental plants. *Plants*, **12**(8), 1667.
- Wojciechowska, R., Hanus-Fajerska E., Kamińska I., Koźmińska A., Długosz-Grochowska O. and Kapczyńska A. (2019). High ratio of red-to-blue LED light improves the quality of *Lachenalia* 'Rupert' inflorescence. *Folia Horticulturae*, **31**(1), 93-100.
- Wang, J.W. (2014). Regulation of flowering time by the miR156-mediated age pathway. *J. Exp. Bot.*, **65**(17), 4723-4730.
- Zheng, L. and Van Labeke M.C. (2017). Long-term effects of red- and blue-light emitting diodes on leaf anatomy and photosynthetic efficiency of three ornamental pot plants. *Front. Plant Sci.*, **8**, 917.