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LED Lighting: Transforming Floriculture for Quality and Sustainability

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The global floriculture market, valued at over USD 52 billion in 2022, is growing as consumer demand for quality cut flowers and potted plants increases worldwide. Growers are under increasing pressure from climate variability, limited land, higher energy costs, and major post-harvest losses. In this tough environment, light has become a key tool for enhancing productivity and quality. Light is essential for photosynthesis and serves as a key environmental signal that influences plant structure, flowering timing, pigmentation, and natural defense responses.

Traditionally, greenhouse growers used sunlight along with incandescent, fluorescent, or High-Pressure Sodium (HPS) lamps. HPS lamps provide high light output but lack spectral precision, generate substantial heat, and use a lot of electricity. In contrast, LEDs mark a significant change in protected cultivation. They provide excellent electrical efficiency, extended operational lifespans, and the ability to customize specific wavelengths into tailored "light recipes. This article examines how current LED strategies are transforming ornamental crop production and why their adoption is crucial for sustainable and profitable floriculture.

Plants detect light using specialized photoreceptors such as phytochromes, cryptochromes, and phototropins. These proteins absorb specific wavelengths and trigger signaling cascades that control growth, development, and metabolism, known as photomorphogenesis. Different species respond uniquely to spectral composition, so understanding these interactions is crucial for optimizing ornamental traits. LEDs enable growers to advance past basic lighting. Producers can influence plant form and function by adjusting the ratios of blue (400–500 nm), red (600–700 nm), and far-red (700–800 nm) light. Unlike broad-spectrum sources, LEDs provide focused photons with little energy loss, making them perfect for controlled-environment agriculture and greenhouse use.

Controlling Plant Structure with Light Spectrum

One key advantage of LED technology is its ability to precisely manage plant architecture. Excessive stem elongation lowers visual quality and transportability, often requiring chemical growth retardants. Research shows that more blue light significantly lowers plant height in species like poinsettia (*Euphorbia pulcherrima*), resulting in compact, marketable specimens. End-of-day blue light treatments have decreased Petunia height by 12–14% without affecting bloom timing.

Responses are very specific to each species. Blue light usually inhibits extension growth, but some bedding plants might show longer internodes with continuous blue LED exposure, depending on the cultivar and intensity. Far-red light promotes stem elongation and leaf expansion, as seen in snapdragon and some rose cultivars. The key for growers is to determine species-specific thresholds and modify red-to-blue or red-to-far-red ratios as needed. Using supplemental LED lighting along with lower levels of plant growth regulators can improve compactness and branching in ornamental transplants like geraniums and pansies.

Managing flowering for a continuous supply throughout the year

Photoperiod-sensitive ornamentals need careful day-length control to trigger flowering. LEDs have changed production by allowing precise photoperiod extension and night-break treatments. In long-day plants like Lachenalia, high-red LED ratios (90:10 Red:Blue) yield the longest inflorescences and the most floret counts. Far-red enrichment can speed up flowering in snapdragon and Pelargonium by as much as nine days, enabling better scheduling for market windows. Blue light can override traditional photoperiodic limits. In chrysanthemum (Chrysanthemum morifolium), a traditionally obligate short-day plant, adding a long-day photoperiod with low-intensity blue light (10 μmol m^{-2} s^{-1}) effectively triggered flower bud formation. This discovery provides an efficient alternative to labor-intensive blackout systems, allowing for off-season production while saving on labor and infrastructure costs.

Improving colour, scent, and nutrition

The value of ornamentals relies significantly on colour stability and intensity. Anthocyanin pigments, which give red and purple colors, respond strongly to light quality. Research on Lachenalia 'Rupert' indicates that adding 10–20% blue light boosts corolla anthocyanin levels by about 35% compared to using only red light. EOP blue treatments enhance foliage color in purple-leafed Pennisetum and Pelargonium, resulting in darker, more vibrant plants that fetch higher market prices. Fragrance, an important quality trait, is also affected by spectral composition. In snapdragon (Antirrhinum majus), blue light significantly boosts terpenoid emission, including ocimene and myrcene, by activating cryptochrome receptors and certain transcription factors. Orchid species such as Phalaenopsis violacea show increased monoterpene levels under blue light, indicating that specific lighting can enhance the scent and market uniqueness of cut flowers. Light quality directly influences the nutraceutical value of edible ornamentals and medicinal floricultural crops. Red light boosts naringenin and chlorogenic acid in chrysanthemum leaves, while moderate intensities with green light increase carotenoid and phenolic content in Tagetes and Celosia. Continuous lighting at 200 μmol m^{-2} s^{-1} enhances flower yield and antioxidant capacity in calendula, leading to better post-harvest shelf life and functional food value.

Enhancing Natural Defenses with Light

Artificial lighting can act as a non-chemical trigger for plant defense. Supplemental red or blue LEDs enhance cold tolerance in Tagetes, Antirrhinum, and Petunia by improving membrane stability and raising abscisic acid (ABA) levels—up to 4.4-fold in some instances. This effect increases survival rates during early spring transplanting and minimizes crop losses from unexpected frost. Spectral tuning also aids in disease management. Monochromatic red light effectively reduces powdery mildew (Podosphaera pannosa) on greenhouse roses by preventing spore release. In contrast, blue light may sometimes worsen mildew symptoms in some cultivars, even though it boosts flavonol content. Balanced red-blue-green spectra enhance the reproductive success of biological control agents like Orius laevigatus, underscoring the significance of broad-spectrum lighting in pest management programs.

Conclusion

Artificial lighting has transformed from a basic replacement for sunlight into a precise tool for managing crops. By adjusting LED spectra, intensities, and photoperiods, floriculture producers can shape plant structure, align flowering times, enhance colour and fragrance, and strengthen crops against environmental stresses, all while significantly reducing energy costs. For growers aiming to compete in a challenging global market, mastering light recipes is essential; it underpins modern, sustainable floriculture.

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