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LIGHT EMITTING DIODES IN VEGETABLE PRODUCTION SYSTMES

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Abstract– LEDs have become the predominant future lighting system for greenhouse crop production. The LEDs are popularly applied in photoperiod lighting, vegetable transplant production, graft-healing, greenhouse production and quality enhancement. As the LED technology advances, they improve the quality of vegetable transplants and produces. The spectral control reduce production costs and increase the value of specialty crops with promoted flavor and sensory traits. The Horticultural LED will continue to grow more hardware configurations and control protocols. LEDs provide comprehensive tool for plant environment for manipulation of plant function.

INTRODUCTION

The lighting systems are not originally designed for plant growth and development. Horticulture lighting is a borrowed technology from the lighting industry. The light is the essential for plant photosynthesis, altering which the production can be improved. The lighting systems are employed as two main purposes *viz*., sole-source lighting and supplemental lighting. In 1950s, incandescent lamps were used as standard lighting for photoperiod control inside the greenhouses (Downs *et al*., 1958). In 1970s, the combined usage of fluorescent + incandescent lamps were used in growth chambers (Bickford, 1979). Later in 1980s, the previously used lamps were replaced by high-intensity discharge lamps, which rapidly became the standard for supplemental lighting in greenhouses and sole-source lighting in growth chambers (Tibbitts *et al*., 1983). Despite their familiarity, the above lamps had serious limitations such as limited photon output, short effective life span, high voltage requirement, intense heat emission that demands spatial separation from plants, thereby accommodating more space inside the greenhouses (McCree, 1984). The light emitting diodes (LEDs) emerged as a revolution in lighting technology and it was found to be free from the issues of the other types of lamps.

The LED is a light source that does not use a filament or gas discharge, unlike the traditional lamps. The movement of the electrons inside the semiconductor material produces illumination, which the mechanism that the LEDs work on (Held, 2009). The LEDs come in a wide range of wavelengths ranging from UV-C (250 nm) to near-infrared rays (1000 nm). This technology employs wide range of light wavelength favoring specific plant processes enabled the LEDs to become more familiar. Table 1 discusses the advantages and disadvantages of LEDs.

Wavelengths of interest

The plants absorb the light through many classes of photoreceptors namely phytochromes,

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Table 1. Advantages and disadvantages of LEDs.

Sl. No.	Advantages	Disadvantages
1	Control on spectral output and light intensity	High hardware costs
2	Rapid turn on and off	Requirement of AC to DC power converters
3	Easy incorporation into electronic circuits	
4	Reduced operational costs	
5	Long operating life	
6	Low radiant heat output	
7	Ability to place close to plant canopy without any harm to the plants, due to low heat output	
8	No glass envelops and toxic materials	
9	Safer than other lamp types	

cryptochromes, phototropins, etc. The phytochromes are the primary photoreceptors that regulate flowering in crops. The phytochromes absorb red and far-red wavebands, cryptochromes absorb blue light and UV-A and the phototropins absorb the blue light.

There are several light wavebands of interest to plant growers and are represented in Table 2. The most commonly used waveband is the red wavebands including 627 nm and 660 nm. It is to be noted that these wavebands are closer to the range of maximum chlorophyll absorption peak and that's why they are widely used. The UV and blue wavebands (365, 400, 450 and 470 nm) are absorbed by the cryptochrome pigments. The green waveband (540 nm) is also used owing to its improved foliar penetration that eventually increases canopy photosynthesis. The blue LEDs, in combination with phosphors, provide wide spectrum of light through which white light is also generated (Olle and Virsile, 2013).

Table 2. Wavebands of horticulture interest

Sl. No.	Waveband	Wavelength (nm)
1	UV-C	250
2	Blue	400-500
3	Green	500-600
4	Red	600-700

LED lighting systems - types

There are three LED configurations widely employed in horticulture lighting system. They are applied either as sole-source, supplemental or photoperiodic lighting. An illustration of different lighting configuration is presented in Fig. 1.

Intracanopy lighting

In this configuration, the LED lamps are placed in between the plants. Since, LEDs emit a very low radiant heat they are eligible to be placed closer to the plant canopy, maximizing the light efficiency. It is implemented either as vertical or horizontal configurations. In vertical orientation, the light is provided only where it is required. Whereas, in horizontal orientation avoids interefence with watering systems and require less hardware.

Overhead point source

This configuration consists of light fixture with group of LEDs that provide light output in a cone pattern to cover a broad area. This configuration is effective for photoperiodic lighting, however, there is a significant light loss due to scattering.

Besides, there is a general disadvantage in the overhead lighting. In the planophile crop stands, the leaves are present in a perpendicular fashion to the

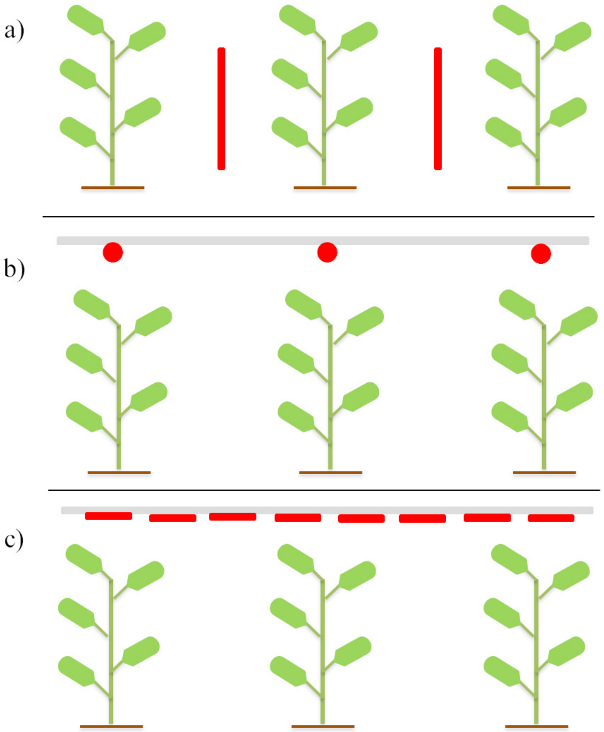

Fig. 1. Different configurations of LED lighting in horticulture system
a) Intracanopy lighting system; b) Overhead pointed lighting system; c) Overhead distributed lighting system

overhead light. This results in mutual shading of lower leaves by the upper leaves. This leads to net carbon loss via respiration, premature leaf drop, flower bud and fruit abortion.

Overhead distributed source

In contrast to the point source, the LEDs are distributed over a wider area to provide diffuse irradiance. This is being employed as sole-source lighting in growth chambers and supplemental lighting in greenhouses. Due to their low radiant heat output, LEDs can be placed in close proximity to the plants.

Applications of LEDs in vegetable production systems

The LEDs are applied in vegetable production system as to provide photoperiod lighting, lighting to vegetable transplants and grated seedlings, lighting to greenhouse vegetable production and lighting to enhance quality parameters of vegetable crops. They are discussed below.

Photoperiodic lighting

In plants, the length of light and dark periods regulates flowering. Based on photoperiod, the plants are classified as long-day, short-day and day-neutral plants. Though they appear as to be classed based on day length, this photoperiodic response is determined by the duration of dark period (critical night length) that a plant is exposed to. In brief, the short-day plants flowers rapidly under uninterrupted dark period that is longer than the species-specific critical night length. Similarly, the long-day plants flowers rapidly when dark periods are shorter than the critical night length.

When the ambient photoperiod is shorter, long day conditions can be created by placing lamps at the onset of end of the day until a desired photoperiod and is called day-extension lighting. Another approach is to operate lighting during a long night (night-interruption lighting). Generally, 4 hours of night-interruption lighting is recommended to attain rapid flowering in long-day plants. As the daylength is shorter, low-intensity lighting is used to inhibit flowering of short-day plants or to promote flowering in long-day plants.

Night-interruption lighting with a moderate to high red: far red inhibits the flowering in short-day plants. The efficacy of night-interruption lighting is decided by its intensity. Some long-day plants flower rapidly when day-extension or night-interruption lighting contain red and far-red light. Provision of night-interruption with blue light would inhibit flowering of short-day plants and promote flowering of long-day plants.

Vegetable transplants and grafts under LEDs

High quality seedlings are a major prerequisite for a productive vegetable cultivation. In developed nations, vegetable seedlings and grafts are grown in simple greenhouses under advanced microclimate control system including supplemental lighting. The main objective of supplemental lighting is to enhance seedling growth and development. The LED lighting are reported to improves seedling growth and morphology and reduces operational costs that incur than the traditional lamps.

The transplant quality is observed through visual inspection for compactness, vigor and color. The vigorous vegetable transplants with developed roots and leaves, short internode and thick stem are preferable. For grafts, the rootstock seedling should essentially be taller i.e. long hypocotyls to attain good graft-success. Liu *et al.* (2011a) reported that combined usage red + blue wavebands produced stronger, shorter tomato seedlings, whereas the tomato seedlings grown under monochromatic red LEDs had longest hypocotyl. Gomez and Mitchell (2015) found that the hypocotyl diameter and leaf area increased with addition of blue light, when provided as supplemental lighting.

LEDs are also reported to enhance photosynthesis and growth. Nanya and others (2012) concluded that the tomato seedlings showed greater dry mass under 660 nm red light and 450 nm blue light. They showed that a larger proportion of blue light is not beneficial for tomato seedling growth. The decline in dry matter by blue light is attributed to lower photosynthetic quantum efficiency of blue light. Under 100 per cent red LEDs, tomato plants showed higher shoot fresh and dry weight (Wollaeger and Runkle, 2014).

Graft healing of vegetable grafts was found successful with LED lighting. The healing process lasts for 5-7 days and requires lighting to maintain higher photosynthetic rate. Jang and team (2013) concluded that the 100 per cent red LED light produced epinastic seedling in pepper. Addition of blue light with red light eliminated this abaxial leaf curling. They also found that under 100 per cent blue light, grafted seedlings elongated.

Greenhouse vegetable production under LEDs

Hogewoning *et al.* (2007) were the first to work with LEDs for tomato production under greenhouse. They reported that the maximum photosynthetic capacity of lower, older leaves increase after irradiation with narrowband lighting. This indicated that the leaves can reacclimate their photosynthetic capacity to higher light intensities. In the intracanopy lighting system, both vertical and horizontal interlighting work with increased efficiency by allowing direct light into the canopy of plants.

Massa and others (2005) proved that intracanopy lighting as a sole-source lighting could delay senescence in cowpea. Hovi *et al.* (2004) provided partial interlighting with hybrid lighting (overhead + intracanopy lighting) increased fruit yield, increased percentage of good quality fruits and prolonged post-harvest life. Trouwborst *et al.* (2010) showed that the hybrid supplemental lighting enhanced photosynthesis in lower leaf layers and increased dry mass allocation to leaves. Lu *et al.* (2012) proved LEDs were efficient in promoting fruit fresh mass gain, due to greater light penetration into the canopy by green wavelength from the white LEDs.

Vegetable quality enhancement through LED lighting

Stutte and others (2009) studied that under blue LEDs, lettuce showed purple-leaf phenotype, indicating that blue light promoted phenolic and anthocyanin biosynthesis. Li and Kubota (2009) showed that the supplemental red light increased phenolics, blue light and UV-A increased xanthophylls, carotenoids and chlorophylls. Whereas, far-red light decreased anthocyanins, carotenoids and chlorophylls in the leaves of baby leaf lettuce. Chinese cabbage grown under combination of red and blue LEDs increased fresh and dry biomass, soluble proteins and photosynthetic pigments (Fan *et al*., 2013b).

Lefsrud and team (2008) reported that under red LEDs, sinigrin and lutein were recorded the highest in kale leaves. It was also noted that the blue LEDs promoted carotenoid accumulation. Kopsell and Sams (2013) showed that the broccoli microgreens under red and blue LEDs (627 and 470 nm, respectively) found to have higher levels of carotenoids, glucosinolates and micronutrients. Mattson and Harwood (2012) evaluated arugula under red and blue LEDs as sole-source lighting. They found a higher level of flavonoid that was induced by higher amount of light.

CONCLUSION

LEDs have become the predominant future lighting system for greenhouse crop production. The LEDs are popularly applied in photoperiod lighting, vegetable transplant production, graft-healing, greenhouse production and quality enhancement. As the LED technology advances, they improve the quality of vegetable transplants and produces. The spectral control reduce production costs and increase the value of specialty crops with promoted flavor and sensory traits. The Horticultural LED will continue to grow more hardware configurations and control protocols. LEDs provide comprehensive tool for plant environment for manipulation of plant function.

REFERENCES

Bickford, E. 1979. Radiation: critique II. (Eds. Tibbitts, T. and Kozlowski, T.), *Controlled Environment Guidelines for Plant Research.* Academic Press, New York, p. 47-54.

Downs, R., Borthwick, H. and Piringer, A. 1958. Comparison of incandescent and fluorescent lamps for lengthening photoperiods. *Proc. Am. Soc. Hort. Sci.* 71 : 568-578.

Fan, Z.Z., Zang, J., Xu, Z.G., Guo, S.R., Jiao, X.L., Liu, X.Y. and Gao, Y. 2013. Effects of different light quality on growth, chlorophyll concentration and chlorophyll biosynthesis precursors of non-heading Chinese cabbage (*Brassica campestris* L.). *Acta Physiol. Plant.* 35 : 2721-2726.

Gómez, C. and Mitchell. C.A. 2015. Growth responses of tomato seedlings to differentspectra of supplemental lighting. *Hort Science.* 50 : 1-7.

Held, G. 2009. *Introduction to Light Emitting Diode Technology and Applications.* Taylor & Francis Group, Boca Raton, FL.

Hogewoning, S.W., Trouwborst, G., Engbers, G.J., Harbinson, J., van Ieperen, W., Ruijsch, J., Schapendonk, A.H.C.M., Pot, C.M. and van Kooten, O. 2007. Plant physiological acclimation to irradiation by light emitting diodes (LEDs). *Acta Hort.* 761 : 183-191.

Hovi, T., Näkkilä, J. and Tahvonen, R. 2004. Interlighting improves production of year round cucumber. *Sci. Hort.* 102 : 283-294.

Jang, Y., Mun, B., Seo, T.,Lee, J., Oh, S. and Chun, C. 2013. Effect of light quality andintensity on the carbon dioxide exchange rate, growth, and morphogenesis of graftedpepper transplants during healing and acclimatization. *Korean J. Hort. Sci. Technol.* 31 : 14-23.

Kopsell, D.A. and Sams, C.E. 2013. Increases in shoot tissue pigments, glucosinolates, and mineral elements in sprouting broccoli after exposure to short-duration blue light fromlight emitting diodes. *Hort Science.* 138: 31-37.

Lefsrud, M., Kopsell, D. and Sams, C. 2008. Irradiance from distinct wavelength light-emitting diodes affect secondary metabolites in kale. *Hort Science.* 43 : 2243-2244.

Li, Q. and Kubota, C. 2009. Effects of supplemental light quality on growth and phytochemicals of baby leaf lettuce. *Environ. Exp. Bot.* 67 : 59-64.

Liu, X.Y., Guo, S.R., Xu, Z.G. and Jiao, X.L. 2011. Regulation of chloroplast ultrastructure, cross-section anatomy of leaves, and morphology of stomata of cherry tomato by different light irradiations of light emitting diodes. *Hort Science.* 46 : 217-221.

Lu, N., Maruo, T., Johkan, M., Hohjo, M., Tsukagoshi, S., Ito, Y., Ichimura, T. and Shinohara, T. 2012. Effects of supplemental lighting with light-emitting diodes (LEDs) on tomato yield and quality of single-truss tomato plants grown at high planting density. *Environ. Control Biol.* 50 : 63-74.

Massa, G.D., Emmerich, J.E., Mick, M.E., Kennedy, R.J., Morrow, R.C. and Mitchell, C.A. 2005. Development and testing of an efficient LED intracanopy lighting design for minimizing equivalent system mass in an advanced life-support system. *Gravit. Space Biol. Bull.* 18 : 87-88.

Mattson, N.S. and Harwood, E.D. 2012. Effect of light regimen on yield and flavonoid content of warehouse grown aeroponic *Eruca sativa*. *Acta Hort.* 956 : 417-422.

McCree, K. 1984. Radiation levels in growth chambers fitted with high intensity discharge lamps, with or without thermal barriers. *Crop Sci.* 24 : 816-819.

Nanya, K., Ishigami, Y., Hikosaka, S. and Goto. E. 2012. Effects of blue and red light on stemelongation and flowering of tomato seedlings. *Acta Hort.* 956 : 264-266.

Olle, M. and Virsile, A. 2013. The effects of light-emitting diode lighting on greenhouse plant growth and quality. *Agr. Food Sci.* 22 : 223-234.

Stutte, G.W.,Edney, S. and Skerritt, T. 2009. Photoregulation of bioprotectant content of red leaf lettuce with light-emitting diodes. *Hort Science.* 44 : 79-82.

Tibbitts, T., Morgan, D. and Warrington, I. 1983. Growth of lettuce, spinach, mustard, andwheat plants under four combinations of high-pressure sodium, metal halide, and tungsten halogen lamps at equal PPFD. *J. Am. Soc. Hort. Sci.* 108 : 622-630.

Trouwborst, G., Oosterkamp, J., Hogewoning, S.W., Harbinson, J. and van Ieperen, W. 2010. The responses of light interception, photosynthesis and fruit yield of cucumber to LED lighting within the canopy. *Physiol. Plant.* 138 : 289-300.

Wollaeger, H.M. and Runkle, E.S. 2014. Growth of impatiens, petunia, salvia, and tomato seedlings under blue, green, and red light-emitting diodes. *Hort Science.* 49 : 734-740.