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AN OVERVIEW OF LED LIGHTING IN AGRICULTURE FOR THE GROWTH AND DEVELOPMENT OF PLANTS

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Abstract

The overall aim of the work was to investigate the applicability of solid-state or semiconductor LED lighting technology in plant growth. This is accomplished by an extensive review of related research work conducted so far and of the results gathered from the growth tests performed. The work is concerned with the basic concepts regarding the photosynthetic process in plants growth with artificial lighting. Comparative study of light generated by conventional light sources and modern LED light sources is also elaborated in this paper.

Keywords:
Artificial Lighting,
Photosynthesis,
Light Spectrum,
Luminous Efficiency etc

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Introduction

Today, the world is at doorstep of technical revolution, and this technical revolution is touching and changing every aspect of human life. The most important thing required for human beings is a food; varieties of plants are used as food in our daily life such as salads, vegetables, pulses, grains etc. so basically agricultural development is also the main focus of the world to fulfill the needs of increasingly growing population of the world in limited agricultural land. Since, due to increasing land requirements of industries, the overall area agricultural land is shrinking. So it is the need of the world that, we should increase yield of agricultural products to fulfill the growing need of food.

Now day's modern technologies are being used in agricultural sectors like automatic farm equipments and modern irrigation systems. Different types pesticides and fertilizers are also used for the fast growth of crops. But extensive use of pesticides and fertilizers results in serious health implications to human beings and environment. So this paper suggests a technical solution to the fast growth of plants. As we know temperature, light and water are basic things required for the growth of plant but light plays the vital role in the growth and development of plant. Solar radiation is the primary source of energy which maintains the life of living things on earth. The spectral waveband of solar radiation is ranging from 300 nm to 1000 nm and photosynthetically active radiation required for plant growth is 400 nm to 700 nm. [1]

Photosynthesis is the process occurring in green plants which uses sunlight and converts it into chemical energy to synthesize nutrients from carbon dioxide and water. Photosynthesis in plants generally involves the green pigment chlorophyll and generates oxygen as a by-product and light energy plays crucial role in process of photosynthesis. This paper suggests use of artificial lighting for the growth and development of plants.

Artificial lighting using LEDs for growth of plants

Application of artificial lightning has been used as light source for the growth of plants incandescent, fluorescent, high pressure mercury and high pressure sodium lamps are the conventional light sources used in the world from the last century. Generally these light sources emit light by heating the metal filament; this phenomenon is known as incandescence. Heat generated by these lamps raise the ambient temperature in the indoor farming, which may affect the growth and quality of plants, to control this heat cooling systems are required which may increase electricity consumption. So the better substitutes for these conventional light sources are LED lights, since LEDs are solid state devices which are

able to emit light from semiconductor diode chip, this light is in the form of electromagnetic radiation which is different from the radiation generated by incandescent lights. The incandescent light source emits radiation due to heating of metal filament but LEDs emit light due to transition of electrons and holes. Although the conventional lamps have capacity to enhance quality, quantity and yield of plants, they all have certain limitations like high power consumption. Modern LED technology has emerged as promising light system for horticulture. This system not only emerged as energy efficient for agriculture but also opened up new paths in the studies of crop response to different wavelengths and quantity of radiations.

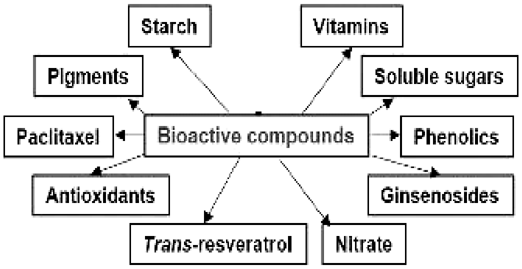
Light Emitting Diodes

LED is a solid state device which works on principle of electroluminescence, constructed by using semiconductor material. Electroluminescence is process of emission of light when electron shifts from higher energy level to lower energy level and radiates excess amount of energy in the form light. The phenomenon is first observed by H.J. Round in 1927 while working with Silicon carbide; In 1955 R. Braunstein observed emission of infrared light from semiconductor alloys. Emission of infrared light from GaAs was accidentally observed by James Biard and Gary Pittman (1961) of Texas Instruments which patented by them as semiconductor radiant diode" in 1962 and this was the first light emitting diode, In the same year Nick Holonyak Jr. discovered the world first LED producing visible light using a gallium arsenide Phosphide (GaAsP). [2] M.G. Craford, student of Holonyak discovered GaAsP based yellow LED; In 1994 Shuji Nakamura designed high-brightness blue LED fabricated by using Indium Gallium Nitride, this newly designed diode had peak emission wavelength of 450 nm, which is found to suitable for use in studies of plat growth and development. Various semiconductor materials were used on the basis Holonyaks GaAsP model to design red, green, blue, and white LEDs. Evolution of LEDs is given in following table.

1960-70		**1970-80**		**1980-90**		**1990-2000**	
GaAsp	Red	GaAsp:N	Red, Yellow	AlGaAs	Red	AlGaInP/GaP	Red, Orange, Yellow
GaP:Zn,O	Red	GaN	Blue	-	-	InGaN	Blue
GaP:N	Green	-	-	-	-	-	-

Table.1

Photo synthesis the base of food production and this process is modified in to plants grown in to artificial lights. It is observed from numerous studies that controlled amount of light enhances the postharvest quality and shelf life of crops; it also enhances the nutrients and bioactive compounds production. Bioactive compounds in plants are known as primary or secondary metabolites, UV radiation can be used generate secondary metabolites to give aroma, color and taste to the plant. [3] In comparison with the UV, visible light also works as bactericide to enhance food safety and preservation, but these conventional light sources generate excessive heat, that effect on growth and development of plants. It is observed that red light is more effective in improving the photosynthesis compared with blue and green light. For example red light exposed to grape plant in green house increased leaf area. Combination of green and red light is more effective than monochromatic red light; it gives better excitation to the photoreceptors resulting in higher photosynthetic activity as compared with the monochromatic blue or red light. [4]



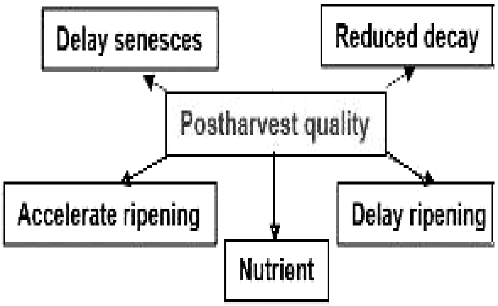


Fig.1

Fig.2

LEDs are the light sources that emit the light within narrow bandwidth having high photon flux and minimum thermal effects. Also it is very convenient to integrate LEDs In small electronic systems. Robustness, compactness, and long half-life are the additional characteristics due to which these types of systems are becoming popular and cost effective.

It is also observed that quality of light affects the photo-oxidative properties of plant by changing the photo-oxidative defense system. LEDs can also be used to improve plant biomass and nutritional content, narrow bandwidth LEDs can accumulate volatile compounds which related with aroma and taste of the flowers and food.

These characteristics of LED make it useful in agricultural applications. Following are factors of artificial lighting system that affects quality and growth of plants. Postharvest wastage of fruits and vegetables can be a challenge for the agricultural scientists but LEDs are now becoming popular as a tool for the sustainable practices. Single spectral blue light reduces the post harvest decay time in fruits when compared to the dark conditions. [3] Particular wavelengths of light like wavelength of Red, Green and Blue can generate resistance in crops against the various diseases. The use of single spectral blue and red light resulted in tremendous improvements in yield and quality of vegetables and fruits compared with white and fluorescent light. Studies conducted during early 1990’s concluded that LEDs are useful in plant growth in space also, the main reason for this application is energy efficient potential and the fact that percentage of non-photosynthetic emission of LEDS was very low as compared with conventional lamps.

Different features of light sources such as luminous efficiency, Spectral quality, power requirement, robustness, heat emission and ease of implementation and disposal with respect to plants is discussed below.

Spectral Quality

Availability of proper and sufficient amount of light plays the vital role in growth and development of plant. Incident spectrum and photon flux density are factors that maintains the plant growth. Generally red, infrared and blue light from incident spectrum is utilized by plants for the process of photosynthesis. LEDs are monochromatic light sources which can emit light with specific wavelength, as we know variety of LEDs are in the market with different colors and wavelengths, so it is possible to use wide spectrum of light in plant growth, LED artificial lighting offers peak wavelength emission that matches with the absorption peak of photoreceptor. Thus it possible to built LED panels with different controls such as intensity control.

Luminous efficiency and Power Requirement

A truthful conversion of electrical energy in to light is energy is very important factor in selection of light source, which is known as luminous efficiency, it is measure of luminous flux generated by lamp per watt electricity consumed (lm/W). Power requirement of lamp is known as electrical power in terms of wattage required by the lamp. Luminous efficiency is applicable only when spectral output is in visible range. Thus light sources those are able to emit infrared and ultraviolet light would have lower luminous efficiencies. HPS and Metal halide lamps are having highest luminous efficiencies but power consumption of these lamps. Advancements in LED technology is giving rise to the LED lights with better efficiency and power required by LEDs is relatively low compared with conventional lamp.

Lamp type	**Spectral output**	**Luminous efficacy (lm/W)**	**Power requirement (W)**	**Life span (h)**
Incandescent	Broad spectrum	20	15–1000	1000
Fluorescent	Broad spectrum	100-120	5–125	1000–30,000
HPM	Broad spectrum	60	100–250	10,000–20,000
HPS	Broad spectrum	80–125	35–1000	10,000–30,000
Metal halide	Broad spectrum	100–120	35–400	10,000–20,000
LED	Specific wavelengths	80–150	0.1–5	>50,000

Table.2 [2]

Heating of lamp

Conventional lamps are able to emit light by heating up the metal filament due to which a desirable amount of light generates. Excess heat exposing to plants is hazardous for their growth and development. Incase indoor farming this heat generated by lamp increases load on cooling systems used for maintain ambient temperature. Like all other conventional lamps LEDs also generate heat, when electricity is applied to it, but the amount of heat generated by LEDs negligible as compared with conventional lamps

Robustness and Safety

Size and robustness of lamps is also an important factor in artificial light farming, small size lamps occupy very small area which provides more space for the growth of plants. Conventional lamps consume relatively more area due to the way of their design where it is fitted in to outer fixture with inner reflective coating. LED is the device having very small size constructed within very small reflective cavity, thus it is not only robust but also easy to handle and having greater life span than conventional lamps.

In this way, the artificial lighting system allows us versatile control of light intensity and spectrum. Ultimately, the control of biotic parameters such as CO2 concentration, temperature, daylight availability and humidity could be also integrated within the same control system together with lighting for more controlled environment in the green house farming, optimizing the crop productivity and the overall management.[5]

One of the major limitations of this technology is that, the spectral condition of each and every crop is unknown. Several factors, including enhanced luminous efficacy of LEDs, field use efficiency, manufacturing cost, and energy consumption, will determine the future of its use.

Conclusion

Plants need light with the wavelength in the range of 400 nm to 700 nm for the process of photosynthesis. Various research studies stated plants grow and develop more efficiently with

LED or artificial light sources than conventional light sources. Red or blue or combination red and blue light gives more efficient environment for the growth of plants.

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