“ Fabrication of Artificial Lighting System for Orchid Culture ”

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Physics

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DECLARATION

I, Parminder Singh, hereby declare that the work which is being presented in this dissertation entitled "Fabrication of Artificial Lighting System for Orchid Culture" in partial fulfilment of the requirements for the award of degree of Master of Science in Physics from Thapar Institute of Engineering and Technology (Deemed University) Patiala, is an authentic record of my own work carried out under the guidance of Dr. Soumendu Jana. I have not submitted the matter presented in the dissertation in any other university/institute of the award of any other degree.

DATE: 02-08-2018

Parminder Singh

Signature of the student

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This is to certify that the above statement made by the student is correct to the best of my knowledge and belief.

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ABSTRACT

As a replacement to conventional lighting system, LED has been demonstrated to be an artificial lighting source for controlled environment agriculture. LED lighting systems have a number of advantages over other lamps currently used in the controlled environment agriculture. One is the ability to control the spectral output of the lighting system, which something not easily done with broad spectrum sources like florescent lamps or other lamps. The ability to control the spectral output can also be used to influence the plant morphology. Special lighting modes might possibly even be used to enhance disease or injury visualization. The LED lighting systems can be configured to produce very high light levels (well in excess of full sunlight if desired), but even at high light outputs, they can be operated in close proximity to plant tissue because they have very low radiant heat output when cooled properly by suitable methods. LEDs have a very long operating life; current LED technologies are rated as maintaining 70% of their original luminous output after 50,000 h, and this is probably a constant number as long as the devices are cooled properly by suitable methods.

In Orchid Flowering Culture, two types of flowering techniques are used, single story and multi-story. When using artificial lighting, uniformity and constant quality of the light spectrum is very important for a constant quality of flower production. By varying light intensity and color ratio, the best recipe for the orchids was found. The growth of a plant is strongly determined by the total number of photons that it absorbs in the PAR region. In winter there is often too little natural light for plants to grow and continue to produce good flowers and fruits. Orchids like a lot of light, but they do not like direct sunlight. Using artificial lighting for orchids gives you the advantage of being able to control the light better and apply strong light that is not as strong as sunlight. Lack of flowering in common household orchids is often a problem of low light conditions. LED circuits can be designed in series or in parallel positions. Several LEDs can be connected at the same time in a series. Such a design prolongs the battery life by lighting several LEDs with the same current as just one LED. So we prefer series connected LED circuit panels.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Although humanity's quest of civilization dates back to antiquity, it was not until the latter half of the last century that developments were being made possible due to the advancements in the areas of electronics and semiconductor physics. Light play a main role in regulate plant germination and development. The quality of light and intensity of light and also the photoperiod are very crucial for growth of plant. But the sunlight is not as sufficient for the cultivation of the plants. The photo-oxidant changes given by lighting situations (sunlight) may lead the action of anti-oxidant protection system. So like other parameters, light is also playing a big role in rich plant cultivation. In last 20-30 years, there was huge research on plant tissue culture done by various scientists. The approach of the controlled environment agriculture in greenhouses and other closed plant production system has emerged as a good and sustainable alternative means of the crop production. Orchids are one of the broad and most alluring families of plants which has more than 900 generations, with over 26,000 species, and these are broadly distribute in all world. In forest conditions, production of orchid flower is too slow. It takes many years to obtain only a single flower specie. So, it is an urgent issue to follow suitable approach and paths to beaten this problem.

1.2 Role of Artificial Lighting System (LED) in Controlled Environment Agriculture

The light source mainly uses in tissue culture and horticulture is fluorescent light lamp, metal halide lamp and other lamps. From all these lighting systems, fluorescent lamps are most popular then others. We know that, given lighting systems gives a very wide range of wavelength from 360 to 740 nm and gives very less standard of light to plants. They emit light of very low PPFD and having less lifetime which decrease their effectiveness in plant tissue culture and horticulture systems when the main motive is to make more production. Very fast

improvement of the LEDs technology is to uses of new types of semi-conductors and to possible the implementation it into the area of Tissue culture and Horticulture. [1]

1.2.1 Why LEDs?

As a replacement to previously used light systems, LEDs are the best source of light among all the lighting systems which are used in previous years. In tissue culture and horticulture, LED light systems have many advantages over traditionally used lighting systems. The main advantage is to control the spectrum of the output light intensity, which is not easily applicable on the previously used lamps like Fluorescent lamps. This ability of LEDs is very useful in the treatment of diseases in a plant cultures. When a system require, a LED lighting system produce the light of very high intensity with very low heat production. So it is very easy to solve this low heat production problem. The lifetime of a LED is very long with compare to the traditional lamps. LEDs are maintain their 70% of actual output after 50,000 hours and it is further expand the life time of LED with help of suitable techniques of cooling.

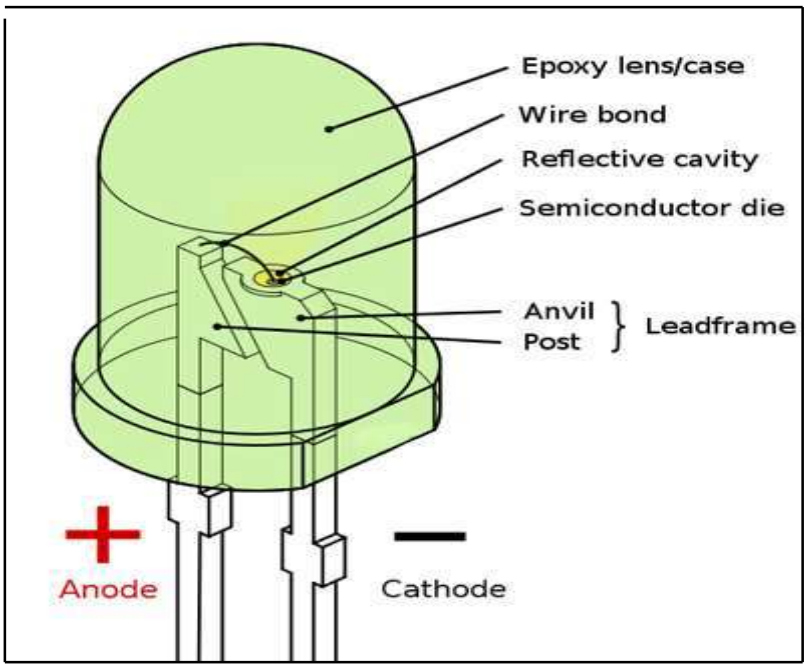

Figure 1.1: Basic schematic diagram of a simple Light Emitting Diode (LED)

The current drive through and temperature of the junction of LED are then main components of the lifetime of a LED in many conditions. LEDs show instant action on any on or off input. LED do not need any time for warmup and turn on instantly. LEDs are easily programmed through digital control system and integrate into it. This quality of complex controlling is not proposed by any other lighting device. LEDs can continuously varying in between low to high and custom the spectrum of output and give sunrise and sunset like conditions to plants. Configuration of LEDs is also set for control the particular zone of the panel of LEDs [3]. In the area of horticulture, the price of one lamp is very high because Horticulture needs very high output intensity bulbs as a lighting system. So LEDs reduce the cost of replacement, labor, heat production etc. in the Horticulture system, because in LED system no replacement is need.

1.2.2 Role of wavelength of light in plant propagation

In large scale plant production it is very necessary to optimize the lighting pattern. LEDs need very low electric current to on and this is very high in case of Fluorescent lamp and other lamps. So, the electric energy need to operate a lamp is equal to the energy need to operate too LEDs at one time. It is nearly three times more light is given by LEDs as compare to lamps at same operating voltage. For large scale production more research in need to reduce the power consumption of LEDs.

All types of LEDs emit light wavelength between ultra-violet to infrared and more, and a plant only deal with wavelength of range 400 nm to 700 nm i.e. red and blue colors are optimized by plants. Blue and red light is suitable for the plant production because these lights improve chlorophyll production and prevent from many diseases. On the other hand red light is need for germination of the flower and growth of the plant. We use tuner for tuning the wavelength of the LED's according to requirement of plant. [4]

In early years LEDs are used as power indicator of the light and when the advance study is done on this and now a day, the LED lights have very high intensity of light. Red color LED is developed in early years but blue color LED is invented recently. Without blue light it is very difficult to make a lighting system, but now by using blue LED lights we fabricate a suitable lighting system for Tissue culture and Horticulture. A plant needs combination of red and blue lights and other then these colors no color is need except special need. So, plants need only 450-

500 nm and 630-700 nm wavelengths for propagation. Current studies gives a fact that a plant or a flower is propagate under the effect of LED lighting system.

1.3 Applications of LEDs in Controlled Environment Agriculture as Light Source

The important application of the LED is that it emit light intensity in very small range of wavelength. Now a days LED systems for plants, capable to a control of spectrum of emitted light from the LED. But it is possible to mix all the wavebands, from violet to far-red light i.e. all lights are mixed in one light. Both spectrum and PPFD can also adjusted to physical needs of plant tissues, therefore the LED light is used because of very advance applications in comparison with fluorescent, sodium lamps or other lamps.

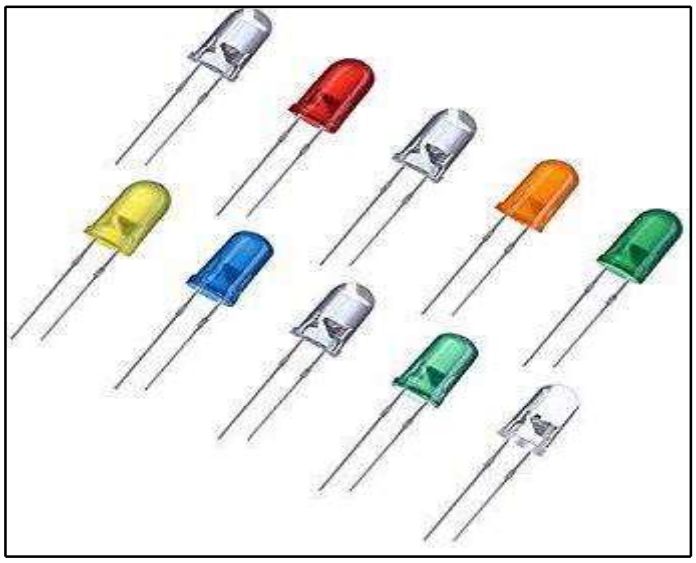

Figure 1.2: Main advantage of a LED i.e. it is available in so many colors.

1.3.1 Selection of suitable light treatment

It is very interesting thing to choose the perfect LED for the plant growth and germination. LEDs having very long lifetime as compared to other lighting sources. Among too many light sources,

most popular source of light in orchid flowering culture is fluorescence lamps with white light having a very vast range of wavelengths (350nm to750 nm). The maxima in the light spectrum of other lighting systems are not same as the spectrum required for the plant. This need is designate by absorption spectrum of light intensity which is suitable for the photon receptors of plant i.e. chlorophyll and carotenoid. Therefore, the most appropriate source of lighting for plant tissue culture and horticulture is light emitting diode (LED) specially red color and blue color LEDs.

1.3.2 Concept of Photo-synthesis Photon Flux Density

We know that in previous years the concept of artificial lighting system is main topic to study in controlled environmental agriculture. So the intention is paid to efficiency of light. In LED lighting system, there are many complications like energy consumption, supplementary lighting etc. and these complications are increases the cost of production. The concept used to determine the efficiency of light is called Photo-synthesis Photon Flux Density (PPFD). [5]

Now a days, LED panels are mostly applied to operate growth and germination of all species produced in tissue culture and horticulture. These LED made to a control the spectrum of light intensity which is emitted. Therefore the LED lighting is used in comparison of other lighting systems like HPS bulbs. Due to advancement of LED technologies and the knowledge about effect of quality of light on the production and growth of plant, LED systems are suitable for orchid flowering culture lighting system. But in case of greenhouse system, natural light is fall on the plants, given by the artificial light system daily about 16 to 17 hours every day with the intensity from 80 to 1900 μ mole m^{-2} s^{-1}. This is not an efficient lighting system in norms of orchid culture. So here we divert the concept of Orchid Culture from Greenhouse system. [6]

Orchid flowering plant needs a constant duration lighting about 16 to 17 hours per day. So it is also very important to slow down the transformation of lighting to darkness. It is very interesting area to research to select suitable lighting treatment to Orchid flowers because fabrication of this type of lighting system is very difficult. Like horticulture the Orchid culture also need photoperiod of 16 hours every day and light intensity around 50 μ mole m^{-2} s^{-1}. So, because of the required light intensity is different than greenhouse, the results for Orchid culture is also very complicated then greenhouse system

.

Figure 1.3: Basic model of Orchid Flower propagation by using LED panel.

The whole arrangement of LED lights is also effect the plant production of a system. Another thing which is most effect the plant growth is Light, manipulates its production and germination. Plants are very sensitive about wavelength, quality and lifetime of the light. The other factors affect the plant growth is direction, diffraction and distance of the light source. Time duration of lighting system in every day is also effect the growth of a plant. The circuit of LED panel is designed in any manner i.e. either in series or parallel circuit.]: LEDs are produce very low heat and therefore the are set very close to the canopy of plants and perfect for intra-cover lighting.

The previous researches done on the Orchid Flower culture is indicate that the direct sunlight is no sufficient for the growth and germination of the flower and it is very important to resolve the lighting conditions for a good germination of the flower.

CHAPTER 2

LITRATURE SURVEY

2.1 Literature Reviews

Light emitting diodes gives very high intensity of light with very low heat production. In all controlled environmental agriculture systems i.e. Tissue culture, Horticulture, Orchid culture etc. are operate under LED lighting system due to very low heat production. These LEDs are placed near to the plant by making its panels. The complications about the spectrum of light intensity are also removing by the LEDs. But it is not specifically described till now what is the response of a plant on the various colors of the different wavelengths. So it is an open issue for further research.

Different color of light gives different effect on the germination and production of flower in Orchid Flowering Culture. Most of the researches give the idea that red and blue light is most important for the suitable lighting system. Plants don't need green light in the lighting system because green color is not absorbed by plants. It is also because of the green color of the leaves. With help of LEDs, the flexibility is achieved in light spectrum, transformation of light from low to high intensity and many other manners. Economically, LED is the best lighting system for the production of plants and flowers. It decreases the cost of production in all controlled environment agricultures. So, more study is required on the topic of the effect of LED lights on different flowers and plants. For example; Orchid Flower.

Batschauer A, (1999) [7]: Plant, as a organism, is specially effected by surrounding. Another thing which is most effect the plant growth is Light, manipulates its production and germination. Plants are very sensitive about wavelength, quality and lifetime of the light. The other factors affect the plant growth is direction, diffraction and distance of the light source. Time duration of lighting system in every day is also effect the growth of a plant.

Zeidler et al. 2013, Watanabe 2011 [8]: The sufficient light is needed to a crop for its growth in agriculture. Traditional lighting systems produce very big amount of heat. To remove this heat we need air-conditioner. So generally we consume about 30 to 40% cost only for enlighten the plants.

Tokuno A, Ibaraki Y, Ito S, Araki H, Yoshimura K, Osaki K (2012) [9]: LEDs are produce very low heat and therefore the are set very close to the canopy of plants and perfect for intra-cover lighting. In this lighting system the light source is set inside of the cover of plant, e.g. tomato production.

Tewolde FT, Lu N, Shiina K, Maruo T, Takagaki M, Kozai T, Yamori W (2016) [10]: All the complications about the spectrum of light intensity is solved by the implementation of LEDs in Tissue culture and Horticulture. LEDs having very narrow range of wavelength and very high intensity. A particular wavelength is used to do a particular work. For example, Violet-Blue LED light is used to protect plants from many diseases.

Ibaraki Y, Shigemoto C (2013) [11]: The whole arrangement of LED lights is also effect the plant production of a system . Another thing which is most effect the plant growth is Light, manipulates its production and germination. Plants are very sensitive about wavelength, quality and lifetime of the light. The other factors affect the plant growth is direction, diffraction and distance of the light source. Time duration of lighting system in every day is also effect the growth of a plant. The method used to find out the efficiency of the light in highly related to the bio mass.

Zeidler C, Schubert D, Vrakking V (2013) [12]: Zeidler published a research on the economic and technical point of view to build a multi-story farms. He give the idea that, when we arrange all canopies in vertical manner then the annual production cost is reduced about 30% and electricity cost is reduced by 60% approximately.

Dutta Gupta and Jatothu 2013 [13]: The spectra and PPFD can be manipulate as required by the plant, so due to this LEDs are more promisingly used in the Tissue culture and Horticulture with compare to HPS and Fluorescent lamps. Also LEDs generate less heating effect then other systems. Because of this we place LEDs very close to the plant without any risk of damage.
This is why we use LEDs as priority.

Luan et al. 2015 [14]: A low intensity light of blue color is required to produce an Orchid naming Paphiopedilum-delenatii with compare to combination of red and blue color light.

2.2 Gapes in Current Research

In current days, LEDs are used in all Controlled agriculture systems and it gives very advance researches in area of Orchid flowering with comparison to other lighting techniques. With the help of LEDs we obtain Orchid flowers with help of Tissue Culture technology. It is very important to adjustment of spectrum of the light intensity of LEDs as a plant requires. It is also a big issue to increase the rate of growth of flower in Orchid culture.

2.3 Objectives of Thesis

Fabrication of artificial lighting system for Orchid Culture.

CHAPTER 3

FABRICATION OF A SUITABLE LED PANEL FOR ORCHID FLOWERING CULTURE

3.1 Introduction

In this chapter 3, we study the fabrication of various types of LED panels, which are suitable for Orchid Flowering. The performance of the panel is based on the intensity reached on the Flowering spices. In the past the only way to achieve the intensity needed for various stages of Orchid Flowering growth is High-Intensity Discharge Lights. To provide an efficient alternate to traditional lighting in Orchid Flowering in Plant Growth Cabinets, we start using LED lights by making its panels.

LEDs are basically monochromatic light sources and LEDs of all type of wavelengths of visible region are available. So, large verity of light spectra can be obtained in a LED panel by using specific LEDs of suitable wavelength.

3.1.1 Specifications of Orchid Flowering Culture

Getting the right amount of light on the flower is crucial to its development. Much research has been undertaken over the years surrounding the great benefits of the artificial light and the amount needed to encourage the photosynthesis and other growth factors. In the last few years most of the research is in the field has been dedicated towards LEDs and whether they are ready to be applied to the Orchid Flowering Culture. LED is a semiconductor solid state device and having various advantages to the Orchid culture. For example; increase rate of root growth, accelerate flowering, controlling growth of plants and it is very economical in electricity and space manners. In winter session, where the sunlight intensity is quite low, LEDs show best results in these conditions. [15]

3.1.2 Basic concept of LED panel

In Orchid Flowering Culture, two types of flowering techniques are used, single story and multi-story. When we use LED light system, uniform and constant light intensity of lighting system is quite important for regular production of plants and flowers. When we vary intensity and ratio of colors, the most appropriate light combination is found. The propagation of flower in Orchid culture is depending on PPFD. In winter session the intensity of sunlight is very low as compare

to normal days. With help of LEDs we can produce good quality of flowers and fruits. In orchid culture, a flower needs very much amount of light, but not sunlight. So, we need artificial lighting system for Orchid flower for more advances in light controlling and duration of light. In domestic level, orchids are not propagated properly. It is because of very low quality of light from lighting system. The circuit of LED panel is designed in any manner i.e. either in series or parallel circuit. But it is very economical in electricity manner to use LEDs in series. In series circuit, the lifetime of the battery is increase because this circuit is consuming electricity equal to a single LED. So we prefer series connected LED circuit panels.

An LED panel was fabricated using 100 LEDs. The LEDs are of two types: Red and Blue. So, red light is encourages flowering in the Orchid culture and blur color light is encourages fruit growth. The light recipe of these light systems is best and suitable for propagation of flowers in Orchid culture. An LED panel of dimension 15×15 inches was fabricated by using red and blue LEDs. PPFD is another interesting parameter in artificial lighting system. It's a big challenge to maintain PPFD in this LED panel fabrication. When we use low voltage LEDs then the light intensity reaches at canopy is of low PPFD. So when we use high voltage LEDs then the electric energy consumption is increase. Then it is more important to use suitable LEDs which give sufficient PPFD to canopy. PPFD required for basic Orchid flower is about 50 μ mole m^{-2} s^{-1}.

3.2 MATLAB Analysis

We design the panel by using MATLAB programming to ensure uniform intensity fallen on the each and every plant. By changing the difference between two LEDs we program its quantity of intensity fallen on the plant surface and make different graphs of different LED panels. The equation used in program is as follows:-

$$\varphi = Ae^{-\left(\frac{(x-l)^2}{a^2}+\frac{(y-m)^2}{b^2}\right)} \quad \text{……..(1)}$$

In MATLAB programming the parameters used are as follows:-

- x,y = Dimensions of the LED panel.
- l,m = Difference between two consecutive LEDs in two different directions.
- a,b = Profile Width of a LED light intensity spectrum on the x and y axis respectively.
- A = Amplitude of the spectrum of LEDs.

3.2.1 Comparison of graphs

Now by changing the difference between two adjacent LEDs we plot graphs by using MATLAB programming we plot different

(A) When l=2 and m=2

When we take l and m values equal to 2 then graph plotted by MATLAB programming, which is given below:-

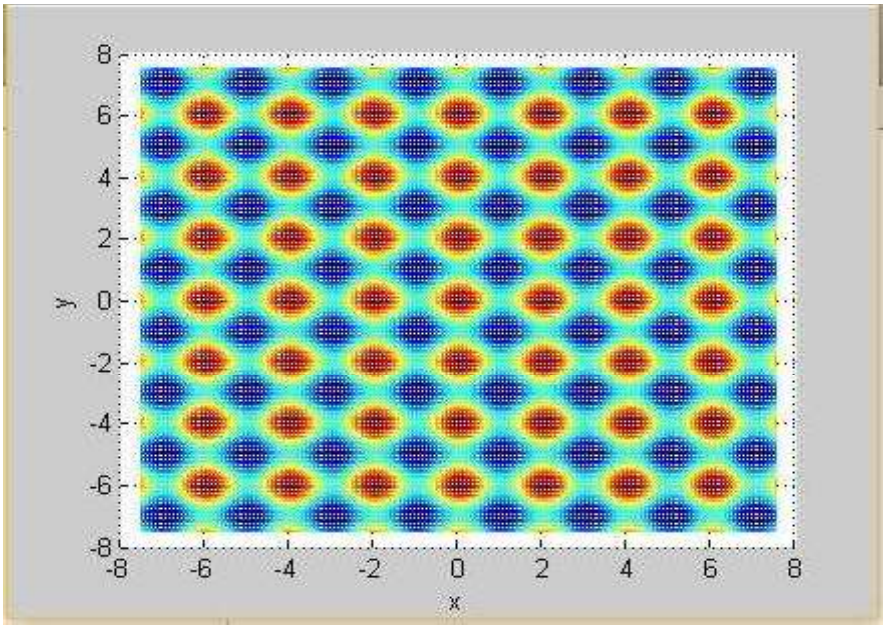

Figure 3.1: When l=2 and m= 2

Now when each LED is 2 inches far from adjacent LEDs then the graph plotted by the MATLAB programming is as shown above. It is very interesting to see the graphs shown by the MATLAB programming. The intensity spectrum shown by the values of l and m is not as sufficient as we required in the Orchid Flowering Culture. We can see that the intensity reaches on the surface of the tray is not as uniform as which is required. In plot, the dark red color indicates very high intensity of light and bluish green color indicates low intensity of light which is reaches at the surface of the tray.

(B) When l=1.8 and m=1.8

Now by using the given values of the l and m graph plotted by MATLAB is as below:-

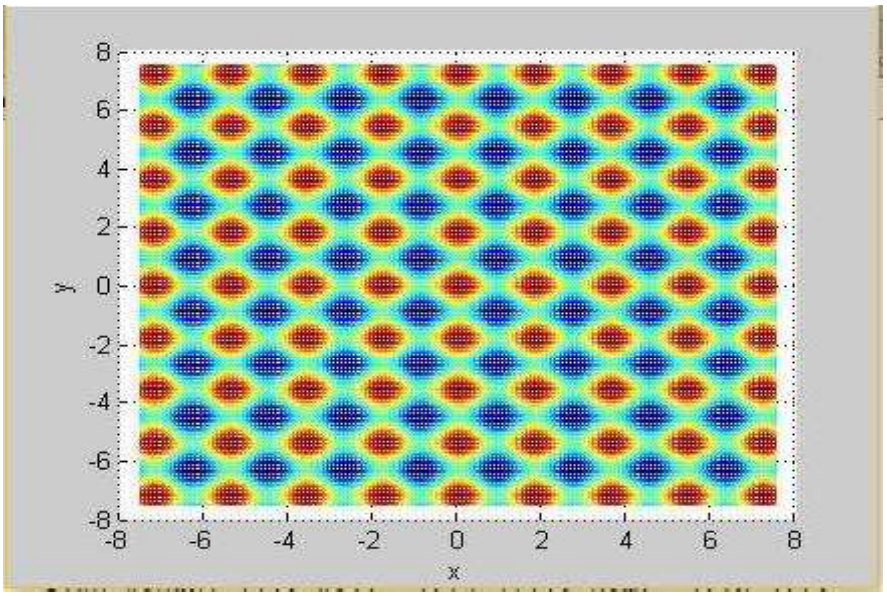

Figure 3.2: When l= 1.8 and m= 1.8

(C) When l=1.7 and m=1.7

By using above values, the graph platted by the MATLAB programming is as given below:-

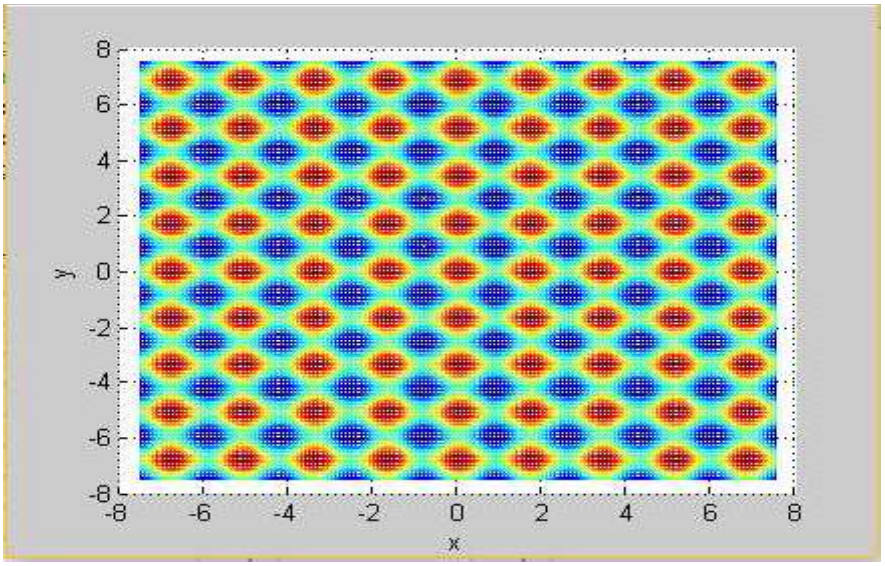

Figure 3.3: When l= 1.7 and m= 1.7

(D) When l=1.5 and m=1.5

By using above values of l and m, the graph plotted by MATLAB programming is as shown as follows:-

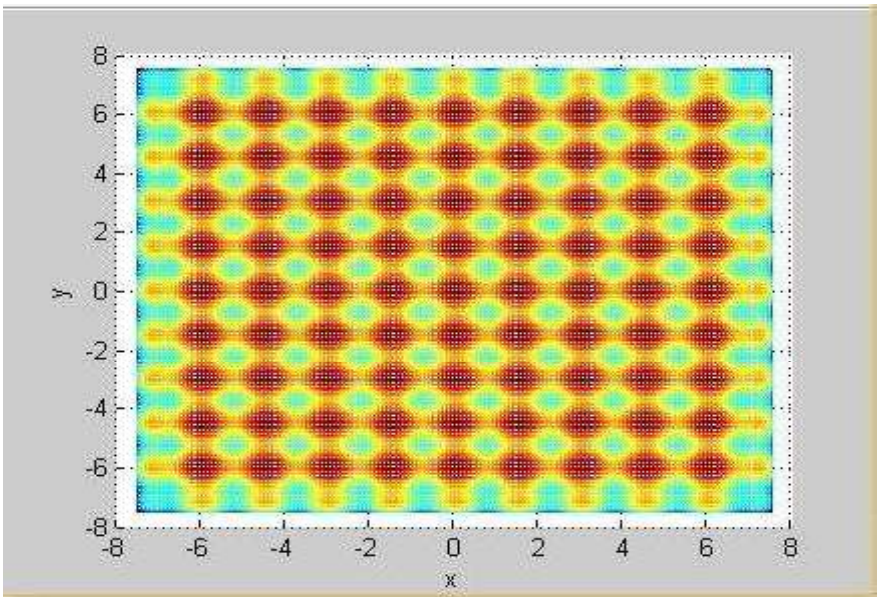

Figure 3.4: Graph when l=1.5 and m=1.5

Now when each LED is 1.5 inches far from adjacent LEDs then the graph plotted by the MATLAB programming is as shown above. We can see that the intensity reaches on the surface of the tray is not as uniform as which is required. So it is a big issue arise in terms of uniformity of lighting system in our panel and it is a very important to deal with this problem in our panel. In plot, the dark red color indicates very high intensity of light and bluish green color indicates low intensity of light which is reaches at the surface of the tray. The amplitude and intensity of a single LED is constant in current condition.

(E) When l= 1.4 and m= 1.4

Now we change values of l and m to 1.4 and then the graph plotted by MATLAB by using given values is as shown below:-

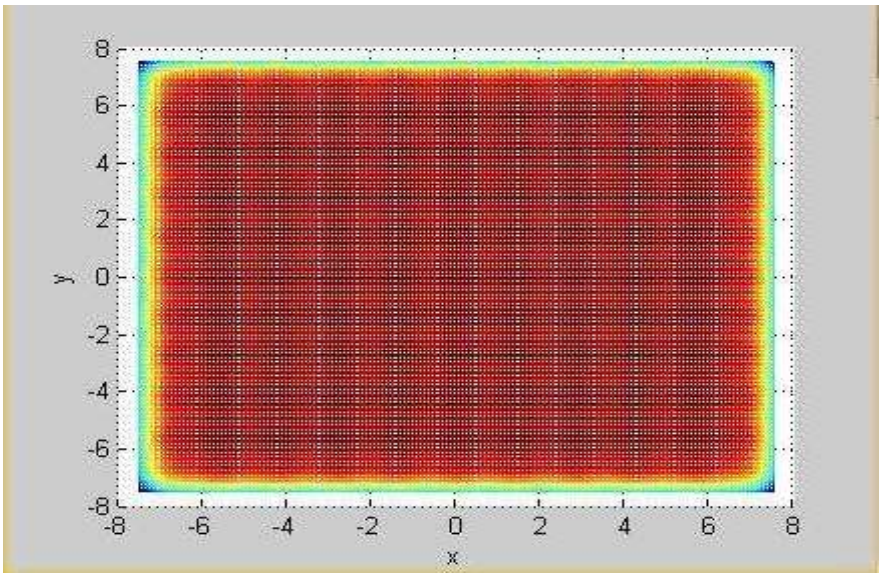

Figure 3.5: When l= 1.4 and m= 1.4

We can see that the intensity reaches on the surface of the tray is nearly as uniform as which is required but not accurately.

.

(F) When l=1.3 and m=1.3

The graph plotted by MATLAB by using given values is as shown below:-

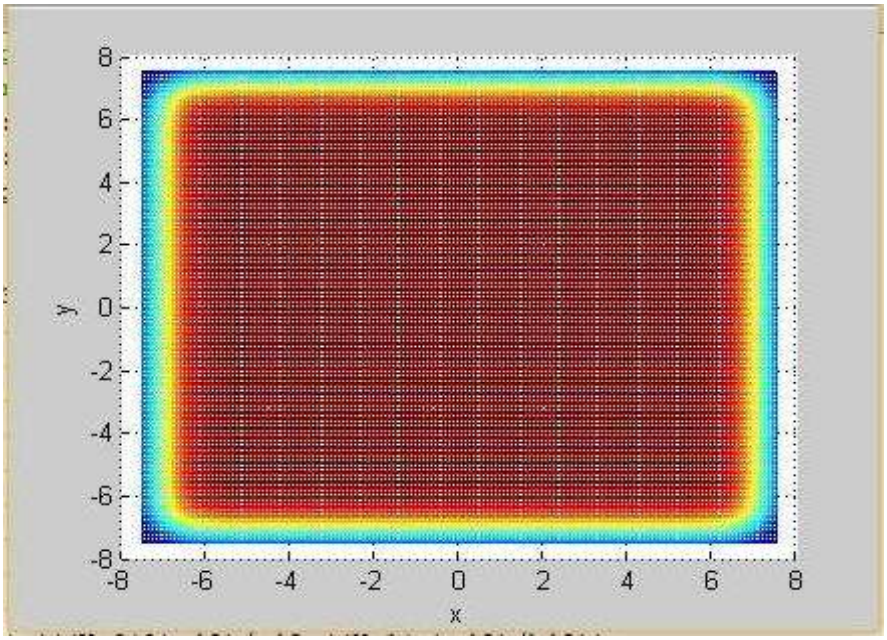

Figure 3.6: When l= 1.3 and m= 1.3

From above graph we can see that when we reduce the difference between two adjacent LEDs then the uniformity of the light intensity is increase at big scale. It is only because of overlapping of the intensity spectrums of LEDs. It is a big issue to solve. It is like a perfect case for a LED panel because in this case the light which is reach on the surface is uniform and the number of LEDs used is also uniform. It is interesting to see that without increasing number of LEDs we can change the intensity pattern on the surface of tray only by varying the difference between two adjacent LEDs i.e. l and m. But there is a complication arises due to low light intensity at the corners of the tray.

From all previous plots we can see that when we reduce the values of l and m i.e. difference between two adjacent LEDs, then the uniformity of the light intensity is increased in a good quantity. So these plots are very useful to fabricate a suitable LED panel for an orchid flowering culture.

After studying the graphs plotted by MATLAB programming by varying the value of l and m i.e. difference between two adjacent LEDs, we can conclude that, if the difference between two LEDs decease, the uniformity of light intensity is increase. But if we increase number of LEDs in panel then the initial cost of the panel is high. So it is very important to maintain ratio between number of LEDs in the panel as well as light intensity fallen on the surface of the tray.

3.3 Fabrication of LED panel

The previous researches done on the Orchid Flowering is indicate that the direct sunlight is no sufficient for the growth of the flower and it is very important to resolve the lighting conditions for a good germination of the flower. In previous years the Fluorescent bulbs are used to lighting the Orchid flower, but these bulbs are not as good. So we use LEDs by replacing them because of many advantages over Fluorescent bulbs. By using all assumptions we fabricate a suitable LED panel by using red and blue LEDs. When we switch on the LED panel circuit then the combination of two different light colors is fall on the plants. Few pictures of panel are as shown below:-

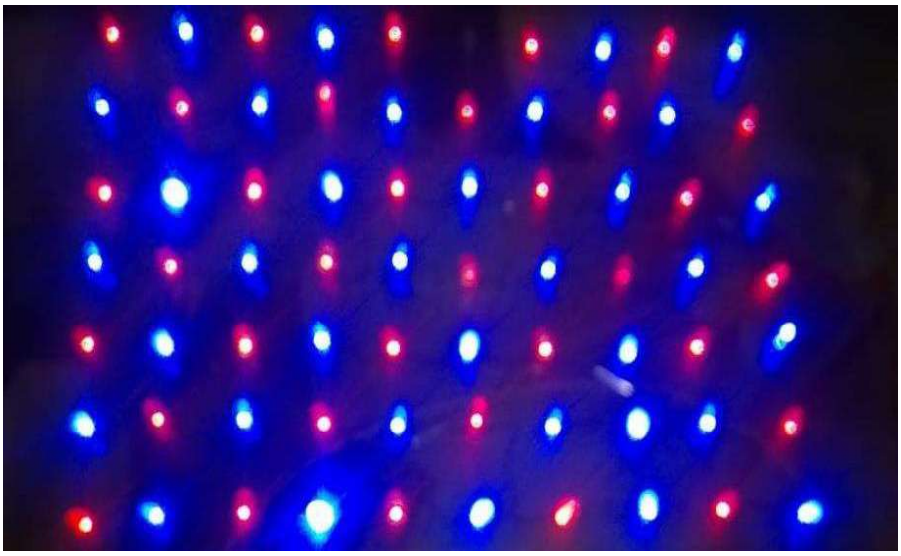

Figure 3.7: Fabricated LED panel picture 1.

The LEDs used are of two types: Red and Blue. So, it is very important to speak that, red light encourages flowering and blue light encourages fruit growth. Light that is strong in these wavelengths is best for growing plants. Plants don't absorb much green light and this is mostly reflected, hence the green color of leaves.

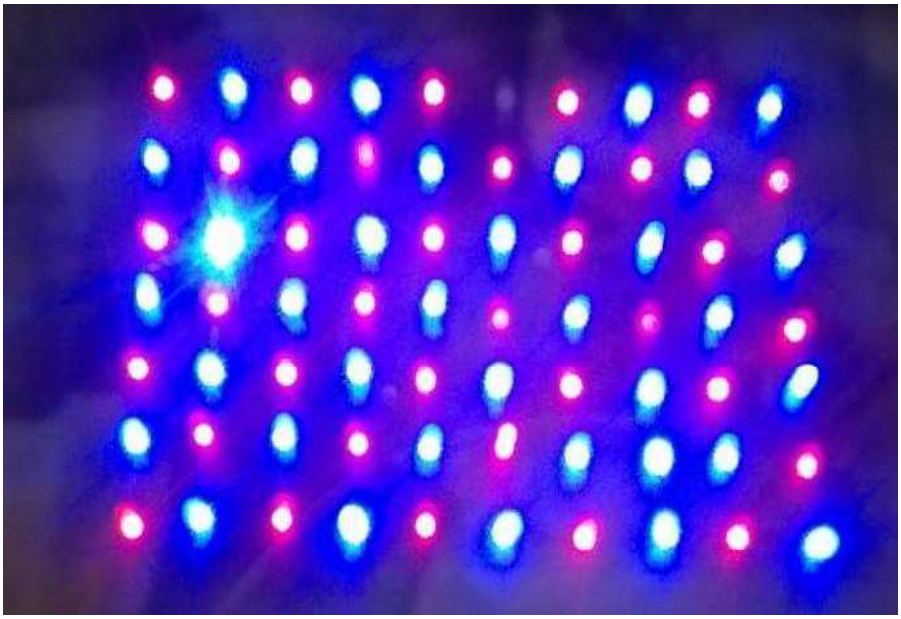

Figure 3.8: Fabricated LED panel picture 2

In this LED panel all the specifications discussed above is fulfilled. So we can conclude that this panel is suitable for the Orchid Flowering Culture.

3.4 Conclusion

To reduce the production cost in Orchid Flowering Culture we use LEDs by removing previously used HPS bulbs, CFL bulbs or other conventional lighting systems. We fabricate LED panel by using red and blue LEDs to reduce the loss of light intensity because a plant is need only red and blue light for propagation and growth for tissue. Moreover, the complications about uniform light intensity are also solved by using MATLAB programming. The requirements on stage specific lighting are lessened by using tuner and manipulate the wavelength of LEDs. These results are very useful in the world of Orchid Flowering Culture. These LED panels are very useful for the Orchid Flower producers in a revolutionary way because, these panels offers many advantages when compared to previous conventional lighting sources in terms of power consumption, heat production, wastage of unwanted wavelengths of light and many other terms.

3.5 Further Scope

In this thesis we fabricate LED panel by using red & blue LEDs and make sure about uniformity of light intensity fall on the canopy. This work could be extended to advance techniques for increase the growth of Orchid flowers. So, special intention is need in this issue. The concept of adjustment of spectral composition of LEDs is also open for the further research. However, further research is needed in the advancement in the light absorption spectrum to accelerate the flowering in Orchid culture. Other than that it is also need a focus on the requirement of other light colors for other issues like enzyme activity etc.

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