Design and Implementation of LED Plant Grow Lamps with Optimal Dimmer

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I. Introduction

In recent years, global warming has caused the global temperature to rise and global climate to change drastically. Every country is desperate to find solutions, especially when food is in insufficient supply. To ensure that demand and supply of crop production is in balance, effective use of greenhouse engineering technique offers our country a great advantage in terms of global quality agriculture and provides a solution with respect to food demand and supply. Meanwhile, the development of greenhouse engineering technique can not only overcome the weather uncertainties but also promote agricultural productivity in districts with limited space, barren fertility and extreme weather.

The advantage of open-type greenhouse system is the radiation environment with natural light. Nevertheless, the season and geographical environment affect the strength of lighting. The use of artificial light source can solve the problem of insufficient light exposure. The drawback of using fluorescent lamps or high pressure sodium lamp as lighting source is high cooling costs. Due to development of photoelectric technology, the design of high brightness LED has progressed in terms of amount of light, luminous efficiency, and priced aspects. This technique can apply to cultivation of leaf vegetables category and utilize the multi-layer cultivation frame to create high production in crop and value in small cultivation space. The ultra-high brightness LED can affect the growth of plant, which includes lettuce, strawberries, and Phalaenopsis, etc [1].

In recent years, many companies have developed different LED plant grow lamps and multi-layer cultivation frames. However, the integration of plant growth characteristics and analysis of effect of LED light response on plant are lacking. The reliable LED parameter adjustment tool is necessary to develop LED plant grow lamps dimming system. In addition, the use of extra timer can only be used to turn on/off the power of all LED light bar and to adjust the LED photoperiod. The adjustment of light quality and light density ratio is also to be achieved by replacing the light bar or changing the different color LED light bar. However, it can result in huge human cost. Therefore, it is necessary to combine the LED dimming control with computer to achieve the purpose of automated crop production.

The 21st century will be the ecological agriculture, while physical agriculture is one topic of them. How to implement different light fertilizer to achieve regulation of plant growth and increase in production, high efficiency, quantity, disease-resistance, and anti-pollution means a lot for the promotion of the development of modern agriculture.

II. Design Concept

Is LED plant grow lamp environment-friendly in view of its current popularity? Is it beneficial to plant growth on account of the indiscriminating use of high-power and combination of different LED quantity? Is the quality of plant without supplementary light superior to that of plant with supplementary light? Those are the topics that concern scholars and experts. However, it is for sure that the light of physiological of plant is complex and the single use of specific combination of LED light does not meet the demand of plant in terms of its growth. Thus, we are desperate to develop an LED dimming system suitable for plant in each growth period. Nevertheless, it is a pity not to utilize natural sunlight but use LED instead. Consequently, proper use of LED artificial supplementary light is the major purpose to develop LED plant grow lamp control system, which is which is suitable for the growth of plant in different stage.

The use of artificial LED plant grow lamp is effective in leafy vegetables, especially in lettuce which many scholars have claimed in their literature. However, whether all of the LED plant grow lamp is suitable for all plant takes a long time to research and discuss. There are several design problems of LED plant grow lamp in market that can affect the crop production.

1. LED grow light bar: Fixed color temperature and light quality; It is hard to expand or replace the light bar with different light quality. In addition, the light bar consumes all the power of LED under the power switch turned on. It is not suitable for the energy efficiency case.
2. LED lighting controller: No dimming function/ semi-dimming function/function button; extra timer/intra timer; the fixed light quality; the use of digital function on the liquid crystal display (LCD) screen is inconvenient and complex for farmers.
3. The LED bar designer often utilizes different resistance value to adjust light strength. As a result, the excessive heat is generated by the resistance, which results in reduction of LED lighting efficiency and energy consumption.

III. Technical Development

The proposed system consists of micro-chip controller, pulse width modulation (PWM) module, and MOSFET circuit, which are divided into sixteen groups. Each group can control nine sets for full color LED module. The microcontroller module is produced by the MICROCHIP Company and it combines a micro-controller PIC16F887, EEPROM memory chip, serial transmission interface (RS-232), serial to parallel interface (SPI), Inter-Integrated Circuit (I2C) communication modules, etc. The greatest feature of the I2C module lies in the use of communication clock pin and data pin of the PIC micro-controller and the connection of one pull-up resistance to these two signal pins to accomplish the I2C serial data communication interface. PCA9634 IC, produced by PHILIPS Company, can control different IC function and has 16 channel outputs. Digital to Analog Converter (DAC) is used to convert the digital signal to analog signal in order to control the higher power LED module. The C language is utilized to write the control firmware program and the human machine interface is designed by utilizing Visual BASIC language. The hardware and software specification is as follows:

1. LED drive module: It is necessary to integrate light parameters (different light source/ light quality/illumination/wavelength) with LED dimming system to improve experiment efficiency.
2. The LED light bar combines different colors of high power LED which consists of red, blue, and white. The user can adjust different light quality through the setup of modulation value from the human-machine interface in the computer.
3. The high power LED controller with three-loops can control the eight LED light bars and each of them consumes 24W under LED full lighting. RS-232 to USB wire is utilized to communicate LED light dimming with computer.

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4. The LED lighting parameter management: To record and store the experiment parameters into hard disk through the software interface.
5. Hardware and software module can be separated: The proposed technique can setup the LED light parameters through the human-machine interface and have the parameters burned into the microchip. After this process, we can remove the RS-232 communicator interface from the LED dimming controller to achieve the purpose of independent control.
6. The user can adjust 10 sets of LED light quality/intensity on the LED dimming controller.

IV、Technological Competitiveness

The proposed system has market competitiveness shown as follows:

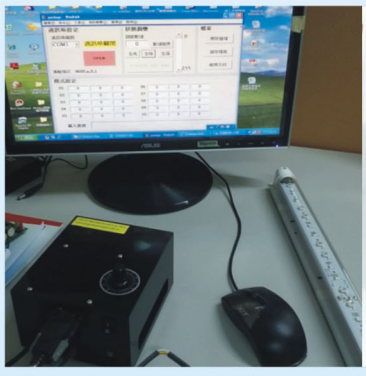
1. Easy to replace the LED light bar in order to facilitate different types of plant.
2. LED light quality ratio optimization: To collect the related LED plant grow lamp literatures from year 2000 and select the best LED light quality ratio to serve as the color of LED light bar.
3. To optimize the LED light quality and density ratio: 10 different light color combinations for LED lighting control.
4. To setup 10 sets of light density and quality ratio through the human-machine interface and analyze the effect of different colors of LED on physiology of plant growth.

V. R&D Result

The above design method takes into consideration the easy operation for farmers to cultivate plants. Thus, we give up the time scheduled human-machine interface [2][3][4], whose drawback is the requirement of one computer. Farmers can set up photoperiod through traditional timer. Farmers only need to open the human-machine interface and set up ten sets of different light quality and density ratio based on expert database and the plant type. Then, the parameter is burned into the controller and then they can do without computer. Afterwards, the ten sets of LED dimmer on the controller are utilized to adjust the required light quality and density ratio. Fig. 1 illustrates the version of completed software development, which can set up different order of modulation so as to reach different LED light quality based on different loop. Besides, this interface can store LED lighting parameters.

Fig. 2 demonstrates the completed product. It shows that we can adjust ten sets of different LED light quality and density ratio through the knob operation on the controller. This product is quite suitable for the research with regards to the plant growth in different stage and is also competitive on market. The research result is successful in cultivating plants such as lettuce. This technique is under application for patent and is feasible in its future application to automated cultivation system.

Fig. 1. The human-machine interface.



(a) Hardware and software appearance

(b) proposed controller appearance

(c) The LED dimming control system

(d) Blue light display

Fig. 2. Proposed LED lighting control system

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