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Design of Multispectral Complementary Light System Based on LED Light Source

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Abstract: In order to meet the light, spectral and environmental requirements for vegetables growth in greenhouses, LED-based multi-spectrum plant fill light fixtures are designed. Its proximity to the desired spectrum is achieved by controlling LEDs of different wavelengths to produce different light intensities. And it forms the LED lamps and lanterns lighting system with the LED light controller, PC and APP software. The replenishment system can be selected from a variety of different wavelength spectra, realizing the functions of free fitting of high-power LED spectra, continuously adjustable light intensity, and free setting of the light cycle, and at the same time realizing precise replenishment according to the needs of different plant species for suitable light environments.

Keywords: Greenhouse; Light; LED; Control system; Vegetables.

1. Introduction

Plants often have to experience complex and changing light environment in the growth process, which directly affects the plant photosynthesis, physiological metabolism and growth and development. Light is one of the basic factors for plant growth and development. And photosynthesis is a key link in plant growth and synthesis of organic matter. Light has a regulatory effect on plant growth and development, morphological composition, photosynthesis, material metabolism and gene expression. The control of plant morphogenesis and growth and development through light regulation is an important technology in the field of plant facility cultivation. Supplementary light is an important means of light environment regulation in the process of facility vegetable production, which can effectively promote the growth and development of vegetable crops, and it is an important choice to improve the yield and quality of vegetable crops through scientific means of supplemental light.

Luminous environment control is an important part of improving the greenhouse environment and a condition that cannot be ignored for vegetable production. Therefore, modern greenhouses commonly use artificial light sources to improve vegetable production capacity and develop light management procedures and comply with them according to the technical characteristics of greenhouse environment, equipment, and light sources. Celery, a vegetable is often consumed by Chinese consumers. According to the characteristics of celery's different light environment requirements at different growth stages [1], LED is used as a light source, and computerized lighting control technology is introduced into the field of greenhouse vegetables to conform to the growth characteristics of celery and design an automated lighting system suitable for greenhouses. The lighting system can be accurately set and effectively controlled according to different light requirements [2].

Ambient light intensity outside the greenhouse is a gradual change from sunrise to sunset throughout the day. Most of the current greenhouse light environment rely on artificial control methods, do not have the ability to automatically adjust the fill light system according to the change of light intensity outside the greenhouse outside, it will result in the light environment light is too strong or too weak, low efficiency and high energy consumption and other issues. In this paper, we design the brightness automatic control system, combining natural light and LED fill light system, in the case of insufficient natural light in the greenhouse, using the dimming system to dynamically control the brightness of the LED light source, so that the greenhouse is well lit, to meet the greenhouse crop for the light demand [3]. We have realized the continuous adjustable brightness, high precision and sensitive response, which can effectively solve the problem of lighting efficiency in the greenhouse, and comprehensively consider the requirements of precision, sensitivity and power consumption. This makes the system has a good application prospect.

2. Lighting supply node

LED is an electroluminescent light source and a semiconductor device that can directly convert electric energy into visible light and radiant energy. Compared with incandescent lamps, low-pressure mercury lamps, high-pressure mercury lamps and other electric lamps, it has the advantages of energy saving and environmental protection, good spectral performance, beam concentration, easy to control, safety, reliability, durability, application flexibility, etc., and it is the ideal lighting appliance [4]. LED is a low-voltage microelectronic product, which has been successfully integrated with the computer technology, embedded control technology, and network communication technology, etc. The LED fill-in light can accurately regulate the quality of the light and the intensity of light, which not only can meet the needs of plant growth and development, but also can significantly reduce the energy compared with other lighting supply source. LED lighting supply can precisely regulate the light quality and intensity, not only to meet the needs of plant growth and development, but also can significantly reduce energy consumption and production costs compared with other lighting supply source. LED has been widely used in the production of facilities in recent years [4].

2.1. LED light distribution

Sunlight is a necessary condition for plants to carry out photosynthesis, but sunlight is so easily constrained by weather, geographic location, time and other factors that it's not purely relying on sunlight meet the lighting requirements of plants. Thus, it is necessary to artificially create a light source to supply light to plants. Because of the spectrum of LED is very full, we can use red (R), blue (B) and violet (P) LEDs for a reasonable configuration, as a supplemental light source to use. Relevant studies have shown that celery has different requirements for the light environment at different growth stages, and red light helps to increase plant height, number of leaves, petiole length, soluble sugar, and reduce the root-crown ratio; blue light helps to increase the mass fraction of soluble proteins and reducing sugars in celery, and to reduce the mass fraction of cellulose and nitrate; and violet light helps to promote the growth of celery, as well as the distribution and accumulation of assimilated products to the nutrient organs.

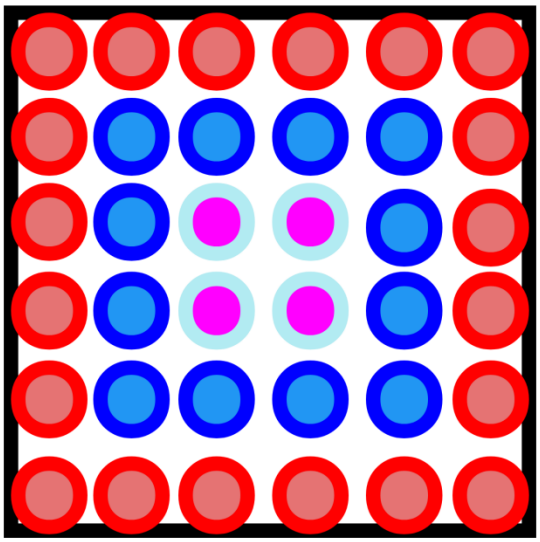


Figure 1. Schematic diagram of LED light distribution

According to the light absorption characteristics of crops and the advantageous features of LED light source, LEDs are used as the light source for crop growth, and then multiple LEDs are assembled and designed to meet the light demand of greenhouse plants. LED light-emitting arrays are difficult to achieve uniform illumination due to the light-emitting properties of LEDs, and unevenly illuminated areas can produce glare or shadows. The LED fixture we designed consists of multiple LEDs combined into an LED array with square planar light distribution, which is uniformly arranged with a combination of 20 red (660nm) LEDs, 12 blue (460nm) LEDs, and 4 violet (390nm) LEDs, as shown in Figure 1. Due to the different colors of different LED driving voltage, 20 red LEDs are connected in series in 4 groups (5 1 group) and then connected in parallel, 12 blue LEDs are connected in series in 3 groups (4 1 group) and then connected in parallel, and 4 violet LEDs are connected in series. Then, through the LED driver circuit of the light-emitting unit of each 1 LED lumen ratio (luminous brightness) to control the adjustment. The light-emitting unit can then emit red, blue, violet and other colors of light, and the brightness and color saturation can be adjusted according to the needs of the greenhouse to meet the crop photosynthesis on the light source needs.

2.2. Drive Circuit

LEDs have the advantages of easy control, fast response, etc., and are very suitable for dimming using PWM pulse width modulation. With pulse width modulation, the intensity of light is controlled by changing the pulse duty cycle of the LED drive current. This is the technique of repeatedly switching the LED driver on and off using digital pulses to control the duration of the high level. The controller realizes the change in the output current of the driver to regulate the LED luminous brightness by generating digital pulses with adjustable duty cycle. LED lights with PWM dimming are characterized by simple operation, multiple dimming levels, no additional energy loss, high luminous efficiency and easy remote control.

The function of dimming driver module is to ensure that there is a stable level output to regulate the brightness of the lighting equipment. PT4115 chips can be converted directly into a DC voltage stable constant current output. Its peripheral circuit is very simple. And it is widely used in the driving of lighting equipment. The main control chip controls the PT4115 drive chips through three PWM signals to realize dimming. The core part of the PT4115 drive circuit includes the input voltage regulator, power MOS tube, LED load and protection circuit, etc. The input voltage regulator is responsible for stabilizing the input voltage to provide stable DC voltage for the LED load; the power MOS tube is responsible for regulating the output current to realize the constant current drive of the LED load; the LED load is the actual LED lamp beads; the protection circuit includes over-temperature protection and over-current protection, etc., to ensure the safety of the circuit and the LED load.

2.3. Drive Circuit

Lighting supply node is responsible for realizing the dynamic regulation of the light environment, uploading the light environment information collected by the data collection point to the main control chip, and realizing the regulation of the light environment according to the amount of lighting supplementation received, so the main work of the lighting supply node is to realize the accurate control of the light environment (light intensity). Greenhouse working conditions are complex and humid, so it is not suitable to use the traditional lighting control system complex wiring construction.

The system selects STC8A as the control chip, and designs the circuit using the illumination sensor BH1750. As the intelligent lighting control system, it has the advantages of good scalability and more functions to realize the fine and intelligent control of LED lamps and lanterns. Illuminance acquisition is the core of the entire intelligent lighting system and the master control chip on the complementary nodes of the regulatory basis. Illuminance sensor should accurately collect the illuminance value of the region in which it is located and then feedback to the master control chip up to the system can operate effectively. Illuminance sensor BH1750 is a digital light intensity sensor for two-wire serial bus interface, through the I2 C data transmission analog signal protocol. BH1750 can be sensitive to detect the intensity of visible light, the direct collection of light intensity, and in the form of data, through the peripheral circuitry will be transmitted to the level of the control chip for processing in order to achieve the control of the LED lamps and lanterns.

STC8A chip controls PT4115 driver chip to realize

dimming through 3-channel PWM signal, and the external Wi-Fi module realizes the communication with the main controller and data collection nodes. Lighting supply controller will upload light environment's light intensity data in which collected by environment node through the Wi-Fi module to the main controller. The main controller gets the light supplement data of the corresponding light supplement node according to the light supplement control strategy and environmental data processing, and feeds back to the corresponding light supplement controller, which then dims the light according to the feedback light supplement.

3. LED lighting control system

The control system adopts Android platform as the carrier of terminal module, and the APP software is designed through Android platform. According to the system requirements, the terminal software needs to realize the storage and setting of light recipe parameters, receive and display the light environment data and light data sent by the main controller, and realize the sending of control commands at the same time. We should separately design data, display interface and business logic [5]

In the main interface of APP, it can realize the remote monitoring of the light nodes, and the monitoring includes the light parameters of the lighting supply nodes (light intensity of red light, blue light and violet light). In the main interface, you can also choose to remotely monitor different lighting supply nodes. And at the same time, in order to facilitate the user to observe and analyze, the historical data interface is designed, so that the user can retrieve the information of the light environment parameters in any period of time and display it in the form of a graph, which is convenient for the user to intuitively understand the trend of the light environment of plant growth. Users can view the trend of different colors of light and understand the light environment parameters of different time periods.

In the light control interface of plants, it is possible to realize the retrieval and setting of plants light configuration. In the plants light configuration interface, the user can select the light formula of the corresponding plant or set the light formula by himself to realize the control of lighting supply node. The workflow is as follows: the Android terminal synchronizes the light configuration parameters selected or set by the user to the cloud database through the Web server, and the Web server sends the light configuration parameters and control instructions to the main controller according to the requirements of the Android client to realize the control of the light supplement node. Users can select the light configuration of a specific plant for light supply control according to the demand, or they can set the light supply parameters by themselves, and the design includes illumination, light quality ratio and light cycle, while the threshold value of the environmental data can be set.

4. Lighting supply experiment

The experiment was carried out in the demonstration site of supplementary light in vegetable greenhouse, and the supplementary light of celery was studied with the designed LED light source, which was divided into two celery production greenhouses. Two greenhouses were used with celery seeds of different varieties, homogeneous soil, homogeneous fertilizers, homogeneous pesticides, the same amount of water, and the same temperature and humidity, etc. Celery in the 2 greenhouses served as a sample for comparison with each other. After the celery germinated, we began to study the effect of supplemental light from LED light source on the growth of celery seedlings. The results and analysis of the effect of supplemental light on the quality of celery seedlings, tracking and moving the comparison sample.

Comparative experiments show that LED light source can promote celery aboveground growth leaf area expansion, make the strong seedling index large and dry matter accumulation more, and improve the celery plant height and plant width.

5. Conclusion

LED lamps are used to irradiate celery at close range and point-by-point irradiation with different wavelengths at different positions in the space, so as to achieve the light supplement effect better than traditional electric light source lamps and irradiation methods by using light sources with less energy consumption. In this way, not only can we realize the light supplementation for the low position of the intensively planted celery according to the need, but also can realize the light supplementation for different parts of the same celery with different kinds of light.

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