Physiological Effects of Artificial Light Environment on Rice in Ecological Landscape

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Abstract. Artificial light sources have been widely used in urban night lighting and country road lighting. Landscape lighting makes plants, buildings and various urban or rural structures covered with prosperous cloaks, and the transformation of light and shadow makes the landscape environment more beautiful. However, while creating a unique lighting landscape, the light source often neglects the influence of its light environment on the physiological morphology of plants. More often, it causes light pollution, chaotic light, and environmental damage. Therefore, this paper reviews the research on the effects of artificial light environment on rice physiological morphology as an example. The design of light source in the direction of ecological landscape should be more in line with the requirements of plant growth, and achieve "material-oriented".

Keywords: Artificial Light Environment, Ecological Landscape, Physiological Impact, Rice

1. Comprehensive Study of Rice by Artificial Light Environment
The light environment mainly refers to the three dimensions of light quality, illuminance and illumination time. Artificial light sources mainly include high-pressure sodium lamps, fluorescent lamps, metal halide lamps, incandescent lamps, LEDs and laser lamps. The comprehensive research on artificial light environment for rice mainly includes: comparative study of different artificial light sources; lateral study under the conditions of light quality, illuminance and illumination time; longitudinal study affecting the content of organic matter and other traits in rice; study of different growth stages such as seedling stage, filling period, heading period, etc. The analysis is summarized as shown in Figure 1:

1) Static research, mainly the study of the physiological shape and organic matter content of rice in the light environment;
2) Dynamic research is to study the effects of light conditions in rice respiration, photosynthesis, lipid metabolism, morphogenesis of seedlings and three-dimensional seedling rooting. The light conditions at this time are changed by the type of rice in the area where the rice is planted;
3) Applied research refers to the optimization of rice growth through artificial light source control, mainly in the production of planting seedlings, plant light fill light cultivation and so on.
2. Light Characteristics of Rice
The light environment affects the series of life processes such as photosynthesis, photomorphogenesis and photoperiod regulation of plants, thus affecting the growth and external quality of plants. When the rice is in the environment of shading, low light, etc., the accumulation of net photosynthetic products is reduced or even zero. The effects of shading on rice yield and grain filling at different growth stages and its performance is shown in Table 1.

Table 1. Effects of shading on rice yield and grain filling at different growth stages

| Period               | Yield                          | Fullness       | Rate of enrichment |
|----------------------|--------------------------------|----------------|-------------------|
| Tiller period        | Reduced production by 17.34%   | Reduced by 3.00% | Reduced by 4.03%  |
| Jointing and booting stage | Reduce production by 41.35%   | Increase by 3.84% | Increase by 9.94% |
| Grouting period      | Production decline reached 53.93% | /              | /                 |

Therefore, suitable light conditions are of great significance to improve the ecological stability of high yield rice. In addition, as an economic crop, it is also used in the landscape (multicolored rice, etc.), and its artificial light environment regulation research also provides a reference for its landscape development.

Rice is a short-day sunshine crop. Saturated illuminance and sufficient illumination hours are important guarantees for increasing rice growth rate, shortening growth period and growth cycle, and improving flowering quality and yield. The photosensitivity of rice means that its photoperiod is controlled by short daylight, and shortening the sunshine time promotes rice panicle differentiation and increases the sunshine time to delay panicle differentiation. Moreover, the photosensitivity of rice varies greatly among different varieties, among which the mid- and late-rice varieties have strong photosensitivity, and the early rice has weak photosensitivity. Therefore, whether rice is used as a field
economic crop or an agricultural landscape plant, the length of artificial illumination should be different with different stages of rice growth.

3 The Effect of Artificial Light Environment on Rice

The light environment consists of three parts: light quality, illuminance and illumination time. Different rice varieties, different rice growth stages, and light environment have different effects on rice growth status and quality. According to Zhang Xijuan et al.: Using LED light source to supplement light to cultivate two varieties of rice seedlings, orthogonal experiments showed that the two seedlings of rice were affected by light-filling factors, such as light quality > fill light time > light intensity. And the impact is significant. In terms of root-shoot ratio, the two varieties showed different performances, and the light factor effects also varied. The effects of light quality on the root-shoot ratio of the two varieties were significant, and the effects of light intensity and fill light time on the root-shoot ratio were not significant [1]. In addition, in the rice experiment of only nighttime light supplementation, Zhang Xijuan studied that the effect of the root-crown ratio of the two varieties on the light-retaining factor is light quality > light intensity > fill light time. Among them, only the effect of light quality on the root-shoot ratio reached a significant level. From the perspective of the strong seedling index, the three factors have different effects on the two varieties of rice, and the light intensity effects are the weakest [2]. It is found that the light-to-light ratio has a great influence on the ratio of root to shoot, and the light intensity has the least influence on the seedling index.

3.1 Effects of Light Quality on Rice

Light quality directly or indirectly regulates plant photosynthesis, photomorphogenesis, material metabolism and gene expression. Different plant species or different growth stages of the same species and different organs respond differently to the same light quality, showing the complexity and diversity of light quality in biological reactions. The light wave band affected by plant growth is visible light of 350-720 nm, and the dominant role is red orange light of 610-720 nm and blue-violet light of 400-510 nm. The red-orange light energy and blue-violet light energy absorbed and utilized account for about 60%-65% and 8%-10% of the physiological radiation of the light source, respectively. Therefore, the light of these two types of bands is a light quality factor that plays a decisive role in the growth and development of plants. And rice leaves have strong absorption and utilization in the vicinity of light wavelengths of 400-500 nm and 680 nm.

![Figure 2. Plant absorption spectrum](image)

Rice seedlings showed inhibition of seedling height under blue light: increased seedling root activity, total absorption area and active absorption area; also regulated the morphogenesis of rice seedlings by affecting chloroplast development promoting organic matter accumulation. Therefore, in rice seedling stage, rice plants are short and strong under single-wave blue light, and the quality of seedlings is the best. LED red light promotes the growth of seedlings, and the number of seedlings and uniformity are better [3]. Rice seedlings under red light showed significant growth of rhizomes and increased soluble sugar and starch content in leaves of the five-leaf stage, which facilitated the distribution of photosynthetic products to vegetative organs. And the activity of intracellular catalase and peroxidase is enhanced.

The difference of other light quality effects on rice showed that the net photosynthetic rate of rice seedlings was different under the same photon number, which was yellow light > red light > green light > blue light > violet light. Yellow light can significantly increase the plant height and leaf pigment content in the early stage of seedling growth. The number of blades is represented by blue light.
illumination > white light > red light = yellow light. The order of absorption of light by rice leaves is blue ≥ red light > yellow light > far red light, and blue light has a wider absorption range than red light. The plant fresh weight ratio is blue light>red light=white light>yellow light, while fresh weight/plant height and appearance are the best blue light. However, more studies have shown that the red-blue complex light is superior to the single-quality light treatment for the growth and development of rice and the quality of seedlings [3], for example, plant height, seedling uniformity, proportion of standard seedlings, increase of number of roots in three-leaf stage, stem diameter, seedling index, root activity and soluble sugar content and the fresh, dry quality, strong seedling index, leaf soluble sugar and sucrose content of the five-leaf seedlings.

The intensity of photosynthesis can be judged by the chlorophyll content that can be passed within a certain range. Among them, chlorophyll a absorbs the peaks of 430 nm and 660 nm, and chlorophyll b absorbs the peaks of 450 nm and 643 nm. Blue light is conducive to chlorophyll accumulation. In general, it is considered that the photosynthetic energy efficiency of green light is equal to zero, but the promotion of green light is stronger than that of red light in the photosynthesis of sunflower. Some scholars believe that the reason may be that green light makes cryptochromes and phytochromes more easily absorbed to initiate photomorphogenesis. Therefore, some studies have attempted to add other spectra on the basis of red-blue composite light, and the results show that it is more conducive to plant growth. Wu Dan [4] and other researches on rice seedlings prefer red light, and the stem diameter, leaf area and white root number of green light rice added after reducing the proportion of red light did not decrease. Increasing the amount of blue light in the light environment and adding short-wave red light 630 nm can make up for the decrease of rice biomass accumulation caused by the decrease of the total amount of red light. The addition of 630 nm short-wave red light and 510 nm green light on the basis of red-blue light mixing can broaden the spectral width, which is more conducive to seedling growth and yield higher soluble protein content and bioaccumulation. In addition, the addition of short-wave red light can improve the scavenging ability of hydrogen peroxide and enhance the activity of the body. Short-wave red light (630nm) not only compensates for the decrease in the activity of these three enzymes due to the increase in the amount of blue light, but also enhances the activities of the enzymes SOD, APX and GR. The shorter the wavelength, the higher the energy of the photon, so the short-wave red light has a higher energy than the photon contained in the long-wave red light of 660 nm. Reducing the total amount of red light and adding short-wave red light may be the reason for the obvious growth of rice growth.

Therefore, the light morphogenesis effect of rice does not precisely define the spectral demand, which varies with different varieties and different growth periods. This requires a deeper study of the changes in the demand for light quality of different varieties of rice at different growth stages and the appropriate proportion of combined light, providing a theoretical reference for the more efficient and energy-saving artificial light source application in rice planting seedling scale. It also provides a more ecological and scientific theoretical basis for the lighting design of agricultural landscapes.

3.2 Influence of Illuminance on Rice

Illuminance is also an important photo-environmental factor affecting rice growth and an important ecological factor affecting photosynthetic rate. Different plants have different illuminance requirements. Light intensity and humidity affect the diurnal variation of rice photosynthesis by affecting stomatal conductance and ribulose-1, 5-bisphosphate carboxylase oxygenase. The photosynthesis rate of rice leaves increases with the increase of light intensity within a certain range, but if it grows under strong light conditions for a long time, that is, the light required for CO2 assimilation will lead to the decline of photosynthetic capacity. In the case of reduced light intensity, the length and width of rice flag leaves increased, but the thickness of mesophyll became thinner, and the number of mesophyll cells, cell volume and total cell surface area per unit leaf area decreased. Other studies have found that the growth quality of seedlings is better when the illuminance is 4000Lx. In most parts of China, the natural light intensity in the greenhouse in the morning and sunny days of March and April is about 1450-2050Lx respectively, and the light intensity at 4:00 and 5:00 is about
2100 and 1650Lx respectively, while the light intensity in rainy days is generally less than 2000Lx. Therefore, the fill light intensity needs to reach 2000Lx. Ma Xu [5] and others studied that the best fill light intensity is 2500Lx, and the fill time should be selected from 7:30 to 10:30 in the morning and 3:00 to 6:00 in the afternoon. The intensity is between 1500 and 3000 Lx, and the nighttime fill light is 3 to 5 hours. The quality of seedlings is the closest to the state under natural light, which is in line with the machine insertion standard in production and is suitable for field production [6].

Therefore, according to the photo-lightness of rice, it is possible to study and determine the optimal illuminance of different rice varieties suitable for different periods, and then according to the daily variation of external environmental illuminance, the illuminating illuminance required for rice daily cycle can be analyzed. Combined with the analysis and statistics of big data and the technical means of artificial intelligence, it is believed that we can design a light environment control system suitable for rice and even more horticultural plants.

3.3 Effect of Light Time on Rice Growth
Prolonging the illumination time of plant growth is another important light environmental factor that increases plant photosynthesis, increases photosynthetic yield, and improves seedling morphology. The longer the illumination time received by plants, the longer the photosynthesis time, and the more the accumulation of photosynthetic products, the more favorable the vegetative growth of plants. Zhang Xijuan et al studied the effects of nighttime light supplementation on the growth of rice seedlings, and the seedling index was the highest when the light was filled for 4 hours [2]. The results showed that the supplemental light could promote the growth of rice seedlings, and the effect of supplementing white light for 4h was the most obvious, followed by yellow light 2h. In addition, in different seasons, the fill light time should be adjusted according to the change of the length of natural sunshine. In the short sunshine season, the fill light time is longer, but generally does not exceed 4 hours per day, and vice versa. In artificial light supplementation, it is to increase the illuminance and extend the fill time under suitable light quality ratio to increase the photosynthetic rate, increase the accumulation of organic matter, cultivate strong seedlings, and improve the appearance quality of plant monomers.

3.4 Research Trends in Light Environment on Rice Growth
Light also regulates the morphogenesis of seedlings through light signal transduction, controls the differentiation, structure and function of cells, and finally induces and regulates the development of tissues and organs. It is a low-energy reaction in which light acts as an environmental signal to excite photoreceptors, pushing a series of reactions within the cell, ultimately resulting in changes in morphological structure [7]. In view of the above three light environmental factors, relevant scholars further studied the effects of different red and blue light factors of LED light source on rice seedling growth and morphogenesis, studied the optimum red-blue ratio and comprehensively considered other plant growth factors to create an optimal light environment atmosphere. In the aspect of rice planting and seedling supplementation, it is of great significance to study how LED light source can achieve on-demand light supplement in densely planted and layered crops, which provides theoretical basis for practical production and application [2].

Liu Xiaoying et al [7] pointed out that rice has more leaves in the treatment of LED red and blue light 7:4 and 4:7, and more biomass is distributed in the upper part, especially in the leaves. Xu Renliang et al [3] used natural light and trichromatic fluorescent lamps (TFL) as the control, using LED light source to study the effects of different blue-red combined light (3B: 2R, 2B: 3R) on rice seedling quality. From the morphological and physiological indicators, the rice seedlings treated with the LED blue-red ratio of 2:3 were superior in quality. Liu Xiaoying et al. applied research to propose the addition of other spectra based on red and blue light in view of the effects of red and green light at different wavelengths, which has important theoretical references for the precise regulation of rice in rice planting [8]. The application research of Ma Xu [5] and others is to use Ecotect software to simulate and simulate the greenhouse light environment, and then to study the effects of different red
and blue light ratios and illuminance on the quality of rice seedlings based on the simulation results. The results showed that: (1) The light environment with red-blue ratio of 10:1 and illuminance of 2500 lx promoted the growth of rice stems. (2) When the ratio of red to blue light was 8:1, the organic matter accumulation and root-knotting effect of rice seedlings were better, and the seedling index was higher. (3) The influence of red-blue light on the quality of seedlings is greater than the influence of illuminance than the spacing of enamel layers. (4) The best light-filling conditions are red-blue light ratio of 8:1, illuminance of 2,500 lx, and seedling layer spacing of 45 cm.

In order to produce the best light, it is necessary to have a certain understanding of the canopy structure, leaf size, row spacing and density of different crops in order to design the most uniform illumination system. Under the condition of ensuring a certain utilization of light energy, measures such as appropriately reducing the irradiance of light, increasing the ratio of scattered light, intermittent irradiation or alternating irradiation of strong and weak light can save certain basic investment and reduce investment cost. This also provides theoretical basis and research ideas for artificial light environment in plant irradiation treatment.

4. Advantages and Development of Artificial Light Source in Rice Application
LED (light emitting diode) as the fourth generation of new lighting source, has the ecological advantages of small size, pure light quality, high luminous efficiency, good durability, long service life and low energy consumption. Moreover, the LED spectrum can be accurately set according to the plant growth demand spectrum. Therefore, it has received much attention in the application of plant cultivation. The accuracy of spectral regulation is an important guarantee for factory rice breeding. It enables the production of intensive plant plants with high performance, low heat load and compact space. The commonly used light source in tissue culture is fluorescent light, but rice tissue culture is not only long in cycle but also cumbersome. Previous studies on light regulation showed that the growth of rice under LED illumination was better than that of fluorescent lamps. It has also been found that both Xenon metal halide lamps and LED illumination systems can provide the spectral energy distribution and uniform illumination required by CELSS. However, the lighting efficiency of LED lighting systems is five times higher than that of Xenon metal halide lamps. Rice requires high light quantity and is a crop suitable for high-power semiconductor lasers for planting experiments. Regarding the application of laser on rice, the rice cultivated with LD was earing two weeks earlier than the rice cultivated with high-pressure sodium lamp, and all the ears had straw, and all the straws were mature, so the yield of rice was high. It is basically described that a semiconductor laser which is advantageous for photo synthesis can be used to grow plants.

The laser has a very high radiant energy flow, high power density, excellent coherence, monochromaticity and excellent directivity. Very short pulses can also be formed, and each pulse has a large amount of energy, so the peak power is very high. The research on the effect of laser on plant growth regulation focuses on the application of laser pretreatment seeds, such as seed germination, seedling growth and development, enzyme activity, physiological and biochemical effects and laser treatment mechanism. It also includes effects on physiological and biochemical effects of plants under environmental stress, enhancing plant resistance to UV-B radiation damage, and improving plant resistance to drought stress and freezing resistance. Laser can increase crop yield, increase plant photosynthetic efficiency, apical mitotic frequency and so on. Moreover, low-dose He-Ne laser has certain effects on rice isoenzyme, lipase, cytochrome oxidase, nitrate reductase, amylase GSA, CAT. Therefore, in the context of the development of new light sources, it is also feasible to improve the configuration of the light source to achieve the ecological illumination in the landscape.

5. Prospects of Artificial Light Environment on Rice Physiology in Ecological Landscape
Taking rice as an example to study the reasonable combination of light quality, illuminance and illumination time of artificial light environment is an important factor and key means to improve the quality of rice seedlings, rice yield and enhance the nutritional value of grain. The new photoelectric technology (LED, LD) and traditional artificial light sources (high-pressure sodium lamps, fluorescent
lamps, metal halide lamps, incandescent lamps) in other plant physiological forms are worthy of our deeper systematic exploration and discussion. Whether in the efficient industrialization of ecological agriculture or the construction of urban landscape plants, the application of lighting design penetrates into all aspects. How to refine the ecological use of our limited resources to design a human landscape that is aesthetic, human and even physical is what we really pursue. From the selection of seedlings to planting and cultivation to reproduction, the regulation and design of the lighting technology system is crucial, which can greatly enhance its economic value and plant quality. In addition, artificial optoelectronic technology combined with the development of big data collection and analysis and artificial intelligence can even solve a series of light environment regulation problems of garden plants from nursery to field planting. Make crops and horticultural crops grow better in the landscape environment that optimizes the light source. This is an effective way and research trend to solve problems such as light pollution in the ecological landscape and uncoordinated design of the light environment, and is an extension and application of ecological techniques in the landscape.

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