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Rice Seedlings Growth at Multiple Shelves and Light Substitution in Greenhouse

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ABSTRACT

Rice is Indonesia's first staple food crop, planted throughout the year in irrigated rice fields. Finding an efficient method of producing rice seedlings outside the paddy fields is necessary. This research aims to determine the optimal shelf levels in open fields to support seedling rice growth and chlorophyll content and identify suitable lighting alternatives to light-emitting diode (LED) growth lights for supporting indoor seedling rice growth. This study used thirteen treatment variations, each repeated five times in a Randomized Block Design. The observational data were analyzed utilizing ANOVA, standard deviation, correlation, and the Honesty Significant Differences (HSD) test at a 5% significance level. The study's results were in the open field. The seedlings on the third level of shelves received the highest intensity of sunlight so that the chlorophyll content, seedling height, and number of leaves were relatively higher than those on the second and first level shelves. In greenhouse cultivation, the substitution for LED grows light until 150 Watts between 12 and 14 hours, causing low light intensity, chlorophyll levels, seedling height, and fewer leaves than in open fields.

Keywords: LED growth light; Lighting substitutes; Indoor rice growth; *Oryza sativa*; Shelves level

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INTRODUCTION

In Indonesia, rice crops (*Oryza sativa* L.) are produced throughout the year in irrigated paddy fields as the leading staple food. Rice is the most essential food crop in human nutrition and caloric intake, providing more calories for humans to consume worldwide. Usually, rice production begins with rice nurseries according to the desired variety to provide the needed rice seedlings at the right time and in sufficient quantities.

The year-round availability of seedlings is essential for sustaining rice production. The nurseries for rice production seedlings often take land for several weeks. To minimize land use for rice seedlings production in the rice field, there is a method to produce rice seedlings on various levels of shelves and in the greenhouse using artificial light sources. Rice nurseries on multi-level shelves and greenhouses thrive when key environmental resources are available.

Light is an essential environmental factor affecting plant growth, development, and phytochemical biosynthesis. The photosynthetic activity of light is wavelength-dependent, typically defined as light with a wavelength range from 400 to 700 nm (Liu and van Iersel 2021) Light intensity, light quality, and photoperiodicity strongly influence plant physiological processes. Light intensity, a measure of light energy per unit area, directly influences key physiological processes such as photosynthesis, photomorphogenesis, and stomatal regulation. Plants require adequate photoperiodicity for photosynthesis (Xu et al. 2020). On multi-level shelves, there is a problem with receiving solar radiation at each level of the shelves because objects on the shelves above will block the light reception for plants on the shelves below. Usually, the plants on the lower shelves receive only diffuse sunlight. Several factors that influence the rate of photosynthesis are light, carbon dioxide concentration, supply of water, chlorophyll content, yield accumulation photosynthesis, temperature, leaf resistance to diffusion-free gas, and factor protoplasm (Kaiser et al. 2015; Demmig-Adams et al. 2017; Xin et al. 2019). Chlorophyll is an essential photosynthetic pigment for the plant, mainly determining photosynthetic capacity and, hence, plant growth (Li et al. 2018).

An essential problem of rice nurseries in greenhouses is the lack of solar radiation, which plants accept. Light-emitting Diodes (LED) are increasingly used as a source of artificial light in controlled environments because they emit specific wavelengths with adjustable intensity, providing opportunities to tailor light conditions to plant

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requirements. LED lamps emitting useful wavelengths for photosynthesis reduce the adverse effects of solar radiation and the lack of greenhouses. Light-emitting diodes (LEDs) have received wide attention in recent years for use in controlled environmental agriculture, as they now have superior efficacy over traditional lighting technologies (Liu and van Iersel 2021). In greenhouse cultivation, irradiation of plants using LEDs can be adjusted to increase the photosynthetic period by more than 12 hours. Rice (*Oryza sativa*) flowers quickly when exposed to short days (facultative), whereas Arabidopsis thaliana blooms faster under longer days (Brambilla and Fornara 2013). The experimental result of Wang et al. (2022) shows that after 21 days of storage, Chinese cabbage leaves stored under white light conditions were still green, whereas those under dark conditions lost most of their green pigment and became senescent. The role of light in the process of chlorophyll synthesis is vital.

Recently, there has been a lack of information about rice nurseries on multilevel shelves and the influence of LED lights on supporting the growth of rice seedlings and their chlorophyll content in greenhouse cultivation. This research aimed to (1) determine the level of shelves that support the best seedling rice growth and chlorophyll content in an open field and (2) determine the lighting substitutes of LEDs growth light that support the rice growth seedling in a greenhouse.

MATERIALS AND METHODS

Location and experiment setup

This experiment was conducted in an experimental garden of the Agricultural and Business Faculty, Universitas Kristen Satya Wacana in Salatiga, 540 meters above sea level (MASL). The object of this experiment was rice seedling growth of the Situbagendit variety, planted in buckets of 20 cm diameter size. Each bucket planted five rice seeds. This experiment consists of thirteen treatments (Table 1), divided into two locations. Three treatments were conducted outdoors in the open field, while ten treatments were performed indoors in the greenhouse. Each treatment is repeated five times in a Randomized Block Design.

Materials and analysis of data

Situbagendit rice seeds were tested for germination in the lab using a rolled paper method and stored in a seed germinator. The rice seeds used in this experiment were 88% seed germination. The rice nursery in the open field consists of three shelves. The first shelves level is T1, the second is T2, and the third is T3. Each treatment was replicated five times, and each experimental unit consisted of four buckets. The energy source to support seedlings' growth in the open field comes from sunlight (solar radiation). The intensity of solar radiation that reaches each level of shelves is measured using a lux meter at 08.30-09.00 every two days, so there are ten measurements during the experiment for each treatment. The type of lux meter is Smart Digital Luxmeter Sensor AS803.

The rice nursery in the greenhouse (indoor) consists of two and three levels of shelves, which were used to place buckets for the rice nursery of ten light source treatments. The variation of light source was T4; T5;T6;T7;T8;T9;T10;T11;T12 and T13. The energy source to support seedlings' growth in the greenhouse (indoors) comes from diffuse solar radiation and LED growth light. Solar radiation diffuses the sunlight that enters the greenhouse because it is reflected by various objects outside and inside the greenhouse; it is not direct solar radiation.

Table 1. The thirteen treatments in this experiment

Treatments	LED Growth Light @ 30 Watt	Exposure Time (hour)	Sunlight	Levels of Shelves
T_1: First Level of Shelves	-		Direct	1
T_2: Second Level of Shelves	-		Direct	2
T_3: Third Level of Shelves	-		Direct	3
T_4: GL_{150W}, 12 h+df,L_1	5GL =150 W	12	Diffuse	1
T_5: GL_{150W},12 h,L_2	5GL =150 W	12	None	2
T_6: GL_{90W}, 12 h + df,L_1	3GL = 90 W	12	Diffuse	1
T_7: GL_{90W},12 h + df, L_2	3GL = 90 W	12	Diffuse	2
T_8: GL_{90W},12 h,L_3	3GL = 90 W	12	None	3
T_9: GL_{90W},14 h + df, L_1	3GL = 90 W	14	Diffuse	1
T_{10}: GL_{90W},14 h + df,L_2	3GL = 90 W	14	Diffuse	2
T_{11}: GL_{90W},14 h, L_3	3GL = 90 W	14	None	3
T_{12}: GL_{150W},14 h + df, L_1	5GL = 150 W	14	Diffuse	1
T_{13}: GL_{150W},14 h,L_2	5GL = 150 W	14	None	2

Remarks: GL = LED growth light, h = hours; df = diffuse sunlight; L = level of shelves, T= treatment

LED growth lights are LED lamps that radiate light with various wavelengths, useful for photosynthesis and environmental heat energy. In this experiment, the LED growth light was used with the following specifications: brand of RoHS; Operating Voltage: AC 85 Volt-265 Volt; Power: 30 Watt; Led Qty: 22 Red+12 Blue+2 White+2 Infra-Red (IR)+ 2 Ultra Violet (UV) = 40 LED; Wave Length: 625-630 nm; 445-470 nm; 730 nm (IR); 380 nm (UV), 6500 K (White); Led Chip: SMD; Housing: Aluminum; Base: E27; Dimension: 60 x 95 mm; Net Weight: 142 gram.

The intensity of light that reaches each level of shelves is measured using a lux meter at 08.30-09.00 every two days, so measurements were taken ten times during the experiment. The type of lux meter is Smart Digital Luxmeter Sensor AS803. In treating the LED growth light, every four buckets of each replicate were covered with a black cloth, and a fan was provided to control the temperature and air circulation inside. LED irradiation was automatically carried out for 12 and 14 hours a day using a timer according to the treatments. Each experimental unit was placed in a bucket containing media sourced from the rice field and maintained in a moist condition. Situbagendit rice seeds were planted in five buckets at a distance. The chlorophyll content of leaves was measured using a UV Vis spectrophotometer.

The experiment was conducted for 3 weeks to observe the growth of rice seedlings. Several parameters observed in this study included light intensity, the height of rice seedlings, the number of leaves, and leaf chlorophyll content. Data from this experiment were analyzed using standard deviation, correlation, analysis of variance, and the Honesty Significant Difference test at a 5% level.

RESULTS AND DISCUSSIONS

The performance of seedlings rice on each level of shelves on the open field

In the open field (Table 2), rice seedlings on the third level of shelves received the highest sunlight intensity (lux) than other levels below because the plant was exposed directly to the sunlight without any obstructions. The intensity of sunlight on the second level of shelves decreases, and the lowest is received on the first level due to obstructions from objects above it.

Light is a critical environmental factor influencing plant growth, development, and phytochemical biosynthesis over both short and long periods. This influence is attributed to the effects of radiation intensity and spectral composition (Bian et al. 2015; Thoma et al. 2020; Proietti et al. 2021; Grunwald et al. 2024). To a major extent, solar radiation determines plant photosynthesis and related terrestrial carbon uptake, the heat balance of agricultural surfaces, and, hence, the temperatures of crop canopies, soil, and air. Solar radiation has been reported to be the primary factor regulating the growth of crops (Stanhill and Cohen 2001). Solar radiation reaches the plants freely in the open field unless an obstacle exists. Every object around the plants can block sunlight from reaching the plant directly or reflecting the sunlight, so the plants receive indirect sunlight. In the atmospheric factors, light is considered the foremost component in the regulation of diverse plant processes, including germination, seedling development, metabolism, photosynthesis, Photomorphogenesis, Photoperiodism, and circadian rhythms in plants (Singhal et al. 2019; Legris 2023).

The highest light intensity received by the plants located at the top position (third level, with a height of 3 meters from the ground surface) supports their growth, resulting in an average height of 35.33 ± 2.4 cm at 3 weeks of age and the number of leaves is also close to 4 (3.86 ± 0.3). This is because, at this height, the seedlings can receive sunlight in full without any obstructions, thus effectively fulfilling their need for light energy for photosynthesis and other biochemical processes. Of all the solar radiation emitted, only certain wavelengths are utilized by plants for photosynthesis, specifically within the range of 380-700 nm, which corresponds to visible light. Research conducted by (Suyanto et al. 2011) showed that the red wavelength (680 nm) is the most effective for the growth phase of tomato plant nurseries (including plant height, chlorophyll-a content, and growth rate) compared to other wavelengths.

The rice seedlings located on the second level of the shelves (1.5 meters above the ground surface) receive lower sunlight intensity due to obstructions from plants, buckets, and baseboards on the third level above. The decrease in sunlight intensity on the second level is about 39%, affecting the rice seedlings' height and number of leaves compared to those on the third level. The average height of rice seedlings on the second level is 28.46 ± 2.1 cm, and the number of leaves is 3.31 ± 0.1. The lowest plant height, number of leaves, and chlorophyll content occur in the rice seedlings on the ground floor (first level of shelves). On the ground floor, the seedlings receive only 22% of the sunlight intensity compared to the light intensity on the third floor, caused by the shading from the objects above them. The average height of rice seedlings on the ground floor is 24.39 ± 1.2 cm, and the number of leaves is 3.05 ± 0.1.

Table 2. The effect of shelf height position on light intensity, chlorophyll content, and performance of rice seedlings

Level of Shelves	Light Intensity (Lux)	Chlorophyll ($mg.g^{-1}$)	Correlation (Lux-Chlorophyll)	Seedling Height (cm)	Correlation (Lux-seedling height)	Leaves number	Correlation (Lux-Leaf)
T_1: First level	1807 ±160.2	19.225 ± 2,2		24.39 ± 1.2		3.05 ± 0.1	
T_2: Second level	3200 ± 447.2	28.903 ± 2,1	0.709	28.46 ± 2.1	0.886	3.31 ± 0.1	0.993
T_3: Third level (top)	8200 ± 836.7	29.558 ±2,8		35.33 ± 2.4		3.86 ± 0.3	

In Table 2, there is a positive and strong correlation between light intensity (lux) and total chlorophyll content (0.709), the height of seedlings (0.886), and the number of leaves of rice seedlings (0.993). This indicates that light intensity is an essential external factor for seedling growth. Increasing the intensity of solar radiation will enhance chlorophyll content, plant height, and the number of leaves in rice seedlings. Leaves that are exposed to more sunlight contain more chlorophyll than those that receive less sunlight (Lawendatu et al. 2020). Chlorophyll is the main pigment found in chloroplasts and is located inside the thylakoids (Amelia and Kurniawan 2021).

Chlorophyll absorbs sunlight and facilitates photosynthesis, making it a crucial pigment in the photosynthetic reaction center (Ai and Banyo 2011). Photosynthesis is the most important source of energy for plant growth (Li et al. 2018). Once seedlings emerge on the soil surface (field emergence), they will be exposed to sunlight, leading to chlorophyll synthesis. The chlorophyll in the leaves absorbs electromagnetic waves from solar radiation to carry out the process of photosynthesis. The assimilates produced from photosynthesis are used in cell division and the enlargement of new cells in rice seedlings, contributing to increased height and leaf number. The formation of new cells through cell division requires energy and cellular materials. The assimilates from photosynthesis play a crucial role as a source of energy and cellular materials during seedling growth.

The production of rice seedlings in the open field using a source of energy from sunlight must be attended to in terms of sunlight reception. Solar radiation is abundant, but the inhibiting factors to reaching the leaves as the center of photosynthesis must be minimized to fulfill the need for solar energy. Even though the rice seedlings grow for only a few weeks, the quality of the seedlings will influence the subsequent growth.

Seedling rice performance in the greenhouse (indoor) using variation of light sources and levels of shelves

In indoor cultivation (Table 3), it is shown that the addition of diffuse sunlight increases light intensity (lux) compared to the treatment using full-spectrum LED growth lights at 90 watts and 150 watts, applied for 12 or 14 hours of irradiation per day. Higher environmental light intensity boosts chlorophyll content, plant height, and leaf count, showing that diffuse sunlight is vital for rice seedling growth. This diffuse sunlight increases the available energy in the environment and emits wavelengths that are beneficial for photosynthesis.

The LED growth lights used in this experiment consist of red, blue, white, ultraviolet, and infrared wavelengths of 625-630 nm, 445-470 nm, 730 nm (IR), 380 nm (UV), and 6500 K (white). Okamoto et al. (2020) mention that blue and red wavelengths are adequate for the induction and accumulation of chlorophyll, carotenoids, and the two major potato glycoalkaloids, α-solanine and α-chaconine. In contrast, none of these compounds accumulate in darkness or under far-red light. Prior research has demonstrated that the wavelength range from 430 to 500 nm effectively stimulates pigmentation, the metabolism of secondary metabolites, photosynthetic function, and the development of chloroplasts (Yavari et al. 2021). The LED growth lights used in this study emitted wavelengths ranging from 380 nm to 730 nm, indicating that these LEDs provide the necessary light quality for stimulating pigmentation and chloroplast development. Afandi et al. (2021) conclude that artificial lighting can improve the seedling process during the rainy season when low light conditions are common. Plants under artificial lighting show better growth than those in low-light environments, as low light can cause etiolation.

Germination and seedling growth are crucial for the early establishment of plants (Prakash et al. 2016). Red light influences leaf expansion and hypocotyl elongation; when combined with blue light, green light positively affects plant growth, including leaf development and early stem elongation (Kwon et al. 2015). Light quality strongly influences photosynthesis since light with wavelengths ranging from 400 to 700 nm is the most effective for photosynthetic activity. Although most studies on photosynthesis have focused on this wavelength range, far-red light (700-800 nm) plays a significant role in mediating plant growth and developmental processes, particularly in shaded environments (Tan et al. 2022).

In this experiment, the intensity of the LED growth lights used has not yet reached levels comparable to those emitted by diffuse sunlight and is much lower than direct sunlight. Consequently, these LED lights cannot adequately replace the natural light provided by sunlight to support rice seedling growth. Yavari et al.(2021) note that both the quality and quantity of light significantly impact photosynthetic activity and the functioning of photosystems.

Of all the treatments (Figure 1), it can be observed that the highest light intensity was recorded in rice seedlings on the third level of outdoor shelves, while the lowest intensity was found in the greenhouse using a 90-watt LED growth light. Diffuse sunlight entering the greenhouse significantly increases the light intensity, matching that received on the first level of the outdoor shelves. In general, outdoor rice seedlings' growth performance was better than indoor seedlings due to higher light intensity and chlorophyll content. Although the LED growth light emits various wavelengths necessary for photosynthesis, the intensity used in this experiment (90 watts and 150 watts) does not provide sufficient energy to support seedling growth.

Table 4 shows that the best rice seedling performance occurred on the third level of shelves placed in the open field. The abundant solar radiation at the top of the shelves provides sufficient energy for all plant metabolic processes. Solar radiation contains various wavelengths that contribute to both photosynthesis and environmental energy, which can enhance enzyme activity. When the seedlings emerge on the surface of the media, the ample solar energy fully supports their metabolic processes, promoting further growth. The most crucial processes include the synthesis of chlorophyll and metabolites that are essential for enhancing bioenergy, as well as microelements needed for cell division and enlargement.

Table 3. The impact of lighting sources on seedling rice performance at various shelf levels

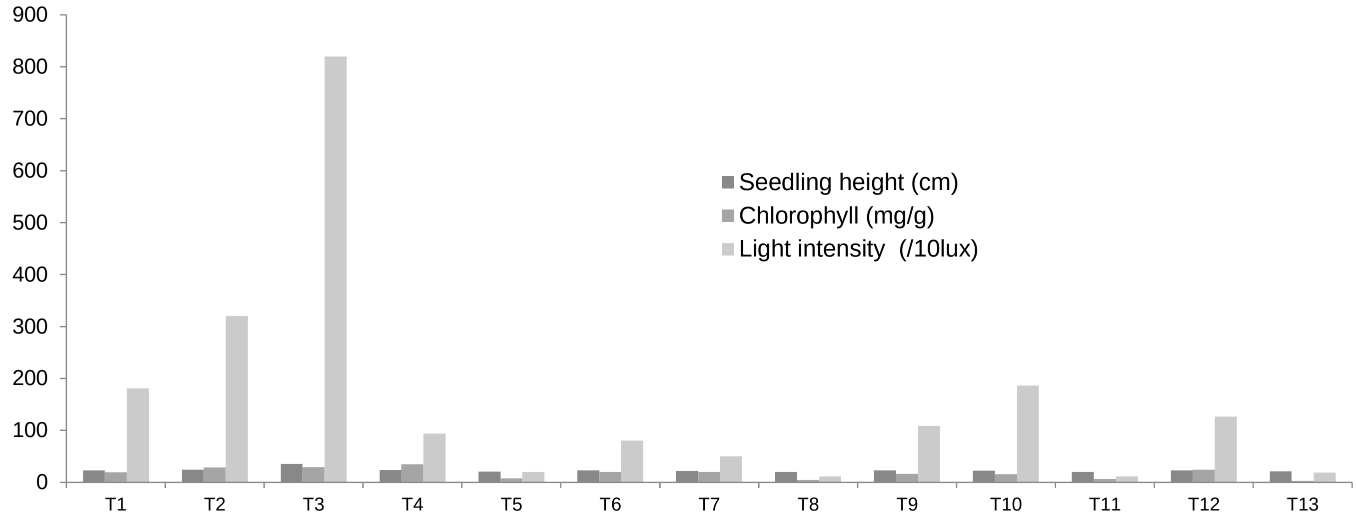
Treatments	Light Intensity (Lux)	SD	Chlorophyll ($mg.g^{-1}$)	Seedling Height (cm)	SD	Leaves	SD
T_4: GL_{150W} , 12 h + df, L_1	942	179.2	34.874	23.65	2.6	2.00	0.00
T_5: GL_{150W} ,12 h , L_2	200	17.3	7.612	20.88	1.5	2.90	0.05
T_6: GL_{90W} , 12 h + df, L_1	804	191.0	20.095	23.27	2.6	2.00	0.00
T_7: GL_{90W} ,12 h + df, L_2	503	199.1	20.050	21.82	0.9	2.55	0.28
T_8: GL_{90W} ,12 h, L_3	117	36.3	4.709	19.94	0.9	3.00	0.00
T_9: GL_{90W} ,14 h + df, L_1	1086	210.8	16.688	23.01	2.3	2.00	0.00
T_{10}: GL_{90W} ,14 h + df, L_2	1863	57.2	15.816	22.59	2.2	3.00	0.00
T_{11}: GL_{90W} ,14 h, L_3	112	27.7	6.393	20.03	0.6	2.88	0.11
T_{12}: GL_{150W} ,14 h + df, L_1	1266	221.8	24.414	23.49	1.8	3.00	0.00
T_{13}: GL_{150W} ,14 h , L_2	186	16.5	2.923	21.52	3.9	2.88	0.11

Remarks: GL = LED growth light; W = Watt; h = $hour.day^{-1}$; df = diffuse sunlight; L = level of shelves.

Table 4. The effect of shelves level and source of light on the height and number of leaves of rice seedlings

Treatments	Height of seedlings (cm)	Number of leaves
T_1: First Level of Shelves	24.39±1.24 c	3.05±0.10 c
T_2 : Second Level of Shelves	28.46±2.09 b	3.31±0.15 b
T_3: Third Level of Shelves	35.33±3.31 a	3.86±0.31 a
T_4: GL_{150W}, 12 h+df,L_1	23.65±2.62 dc	2.00±0.00 e
T_5: GL_{150W},12 h,L_2	20.88±1.47 dc	2.90±0.05 c
T_6: GL_{90W}, 12 h+ df,L_1	23.27±2.64 dc	2.00±0.00 e
T_7: GL_{90W},12 h+ df, L_2	21.20±0.91 dc	2.55±0.28 d
T_8: GL_{90W},12 h,L_3	19.94±1.26 d	3.00±0.00 c
T_9: GL_{90W},14 h + df, L_1	23.01±2.31 dc	2.00±0.00 e
T_{10}: GL_{90W},14 h+df,L_2	22.59±2.20 dc	3.00±0.00 e
T_{11}: GL_{90W},14 h, L_3	20.03±0.58 d	2.88±0.11 c
T_{12}: GL_{150W},14 h + df, L_1	23.49±1.83 dc	3.00±0.00 c
T_{13}: GL_{150W},14 h,L_2	21.52±5.89 dc	2.88±0.11 c
Significance (ρ) of ANOVA	**0.0001**	**0.0001**

Remarks: numbers followed by the same letters are not significantly different at the 5% Honesty Difference Test



Remarks: T1: First Level of Shelves; T2 : Second Level of Shelves; T3: Third Level of Shelves; T4: GL150W, 12 h+df,L1; T5: GL150W,12 h,L2; T6: GL90W, 12 h+ df, L1; T7: GL90W,12 h+ df, L2; T8: GL90W,12 h,L3; T9: GL90W,14 h + df, L1; T10: GL90W,14 h+df,L2; T11: GL90W,14 h, L3; T12: GL150W,14 h + df, L1; T13: GL150W,14 h,L2.

Figure 1. The performance of rice seedlings on the open field, greenhouse, in several levels of shelves and variations of the light sources

The production of rice seedlings in open fields, based on solar radiation, is efficient and more reliable. The abundance of solar energy throughout the year in tropical regions presents sustainable rice seed production opportunities. Thus, using multiple levels of shelves in a controlled manner, without diminishing the reception of solar energy to levels that inhibit seedling growth, should be encouraged.

In contrast, the growth performance of rice seedlings in greenhouse cultivation is lower than that of seedlings in the open field. While the diffuse sunlight entering the greenhouse increases light intensity (Table 3), there has not been a significant improvement in seedling growth performance (Table 4). The lowest growth performance of rice seedlings occurred in the greenhouse, which relies solely on full-spectrum LED irradiation. This study demonstrates that light sources as energy for photosynthesis significantly affect the growth of rice seedlings.

This experiment demonstrates that rice seedlings can be cultivated on multiple levels of shelves in open fields, leading to higher efficiency in land use. However, a significant challenge is the reduced amount of direct sunlight received by seedlings on the lower shelves, as they primarily receive diffuse sunlight. While diffuse sunlight emits wavelengths essential for photosynthesis, its energy is lower than that of direct sunlight, resulting in a weaker capability to drive biosynthetic reactions. Consequently, the intensity of sunlight diminishes on lower shelves, impacting chlorophyll content and seedling growth performance.

This study concludes that while rice seedlings can be grown in a greenhouse environment, providing a sufficient energy source for photosynthesis and enzyme activities is essential. Diffuse sunlight and LED grow lights can support these processes, but their intensity must be carefully managed to achieve optimal rice seedling growth. The performance of rice seedlings as planting materials in the field is crucial; weak seedlings contribute to higher mortality rates, uneven growth, and ultimately negative impacts on yields.

Furthermore, artificial light influences seed germination, leaf growth, photosynthesis, and, importantly, flowering plants' photoperiodic and circadian rhythms (Singhal et al. 2022). Among various artificial light sources, light-emitting diodes (LEDs) are the most promising options for plant lighting due to their ability to positively affect plant growth and reproduction by adjusting light quality, intensity, and photoperiod (Novinanto and Setiawan 2020; Zou et al. 2020).

Utilizing diffuse sunlight alone is insufficient to support rice seedlings' growth, whether planted in open fields or greenhouses. The intensity of diffuse sunlight varies significantly, depending on several factors. In greenhouse environments, the variation is affected by the building materials, the level of ventilation, and other design elements. In open fields, numerous factors contribute to the dynamics of receiving diffuse solar radiation, making it challenging to optimize sunlight exposure.

LED grow lights can be used as a controllable energy source for rice seedlings to enhance photosynthesis. This study indicates that when employing LEDs to support the growth of rice seedlings, a power level exceeding 150 watts for 12 to 14 hours of lighting is recommended. To produce strong and healthy planting material, the duration of exposure to light should be at least 10 to 14 hours (Efremova et al. 2020).

LED are advantageous because they have a compact size, a long lifespan, and high emission efficiency. Additionally, they allow for precise control over light quality due to their narrow spectral bands (Lee et al. 2015). As a result, LED grow lights can compensate for the lack of sunlight in greenhouses by providing the necessary wavelengths for photosynthesis, thereby facilitating rice seedling production across multiple shelf levels and enhancing the overall efficiency of greenhouse use.

CONCLUSIONS AND SUGGESTIONS

The highest chlorophyll content, seedling height, and number of leaves in rice seedlings are observed on the third level of shelves in open fields. In contrast, exposing seedlings to LED grow lights of 90 or 150 watts for 12 or 14 hours in a greenhouse has not been sufficient to achieve growth and chlorophyll content comparable to those cultivated in open fields. Although the addition of diffuse sunlight in the greenhouse increases light intensity and chlorophyll content, the seedlings' height and number of leaves remain lower than those of their outdoor counterparts.

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