Design of Artificial Light for Nursery Chamber of Zoysia Matrella

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Abstract. Zoysia matrella has a prolonged growth rate in its cultivation, including in the nursery phase, caused by environmental conditions, such as lack of light. Therefore, in this study, an automatic Zoysia matrella nursery chamber was designed with an artificial light control system that can adapt to ambient light to support the growth process of Zoysia seedlings. With the automatic control system and light stability control needed by Zoysia, it is hoped that it can reduce the length of time for seeding. In artificial light control, the ambient light causes the light precision level not to match the set value. In this research, a designed artificial control system to help adapt to light needs is a closed-loop control system. With a close loop system, the intensity of light to support the growth of zoysia seedlings can be controlled according to the set point, with a precision level of 3%, and can adapt to an average time of 11 s.

Keywords: Zoysia matrella · nursery chamber · artificial light · closed-loop control system · seedling

1 Introduction

Zoysia is a type of turfgrass with several functions, such as ecological, environmental, and economic effects. Zoysia has several types: Zoysia matrella, which is widely used for garden grass, golf courses, and football fields [1, 2]. In addition, this type of ornamental plant can also be used as a soil conservation medium to reduce runoff, increase infiltration rates, purify water from sediments and pollutants, control erosion, and improve soil quality [3]. This grass is also suitable for green roofs due to its aesthetic value and ability to maintain ambient temperature [2]. Therefore, this type of Zoysia grass has a relatively high economic value.

Problems also follow the attractive potential of the Zoysia plant in the cultivation process, where the provision of seeds, both from seeds and stolons, takes a long time. Zoysia seeds take 10–15 days to germinate and 8–12 weeks to transplant after the germination phase. The length of the process varies depending on the variety and microclimate conditions, such as germination temperature [4], soil temperature [5], and soil moisture [2, 6]. The adequacy and availability of light influence temperature and soil moisture in

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the plant microenvironment strongly, where light dramatically affects plant growth and [7], including in the nursery [8]. Lack of light causes conditions that are not optimal for the growth of landscape grass, so it requires adding artificial light to cover this deficiency [5].

Artificial light technology to optimize plant production was developed from various lamps such as LED lamps, fluorescent lamps, and incandescent lamps [9]. The application of artificial light such as Light Emitting Diode (LED) as a light source in producing young plants results in high density and relatively short harvest time [10]. The use of appropriate blue and red-light spectrum can overcome the limitations of light in plant production [11, 12], so it is widely used in PFAL technology (plant factory with artificial lighting).

A nursery system with plant factory technology with artificial light in the form of a nursery chamber can overcome the need for seeds. Breeding by generative (seed) in the nursery chamber can produce seeds in greater quantity due to controlled environmental conditions [13]. Therefore, using artificial light is one of the solutions for zoysia grass nurseries. However, changing ambient light conditions can also affect the amount of light intensity required by plants. Therefore, automatic control is needed that can maintain the value of the power of the light produced in accordance with what plants need. In order to provide a precise experimental device for plant nurseries, artificial light design is needed according to the plant's needs. In this paper, a zoysia nursery chamber will be designed using artificial light with adjustable light intensity to determine the best growth rate in zoysia nurseries. The nursery chamber design with an open side will allow the room's light to enter. The room's light directly increases the light intensity the plant gets. Closed-loop control is needed to obtain precise lighting to avoid the influence of the room's light intensity.

2 Methods

2.1 Plant Factory for Nursery Chamber

A plant factory is an indoor vertical farming system aimed at the efficient production of quality crops. The plant factory consists of several plant cultivation technologies, such as environmental control technology and biological technology, which can control pests and plant diseases without pesticides or other chemicals and protect plants from physical harm. The plant factory includes photosynthetic systems, humidity, temperature, air circulation, fertilization and irrigation, seeding, control and monitoring centers, and Internet of Things (IoT) systems [14].

A nursery system with plant factory technology in the form of a nursery chamber can overcome the need for seeds. Breeding by the generative way (seeds) in the nursery chamber can produce more significant quantities due to controlled environmental conditions. In such a controlled environment, the nursery phase is separate from the cultivation phase due to differences in plant density and environmental factors [13]. The environmental factor in the nursery process that often becomes an obstacle is the availability of sunlight.

The maximum power/intensity of light throughout the growing period is essential for plant growth and development [15], including in the seedling phase. The adequacy of

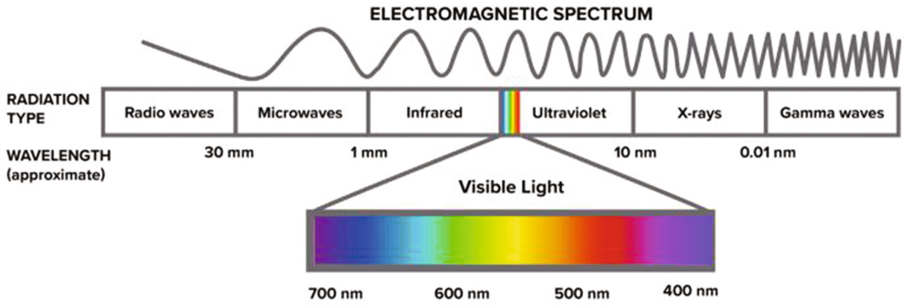

Fig. 1. Electromagnetic Spectrum. Reprinted from Journal of American Academy of Dermatology, Vol. 86 Issue. 3, Henry W. Lim, Indermeet Kohli, Eduardo Ruvolo, Ludger Kolbe, Iltefat H. Hamzavi, Impact of visible light on skin health: The role of antioxidants and free radical quenchers in skin protection, S29, Copyright (2022), with permission from Elsevier.

light in the plant nursery process can be overcome by using artificial light that is applied indoors [16].

2.2 Artificial Growth Light Technology

Various lamp types are used in Artificial light technology to optimize plant products, such as LED lamps, fluorescent lamps, and incandescent lamps [9]. These lamps are selected based on the spectrum of visible light produced. The visible light spectrum is the visible spectrum of electromagnetic waves ranging from 380 to 750 nm [17]. Each wavelength represents color, as can be seen in Fig. 1.

Light sources have high efficiency because they are close to the plant surface. However, energy consumption per planting unit area is high, namely, 240–300 W/m^2 [18]. Advanced LED technology makes it possible to make LEDs with specific wavelengths, such as the 623 nm peak representing the red color spectrum or the 465 nm peak representing the blue color spectrum. Using LEDs at specific wavelengths with adjustable intensity can provide advantages in light quality for the photosynthesis process, such as ease of adapting to plant characteristics and growth and lower costs because of not using all spectrums. LED technology is also more environmentally friendly because it does not emit excessive heat or toxic emissions and is more stable than other artificial light types [19].

2.3 Zoysia Matrella

Zoysia spp is grass found in tropical areas, such as Indonesia. It has the potential to be used as garden grass, golf course grass, and soccer fields [1]. This Zoysia grass can spread laterally/sideways using the plant's body parts in rhizomes and stolons [20]. Zoysia grass has many species, and the most used for football fields are Zoysia japonica and Zoysia matrella.

Zoysia matrella has a prolonged growth rate, with a higher heat tolerance than Zoysia japonica. The leaf texture of Zoysia matrella is softer than Zoysia japonica [21]. So, this

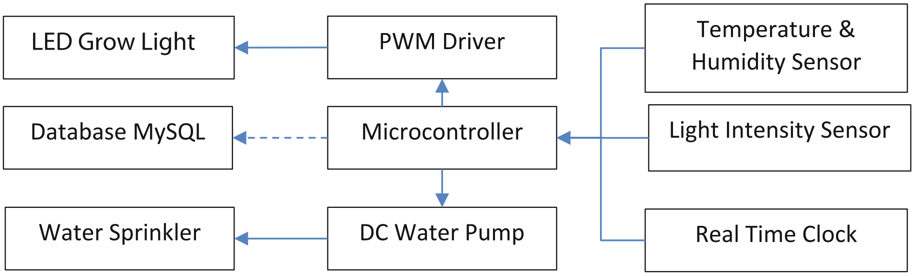

Fig. 2. Block Diagram of Nursery Chamber

grass is used widely as golf course grass in Asia. The growth rate is very slow, requiring proper maintenance in the nursery phase and cultivation and application in the field/field. Appropriate maintenance measures such as increasing fertilization from 48.8 kg/ha to 96.7 kg/ha on Zoysia matrella grass slabs have been shown to increase the percentage of area cover [22]. In addition, the intensity of sunlight also affects the growth of this Zoysia grass [1], although the Zoysia species is very tolerant of heat stress and drought.

2.4 Design of Nursery Chamber for Zoysia Matrella

The proposed nursery chamber is made for Zoysia matrella grass. This nursery chamber is equipped with artificial light technology as a substitute for sunlight and a sprinkler (sprayer) connected to a realtime clock (RTC) to regulate the watering period. The block diagram of the nursery chamber implemented on Zoysia matrella grass is shown in Fig. 2.

The nursery chamber uses a light intensity sensor to read the light intensity from the lamp that reaches the surface of the seedling. This sensor will send digital data serially to the microcontroller so the light can be brighter or dimmer according to the sensor readings. Meanwhile, the microcontroller uses the real-time clock to determine the watering period by activating the water pump connected to the sprinkler. Besides light intensity, this chamber is equipped with a temperature/humidity sensor that reads the temperature/humidity of the room in the nursery chamber.

Every data read on the microcontroller will be stored in the MySQL database and accessed at any time. The MySQL database will store data on the date, time, light intensity, temperature, and humidity that are read by the sensor. The design of the nursery chamber for Zoysia matrella with 35 cm x 35 cm x 35 cm dimension (outside) is illustrated in Fig. 3. The distance between the canopy (plant top) and lamp placement is set as far as 30 cm with the assumption that it does not cause damage to plants due to excessive heat [23, 24].

2.5 Closed Loop Control System for Artificial Growth Light Intensity

The artificial growth light in the nursery chamber uses a closed loop system to maintain light intensity according to the set point, as shown in Fig. 4. This system uses a microcontroller WeMos D1 R1 as a controller to adjust the intensity of the artificial light through the PWM Driver. As for the automatic irradiation setting, Real Time Clock

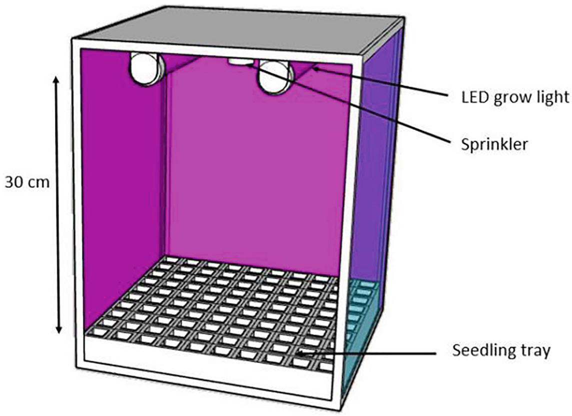

Fig. 3. Design of Nursery Chamber

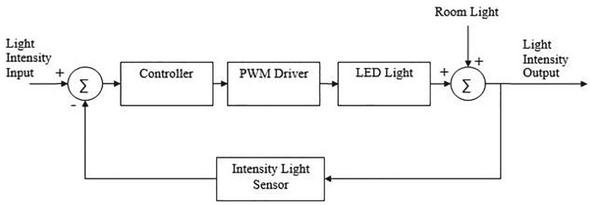

Fig. 4. Closed Loop System for Light Intensity Control

(RTC) is used, with 16 h of irradiation time for Zoysia matrella. A light intensity sensor is added to adjust the suitability between the specified intensity and the system's output, which is affected by the presence of ambient light.

The artificial growth light used is LEDs light combining red and blue colors. The LED lights used are the High Power LED (HPL) in royal blue (460 nm) and red (625 nm). The HPLs are arranged in series with a composition of four red HPLs and one blue HPL to get a red: blue ratio of 4:1. HPLs circuit is arranged in the nursery chamber as shown in Fig. 5.

The HPLs circuit requires an input voltage of 12 V with a power of 9.84 Watts. The light intensity on this proposed nursery chamber is adjustable at 20 μmol/m^2/s, 40 μmol/m^2/s, 60 μmol/m^2/s, 80 μmol/m^2/s, and 100 μmol/m^2/s for any conditions by changing the PWM setting. Four red LEDs are connected in series, and three blue LEDs are connected in series because the voltage specifications on the red LED and the blue LED are different. The red and blue light intensity are equal by adding a resistor in each series circuit. To adjust the intensity of the light produced from the LED lamps, a circuit, as shown in Fig. 6, is needed, which can be controlled with the PWM mode generated by the microcontroller.

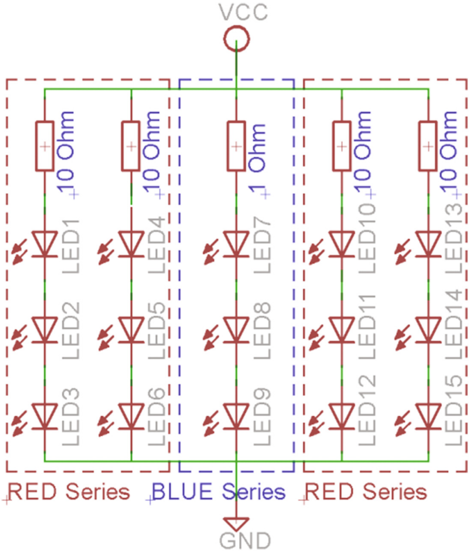

Fig. 5. HPL Light Circuit Design

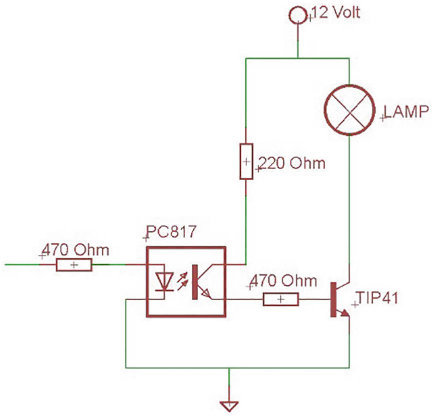

Fig. 6. PWM Circuit

3 Results and Discussion

The nursery chamber design has been created and tested in the laboratory, as shown in Fig. 7. Meanwhile, for an HPL circuit in one nursery chamber, three blue and 12 red LEDs require a maximum voltage (12 V) to get the highest intensity of 1221 lx. The comparison of the voltage used to produce a certain light intensity is shown in Fig. 8.

As shown in Fig. 8, intensity is obtained (lights on) at a voltage of 8.5 V for intensity of 182 lx, and the highest intensity is at 12 V for intensity of 1221 lx. The correlation index between the light intensity and the required voltage is the value of R2 = 0.9812.

Fig. 7. Hardware Realization of Nursery Chamber

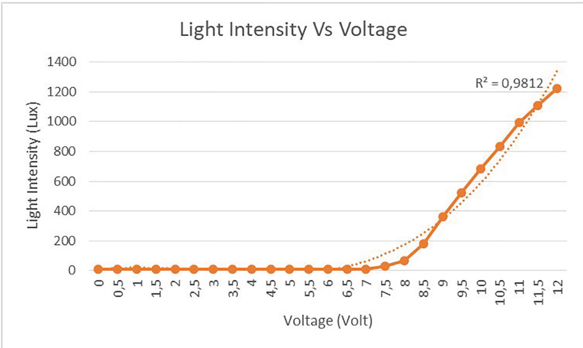

Fig. 8. Comparison of Light Intensity VS Voltage

The light intensity is adjusted in several conditions and compared with a light intensity meter (lux meter), as in Fig. 9, where the conversion of 1 μmol/m^2/s is 11 lx.

Based on the test results in Fig. 9, the average error of reading the light intensity between the measuring instrument sensors (lux meter) is 1.05%. This sensor accurately reads the light intensity produced by artificial light. By implementing a closed loop control system, the nursery chamber's artificial light system can adapt to ambient light's influence. Testing the accuracy of the sensor with a measuring instrument under the influence of ambient light can be seen in Table 1. The system can adapt to the average time needed of 11 s with a 3% error.

4 Conclusion

The artificial light system, which was designed using a closed loop control system in the nursery chamber, can adapt well to the effects of ambient light with an average error of

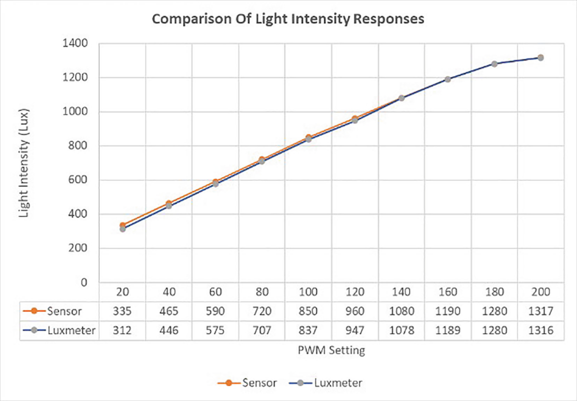

Fig. 9. Comparison of Light Intensity Sensor and Lux Meter VS PWM Setting

Table 1. Adaptable Time

Setpoint + Ambient Light (Lux)	Mix Intensity (Lux)	Error (Lux)		Periode to Stable (s)
338	325,8	12,2	4%	14
450	427,5	22,5	5%	4
564	545,0	19,0	3%	10
676	647,5	28,5	4%	6
789	764,2	24,8	3%	6
902	900,0	2,0	0%	9
789	769,2	19,8	3%	13
1014	981,7	32,3	3%	7
1127	1115,8	11,2	1%	13
1240	1200,0	40,0	3%	18
1015	988,3	26,7	3%	15
1127	1100,0	27,0	2%	11
1240	1211,7	28,3	2%	11
1466	1450,0	16,0	1%	13
1240	1218,3	21,7	2%	12
1352	1320,0	32,0	2%	11
1465	1443,3	21,7	1%	12
1578	1525,0	53,0	3%	15
AVERAGE		3%		11,1

3% and an adaptation time of 11 s. Based on the design and testing results, the nursery chamber, equipped with artificial light, is suitable for use in the zoysia grass nursery process.

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References

1. R. Rahayu, M. Mujiyo, R. Ramadhan, G. M. Yang, and J. S. Choi, "Effect of Shading and Mowing on the Growth of Indonesia's Native Zoysia grass in Silty Clay Soil," *Caraka Tani J. Sustain. Agric.*, vol. 35, no. 2, p. 317, 2020, https://doi.org/10.20961/carakatani.v35i2.40303.
2. T. Liu, J. Li, and J. Zhang, "Rootzone mixture affects the population of root-invading fungi in zoysiagrass," *Urban For. Urban Green.*, vol. 37, no. October 2017, pp. 168–172, 2019, https://doi.org/10.1016/j.ufug.2018.04.007.
3. J. A. Monteiro, "Ecosystem services from turfgrass landscapes," *Urban For. Urban Green.*, vol. 26, pp. 151–157, 2017, https://doi.org/10.1016/j.ufug.2017.04.001.
4. K. Charif *et al.*, "Germination of some turfgrass species used in the green spaces in eastern Morocco," *Mater. Today Proc.*, vol. 13, pp. 713–719, 2019, https://doi.org/10.1016/j.matpr.2019.04.032.
5. T. Matsubara, Y. Kosugi, S. Takanashi, and K. Otsuka, "Gas exchange and growth/decline model of C 3 turfgrass fields under various light conditions," *Ecol. Modell.*, vol. 397, no. October 2017, pp. 107–121, 2019, https://doi.org/10.1016/j.ecolmodel.2018.09.012.
6. S. E. Koerner and S. L. Collins, "Interactive effects of grazing, drought, and fire on grassland plant communities in North America and South Africa," *Ecology*, vol. 95, no. 1, pp. 98–109, 2014, https://doi.org/10.1890/13-0526.1.
7. K. H. Son, Y. M. Jeon, and M. M. Oh, "Application of supplementary white and pulsed light-emitting diodes to lettuce grown in a plant factory with artificial lighting," *Hortic. Environ. Biotechnol.*, vol. 57, no. 6, pp. 560–572, 2016, https://doi.org/10.1007/s13580-016-0068-y.
8. T. Seedapalee, C. Inkham, S. Ruamrungsri, S. Jogloy, and P. Hongpakdee, "Physiological responses of sun choke's seedlings under different wavelength LED lighting," *Sci. Hortic. (Amsterdam).*, vol. 282, no. January, p. 110029, 2021, https://doi.org/10.1016/j.scienta.2021.110029.
9. A. R. Restiani, S. Ttriyono, A. Tusi, and R. Zahab, "The Effect Of Lamp Types On The Growth And Production Of Lettuce Grown In An Indoor Hydrophonic System," *J. Tek. Pertan. Lampung*, vol. 4, no. 3, pp. 219–226, 2015.
10. Y. Park and E. S. Runkle, Far-red radiation promotes growth of seedlings by increasing leaf expansion and whole-plant net assimilation, vol. 136. Elsevier B.V., 2017. https://doi.org/10.1016/j.envexpbot.2016.12.013.
11. N. Lu, C. Song, T. Kuronuma, H. Ikei, Y. Miyazaki, and M. Takagaki, "The possibility of sustainable urban horticulture based on nature therapy," *Sustain.*, vol. 12, no. 12, pp. 1–11, 2020, https://doi.org/10.3390/su12125058.
12. R. Fan *et al.*, "CFD simulation of the airflow uniformity in the plant factory," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 560, no. 1, 2020, https://doi.org/10.1088/1755-1315/560/1/012074.

13. Z. Yan, D. He, G. Niu, and H. Zhai, "Evaluation of growth and quality of hydroponic lettuce at harvest as affected by the light intensity, photoperiod and light quality at seedling stage," *Sci. Hortic. (Amsterdam).*, vol. 248, no. August 2018, pp. 138–144, 2019, https://doi.org/10.1016/j.scienta.2019.01.002.
14. F. Tian, "Study and optimization of lighting systems for plant growth in a controlled environment," *Chem. Process Eng.*, 2016.
15. A. F. Pratiwi, S. W. Utami, and G. M. Aji, "Rancang Bangun Chamber Sistem Hidroponik Dalam Ruangan Dengan Menggunakan Cahaya Buatan," pp. 76–80, 2021.
16. A. F. Pratiwi, G. M. Aji, S. W. Utami, and A. Kristiningsih, "Penerapan Cahaya Buatan Pada Chamber Semai Tanaman Hidroponik Di KWT Sekar Arum," vol. 3, no. 1, 2022.
17. H. W. Lim, I. Kohli, E. Ruvolo, L. Kolbe, and I. H. Hamzavi, "Impact of visible light on skin health: The role of antioxidants and free radical quenchers in skin protection," Journal of the American Academy of Dermatology, vol. 86, no. 3, pp. S27–S37, Mar. 2022, https://doi.org/10.1016/j.jaad.2021.12.024.
18. C. Stadler, "Effects of lighting time and light intensity on growth, yield and quality of greenhouse tomato," *Environ. Sci.*, 2012.
19. L. Wang, H. Zhang, X. Zhou, Y. Liu, and B. Lei, "A dual-emitting core-shell carbon dot-silica-phosphor composite for LED plant grow light," *RSC Adv.*, vol. 7, no. 27, pp. 16662–16667, 2017, https://doi.org/10.1039/c7ra00227k.
20. C. Reynolds, "Zoysiagrass," 2014.
21. D. D. Loch, "Zoysias: the environmental turfgrass," *Aust. Turfgrass Manag. J.*, vol. 15, no. 1, pp. 45–49, 2013.
22. N. Ntoulas, P. A. Nektarios, E. Charalambous, and A. Psaroulis, "Zoysia matrella cover rate and drought tolerance in adaptive extensive green roof systems," *Urban For. Urban Green.*, vol. 12, no. 4, pp. 522–531, 2013, https://doi.org/10.1016/j.ufug.2013.07.006.
23. E. Goto, "Plant production in a closed plant factory with artificial lighting," *Acta Hortic.*, vol. 956, pp. 37–49, 2012, https://doi.org/10.17660/ActaHortic.2012.956.2.
24. E. Y. Kim, S. A. Park, B. J. Park, Y. Lee, and M. M. Oh, "Growth and antioxidant phenolic compounds in cherry tomato seedlings grown under monochromatic light-emitting diodes," *Hortic. Environ. Biotechnol.*, vol. 55, no. 6, pp. 506–513, 2014, https://doi.org/10.1007/s13580-014-0121-7