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Temperature, Relative Humidity and Photosynthetic Photon Flux Density Affects the Growth of *Phyllanthus niruri* L. Seedling

Suhu, Kelembaban Relatif dan Kepadatan Photon Fluks Fotosintesis Mempengaruhi Pertumbuhan Bibit Phyllanthus niruri L.

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ABSTRAK

Untuk memperoleh bibit berkualitas tinggi, pengaruh suhu, kelembaban relatif, dan kerapatan fluks foton fotosintesis (PPFD), benih *Phyllanthus niruri* L. (meniran) diteliti pada lingkungan iklim mikro (suhu, kelembaban relatif, PPFD) yang berbeda. Penelitian ini dilakukan pada bulan Februari hingga Mei 2024 di greenhouse dan screen house percobaan Badan Riset dan Inovasi Nasional, Banten, Indonesia. Parameter iklim mikro diamati tiga kali sehari pada pukul 8 pagi, 12 siang, dan 3 sore selama penelitian. Kedua lingkungan tersebut memiliki perbedaan iklim mikro yang signifikan. Rata-rata suhu, kelembaban relatif, dan PPFD lingkungan 1 adalah 35,30±5,04 ºC, 60,95±17,40%, dan 483,33±406,00 µmol m^{-2} S^{-1}, sedangkan lingkungan 2 adalah 33,07±4,84 ºC, 70,47±16,63% dan 356,4±339,55 µmol m^{-2} S^{-1}. Semua perlakuan diulang sebanyak 18 kali. Setelah perlakuan selama 21 hari pada tahap pembibitan, dilakukan pengamatan terhadap bibit *P. niruri*, meliputi laju perkecambahan, jumlah daun, panjang pucuk, dan indeks kandungan klorofil. Hasil penelitian menunjukkan bahwa laju perkecambahan, jumlah daun, panjang pucuk, dan indeks kandungan klorofil berbeda nyata antara bibit *P. niruri* pada kedua lingkungan. *Phyllanthus niruri* yang tumbuh pada lingkungan 1 memiliki laju perkecambahan yang lebih tinggi dibandingkan pada lingkungan 2, demikian pula halnya dengan jumlah daun, panjang tunas, dan indeks kandungan klorofil. Penelitian awal ini menunjukkan bahwa bibit *P. niruri* tumbuh lebih baik pada lingkungan dengan suhu, kelembaban relatif, dan PPFD masing-masing 35,30±5,04 ºC, 60,95±17,40%, dan 483,33±406,00 µmol m^{-2} S^{-1}.

Kata Kunci:

iklim mikro;

kelembaban relatif;

meniran;

photosynthetic photon flux density;

suhu.

Keywords:

meniran;

microclimate;

temperature;

photosynthetic photon flux density;

relative humidity.

ABSTRACT

In order to obtain high-quality seedlings, the effects of temperature, relative humidity, and photosynthetic photon flux density (PPFD), the seed of Phyllanthus niruri L. (meniran) were investigated in different microclimate (temperature, relative humidity, PPFD) environments. The present study was conducted from February to May 2024 at the experimental greenhouse and screen house of the National Research and Innovation Agency, Banten, Indonesia. Microclimate parameters were observed thrice daily at 8 am, 12 pm, and 3 pm during the research. The two environments significantly differ in microclimate. The average temperatures, relative humidity, and PPFD of environment 1 are 35.30±5.04 ºC, 60.95±17.40%, and 483.33±406.00 µmol m^{-2} S^{-1}, while environment 2 are 33.07±4.84 ºC, 70.47±16.63% and 356.4±339.55 µmol m^{-2} S^{-1}. All treatments were repeated 18 times. After the 21-day treatment during the seedling stage, P. niruri seedlings were observed, including the germination rate, number of leaves, shoot length, and chlorophyll content index. Results showed that the germination rate, leaves, shoot length, and chlorophyll content index significantly differ between P. niruri seedlings in both environments. Phyllanthus niruri that grow in environment 1 have a higher germination rate than in environment 2, likewise, the number of leaves, shoot length, and chlorophyll content index. This initial research showed that P. niruri seedling grows better in an environment with temperature, relative humidity, and PPFD, respectively 35.30±5.04 ºC, 60.95±17.40%, and 483.33±406.00 µmol m^{-2} S^{-1}.

INTRODUCTION

Phyllantus niruri L. or *meniran*, a weed found in tropical and subtropical regions, is also a medicinal plant with medicinal properties. *P. niruri* has been used to treat various health conditions, including bronchitis, leprosy, anemia, urinary discharge, asthma, and skin diseases (Mao et al., 2016; Paithankar et al., 2011). *Phyllanthus niruri* has numerous medicinal properties, including flavonoids, alkaloids, tannins, lignans, terpenoids, polyphenols, and saponins. These bioactive compounds contribute to the plant's antiviral, antibacterial, hypolipidaemic, hypoglycaemic, analgesic, anti-inflammatory, cardioprotective, anti-urolithiasis, and antihyperglycaemic effects (Lee et al., 2016; Rusmana et al., 2017). Tambunan et al. (2019) found that *P. niruri* herbal extracts meet quality standards, with phytochemical screening revealing flavonoids, saponins, tannins, quinones, triterpenoids, coumarins, and essential oils, and the 70% ethanol extract showed potent antioxidants.

As a weed that has changed its function to become a cultivated medicinal plant, optimal cultivation of *P. niruri* needs to be studied further, especially at the seedling stage. Seedling is a critical stage in plant growth, marking the transition from germination to self-sufficiency. It involves root system development, rapid shoot growth, and the establishment of autonomy. Seedlings are more vulnerable to environmental factors, making this stage crucial for their adaptation. The stage also influences the plant's architecture, including the root system, stem, and leaves. This stage sets the stage for subsequent growth, including vegetative and reproductive phases. A strong foundation established during seedling can lead to healthier and more productive plants in later stages (Hanley et al., 2004).

The previous study showed that the planting medium used to grow *P. niruri* plants combines soil, husks, and manure. The ratio used in soil composition: husks: manure, respectively 1: 1: 1. This comparison of the composition of the planting media provides good growth of *P. niruri* seedlings (Susanti & Larasati, 2018). Research related to *P. niruri* cultivation has been carried out by Khoirunisa et al. (2021), while research related to *P. niruri* seedlings shows that the storage container and storage time have a significantly different effect on the germination of *P. niruri* seeds. The interaction between storage temperature and storage time as well as the interaction between storage container and storage time had significantly different effects on germination (Listyana et al., 2019).

However, research related to establishing seedlings, especially the specific microclimate for *P. niruri*, has never been studied before. Microclimate and seedling stages are closely related because microclimate plays a significant role in seedling growth by influencing factors such as temperature, light, water, humidity, and air circulation. Understanding these interactions is crucial for optimizing seedling growth and ensuring healthy development. Microclimate, the climatic elements near plants, regulates physiological reactions and energy exchange processes. Lack of optimal climatic elements can lead to decreased crop productivity. Microclimatic modifications can help maintain optimal conditions for better crop growth and yield. Short-term farm-level adjustments can help maintain a favorable crop microclimate, ensuring food security and sustainability of natural resources under changing climatic conditions (Kingra & Kaur, 2017).

This research aims to determine the optimal microclimate, such as air temperature, humidity, and photosynthetic photon flux density (PPFD) for growing *P. niruri* at the seedling phase. We grow seedlings in two environments with different microclimate conditions and measure growth seedling parameters such as the number of seedlings growth, number of leaves, shoot length, and chlorophyll content index (CCI).

METHODOLOGY

The research was conducted from February to May 2024. This research was carried out in two experimental environments, a greenhouse as Environment 1 and a screen house as Environment 2 in the LAPTIAB, National Research and Innovation Agency located at latitude 6°21'27.99 "S and longitude 106°39'51.75 "E, 57.30 m above sea level.

Phyllanthus niruri seeds were obtained from Wuluhan, Jember. Microclimate conditions such as temperature, humidity, and PPFD were recorded during the experiment. Microclimate parameters were observed thrice daily at 8 am, 12 pm, and 3 pm. Temperatures and relative humidity of the environment were measured by thermometer and hygrometer HTC-1. Photosynthetic photon flux density measured by MQ-500: Full-Spectrum Quantum from Apogee Instruments.

The research was arranged and followed by Nawfetrias et al. (2024) with modifications. The research was arranged in a randomized block design with 18 replications. *Phyllanthus niruri* seeds were planted on a medium consisting of topsoil: rice husk: manure (1:1:1) in a 15 x 15 cm plastic pot. Watering plants are maintained under the same environmental conditions to ensure water does not hamper biological activity. We water the plants once in the morning. After the 21-day treatment during the seedling stage, *P. niruri* seedlings were observed, including the germination rate, number of leaves, shoot length, and chlorophyll content index (CCI) using SPAD-502 Plus from Konica Minolta by clamping the device onto the third leaf from the top.

Data was collected from three samples from each unit plot. Data were statistically analyzed with ANOVA at 5% using Minitab 20.3, and further tested by a Tukey Honestly Significant Difference (HSD) multiple range test at a 95% confidence level.

RESULT AND DISCUSSION

The microclimate of each growing environment was observed during the research. The temperature, relative humidity, and PPFD in both growth environments are significantly different (Table 1). The temperature and PPFD of Environment 1 are higher than Environment 2, otherwise relative humidity of Environment 1 is lower than Environment 2.

The analysis of variance on growth parameters showed different environments with different microclimates significantly influenced the germination rate, shoot length, number of leaves, and chlorophyll content index (Table 2.). R-square is a measure of the influence of an independent variable on an endogen variable. It is categorized into strong, moderate, and weak values, with values ranging from 0 to 1. The R-square value is used to evaluate the influence of a specific independent variable on a dependent variable. The R-square value of 0.75 belongs to the strong category, the square R-value of 0,50 belonging to the moderate category, and the R-square value of 0.025 belongs to the weak category (Hair et al., 2011). All growth

Table 1. Temperature, relative humidity, and photosynthetic photon flux density of the experimental environment from March to April 2024

Location	Microclimate parameters		
	Temperature (°C)	Relative humidity (%)	PPFD (µmol m^{-2} S^{-1})
Environment 1	35.30±5.04a	60.95±17.40b	483.33±406.00a
Environment 2	33.07±4.84b	70.47±16.63a	356.4±339.55b

PPFD : Photosynthetic Photon Flux Density parameters have an R-square value of 77.90% - 82.39%. This value indicates that two different environments as independent variables significantly impact explaining the variation of growth parameters as dependent values, indicating a stronger relationship between the treatment and the outcome. The R-square value is particularly useful in experimental design because it provides a way to quantify the effect size of the treatment

The Tukey's HSD multiple range test indicated that the germination rate in Environment 1 is higher than in Environment 2 (Figure 1A). Germination is a complex process influenced by genetic factors and environmental conditions (Li et al., 2022). The observed decrease in germination rates after 14 days is attributed to the earlier germination of some seeds, which adapt better and create less favorable conditions for those that have not yet sprouted (Salekin et al., 2023). Additionally, a reduction in the availability of nutrients such as nitrogen, phosphorus, and potassium in the media contributes to lower germination percentages, as these nutrients are essential for supporting metabolic processes during germination (Kristó et al., 2023).

Table 2. Summary of the analysis of the growth parameters of Phyllanthus niruri in two different environment treatment

Growth parameters	R-square (%)	Environment
Germination rate	80.43	**
Shoot length	82.39	**
Number of leaves	77.90	**
Chlorophyll Content Index	80.81	**

ns : Non-significant difference
* : Significant difference at the 0.05 level (ANOVA and Tukey's HSD multiple range test)
** : Significant difference at the 0.01 level

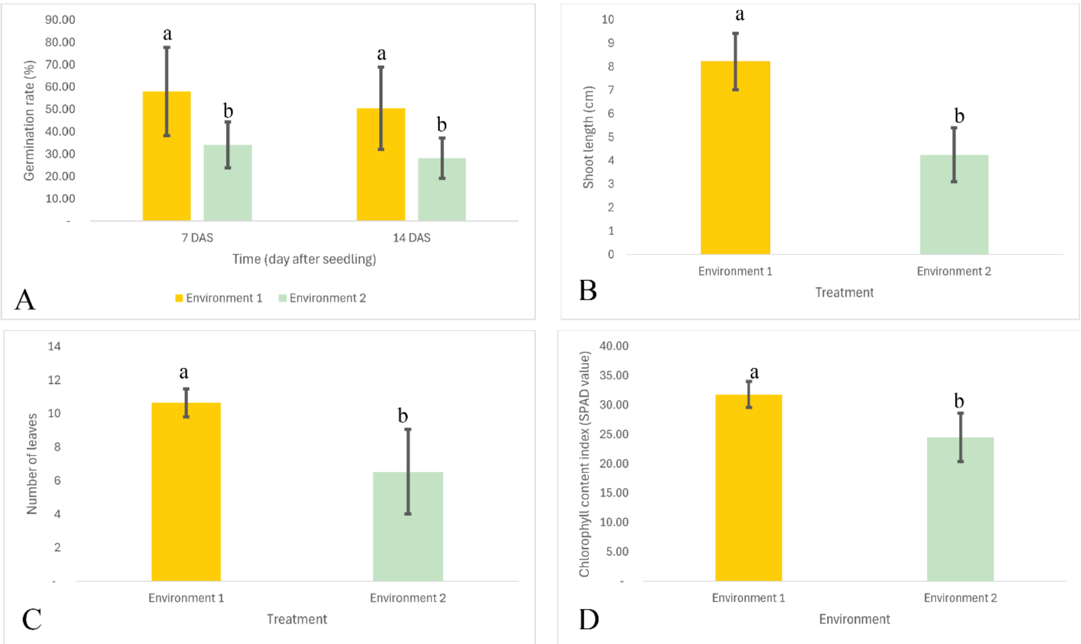

Figure 1. The effect of different environments on germination rate (A), shoot length (B), number of leaves (C), chlorophyll content index (D) on Phyllanthus niruri seedling. Environment 1: temperature 35.30±5.04 °C, relative humidity 60.95±17.40%, PPFD: 483.33±406.00 µmol m^{-2} S^{-1}. Environment 2: temperature 33.07±4.84 °C, relative humidity 70.47±16.63%, PPFD: 356.4±339.55 µmol m^{-2} S^{-1}

Furthermore, Environment 1 exhibits higher temperatures and photosynthetic photon flux density (PPFD) compared to Environment 2, while the relative humidity in Environment 1 is lower. These results suggest that P. niruri seedlings thrive in conditions with a temperature of 35.30±5.04 °C, relative humidity of 60.95±17.40%, and PPFD of 483.33±406.00 µmol m^{-2} s^{-1}. These factors are crucial, as temperature, relative humidity, and PPFD directly influence physiological processes such as photosynthesis, respiration, and transpiration. Each plant species has its unique optimal growth conditions, shaped by factors like evolutionary history, natural habitat, and metabolic requirements (Amitrano et al., 2020; Assefa & Gobena, 2019; Dumitrescu & Ghiaus, 2019; Rabbi et al., 2019; Yu et al., 2023). Although P. niruri is classified as a weed, our findings indicate that its seeds necessitate a specific microclimate for optimal growth, as evidenced by the better performance of P. niruri seedlings in Environment 1 compared to Environment 2.

Shoot length at Environment 1 was higher than Environment 2 based on Tukeys's HSD multiple range test (Figure 1B). Environment 1 has temperature and PPFD higher than Environment 2, while the relative humidity of Environment 1 is lower than Environment 2. Environment 1 has temperatures, relative humidity, and PPFD respectively 35.30±5.04 ^{o}C, 60.95±17.40% and 483.33±406.00 µmol m^{-2} S^{-1}. Shoot length, which is closely correlated with internode elongation, can be influenced by specific microclimates such as light intensity. Internode elongation in soybean plants is significantly influenced by the intensity of Parabolic Aluminized Reflector (PAR), blue, red, and far-red light in the canopy. As density and depth increase, the strongest elongation occurs in the middle of the stem, leading to increased shoot length. Mono-light far-red promotes elongation, while red and blue act as inhibitors (Xu et al., 2021). Internode elongation is also influenced by specific temperatures and relative humidity (Allen et al., 2018). Factors such as temperature, humidity, and light can impact plant growth, and plants have evolved to adapt to these microclimates. Understanding these microclimates and how they impact plant growth is essential for effective plant management and conservation strategies. Accurate knowledge of plant requirements and microclimate parameters can help design adaptive control strategies for cost-effective and competitive production (Shamshiri et al., 2018).

The number of leaves in Environment 1 is higher than in Environment 2 (Figure 1C). Environment 1 has temperature and PPFD higher than Environment 2, while the relative humidity of Environment 1 is lower than Environment 2. These results indicate that *P. niruri* seedlings produce more leaves in environments with temperatures, relative humidity, and PPFD respectively 35.30±5.04 ^{o}C, 60.95±17.40%, and 483.33 ± 40600 µmol m^{-2} S^{-1} for maximize photosynthetic for leaves formation. Specific microclimates have a relation with the number of leaves because these conditions provide the optimal environment for photosynthesis, respiration, and transpiration, which are crucial processes for plant growth. Microclimates can influence leaf growth by affecting factors such as temperature, humidity, light, and wind, which directly impact the physiological processes of plants. The changed temperature environment under the increased diffuse light film improved the net photosynthetic rate of tomato leaves. Therefore, more homogeneous PPFD and appropriate temperature environments promote leaf photosynthesis and increase yield (Zheng et al., 2020).

The Tukeys's HSD multiple range test showed that the chlorophyll content index in Environment 1 is higher than in Environment 2 (Figure 1D). Environment 1 has temperature and PPFD higher than environment 2, while the relative humidity of environment 1 is lower than environment 2. These results indicate that *P. niruri* seedling requires a growing environment with temperatures, relative humidity, and PPFD respectively 35.30±5.04 ^{o}C, 60.95±17.40%, and 483.33±406.00 µmol m^{-2} S^{-1} for maximize photosynthetic for leaves formation. The chlorophyll content index, a key indicator of plant physiology, is influenced by microclimate factors like light intensity, temperature, and water availability, affecting photosynthesis rate. For instance, high light intensities can lead to increased chlorophyll content due to enhanced photosynthesis, while low light conditions may result in lower chlorophyll levels. Shade treatment reduces plant transpiration compared with plants in full photosynthetic photon flux density, but it also reduces photosynthesis sensitivity (Massaci et al., 2000) and tends to increase leaf nutrient concentrations and leaf chlorophyll content (Minotta & Pinzauti 1996). The chlorophyll content index is closely related to temperature in the environment. The relationship between chlorophyll content and temperature is complex, as it can directly and indirectly affect the plant's ability to produce chlorophyll. Our result showed that the optimum temperature to increase the chlorophyll content of *P. niruri* seedlings is 35.30±5.04 ^{o}C. This result aligns with the research conducted by Sarkar et al. (2021) and Talebi (2011) that showed chlorophyll content is generally highest when plants are grown within their optimal temperature range. At their optimal temperature, photosynthesis is most efficient, and chlorophyll production is maximized. Temperatures that are too high or too low can negatively impact chlorophyll content. High temperatures can cause chlorophyll degradation, leading to reduced chlorophyll levels. Low temperatures can slow down photosynthesis, also resulting in lower chlorophyll content.

Environment 1 provides better growth conditions compared to Environment 2 based on growth parameters starting from the germination rate, shoot length, number of leaves, and chlorophyll content index. This indicates that *P. niruri* grows well in a microclimate with temperatures, relative humidity, and PPFD respectively 35.30±5.04 °C, 60.95±17.40%, and 483.33±406.00 µmol m^{-2} s^{-1}. Environment 1 receives more sunlight due to its location and conditions, which are more open compared to Environment 2. The intensity of sunlight that is cast into the environment will cause temperature changes in the environment that receives it. Light intensity is a crucial factor in plants, playing a role as a growth regulator and plant development regulator (Simlat et al., 2016). The increase in temperature caused by the higher light intensity will stimulate an increase in plant enzyme activity (Dusenge et al.,2019). This triggers the formation of healthy roots and shoots during the seedling phase and can enhance plant growth (Grossnickle & MacDonald, 2018). This positive effect on plant growth is demonstrated by the plants in Environment 1 growing more optimally compared to those in Environment 2.

CONCLUSION

The germination rate, the number of leaves, shoot length, and chlorophyll content index significantly differ between *P. niruri* seedlings in both environments. *Phyllanthus niruri* that grow in Environment 1 have a higher germination rate than in Environment 2, likewise, the number of leaves, shoot length, and chlorophyll content index. This initial research showed that *P. niruri* seedling grows better in an environment with temperature, relative humidity, and PPFD, respectively 35.30±5.04 °C, 60.95±17.40%, and 483.33±406.00 µmol m^{-2} S^{-1}.

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REFERENCE

Allen, L. H., Zhang, L., Boote, K. J., & Hauser, B. A. (2018). Elevated temperature intensity, timing, and duration of exposure affect soybean internode elongation, mainstem node number, and pod number per plant. *The Crop Journal*, *6*(2), 148–161. https://doi.org/10.1016/j.cj.2017.10.005

Amitrano, C., Arena, C., De Pascale, S., & De Micco, V. (2020). Light and Low Relative Humidity Increase Antioxidants Content in Mung Bean (Vigna radiata L.) Sprouts. *Plants*, *9*(9), 1093. https://doi.org/10.3390/plants9091093

Assefa, A., & Gobena, A. (2019). Review on Effect of Shade Tree on Microclimate, Growth and Physiology of Coffee Arabica: In case of Ethiopia. *International Journal of Forestry and Horticulture*, *5*(3), 31–46. https://doi.org/10.20431/2454-9487.0503004

Das Sarkar, S., Sarkar, U. K., Naskar, M., Roy, K., Bose, A. K., Nag, S. K., Karnatak, G., & Das, B. K. (2020). Effect of climato-environmental parameters on chlorophyll a concentration in the lower Ganga basin, India. *Revista de Biología Tropical*, *69*(1), 60–76. https://doi.org/10.15517/rbt.v69i1.42731

Dumitrescu, I. L., & Ghiaus, A.-G. (2019). An overview of the microclimate conditions inside healing chambers. *E3S Web of Conferences*, *85*, 01009. https://doi.org/10.1051/e3sconf/20198501009

Dusenge, M. E., Duarte, A. G., & Way, D. A. (2019). Plant carbon metabolism and climate change: elevated CO2and temperature impacts on photosynthesis, photorespiration and respiration. *New Phytologist*, *221*(1), 32–49. https://doi.org/10.1111/nph.15283

Grossnickle, S. C., & MacDonald, J. E. (2018). Why seedlings grow: influence of plant attributes. *New Forests*, *49*(1), 1–34. https://doi.org/10.1007/s11056-017-9606-4

Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2011). *Multivariate Data Analysis* (7th ed.). Pearson Prentice Hall. https://www.google.co.id/books/edition/Multivariate_Data_Analysis/JlRaAAAAYAAJ?hl=en&gbpv=0&bsq=Multivariate Data Analysis

Hanley, M. E., Fenner, M., Whibley, H., & Darvill, B. (2004). Early plant growth: identifying the end point of the seedling phase. *New Phytologist*, *163*(1), 61–66. https://doi.org/10.1111/j.1469-8137.2004.01094.x

Khoirunisa, I., Budiman, & Kurniasih, R. (2021). Pengaruh Kadar Air Tanah Tersedia Dan Pengelolaan Pupuk Terhadap Pertumbuhan Meniran

(Phyllanthus niruri). *Jurnal Pertanian Presisi (Journal of Precision Agriculture)*, *5*(2), 138–146. https://doi.org/10.35760/jpp.2021.v5i2.5285

Kingra, P. K., & Kaur, H. (2017). Microclimatic Modifications to Manage Extreme Weather Vulnerability and Climatic Risks in Crop Production. *Journal of Agricultural Physics*, *17*(1), 1–15. https://www.researchgate.net/publication/331248969_Microclimatic_Modifications_to_Manage_Extreme_Weather_Vulnerability_and_Climatic_Risks_in_Crop_Production_Journal_of_Agricultural_Physics

Kristó, I., Vályi-Nagy, M., Rácz, A., Irmes, K., Szentpéteri, L., Jolánkai, M., Kovács, G. P., Fodor, M. Á., Ujj, A., Valentinyi, K. V., & Tar, M. (2023). Effects of Nutrient Supply and Seed Size on Germination Parameters and Yield in the Next Crop Year of Winter Wheat (Triticum aestivum L.). *Agriculture*, *13*(2), 419. https://doi.org/10.3390/agriculture13020419

Lee, N. Y. S., Khoo, W. K. S., Adnan, M. A., Mahalingam, T. P., Fernandez, A. R., & Jeevaratnam, K. (2016). The pharmacological potential of Phyllanthus niruri. *Journal of Pharmacy and Pharmacology*, *68*(8), 953–969. https://doi.org/10.1111/jphp.12565

Li, Y., Liang, Y., Liu, M., Zhang, Q., Wang, Z., Fan, J., Ruan, Y., Zhang, A., Dong, X., Yue, J., & Li, C. (2022). Genome-Wide Association Studies Provide Insights Into the Genetic Architecture of Seed Germination Traits in Maize. *Frontiers in Plant Science*, *13*(930438). https://doi.org/10.3389/fpls.2022.930438

Listyana, N. H., Widyastuti, R., & Widyantoro, W. (2019). PENGARUH WADAH, SUHU DAN WAKTU SIMPAN TERHADAP PERKECAMBAHAN BENIH MENIRAN (Phyllanthus niruri L.). *Jurnal Tumbuhan Obat Indonesia*, *12*(2), 75–82. https://doi.org/10.22435/jtoi.v12i2.1126

Mao, X., Wu, L.-F., Guo, H.-L., Chen, W.-J., Cui, Y.-P., Qi, Q., Li, S., Liang, W.-Y., Yang, G.-H., Shao, Y.-Y., Zhu, D., She, G.-M., You, Y., & Zhang, L.-Z. (2016). The Genus Phyllanthus : An Ethnopharmacological, Phytochemical, and Pharmacological Review. *Evidence-Based Complementary and Alternative Medicine*, *2016*(1), 1–36. https://doi.org/10.1155/2016/7584952

Massaci, A., Pietrini, F., Centritto, M., & Loreto, F. (2000). MICROCLIMATE EFFECTS ON TRANSPIRATION AND PHOTOSYNTHESIS OF CHERRY SAPLINGS GROWING UNDER A SHADING NET. *Acta Horticulturae*, *537*(537), 287–291. https://doi.org/10.17660/ActaHortic.2000.537.32

Minotta, G., & Pinzauti, S. (1996). Effects of light and soil fertility on growth, leaf chlorophyll content and nutrient use efficiency of beech (Fagus sylvatica L.) seedlings. *Forest Ecology and Management*, *86*(1–3), 61–71. https://doi.org/10.1016/S0378-1127(96)03796-6

Nawfetrias, W., Nurhangga, E., Aprianti, R., Himawati, S., Shodiq, A. W., Zulkarnaen, I., Devy, L., Esyanti, R.

R., & Faizal, A. (2024). Drought stress response in Phyllanthus niruri L.: A potentially medicinal plant. *AIP Conference Proceedings*, *2957*(1), 040024. https://doi.org/10.1063/5.0183955

Paithankar, V. V, Raut, K., Charde, R., & Vyas, J. (2011). Phyllanthus Niruri: A magic Herb. *Research in Pharmacy*, *1*(4), 1–9. https://updatepublishing.com/journal/index.php/rip/article/view/215

Rabbi, B., Chen, Z.-H., & Sethuvenkatraman, S. (2019). Protected Cropping in Warm Climates: A Review of Humidity Control and Cooling Methods. *Energies*, *12*(14), 2737. https://doi.org/10.3390/en12142737

Rusmana, D., Wahyudianingsih, R., Elisabeth, M., Balqis, B., Maesaroh, M., & Widowati, W. (2017). Antioxidant Activity of Phyllanthus niruri Extract, Rutin and Quercetin. *The Indonesian Biomedical Journal*, *9*(2), 84. https://doi.org/10.18585/inabj.v9i2.281

Salekin, S., Hossain, M. N., Alam, M. A., Limon, S. H., & Rahman, M. S. (2023). Inter-specific competition between seeds and seedlings of two confamilial tropical trees. *Community Ecology*, *24*(3), 333–342. https://doi.org/10.1007/s42974-023-00165-3

Shamshiri, R. R., Jones, J. W., Thorp, K. R., Ahmad, D., Man, H. C., & Taheri, S. (2018). Review of optimum temperature, humidity, and vapour pressure deficit for microclimate evaluation and control in greenhouse cultivation of tomato: a review. *International Agrophysics*, *32*(2), 287–302. https://doi.org/10.1515/intag-2017-0005

Simlat, M., Ślęzak, P., Moś, M., Warchoł, M., Skrzypek, E., & Ptak, A. (2016). The effect of light quality on seed germination, seedling growth and selected biochemical properties of Stevia rebaudiana Bertoni. *Scientia Horticulturae*, *211*, 295–304. https://doi.org/10.1016/j.scienta.2016.09.009

Susanti, D., & Larasati, O. G. D. (2018). the Effect Composition of Plant Medium In Quinine Weed (Phyllanthus niruri L.) Nursery. *Jurnal Pengembangan Penyuluhan Pertanian*, *15*(28), 1–9. https://www.researchgate.net/profile/Rina-Muryani/publication/336754614_Pengaruh_Penambahan_Kunyit_Dan_Jahe_Dalam_Ransum_Terhadap_Eritrosit_Leukosit_Dan_Hemoglobin_Puyuh_Jantan_Effect_Of_Addition_Turmeric_And_Ginger_Powder_In_The_Ration_On_Erythrocytes_Le

Talebi, R. (2011). Evaluation of chlorophyll content and canopy temperature as indicators for drought tolerance in durum wheat (Triticum durum Desf.). *Australian Journal of Basic and Applied Sciences*, *5*(11), 1457–1462. https://ajbasweb.com/old/ajbas/2011/November-2011/1457-1462.pdf

Tambunan, R. M., Swandiny, G. F., & Zaidan, S. (2019). Uji Aktivitas Antioksidan dari Ekstrak Etanol 70% Herba Meniran (Phyllanthus niruri L.) Terstandar. *Jurnal Ilmu Kefarmasian*, *12*(2), 60–64. https://ejournal.istn.ac.id/index.php/saintechfarma/article/view/444/343

Xu, Y., Wang, C., Zhang, R., Ma, C., Dong, S., & Gong, Z. (2021). The relationship between internode elongation of soybean stems and spectral distribution of light in the canopy under different plant densities. *Plant Production Science*, *24*(3), 326–338. https://doi.org/10.1080/1343943X.2020.1847666

Yu, H., Yu, H., Zhang, B., Chen, M., Liu, Y., & Sui, Y. (2023). Quantitative Perturbation Analysis of Plant Factory LED Heat Dissipation on Crop Microclimate. *Horticulturae*, *9*(6), 660. https://doi.org/10.3390/horticulturae9060660

Zheng, L., Zhang, Q., Zheng, K., Zhao, S., Wang, P., Cheng, J., Zhang, X., & Chen, X. (2020). Effects of Diffuse Light on Microclimate of Solar Greenhouse, and Photosynthesis and Yield of Greenhouse-grown Tomatoes. *HortScience*, *55*(10), 1605–1613. https://doi.org/10.21273/HORTSCI15241-20