JPPIPA 11(9) (2025)

Jurnal Penelitian Pendidikan IPA

http://jppipa.unram.ac.id/index.php/jppipa/index

Response of Okra to the Application of Combined Lamtoro Liquid Organic Fertilizer and Rice Hush Ash on Growth and Chlorophyll Content

Siti Humaira[1*], Muhibbuddin[1], Hafnati Rahmatan[1], Djufri[1], Samingan[1]

[1] Department of Biology Education, Faculty of Teacher Training and Education, Universitas Syiah Kuala, Banda Aceh, Indonesia.

Received: June 19, 2025
Revised: September 03, 2025
Accepted: September 25, 2025
Published: September 30, 2025

Corresponding Author:
Siti Humaira
sitihumaira.mbio23@edu.usk.ac.id

DOI: 10.29303/jppipa.v11i9.12231

Abstract: The productivity of okra (Abelmoschus esculentus L.) can be improved through the utilization of locally available organic materials, such as a combination of liquid organic fertilizer (LOF) derived from Leucaena leucocephala leaves and rice husk ash. This research aimed to evaluate the effects of the combination of these two organic inputs on the growth and chlorophyll content of okra plants. The experiment employed a factorial Completely Randomized Design (CRD) 4×4 with two factors: concentration of Leucaena-based LOF (0%, 10%, 20%, and 30%) and dosage of rice husk ash (0%, 5%, 10%, and 15%), each with three replications. Observed parameters included plant height, fresh weight, and total chlorophyll content. The results showed that the LOF treatment, rice husk ash treatment, and their interaction had significant effects ($p < 0.05$) on all three parameters. The combination of 30% LOF and 15% rice husk ash (A3B3) produced the highest values for plant height (62.53 cm), fresh weight (158.93 g), and total chlorophyll content (25.72 mg/L). These findings indicate that the combined application of LOF and rice husk ash can effectively enhance physiological efficiency and vegetative growth in okra plants.

Keywords: Chlorophyll; Lamtoro; Liquid organic fertilizer; Okra; Rice husk ash

Introduction

Okra (*Abelmoschus esculentus* L.) is a high-value horticultural commodity that is gaining popularity due to its nutritional benefits, including antioxidant, antidiabetic, and cholesterol-lowering properties (Elkhalifa et al., 2021; Salsabila et al., 2023). Its rich nutritional profile positions okra as a promising candidate for functional food development. Despite the increasing demand, okra productivity in Indonesia remains relatively low (Fuskhah et al., 2022; Haryanta et al., 2024; Rian et al., 2024). One contributing factor is the decline in soil fertility caused by excessive use of inorganic fertilizers, which disrupts nutrient balance and soil microbial activity, ultimately affecting plant growth and physiological functions (Nooraminah et al., 2023; Panjaitan et al., 2023; Mendrofa & Gulo, 2024).

The application of liquid organic fertilizer (LOF) offers a sustainable approach to enhancing agricultural productivity, as it can improve soil physical, chemical, and biological properties while supplying nutrients in a gradual and environmentally friendly manner (Asmawanti S et al., 2022; Waruwu et al., 2024). One potential local material for LOF production is Leucaena leucocephala (lamtoro) leaves, which are known to contain essential macronutrients such as nitrogen (N), phosphorus (P), potassium (K), and magnesium (Mg) (Thamaga et al., 2021; Ramadhan & Sabli, 2024). These elements play critical roles in plant development: nitrogen is essential for protein synthesis and tissue

How to Cite:
Humaira, S., Muhibbuddin, Rahmatan, H., Djufri, & Samingan. (2025). Response of Okra to the Application of Combined Lamtoro Liquid Organic Fertilizer and Rice Hush Ash on Growth and Chlorophyll Content. *Jurnal Penelitian Pendidikan IPA*, *11*(9), 487–493. https://doi.org/10.29303/jppipa.v11i9.12231

formation; phosphorus is involved in energy transfer and root development; potassium regulates osmotic balance and enzyme activation; and magnesium, as a core component of the chlorophyll molecule, is directly involved in photosynthesis (Albari, 2018; Virgiawan et al., 2023; Anwar et al., 2025). According to Ramadhan et al. (2024) and Pane et al. (2024), Leucaena leaves contain approximately 3.48% nitrogen, 0.2% phosphorus, 2.06% potassium, and 0.33% magnesium. However, the relatively low phosphorus content may be a limiting factor, as phosphorus is vital for root formation and energy metabolism in plants. To address this limitation, rice husk ash, which is rich in silica and potassium, can be used as a complementary soil amendment. Silica not only improves soil structure and enhances phosphorus uptake efficiency but also strengthens plant tissues against abiotic stress. Rice husk ash typically contains 87–97% silica and 1–5% potassium (França et al., 2017; Al-Rubie et al., 2024).

The nitrogen and magnesium supplied by Leucaena-based LOF, along with the silica from rice husk ash, are known to play crucial roles in chlorophyll synthesis—the primary photosynthetic pigment in plants. Chlorophyll is vital for the photosynthesis process, which provides the energy necessary for plant growth and development (Mandal & Dutta, 2020; Ardani & Sujalu, 2019). Consequently, increasing chlorophyll content directly enhances the plant's capacity to produce biomass, such as plant height and fresh weight. In other words, chlorophyll not only reflects the physiological status of the plant but also serves as a prerequisite for optimal growth (Kalaji et al., 2016; R. Zhang et al., 2022; Sumardiharta & Ardi, 2001).

However, although the individual benefits of these organic materials have been previously studied, research integrating the combined use of Leucaena-based LOF and rice husk ash—particularly in relation to their effects on chlorophyll content and okra plant growth—remains limited. Moreover, few studies have emphasized the interconnection between physiological enhancement via chlorophyll content and morphological responses through growth indicators.

Therefore, this research aims to evaluate the effects of Leucaena-based liquid organic fertilizer and rice husk ash, both individually and in combination, on the growth and chlorophyll content of okra plants. This research is expected to fill the knowledge gap regarding the synergy between biologically and mineral-based organic fertilizers on two major aspects of plant performance in an integrated manner and to serve as a reference for developing sustainable, locally based horticultural cultivation practices.

Method

Location and Time of Research

This research was conducted from February to May 2025. The preparation of the liquid organic fertilizer (LOF) was carried out in Deah Raya Village, Syiah Kuala Subdistrict, Banda Aceh City. The experimental treatments on okra plants were conducted in Lamgapang Village, Krueng Barona Jaya Subdistrict, Aceh Besar District.

Experimental Design

The experiment employed a factorial Completely Randomized Design (CRD) with a 4×4 arrangement, consisting of two treatment factors. The first factor was the concentration of Leucaena leaf-based LOF:

- A0 = 0% (control, 1000 mL water)
- A1 = 10% (100 mL LOF + 900 mL water)
- A2 = 20% (200 mL LOF + 800 mL water)
- A3 = 30% (300 mL LOF + 700 mL water)

The second factor was the dosage of rice husk ash:

- B0 = 0% (4000 g of soil)
- B1 = 5% (200 g rice husk ash + 3800 g soil)
- B2 = 10% (400 g rice husk ash + 3600 g soil)
- B3 = 15% (600 g rice husk ash + 3400 g soil)

Each treatment combination was replicated three times, resulting in a total of 48 experimental units. The test plant used was okra (Abelmoschus esculentus L.), F1 Greenie variety, grown in polybags filled with homogeneous soil media.

Preparation of Leucaena Leaf Liquid Organic Fertilizer

A total of 2.5 kg of fresh Leucaena leaves were blended and mixed with 5 L of water, 250 mL of molasses, 250 mL of EM4 (Effective Microorganisms-4), and 1 L of rice washing water. The mixture was fermented in a sealed container for 28 days. After fermentation, the liquid was filtered and used according to the treatment concentrations.

Preparation of Rice Husk Ash

Rice husk ash was produced by burning the husks in a perforated cylindrical metal drum. The husks were inserted and burned using a chimney system to minimize smoke and control combustion temperature. Once the husks uniformly turned black, the process was halted by dousing with water for cooling.

Planting and Maintenance

Okra seeds were soaked for 12 hours prior to direct sowing in polybags at a depth of approximately 3 cm, with one seed per hole. Plants were watered daily at 4:00–5:00 PM (WIB, Western Indonesian Time). Weeding was performed manually. Harvesting was conducted at 80 days after planting (DAP).

Treatment Application

The LOF treatments were applied via soil drenching starting from 14 DAP, with a 10-day interval between applications. The total application volume was kept consistent across all units. Rice husk ash was applied once, 7 days after planting, by broadcasting onto the soil surface according to the respective dosage.

Observed Parameters

The parameters measured in this research included:

- Plant height (cm): measured from the soil surface to the apical growth point every 10 days until the final observation.
- Fresh plant weight (g): total biomass weight recorded at the end of the vegetative phase (80 DAP).
- Total chlorophyll content (mg/L): determined through spectrophotometric analysis.

Chlorophyll Content Analysis

A total of 0.5 grams of fresh okra leaves from each experimental unit were extracted using 25 mL of 95% ethanol and filtered. The filtrate was then measured using a Spectronic 20D+ spectrophotometer at wavelengths of 649 nm and 665 nm. Chlorophyll content was calculated based on the method of Wintermans and De Mots using the following equations:

- Chlorophyll a (mg/L) = $(13.7 \times OD_{665}) - (5.76 \times OD_{649})$
- Chlorophyll b (mg/L) = $(25.8 \times OD_{649}) - (7.7 \times OD_{665})$
- Total chlorophyll (mg/L) = $(20 \times OD_{649}) + (6.1 \times OD_{665})$

Data Analysis

The data for plant height, fresh plant weight, and total chlorophyll content were analyzed using two-way Analysis of Variance (ANOVA) at a 5% significance level to determine the effects of Leucaena leaf LOF, rice husk ash, and their interaction.

Result and Discussion

Plant Height

The application of Leucaena-based liquid organic fertilizer (LOF), rice husk ash, and their interaction had a significant effect on the plant height of okra ($p < 0.05$). The treatment combination A3B3 (30% LOF and 15% rice husk ash) resulted in the tallest plants, reaching an average height of 62,53 cm, while the control treatment (A0B0) produced the shortest plants, with an average height of 22,78 cm (Table 1). The interaction graph in Figure 1a illustrates that increasing the LOF concentration from 0% to 30% tended to result in increased plant height, particularly when combined with 10% and 15% rice husk ash. At lower ash dosages (0–5%), the increase in plant height was less pronounced compared to higher ash levels. This pattern suggests that the plant response to LOF becomes more optimal when supported by an adequate amount of rice husk ash.

Table 1. Mean Value of Plant Height, Fresh Weight, and Chlorophyll Content of Okra Under Various Combinations of Lamtoro Liquid Organic Fertilizer and Rice Hush Ash

Treatments Combinations	Plant Height (cm)	Fresh Weight (g)	Chlorophyll Content (mg/L)
A0B0	22.78	31.93	17.46
A0B1	24.16	44.80	19.13
A0B2	25.59	52.77	20.13
A0B3	34.39	65.57	20.56
A1B0	27.54	60.80	20.54
A1B1	36.46	68.50	20.95
A1B2	37.72	72.20	21.69
A1B3	44.95	87.90	22.39
A2B0	40.72	75.93	21.83
A2B1	47.30	93.60	22.56
A2B2	48.64	116.20	22.81
A2B3	56.33	121.53	23.33
A3B0	42.74	81.50	21.95
A3B1	58.42	123.80	24.05
A3B2	60.52	135.77	24.93
A3B3	62.53	158.93	25.72

Fresh Plant Weight

The application of Leucaena LOF, rice husk ash, and their interaction also significantly affected the fresh weight of okra plants ($p < 0.05$). The A3B3 treatment yielded the highest fresh weight at 158.93 g, while the A0B0 treatment showed the lowest value at 31.93 g (Table 1). The interaction plot in Figure 1b displays a consistent increase in fresh weight with increasing LOF concentration, particularly at 10% and 15% rice husk ash dosages. These results indicate that the combination of

biologically based organic input (LOF) and mineral input (ash) exerts an accumulative effect on the increase in fresh biomass.

Total Chlorophyll Content

Total chlorophyll content was also significantly influenced by both the individual treatments and the interaction between LOF and rice husk ash ($p < 0.05$). The highest total chlorophyll content was observed in the A3B3 treatment (25.72 mg/L), whereas the lowest was recorded in the control treatment A0B0 (17.46 mg/L) (Table 1). The interaction graph in Figure 1c shows a positive correlation between increasing LOF concentration and total chlorophyll content, particularly when combined with ≥10% rice husk ash. The upward trend of the graph across treatment combinations suggests a sustained enhancement of chlorophyll synthesis, with no apparent saturation point, indicating that the combined application of these two materials consistently supports chlorophyll formation.

A summary of observational data on three primary parameters- plan height, fresh weight, and total chlorophyll content of okra- under various combinations of treatments is presented in Table 1. Visual representations of each parameter are separately illustrated in Figure 1a, 1b, and 1c.

The findings of this research demonstrate that the combined application of Leucaena-based liquid organic fertilizer (LOF) and rice husk ash had a significant effect on the plant height, fresh weight, and total chlorophyll content of okra plants. These three parameters are interrelated and function as components of the plant's integrated physiological system. The increase in chlorophyll content, as a key physiological indicator, reflects enhanced photosynthetic efficiency, which ultimately leads to greater energy production and the synthesis of organic compounds necessary to support morphological growth, including plant height and biomass accumulation.

Chlorophyll is a critical pigment in the photosynthesis process, and its synthesis is strongly influenced by the availability of nitrogen and magnesium. Nitrogen plays a role in the synthesis of proteins and enzymes involved in chloroplast formation, while magnesium serves as the central atom in the chlorophyll molecule structure (Xie et al., 2024; Benchasri, 2012). Both elements are present in Leucaena leaf LOF (Parna et al., 2025; Idawati, 2012), making its application a potential means to enhance chlorophyll content in plants. The increase in chlorophyll levels due to LOF application allows plants to capture light more efficiently and enhances the rate of photosynthesis.

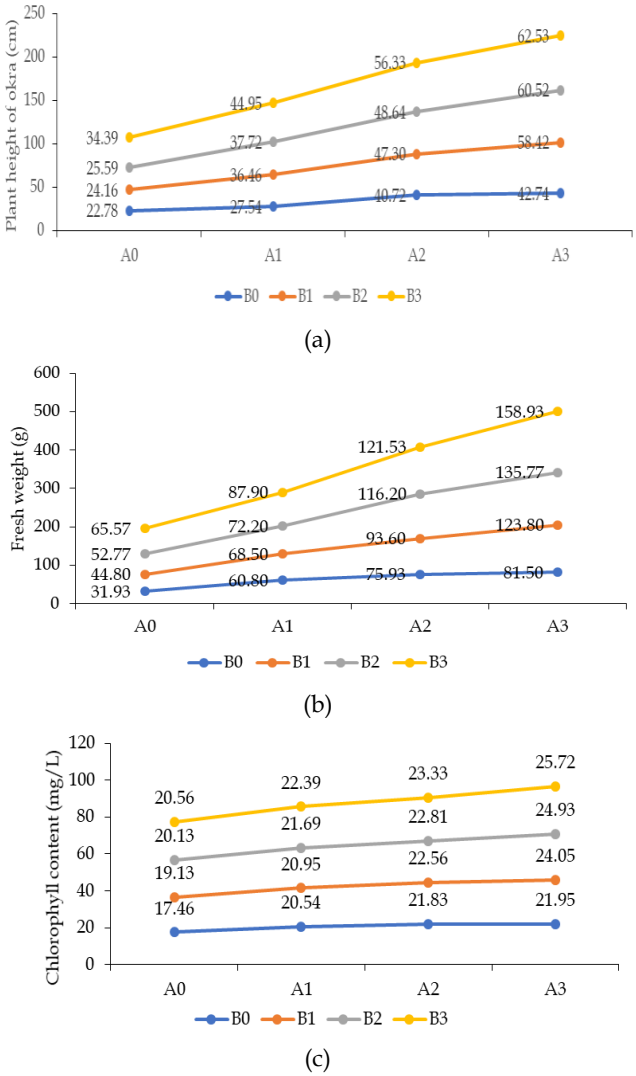

Figure 1. Effects of combined treatments of lamtoro liquid organic fertilizer and rice husk ash on (a) plant height, (b) fresh weight, and (c) chlorophyll content

Efficient photosynthesis leads to the production of a greater quantity of assimilates, such as sugars and other carbon compounds, which are then transported through the phloem to actively growing organs like stems and leaves (X. Zhang et al., 2022; Naz et al., 2012). This process explains the observed increase in plant height in the highest treatment combination (A3B3). The potassium content in LOF facilitates the translocation of photosynthetic products to the apical meristems by maintaining osmotic pressure and regulating stomatal opening (Sardans & Peñuelas, 2021; Naritatih et al., 2013). Meanwhile, rice husk ash complements the nutrient content of LOF, particularly by supplying phosphorus, which is essential for ATP synthesis as a source of metabolic energy (Mosharrof et al., 2021; Ali et al., 2013; Wibowo et al., 2012). Additionally, the silica in rice husk ash contributes to the strengthening of cell walls and leaf tissues, and it enhances the uptake

efficiency of other essential nutrients (Murniati & Bimasri, 2022; Jiang et al., 2017).

The relationship between increased chlorophyll content and plant growth is not linear, but rather mutually reinforcing. Higher chlorophyll levels promote optimal photosynthesis, which in turn increases assimilate production that is distributed throughout the plant to support organ development, including morphological growth such as plant height and fresh weight (Widyawati et al., 2023; Ramdani et al., 2024; Purba et al., 2021). Fresh plant weight reflects biomass accumulation derived from photosynthetic products along with water and nutrient absorption from the soil (Sania et al., 2025; Fageria et al., 2009). The increase in fresh weight observed in the combination treatments indicates that the plant's metabolic system functioned more efficiently due to the balanced nutrient availability provided by both organic materials.

In conclusion, the observed increases in plant height, fresh weight, and chlorophyll content are the result of physiological and morphological responses to optimal nutrient conditions. The combination of Leucaena LOF and rice husk ash functions synergistically as an integrated fertilization system. Leucaena LOF supplies nitrogen, potassium, and magnesium, supporting tissue formation and photosynthetic activity, while rice husk ash contributes silica and phosphorus, promoting metabolic energy production and tissue reinforcement. This mutually reinforcing interaction renders the A3B3 treatment combination the most effective in enhancing the overall performance of okra plants.

Conclusion

The combined application of Leucaena leaf liquid organic fertilizer (LOF) and rice husk ash was proven to significantly influence plant height, fresh weight, and total chlorophyll content of okra plants. The best treatment combination was achieved with 30% LOF and 15% rice husk ash (A3B3), which resulted in the most optimal vegetative growth and physiological status of the plants. These findings indicate that the synergy between biologically derived and mineral nutrient sources in the combined treatment can enhance photosynthetic efficiency and overall biomass accumulation. Therefore, the use of Leucaena LOF and rice husk ash represents an effective and sustainable organic fertilization strategy for okra cultivation.

Acknowledgments
The author would like to express sincere gratitude to the academic supervisors for their guidance and direction throughout the research process. Appreciation is also extended to the Biology Laboratory, Department of Biology Education, Faculty of Teacher Training and Education, Universitas Syiah Kuala, for the facility support provided. Special thanks are given to the Meteorology, Climatology, and Geophysics Agency (BMKG) for supplying the online climate data used in this.

Author Contributions
Conseptualization, S.H, M, H.R; methodology S.H, and M; resources, S.H; writing original draft preparation, S.H and M; writing review and editing S.H, H.R. All authors have read and agreed to published version of the manuscript.

Funding
This research received no external funding.

Conflicts of Interest
The authors declare no conflict of interest.

References

Albari, J. (2018). Peranan pupuk nitrogen dan fosfor pada tanaman kelapa sawit (Elais guineensis Jacq.) belum menghasilkan umur tiga tahun. *Buletin Agrohorti*, *6*(1), 42-49. https://doi.org/10.29244/agrob.v6i1.16822

Ali, S., Javed, H. U., Rehman, U. R. N., Sabir, I. A., Naeem, M. S., Siddiqui, M. Z., Saeed, D. A., & Nawaz, M. A. (2013). Foliar application of some macro and micronutrients improves tomato growth, flowering and yield. *International Journal of Biosciences, 3*(10), 280-87. http://dx.doi.org/10.12692/ijb/3.10.280-287

Al-Rubie, J. A. J., & Abdulkareem, M. A. (2024). Phosphorus and silicon uptake by corn (*Zea mays* L.) in response to silicon application in calcareous soil. *Nabatia*, *12*(2), 103–119. https://doi.org/10.21070/nabatia.v12i2.1644

Anwar, C., Wonggo, D., Mongi, E., & Dotulong, V. (2025). Macro and micro nutrients in the soil of the mangrove forest area, bunaken marine park. *Jurnal Ilmiah Platax*, *13*(1), 174–181. https://doi.org/10.35800/jip.v13i1.60807

Ardani, A., & Sujalu, A. P. (2019). Pengaruh pupuk Organik air Nasa dan Pupuk NPK Mutiara Terhadap Pertumbuhan dan Hasil Tanaman Tomat(Lycopersicum escelentum Mill) Varietas Servo F1. *Agrifor: Jurnal Ilmu Pertanian dan Kehutanan, 18*(1), 8996. Retrieved from http://repository.untag-smd.ac.id/101/1/4110-8916-2-PB_2.pdf

Asmawanti, S. D., Riski, M. H., Cibro, R. J., & Ilahi, F. R. (2022). Pemanfaatan limbah dapur sebagai pupuk organik cair (POC) untuk budidaya tanaman di lingkungan perkarangan masyarakat kelurahan surabaya kecamatan sungai serut. *Tribute: Journal of Community Services*, *3*(2), 101–107. https://doi.org/10.33369/tribute.v3i2.23887

Benchasri, S. (2012). Okra (Abelmoschus esculentus L. Moench) as a Valuable Vegetable of the World. *Ratar.Povrt.*, *49*(10), 105-112. https://doi.org/10.5937/ratpov49-1172

Elkhalifa, A. E. O., Alshammari, E., Adnan, M., Alcantara, J. C., Awadelkareem, A. M., Eltoum, N. E., Mehmood, K., Panda, B. P., & Ashraf, S. A. (2021). Okra (*Abelmoschus esculentus*) as a potential dietary medicine with nutraceutical importance for sustainable health applications. *Molecules*, *26*(3), 1–21. https://doi.org/10.3390/MOLECULES26030696

Fageria, N. K., Filhoa, M. P. B., Moreirab, A., & Guimaresa, C. M. (2009). Foliar fertilization of crop plants. *Journal of Plant Nutrition, 32*(6), 1044-64. http://dx.doi.org/10.1080/01904160902872826

França, A. A., Schultz, J., Borges, R., Wypych, F., & Mangrich, A. S. (2017). Rice husk ash as raw material for the synthesis of silicon and potassium slow-release fertilizer. *Journal of the Brazilian Chemical Society*, *28*(11), 2211–2217. https://doi.org/10.21577/0103-5053.20170072

Fuskhah, R., Fuskhah, E., & Sumarsono. (2022). Respon pertumbuhan dan produksi tanaman okra (*Abelmoschus esculentus* L.) akibat waktu pemangkasan pucuk dan jarak tanam yang berbeda. *Journal Agro Science*, *1*(1), 1–10. Retrieved from https://ejournal2.undip.ac.id/index.php/aesj/article/view/15383

Haryanta, D., Widya, S. A., & Aritonang, E. A. (2024). Kajian pertumbuhan dan hasil okra (*Abelmoschus esculentus* L.) dengan aplikasi beberapa jenis pupuk kandang study growth and yield of okra (*Abelmoschus esculentus* L.) with manure application. *Agrocentrum*, *2*(1), 20–28. Retrieved from https://www.researchgate.net/publication/391481977

Idawati, N. (2012). *Peluang Besar Budidaya Okra*. Yogyakarta: Pustaka Baru Press.

Jiang, C., Jokhan, M., Hohjo, M., Tsukagoshi, S., Ebihara, M., Akio Nakaminami, A., & Maruo, T. (2017). Photosynthesis, plant growth, and fruit production of single-truss tomato improves with supplemental lighting provided from underneath or within the inner canopy. *Scientia Horticulturae,* 222, 221-29. Retrieved from https://ui.adsabs.harvard.edu/link_gateway/2017ScHor.222..221J/doi:10.1016/j.scienta.2017.04.026

Kalaji, H. M., Jajoo, A., Oukarroum, A., Brestic, M., Zivcak, M., Samborska, I. A., Cetner, M. D., Łukasik, I., Goltsev, V., & Ladle, R. J. (2016). Chlorophyll a fluorescence as a tool to monitor physiological status of plants under abiotic stress conditions. *Acta Physiologiae Plantarum*, *38*(4). https://doi.org/10.1007/s11738-016-2113-y

Mendrofa, M.T., dan Gulo, D. (2024). Pengaruh pupuk organik terhadap perbaikan struktur dan stabilitas tanah. *Jurnal Ilmu Pertanian Dan Perikanan*, *01*(1), 105–110. https://doi.org/10.70134/penarik.v2i2.72

Mosharrof, M., Uddin, M. K., Sulaiman, M. F., Mia, S., Shamsuzzaman, S. M., & Haque, A. N. A. (2021). Combined application of rice husk biochar and lime increases phosphorus availability and maize yield in an acidic soil. *Agriculture (Switzerland)*, *11*(8). https://doi.org/10.3390/agriculture11080793

Murniati, N., & Bimasri, J. (2022). Peran biosilika abu sekam paditerhadap produksi tanaman padi sawah. *Jurnal Ilmu Pertanian Kelingi*, *1*(1), 1–9. https://doi.org/10.58328/jipk.v1i1.6

Nariratih, I., Damanik, B., Majid, M., Sitanggang, G., & Sitanggang, G. (2013). Ketersediaan nitrogen pada tiga jenis tanah akibat pemberian tiga bahan organik dan serapannya pada tanaman jagung. *Jurnal Agroekoteknologi Universitas Sumatera Utara, 1*(3), 94978. https://doi.org/10.32734/jaet.v1i3.2645

Naz, R. M. M., Muhammad, S., Hamid, A., & Bibi, F. (2012). Effect of boron on the flowering and fruiting of tomato. *Sarhad Journal of Agriculture, 28*(1), 37-40. Retrieved from https://www.cabidigitallibrary.org/doi/full/10.5555/20123208304

Nooraminah, N. F., Wulandari, R. A., & Ilmiah, H. H. (2023). Pengaruh kombinasi pemupukan organik dan anorganik terhadap pertumbuhan dan kandungan flavonoid kangkung darat (*Ipomoea reptans* Poir) varietas bangkok dan varietas serimpi. *Vegetalika*, *12*(4), 312. https://doi.org/10.22146/veg.82224

Pane, F. A., & Juanda, B. R. (2024). Pengaruh pemberian pupuk organik cair daun lamtoro (*Leucaena leucocephala*) dan dosis pupuk kandang sapi terhadap pertumbuhan dan produksi tanaman melon (*Cucumis melo* L.). *Jurnal Penelitian Agrosamudra*, *11*(1), 29–38. https://doi.org/10.33059/jupas.v11i1.7745

Panjaitan, R. M. P., Parangin-angin, J. D., Simbolon, D. A. S. H. D., Aryandi, B. S. R., Pratama, J., Pulungan, M. A., Ginting, M. S., & Maisarah. (2023). Pengaruh pupuk organik dan anorganik terhadap sifat kimia tanah pada perkebunan rio. *Madani: Jurnal Ilmiah Multidisiplin*, *1*(9), 483–488. https://doi.org/10.5281/zenodo.13855355

Parna, Y. D., Marisa, J., & Tarigan, R. A. (2025). Effectiveness of liquid organic fertilizer application of lamtoro leaves and quail manure fertilizer on

melon plants (*Cucumis melo* L) growth and production. *Jurnal Agronomi Tanaman Tropika (Juatika)*, *7*(1). https://doi.org/10.36378/juatika.v7i1.3994

Purba, T., Situmeang, R., & Rohman, H. F. (2021). *Pemupukan dan Teknologi Pemupukan*. Medan: Yayasan Kita Menulis.

Ramdani, D., Nasrudin., & Saleh, I. (2024). Hubungan kandungan klorofil, luas daun, dan hasil tanaman padi gogo akibat pengaturan jarak tanam dan pemberian pupuk kompos. *Jurnal Triton*, *15*(2), 388–399. https://doi.org/10.47687/jt.v15i2.780

Ramadhan, R. Z., & Sabli, T. E. (2024). aplikasi POC daun lamtoro dan NPK pelangi terhadap pertumbuhan serta hasil produksi tanaman terung ungu (*Solanum melongena* L.). *Jurnal Agroteknologi Agribisnis Dan Akuakultur*, *4*(2), 152–166. https://doi.org/10.25299/jaaa.2024.18903

Rian, S., Maulidi, & Warganda. (2024). Growth and Yield Response of Okra to The Application of Wood Ash and Npk Fertilizer on Alluvial Soil. *Journal of Agriculture on Tropical Land,* *2*(1). https://doi.org/10.26418/akha.v2i1.73826

Salsabila, D. M., Damayanthi, E., & Nasution, Z. (2023). Nutraceutical potential of encapsulated purple okra (*Abelmoschus esculentus* L. Moench) extract. *Media Gizi Indonesia*, *18*(3), 201–211. https://doi.org/10.20473/mgi.v18i3.201-211

Sania, H., Fevria, R., Vauzia, V., Razak, A., Yulkifli, Y., & Mutiar, S. (2025). Effect of sensor and based NPK on the growth of pakcoy (*Brassica rapa* l.) cultivation hydroponic. *Jurnal Biologi Tropis*, *25*(1), 807–813. https://doi.org/10.29303/jbt.v25i1.8514

Sardans, J., & Peñuelas, J. (2021). Potassium control of plant functions : ecological and agricultural implications. *Plants*, *10*(2). https://doi.org/10.3390/plants10020419

Sumardiharta, D. A., & Ardi, A. (2001). Pengunaan Pupuk dalam Rangka Peningkatan Produktifitas Lahan Sawah. *Jurnal Penelitian dan Pengembangan Pertanian,* *20*(2), 67-82. https://doi.org/10.26418/akha.v2i1.73826

Thamaga, M. W., Mokoboki, H. K., Sebola, N. A., & Ravhuhali, K. E. (2021). Apparent digestibility and nutritional composition of *Leucaena leucocephala* (Lam) leaf meal incorporated in the diets of black australorp and potchefstroom koekoek chicken breeds. *Tropical Animal Health and Production*, *53*(5). https://doi.org/10.1007/s11250-021-02922-w

Virgiawan, Y. G., Andayani, N., & Kautsar, V. (2023). Pengaruh dosis pupuk P terhadap pertumbuhan bibit turnera subulata pada jenis tanah yang berbeda. *Agroforetech*, *1*(9), 1553–1559. Retrieved from https://jurnal.instiperjogja.ac.id/index.

Waruwu, N. N., Gea, D. S. P., Laoli, O., Waruwu, A. S., & Lase, N. K. (2024). Kajian literatur : pengaruh pupuk organik cair terhadap pertumbuhan dan hasil tanaman di lahan kering. *Hidroponik : Jurnal Ilmu Pertanian Dan Teknologi Dalam Ilmu Tanaman*, *1*(3), 28–39. https://doi.org/10.62951/hidroponik.v1i3.146

Wibowo, A., Purwanti, Setyastuti., & Rabaniyah, R. (2012). Pertumbuhan dan Hasil Benih Kedelai Hitam Malika yang Ditanam Secara Tumpangsari dengan Jagung Manis (Zea mays Kelompok Saccharata). *Vegetalika,* *1*(4), 1-10. https://doi.org/10.22146/veg.1591

Widyawati, N., Herawati, M. M., Kurnia, T. D., Murdono, D., Simanjuntak, B. H., & Setiawan, A. W. (2023). Kandungan klorofil, pertumbuhan dan hasil vertikultur padi (*Oryza sativa* L.) varietas situ bagendit. *Vegetalika*, *12*(3), 256. https://doi.org/10.22146/veg.83196

Xie, K., Pan, Y., Meng, X., Wang, M., & Guo, S. (2024). Critical leaf magnesium thresholds for growth, chlorophyll, leaf area, and photosynthesis in rice (*Oryza sativa* L.) and Cucumber (*Cucumis sativus* L.). *Agronomy*, *14*(7). https://doi.org/10.3390/agronomy14071508

Zhang, R., Yang, P., Liu, S., Wang, C., & Liu, J. (2022). Evaluation of the methods for estimating leaf chlorophyll content with SPAD chlorophyll meters. *Remote Sensing*, *14*(20). https://doi.org/10.3390/rs14205144

Zhang, X., Zhai, P., & Huang, J. (2022). Leaf carbon exchange of two dominant plant species impacted by water and nitrogen application in a semi-arid temperate steppe. *Frontiers in Plant Science*, *13*. https://doi.org/10.3389/fpls.2022.736009