Agro Bali : Agricultural Journal
Vol. 8 No. 2: 657-665, July 2025 e-ISSN 2655-853X
https://doi.org/10.37637/ab.v8i2.1919

Morphological Characterization and Phytochemical Analysis of Moringa Plant (*Moringa oleifera* L.) Different Altitudes in Bali

Jeni Rambu[1], I Nyoman Rai[1♥], and Rindang Dwiyani[2]
[1]Master of Dryland Agriculture Study Program, Udayana University, Denpasar, Indonesia
[2]Agrotechnology Study Program, Udayana University, Denpasar, Indonesia
♥Corresponding author email: rainyoman@unud.ac.id

Article history: submitted: August 11, 2024; accepted: July 28, 2025; available online: July 30, 2025

Abstract. The Moringa plant (Moringa oleifera L.) is a plant that has many benefits and has long been used by various groups throughout the world. Almost all parts of this magical plant can be used for multiple purposes. Moringa plants spread and adapt to different environments, increasing phenotypic and phytochemical diversity. The research was conducted at three altitudes in Bali, lowlands, medium, and highlands from December 2023–May 2024. The study was conducted to determine differences in morphological characters and phytochemical content of Moringa plants. This research used UPGMA analysis to determine the relationship based on morphological characters, flavonoids, tannins, and vitamin E using a UV-Vis Spectrophotometer, while the antioxidant activity test was carried out using the DPPH method. The results of the identification of morphological characters showed differences in qualitative characters, which were seen in leaf color and flower color, while quantitative characters were seen in leaf length, leaf thickness, pod length, and number of seeds. Nine Moringa accessions showed differences in phytochemical content. The highest flavonoid and vitamin E content in the lowlands are (599.961 mg QE/100 g) and (599.961 mg QE/100 g), tannins in the medium plains (368.140 mg TAE/100 g), and the highest IC50 in the highlands (54.94 ppm).

Keywords: altitude impact; antioxidant activity; *Moringa oleifera*; morphological diversity; phytochemical

INTRODUCTION

The Moringa oleifera L. plant is known for its numerous health and nutritional benefits. It is often referred to as the "miracle tree" because almost all parts of the plant, from the leaves and seeds to the flowers and roots, possess high nutritional and medicinal value. Moringa contains high levels of protein, vitamins, and minerals, as well as phytochemical compounds such as flavonoids, saponins, and tannins, which have potential as antioxidants, anti-inflammatory agents, and antimicrobial agents (Muhl, 2016; Tshabalala, 2020).

The morphological and phytochemical diversity of Moringa plants is strongly influenced by various environmental factors, one of which is altitude. Altitude can influence climatic conditions such as temperature, humidity, and light intensity, which in turn can affect plant growth and phytochemical content. Therefore, research on morphological characterization and phytochemical analysis at various altitudes is crucial to understanding how these environmental factors influence the quality and quantity of phytochemical components in Moringa plants (Rachmawatie et al., 2022; William et al., 2014).

Bali, as one of the regions in Indonesia with significant altitude variation, is an ideal location for this research. With its varying altitudes from coastal areas to mountainous areas, Bali offers diverse environmental conditions to study the effect of altitude on the morphology and phytochemical content of moringa plants. Morphological and phytochemical diversity in a plant occurs when the same plant's genetic makeup is grown in different locations. Morphological diversity directly reflects the plant's characteristics (Sobari & Wicaksana, 2017; Usman et al., 2021).

To date, no research has examined the morphological diversity and phytochemical content of moringa plants at different altitudes in Bali. Therefore, this study aimed to explore the differences in morphological

e-ISSN 2655-853X
https://doi.org/10.37637/ab.v8i2.1919

characteristics and phytochemical content of moringa plants grown at different altitudes in Bali. This research will not only provide useful scientific information but also assist farmers and health practitioners in optimizing moringa cultivation and utilization in Bali.

METHODS

Exploration and identification of Moringa plants were carried out in lowland, medium, and highland areas in Bali, while phytochemical analysis was conducted at the Mathematics and Natural Sciences Laboratory of Udayana University, which took place in December 2023-March 2024. The tools and materials used were analytical scales, mucus, measuring flasks, calipers, UV-vis spectrometers, cameras, writing instruments, Moringa leaf powder, magnesium powder, HCl, FeCl3, 90% ethanol, DPPH Whatman filter paper, aluminum foil, plastic wrap, and tissue rolls. UPGMA analysis was used to examine kinship relationships based on morphological characters, flavonoids, tannins, and vitamins using a UV-Vis Spectrophotometer. Antioxidant activity was measured by the DPPH method. Quantitative morphological data were analyzed using ANOVA.

RESULTS AND DISCUSSION

This study obtained moringa plants from lowland, midland, and highland areas, providing a deeper understanding of the morphological differences and phytochemical content of moringa (Moringa oleifera L.) grown at different altitudes in Bali. The results of the Moringa kinship analysis using the UPGMA method with a Similarity Index showed clusters clustered on a scale of 44.52 to 1. A Similarity Index of 44.52 or 44.52% formed two clusters, A and B, with a similarity below 50% (Figure 1).

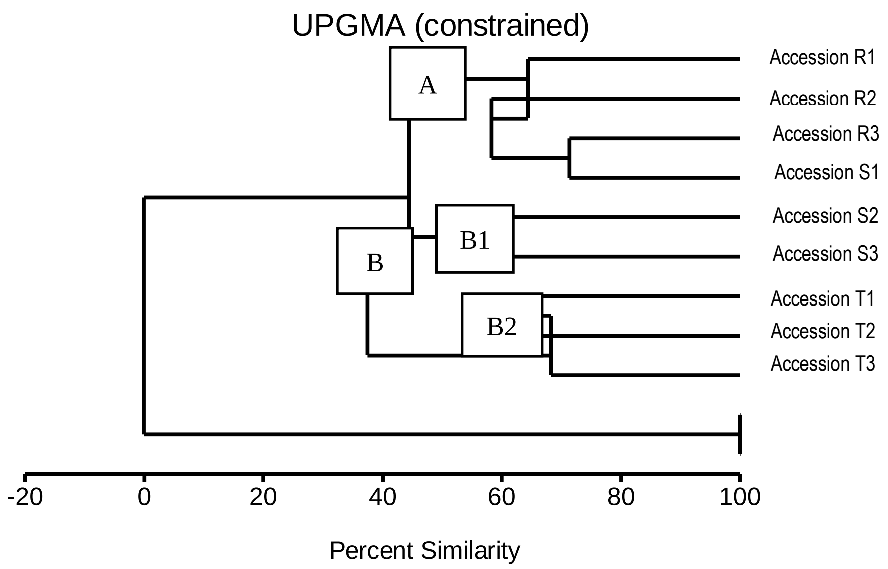

Figure 1. Dendrogram of qualitative morphological characters

According to Darmawati (2020), two or more objects are categorized as morphologically similar if their similarity is greater than 50%. Therefore, the qualitative or phenotypic relationship between these nine Moringa accessions is categorized as distantly similar, as the similarity between clusters A and B is below 50%. This is supported by differences in leaf color. The leaves in the lowlands and midlands are darker green compared to the lighter green in the highlands (Figure 2). According to Ajhar et al. (2018), Moringa leaf color is more influenced by genetic traits than by the growing environment. This aligns with Wulantika (2019), who stated that qualitative

e-ISSN 2655-853X
https://doi.org/10.37637/ab.v8i2.1919

traits such as Moringa leaf and flower color are controlled by a single major gene, a gene with a significant influence, so environmental influences are minimal.

Figure 2. Moringa leaves from the lowlands (a) and highlands (b)

The results of the kinship relationship of Moringa plants from low, medium and high plains identified based on quantitative morphological characters in several variables, namely tree height, stem diameter, leaf length, leaf width, leaf thickness, leaf blade length, leaf blade width, number of leaf veins, flower stalk length, number of stamens, stamen length, number of petals, pod length, and number of seeds, show that all accession samples are separated by two large clusters A and B with a similarity level below 50%, namely 40% (Figure 3).

According to Abdulazeez et al., (2025), the growing environment greatly influences the determination based on morphological markers. Environmental conditions and lack of nutrients for Moringa plants greatly influence the differences in tree height, stem diameter, One of the environmental factors that influence plant growth is altitude, in line with the results of research that has been done, the highest data obtained from each variable such as plant height, leaf length, leaf width, leaf thickness, leaf blade length, leaf blade width, number of flowers, flower length, flower width, pod length and the highest number of Moringa seeds were obtained from the lowlands of each variable in Moringa accessions. According to Ayu et al. (2016) stated that optimal vegetative growth in a plant variety is due to the variety having adapted to its growing environment and in line with Lubis (2017) that plant response to the environment can be seen from the increase or decrease in plant size which is a combination of genetic and environmental factors determined by climate, weather, temperature and nutrient composition in the soil. One environmental factor influencing plant growth is altitude. Research has shown that the highest data for each variable, such as plant height, leaf length, leaf width, leaf thickness, leaf blade length, leaf blade width, flower number, flower length, flower width, pod length, and moringa seed number, are found in lowlands. Environmental factors that support optimal plant growth include better water availability, warmer temperatures, richer soil nutrients, lower wind pressure, and a longer growing season.

According to Malhi et al. (2020), rainfall is often higher in lowlands and water distribution is more even than in highlands. These conditions provide trees with better access to water, which is crucial for tree height growth and the development of other organs. Furthermore, warmer temperatures in lowlands support higher photosynthetic activity and faster metabolism. Warmer temperatures also reduce the risk of damage from frost or extremely low temperatures, which often occur in highlands. Anderson (2020) added that soil nutrients are also a factor influencing plant growth and development.

e-ISSN 2655-853X
https://doi.org/10.37637/ab.v8i2.1919

Meanwhile, in mid- and highland areas, temperatures are lower and temperature fluctuations between day and night are greater. Low temperatures slow the rate of photosynthesis and plant metabolism, which directly impacts tree growth. Furthermore, the risk of frost can cause damage to plant tissue (Johnstone, 2021). Bruelheide et al. (2018) and Scholten et al. (2017) stated that soil in highlands is often thinner, rockier, and less fertile, resulting in lower nutrient availability. Furthermore, water drains more quickly on sloping land, so trees in highlands often experience water shortages that inhibit growth. Furthermore, highlands also receive more UV radiation due to the thinner atmosphere. The varying environmental conditions where plants grow can affect the content of secondary metabolites, such as phytochemicals.

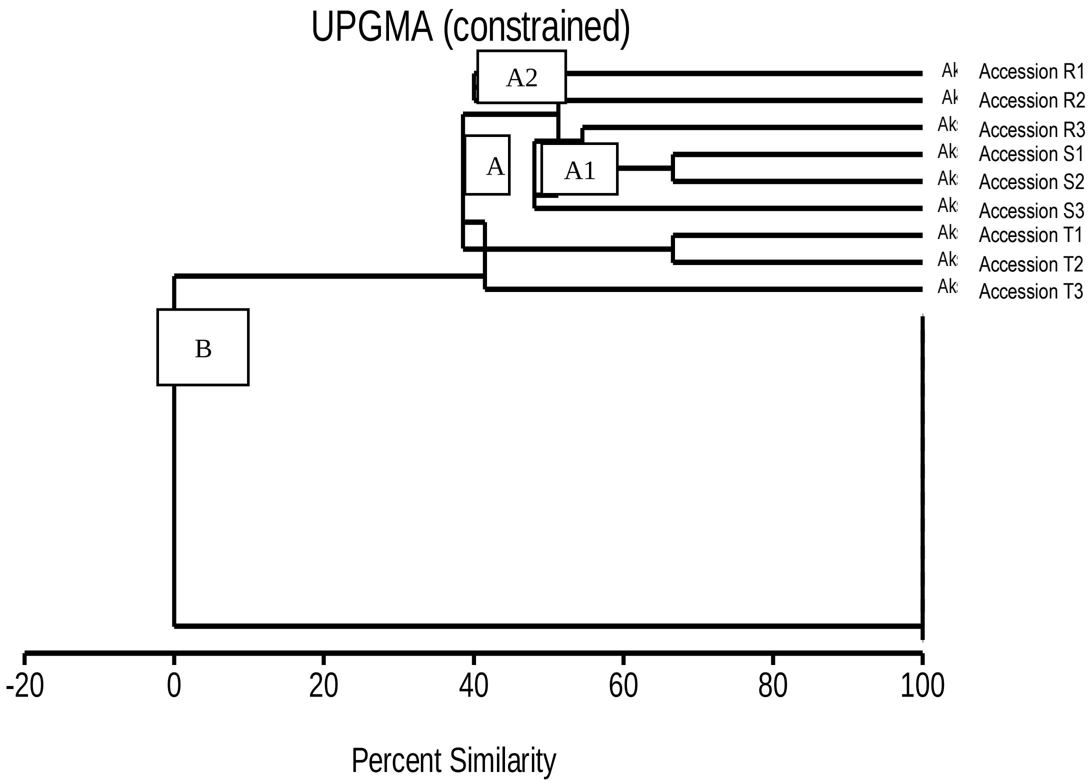

Figure 3. Dendrogram of quantitative morphological characters

The highest flavonoid content of moringa leaves was obtained in the lowland R3 accession of 599.97% compared to the medium land S1 accession of 209.75% in accordance with the statement of Safa et al. (2014), that the total flavonoid content is considered high if the value obtained is >70 mg GAE/g. The flavonoid phytochemical content produced with high concentrations can be influenced by environmental factors. One of the most important environmental factors is the altitude where the moringa plant grows. From this study, it can be seen that altitude can affect the Flavonoid content of moringa leaves; the highest flavonoid content is obtained from the lowlands. Lowlands have optimum environmental factors for the formation of secondary metabolites, especially flavonoids in moringa plants, lowlands have the highest temperature and light intensity compared to medium and highlands, so it is possible that the process of photosynthesis and flavonoid biosynthesis at this altitude can run optimally. Lowlands have the highest temperature and light intensity compared to medium and highlands,

e-ISSN 2655-853X
https://doi.org/10.37637/ab.v8i2.1919

so it is possible that the process of photosynthesis and flavonoid biosynthesis at this altitude can run optimally. Flavonoid biosynthesis is produced through a combination of shikimic acid and malonic acid pathways, both of which are derived from carbohydrates through the glycolysis process (Julianti et al., 2021). The highest tannin content was obtained by accession S1 and there was an increase of 368.14% compared to accession R1 (Table 1).

Tannins are often produced in response to environmental stress, including temperature, light intensity, water availability, and plant-microorganism interactions. According to Dixon & Paiva (1995), in temperate latitudes, temperatures are usually less extreme than in cooler highlands or hotter lowlands. These moderate temperatures can increase enzymatic activity that plays a role in tannin synthesis. Kitamura (2022) added that in temperate latitudes, light intensity is usually quite high but less extreme.

Sufficient light can increase photosynthesis, which then provides more precursors for the synthesis of secondary compounds such as tannins. Another important factor is water. Guo et al. (2021) stated that insufficient water availability in temperate latitudes can cause mild stress in plants. This stress can stimulate tannin production as part of the plant's defense mechanism against dehydration or pathogen attack. Meanwhile, the highest vitamin E content was obtained in the highland T2 accession at 82.85% compared to the lowland R2 accession at 17.39% (Table 1). Vitamin E, or tocopherol, is an important antioxidant that protects plant cells from oxidative damage.

Table 1. Flavonoid, Tannin, and Vitamin E levels of Moringa accessions at three different altitudes in Bali

No	Moringa accession	Flavonoid (mg QE/100 g)	Tannin (mg TAE/100 g)	Vitamin E (mg tocopherol/100 g)
1	R1 accession	398.406	158.675	66.810
2	R2 accession	356.266	308.499	17.393
3	R3 accession	599.961	350.227	79.115
4	S1 accession	209.754	368.140	29.354
5	S2 accession	548.867	326.835	58.722
6	S3 accession	386.373	299.659	79.267
7	T1 accession	277.359	323.300	58.056
8	T2 accession	239.781	280.458	82.858
9	T3 accession	296.093	279.800	65.285

Description: R1-R3: moringa samples from lowlands, S1-S2: moringa samples from midlands, T1-T3: moringa samples from highlands, QE: Quercetin Equivalent, TAE: Tannic Acid Equivalent

Vitamin E content is often higher in plants grown at high altitudes compared to low or medium altitudes due to the influence of UV radiation intensity at higher altitudes, due to the thinner atmospheric layer. Higher UV exposure encourages plants to produce more antioxidants, including vitamin E, as a protective mechanism against UV damage Li & Schemske (2021), then Espley & Jaakola (2023) added that at high altitudes, plants often experience more extreme stress conditions, such as colder temperatures and greater temperature fluctuations between day and night. This higher oxidative stress

e-ISSN 2655-853X
https://doi.org/10.37637/ab.v8i2.1919

stimulates increased vitamin E production to protect plant cells from oxidative damage. Lower temperatures at high altitudes can induce a stress response in plants. One adaptive response of plants is to increase the synthesis of antioxidant compounds such as vitamin E. Lower air pressure at high altitudes reduces oxygen availability, which can affect plant metabolism and stimulate the production of protective compounds such as vitamins. Plants grown at high altitudes have also often experienced natural selection that encourages plants to develop higher levels of antioxidants as part of adaptation to harsher environments (Meng et al., 2025). In contrast to the flavonoid, tannin, and vitamin E content, the highest antioxidant activity (IC50) of moringa leaves was found in the highland moringa accession code T9, at 54.94 ppm, but it has a strong antioxidant activity category compared to other accessions that have low IC50 values but have very strong antioxidant activity categories. The antioxidant activity in this study showed that the lowland moringa accession code R3 contained the highest flavonoid content with a value of 599.961 mg QE/100 g, but had a low IC50 result of 43.79 ppm, compared to the T9 moringa accession which had the lowest flavonoid value at 296.093 mg QE/100 g, but showed the highest IC50 concentration value at 54.94 ppm (Table 2).

Table 2. Antioxidants (IC50) of kolor accessions at three different altitudes in Bali

No	Accession	IC_{50} value (ppm)	Antioxidant activity categories
1	R1	41.11	Very strong
2	R2	24.49	Very strong
3	R3	43.79	Very strong
4	S1	31.92	Very strong
5	S2	39.33	Very strong
6	S3	44.82	Very strong
7	T1	32.70	Very strong
8	T2	54.94	Strong
9	T3	39.20	Very strong

According to Siswoyo et al. (2016), one of the influencing factors is the environment in this case the height of the growing place of the Moringa plant that the high calcium (Ca) nutrient around the plant can function as an enzyme activator by affecting the secondary metabolite pathway, so that the flavonoid content in the leaves of tabat barito (Ficus deltoidei) increases and is able to influence the process of antioxidant activity supported by Sulasiyah et al. (2018), stating that one of the important influences in increasing antioxidant activity is the flavonoid content, this content is the strongest main compound that plays an active role as an antioxidant in the phenol group and in line with Nur et al. (2019) that there is a correlation between flavonoids and antioxidant activity, such as the flavonoid content which has a significant positive correlation with antioxidant activity.

CONCLUSION

Qualitative morphological characters show differences in lowland, medium, and highland moringa, showing differences in leaf and flower color. Quantitative characters show differences in plant height, leaf length, leaf width, leaf thickness, pod length, and number of seeds. The kinship relationship based on qualitative morphological characters shows that lowland moringa, namely R1, R2, R3, and midland moringa, namely S1, form a separate cluster with a similarity index of 58.33%. Meanwhile, quantitative morphological characters show that highland moringa, T1, T2, and T3, form

e-ISSN 2655-853X
https://doi.org/10.37637/ab.v8i2.1919

a separate cluster with a similarity level of 67%. In general, the data from the UPGMA analysis, both quantitative and qualitative, show that altitude influences morphological differences. 2. The highest flavonoid and vitamin E content in the lowlands is (599.961 mg QE/100 g) and (88.858 mg TOCOPHEROL/100 g), the highest tannin in the medium plains is (368.140 mg TAE/100 g), and the highest antioxidant activity (IC50) in the highlands is 54.94 ppm. The relationship between morphological and phytochemical characteristics in Moringa leaves varies based on altitude. In the lowlands, the leaves tend to be thicker and greener due to the high light intensity and hot temperatures that stimulate leaf growth and flavonoid production.

REFERENCES

Abdulazeez, A., Abubakar, G.A., Shuaib, M.B., Abdullahi, K.M., Muhammad, A. & Ahmad, A.M. (2025). Effect of <i>Moringa oleifera</i> leaf powder and NPK fertilizer on soil properties and growth of pearl millet in Sudan savannah. *Journal of Agriculture and Environment*, *20*(2), 219–232. https://doi.org/10.4314/jagrenv.v20i2.19

Anderson, J. T. (2020). Soil fertility and tree growth in tropical forests. *Plant and Soil*, *451*(1–2), 1–16.

Ayu, N. G., Abdul, R., & Sakka, S. (2016). Pertumbuhan dan Hasil Dua Varietas Bawang Merah (Allium ascaloonicum L.) pada Berbagai Jarak Tanam. *Agroteknis*, *4*(5), 530–536.

Bruelheide, H., Dengler, J., Purschke, O., Lenoir, J., Jiménez-Alfaro, B., Hennekens, S. M., Botta-Dukát, Z., Chytrý, M., Field, R., Jansen, F., Kattge, J., Pillar, V. D., Schrodt, F., Mahecha, M. D., Peet, R. K., Sandel, B., van Bodegom, P., Altman, J., Alvarez-Dávila, E., … Jandt, U. (2018). Global trait–environment relationships of plant communities. *Nature Ecology and Evolution*, *2*(12), 1906–1917. https://doi.org/10.1038/s41559-018-0699-8

Darmawati, I. A. P. (2020). *Eksplorasi dan Karakterisasi Fenotipe-Genotipik Anggrek Dendrobium Forma Bali, serta Evaluasi Kompatibilitas Hibridisasinya*. Universitas Udayana.

Dixon, R. A., & Paiva, N. L. (1995). Stress-Induced Phenylpropanoid Metabolism. *The Plant Cell*, 1085–1097. https://doi.org/10.1105/tpc.7.7.1085

Espley, R. V., & Jaakola, L. (2023). The role of environmental stress in fruit pigmentation. *Plant, Cell & Environment*, *46*(12), 3663–3679. https://doi.org/10.1111/pce.14684

Guo, Y., Lin, J., & Wang, X. (2021). Rapid detection of temperate bacteriophage using a simple motility assay. *Environmental Microbiology Reports*, *13*(5), 728–734. https://doi.org/10.1111/1758-2229.12991

Johnstone, J. (2021). Alpine Plant Life: Functional Plant Ecology of High Mountain Ecosystems. By Christian Körner. *Mountain Research and Development*, *41*(4). https://doi.org/10.1659/mrd.mm265.1

Julianti, R. F., Nurchayati, Y., & Setiari, N. (2021). Pengaruh Konsentrasi Sukrosa dalam Medium MS terhadap Kandungan Flavonoid Kalus Tomat (Solanum lycopersicum syn. Lycopersicum esculentum). *Metamorfosa: Journal of Biological Sciences*, *8*(1), 141–149.

Kitamura, T. (2022). Light intensity and its impact on plant secondary metabolites. *Journal of Plant Research*, *135*(2), 255–263.

Li, Y., & Schemske, D. W. (2021). UV radiation and its effects on plant secondary metabolism. *Plant Physiology*, *185*(1), 86–94.

Lubis, R. A. (2017). UJI Beberapa Varietas Dan Pemberian Pupuk Biobost Terhadap Pertumbuhan Dan Produksi Bawang Merah (*Allium ascolonicum*

 e-ISSN 2655-853X
https://doi.org/10.37637/ab.v8i2.1919

L.). *BIOLINK (Jurnal Biologi Lingkungan Industri Kesehatan)*, *3*(2), 113–123. https://doi.org/10.31289/biolink.v3i2.842

Malhi, Y., Franklin, J., Seddon, N., Solan, M., Turner, M. G., Field, C. B., & Knowlton, N. (2020). Climate change and ecosystems: threats, opportunities and solutions. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *375*(1794), 20190104. https://doi.org/10.1098/rstb.2019.0104

Meng, Y., Li, P., Xiao, L., Liu, J., Zhang, C., Yang, S., Zhang, X., Wang, Y., Wang, T., & Wang, R. (2025). Differences in the home-field effects of litter decomposition modulate changes in soil microbial nutrient limitations: insights from eco-enzyme stoichiometry. *CATENA*, *258*, 109289.

Muhl, Q. (2016). The embryo, Endosperm and seed coat structure of developing Moringa oleifera seed. *South African Journal of Botany*, *106*, 60–66. https://doi.org/10.1016/j.sajb.2016.05.009

Nur, S., Sami, F. J., Awaluddin, A., & Afsari, M. I. A. (2019). Korelasi Antara Kadar Total Flavonoid dan Fenolik dari Ekstrak dan Fraksi Daun Jati Putih (Gmelina Arborea Roxb.) Terhadap Aktivitas Antioksidan. *Jurnal Farmasi Galenika (Galenika Journal of Pharmacy) (e-Journal)*, *5*(1), 33–42. https://doi.org/10.22487/j24428744.2019.v5.i1.12034

Rachmawatie, S. J., Purwanto, E., Sakya, A. T., & Dewi, W. S. (2022). Growth and content of N, P, K, Fe in rice plants with liquid organic fertilizer application of moringa leaf. *IOP Conference Series: Earth and Environmental Science*, *1114*(1), 12078.

Scholten, T., Goebes, P., Kühn, P., Seitz, S., Assmann, T., Bauhus, J., Bruelheide, H., Buscot, F., Erfmeier, A., Fischer, M., Härdtle, W., He, J.-S., Ma, K., Niklaus, P. A., Scherer-Lorenzen, M., Schmid, B., Shi, X., Song, Z., von Oheimb, G., … Schmidt, K. (2017). On the combined effect of soil fertility and topography on tree growth in subtropical forest ecosystems—a study from SE China. *Journal of Plant Ecology*, *10*(1), 111–127. https://doi.org/10.1093/jpe/rtw065

Siswoyo, S., Batubara, I., & Aristyanti, D. (2016). Tempat Tumbuh dan Kandungan Flavonoid Total Daun Tabat Barito (Ficus deltoidea Jack.). *Proceeding of Mulawarman Pharmaceuticals Conferences*, *3*, 78–86. https://doi.org/10.25026/mpc.v3i2.91

Sobari, E., & Wicaksana, N. (2017). Keragaman Genetik dan Kekerabatan Genotip Kacang Bambara (Vigna subteranea L.) Lokal Jawa Barat. *Jurnal AGRO*, *4*(2), 90–96. https://doi.org/10.15575/1654

Sulasiyah, S., Sarjono, P. R., & Aminin, A. L. N. (2018). Antioxidant from Turmeric Fermentation Products (Curcuma longa) by Aspergillus Oryzae. *Jurnal Kimia Sains Dan Aplikasi*, *21*(1), 13–18. https://doi.org/10.14710/jksa.21.1.13-18

Tshabalala, T. (2020). Predicting the spatial suitability distribution of Moringa oleifera cultivation using analytical hierarchical process modelling. *South African Journal of Botany*, *129*, 161–168. https://doi.org/10.1016/j.sajb.2019.04.010

Usman, A., Soba, T. M., & Daniel, Y. (2021). Assessment of Early Growth Response of Moringa oleifera, Faidherbia albida and Cassia fistula to Liquid Organic Fertilizers in the Nursery. *Journal of Agricultural Economics, Environment and Social Sciences*, *7*(2), 128–137.

William, J. A., Iddrisu, L. N., Damian, T.-D., Kwame, O.-B., & Kwami, B. K. (2014). Nutrient composition of Moringa oleifera leaves from two agro ecological zones in Ghana. *African Journal of Plant Science*, *8*(1), 65–71. https://doi.org/10.5897/AJPS2012.0727