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The Use of Peat Soil for Cultivating Ginger (*Zingiber officinale*) using Several Types of Ash and NPK Fertilizer

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ABSTRACT

Background: Ginger is a highly demanded commodity that serves multiple purposes, including as a spice and a key ingredient in medicine. Since Indonesia has experienced a decrease in ginger production from 307,241.52 tons in 2021 to 247,455.49 tons in 2022, it is imperative to boost productivity. Kalimantan is dominated by peatlands, so farmers in West Kalimantan must optimize their management of peat soil to achieve the greatest possible yield.

Methods: Research was conducted in Tanjungpura University, Pontianak City, Indonesia from May 1st to November 28th 2023. The study used a factorial randomized block design, with ash type (cow manure, rice husk, wood and coconut fiber) and NPK fertilizer dose (600-1200 kg/ha).

Result: Different types of ash have varying effects on the growth and yield of ginger plants in peat soil. Cow manure ash is the most effective based on the dry weight of the plant, the number of tillers and the fresh weight of the rhizomes. However, NPK fertilizer doses did not significantly impact the growth and yield variables of ginger plants in peat soil.

Key words: Ameliorant, Ginger productivity, Peat soil fertility.

INTRODUCTION

Ginger (*Zingiber officinale*) is a versatile commodity that is in high demand for various purposes. Apart from its use as a spice, ginger is also an important raw material for medicines used to treat multiple diseases (Rahmani *et al*., 2014). Therefore, the demand for ginger raw materials is expected to continue rising, both for domestic needs due to the increase in population and for exports. In 2021, ginger production in Indonesia was 307,241.52 tons, but in 2022, it declined to 247,455.49 tons (Badan, 2023). Based on this data, it is necessary to make efforts to increase ginger productivity to meet the needs of the community and export demand. In West Kalimantan, peat soil is used for ginger cultivation, but farmers still need to manage it optimally to achieve the highest yield.

Proper management of peat soil as a growing medium for ginger plants has excellent prospects for supporting increased productivity. The peat land used for cultivation in West Kalimantan is 694,714 ha out of a total peat area of 1,729,980 ha (Agus *et al*., 2011). Furthermore, according to (Miettinen *et al*., 2016), peat land used as agricultural land in West Kalimantan reached 550,340 ha. Based on the results of analysis by the Chemistry and Soil Fertility Laboratory of the Faculty of Agriculture, Tanjungpura University, in 2023, the chemical content of peat soil has a pH value of 3.46, a total N content of 1.79, P_2O_5 65.92 ppm and potassium 0.24 [$cmol^{(+)}kg^{-1}$]. The condition of the peat soil is very acidic, the total nitrogen and phosphorus levels are very high and potassium is low (LPT, 1983).

The acidity level of peat soil can be an essential factor in determining the availability of nutrients for plants and can cause decreased plant productivity (Astuti *et al*., 2022; Sinaga *et al*., 2022). Several studies have found that the application of cultivation technology through the use of organic materials and fertilizer regulation can increase peat soil fertility and support increased plant growth and yields (Fiasconaro *et al*., 2022; Ismaeili 2022; Utami and Indrawati 2024).

Providing ash as an ameliorant material can be an appropriate strategy for improving the quality of peat soil. This is because ash is alkaline and can increase the pH of peat soil and the high Na content can help neutralize organic acids that are toxic to plants, such as carboxylic acids and phenolic acids (Prasetyo 1996). In addition, ash's role in the soil can add nutrients to plants, significantly increasing growth plant (Saarsalmi *et al*., 2010; Błońska *et al*. 2023). According to Dhindsa *et al*. (2016) ash supports improvements in soil properties, namely texture, structure and bulk density, which are crucial for plant growth and development. There are several types of ash based on the

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raw material from which it is made, which can be used to increase peat soil fertility and plant growth (Marlina 2015; Nurvitha 2016; Navarin *et al*., 2021). However, the best type of ash that can increase ginger productivity in peat soil has yet to be discovered.

NPK fertilization can be a supporting factor in supplying nutrients to ginger plants on peat soil because the availability of nutrients for plants may need to be utterly sufficient due to the application of ash. The application of NPK fertilizer can accelerate and optimize plant growth and development (Fiolita *et al*., 2017). NPK fertilizer applied to plants can increase nutrient absorption of plants, as well as increase the growth and development of plant (Bernstein *et al*., 2019; Yamika *et al*., 2021; Bentamra *et al*., 2023). This is related to the role of nitrogen in preparing amino acids, nucleic acids, nucleotides and chlorophyll, phosphorus plays a role in storing and transferring energy and potassium as an enzyme activator and helps transport assimilation results from the leaves to all plant tissues (Mato *et al*., 2022). Therefore, to manage peat soil to increase the growth and yield of ginger plants, further studies are needed regarding the treatment of ash types and doses of NPK fertilizer.

MATERIALS AND METHODS

The research was conducted in Tanjungpura University, Pontianak City, West Kalimantan Province, Indonesia. The research is from May 1st to November 28th 2023. Peat soil is used with a level of fabric decomposition and ginger seeds are used with white ginger. The experiment was carried out with a factorial randomized block design. The first factor was treating ash type with 4 levels (cow manure ash, rice husk ash, wood ash and coconut fiber ash). The second factor was NPK fertilizer with 4 doses (600 kg ha^{-1}, 800 kg ha^{-1}, 1,000 kg ha^{-1}, 1,200 kg ha^{-1}). Each treatment combination was set for 3 repetitions.

The research was carried out by clearing the peat land from shrubs and the next stage was processing the land and creating experimental plots with an area of 1.2 m × 5 m and a distance between plots of 1 m. Each type of ash is applied at the beginning of land preparation by making a row on the treatment plot. The ash used is 20 tons ha^{-1} and then the treatment plot (planting media) is incubated for 2 weeks.

The ginger seeds that have been sown are then transplanted into each treatment plot at a distance of 30 cm × 40 cm. Embroidery of dead seeds is carried out a maximum of 7 days after planting (DAP). NPK fertilization is carried out in 3 stages, namely when transplanting, when the plants are 1 month and when the plants are 2 months. The dose of NPK fertilizer applied is adjusted to each treatment. Ginger plant care is done by weeding weeds and controlling pest and disease attacks.

The growth and yield of ginger plants were observed by measuring plant height using a meter starting from the base of the stem to the highest growing point at the plant age 20 weeks after planting (WAP). The dry weight of the top of the plant was observed by drying it in an oven at 90°C for 24 hours and weighing it using an analytical balance. The number of tillers was counted from the shoots that appeared on each clump and the fresh weight of the rhizomes was weighed using an analytical balance.

The statistical analysis used the analysis of variance (ANOVA) to test the level of influence of the treatment factors, type of ash and dose of NPK fertilizer on the growth and yield of ginger plants. Furthermore, the honestly Significant difference is carried out to determine if there is a real effect on the observed variable with a confidence level of 95%, intending to test the level of difference that occurs at each treatment level (Gaspersz, 1991).

RESULTS AND DISCUSSION

The study of the growth of ginger plants is described based on the variables of plant height and dry weight of the top of the plant and this is a result of the process of cell division and enlargement, which will form an expansion of plant tissue in the vegetative phase so that in the long term it will increase plant biomass (Hilty *et al*., 2021). Meanwhile, the yield of ginger plants in the research was described based on the increase in the number of tillers and the fresh weight of the rhizomes. The formation of saplings in each ginger clump will form new rhizomes positively correlated with increased rhizome weight (Putri and Maizar 2023). The formation and enlargement of ginger rhizomes is caused by the increasing accumulation of starch collected in the sink (Krishnamurthy and Kandiannan 2021), ultimately increasing the economic value obtained (Patra and Podar, 2023).

Height of plants

The height of the ginger plants was significantly influenced by the use of various types of ash, while NPK fertilizer showed the same results. The HSD test results showed that the ash from wood waste obtained the highest plant height growth, significantly higher by 4.09% compared to rice husk ash but not different from the plant height in treating cow manure ash and coconut fiber ash (Table 1).

Dry weight of the top plants

The dry weight of the top part of the ginger plants showed a significant influence from the use of various types of ash, while NPK fertilizer showed the same results. The results of the HSD test showed that the dry weight of the top part of the plant from cow manure ash obtained the highest results and was significantly heavier by 5.79% than the dry weight with the rice husk ash treatment, but was not different compared to the wood ash and coconut fiber ash treatments (Table 2).

Number of tillers

The number of ginger tillers showed a significant influence from using various types of ash, while NPK fertilizer showed the same results. The HSD test results showed that the highest number of tillers in the cow manure ash treatment

was significantly greater by 8.98% compared to the number of tillers in the rice husk ash treatment. Still, they were not different in the wood ash and coconut fiber ash treatments (Table 3).

Fresh weight of rhizomes

The fresh weight of ginger rhizomes in the ash treatment showed a significant effect. Still, the same results were obtained when using various doses of NPK fertilizer. The HSD test results showed that the fresh weight of rhizomes was highest in the cow manure ash treatment, which was significantly heavier by 2.28% compared to the new weight of rhizomes in the rice husk ash treatment, but not different compared to the wood ash and coconut fiber ash treatments (Table 4).

The use of various types of ash for the growth and yield of ginger plants in this study showed a significant influence on all variables observed in the development and yield of ginger plants on peat soil. Ash improves soil physicochemical properties, such as pH, CEC, BD and PD and increases the availability of macro and micro soil nutrients, which are beneficial for the growth and development of plants (Doli *et al*., 2020). However, each type of ash used on plants has a different nutrient content (Table 5). Various types of ash used for plants have different abilities in increasing soil fertility, which in the end will have other effects depending on the ash source provided (Riono and Apriyanto 2020; Ermiwati *et al*., 2021; Suharti *et al*., 2021).

Table 1: The height of plants produced in the treatment of various types of ash and doses of NPK fertilizer.

Type of ash	NPK fertilizer (kg ha^{-1})				Average
	600	800	1,000	1,200	
	(cm)				
Cow manure	89.80	86.70	93.50	81.30	87.80ab
Rice husks	77.80	86.50	74.00	66.30	76.20b
Wood Ash	93.30	84.50	94.30	88.30	90.10a
Coconut fiber	87.50	89.50	81.20	84.30	85.60ab
Average	87.10a	86.80a	85.80a	80.10a	

Note: The numbers followed by the same letters according to the column or row are not significantly different based on the HSD test in the 5% level.

Table 2: The dry weight of the top plants produced in the treatment of various types of ash and doses of NPK fertilizer.

Type of ash	NPK fertilizer (kg ha^{-1})				Average
	600	800	1,000	1,200	
	(g)				
Cow manure	27.70	22.10	27.70	26.40	25.80a
Rice husks	19.90	23.20	19.40	19.60	20.50b
Wood ash	26.20	21.00	23.10	20.50	22.70ab
Coconut fiber	21.30	22.20	20.80	25.70	22.50ab
Average	23.80a	22.10a	22.60a	23.10a	

Note: The numbers followed by the same letters according to the column or row are not significantly different based on the HSD test in the 5% level.

Table 3: Number of tillers produced in the treatment of various types of ash and doses of NPK fertilizer.

Type of ash	NPK fertilizer (kg ha^{-1})				Average
	600	800	1,000	1,200	
	(tiller)				
Cow manure	14.00	13.30	15.50	14.20	14.30a
Rice husks	7.20	13.00	9.80	10.20	10.00b
Wood ash	10.80	10.70	12.00	11.30	11.20ab
Coconut fiber	12.50	12.50	11.50	13.20	12.40ab
Average	11.10a	12.40a	12.20a	12.20a	

Note: The numbers followed by the same letters according to the column or row are not significantly different based on the HSD test in the 5% level.

Table 4: Fresh weight of ginger rhizomes produced in the treatment of various types of ash and doses of NPK fertilizer.

Type of ash	NPK fertilizer (kg ha^{-1})				Average
	600	800	1,000	1,200	
	(g)				
Cow manure	423.50	370.30	433.10	431.40	414.60a
Rice husks	297.90	404.80	312.70	330.50	336.50b
Wood ash	386.20	375.80	383.00	325.30	367.60ab
Coconut fiber	324.20	392.50	315.60	408.60	360.20ab
Average	357.90a	385.90a	361.10a	374.00a	

Note: The numbers followed by the same letters according to the column or row are not significantly different based on the HSD test in the 5% level.

Table 5: Nutrient content in various types of ash.

Type of ash	pH	Neutralization power	Phosphor	Potassium	Calcium	Magnesium
				(%)		
Cow manure	10.92	53.13	2.48	1.83	2.41	0.48
Rice husks	8.97	13.75	0.28	0.94	0.28	0.06
Wood ash	10.63	21.14	0.76	2.03	2.50	0.87
Coconut fiber	10.41	43.00	1.45	1.71	0.47	0.31

Source: Soil Chemistry and Fertility Laboratory, Faculty of Agriculture, Tanjungpura University.

The height of ginger plants treated with wood ash obtained better results than other treatments. However, it was not significantly different from the treatment with cow manure ash and coconut fiber ash. This is because wood ash has higher potassium levels than other ash types (Table 5). Potassium is a macronutrient that plants need in abundant amounts besides phosphorus and nitrogen (Rawat *et al*., 2022).

The higher availability of potassium elements in the soil can cause the plant's ability to absorb potassium to be higher so that it can support the increase in plant height and this is related to the role of potassium in stimulating cell division and encouraging plant growth and photosynthesis processes (Hasanuzzaman *et al*., 2018; Sardans and Peñuelas, 2021). Plants that lack the element potassium cause photosynthetic CO_2 fixation to decrease, which ultimately results in the utilization of assimilate for plant growth not being optimal (Waraich *et al*., 2012).

The dry weight of the top of plants, the number of tillers and the fresh weight of the rhizomes showed that the application of ash sourced from cow manure was better. However, it was similar to the treatment of wood ash and coconut fiber ash (Table 2, Table 3, Table 4). This is because the phosphorus nutrient content in cow manure ash is higher than in other ash (Table 5). Phosphorus, as a plant macronutrient, is vital in producing adenosine triphosphate (ATP), which provides energy for photosynthesis (Malhotra *et al*., 2018).

Lack of phosphorus for plants can cause ATP production to be hampered, resulting in photosynthesis in plants not running optimally, ultimately impeding plant growth and development (Khan *et al*., 2022). Several studies have found that plants experiencing a lack of phosphorus cause the rate of plant photosynthesis to be hampered, causing plant development and production to decrease (Carstensen *et al*., 2018; Iqbal *et al*., 2023; Saengwilai *et al*., 2023). In general, the effect of NPK fertilizer in this study did not have a significant impact in increasing the growth and yield of ginger plants, as seen from various doses of NPK fertilizer, there was no difference in yield in plant height, dry weight of the top of the plant, number of tillers and fresh weight of rhizomes. The ash can cause this applied being able to increase the soil pH, as observed in peat soil that has been incubated using ash, there was an increase with an average pH value of 7.2 and the conditions for growing ginger plants require a soil pH of 6.8-7.4 (Balai, 2010).

According to Wijayanti *et al*. (2023), the increasing pH value in peat soil is the cause of the higher availability of nutrients for plants. So, in this condition, NPK fertilization with a low dose still produces the same plant growth and production as treatment with a higher NPK fertilizer dose because the plant's nutrient requirements are already available in the soil.

CONCLUSION

The research reveals that the type of ash used in the soil has a significant impact on the growth and yield of ginger plants in peat soil. The study found that different types of ash have varying effects on plant growth and productivity. Among all the types of ash used, cow manure ash was found to be the most effective for producing growth and yield of ginger plants. This conclusion was drawn after considering several factors such as the dry weight of the plant, the number of tillers and the fresh weight of the

rhizomes. On the other hand, the use of different doses of NPK fertilizer did not have a significant impact on the growth and yield of ginger plants in peat soil. This implies that the use of cow manure ash can be a more effective approach for enhancing the productivity of ginger plants in peat soil.

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Authors' contributions

All authors contributed equally to the research and discussion of the manuscript data obtained. Radian is the main researcher who initiated the idea of this research and Tatang Abdurrahman is a member of the research implementation team who contributed further to the writing of this paper. All authors have proofread and approved the final version of this manuscript.

Conflict of interest

The authors declare no conflict of interest.

REFERENCES

Agus, F., Hairiah, K., Mulyani, A. (2011). Measuring Carbon Stock in Peat Soil. Bogor: World Agroforestry Centre and Indonesian Centre for Agricultural Land Resources Research and Development.

Astuti, A.A.R., Nuraini, Y., Baswarsiati, B. (2022). Utilization of trichocompost and cow manure to improve soil chemical properties, growth and production of garlic plants (*Allium sativum* L.). Journal Tanah dan Sumberdaya Lahan. 9(2): 243-253. doi: 10.21776/ub.jtsl.2022.009.2.5.

Badan, P.S. (2023). Biopharmaceutical (medicinal) plant production, 2021-2022. https://www.bps.go.id/id/statistics-table/2/NjMjMg=/produksi-tanaman-biofarmaka-obat-.html.

Balai, P.T.O.A. (2010). Cultivation of Ginger, Galangal, Turmeric and Ginger (2nd printing). Jakarta: Balai Penelitian dan Pengembangan Pertanian.

Bentamra, Z., Medjedded, H., Nemmiche, S., Benkhelifa, M., DOS Santos, D.R. (2023). Effect of NPK fertilizer on the biochemical response of tomatoes (*Solanum lycopersicum* L.). Not. Sci. Biol. 15(3): 11516. doi: 10.55779/nsb15311516.

Bernstein, N., Gorelick, J., Zerahia, R., Koch, S. (2019). Impact of N, P, K and humic acid supplementation on the chemical profile of medical cannabis (*Cannabis sativa* L). Front. Plant. Sci. 10. doi: 10.3389/fpls.2019.00736.

Błońska, E., Prażuch, W., Boroń, P., Lasota, J. (2023). Effects of wood ash on the soil properties and fungal community structure in a beech forest in Poland. Geoderma Regional. 34: e00676. doi: 10.1016/j.geodrs.2023.e00676.

Carstensen, A., Herdean, A., Schmidt, S.B., Sharma, A., Spetea, C., Pribil, M., Husted, S. (2018). The impacts of phosphorus deficiency on the photosynthetic electron transport chain. Plant Physiol. 177(1): 271-284. doi: 10.1104/pp.17.01624.

Dhindsa, H.S., Sharma, R.D., Kumar, R. (2016). Role of fly ash in improving soil physical properties and yield of wheat (*Triticum aestivum*). Agricultural Science Digest. 36(2): 97-101. doi: 10.18805/asd.v36i2.10626.

Doli, Asma, Ashok, K. (2020). Growth with some biochemical responses in two cultivars of *Cicer arietinum* L. to Fly ash amended soil. Indian J. Agric. Res. 55(2): 163-168. doi: 10.18805/IJARe.A-5439.

Ermiwati, Radian, Budi, S. (2021). The effect of wood ash on the growth of taro plant in the peat soil. Journal Sains Pertanian Equator. 10(4): 1-7.

Fiasconaro, M.L., Abrile, M.G., Hintermeister, L., Antolin, M.D.C., Lovato, M.E. (2022). Application of different doses of compost as a substitution of the commercial substrate in nursery for pepper and tomato seedlings. International Journal of Recycling of Organic Waste in Agriculture (IJROWA). 11(4): 411-426.

Fiolita, V., Muin Abdurrani, F. (2017). The use of NPK mutiara fertilizer for enhancement growth of gaharu plants *Aquilaria* spp. on open area in ultisol. Journal Hutan Lestari. 5(3): 850-857.

Gaspersz, V. (1991). Experiment Design Methods. Bandung: ARMICO.

Hasanuzzaman, M., Bhuyan, M., Nahar, K., Hossain, Md, Mahmud, J., Hossen, M.d., Masud, A., Moumita, Fujita, M. (2018). Potassium: A vital regulator of plant responses and tolerance to abiotic stresses. Agronomy. 8(3): 31. doi: 10.3390/agronomy8030031.

Hilty, J., Muller, B., Pantin, F., Leuzinger, S. (2021). Plant growth: The What, the How and the Why. New Phytologist. 232(1): 25-41. doi: 10.1111/nph.17610.

Iqbal, A., Qiang, D., Xiangru, W., Huiping, G., Hengheng, Z., Xiling, Z., Meizhen, S. (2023). Genotypic variation in cotton genotypes for low phosphorus tolerance and efficiency under different growth conditions. Gesunde Pflanzen. 75(5): 1975-1993. doi: 10.1007/s10343-022-00823-y.

Ismaeili, F. (2022). Municipal solid waste compost and its derivatives, a suitable alternative to peat moss in the growth of Dracaena marginata tricolor. International Journal of Recycling Organic Waste in Agriculture. 11(2): 277-289.

Khan, Y., Shah, S., Hui, T. (2022). The roles of arbuscular mycorrhizal fungi in influencing plant nutrients, photosynthesis and metabolites of cereal crops-a review. Agronomy. 12(9): 2191. doi: 10.3390/agronomy12092191.

Krishnamurthy, K.S., Kandiannan, K. (2021). Source sink relationship, dry matter and starch partitioning in developing ginger rhizomes during different growth stages. Journal of Plantation Crops. 49(1): 14-19. doi: 10.25081/jpc.2021.v49.i1.7056.

LPT, (1983). Criteria For Assessing the Chemical Properties of Soil. Kementerian Pertanian, editor. Bogor: Balai Penelitian dan Pengembangan Pertanian Departemen Pertanian.

Malhotra, H., Vandana, Sharma S., Pandey, R. (2018). Phosphorus nutrition: Plant growth in response to deficiency and excess. In: Plant nutrients and abiotic stress tlerance. Singapore: Springer Singapore. pp: 171-190.

Marlina (2015). The effect of cow manure and husk ash on the growth of yellow ginger seedlings (*Zingiber officinale* Rosc). Lentera: Journal Ilmiah Sains dan Teknologi. 15(14): 79-84.

Mato, A.P.L., Yohanes, P.S., Ida Bagus, K.M. (2022). The effect of compost and NPK fertilizers on the growth and yield of shallots. Agriwar Journal. 2(2): 49-54. doi: 10.22225/aj.2.2.2022.49-54.

Miettinen, J., Shi, C., Liew, S.C. (2016). Land cover distribution in the peatlands of Peninsular Malaysia, Sumatra and Borneo in 2015 with changes since 1990. Glob. Ecol. Conserv. 6: 67-78. doi: 10.1016/j.gecco.2016.02.004.

Navarin, M., Saidy, A.R., Septiana, M. (2021). The effect of providing various types of ash on the availability of nitrogen nutrients in peat soil. Agroekotek View. 4(3): 141-146.

Nurvitha, L. (2016). The effect of ash and manure on the growth and yield of ciplukan plants (*Physalis angulata* L.) on peat media. 9(1): 33-41.

Patra, S.K., Podar, R. (2023). Evaluation of yield, economics and various indices of water productivity of ginger under flexible moisture regime and nutrient management. Journal of Crop and Weed. 19(1): 36-42. doi: 10.22271/09746315.2023.v19.i1.1656.

Prasetyo, T.B. (1996). Behavior of Toxic Organic Acids in Peat Soil Treated With Na Salts and Several Cu Microelements in Relation to Rice Yield. [Bogor]: IPB University.

Putri, W.W., Maizar (2023). Response to growth and production of red ginger (*Zingiber officinale* Var Rubrum.) plants on a variety of planting media and liquid organic fertilizer of banana peel enhanced with NPK. Journal Agroteknologi Agribisnis dan Akuakultur. 3(2): 33-42.

Rahmani, A.H., Sharbani, F.M. Al Aly, S.M. (2014). Active ingredients of ginger as potential candidates in the prevention and treatment of diseases *via* modulation of biological activities. Intenational Journal of Physiology, Pathophysiology and Pharmacology. 6(2): 125-136.

Rawat, J., Pandey, N., Saxena, J. (2022). Role of potassium in plant photosynthesis, transport, growth and yield. In: Role of potassium in abiotic stress. Singapore: Springer Nature Singapore. p. 1-14.

Riono, Y., Apriyanto, M. (2020). Utilization of rice husk ash in fertilizing green beans (*Vigna radiate* L.) in peatlands. Selodang Mayang: Journal Ilmiah Badan Perencanaan Pembangunan Daerah Kabupaten Indragiri Hilir. 6(2): 60. doi: 10.47521/selodangmayang.v6i2.164.

Saarsalmi, A., Smolander, A., Kukkola, M., Arola, M. (2010). Effect of Wood Ash and Nitrogen Fertilization on Soil Chemical Properties, Soil Microbial Processes and Stand Growth in Two Coniferous Stands in Finland. Plant Soil. 331(1-2): 329-340. doi: 10.1007/s11104-009-0256-y.

Saengwilai, P.J., Bootti, P., Klinnawee, L. (2023). Responses of rubber tree seedlings (*Hevea brasiliensis*) to phosphorus-deficient soils. Soil. Sci. Plant. Nutr. 69(2): 78-87. doi: 10.1080/00380768.2022.2164675.

Sardans, J., Peñuelas, J. (2021). Potassium control of plant functions: Ecological and agricultural implications. Plants. 10(2): 419. doi: 10.3390/plants10020419.

Sinaga, M.J., Atikah, T.A., Zubaidah, S. (2022). Effect of applying biological fertilizer and SP-36 to increase tomato (*Solanum Lycopersicum* L.) yield on inland peat soil. Daun: Journal Ilmiah Pertanian dan Kehutanan. 9(1): 40-49. doi: 10.33084/daun.v9i1.3628.

Suharti, W.S., Bahtiar, J., Kharisun, K. (2021). The effect of various sources of silica on the growth and resistance of rice plants infected with *Rhizoctonia solani*. Journal Pertanian Terpadu. 9(1): 26-39. doi: 10.36084/jpt..v9i1.297.

Utami, S.N.H., Indrawati, U.S.Y.V. (2024). Oil palm empty fruit bunch biochar fertilizer as a solution to increasing the fertility of peat soil for sustainable agriculture. International Journal of Recycling of Organic Waste in Agriculture (IJROWA). 13(1): 1-11.

Waraich, E.A., Ahmad, R., Halim, A., Aziz, T. (2012). Alleviation of temperature stress by nutrient management in crop plants: A review. J. Soil. Sci. Plant. Nutr. 12(2): 221-244. doi: 10.4067/S0718-95162012000200003.

Wijayanti, F., Aditya, H.F., Jaya, A., Ramadhani, W.S., Tarigan, R.A. (2023). Effect of Land use Differences on pH and Available Phospor in Peatland, Kelampangan, Central Kalimantan. In: Nusantara Science and Technology Proceedings. Galaxy Science. pp: 24-27.

Yamika, W.S.D., Simbolon, G.P., Waluyo, B., Aini, N. (2021). Effect of NPK fertilizer on nutrient uptake, growth, yield and beta-carotene of cutleaf groundcherry (*Physalis angulata* L.) of genotypes. Indian J. Agric. Res. 55(6): 667-673. doi: 10.18805/IJARe.A-637.