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The effect of organic matter on soil organic carbon and water spinach grown in gold mine tailings

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ABSTRACT

The disposal of tailings generated from mining activities poses environmental challenges due to their low fertility and limited suitability for plant growth. This study aimed to investigate the potential of cow manure application in improving the organic-C content of tailings and enhancing the growth of water spinach (*Ipomoea reptans*). This experiment was laid out in a randomized block design with five treatments and five replications. The treatments involved the application of cow manure at different doses and control, which consisted of; (A) Control, (B) 150 g, (C) 300 g, (D) 450 g, (E) 600 g. The results revealed a significant increase in the organic-C content of tailings following the application of cow manure. The highest organic-C content of 7.47% was achieved with the application of 600 g of cow manure. The application of 150 g of cow manure resulted in the tallest plants with higher fresh and dry weights. The findings from this study underscore the importance of organic amendments in enhancing the organic-C content and promoting plant growth in low fertility growth medium. Further research on the long-term effects and optimization of cow manure application in tailing-based growth substrates is recommended to enhance soil fertility and maximize plant productivity.

Contribution/Originality: The findings contribute to knowledge on sustainable utilization of mining waste and the potential of organic amendments to transform a low fertility medium into fertile growth substrates.

1. INTRODUCTION

Mining activities can lead to environmental damage, especially when illegal mining operations neglect post-mining land rehabilitation. Illegal mining activities are recognized as a significant cause of environmental degradation, resulting in issues such as water pollution, soil degradation, and limited access to agricultural land [1]. In Indonesia, illegal gold mining, commonly known as PETI (unlicensed gold mining activity) is undertaken by individuals, groups of people, or legal entities that lack permits from central or regional government agencies as stipulated by relevant regulations [2]. In Karanglayung Village, Karangjaya District, Tasikmalaya Regency, gold mining activities were conducted by rural communities. These operations utilized underground methods and employed the amalgamation technique with the use of mercury (Hg), resulting in the generation of mercury (Hg) contimated tailings as waste material. Tailings refer to the residual material remaining after valuable elements

are separated from ores through a mineral processing and extraction process [3].

Gold mine tailings possess unfavorable physical and chemical characteristics [4]. The tailings dominantly consist of sandy to silty materials and have low water storage capacity, along with low cation exchange capacity (CEC) and nutrients content [5]. Mine tailings characterized by extreme pH, which can be highly acidic or extremely alkaline [4] and considered to have low fertility for supporting plant growth optimally. Therefore, it is necessary to improve the quality of the tailings before cultivating crops in tailings. This can be achieved by increasing the levels of organic matter and nutrients within the tailings.

The application of manure has been found to significantly enhance soil quality by increasing the level of soil organic carbon (SOC) [6]. Organic matter present in manure serves as a source of energy for soil microorganisms, which significantly increases microorganisms activity and the availability of nutrients supply [7]. A study by Gross and Glaser [8] showed that out of 276 treatments of manure application on agricultural soil, the average increase in organic carbon was 35.4%. Soil organic matter enhances soil physical, chemical, and biological processes and properties Blanco-Canqui, et al. [9]. Agbede, et al. [10] reported that the application of 20 and 30 mg ha^{-1} of manure resulted in a 31% and 36% increase in soil total porosity. The improvement of soil porosity creates an optimal medium for root development and facilitates adequate air supply to the roots [11].

The utilization of cow manure as a fertilizer is highly to enhance plant productivity on tailings. Cow manure contains plant nutrients, such as carbon (C), nitrogen (N), phosphorus (P), calcium (Ca), and Magnesium (Mg) which stimulate plant growth and provide the necessary nutrients for increased biomass yield [12]. Both macro and micronutrients can be directly supplied to the growth media by organic amendment input [13]. The availability of soil nutrients affects root growth and development. Bauer [14] stated that soil organic matter also affects bulk density, with higher organic matter content leading to lower bulk density in the soil. The application of manure improves soil structure, enhancing the plants ability to absorb water and nutrients, thereby promoting plant growth [15].

In order to increase the nutrient content in tailing for supporting plant growth and yield of leafy vegetable, application of cow manure is needed. Water spinach plant (*Ipomoea reptans*), commonly known as Kangkung in Indonesia, is extensively cultivated in Indonesia. The plant that belong to the family Convolvulaceae is easy to cultivate, and have high nutritional value, including energy, fat, carbohydrate, calcium, phosphorus, iron, and vitamin A, B, C [16]. This plant can thrive in lowland and highland areas and typically are harvested at approximately 4-5 weeks after sowing [17]. The objective of this pot experiment was to investigate the potential of cow manure application in improving the organic carbon content of tailings and enhancing the growth and yield of water spinach plant.

2. MATERIALS AND METHODS

2.1. Experimental Implementation

The experiment was conducted in a greenhouse located at the experimental field at Faculty of Agriculture Universitas Padjadjaran, from November 2022 until February 2023. The altitude of experimental field was approximately 752 m above sea level. The gold mining tailings used in this experiment were collected from PETI area in Karanglayung Village, Karangjaya District, Tasikmalaya Regency, Indonesia which located in tropical region (Figure 1). The geographic coordinates of goldmine area are approximately 7˚26'40.574608"S and 108˚21'23.417662"E with an elevation of 430 m above sea level.

The tailings were obtained from 3-months-old stockpiles. Prior to treatment, various properties of the tailings were determined to assess tailings characteristics. The determinations included, organic-C, total-N, C to N ratio, available P, P potential, K potential, exchangeable cations, exchangeable Al, exchangeable H, cation exchange capacity (CEC), and texture.

Figure 1. Illegal gold mine in Karanglayung Village, Karangjaya District, Tasikmalaya Regency where Tailings was Collected.

Cow manure was obtained from a cattle farm from Faculty of Animal Husbandry, Universitas Padjadjaran. Characteristics of pH, organic-C, total-N, C to N ratio, total-P, total-K, and water content of cow manure are presented in Table 2. The water spinach varieties utilized in this study was water spinach cv Bangkok LP1 produced by East West Seed Indonesia Co. The seeds were sown on mixed growing media comprising 1 kg of tailings combined with varying doses of cow manure. The plants were cultivated in polybags measuring 25 cm in depth and 25 cm in diameter.

2.2. Experimental Design

The experimental design employed in this study was a Randomized Block Design, consisting of five treatments and five replications. The treatments involved the application of cow manure at different doses and control, which consisted of; (A) Control, (B) 150 g manure + 1000 g tailings, (C) 300 g manure + 1000 g tailings, (D) 450 g manure + 1000 g tailings, (E) 600 g manure + 1000 g tailings. The control plants did not receive the manure. To set up the experiment, polybags were filled with one kilogram of tailings, then the manure was added according to the respective treatment doses. The mixture was incubated for three days. In each polybag, three water spinach seeds were sown into individual planting holes. The planting holes had a depth of 5 cm, and there was a 5 cm spacing between each planting hole.

Application of N-P-K compound fertilizer (16-16-16) was carried out at 15 days after planting. The fertilizer was incorporated into a 5-cm deep hole at the dose of 2.25 gram per polybag. The plants were maintained for 35 days in the greenhouse.

2.3. Experimental Parameters

At 35 days after planting (DAP), the plants were harvested. Three intact plants were selected for harvesting. The plant roots were carefully separated from the soil and rinsed with tap water. Excess water was removed using

kitchen paper. The fresh weight of the shoots (leaves and stems) and roots was measured. Both the shoot and root biomass were placed in paper bags and dried in an oven at 70°C for 2 days or until a constant weight was achieved. The shoot height of the plants was measured once a week, starting from one week after planting until the time of harvest. To determine the organic carbon content of the substrate, the Walkley and Black method was employed. Prior to analysis, the substrate samples were homogenized, air-dried, mashed, and passed through a 2-mm laboratory sieve.

2.4. Data Analysis

All the data collected were analyzed using analysis of variance (ANOVA) to assess the impact of cow manure dosage on the experimental parameters. If the results indicated a significant influence, further analysis was conducted using Duncan's Multiple Range Test (DMRT) at a significance level of 5%. The statistical analysis was performed using the SPSS software.

3. RESULTS

3.1. Tailings and Cow Manure Properties

Table 1 shows the pH values of the tailings, with a pH (H_2O) of 8.08 and a pH (KCl) of 7.76. The slight difference of less than 0.5 between these two values indicates that the tailings are predominantly composed of variable charge minerals. The organic carbon content of the tailings is relatively low which only 1.57%. Similarly, the total nitrogen content is low at 0.16%, resulting in a low C:N ratio of 9.81%. The availability of phosphorus in the tailings is classified as moderate, with a content of 9.45 ppm. However, the P potential content is high at 42.49 mg/100g, while the K potential content is low at 12.28%. The exchangeable cations of tailings are low for K^+ and Na^+, while high for (Ca^{+2} and Mg^{+2}). The tailings exhibit a very low cation exchange capacity of 3.51 cmol/kg. In terms of texture, the tailings have a silty clay texture, consisting of 2% sand, 57% silt, and 41% clay.

Table 1. Chemical and physical properties of Tailings at Karangjaya District.

No.	Parameter	Result	Method
1	pH (H_2O)	8.08	Potentiometry, pH meter (1:5)
2	pH (KCl 1N)	7.76	Potentiometry, pH meter (1:5)
3	Organic-C (%)	1.57	Walkley and Black
4	Total-N (%)	0.16	Kjeldahl, Titrimetry
5	C:N ratio	9.81	Calculation
6	Available P (ppm P)	9.45	B/O Extract, Spectrophotometry
7	P potential (mg/100g)	42.49	25% HCl Extract, Spectrophotometry
8	K potential (mg/100 g)	12.28	25% HCl Extract, AAS
9	Exchangeable cations:		
	K (cmol/kg)	0.18	NH_4OAc (pH 7), AAS
	Na (cmol/kg)	0.21	NH_4OAc (pH 7), AAS
	Ca (cmol/kg)	15.03	NH_4OAc (pH 7), AAS
	Mg (cmol/kg)	6.82	NH_4OAc (pH 7), AAS
10	Al-dd (cmol/kg)	0.25	KCl 1 M Extract, Titrimetry
11	H-dd (cmol/kg)	0.19	KCl 1 M Extract, Titrimetry
12	Cation exchange capacity (cmol/kg)	3.51	NH_4OAc (pH 7), Titrimetry
13	Texture		
	Sand (%)	2	Hydrometry
	Silt (%)	57	
	Clay (%)	41	
14	Texture	Silty clay	

Based on proximate analysis, tailings typically exhibit a low fertility status. The low nutrient content in tailings can hinder plant growth. Therefore, it is necessary to enhance the properties of tailings by applying cow

manure, which can increase fertility and support plant growth. The cow manure utilized in this experiment contains high levels of nutrients that are beneficial for plant growth Table 2.

Table 2. Chemical properties of cow manure used in the study.

No.	Parameter	Result	Method
1	pH	6.05	Potentiometry, pH meter (1:5)
2	Organic-C (%)	41.09	Walkley and Black
3	Total-N (%)	2.06	Kjeldahl, Titrimetry
4	C:N Ratio	19.95	Calculation
5	Total-P (%)	0.56	25% HCl Extract, Spectrophotometry
6	Total-K (%)	0.29	25% HCl Extract, Spectrophotometry
7	Water content (%)	19.03	Oven dry

3.2. Organic Carbon Content

The effect of cow manure application at different doses on the organic carbon content of the tailing-based substrate is presented in Figure 2. As the dose of manure application increases, the organic-C content of the growth substrate also increases. The application of 600 g manure polybag^{-1} resulted in the highest C-organic level in the growth substrate. The organic-C content of the tailing-based substrate experienced a significant increase of 376%, rising from 1.57% before the experiment to 7.47% after the treatment. In contrast, the control treatment, which did not receive the manure, exhibited the lowest organic carbon content. However, it still showed an increase of 25% from 1.57% before the experiment to 1.96%.

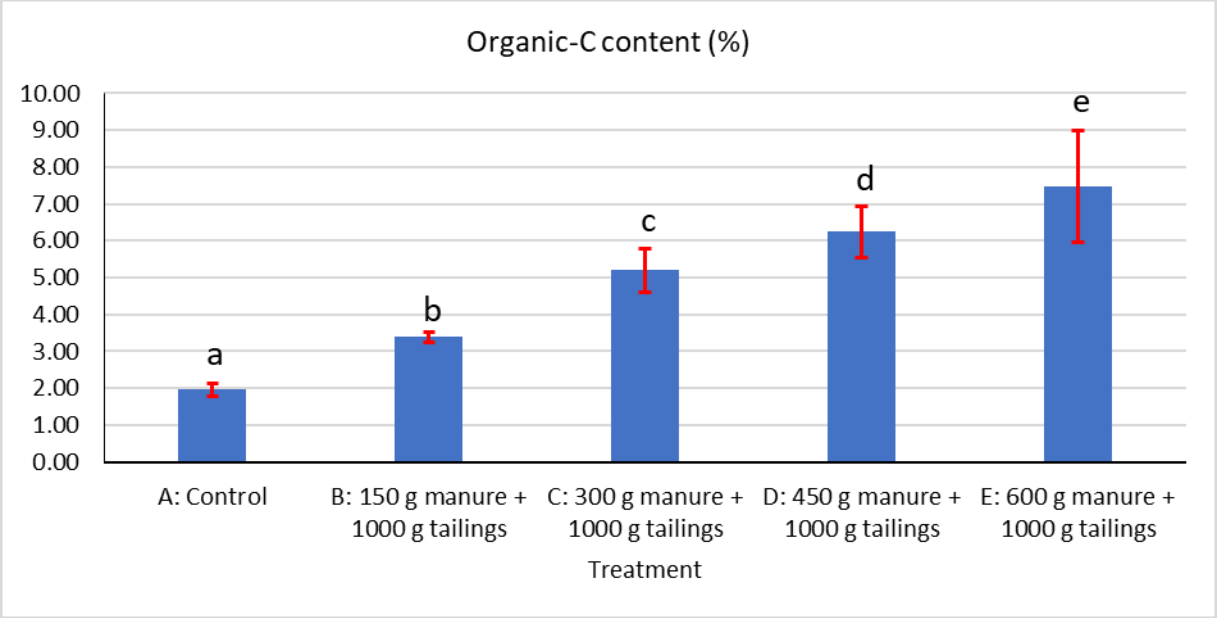

Figure 2. The effect of manure application on organic carbon content of tailing-based substrate grown with water Spinach.
Note: Different letters on the top of standard-deviation bars indicated the significant difference based on the Duncan Multiple Range Test at $p \leq 0.05$.

3.3. Plant Height (cm)

Figure 3 shows the results of Duncan's Multiple Range Test (DMRT) at a 95% confidence level for the average height of water spinach plants at 7, 14, 28, and 35 days after planting (DAP). The application of cow manure at different doses has varying effects on the average height of water spinach plants. The highest plant height was observed in the treatment where 150 g of manure was applied per polybag, resulting in an average height of 21.83 cm. The application of the highest doses of cow manure produced plants with a height of 18.9 cm, which did not show a significant difference compared to the application of 300 g and 450 g of manure. Control plants exhibited the lowest height compared to the plants that received different doses of manure application.

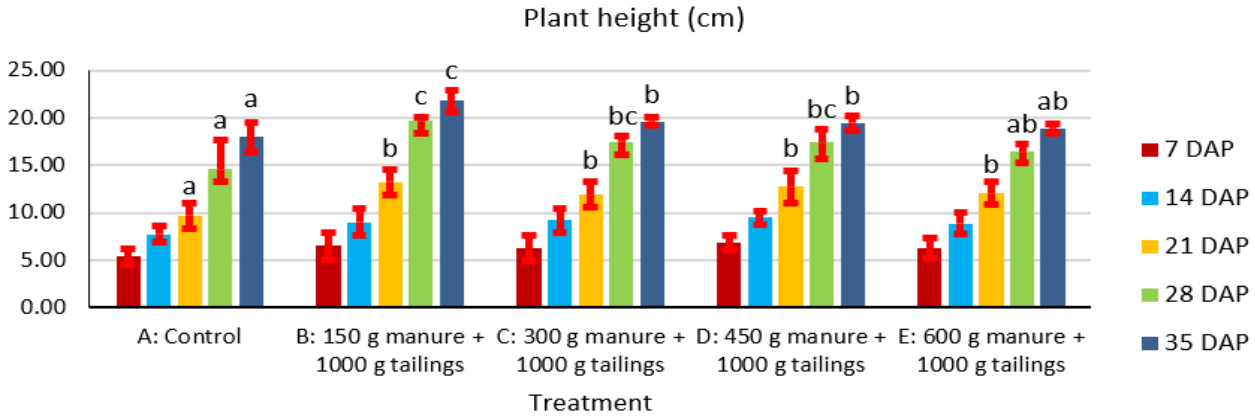

Figure 3. The effect of manure application on shoot height of 5-weeks old water Spinach.

Note: Different letters on the top of standard-deviation bars indicated the significant difference based on the Duncan Multiple Range Test at $p \leq 0.05$.

3.4. Plant Fresh and Dry Weight (g)

The effect the cow manure application on fresh and dry weight of water spinach plants showed in Figure 4. Manure application at a dose of 150 g polybag^{-1} produced the highest fresh and dry weights. This treatment showed a significant difference compared to the control treatment and the application of 300 g, 450 g, and 600 g manure polybags^{-1}. The growth and yield of the control plants were the lowest compared to the plants that were applied manure at various doses (Figure 5).

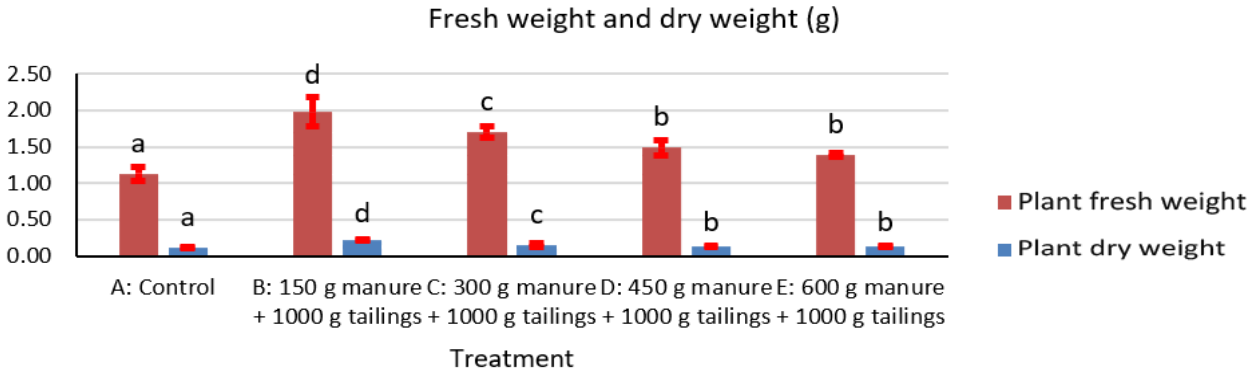

Figure 4. The effect of manure application on fresh and dry weight of 7-weeks old water spinach.

Note: Different letters on the top of standard-deviation bars indicated the significant difference based on the Duncan Multiple Range Test at $p \leq 0.05$.

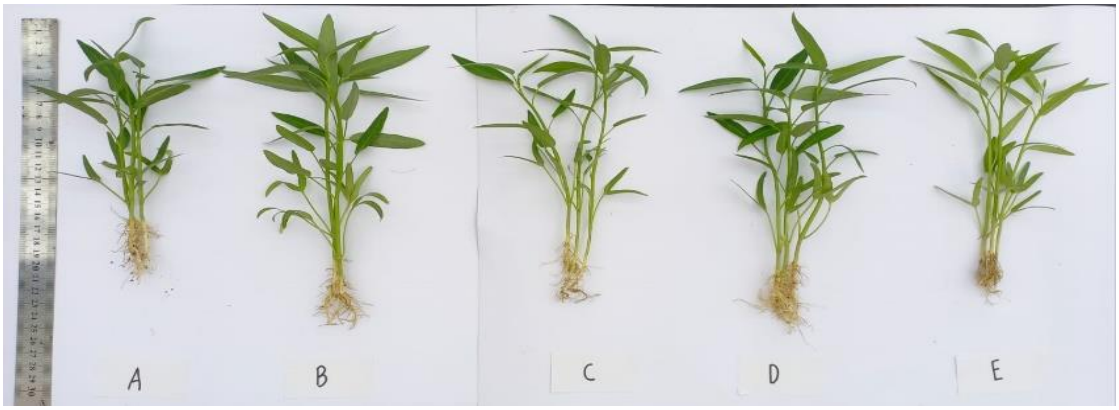

Figure 5. Performance of water spinach plant on harvest time at 35 days after sowing.

4. DISCUSSION

Soil organic carbon is a main component of soil organic matter. The application of manure can enhance the organic matter content of soil [18]. In this study, the organic carbon content in the tailings increased as the result of the manure application which had a very high organic-C content (29.25%). This experiment shows that increasing

the dose of manure applied to the tailings resulted in higher organic carbon content.

The amount of soil organic matter and soil organic carbon are the major drivers of biodiversity in the soil and used as an energy and nutrient source for soil microorganism which important for soil biological processes [19]. The application of organic matter stimulates the activity of soil microorganisms by increasing their populations and nutrient availability, especially for nutrients like nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg), which are essential for plant growth [20]. The addition of manure to the soil also enhances the biomass and diversity of beneficial soil microorganisms, which play important roles in soil nutrient cycling. The presence of soil beneficial microbes can accelerate the decomposition processes of organic substances and mineralize the organic N and P into inorganic, so it can be absorbed by the plants [7].

The growth and yield of plant grown in marginal soil have to be improved by the application of organic matter as fertilizer which could increase soil microorganism population and the availability of nutrients [12]. Plant height could increase due to the supply of nutrients contained on cow manure absorbed by the plants. The availability of macronutrient, especially nitrogen required during the initial growth stages of plants. Nitrogen plays a vital role in promoting plant growth, especially in the vegetative phase, such as the development of roots, stems and leaves, as well as enhancing the rate of photosynthesis [21, 22]. A better root development system expands the area of nutrient uptake and increased the water and nutrient uptake [23].

The organic input to the tailings can improve soil aggregate stability by increasing microbial activity [24]. During the decomposition process of organic matter, the microbes produced large amounts of polysaccharides which have a function to stick soil particles together into aggregates and leads to the soil structure improvement [9]. Enhanced soil aggregate stability improves soil porosity, allowing for better nutrient and water storage capacity, while also reducing soil erosion and nutrient loss [25]. The improvement in soil particles and structure also enhances soil porosity, which is important for supporting plant growth and development. Adequate soil porosity allows for better root penetration, nutrient uptake, and water movement, ultimately leading to increased crop yields [26].

Adequate supplies of macronutrients and micronutrients are essential for achieving high crop yields in agricultural cultivation [27]. The application of manure in this experiment resulted in increased crop yields, as shown in Figure 5. The increased of plant growth can lead to higher fresh and dry weights of the plants [28]. The application of manure can enhance vegetative growth by improving soil water holding capacity, promoting good aeration and drainage, and facilitating root growth. These factors contribute to better nutrient absorption and translocation within the plant [29]. By improving soil fertility and nutrient availability, manure application supports optimal plant growth, leading to increased yields in agricultural crops.

Fresh and dry weights are the result of the accumulation of organic compounds synthesized through photosynthesis and nutrient absorption. The application of manure can increase the nitrogen content in the soil, which in turn enhances the nitrogen content in leaf tissues. Nitrogen is an essential component of plant metabolism, and its availability can influence various physiological processes, including photosynthesis and nutrient assimilation [30]. Dry weight represents the net assimilation of carbon dioxide (CO_2) by the plant, which is influenced by factors such as solar radiation absorption and the efficiency of energy utilization for photosynthesis. Carbohydrates produced during photosynthesis are translocated from photosynthetically active tissues to other plant organs such as roots, flowers, and seeds, contributing to dry matter accumulation [31].

5. CONCLUSION

The application of cow manure increased organic carbon content on tailing-based growth substrate, plant growth, and yield of water spinach plants grown in the tailing-based medium.

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Institutional Review Board Statement: The Ethical Committee of the Universitas Padjadjaran, Indonesia has granted approval for this study.
Transparency: The authors state that the manuscript is honest, truthful, and transparent, that no key aspects of the investigation have been omitted, and that any differences from the study as planned have been clarified. This study followed all writing ethics.
Data Availability Statement: The corresponding author may provide study data upon reasonable request.
Competing Interests: The authors declare that they have no competing interests.
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REFERENCES

[1] E. A. Obeng *et al.*, "Impact of illegal mining activities on forest ecosystem services: local communities' attitudes and willingness to participate in restoration activities in Ghana," *Heliyon*, vol. 5, no. 10, p. e02617, 2019. https://doi.org/10.1016/j.heliyon.2019.e02617

[2] U. W. Soelistijo, "Control of illegal mining (PETI) in Indonesia: Policy and program," *Indonesian Mining Journal*, vol. 14, no. 1, pp. 1-16, 2011.

[3] K. Wang, Z. Zhang, L. Zhu, X. Yang, M. Chen, and C. Yang, "Comparative life cycle assessment of conventional and dry stack tailings disposal schemes: A case study in Northern China," *Minerals*, vol. 12, no. 12, p. 1603, 2022. https://doi.org/10.3390/min12121603

[4] R. Hindersah, R. Risamasu, A. M. Kalay, T. Dewi, and I. Makatita, "Mercury contamination in soil, tailing and plants on agricultural fields near closed gold mine in Buru Island, Maluku," *Journal of Degraded and Mining Lands Management*, vol. 5, no. 2, pp. 1027-1034, 2018. https://doi.org/10.15243/jdmlm.2018.052.1027

[5] M. C. Laker, "Environmental impacts of gold mining with special reference to South Africa," *Mining*, vol. 3, no. 2, pp. 205-220, 2023. https://doi.org/10.3390/mining3020012

[6] G. Govers, R. Merckx, V. K. Oost, and V. B. Wesemael, *Managing soil organic carbon for global benefits: A STAP technical report*. Washington, DC: Global Environmental Facility, 2013.

[7] E. Graham, S. Grandy, and M. Thelen, "Manure effects on soil organisms and soil quality," *Emerging Issues in Animal Agriculture. Michigan State University Extension*, pp. 1-6, 2009.

[8] A. Gross and B. Glaser, "Meta-analysis on how manure application changes soil organic carbon storage," *Scientific Reports*, vol. 11, no. 1, p. 5516, 2021. https://doi.org/10.1038/s41598-021-82739-7

[9] H. Blanco-Canqui *et al.*, "Soil organic carbon: The value to soil properties," *Journal of Soil and Water Conservation*, vol. 68, no. 5, pp. 129A-134A, 2013.

[10] T. M. Agbede, A. O. Adekiya, and E. K. Eifediyi, "Impact of poultry manure and NPK fertilizer on soil physical properties and growth and yield of carrot," *Journal of Horticultural Research*, vol. 25, no. 1, pp. 81-88, 2017. https://doi.org/10.1515/johr-2017-0009

[11] A. Hewitt, *Soil properties for plant growth: A guide to recognising soil properties relevant to plant growth and protection*. Lincoln: Manaaki Whenua Press. Landcare Research Science Series, 2004.

[12] A. P. Musdalifah, A. M. Kandari, R. Hasid, A. Bahrun, S. Mamma, and A. Madiki, "Effect of cow manure on growth and production of peanut plants in sub optimal land," *Asian Journal of Agricultural and Horticultural Research*, vol. 8, no. 2, pp. 38-47, 2021. https://doi.org/10.9734/ajahr/2021/v8i230114

[13] L. van Zwieten, "The long-term role of organic amendments in addressing soil constraints to production," *Nutrient Cycling in Agroecosystems*, vol. 111, no. 2-3, pp. 99-102, 2018. https://doi.org/10.1007/s10705-018-9934-6

[14] A. Bauer, "Influence of soil organic matter on bulk density and available water capacity of soils," *Farm Research*, vol. 31, no. 5, pp. 44-52, 1974.

[15] M. Simarmata, L. Susanti, and N. Setyowati, "Utilization of manure and green organic composts as alternative fertilizers for cauliflower production," *Journal of Agricultural Technology*, vol. 12, no. 2, pp. 311-319, 2016.

[16] N. Hidayati, P. Rosawanti, F. Yusuf, and N. Hanafi, "Kajian Penggunaan Nutrisi Anorganik terhadap Pertumbuhan Kangkung (Ipomoea reptans Poir) Hidroponik Sistem Wick: Study of the use of inorganic nutrition on the growth of Kale (Ipomoea reptans Poir) wick hydroponics system," *Daun: Jurnal Ilmiah Pertanian dan Kehutanan*, vol. 4, no. 2, pp. 75-81, 2017. https://doi.org/10.33084/daun.v4i2.81

[17] S. D. Pohan, "The effect of organic fertilizers on growth and yield of water Spinach (Ipomoea reptans Poir)," *JERAMI Indonesian Journal of Crop Science*, vol. 3, no. 2, pp. 37-44, 2021. https://doi.org/10.25077/jijcs.3.2.37-44.2021

[18] A. Bot and J. Benites, " The importance of soil organic matter: Key to drought-resistant soil and sustained food production," Food & Agriculture Organization No. 80, 2005.

[19] P. Laban, G. Metternicht, and J. Davies, *Soil biodiversity and soil organic carbon: Keeping drylands alive*. Gland, Switzerland: IUCN, 2018.

[20] A. Loss, R. D. R. Couto, G. Brunetto, M. D. Veiga, M. Toselli, and E. Baldi, "Animal manure as fertilizer: Changes in soil attributes, productivity and food composition," *International Journal of Research Granthaalayah*, vol. 7, no. 9, p. 307, 2019. https://doi.org/10.29121/granthaalayah.v7.i9.2019.615

[21] A. Fathi, "Role of nitrogen (N) in plant growth, photosynthesis pigments, and N use efficiency: A review," *Agrisost*, vol. 28, pp. 1-8, 2022.

[22] R. Rahmawati, "Effect of nitrogen fertilizer on growth and yield of Maize composite variety Lamuru," *Agrotech Journal*, vol. 2, no. 2, pp. 36-41, 2017. https://doi.org/10.31327/atj.v2i2.310

[23] A. Suyanto, A. T. P. Irianti, and R. Suryani, "The effect of provision of chicken manure and local micro-organisms of bamboo shoots on the growth and yield of chickpeas (Phaseolus vulgaris L.) in red yellow podsolic soil," *International Journal of Multi Discipline Science*, vol. 5, no. 1, pp. 15-21, 2022. https://doi.org/10.26737/ij-mds.v5i1.3120

[24] C. Wortmann and C. Shapiro, "The effects of manure application on soil aggregation," *Nutrient Cycling in Agroecosystems*, vol. 80, no. 2, pp. 173-180, 2008. https://doi.org/10.1007/s10705-007-9130-6

[25] S. K. Meena *et al.*, "Impact of long-term nutrient supply options on soil aggregate stability after nineteen years of rice–wheat cropping system," *Land*, vol. 11, no. 9, pp. 1-17, 2022. https://doi.org/10.3390/land11091465

[26] M. Ghorbani *et al.*, "Comparative influence of biochar and zeolite on soil hydrological indices and growth characteristics of corn (Zea mays L.)," *Water*, vol. 14, no. 21, p. 3506, 2022. https://doi.org/10.3390/w14213506

[27] J. Gerke, "The central role of soil organic matter in soil fertility and carbon storage," *Soil Systems*, vol. 6, no. 2, p. 33, 2022. https://doi.org/10.3390/soilsystems6020033

[28] R. Pandey, V. Paul, and M. P. Singh, "Plant growth analysis," Manual of ICAR Sponsored Training Programme for Technical Staff of ICAR Institutes on "Physiological Techniques to Analyze the Impact of Climate Change on Crop Plants", The Division of Plant Physiology IARI: New Delhi, India-110 012, 2017.

[29] A. El-Magd, M. Zaki, and S. Abou-Hussein, "Effect of organic manure and different levels of saline irrigation water on growth, green yield and chemical content of sweet fennel," *Australian Journal of Basic and Applied Sciences*, vol. 2, no. 1, pp. 90-98, 2008.

[30] I. C. Latifa and E. Anggarwulan, "Nitrogen content, nitrate reductase activity, and biomass of kimpul (Xanthosoma sagittifolium) on shade and nitrogen fertilizer variation," *Nusantara Bioscience*, vol. 1, no. 2, pp. 65-71, 2009.

[31] M. Tränkner, E. Tavakol, and B. Jákli, "Functioning of potassium and magnesium in photosynthesis, photosynthate translocation and photoprotection," *Physiologia Plantarum*, vol. 163, no. 3, pp. 414-431, 2018. https://doi.org/10.1111/ppl.12747