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Effect of Cow Manure on Soil Organic Carbon, Total Nitrogent, and Growth of Choy Sum in Gold Mine Tailings

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ABSTRACT: Mining activities in Bogor, Indonesia produce tailings contaminated with heavy metal Hg that can cause damage to physical, chemical, and soil properties. This research was carried out from October 2022 to February 2023 at greenhouse experiment was conducted in Jatinangor Campus, Faculty of Agriculture, Universitas Padjadjaran, West Java, Indonesia. The use of cow manure (CM) can improve substrate characteristics from tailings. The research was conducted to determine the effect of cow manure on plant height, number of leaves, fresh and dry shoot weight, organic-carbon, and total soil nitrogent. Greenhouse research was set up in Factorial Randomized Block Design. Choy sum plant variety is Shinta were planted 35 days with five treatments and five replications of CM. The used 450 g CM mixed with 550 g tailing gave the highest plant height, number of leaves, fresh and dry shoot weight of plant; organic-carbon, and total nitrogent in substrate. The experiment suggested that tailing mixed with CM is prominent to improve substrate characteristics and growth of choy sum.

KEYWORDS: Choy Sum, Cow Manure, Gold Mine Tailings, Mercury

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INTRODUCTION

Bogor is one of the regency in Indonesia where mining activities are carried out until today in certain area. Mining activities cause soil damage due to the decrease of soil's physical, chemical, and biological properties. Mining by products in the form of tailings usually have low nutrient content for plant growth. Some tailings have low organic carbon (C), total nitrogen (N), phosphate (P), and cation exchange capacity (CEC) available (Hindersah *et al*., 2021).

The gold extraction process in artisanal gold mines usually uses an amalgamator. The amalgamation process using Mercury (Hg) during gold extraction causes Hg contamination in the tailings (Yuliyanti & Aminuddin, 2023). The tailings disposal on agricultural area will cause Hg pollution to the environment, included rivers and paddy fields (Hindersah *et al*., 2020). Excessive Hg accumulation in plants causes imbalances nutrient uptake, futher reduce photosynthesis, growth, and biomass (Singh *et al*., 2023). The use organic matter in tailing-based substrate can help in reduce the biovailability of Hg in the soil and improve plant growth (Proto & Courtney, 2023).

Previous research on mine tailings treated with organic matter stated that applying organic matter can improve soil and plants' physical and chemical characteristics. However, the specific effects on choy sum growth and cow manure use have yet to be explained (Shi *et al.*, 2022). In addition, previous studies have only mentioned the role of organic matter on tailings but have yet to find the correct dose to help improve tailings with low organic-C and total-N content for choy sum growth.

Organic matter can help improve soil conditions. Organic matter has several vital roles, including preventing erosion, retaining water, increasing plant fertility, and increasing soil biodiversity (Ge *et al.*, 2012). Moreover, organic matter such as cow manure (CM) can bind the metals and reduce their bioavailability because it contains several active adsorption sites, including C-C, C--C, OH-, CHO-, -COOH, which can react with heavy metals (Z. Y. Zhang *et al*., 2020). The manure also contained significant amount of Carbon (C) and Nitrogen (N) for supporting plant growth (Chang *et al.,* 2018).

In order to assess the effectivity of CM to improve plant growth in tailing, the used choy sum as test plants is considered. The plants belong to *Brassicaceae* family grow wasily in harsh condition and often used for revegetation plants because they are metal hyperaccumulators without showing phytotoxic symptoms (Dar *et al*., 2018). Plants with hyperaccumulator properties can

accumulate at least 0.01% As and Cd or a minimum of 0.1% Cu, Co, Zn, Pb, or Cr, or 1% Mn and Ni (Harja *et al*., 2023). The objective of this experiment was to determine the influence of various content of cow manure in tailing-based substrate on plant height, number of leaves, fresh and dry shoot weight of choy sum; as well as, organic-C, and total-N in soil.

MATERIALS AND METHODS

Location

The greenhouse experiment was conducted in Jatinangor Campus, Faculty of Agriculture, Universitas Padjadjaran, West Java, Indonesia. The location is tropic, with an altitude of ±725 meters above sea level. Choy Sum Shinta grown in 1 kg of growing media with four compositions of CM and tailings and one control with 100% composition of tailings.

Tailings were collected from the small firm Gold Mine in Cigudeg District, Bogor Regency, Indonesia with geographical coordinates of 6°31'25"S 106°34'36"E (Figure 1). The average temperature in the area is 20º - 30ºC with an annual average temperature of 25°C. Air humidity reaches 70% with an average wind speed of 1.2 m/s. Evaporation of 146.2 mm/month. The tailings have the pH 8,92 (alkaline), the texture is dusty clay; contained 1.03% organic-C, 0.14% total-N, 7.35 C/N ratio, 45.64% P_2O_2 mg/kg, 15.16% K_2O mg/kg, while available P_2O_5 was 9.23% mg/kg, and the cation exchange capacity (CEC) 21.15 cmol/kg. Generally, the tailings are deficient in elements C, N, and low in C/N ratio.

Figure 1. Collected Tailing in Cigudeg District, Bogor Regency, Indonesia

Cow dung fertilizer was obtained from the manure decomposition warehouse of the Faculty of Animal Science, Universitas Padjadjaran. The characteristics of cow dung fertilizer are pH 6.5, organic-C 41.09%, total-N 2.06%, C/N ratio 19.95, and water content 19.03%. The cow dung fertilizer can be used following the Government Regulation of the country of Indonesia no 261 of 2019 concerning organic fertilizers with a minimum organic-C content of 15%, total-N 2%, C/N ratio of less than 25, and water content 8-20%. The choy sum variety used is Shinta, produced by PT East West Seed Indonesia. This choy sum is a hybrid variety that can grow in the lowlands and is usually cultivated during the rainy season. In addition, this variety is resistant to *Plutella* sp. caterpillar attack and wet rot disease.

Experimental Design

This experiment used a randomized block design with the following treatment

p_0. 1000 g tailings (control)
p_1. 112 g CM + 888 g tailing
p_2. 225 g CM + 745 g tailings
p_3. 337 g CM + 663 g tailings
p_4. 450 g CM + 550 g tailings

Each treatment was repeated five times. The pots with p_0 contains 0% CM, p_1 contains 11,2% CM, p_2 contains 22,5% CM, p_3 contains 33,7% CM, p_4 contains 45% CM.

Experimental Setup

Choy sum seeds were sowing in a nursery tray contained Ultisol soil with cow manure with a ratio of 1:1 (w/w). After 14 days, seedlings were transplanted to black polyethylene bag containing tailings-cow manure mixture according to the treatments. The pots stored in the greenhouse with the distance 30 × 30 cm (Figure 2).

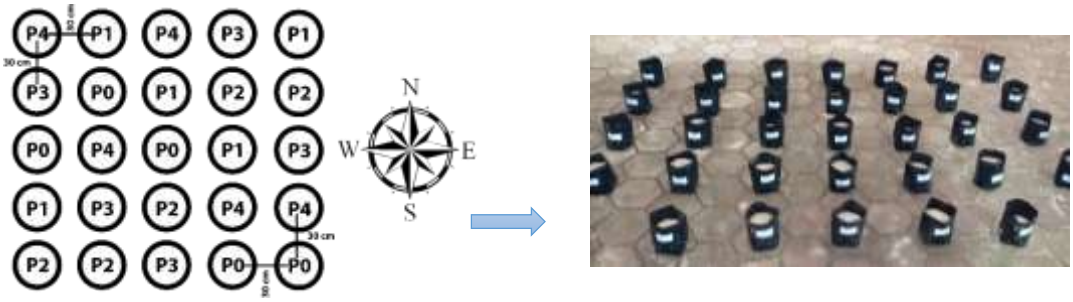

Figure 2. Experimental pot layout based on Randomized Block Design in greenhouse

Application of chemical fertilizer was carried out by using NPK (N-P-K; 16-16-16) fertilizer at 14 and 30 days after planting at a dose of 5 g/plant in every applications. Plants were grown in the greenhouse for 35 days, and samples were taken from as many as five plants per treatment so that there were 25 plants.

Parameters and Statistical Analysis

Plant height was measured using a ruler once week until a month. The fresh shoot weight data was taken after harvest by weighing the intact plants. The dry shoot weight determination was carried after storing plant on paper and then drying them in the oven at 70°C for 48 hours to constant weight.

The measurement of soil organic-C in the substrate was carried out using the Walkley and Black method; while total-N determination was performed using the Kjeldahl method. Analysis method of organic-C and total-N was performed according to the standards of the Soil Research Institute of Indonesia (Balai Penelitian Tanah, 2005). All data were subjected to analysis of variance ($P<0,05$). If the treatment significantly affected the parameter, using the DMRT (Duncan Multiple Range Test). The statistical analysis was performed using IBM SPSS Statistic 26.

RESULTS

Plant Growth

Cow manure application significantly increased plant height. The 45% CM and 55% tailings substrate produced greater plant height than the other treatments and the control substrate (Table 1). However, the application of 11.2% CM only slightly increased plant height. Plant height at week 5 growing on 11.2-45% CM substrate increased by 35%-64% compared to the control.

Table 1. Effect of Cow Manure Application on the Plant Height of Choy Sum Planted on Tailing with Various Consentration of Cow Manure

Treatment	Plant Height (cm) at week			
	2	3	4	5
p_0 = Control	5.46 ± 0.29 a	9.48 ± 0.13 a	10.92 ± 0.42 a	13.96 ± 0.53 a
p_1 = 11.2% CM	6.06 ± 0.55 a	9.44 ± 1.52 a	15.94 ± 0.58 b	18.88 ± 0.50 b
p_2 = 22.5% CM	8.70 ± 0.45 c	14.30 ± 0.24 c	16.28 ± 0.64 b	21.98 ± 0.65 d
p_3 = 33.7% CM	7.56 ± 0.50 b	11.92 ± 0.65 b	15.60 ± 0.42 b	21.20 ± 0.32 c
p_4 = 45% CM	10.22 ± 0.27 d	15.06 ± 0.78 c	19.50 ± 1.45 c	22.92 ± 0.64 e

Note: Numbers in column followed by the same letter are not significantly different according to Duncan's Multiple Range Test ($p<0.05$)

Cow manure application significantly increased plant leaves. The 45% CM and 55% tailings substrate produced larger plant leaves than the other treatment substrates and the control (Table 2). However, applying 11.2% and 22.5% CM only slightly increased plant leaves. Plant leaves at week 5 growing on the 11.2-45% CM substrate increased by 8%-39% compared to the control.

Table 2. Effect of Cow Manure Application on the Plant Leaves of Choy Sum Planted on Tailing with Various Consentration of Cow Manure

Treatment	Leaves at week			
	2	3	4	5
p_0 = Control	2.40 ± 0.55	3.20 ± 0.84 a	4.20 ± 0.84	4.60 ± 0.55 a
p_1 = 11.2% CM	3.20 ± 0.45	4.00 ± 0.71 ab	4.80 ± 0.45	5.00 ± 0.71 ab
p_2 = 22.5% CM	3.20 ± 0.45	4.20 ± 0.45 b	5.00 ± 0.71	5.80 ± 0.84 bc
p_3 = 33.7% CM	3.20 ± 0.45	4.00 ± 00 ab	4.80 ± 0.45	5.40 ± 0.55 ab
p_4 = 45% CM	4.00 ± 0.71	5.20 ± 0.45 c	5.60 ± 0.55	6.40 ± 0.55 c

Note: Numbers in column followed by the same letter are not significantly different according to Duncan's Multiple Range Test ($p<0.05$)

Soil Organic-C and Total-N (%)

Cow manure influenced the increase of organic-C and N in the growing media (Figure 3). Aplication of 33.7% and 45% CM gave the highest organic-C content, as much as 7.48% and 7.87%, respectively. In this experiment, application of 45% CM caused the highest organic-C and total-N of substrate compared to all treatments; the substrate contained 7.87% organic-C and 0.56% total-N. The organic-C value grown on 11.2-45% CM substrate increased by 45%-442%, while its fresh N value increased by 36%-194% compared to the control.

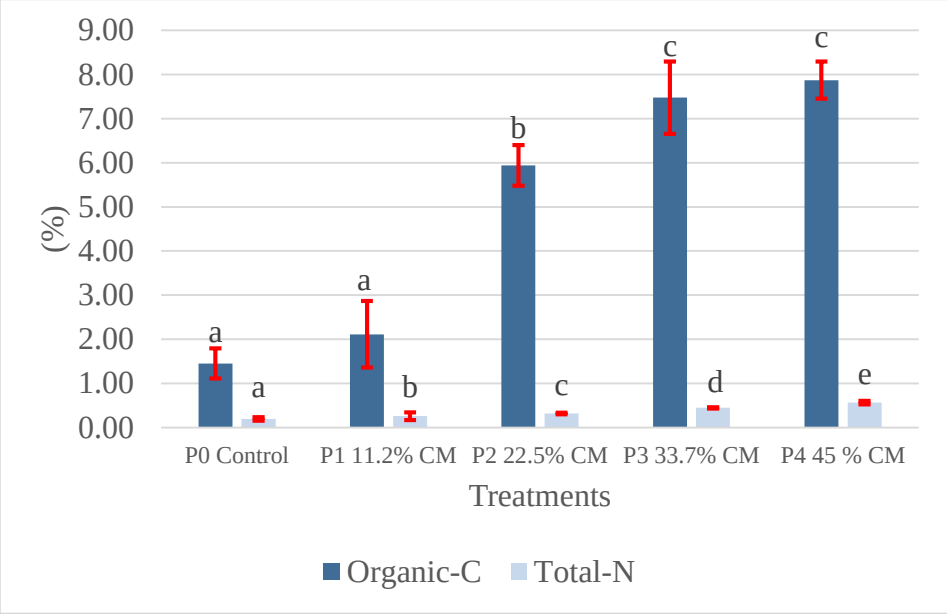

Figure 3. The Effect of Cow Manure Application on Organic-C & Total N of 5-weeks Choy Sum. Different latters on the top of standard-deviation bars indicate the significant difference based on Duncan Multiple Range Test at P ≤ 0.05

Fresh and Dry Shoot Weight

CM application significantly increased plant wet and dry weights. The 45% CM and 55% tailings substrate produced greater plant wet and dry weights than the other treatment substrates and the control (Figure 4). However, applying 11.2% CM only slightly increased crown fresh weight and did not increase crown dry weight. The fresh weight of plants grown in substrates with 11.2-45% CM increased by 93%-378%, while their dry weight increased by 90%-385% compared to the control.

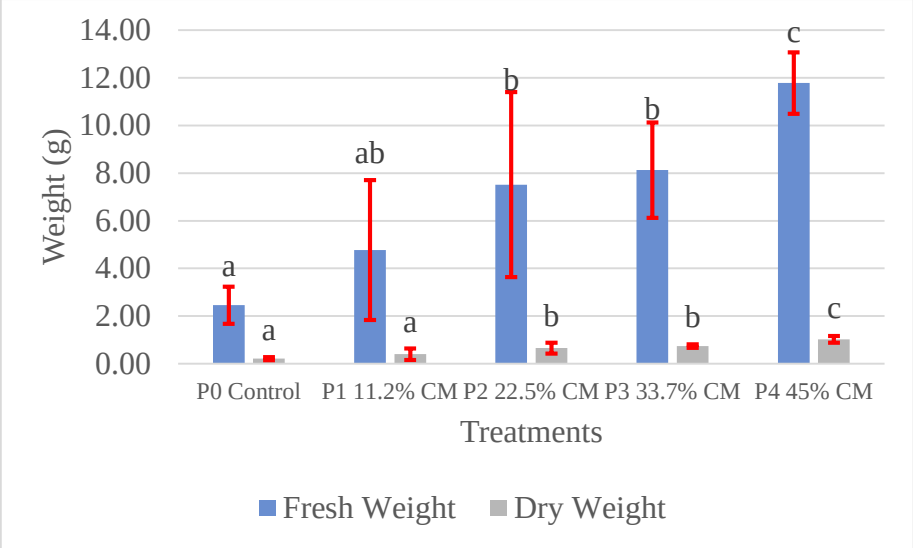

Figure 4. The Effect of Cow Manure Application on Choy Sum Shoot Weight of 5-weeks Choy Sum. Different latters on the top of standard-deviation bars indicate the significant difference based on Duncan Multiple Range Test at P ≤ 0.05

DISCUSSION

Choy sum is a *Brassicaceae* family that can be easily cultivated. This plant can grow in tropical climates with ideal temperatures reaching 30°-32° C. The *Brassicaceae* family has bio-accumulator properties against metals and does not show phytotoxicity in the growth process (Dar *et al*., 2018). The *Brassicaceae* family has genes tolerant of the damage caused by heavy metals (Roy *et al*., 2020). Therefore, sum choy is very suitable to be planted on revegetated land because of its ability to absorb and resistance to metals.

Tailings used as planting media have several limiting factors that make it difficult for plants to grow. The lack of nutrients such as organic-C and total-N will cause the availability of nutrients in plants to be inhibited, and it will affect plant growth (Li *et al*., 2020). Lack of plant nutrients will affect the yield of sum choy plants. Providing organic matter such as cow manure is a solution in increasing soil organic-C and total N because it can increase organic-C and total-N content and improve soil's physical and biological properties (Zhang *et al*., 2019).

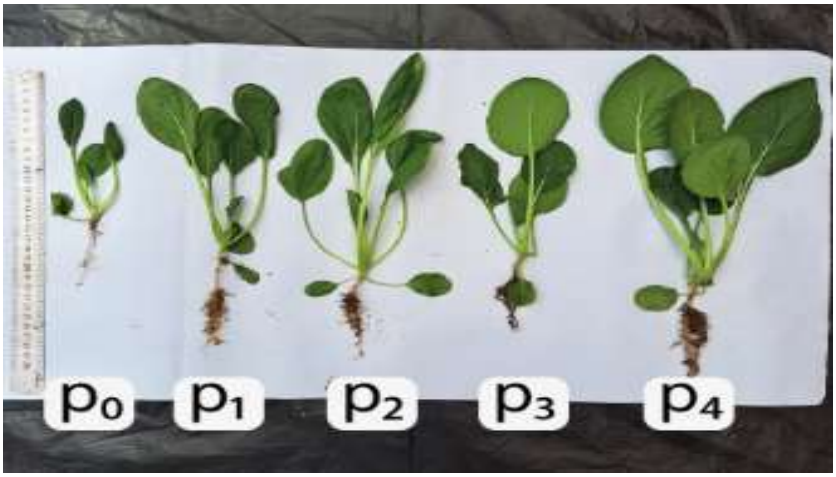

Figure 5. Choy sum growth after 5 week with 5 treatments

Based on Figure 5, the growth of choy sum plants at week 5 looks different. Giving cow manure at a dose of 45% affects the growth of choy sum plants compared to all treatments. Giving cow manure can function as a macro or micronutrient enhancer in plant growth (Schlegel *et al*., 2017). Adequate nutrition and freedom from toxicity can increase plant growth and biomass (Chatzistathis & Therios, 2017).

Adding cow manure in various treatments increased the C and N elements in the substrate. Soil organic-C and total N play an essential role in the availability of nutrients because microbes need N for C decomposition (Jing *et al*., 2021). Nitrogen is needed in significant quantities by plants because it is helpful for cell division, cell enlargement, and photosynthesis. The higher the dose, the higher the N valuable element for plant growth and yield (Ullah *et al*., 2023). In addition, nitrogen is involved in the production of

meristem enzymes, converting photosynthetic products and carbohydrates, ultimately affecting plants dry weight and yield (Nakhaei, 2022).

Organic-C indicates organic matter accumulation that determines soil health (Liptzin *et al*., 2022). Providing cow manure can increase Organic-C in the media to improve the structure and increase aggregates, infiltration, and the ability of the soil to retain water. In addition, organic-C can be a source of nutrients for plants because it contains N and P elements that can be released during the mineralization and decomposition of organic-C to fulfill nutrients for plants (Gerke, 2022).

Cow manure can increase media N because it has a high N content. Plants will absorb nitrogen and help in photosynthesis (Leghari *et al*., 2016). In addition, nitrogen plays an essential role in cell division, so it will affect several plant growth factors, such as leaf surface area and plant biomass, which will affect plant weight and height (Anas *et al*., 2020).

The danger of heavy metals for plants is that they can inhibit various plant metabolisms, such as biomass and another biochemical metabolism, so plant growth and yield are not optimal (M.K, 2023). Organic matter has functional groups such as hydroxyl (-OH) and carboxylate (-COOH) that can help in binding metals to be unavailable to plants (Connor *et al*., 2019). A high dose of cow manure can provide high growth and yield of choy sum plants because the higher dose will provide many nutrients and functional groups, affecting plant growth and yield (Figure 5).

Organic matter can help entangle Hg in the growing media so that it is not available to plants (Zhang *et al*., 2020). Plants that are protected from Hg will not show Hg poisoning. In addition, the ability of organic matter to entangle Hg ranges from 2.34 to 73.70% of the total Hg content in the media, and this will help plant growth to be more optimal when compared to without organic matter treatment (Rozanski *et al*., 2016).

CONCLUSION

The results of this study state that the application of cow manure will affect plant growth, number of leaves, organic C, total N, and fresh and dry shoot weight of plants on gold mine tailings. The 450 g CM dose gave the highest results in several growth parameters, such as plant height and the number of leaves, and plant yields, such as plants' fresh and dry shoot weight. In addition, the 450 g CM dose provided the highest organic-C and total-N in gold mine tailings media.

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