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Phytoremediation of nickel by *Paraserianthes falcataria* with varying levels of manure

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ABSTRACT

The objective of this study were to identify effective variations in fertilizer doses for phytoremediation of heavy metal nickel (Ni) by using sengon plants (*Paraserianthes falcataria*) before being used for post-mining land reclamation. This research is an experimental study, the growth parameters measured include plant height, number of leaves, root length, and plant biomass. The data obtained were analyzed using analysis of variance (ANOVA) and continued with Duncan's test. The manure used consists of chicken manure, calcium carbonate, and rice bran. Variation in fertilizer dose is the ratio between manure to mine soil 40:60 (A), 50:50 (B), 60:40 (C), 70:30 (D), and control without fertilizer (E) with four repetitions time. The results showed that there was a significant difference between the concentration of nickel content before and after the treatment of fertilizer dosing ($p>0.05$), which means that the dose of fertilizer can affect plant growth and phytoremediation abilities. The dose of D fertilizer (70:30) is the most suitable for phytoremediation of heavy metal nickel (Ni) because it shows the highest heavy metal concentration in the roots, which is 3.2 ppm. The plant growth parameters measured showed that the dose of fertilizer B (50:50) was most suitable for increasing plant height and biomass (*P. falcataria*) with a plant height of 27 cm and a biomass of 0.9 g/m2. The dose of C fertilizer (60:40) is most suitable for increasing the number of leaves with an average of 111.5 leaves. Control without fertilizer (E) is most suitable for increasing the root length of *P. falcataria*. Thus, the addition of manure affects the growth of *P. falcataria*, and nickel phytoremediation using *P. falcataria* at the dose of manure D (70:30) can reduce the nickel content in the soil.

Keywords: biomass, *Paraserianthes falcataria*, phytoremediation, reclamation

INTRODUCTION

Mining activities can cause negative impacts on the environment such as land degradation and soil pollution in order it needs to be controlled till damage does not occur outside of normal limits (Bokhari et al., 2016; Eksperusi et al., 2019). Thereby plans are needed to restore environmental functions so that it can be productive again, namely reclamation and restoration (Xamidova et al., 2022). One type that is often be used for mining reclamation activitiy is sengon plants (Juniah and Handayani, 2018; Subhan et al., 2020).

The sengon plant (*Paraserianthes falcataria*) can accumulate heavy metals that pollute the soil (Agus et al., 2016). Heavy metals as a type of metal that has an atomic density greater than 6g/cm3 are found in most areas of the earth, are very persistent, and cannot biodegrade (Cota et al., 2022). Excessive heavy metal content (exceeding quality standards) can inhibit the plant growth and productivity to cause of death (Jamal et al., 2013).

One of method of biological waste treatment is phytoremediation (Chengatt et al., 2022). Phytoremediation is a method that utilizes chlorophyll plants to absorb and accumulate heavy metals derived from the soil thereby reducing soil toxicity (Laghlimi et al., 2015). Phytoremediation of heavy metals is divided into 3 types, namely phytoextraction, phytostabilization, and rhizofiltration. This research focused on rhizofiltration that utilizes plant roots to absorb metals from soil, water, and river liquid waste (Reddy et al., 2022).

The concentration and accumulation of nickel in plants increases with the use of this metal in the fulfillment of nutrients by plants. The rate of nickel absorption is observed to be higher in leaves than in stems and roots (de Paula et al., 2022). In addition, the accumulation of heavy metal of nickel (Ni) also affects root growth, a high concentration of heavy metal of nickel (Ni) will inhibit the growth of the roots of the *Chenopodium quinoa* plant species (Haseeb et al., 2022).

The ability of plants to accumulate heavy metals can be helped by manure, this is evidenced by changes in soil pH, increased growth of corn crops, and significantly changed Cromium (Cr) concentrations after treatment (Abbas et al., 2019). This study was conducted using the sengon plant (*Paraserianthes falcataria*) to identify the most effective dose of manure for the absorption of the heavy metal of nickel (Ni).

METHOD

This research was conducted at the Nursery Hall in Konda District, South Konawe Regency, Southeast Sulawesi Province then analyzed at the Advanced Chemistry Laboratory and Forensic Laboratory of Halu Oleo University. The materials used in this study included fine sand, mining soil, manure (chicken manure, calcium carbonate, bran), and sengon plants (*Paraserianthes falcataria*). The equipment used in this study was hoes, shovels, *polybags* with a size of 10x20 in cm, plastic tubs, machetes, scales, tools for planting and maintaining plants, plant measuring instruments, stationery, cameras, and the *Z-2000 series Atomic Absorption Spectropotometer* (AAS).

The applied research method was an experimental method. The study began by sampling nickel mining soil in Pomalaa, Kolaka Regency, Southeast Sulawesi Province. Furthermore, the planting of sengon plant seeds (*Paraserianthes falcataria*) was carried out in polybags for approximately 3 months. *Polybags* were filled with a mixture of chicken manure fertilizer and post-mining soil as a planting medium. The ratio of chicken manure fertilizer to post-mining soil includes 40% : 60% (A), 50% : 50% (B), 60% : 40% (C), 70% : 30% (D), and control (E) with four repeats. The growth parameters measured include plant height, number of leaves, root length, and plant biomass.

The Data was analysed by using ANOVA and continued with Duncan Test when there was a noticeable difference from variations in fertilizer doses to plant growth. Analysis of the phytoremediation ability of Nickel heavy metals by Sengon plants (*Paraserianthes falcataria*) measured through nickel content in control soils (before treatment) and soils that had been treated A (40:60), B (50:50), C (60:40), D (70:30) as well as sengon plant roots (*Paraserianthes falcataria*) (Bosiacki & Zielezinski, 2011; Chengatt et al., 2022).

RESULTS AND DISCUSSION

The nickel content in the soil before treatment showed a value of 11.45 ppm. After planting for three months, there was a decrease in the heavy metal content of nickel in the soil ranging from 1.96 - 5.9 ppm. This value far exceeds the quality standards of heavy metals in the soil according to PERMEN LH No. 09 of 2006 under normal circumstances a maximum of 0.5 ppm (Pratama, 2021; Haya and Firman, 2022). The lowest decrease in nickel heavy metal content was seen in the control treatment without fertilizer (E) which ranged from 5 - 5.9 ppm. Meanwhile, the highest decrease in nickel heavy metal content was found in treatment A (40:60) with values ranging from 1.96 – 2.2 ppm because it used the optimal dose of manure (Figure 1).

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The results was in accordance with the research conducted by de Melo et al. (2019) by varying four doses of chicken manure fertilizer (4.5; 9; 13.5; and 18 mg of dry weight ha^{-1}) can change the stability of the soil. Maria *et al*. (2014)

also revealed that with the addition of chicken manure fertilizer can lower the heavy metal nickel in agricultural land.

The heavy metal content of nickel in the measured root organs showed varying results. The lowest nickel content was seen in the variation in the dose of manure C (60:40), it respectively showed values in four replays of 0,93 ppm, 0,82 ppm, 0,7 ppm, and 0,8 ppm. At the same time the highest nickel content was found in the root organs with treatment D (70:30) with successive values of 3 ppm, 3,2 ppm, 2,9 ppm, and 3,1 ppm. Treatment A was lower than treatment B with a value range of 1.03 ppm to 1.2 ppm. Treatment E (control) was greater than treatment A and B with a value range of 1.5 ppm to 1.9 ppm (Figure 2).

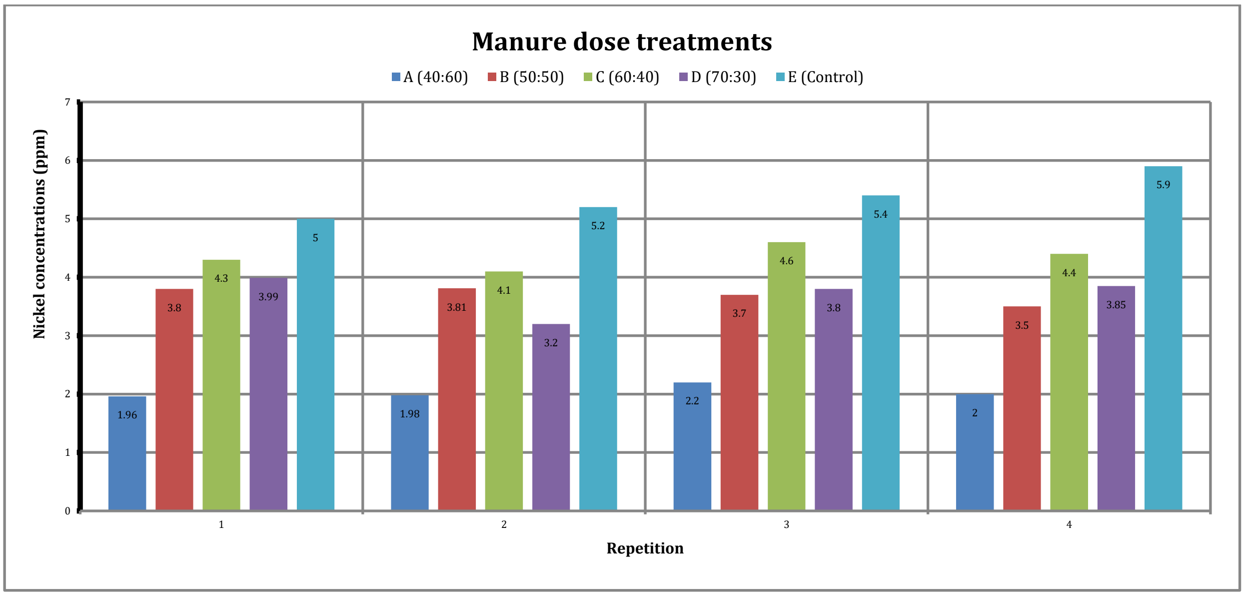

Figure 1. Histogram of nickel content in the soil before and after treatments.

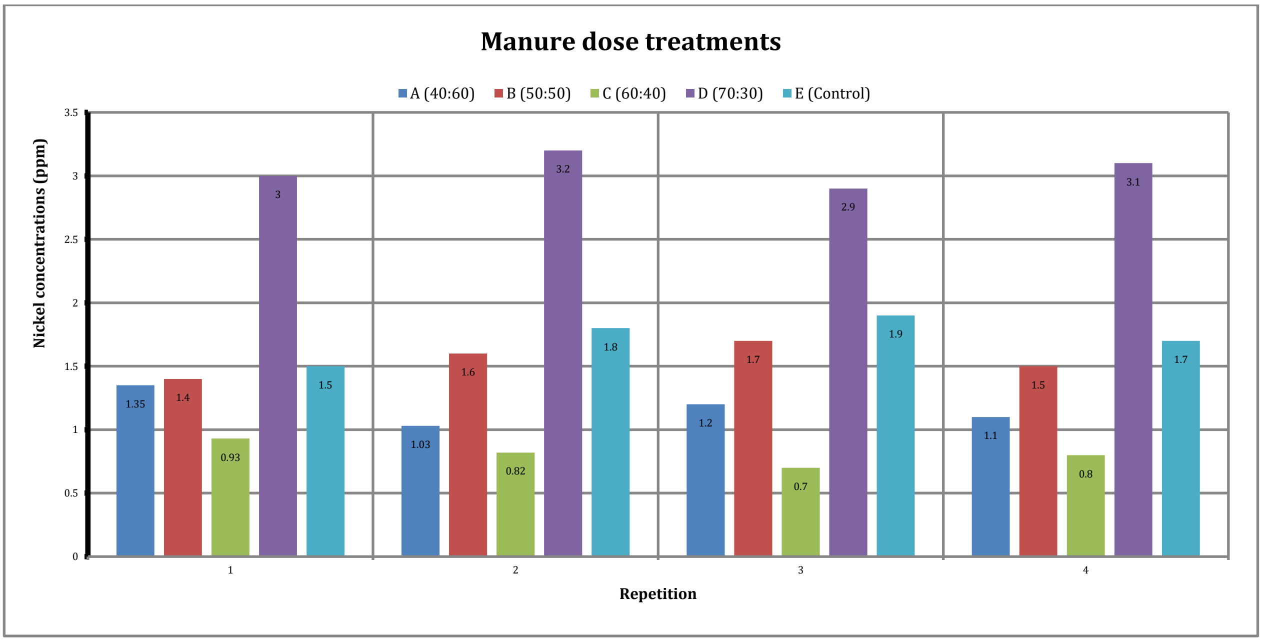

Figure 2. Histogram of nickel content in root *P. falcataria.*

The rate of nickel absorption in sengon roots (*P. falcataria*) depends on the addition of manure in the soil (Fleming et al., 2013; Kumpiene et al., 2013). It was because the addition of manure to the soil will increase the rate of nickel absorption by the roots of *P. falcataria* so that the nickel content in the soil changed. The roots of sengon plants (*P. falcataria*) that can absorb nickel heavy metals optimally were treatment D with a variation in fertilizer doses of 70% and soil concentration of 30% (Figure 2). The dose variation of fertilizer D (70:30) is a dose suitable for the absorption of the nickel in sengon plants (*P. falcataria*). This was in accordance with research conducted by Wei *et al*., (2020) that intensive fertilization in greenhouses has an effect on increasing the accumulation of nickel heavy metals in plants.

In general, all plants can accumulate "essential" metals (Ca, Co, Cu, Fe, K, Mg, Mn, Mo, Na, Ni, Se, V, and Zn) from the soil for their growth and development with variation of concentrations. This ability allows plants to collect "non-essential" metals such as Al, As, Au, Cd, Cr, Hg, Pb, Pd, Pt, Sb, Te, Tl, and U, which do not have an effective biological roles (Ahsan et al., 2022). Metals can not be broken down, and when its concentrations inside plant cells rise beyond thresholds or ideal levels, it can cause heavy metals direct toxicity through changes in cell structure and inhibiting a number of cytoplasmic enzymes (Khalilzadeh et al., 2022).

Khan (2019) found that increased concentrations of heavy metals in the soil can lead to increased plant absorption and have an impact on plant growth. One of the commonly measured plant growth parameters was plant height. Plant height was commonly used in measuring the success of post-mine soil phytoremediation (Halecki & Klatka, 2021; Pidlisnyuk et al., 2022). In this study, sengon plants (*P. falcataria*) with treatment B (50:50) showed significant height additions compared to others (Table 1). The height of the sengon plant (*P. falcataria*) based on the measurement results ranges from 15 to 28 cm. Duncan Test results showed treatments B (50:50) and E (control) were significantly different while treatments A (40:60), C (60:40), and D (70:30) were not significantly different from each other (Table 1).

The number of leaves of the sengon plant (*P. falcataria*) measured from the shoot to base. The measurement results showed that the leaves of the sengon plant (*P. falcataria*) amounted to at least 94 strands (the first test E treatment) and at most 122 strands (the second test C treatment). Duncan Test results showed that treatments B (50:50), C (60:40), and D (70:30) were not significantly different. In contrast, treatments A (40:60) and E (control) were significantly different from each other (Table 1).

Relating to root growth, significant increase in root length seen in sengon plants for treatment of dose variation E (control). The length of the sengon root (*P. falcataria*) is measured after removing it from the *polybag*. The longest root measurement results were found in treatment A (40:60) for the third test with 28 cm, while the shortest root was obtained in treatment B (50:50) of the fourth test and treatment D (70:30) of the first test with 21 cm. Duncan Test results showed treatments A (40:60), C (60:40), and E (30:70) were not significantly different from each other. The treatment that significantly different from each other was B (50:50) and D.

It is suspected that the E (control) was not applied manure, so *P. falcataria* extended its roots further into the soil to absorb nutrients (Kim et al., 2020). Vidakovic (2021) revealed that the roots are capable of developing in response to nutrient and groundwater distribution. The roots develop with the intensive growth of lateral roots in areas rich in nutrients. The same can be seen from the results of Munir's research (2020), root growth is higher in the soil without the addition of coal tailings. Thus, root growth is also an important growth parameter in nickel metal phytoremediation. The lowest measurement of sengon biomass (*P. falcataria*) was 0.2 gr/m2 found in the first and second tests of D (70:30). The highest biomass was seen in the second C (60:40) replay treatment weighing 0.8 gr/m2

(Table 1). Duncan Test results showed that treatment C (60:40) significantly different from treatments A (40:60), B (50:50), D (70:30), and E (control). Sheetal et al. 2016 revealed that the more heavy metals that plants accumulate will cause their biomass to decrease, while other biochemical parameters will increase under the same conditions. This is in accordance with this study where nickel accumulation in sengon roots was highest in treatment D (70:30) but plant biomass was low.

The growth parameters of *P. falcataria* (height, number of leaves, root length, biomass) are closely related to variations in manure doses, nickel concentrations in soils, and successful phytoremediation. Phytoremediation can be said to be successful if plant growth is not disturbed and the plant can accumulate heavy metals in its body (Mishra et al., 2017). The addition of manure with a higher ratio than mine soil causes a reduction in the content of nickel heavy metals in the mine soil so that plant growth is more optimal. Sengon (*P. falcataria*) is a metal accumulator plant that effectively absorbs nickel heavy metals when applied to the addition of manure with a dose of D fertilizer (70:30) compared to the dose of fertilizer E (control). Thus, manure plays a major role in reducing the heavy metal content of nickel in mining soils compared to absorption by the sengon root (*P. falcataria*) itself.

Table 1. Effect of variations in fertilizer doses on growth *P. falcataria*

Growth Parameters	Treatments	Average*	SD
	A	17,1^{c}	1,65
	B	27^{a}	0,82
Plant Height (cm)	C	16,3^{c}	0,36
	D	18,25^{c}	1,26
	E	21,13^{b}	1,65
	A	101,25^{b}	2,06
	B	105,5^{a}	2,08
Number of Leaves (strand)	C	111,5^{a}	9,98
	D	108,5^{a}	3,70
	E	96,5^{c}	2,52
	A	26^{a}	1,83
	B	21,88^{c}	0,63
Root Length (cm)	C	24,70^{a}	0,53
	D	22,68^{b}	1,76
	E	26,40^{a}	0,49
	A	0,40^{b}	0,08
	B	0,37^{b}	0,05
Biomass (gr/m^{2})	C	0,90^{a}	0,26
	D	0,23^{b}	0,05
	E	0,43^{b}	0,10

* The same letter between fertilizer dose treatments showed not significant difference in Duncan test with α=0,05.

CONCLUSION

Phytoremediation of post-mining land nickel using sengon plants (*Paraserianthes falcataria*) is believed to reduce the content of nickel heavy metals. Based on this study, it is known that with the addition of the right dose of chicken manure fertilizer, it can increase the absorption of nickel heavy metals from post-mining soil to sengon plants (*Paraserianthes falcataria*) so that the nickel content in post-mining soils decreases. The dose of fertilizer D (70:30) was best suited for use in phytoremediation of the heavy metal nickel on sengon plants (*Paraserianthes falcataria*). The suggestion for this study is that due to limited data, further research is needed that can be a comparison with the use of higher doses of manure and analysis of heavy metals in leaf organs.

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