Effects of Soil Ameliorants on Growth And Yield of Elephant Grass (*Pennisetum Pupureum*) in Post-Tin Mining Land

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ABSTRACT

Post-tin mining land is dominated by sand fractions and low in organic C content and essential macronutrients. A high yield of elephant grass can be produced on land containing sufficient and constantly available nutrients. This research aimed to determine the effects of mycorrhizae and NPK fertilizer ameliorants on the growth and yield of elephant grass plants in post-tin mining land. This research was arranged in a randomized complete block design with a combination of mycorrhizae and NPK fertilizer doses. Treatments consisted of control (without mycorrhizae and NPK), NPK 100%, mycorrhizae + NPK 25%, mycorrhizae + NPK 50%, and mycorrhizae + NPK 100%. The recommended dose of NPK 100% was 300 kg/ha. The research results demonstrated the significant effects of the combination of mycorrhizae and NPK fertilizer doses on the plant height, number of clumps, and crop production per plot. Applying NPK fertilizer 100% to elephant grass plants resulted in the highest ratoon yields in post-tin mining land.

Keywords: Mycorrhizae; NPK fertilizer; Organic matter; Soil quality.

INTRODUCTION

Post-tin mining land is often found in Bangka Island. According to Asmarhansyah & Hasan (2020); Asmarhansyah (2020), post-tin mining land is considered poor, indicated by the dominance of the sand fraction, low organic C content, low cation exchange capacity, low essential macronutrients, and low exchangeable bases (Agus et al., 2018). Despite having a very low cation exchange capacity, a very low nutrient content (available and total-N, P, K, Ca, Mg), and high toxicities of Zn, Cu, B, Cd, and Ti, Agus et al. (2019) found that the tropical post-tin-mined acid soil (pH 5.34), which was primarily composed of sand particles (88%), still had low toxicities of B, Zn, Cu, Ti, and Cd.Tailings have a low pH of 4 to 5, are deficient in nutrients and microorganisms, and include almost 95% quartz sand (Khodijah et al., 2019a). By raising the pH, accessible P and K, and cation exchange capacity, organic paramagnetic humus and compost additives can enhance soil quality while remaining minimally harmful (Agus et al., 2019). Within the tin mining area of Dwi Makmur Merawang Village, Bangka Regency, the soil content is 7.53% clay, 0.001% total N, 10.88 cmolkg-1 CEC, 51.78% sand texture, 40.69% dust, and 0.097% organic C (extremely low) (Lestari et al., 2019). These results show that post-tin mining land is included in the category of not ideal for agriculture. According to Harwanto et al. (2023), organic matter and pH are important for soil quality because they affect the soil's

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ability to bind and provide plant nutrients and water. Good soil quality maintains and improves plant growth and yield and prevents degradation.

Adding ameliorants and using palm oil waste for bioremediation can boost the productivity of post-tin mining soil (Lestari et al., 2019; Lestari et al., 2020). Providing organic material on post-tin mining land in the form of empty oil palm fruit bunches of 60 tons/ha can reduce the metal Pb content in eggplants cultivated in tailings (Inonu et al., 2020). Providing 25 tons/ha of cow dung compost in the tailings soil can also increase the production and yield of porang plants, which are safe for consumption (Inonu et al., 2023). The use of post-tin-mining land for livestock feed crop cultivation has been widely carried out, one of which is the cultivation of elephant grass.

Elephant grass (*Pennisetum purpureum*) is a type of grass that grows in clumps. Elephant grass is a forage/grass with high nutritional content and is used as cattle feed (Syaiful & Utami, 2020). Elephant grass can adapt very well to various soil types with low fertility levels. Elephant grass can still produce green food crops. Based on the research results of Khodijah et al. (2019b), a growth medium composed of 50% tailings, 40% ultisol, 5% organic material, and 5% NPK is the best for elephant grass growth. Production of elephant grass will increase when planted on land containing sufficient nutrients that are always available. NPK fertilizer, compost, and mycorrhiza can help improve post-tin mining soil. Mycorrhiza is the symbiotic association between fungi and plants that colonize the root cortex tissue. According to Aqma et al. (2020), mycorrhizal fungi have a symbiotic relationship with plant roots to obtain carbohydrates from plants in the form of simple sugar or glucose. Mycorrhizal fungi on plants can help absorb the nutrients that plants need.

NPK fertilizer is a compound fertilizer made by mixing N, P, and K. Providing NPK Mutiara fertilizer (16:16:16) at the correct dose can improve the physical, chemical, and biological properties of the soil, thereby improving the soil structure so that it becomes more fertile (Ramadhan et al., 2022). Providing organic chicken manure and 100% N, P, and K fertilizer can improve the growth and yield of sorghum on post-tin mining land (Lestari et al., 2021). The recommended NPK fertilizer application for livestock feed crops with low nutrient status is 300 kg/ha.

Post-tin mining land use, the dose of mycorrhiza and NPK fertilizer will influence elephant grass plants growth and yield. Providing mycorrhiza to elephant grass on post-tin mining land is one of the efforts to increase elephant grass production on post-tin mining land. The success of elephant grass cultivation is determined by the amount of NPK fertilizer utilized. The purpose of this study was to ascertain how the growth and production of elephant grass plants on post-tin mining ground were affected by combination doses of NPK fertilizer and mycorrhiza. Reforestation in places affected by tin mining can benefit from this research.

MATERIALS AND METHODS

Experimental Site, Time of the Research and Plant Materials

This study was conducted in tin-mining land, Kampoeng Reklamasi Air Jangkang, Riding Panjang, Merawang, Bangka. The study was conducted in September 2022 – March 2023. The materials used were water, elephant grass, lime, compost, mycorrhiza (10 g/plant), and NPK 16:16:16 fertilizer (300 kg/ha).

Experimental Design

The study was set up using a Randomized Block Design and included five treatments: NPK 100% (30 g/plant); control (no NPK or Mycorrhiza); Mycorrhiza 10g+ NPK 25% (7.5 g/plant); Mycorrhiza 10g + NPK 50% (15 g/plant); and Mycorrhiza 10g + NPK 100% (30 g/plant). The 100% NPK dose was 300 kg/ha (30 g/plant). Each treatment was made into 6 replications, resulting in 30 experimental plots.

Procedures

The land used was plotted to be 1.5 m x 1.5 m. The number of research plots was 30 plots. The distance between plots was 1 m. One week before planting, lime and compost were applied. The elephant grass planting materials were made from cuttings that were 1 month old after being sown in polybags. The cuttings were planted directly on the field. Fertilization was carried out three times, at 2, 6, and 9 weeks after planting, using hole fertilization in the root zone. Harvesting was done when the plants were 4 months old by cutting using a sickle.

Observations were made on the plant height, number of clumps, stem diameter, root length, and yield. Plant height was measured from the shoot stem's base to the longest leaf's tip. The number of clumps was obtained by counting the clumps/shoots. The diameter of the rod was measured using a caliper. Root length was measured after pulling out the plant. Yield was observed at the harvest.

Data Analysis

The data obtained were analyzed using Analysis of variance (ANOVA). Significant effects of the treatments were tested using Duncan's Multiple Range Test (DMRT) at the 5% level.

RESULTS AND DISCUSSION

First Harvest Results (H1)

The analysis results of the first harvest showed that applying a combination of mycorrhiza and NPK fertilizer had significant effects on plant height, the number of clumps, stem diameter, and yield of elephant grass cultivated in post-tin mining land (Table 1). Tin mining activities cause a decrease in land quality, including physical, chemical, and biological soil properties (Lestari et al., 2019). The soil analysis revealed that the post-tin mining land in Air Jangkang (the research location) had 66.11% sand, 29.08% silt, and 4.81% clay. Its pH was 6.10, its organic C content was 0.16%, its total N content was 0.09%, its K-dd was 0.01 Mol(+)/kg, its Na-dd was 0.05 Mol(+)/kg, its Ca-dd was 0.17 Mol(+)/kg, and its Mg-dd was 0.16 Mol(+)/kg (Oktaviani et al., 2020). Kurnia and Rohaendi's (2023) study revealed that the Bangka Belitung Islands' post-tin mining land had a moderate to low heavy

Table 1. The growth and yield variations (H1) of elephant grass on post-tin mining land

Observed Variables	Pr > F	Coefficient value (%)
Plant height (cm)	0.0001**	5.39
Number of leaves	0.0039*	18.10
Stem diameter (mm)	0.3927ns	10.17
Fisrt harvest result (kg/plot)	0.0001**	10.90

Remarks: * significant at α 5%, ** significant at α 1%, ns not significant

metal level, which allowed it to be utilized as agricultural land and other productive land. Providing nitrogen fertilizer at various doses significantly increased plant height, leaf length, leaf width and number of leaves, and yield of Pak Chong grass (Rinduwati et al., 2023). According to Khodijah et al. (2019a), this is thought to be due to the greater efficiency of Pb uptake in S.spontaneum compared to the increase in absorption efficiency in *P. purpureum* and *H. acutigluma.*

The results of further test analysis of the first harvest of elephant grass are shown in (Table 2). The 100% NPK fertilizer treatment showed significant effects on all variables. The control treatment gave the lowest results compared to all treatments. The combination treatment of mycorrhiza and NPK fertilizer gave lower results than applying 100% NPK fertilizer without mycorrhiza on the growth and yield of elephant grass plants. This is thought to be due to the direct effect of NPK fertilizer on plants, thereby reducing the role of mycorrhiza. Applying compound fertilizers influences elephant grass's vegetative growth and production. The research results of Rinduwati et al. (2023) showed that applying nitrogen fertilizer at a dose of 225 kg N/ha = 2.5 g N/polybag) provided optimal results on elephant grass. Revegetation of post-tin mining land can use animal feed plants such as elephant grass (Lestari et al., 2022). Elephant grass are forages that have the potential to be used as a source of feed ingredients for livestock (Hakim et al., 2023).

Table 2. Analysis of growth and yield (H1) of elephant grass in post-tin mining land

Treatment	Plant height (cm)	Number of clumps	Stem diameter (mm)	First harvest result (kg/plot)
Control	64.65 d	3.50 c	1.52	14.08 d
NPK 100%	134.87 a	5.62 a	1.55	36.86 a
Mycorrhizal + NPK 25%	109.74 c	4.17 bc	1.53	19.01 c
Mycorrhizal + NPK 50%	114.01 bc	4.45 bc	1.41	21.99 c
Mycorrhizal + NPK 100%	118.30 b	4.58 b	1.51	26.94 b

Remarks: Means followed by same letters in the same row are not significantly different based on DMRT with a 5% significance level.

Ratoon Harvest Result (H2)

The application of mycorrhiza and different amounts of NPK fertilizer significantly impacted the variables of plant height, the number of clumps, stem diameter, root length, root weight, and elephant grass production in post-tin mining ground, according to the analysis of variance results (Table 3).

Table 3. The growth and yield variations (H2) of elephant grass on post-tin mining land

Observed Variables	Pr > F	Coefficient value (%)
Plant height (cm)	0.0001**	7.89
Number of clumps	0.0250*	10.78
Stem diameter (mm)	0.0042*	1.28
Second harvest result/ratoon (kg/plot)	0.0001**	23.57
Root length (cm)	0.3594ns	22.18

Remarks: * significant at α 5%, ** significant at α 1%, ns not significant

The results of the further tests for the second harvest/ratoon of elephant grass are shown in Table 4. The 100% NPK fertilizer treatment showed significant effects on all variables. Mycorrhiza treatment + NPK 50% significantly impacted the number of clumps. The control treatment significantly affected the stem diameter variable, and the control treatment showed the lowest results on the variables of plant height, number of clumps, plant yield, root length, and root weight in post-tin mining land.

Table 4. Analysis of growth and yield (H1) of elephant grass in post-tin mining land

Treatment	Plant height (cm)	Number of clumps	Stem diameter (mm)	Second harvest result (kg/plot)	Root length (cm)
Control	61.55 c	5.75 c	1.53 a	3.20 d	34.50
NPK 100%	87.50 a	18.37 a	1.56 a	15.29 a	66.50
Mycorrhizal +NPK 25%	66.38 c	11.94 b	1.32 c	7.20 c	43.08
Mycorrhizal +NPK 50%	76.08 b	17.45 a	1.41 b	9.65 bc	60.88
Mycorrhizal +NPK100%	78.94 b	15.91 ab	1.46 b	11.59 b	60.58

Remarks: Means followed by same letters in the same row are not significantly different based on DMRT with a 5% significance level.

The appropriate N, P, and K fertilizer dose will affect plant growth and yield. Providing 15 tons/ha of chicken manure and 100% NPK fertilizer (Urea 300 kg/ha, SP-36 200 kg/ha, and KCl 150 kg/ha) showed the best growth and production of sorghum on post-tin mining land compared to applying NPK 50 fertilizer % (Urea 150 kg/ha, SP-36 100 kg/ha and KCl 75 kg/ha (Lestari et al., 2021).

The 100% NPK fertilizer treatment without using mycorrhiza applications gave higher results for all variables than other treatments. This is because NPK fertilizer has provided sufficient nutrients for elephant grass plants on post-tin mining land. Hasibuan et al. (2018), claim that consuming nitrogen (N), potassium (K), and phosphate (P) nutrients will improve the growth and formation of plant vegetative organs, such as stems, leaves, and roots. Elephant grass plant growth and development on post-tin mining ground were not significantly. Basri (2018) added that plant type and variety, soil type, fertilizer type, AMF type, and environmental factors, such as light and temperature, also influenced the effects of mycorrhiza fungal inoculation on growth, P uptake, and plant yield. Rakotoarimanga et al. (2023) stated that cultivation of *Intsia bijuga* with endomycorrhizal host plants made effective endomycorrhizal symbiosis in *Intsia bijuga*.

The mycorrhiza and various doses of NPK fertilizer significantly affected the plant yields. The highest plant yield was found in the plants treated with 100% NPK fertilizer. The percentage of reduction in plant yield after treatment was 77.27% for the control treatment, 58.52% for 100% NPK treatment, 62.12% for mycorrhiza treatment + NPK 25%; 56.12% for mycorrhiza + 50% NPK treatment, and 56.96% for mycorrhiza + 100% NPK treatment.

The results of the first and second harvest/ratoon showed decreasing yields. The percentage of yield reduction from the first to the second harvest was 77.27% for control, 58.52% for 100% NPK treatment, 62.12% for 25% mycorrhiza + NPK treatment, 56.12% for mycorrhiza treatment + 50% NPK, and 56.96% for mycorrhiza + 100% NPK treatment. This decrease in yield is thought to be due to the decreasing organic nutrient content in the soil because the main plant has used it. Hence, the micronutrient content in the soil is insufficient for the needs of elephant grass plants in the second/ratoon harvest. The short vegetative phase before the reproductive phase causes imperfect growth and development of ratoons, which can be seen from the reduction in the number and area of leaves during photosynthesis. The research results of Buyana et al. (2019) showed that the need for nitrogen fertilizer for rice plants was 45-135 kg/ha.

Growth of Elephant Grass Roots in Post-Tin Mining Land

The average root length and root fresh weight of elephant grass plants were obtained after the second ratoon harvest when the plants were 5 months old. The 100% NPK treatment resulted in higher root length and weight values than other treatments. The 100% NPK treatment without using

mycorrhiza showed higher results than without mycorrhiza. The control treatment showed the lowest results compared to the different treatments.

Root growth and development were greater in the 100% NPK fertilizer and the mycorrhiza + 100% NPK treatments compared to the other treatments. The mycorrhiza + 25% NPK and the mycorrhiza + 50% NPK treatments showed fewer roots than the 100% NPK and the mycorrhiza + 100% NPK treatments. The control treatment showed the fewest roots compared to the other treatments. Root growth and development were greater in 100% NPK fertilizer and 100% mycorrhiza + NPK treatments compared to other treatments. The mycorrhiza + 25% NPK and the mycorrhiza + 50% NPK treatments showed fewer roots, while the control treatment showed the fewest roots compared to the other treatments. Good root penetration ability in the 100% NPK fertilizer treatment is characterized by a greater root weight and a more significant number of roots, making it easier for the roots to obtain nutrients and air so that the plants do not lack nutrients. A large number of roots indicates better root development. Mycorrhiza application is thought to have no significant effect on all variables because the level of compatibility of mycorrhiza with plants is low, and the mycorrhizae do not originate from the area of origin of the research. Basri (2018) states that the mycorrhiza used in this study are from different regions. Their adaptation and compatibility with host plants are low when planted on post-tin mining land. Plant type and variety, soil type, fertilizer type, AMF (arbuscular mycorrhizal fungi) type, and other environmental factors, such as light and temperature, play a role in the effects of mycorrhizal fungus inoculation on the growth, P uptake, and plant yield. In tropical post-mining sites, the application of AMF and reforestation with exotic, rapidly growing pioneer legume species of *P. pinnata* significantly enhanced certain chemical soil qualities appropriate for rehabilitation initiatives. According to Lestari et al. (2024), mycorrhiza enhances the growth and yield of pakchong plants on post-tin mining sites in comparison to its absence.

Microscopic observation results showed mycorrhizal infection on plant roots (image not shown). Mycorrhizal infection can be seen on the roots, characterized by hyphae. Applying mycorrhiza can improve the physical and chemical properties of the soil. Still, this study had no significant effect on the growth and yield of elephant grass plants in post-tin mining land. Applying mycorrhiza to elephant grass has not effectively infected plant roots in post-tin mining fields. It is suspected that the presence of mycorrhiza in elephant grass plant roots is not efficient. It is thought that the mycorrhiza used is incompatible with infecting elephant grass plants' roots. Hadianur et al. (2018) added that the compatibility of mycorrhiza with host plants varied greatly depending on the mycorrhizal species and host plant species. Adding organic material to the planting medium before planting and applying NPK fertilizer can increase the pH value of the soil, thereby inhibiting mycorrhizal activity. According to Santana et al. (2022), AMF fungi are often found in dormant conditions at suitable soil pH due to their acidophilic nature. Applying mycorrhiza + a dose of NPK fertilizer did not have a significant effect, presumably because mycorrhiza could not interact with the roots in absorbing nutrients in elephant grass plants in post-tin mining land. According to Thepu et al. (2021), plant nutrient uptake is influenced by a specific dose; an excessive dose will not increase nutrient uptake because plants limit nutrient absorption. Budiastuti et al. (2024) stated that applying NPK on the surface reduced the highest rice biomass.

The land used for previous research had been planted with green beans with the addition of rhizobium treatment in the study of Oktaviani et al. (2020). Treatment of 100% NPK fertilizer showed higher results than Mycorrhiza + 50% NPK; it is suspected that the land used is predominantly sandy, and the organic material in the land is sufficient so that the mycorrhizae do not work. The combination of 10 g mycorrhizae/plant and 50% NPK fertilizer showed the lowest percentage of reduction in yield after ratooning, which was 56.12%, compared to the 100% NPK fertilizer treatment, showing a decrease of 58.52%. It is suspected that giving mycorrhiza 10 g/plant is not practical in promoting the growth of elephant grass in post-tin mining land. Nurmas et al. (2024) showed that the Liquid Organic Fertilizer (LOF) treatment of LOF 30 mL L^{-1} water and AMF 15 g/plant was the best treatment for local corn production on marginal land. The research results of Agus et al. (2018) showed that administering a mycorrhiza at a dose of 4 g/plant had an ineffective effect on *Pongamia pinnata* plant seedlings compared to a dose of 2 g/plant in ex-coal mining soil media. The results of the analysis of animal feed (silage) resulting from elephant grass cultivation on post-tin mining land are <0.75, indicating that it is safe for livestock consumption (Lestari et al., 2022).

CONCLUSION

The 100% NPK fertilizer treatment (300kg/ha) provided the best growth and highest yield of elephant grass (*Pennisetum purpureum*) in post-tin mining land compared to the mycorrhiza + NPK combination treatment. The results of the first and second harvest/ratoon of elephant grass in post-tin mining land showed decreased yields ranging from 56.12%.

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AUTHORS CONTRIBUTIONS

TL designed and conceived the experiments. TL and NSP experimented. NSK and NSP contributed to the preparation of samples and interpretation of the results. The manuscript was primarily composed by TL and DP. All authors provided critical feedback and contributed to the development of the research, analysis, and manuscript.

COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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