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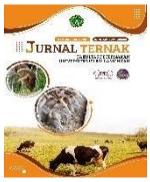

The Growth And Productivity Performance Of Maize (Zea Mayz) Under Water Hyacinth (*Eichhornia Crassipes*) Bokashi Treatment On Ex-Coal Mining Soils

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ABSTRACT

This study investigates the impact of water hyacinth (WH) bokashi applied on stockpiled topsoil from coal mining and utisols areas on maize growth and productivity. Water hyacinth, a locally abundant weed, was processed into bokashi and applied to a mixture of post-mining soil and ultisol at varying concentrations (0%, 12%, 25%, and 50% w/w). Maize plants were cultivated in these media, and growth parameters such as plant height, stem diameter, forage biomass, total biomass, and maize yield were measured weekly. The study employed a Randomized Complete Block Design (RCBD) with four treatments, each replicated four times. Results were analysed using ANOVA and Duncan's Multiple Range Test. The findings demonstrated that WH bokashi could improve the C-organic, nitrogen, P_2O_5, K_2O, and pH levels of the cultivation medium and enhanced maize growth and biomass production. The most effective treatment was 25-50% WH bokashi, which yielded the highest maize productivity. This research highlights the potential of water hyacinth bokashi as an organic amendment for improving degraded soils and supporting sustainable agriculture on reclaimed mining lands.

Amelia Lulu Rosalin Hutabara, et. al./Jurnal Ternak 16 (1) 2025 pp. 59-65
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Introduction

The coal mining sector plays an important role in the economic performance of Indonesia, particularly in the province of South Kalimantan. However, open-pit mining activities also have negative impacts on ecology and the environment (1,2), which is why the government requires mining companies to undertake reclamation and revegetation (Government Regulation No. 78 of 2010, which regulates reclamation and post-mining activities). As a province with the largest population of beef cattle in Kalimantan (3), revegetation by planting forage crops will significantly enhance the value of the land (4). According to Sukarman & Gani (5), expanding agricultural areas by utilizing former mining land is one approach to addressing environmental and food availability issues. A factor that often hinders the success of revegetation programs is the decline in the quality and quantity of topsoil that will be returned to the former excavation site (6). Topsoil stored for long periods experiences anaerobic conditions that cause the topsoil structure to become compacted, low in oxygen, poorly drained, and depleted of nitrogen due to denitrification (7,8). Therefore, restoring topsoil quality is an important step to support successful revegetation. Various studies have demonstrated the effectiveness of organic amendments (OA) such as bokashi in improving soil quality and accelerating revegetation (9–11). Research by Karbeka et al. (12) showed that the application of agricultural waste bokashi in polybags can neutralize soil pH and increase soil nitrogen, phosphorus, and potassium (NPK) content, with the best dose being 250 g of biochar/250 g of bokashi per polybag. Similar results were also demonstrated by Yuliana et al. (13), who stated that chicken manure bokashi could reduce soil acidity by up to 77%. The local biomass of South Kalimantan province with potential use as OA is water hyacinth (WH). Water hyacinth is a weed plant from swamp areas that is abundant in South Kalimantan. To date, no research has identified the potential of WH bokashi as a raw material for topsoil recovery for forage production. This study aims to investigate the effect of WH bokashi applied on the stockpiled topsoil from coal mining and ultisol areas and its impact on forage maize growth.

Method

This research was conducted for five months from July to November 2024. Ex-mining soil were taken from a reclaimed land of the PT Arutmin site Asam-asam in Jorong District, Tanah Laut Regency, South Kalimantan Province. Ultisol were taken from a field in Bajuin District, Tanah Laut Regency, South Kalimantan Province. Soil chemical test was conducted at the Testing Laboratory of Industrial Standardization and Service Provision (Balai Standarisasi dan Pelayanan Jasa Industri), Banjarbaru, South Kalimantan. The production of bokashi, soil incubation, and plant growth experiments were carried out at the Study Program of Feed Technology, Department of Agricultural Industri Technology, Politeknik Negeri Tanah Laut. The materials used in this study included: two weeks old maize seedlings of maize, topsoil taken from the reclaimed area, organic materials in the form of bokashi. The tools used in this study were shovel, pitchforks, hoes, polybags of size 40 cm × 40 cm (diameter × height), hands sprayer, digital cameras, measuring tape, analytical scales 4 digits, ovens, markers.

Preparation of Bokashi

Water hyacinths collected from swamp waters in Angsau Village, Tanah Laut Regency, South Kalimantan. Water hyacinths were washed with tap water to remove dirt and other foreign objects. After separating the roots, the water hyacinth was chopped into pieces of 3-5 cm in size, then wilted under sunlight for 2 days to reduce the moisture content. About 40 kg sun-dried water hyacinth pieces were mixed with 20 kg cow manure, 10 kg rice husks, 20 kg rice brand, and 25 litter of water mixed with 350 ml of EM4 and 300 g of sugar. This mixture was then sprayed with an Em4 solution (250 ml Em4/1 litter of water). The bokashi mixture was placed into a tightly sealed 20-liter plastic container and stored for 30 days. After 30 days, the bokashi in the container was unpacked and observed for

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Amelia Lulu Rosalin Hutabara, et. al./Jurnal Ternak 16 (1) 2025 pp. 59-65
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colour, texture, odour, and chemical analysis. The water hyacinth bokashi is ready to be used after 30 days of fermentation, as it is close to normal temperature, has a dark colour similar to soil, and smells fragrant.
Table 1.

Preparation of Soil Materials and Sampling.
Approximately 10 bags (totalling around 500 kg) of soil from a post-coal mining reclamation site were manually gathered using a hoe, collected from a depth of 0-10 centimetres. The same method was also used to obtain ultisols. In order to collect soil samples, the soil areas were divided into five zones. Each zone was sampled in parallel with the others. The soil sampling followed the "envelope" method, where samples were taken from the maizeers and centre of the study area after the vegetation cover had been removed. Soil samples were taken from a depth of 0-10 centimetres, with each sample weighing between 0.5 and 1.0 kilograms. The samples were air-dried, crushed, and sieved to pass through a 2 mm mesh. Preliminary laboratory analyses were conducted to observe the selected chemical properties of the soil such as pH, Total Nitrogen (N), Organic-C, Potassium level as K_2O, and phosphorus level as P_2O_5.

Preparation of Maize Seedling
A standard 72-cell seedling tray made of durable plastic was selected to ensure uniformity in seedling growth. The tray was then rinsed with distilled water and allowed to air dry. The garden soil used for seedling growth was collected from the topsoil layer of an established garden bed. The soil was air-dried, and any clumps were broken down to ensure uniformity. Maize seeds of the BISI 18 variety, branded as Cap Kapal Terbang, were used to ensure high germination rates and genetic consistency. The seeds underwent pre-sowing treatments to protect against pests and diseases using Acrobat fungicide and Marshall insecticide according to the manufacturer's instructions. The garden soil was evenly distributed into each cell of the seedling tray, lightly compacted to remove air pockets and create a uniform surface. Maize seeds were sown at a depth of 1 cm in each cell. The seedling tray was placed in a shaded environment, avoiding direct sunlight exposure. Watering was performed once a day using a fine mist spray to maintain soil moisture without causing displacement of the seeds. Germination was monitored daily, and any non-viable seeds were recorded and removed.

Preparation of Cultivation Medium
Preparations for maize cultivation medium begin with a 1:1 mixture of post-coal mining soil and ultisols as the base medium. The base medium is then mixed with water hyacinth bokashi at levels of 0% (BOK-0), 12.5% (BOK-1) ,25% (BOK-2), and 50% (BOK-3) (w/w). The formulations are incubated for two weeks and are occasionally mixed to ensure proper aeration during the incubation period.

Cultivation of Maize
After 14 days of incubation, growing media was arranged in 40x40 cm black polyethylene polybags. One-week-old maize seedlings were transplanted into polybags. NPK fertilizer was applied to each polybag at a rate of 300 kg ha^{-1} at 3, and 10 weeks after planting (WAP). The maize was grown for 16 weeks until it developed 1-2 young ears. Maintenance activities include replanting, weeding, watering, and controlling weeds, pests, and plant diseases with appropriate pesticides and fungicides.

Parameters and Measurements
The growth parameters of maize plants observed include plant height, stem diameter, and forage biomass production. Plant growth measurements began at 14 days after the plants were transferred to polybags. Plant height (cm) is measured from the base of the stem to the highest leaf. Stem diameter (cm) is measured using callipers. The diameter is measured from two sides of the stem (right and left directions) at the plant's base. Total biomass (kg/polybag) includes both maize yield and stover production, calculated after harvesting. Maize yield with husks (kg/polybag) is determined by

Amelia Lulu Rosalin Hutabara, et. al./Jurnal Ternak 16 (1) 2025 pp. 59-65

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weighing the maize after separating it from the stover. Forage biomass production (kg/polybag) is measured by weighing the maize stover after harvesting the yield.

Experimental Treatments and Design

This research was structured by treating ex-mining soil and water hyacinth-based bokashi. This study employed a Randomized Complete Blocked Design with one control and three suggested doses for WH-based bokashi treatments, namely: B0: basic media (ex-mining soil + ultisols) + 0% bokashi; B12: basic media + 12% bokashi (w/w); B25: basic media + 25% Bokashi (w/w); and B50: basic media + 50% bokashi (w/w). Each treatment is repeated 4 times on 3 polybags for a total of 48 polybags. The data were analysed using SPSS software version 23.0 (IBM, USA) following the study design and analysis of variance (ANOVA), with subsequent analysis using Duncan's Multiple Range Test at a significance level of α = 5%.

Results and Discussion

The initial soil's chemical properties

Table 1 shows that the ex-mining soil and ultisols has low fertility indicated by low C-organic, low nitrogen, very low to low P_2O_5, very low to low K_2O, low total pH. The results indicate that, without any amendments, the soil would not support maize growth. Most of the data in table 1 are similar to that from previous studies of similar soil conditions (14,15)

Table 1. Chemical properties of ex-mining soil, ultisols, WH bokashi, and cultivation media

Parameters	Ex-coal Mining Soil	Ultisols	WH-Bokashi	Standard*
C-organic (%)	1.14	1.54	36.54	Very Low: < 1 Low: 1-2 Ideal: 2-5 High: > 5
Nitrogen (%)	0.08	0.13	3.03	Very low: <0.05 Low: 0,05 – 0,1 Ideal: 0.1 – 0.2 High: >0.2
P_2O_5 (mg/100 g)	4.941	8.573	11.36	Very low: < 5 Low: 5-10 High: > 20 Ideal: 10-20
K_2O (mg/Kg)	42,233	88.157	90.52	Very Low: < 50 Low: 50-100 Ideal: 150-250 High: >250
pH	3,97	4.85	4.54	Very Low: < 4.5 Low: 4.5 – 5.5 Ideal: 5.5 – 7 High: >7

***(16)**

The effect of WH bokashi on the ex-coal mining soil's chemical properties

Table 2. Chemical characteristics of cultivation medium after application of WH-Bokashi

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Parameters	BOK-0	BOK-1	BOK-2	BOK-3
C-organic (%)	3,36	4,8	5,93	7,46
Nitrogen (%)	0,93	0,78	0,91	0,95
P_2O_5 (mg/100 g)	21,01	43,01	62,11	96,31
K_2O (mg/Kg)	281,02	585,69	905,89	1555,93
pH	5,59	5,96	6,21	6,38

The soil C-organic, nitrogen, P_2O_5, K_2O, and pH levels tended to improve with all treatment types. In terms of pH increases, 25-50% WH-bokashi treatment (BOK-2 and BOK 3) achieved the highest increase after 14 days of incubation from acidic soil pH (3.97–4.85) to more desirable soil pH (6-7) (16).

The effect of WH bokashi on the maize growth

Table 3. WH-Bokashi effect on plant height (cm), stem diameter (mm) and biomass fresh weight (g) of maize in age 16 weeks after planting (WAP)

Treatment	Plant Height	Stem Diameter	Biomass Weight
BOK-0	97,56[a]	11,29[a]	333,75[a]
BOK-1	100,01[a]	11,46[a]	423,75[ab]
BOK-2	111,45[b]	12,6[ab]	562,5[b]
BOK-3	121,28[b]	13,41[b]	591,25[b]

Table 3 shows that the application of 25-50% bokashi (BOK-3) to a planting medium composed of reclaimed mine soil and ultisols resulted in significantly higher plant height, stem diameter, and biomass weight compared to the planting medium without bokashi (Table 3). Kawaty et al. (2023) stated that the application of 15 tons/ha of bokashi to sorghum plants produced the best growth and production response. The application of 20 tons/ha of bokashi made from water weed (*Pistia stratiotes*) yielded the best growth results for pakcoy (*Brassica rapa L.*). The addition of organic could contribute to this by increasing soil enzyme activity and encouraging soil nutrient recycling in the ecosystem. In addition, organic manure improved the absorption of cations and anions in soil particles, and these compounds may be released gradually during crop growth and soil structure improvement. By reducing crusting and serving as an energy source for soil microflora, better root nodulation and nitrogen fixation resulted.

The effect of WH bokashi on the maize nutrient content

Table 4. WH-Bokashi effect on nutrient content of maize in age 16 weeks after planting (WAP)

Treatment	Dry Matter (%)	Organic Matter (%)	Crude Protein (%)	Ether Extract (%)	Crude Fiber (%)
BOK-0	88.81[a]	79.82[a]	22.52	2.66	32.99
BOK-1	89.29[a]	80.40[a]	25.12	2.61	36.31
BOK-2	92.05[ab]	82.26[a]	24.75	2.74	34.49
BOK-3	92.86[b]	85.11[b]	24.12	1.97	37.07

The WH-Bokashi treatment significantly affected the dry matter and organic matter content of maize plants, although it had no significant effect on crude protein, ether extract, and crude fibre content. Cultivation medium containing 50% bokashi showed higher organic matter and dry matter content than medium without bokashi. According to Cristel (17), biofertilizers such as

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bokashi contribute to the biofortification of vegetables through increased nutrient absorption and nutrient use efficient, as well as improved photosynthetic capacity.

Conclusions

Bokashi application of 25-50% (w/w) in a soil medium containing reclaimed mining soil and ultisol resulted in better growth and biomass production. This suggests that bokashi can be used to enhance maize biomass production on reclamation lands.

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