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Growth of Cocoa Seedlings (*Theobroma cacao* L.) on Post-Coal Mining Soils Plus Zeolite

[1] Ida Nursanti, [2] Hayata, [3] Jacky Chandra Saragih
[1, 2, 3] Faculty of Agriculture, Batanghari University, Jl.Slamet Riyadi, Jambi-36121, Indonesia

Corresponding Author: **Ida Nursanti**

Abstract
It is possible that the development of cocoa plants can be carried out on post-coal mining land. The main problem with post-coal mining land is that it is barren, dense and unvegetated, making it susceptible to erosion. One material that can be used to improve land is by adding zeolite. The research aims to determine the growth of cocoa seedlings (*Theobroma cacao* L.) when zeolite is applied to post-coal mining soil in polybags. The research was carried out in an experimental garden located in Pijoan Village, Batang Hari Regency, Jambi and soil analysis was carried out in the Laboratory. The design used in this research used a one-factor Completely Randomized Design (RAL), giving zeolite to post-coal mining soil 4 kg polybag^{-1} with treatment levels K0 = 0g zeolite, K1 = 50 g zeolite, K2 = 100 g zeolite, K3 = 150 g zeolite. Observation; plant height (cm), stem diameter (mm), plant dry weight (g), root dry weight (g). Soil analysis; Available-P, total-N, organic-C, H_2O pH, and soil structure. Data were analyzed statistically using analysis of variance. If the analysis of variance showed a real effect, it was continued with the DNMRT test at the α level of 5%. Research results: (1) Zeolite has no real influence on the height of cocoa plants. (2) Zeolite has a real influence on stem diameter, dry weight of cocoa plants and dry weight of roots. (3) Stem diameter growth in K3 increased by 18.06% compared to K0, plant dry weight t in K3 increased by 25.81% compared to K0, root dry weight in K3 increased by 42.46% when compared to K0.

Keywords: Post-Coal Mining Soil, Zeolite, Cocoa Seeds

Introduction

The cocoa plant (Theobroma cacao L.) is one of the plantation crops which is currently increasing, both in terms of development and market demand. The cocoa commodity is a mainstay source of income for plantation farmers. Not only that, cocoa is also a contributor to the country's foreign exchange earnings, occupying the third position out of five commodities after palm oil and rubber (Fahmid *et al*., 2017) [6].

The development of cocoa plants in Jambi province from 2017-2021 has experienced an increase in the area, production and productivity of cocoa plants which can be seen in Table 1.

Table 1: Area and productivity of cocoa plants in Jambi province in 2017-2021

Year	Area (Ha)	Production (Ton)	Productivity (kg/Ha)
2017	2439	595	585
2018	2617	822	575
2019	2681	826	569
2020	2702	845	540
2021	2929	887	504

Source: Directorate general of plantations (2021)

Table 1 data shows an increase in the area of cocoa planting in Jambi province from 2017-2021. Production in 2017-2021 increased by 292 tons. Meanwhile, the productivity of cocoa plants from 2017-2021 has decreased, in 2017 productivity was 585 kg ha^{-1} and decreased to 504 kg ha^{-1} in 2021.

The high selling price of cocoa has become a driving force for people to continue developing cocoa plantations throughout Indonesia. Fahmid *et al*. (2017) [6] also added that increasing high sales value in the cocoa processing industry is considered very necessary to continue to encourage the development of cocoa plantations, so that they can meet the need for high quality cocoa beans.

The demand for cocoa seeds has increased in line with the development of cocoa plantation development, which has tended to increase recently, and the increase in cocoa planting by plantations is partly due to the relatively high price of cocoa beans. The quality of Indonesian cocoa does not meet standards. This is also shown by the increase in imports of cocoa beans to meet cocoa processing needs in Indonesia. The increasing price of cocoa beans has caused farmers' interest in cultivating cocoa plants to increase rapidly (Dewanta, 2019) [4].

The development of cocoa plantations is determined by the availability of sufficient seeds. Therefore, further development of cocoa seedlings is needed, especially on infertile soil, one of which is post-coal mining soil. According to Subowo (2011) [4], open coal mining results in a decline in soil quality physically, chemically and biologically. Soil degradation is characterized, among other things, by changes in soil layers, namely topsoil mixed with overburden and soil compaction during backfilling.

The main problem with post-coal mining land is that it is barren, dense and unvegetated, making it susceptible to erosion. Erosion will worsen the soil quality of coal mining areas. Covering the surface of post-coal mining land by planting cover crops is an effort to restore and improve environmental quality (Pratiwi *et al*., 2021) [12]. The function of planting cover crops is to reduce the impact force of falling raindrops and reduce the discharge and speed of surface flow which ultimately reduces soil erosion (Jakab *et al*., 2017) [7].

Soil fertility on post-coal mining land is classified as very low. The contents of macro nutrients, namely N, P and K, are all very low in the top and bottom layers (Rizwan *et al*., 2019) [13]. One material that can be used to improve land is the provision of zeolite. Zeolite is a natural mineral with a negative charge, can be neutralized by alkali or alkaline earth metals, has pores filled with K, Na, Ca, Mg ions and H_2O molecules, thus allowing ion exchange and water release back and forth. Come back. The use of zeolite as an adsorbent is able to absorb heavy metals such as Mg, Al and ZnO (Putri and Sabani, 2018) [11].

Nursanti's research results (2019) [9]. Explained that applying 200 grams of zeolite to 10 kg of post-mining soil (equivalent to 20 tons of zeolite ha^{-1}) can increase soil pH, total N, K-dd, available P and soil CEC. Furthermore, from the results of this research it was found that the administration of zeolite 200 g/polybag could increase the results of C-org(%) from 0.16 to 0.73, N-total (%) from 0.11 to 0.28, K-dd (cmol(+)kg-1) from 0.10 to 0.40, P Bray 1 (mg kg -1) from 9.20 to 16.65 from 4m to 6.0, CEC from`15.21 to 23. 04.

Increasing pH by zeolite is possible because the basic cations found in zeolite such as Ca, K and Mg can be exchanged with H+ and Al^{3+} ions. Zeolite can buffer soil pH, acidic soil can be neutralized because zeolite is not acidic (pH 7.2) and can adsorb Al and Fe which cause soil acidity and release basic cations such as Ca, Mg and K. Jabri (2008) [8] explains that zeolite is a mineral that can neutralize soil pH.

Successful growth is determined by internal factors (genetics and hormones) and external factors (climate and quality of growing location). So, it is necessary to experiment with the use of post-coal mining soil media that has been given soil amendments which are expected to have an effect both in nurseries and in the field.

Materials and Methods

This research was carried out in the Pijoan experimental garden, Batang Hari Regency, Jambi and soil analysis at the Basic and Integrated Laboratory at Jambi University.

The materials used are post-coal mining soil as a planting medium from Tempino, 3 month old cocoa seeds, and natural zeolite, manure. The tools used were polybags measuring 40 cm × 25 cm, hoe, analytical scales, measuring tape, paranet, pen, book and oven.

The design used in this research used a one-factor Completely Randomized Design (RAL), applying zeolite to post-coal mining soil 4 kg $polybag^{-1}$ with the following treatment levels. K0 = 0 g zeolite, K1 = 50 g zeolite, K2 = 100 g zeolite, K3 = 150 g zeolite. Each experimental unit consists of 4 plants so there are 12 x 4 = 48 plants, each experimental unit has 3 sample plants.

Observation; plant height (cm), stem diameter (mm), plant dry weight (g), root dry weight (g). Soil analysis; carried out at the beginning and end of the research consisting of: pH H_2O (1:1), total-N (Kjeldahl Method), available-P (Bray Method), organic-C (Walkleanisy Black Method), and soil structure. Data were analyzed statistically using analysis of variance. If the analysis of variance showed a real effect, it was continued with the DNMRT test at the α level of 5%.

Results and Discussion

The results of data analysis from observations of the growth of cocoa seedlings in post-coal mining soil treated with zeolite are shown in Table 2 below:

Table 2: Average Observation Values for Cocoa Seedlings in post-coal mining soil

Zeolite Treatment (g)	Plant Height (cm)	Stem Diameter (mm)	Plant Dry Weight (g)	Root Dry Weight (g)
K0 (0)	59.11 a	7.73 a	60.39 a	9.96 a
K1 (50)	62.44 ab	7.84 a	65.44 b	10.74 a
K2 (100)	62.56 ab	8.96 b	73.15 c	14.13 b
K3 (150)	65.56 b	9.98 c	75.76 d	14.19 b

Keterangan: Numbers followed by the same lower case letters are not significantly different in the DNMRT follow-up test at the α 5% level

Based on the results of analysis of variance on cocoa plant height, it shows that the application of zeolite has no significant effect on cocoa plant height. Meanwhile, the stem diameter, dry weight of the plant and dry weight of the roots showed that the application of zeolite had a real effect. The DNMRT further test at 5% level for each treatment can be seen in Table 2.

Table 3: Results of analysis of soil properties at the beginning and end of the research. Regarding total-N (%), P-available olsen (ppm), (pH H_2O), (Organic-C%)

			End of Research			
S. No	Initial Soil	Properties	K0	K1	K2	K3
1.	Total-N	0,02L	0,04L	0,02L	0,01L	0,009VL
2.	P-available	22,78VL	1031,63H	1049,18H	987,47H	993,35H
3.	pH H_2O	5,328S	6,257SS	6,951N	7,490N	6.925N
4.	Organik-C	0,58SL	1,01L	1,12L	0,94L	1,05L
5.	Structure	Block	Block	granular	granular	granular

Note: Capital letters in each column indicate the criteria for assessing soil properties (LPT, 1983) L: Low, M: Medium, H: High, N: Neutral, VR: Very low, S: Sour, SS: Slightly Sour

Results of analysis of soil properties (Table 3). There was no change in total soil N- from the beginning of the study to the end of the study, namely in the low range. Meanwhile, soil available P-increased numerically at the beginning of the study, it was very low and at the end of the study it became high. Soil pH experienced changes from the beginning of the study to acidic and the end of the study to neutral. Organic-C experienced a change from very low at the beginning of the study and low at the end of the study. The soil structure at the beginning of the research was block shaped and at the end of the research it became granular.

Based on the results of analysis of variance, it shows that the application of zeolite to post-coal mining soil has a real influence on plant height and stem diameter. Giving zeolite to the K3 treatment (150 g polybag^{-1}) can increase plant height by 10.91%, stem diameter by 18.06% compared to without giving zeolite to post-coal mining soil. This is because the application of zeolite can improve the physical, biological and chemical properties of the soil. Nursanti and Supriyanto (2022) [10], explained that the soil on post-coal mining land has a low nutrient content. The addition of zeolite to post-coal mining soil will be able to improve chemical properties such as the pH of the soil which was initially acidic to neutral and the physical properties of the soil which was initially block-shaped to become granular.

The growth in plant height and cocoa stem diameter is due to the application of zeolite to post-coal mining soil which can increase the nutrients available in the soil. This was proven from soil analysis, there was an increase in available P after the soil was treated with zeolite and an increase in soil pH from acid to neutral. According to Shrivastav (2022) [15], the nutrients available in the soil will be absorbed by plants and can increase plant growth, especially in relation to the photosynthesis process.

Factors that influence plant growth consist of internal and external factors. Internal factors are factors found in the seed or plant itself. External factors are factors that exist outside the seed or plant, one that influences growth in terms of external factors, namely the plant media, a good plant media is a media that is able to provide water and nutrients in sufficient quantities for plant growth. This can be found in soil with good air conditioning, stable aggregates, good water holding capacity and sufficient root space (Barrett *et al*., 2016) [2].

Plants experience growth from small to large and develop from a zygote to an embryo, then to an individual that has a set of roots, stems and leaves. One of the characteristics of organisms is that they grow and develop. Growth is defined as a process of increasing the size or volume and number of cells, this process occurs in a non-reversible manner (irreversible). Development is defined as a process towards a more mature state. However, if we examine it more deeply, these processes do not run independently, but go hand in hand. Starting with growth, then continuing with development. Growth and development itself is the result of interactions between internal and external factors. Internal factors include genetic traits (which are inside = genes) and hormones that stimulate growth. Meanwhile, external factors are the environment. This genetic potential will only develop if supported by a suitable environment. Thus, the characters/traits displayed by plants are a combination of genetic factors and environmental factors together.

The role of genes in influencing growth can be explained as follows, genes that determine growth and development are found in cells. Cells are a unit of heredity because they contain genes that are responsible for inheriting traits for the formation of proteins, enzymes and harmonics. The formation of enzymes and harmonics influences various metabolic reactions to regulate and control growth.

Plant media is a growing medium for plants that can supply some of the nutrient elements needed by plants to support good plant growth. Most of the nutrients needed by plants are supplied through plant media. It is then absorbed by the roots and used in plant physiological processes (Barrett *et al*., 2016) [2].

The results of the analysis of various types of zeolite application had a significant effect on the dry weight of cocoa plants and the dry weight of cocoa roots. The average yield of plant dry weight was the highest with a value of 75.76 g (K3) and there was an increase in plant dry weight of 25.81% when compared to K0. The average result of root dry weight was the highest with a value of 14.19 g (K3) and there was an increase in root dry weight of 42.46% when compared to K0. This is due to improvements in the planting media from a block structure to a granule structure. This causes plant roots to develop well and makes it easier for the roots to absorb the nutrients in the soil and use them for plant growth and plant roots.

Root dry weight is used as an indicator of the amount of photosynthate formed for the absorption of nutrients or nutrients from the soil. The dry weight of the roots really depends on the root volume and number of roots of the plant itself, whether or not the volume and number of roots have an effect on the dry weight. An increase in plant dry weight occurs if the photosynthesis process is greater than the respiration process, so that there is a buildup of organic material in the tissues in balanced amounts and growth will be stable (Colalti *et al*., 2019) [3].

Cocoa plants need at least 13 nutrients which are absorbed through the soil. Nutrients N, P, and K are needed in greater quantities. Nutrients Ca, Mg, and S are needed in moderate amounts. The nutrients Fe, Mn, Zn, Cu, B, Mo, and CI are needed by plants in small amounts. Most of the N and P are carried to the growing point, stems, leaves, male flowers, and then transferred to seeds (Agren *et al*., 2012) [1].

The plant growth process consists of cell division, followed by cell enlargement and finally cell differentiation. Growth only occurs in certain locations, namely in the meristem tissue. Meristem tissue is tissue whose cells are actively dividing.

Increasing pH by zeolite is possible because the basic cations found in zeolite such as Ca K and Mg can be exchanged with H^+ and AI^{3+} ions. Zeolite can buffer soil pH, acidic soil can be neutralized because zeolite is not acidic (pH 7.2) and can adsorb Al and Fe which cause soil acidity and release basic cations such as Ca, Mg and K. Jabri (2008) [8] explains that zeolite is a mineral that can neutralize soil pH.

Conclusion

Zeolite has no significant effect on the height of cocoa plants. The highest cocoa plant height was found in the K3 treatment (150 g zeolite polybag^{-1}) at 65.56 cm and there was an increase in cocoa plant height of 10.91% when compared to those without zeolite treatment.

Zeolite has a real influence on stem diameter, dry weight of cocoa plants and dry weight of roots. The growth in stem diameter obtained at K3 (150 g zeolite polybag^{-1}) was 9.98 mm or an increase of 18.06% compared to without zeolite (K0). Meanwhile, the highest dry weight of cocoa plants was obtained at K3 at 75.76 g or an increase of 25.81% compared to K0. The highest roots were found in K3 at 14.19 g or an increase of 42.46% when compared to K0.

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