Effect of compost application on soil fertility parameters and productivity of cocoa (*Theobroma cacao* L.)

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Abstract. Cocoa is one of the plantation crops that has an important role in the national economy, yet its production has decreased due to ineffective plants' treatment. One thing that can be done to solve this problem is applying organic material by effectively applying compost. This study aims to determine cocoa husk compost application on soil fertility and cocoa plant productivity. This research was conducted in Gantarangkeke Village, Gantarangkeke District, Bantaeng Regency, South Sulawesi Province, and took place from March to September 2020. This study used a randomized block design (RBD) as its environmental design. Compost application consists of 5 levels, namely control (0 kg / tree), (2.5 kg / tree), (5 kg / tree), (7.5 kg / tree), (10 kg / tree). The results of the research experiment showed that compost application of 10 kg/tree resulted in a pH of 6.3, CEC value of 27.14 cmol (+) kg\(^{-1}\), organic C content of 2.16%, available P content of 18.1 ppm, K content of 0.46 cmol (+) kg\(^{-1}\), Number of fruit/tree of 9.67 (fruit), number of seeds/fruit of 28.37 (seeds), the weight of 100 dry seeds of 113.17 (g), dry seeds per tree of 315.50 (g), and dry seeds per hectare of 350.50 (kg/ha). Compost application with several different doses had a significant effect on cocoa's growth and production, especially at a dose of 10 kg/tree.

1. Introduction
Cocoa (*Theobroma cacao* L.) is one of the primary commodities that has an important role in the national economy, particularly as an employment provider, income source, and foreign exchange. Given the very important role of cocoa plantations, it is necessary to improve both cacao production and quality [1]. The decline in cocoa production and productivity is generally caused by several factors, such as the plant's age, the use of poor quality planting material, the intensity of pests and disease attacks, and the lack of maintenance by farmers [2].

Maintaining soil fertility is one of the most important aspects of crop cultivation systems, including physical properties of the soil influence plant growth. Soil physical properties affect the growth of plant roots in taking up water and nutrients. The development of plant roots requires loose soil conditions. Plant roots cannot develop properly when the soil is compacted, so the plant will be disturbed in absorbing water and nutrients [3]. In response to this, organic matter plays a role in improving the soil's physical, chemical and biological properties. The content of organic matter in the soil can be increased by applying organic fertilizers such as composted agricultural waste [4].
One of the agricultural, industrial wastes of cocoa plants used as organic material is compost made from cocoa pod husks. Cocoa pod husk compost has various potential benefits, such as a mulch material or source of organic matter, which plays an important role in improving, increasing, and maintaining sustainable land productivity.

2. Methodology

2.1. Place and time
The research was conducted in Gantarangkeke Village, Gantarangkeke District, Bantaeng Regency, South Sulawesi Province. Soil sample analysis was carried out in the Physics, Chemistry, and Soil Fertility Laboratory of the Department of Soil Science, Faculty of Agriculture, Hasanuddin University, Makassar. This research took place from March - September 2020.

2.2. Research design
This research was conducted in an experiment arranged based on a randomized block design (RBD) with 3 replications. The treatment consisted of 5 levels, namely: K0 = without compost, K1 = 2.5 kg of compost / tree, K2 = 5 kg of compost / tree, K3 = 7.5 kg of compost / tree, K4 = 10 kg compost / tree. The data obtained were then analyzed for variance, and if the results had a real effect, then further test was carried out with the Honestly Significant Difference (HSD) test at the 5% level.

2.3. Research implementation
The compost material used in this research is made from the resources around the cocoa plantation area, such as the remaining skin from the harvested fruit, banana stems, Gamal leaves, goat weed, and mole as a decomposer. The compost application was carried out in April. The compost applied in this research was the ripe ones, which have a brownish-black color, a loose structure, and smells like soil. Maintenance was done by watering and weeding, and sanitizing cocoa plants. Cocoa harvesting was carried out in stages, starting from June to August. Drying was done to reduce the moisture content of the cocoa beans. Drying can be done by drying the seeds in the hot sun. The drying time is 15 depending on the weather or 5-7 days. The beans were often flipped so that the color and dryness are even/uniform. Soil samples were taken from Gantarangkeke Village, Gantarangkeke District, Bantaeng Regency, South Sulawesi Province. Soil samples were taken at four points at each treatment sample with a depth of about 20-25 cm.

2.4. Observation parameters
Soil fertility parameters and methods used in the analysis of soil samples in the laboratory.

Table 1. Method of soil analysis in the laboratory.

| No | Parameter                        | Unit                | Method                  |
|----|----------------------------------|---------------------|-------------------------|
| 1  | KTK Value                        | cmol (+) kg⁻¹       | Walkley and black       |
| 2  | Soil Organic C Content           | (%)                 | NH₄OAc pH 7             |
| 3  | Soil P-availability Content      | (ppm)               | Olsen                   |
| 4  | Soil Potassium (K) Content       | cmol (+) kg⁻¹       | Extract HCl 20 %        |
| 5  | Soil pH Value                    |                     | Hydrometer               |

2.4.1. Production parameters of the cocoa plant. The number of fruit harvested was determined at the end of the study by counting all ripe and harvestable fruits from ground level to secondary branches. Harvesting of ripe fruit was done in stages, 16 cocoa pods did not ripen simultaneously, so harvesting was done every time the pods were ripe. The average number of seeds/fruit, the weights of 100 dry seeds, production per tree, and production per hectare were observed at the end of the study.
2.5. Data Analysis  
The observations will be analyzed using variance (ANOVA) at the 95% confidence level. If the effect is significant, further tests will be done using the HSD 0.05 test.

3. Results and discussions

3.1. Soil Fertility Parameters

3.1.1. Soil Cation Exchange Capacity CEC Value. Analysis of variance showed that the compost treatment significantly affected the average soil CEC value (table 2).

| Treatment          | Average | HSD 0.05 |
|--------------------|---------|----------|
| 0 kg/plant (K0)    | 18.20   |          |
| 2.5 kg/ plant (K1) | 18.96   |          |
| 5 kg/ plant (K2)   | 20.65 c | 1.18     |
| 7.5 kg/ plant (K3) | 24.74 b |          |
| 10 kg/ plant (K4)  | 27.14 a |          |

Note: The numbers followed by the same letters in the columns (a, b, c, d) mean that they are not significantly different in the HSD 0.05 test.

The HSD test results in table 2 show that the compost dosages' application showed the highest average soil CEC value is 27.14 (cmol(+)/kg\(^{-1}\)) with a compost dosage of 10 kg/plant and was significantly different from other compost doses.

The increase in the CEC value is influenced by the decomposition process of organic matter, which produces humic compounds that contribute to soil colloids to increase the soil CEC. This increase was also caused by the increase in the negative charge of soil colloids. This negative charge comes from the carboxyl (COOH) and hydroxyl (OH) groups present in organic compounds. This is following the opinion [5], which states that the presence of functional groups of organic compounds can produce some negative charges on soil colloids, the dissociation of COOH and OH groups from organic compounds can increase the negative charge in the soil so that it can increase soil CEC.

3.1.2. Soil organic C content. Analysis of variance showed that the treatment of compost dosages had a highly significant effect on the average soil organic C content.

| Treatment          | Average | HSD 0.05 |
|--------------------|---------|----------|
| 0 kg/plant (K0)    | 1.27 b  |          |
| 2.5 kg/ plant (K1) | 1.95 a  |          |
| 5 kg/ plant (K2)   | 2.04 a  | 0.37     |
| 7.5 kg/ plant (K3) | 2.11 a  |          |
| 10 kg/ plant (K4)  | 2.16 a  |          |

Note: The numbers followed by the same letters in the columns (a, b) mean that they are not significantly different in the HSD 0.05 test.

The HSD test results on table 3 show that the average organic C content (%), the highest average value, namely 2.16% at the compost dose of 10 kg/plant, is significantly different from the other compost.

The application of organic matter in the form of compost can increase the soil organic C content. The increase in soil organic C content can be caused by the release of organic C content from compost [6]. The difference in soil organic matter's value can be caused by the influence of compost application and the decomposition process by soil microbes. In the soil, microbes use organic matter for energy and microbial development.
3.1.3. Available P content (P₂O₅) soil (ppm). Analysis of variance showed that the compost dosages treatment significantly affected the average available P content (P₂O₅).

**Table 4.** Average P-content available at various compost dosages.

| Treatment            | Averages | HSD 0.05 |
|----------------------|----------|----------|
| 0 kg/plant (K0)      | 11.3 c   |          |
| 2.5 kg/plant (K1)    | 13.2 c   |          |
| 5 kg/plant (K2)      | 14.8 bc  | 3.70     |
| 7.5 kg/plant (K3)    | 17.2 ab  |          |
| 10 kg/plant (K4)     | 18.1 a   |          |

Note: The numbers followed by the same letters in the columns (a, b, c) mean that they are not significantly different in the HSD 0.05 test.

The results of the HSD test in table 4 showed the highest average of soil potassium (K) content, namely 0.46 (cmol (+) kg⁻¹) is from the dosage of 10 kg/plant and was significantly different from other compost dosages.

The availability of P in the soil depends on its mobility in the soil and the soil’s pH value [7]. In this study, the compost treatments had higher available P content in the soil than the control treatment or without compost (K0) and produced a fairly good pH value with a pH value ranging from 6.3 - 6.6. Phosphorus content was mostly available at pH ranges between 5.5 - 6.5 [8]. This showed that the compost dosage treatment could increase the P-available content in the soil.

3.1.4. Potassium (K) Content of Soil (cmol (+) kg⁻¹). Analysis of variance showed that the compost dosage treatment had a significant effect on the soil’s average potassium (K) content.

**Table 5.** Average Soil Potassium Content at various compost doses.

| Treatment            | Averages | HSD 0.05 |
|----------------------|----------|----------|
| 0 kg/plant (K0)      | 0.24 d   |          |
| 2.5 kg/plant (K1)    | 0.37 c   |          |
| 5 kg/plant (K2)      | 0.43 b   | 0.05     |
| 7.5 kg/plant (K3)    | 0.40 b   |          |
| 10 kg/plant (K4)     | 0.46 a   |          |

Note: The numbers followed by the same letters in the columns (a, b, c, d) mean that they are not significantly different in the HSD 0.05 test.

The results of the HSD test in table 4 showed the highest average potassium (K) content of the soil has, namely 0.46 (cmol (+) kg⁻¹) appeared in the compost dosage of 10 kg/plant and was significantly different from other compost doses.

The increase in soil potassium content was due to the provision of compost made from the cocoa husk, on which compost made from cocoa shells contained high K. Thus, it can increase soil potassium content. The mineral nutrient content of cacao pods was relatively high, especially K content, which was 6.1% [9].

The compost analysis results showed that, apart from producing good enough nutrients, compost can also bind water to be absorbed by plants so that the translocation of nutrients, especially K⁺ ions can take place correctly. Water can also affect the leaves’ turgor pressure, which is associated with the opening and closing of the stomata; therefore, it can increase CO₂ absorption. The high amount of CO₂ uptake will help plants in the formation of high assimilates. Therefore, energy needs and plant development become available.
3.1.5. Soil Ph Value. Analysis of variance showed that the compost dose treatment had no significant effect on the average soil pH value.

![Figure 1](image-url)

Figure 1. Graph of average soil pH value in various treatments of compost dosage.

Figure 1 showed that the compost dosage treatment showed the highest average soil pH value of 6.6 appeared in the compost treatment 7.5 kg/plant, while the lowest pH value is 6.2 in the control treatment.

Compost application that had been incubated in the decomposition process will release organic compounds, either in the form of organic acids or alkaline cations, which will cause changes in the soil pH value [10]. The rise and fall of soil pH is a function of H⁺ and OH⁻ ions; if the concentration of H⁺ ions in the soil solution increases, the pH will decrease, and if the OH⁻ ion concentration increases, the pH will rise. Organic material that has been decomposed will produce OH⁻ ions that can neutralize H⁺ ions, and organic acids will bind Al³⁺ and Fe²⁺, which can form complex compounds (chelate) so that Al³⁺ and Fe²⁺ have not hydrolyzed again [11].

3.2. Production parameters for cocoa plants

Analysis of variance showed that the treatment of compost dosing had a highly significant effect on the average number of fruits per tree, the number of fruit, the number of seeds per fruit, the weight of 100 dry seeds, the production of dry seeds per tree and the production of dry seeds per hectare.

Table 5. The average number of fruits per tree, number of fruits, number of seeds per fruit, the weight of 100 dry seeds, dry seed production per tree, and dry seed production per hectare at various compost dosages.

| Parameters                          | Treatment | Averages | HSD 0.05 |
|------------------------------------|-----------|----------|----------|
| The average number of fruits per tree | K0        | 4.78 b   |          |
|                                    | K1        | 6.11 ab  |          |
|                                    | K2        | 7.11 ab  |          |
|                                    | K3        | 8.00 ab  |          |
|                                    | K4        | 9.67 a   |          |
| The average number of seeds per fruit | K0        | 14.07 b  |          |
|                                    | K1        | 20.67 ab |          |
|                                    | K2        | 26.03 ab |          |
|                                    | K3        | 28.27 a  |          |
|                                    | K4        | 28.37 a  |          |
| Weight of 100 dry seeds (g)         | K0        | 81.50 b  |          |
|                                    | K1        | 90.70 ab |          |
|                                    | K2        | 103.27 a |          |
|                                    | K3        | 104.93 a |          |
| K4       | 113.17 a |
|----------|----------|
| K0       | 66.20 b  |
| K1       | 123.57 ab|
| K2       | 184.37 ab|
| K3       | 240.47 ab|
| K4       | 315.50 a |

| Dry seed production per hectare (kg/ha) |
|----------------------------------------|
| K0          | 73.50 b   |
| K1          | 137.27 ab |
| K2          | 204.83 ab |
| K3          | 267.17 ab |
| K4          | 350.50 a  |

Note: The numbers followed by the same letters in the columns (a, b) mean that they are not significantly different in the HSD 0.05 test.

The observation results of the parameters of the number of fruits per tree, the number of seeds per fruit, the weight of 100 dry beans, the production of dry beans per tree, and the production of dry beans per hectare had a very significant effect on the compost dosage of 10 kg/tree on cocoa.

These results indicated that the higher the compost dosage, the better the effect on increasing cocoa production and productivity. Fertilization aims to improve and increase soil fertility and soil nutrient content. Increasing the soil’s number of nutrients will positively impact nutrient absorption and plant growth [12]. Nutrient uptake by plants reflects the condition of soil and plant nutrients. If the soil conditions (physical, chemical, and biological characteristics) and the plants are good, the plant roots will absorb nutrients effectively.

The results showed that the cocoa plants applied by the compost dose of 2.5 kg/tree, 5 kg/tree, 7.5 kg/tree, and 10 kg/tree affected cocoa yields. The highest average yield of cocoa was found in the treatment of 10 kg of tree⁻¹. The highest average cocoa yield (315 kg ha⁻¹) was found in the compost treatment of 10 kg tree⁻¹ or the equivalent of 8.16 tons ha⁻¹ with pruned plants [13].

Fruits formed in the first month, not all of them survive until harvesting season and cannot guarantee production because they will experience wilting and miscarriage of fruit within 1 - 2 months, commonly known as Cherelle wilt [14]. The dropping of young fruits (Cherelle wilt) is a unique physiological disease of the cocoa plant, commonly referred to as the physiological thinning effect. The wilting rate can reach around 60-90%, which generally occurs until 50 days. Generally, young fruit wilting occurs in two stages, in 7 weeks after fertilization and about ten weeks after fertilization.

4. Conclusion
Based on the results of the research, it can be concluded that the application of compost dosage has a significant effect on increasing soil fertility, especially in the treatment of compost dosage of 10 kg/plant, which results in a pH of 6.3; CEC: 27.14 cmol (+) kg⁻¹; C-organic: 2.16%; P: 18.8 ppm, K: 0.46 cmol (+) kg⁻¹. Besides, compost also has a significant effect on specific cocoa productivity on the parameters of the number of fruits/trees, the number of seeds/per fruit, the production of 100 dry beans, the production of dry beans/tree, and the production of dry beans/hectare with a compost dosage of 10 kg/plant.

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