Effectivity of Biofertilizer and shoot pruning on yield of cocoa 
(Theobroma cacao L)

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Abstract. This study aims to understand the effectiveness of biofertilizers and shoot pruning in improving cocoa growth and yield. The research was conducted in the "Kebun Dinas Bone-Bone", North Luwu Regency, South Sulawesi Province from February to August 2020. This research was conducted in the form of an experiment arranged in randomized block design (RBD) with 3 replications. The treatment consist of 10 levels, namely: without biofertilizer and not shoots pruned, biofertilizer 9 ml L⁻¹ per tree and not shoots pruned, biofertilizer 18 ml L⁻¹ per tree and not shoots pruned, biofertilizer 27 ml L⁻¹ per tree and not shoots pruned, biofertilizer 36 ml L⁻¹ per tree and not shoots pruned, biofertilizer 0 ml L⁻¹ per tree and shoots pruned, biofertilizer 9 ml L⁻¹ per tree and shoots pruned, biofertilizer 18 ml L⁻¹ per tree and shoots pruned, biofertilizer 27 ml L⁻¹ per tree and shoots pruned, biofertilizer 36 ml L⁻¹ per tree and shoots pruned. Research results show that the concentration of biofertilizer of 32 mL L⁻¹ gave the highest value for number of pods (10 pods), 42.8 seeds of fruits, and yield 0.71 kg per tree or equivalent to 591.67 kg / ha of dry seeds. Pruning the shoots gave the highest number of seeds per fruit of 36.82 and pod index of 20.

1. Introduction
Indonesian cocoa production continued to experience a decline that occurred in the 2013 to 2017 period with the average growth of cocoa production decreasing by 0.93 percent per year. Until 2017, the total area of cocoa in Indonesia was 1,691,334 ha or decreased by 0.59% from 2016 with a production of 688,345 tons or an increase of 4.8% [1].

The productivity of cocoa varies greatly between regions and between provinces, which generally have a productivity level of below 1 ton dry bean / ha / year. This productivity is still below the potential for cocoa production which can reach 2 tons of dry beans / year. The low productivity of cocoa is due to attacks from pest and disease like a cocoa pod borer (CPB) and VSD [2].

Cocoa plants must be pruned regularly so that the rate of photosynthesis is optimal, the net result of photosynthesis is maximum and distribution to the organs that need it runs smoothly [3]. Increasing the productivity of the cocoa plant must be balanced with fertilization, one of which is using biofertilizers. With the use of biofertilizers, the efficiency of nutrient supply will increase so that the use of inorganic fertilizers can be reduced [4].

According description above, it is necessary to conduct research to determine the effectiveness of biofertilizers and shoot pruning on cocoa growth and yield.
2. Methodology

2.1. Study site
The research took place at the Kebun Bibit Bone Bone, Tanalili District, Luwu Utara Regency, South Sulawesi Province from January to June 2020. Located at an average altitude of 41 m above sea level, and coordinate point position of 02° 37’ 01” SL and 120° 36’ 21” EL.

2.2. Experimental design
This research was conducted in the form of an experiment arranged in randomized block design (RBD) with 3 replications. The treatment consist of 10 levels, namely: without biofertilizer and not shoots pruned (k0p0), biofertilizer 9 ml L\(^{-1}\) per tree and not shoots pruned (k1p0), biofertilizer 18 ml L\(^{-1}\) per tree and not shoots pruned (k2p0), biofertilizer 27 ml L\(^{-1}\) per tree and not shoots pruned (k3p0), biofertilizer 36 ml L\(^{-1}\) per tree and not shoots pruned (k4p0), biofertilizer 0 ml L\(^{-1}\) per tree and shoots pruned (k0p1), biofertilizer 9 ml L\(^{-1}\) per tree and shoots pruned (k1p1), biofertilizer 18 ml L\(^{-1}\) per tree and shoots pruned (k2p1), biofertilizer 27 ml L\(^{-1}\) per tree and shoots pruned (k3p1), biofertilizer 36 ml L\(^{-1}\) per tree and shoots pruned (k4p1). There are 10 treatment combinations. Each treatment combination consisted of 4 plants which were repeated 3 times resulted in 120 plants used.

2.3. Plant materials and growth media preparation
Plant materials used in the study was 6 years old MCC02 clone and Biofertilizer is diluted with water and watered around the plant roots. The treatment of shoot pruning is carried out on the branches cocoa that are being flushed by removing of shoot which are still red and half of them left in one tree. Pruning is done every week or when new shoots appear.

2.4. Plant observation
The parameters of this observation were: leaf area of the sample formed (cm\(^2\)), Leaf Mass per Area (LMA), fallen of fruit, assuming fruit to survive, harvested pods, number of seeds per pods, weight of 100 dry seeds, production per tree, pod index

2.5. Data analysis
The data were analyzed using the F test at the 5% and continued with orthogonal contrast tests of if there was a significant effect between treatments.

3. Results and discussion

3.1. Leaf area sample be formed
Results of analysis of variance to the biofertilizers and shoots pruning show that there was no significant effect of the treatment on leaf area. The biofertilizer concentration of 9 mL L\(^{-1}\) without pruning treatment (k1p0) gave the highest average leaf area of 945.71 cm\(^2\) (figure 1).

![Figure 1. Effect of biofertilizer dan pruning of leave area sample.](image-url)
3.2. **Leaf Mass Area (LMA)**

The results of the analysis of variance showed that the application of biofertilizers and shoot pruning had no significant effect on the leaf mass area parameter. The biofertilizer concentration and not pruning (k3p0) gave the highest average leaf mass area of 0.2787.

![Figure 2. Average Leaf Mass Area of cocoa.](image)

3.3. **Fallen of fruit.**

The observations of fall fruit showed that the concentration of biofertilizers and pruning did not have a significant effect. The figure 3 shows the concentration of biofertilizer of 27 mL L\(^{-1}\) and shoots pruning (k3p1) resulted in the highest number of fall fruits value of 2.38. The control treatment without pruning and biofertilizer (k0p0) gave the lowest value of 0.63.

![Figure 3. Effect of biofertilizer dan prunning of fallen fruit.](image)

3.4. **Number of harvested pods**

The results of observations of harvested pods and analysis of variance show that the treatment of biofertilizer concentration and shoot pruning had significant effect. The results of orthogonal contrast test is shown in table 1. The table shows that the average value of the number of pods harvested was higher in not pruned shoot (k1p0, k2p0, k3p0, k4p0) and significantly different from the pruned (k1p1, k2p1, k3p1, k4p1) and significantly different with control (k0p0). Biofertilizer concentration 36 mL L\(^{-1}\) and pruned (k4p1) gave the highest value on the average fruit harvest which is 10, significantly different from the biofertilizer concentration of 0 mL L\(^{-1}\) and not pruned (k0p0).
Table 1. Orthogonal contrast test of harvested pods.

| Treatment | Average of harvested pods | F.table |
|-----------|---------------------------|---------|
|           |                           | 0.05    | 0.01  |
| k0p0 vs others | 7 vs 8.4 | 1.52 | * |
| k1p0 vs k2p0, k3p0, k4p0 | 7.7 vs 9.1 | 0.63 | * |
| k2p0 vs k3p0, k4p0 | 9 vs 9.2 | 0.01 | ns |
| k3p0 vs k4p0 | 9.3 vs 9 | 0.03 | ns |
| k1p0, k2p0, k3p0, k4p0 vs k1p1, k2p1, k3p1, k4p1 | 8.8 vs 7.8 | 2.81 | * |
| k0p0 vs [k1p0, k2p0, k3p0, k4p0] | 9.3 vs 8.3 | 0.36 | ns |
| [k1p1, k2p1, k3p1, k4p1] |         |       |       |
| k1p1 vs k2p1, k3p1, k4p1 | 7.3 vs 7.9 | 0.09 | ns |
| k2p1 vs k3p1, k4p1 | 7 vs 8.3 | 0.53 | * |
| k3p1 vs k4p1 | 6.7 vs 10 | 3.12 | * |

ns= not significant, *=significant.

Figure 4. The regression correlation graph of the average value of the harvested pods after treatment.

Correlation regression analysis showed that the application of biofertilizer and pruned (k1p1, k2p1, k3p1, k4p1) was linearly and not significantly correlated with the value of the pods harvested plants and followed the equation \( y = 0.0074x + 7.9333; r = 0.07 \) ns.

The treatment of biofertilizer concentrations and no pruned (k1p0, k2p0, k3p0, k4p0) correlated positively linearly and significantly different. The higher the concentration of fertilizer applied and not pruned, the higher the fruit is harvested. The average value of fruit harvested for cocoa plants and followed the equation \( y = 0.063x + 7.2667; r = 0.88 \)*.

3.5. Weights 100 dry seeds of cocoa bean

The results of the analysis of variance showed that the treatment of biofertilizer concentration and shoot pruning had no significant effect.
Figure 5. Effect of biofertilizer dan pruning of weigh on 100 dry seeds cocoa bean

Figure 5 above shows that the treatment of biofertilizer and pruning shoot (k0p1) gives the highest seed weight with a value of 179.72 grams and treatment without pruning is 64.66 grams. The treatment (k3p1) give the lowest value 129.36.

3.6. Number of seeds per pods (seeds)
Analysis of variance in the number of seeds per pods showed that the concentration of biofertilizer and shoots pruning had significant effect (table 2).

Table 2. Contras ortogonal test number of seeds per pods

| Treatment                      | Average of seeds per pods | F:table |
|--------------------------------|---------------------------|---------|
| k0p0 vs others                | 35.17 vs 34.51            | 0.01 ns |
| k1p0 vs k2p0, k3p0, k4p0      | 34.39 vs 35.33            | 0.03 ns |
| k2p0 vs k3p0, k4p0            | 37.89 vs 34.04            | 0.5 *   |
| k3p0 vs k4p0                  | 27.83 vs 40.25            | 4.9 **  |
| k1p0, k2p0, k3p0, k4p0 vs     | 35.09 vs 36.82            | 0.95 *  |
| k1p1, k2p1, k3p1, k4p1        |                           | 0.49    | 3.36  |
| k0p1 vs [k1p0, k2p0, k3p0, k4p0] |                           | 22.99 vs 35.95 | 5.87 ** |
| [k1p1, k2p1, k3p1, k4p1]      |                           |         |
| k1p1 vs k2p1, k3p1, k4p1      | 31.89 vs 38.46            | 1.47 *  |
| k2p1 vs k3p1, k4p1            | 38.17 vs 38.61            | 0.01 ns |
| k3p1 vs k4p1                  | 34.33 vs 42.88            | 2.32 *  |

ns= not significant, *=significant, **=very significant.

The orthogonal contrast test in table 2 shows that the mean value of the number of seeds per fruit was higher in pruned plants (k1p1, k2p1, k3p1, k4p1) which was significantly different from the non-pruned plants (k1p0, k2p0, k3p0, k4p0) and significantly different with control (k0p0). The biological fertilizer concentration of 36 mL L⁻¹ and pruned (k4p1) gave the highest average value for the number of seeds of 42.88.
Figure 6. Regression correlation graph of the average number of seed per fruit after treatment.

Correlation regression analysis showed that the application of pruned biofertilizer concentrations (k1p1, k2p1, k3p1, k4p1) had a positive linear correlation with the value of the number of seeds per pods. This means that the higher the concentration of biological fertilizers and pruning results in an increase in the number of seeds per fruit, following the equation \( y = 0.4691x + 25.606; r = 0.896^* \). Treatment of biofertilizer concentrations and not pruning (k1p0, k2p0, k3p0, k4p0) correlated linearly and were not significantly different. The average value of the number of beans per cocoa plant follows the equation \( y = 0.0401x + 34.385; r = 0.122 \) ns.

3.7. The number of cocoa pod assumed survive

The assumptions on the surviving fruit showed that the treatment of biofertilizer concentration and pruning had no significant effect. Figure 7 shows that the treatment of biofertilizer concentration and pruning (k4p0) gave the highest value of 2.09 fruit and treatment (k3p1) gave the lowest value 1.27.

Figure 7. The number of cocoa pods assumed to survive (data transformed).
3.8. Production per Tree (kg)

Based on the results of observations and variance, it showed that the concentration of biofertilizers had a significant effect, shoots pruning and the interaction between the two treatments had no significant effect on production per tree. The results of orthogonal contrast test in table 3 shows that the highest average production value of 0.71 was obtained from the treatment of the biofertilizer concentration of 36 mL L\(^{-1}\) and pruned (k4p1). The treatment of biofertilizer concentration and not pruned (k1p0, k2p0, k3p0, k4p0) gave the highest average value of 0.52, which was significantly different from the pruned (k1p1, k2p1, k3p1, k4p1) and was not significantly different from the control (k0p0).

| Treatment                                      | Average production per tree | F-Table. |        |
|------------------------------------------------|-----------------------------|----------|--------|
| k0p0 vs others                                 | 0.46 vs 0.47                | 0.0005   | ns     |
| k1p0 vs k2p0, k3p0, k4p0                       | 0.44 vs 0.55                | 0.43     | ns     |
| k2p0 vs k3p0, k4p0                             | 0.59 vs 0.52                | 0.18     | ns     |
| k3p0 vs k4p0                                   | 0.41 vs 0.64                | 1.75     | *      |
| k1p0, k2p0, k3p0, k4p0 vs                      | 0.52 vs 0.43                | 2.79     | *      |
| k1p1, k2p1, k3p1, k4p1                         |                             |          |        |
| k0p1 vs [k1p0, k2p0, k3p0, k4p0] [k1p1, k2p1, k3p1, k4p1] | 0.41 vs 0.47                | 0.15     | ns     |
| k1p1 vs k2p1, k3p1, k4p1                        | 0.33 vs 0.46                | 0.56     | *      |
| k2p1 vs k3p1, k4p1                             | 0.37 vs 0.50                | 0.65     | *      |
| k3p1 vs k4p1                                   | 0.29 vs 0.71                | 5.95     | **     |

ns= not significant, *=significant, **=very significant.

![Figure 8. Regression correlation graph of production per tree after treatment.](image)

Correlation regression analysis shows that the application of pruned biofertilizer concentrations (k1p1, k2p1, k3p1, k4p1) has a positive linear and insignificant correlation to the average value of production per tree, the higher the concentration of biofertilizer and pruning results in increased
production per tree, following the equation \( y = 0.0063x + 0.3107; r = 0.53 \). Treatment of biofertilizer concentrations and no pruning (k1p0, k2p0, k3p0, k4p0) correlated positively linearly and significantly different from the average value of production per tree following the equation \( y = 0.0035x + 0.4434; r = 0.49 \).

3.9. Pod index

The analysis of variance showed that the concentration and pruning treatment had a significant effect. The orthogonal contrast test in Table 4 shows that the highest pod index values in the treatment of biological fertilizer concentration and pruning (k1p1, k2p1, k3p1, k4p1) were significantly different from the treatment of biological fertilizer concentrations and were not trimmed (k1p0, k2p0, k3p0, k4p0) and not significantly different from the control (k0p0). The biological fertilizer concentration of 0 mL L\(^{-1}\) and pruned (k0p1) gave the highest index value of 24.8 and the treatment of biological fertilizer concentration of 32 mL L\(^{-1}\) and pruned (k4p1) gave the lowest value of 14.2.

**Table 4. Orthogonal contrasts on test pods index.**

| Treatment | Average of pod index | F\(table\) 0.05 | F\(table\) 0.01 |
|-----------|----------------------|-----------------|-----------------|
| k0p0 vs others | 16.8 vs 19.7 | 0.35 ns |              |
| k1p0 vs k2p0,k3p0,k4p0 | 18.1 vs 18.2 | 0.00001 ns |              |
| k2p0 vs k3p0, k4p0 | 17.1 vs 18.7 | 0.1 ns |              |
| k3p0 vs k4p0 | 23.2 vs 14.2 | 3 * |              |
| k1p0,k2p0,k3p0,k4p0 vs k1p1,k2p1,k3p1,k4p1 | 18.2 vs 20.0 | 1.23 * |              |
| k0p1 vs [k1p0,k2p0,k3p0,k4p0] [k1p1,k2p1,k3p1,k4p1] | 24.8 vs 19.1 | 1.32 * | 0.49 3.36 |
| k1p1 vs k2p1,k3p1,k4p1 | 23.8 vs 18.7 | 1.03 * |              |
| k2p1 vs k3p1,k4p1 | 19.2 vs 18.5 | 0.02 ns |              |
| k3p1 vs k4p1 | 22.8 vs 14.2 | 2.72 * |              |

ns= not significant, * = significant.

**Figure 9. Regression correlation graph of pod index.**

Correlation regression analysis showed that the concentration of biofertilizers and pruned treatments (k1p1, k2p1, k3p1, k4p1) correlated with the mean pod index value. This means that the higher the concentration of biological fertilizers and pruning results in a decrease in the pod index value, following...
the equation \( y = -0.2481x + 25.409; r = 0.6609 \). Treatment of biofertilizer concentrations and not pruned \((k1p0, k2p0, k3p0, k4p0)\) correlated linearly and significantly different from the pod index average value following the equation \( y = -0.002x + 7.913; r = 0.0089 * \).

Plant growth and development is controlled by genetic and environmental factors. The results of the experiment showed that the concentration of biofertilizers and pruning treatment did not affect the leaf area and LMA (leaf mass area) parameters. This is supported by previous experiments which stated that \textit{Azotobacter chroococcum} inoculation had no significant effect on the number and leaf area of cocoa seeds [5]. The application of organic fertilizers (compost) and biofertilizers had a significant effect on P, K, Ca and Na but had no significant effect on N and Mg on the results of the analysis of the leaf tissue of the cocoa plants. same soil analysis showed that no different N content [6]. According to Wood \\& Lass, 1985 in [5] that light intensity affects leaf thickness and chlorophyll content of cocoa plants, leaves under the shade are wider and green in color than leaves that get full light.

In general, most buds pruning cocoa crop does not affect the variable that is observed. This is presumably because not all cacao plants at the time of the experiment experienced a flush, there were some plants that sprouted but some did not sprout at all [2] the difference in maximum and minimum temperature around the canopy when it reaches 9 ° C, the cocoa plant will experience a flush.

The overall results showed that the use of biofertilizer gave the highest value on the number of seeds, production per tree and pod index with a concentration of 36 mL L\(^{-1}\). It is suspected that the application of compost for oil palm empty bunches for cocoa plants at a dose of 1 kg / tree given before treatment affects the working effectiveness of biofertilizers in the nutrient needs of the cocoa plant. This is in accordance with [7], which states that the addition of 5 kg of organic material in the form of compost can increase the yield of kakao fruit because organic matter is a secondary provider of additional nutrients for plants [6]. Compost (organic fertilizer) together with biofertilizers gave the highest yields on the number of fruit harvested and the average weight per fruit.

This is possible because compost and bio-fertilizers contain a lot of microorganisms which will produce growth hormones that can stimulate and develop hair roots so that the areas for searching for nutrients are even wider. Thus, it can add more nutrients as nutrients that can be translocated to the parts of the plant, including the resulting fruit [8].

Oil palm empty bunch compost is organic material that contains the main nutrients N, P, K, and Mg. If nitrogen is sufficient, the leaves of the plant will grow well so that it helps to process photosynthesis. Apart from being thought to be able to improve the physical properties of the soil, EFB is also able to increase the efficiency of fertilization so that the compound fertilizer used for cocoa nurseries can be reduced [9].

4. Conclusion

Research results showed that the concentration of biofertilizer 32 mL L\(^{-1}\) gave the highest value for: 10 pod, 42.8 seeds of pods, and yield 0.71 kg per tree or equivalent to 591.67 kg / ha of dry seeds cocoa bean. Pruned of shoots gave the highest value for stomata density 104.43 mm\(^2\), stomata opening area of 0.0013 mm\(^2\), number of seeds per pods was 36.82 and pod index of 20.

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