Improvement of robusta coffee performance with conservation and fertilizer treatment in Air Naningan District, Tanggamus Regency, Lampung

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Abstract. Lampung Province is one of the coffee-producing centers in Indonesia, especially robusta coffee. One of the coffee producing centers is in Air Naningan District, Tanggamus Regency. So far, most farmers manage conventional coffee plantations without any conservation nor fertilization. The study aimed to compare the performance of coffee growth between conservation and fertilization treatments with conventional treatments. Conservation treatment was carried out by making trenches around the coffee plantations. At the same time, fertilizer was given in the form of organic fertilizer as much as 10 kg plant\(^{-1}\) y\(^{-1}\), and inorganic fertilizer in the form of Rock Phosphate 240, Urea 400, and KCl 320 g plant\(^{-1}\) y\(^{-1}\). The study showed that the conservation and fertilization could improve the performance of coffee plants, based on the agronomic performances, such as a better growth (canopy and leafy branches, shiny green leaves, and low leaf rust disease (<5%)) and stems and branches attacked (<5%). The yield of coffee was also increased by around 333%. The study indicates that the combination of land conservation and fertilization could be adopted as a standard procedure for increasing coffee production in Lampung Province.

1. Introduction
Lampung Province is one of the coffee-producing centers in Indonesia, especially robusta coffee. Robusta coffee production in this area in 2014 reached 131,501 t with a planted area of 173,670 ha [1]. The average productivity of the farmers' coffee in Lampung is still less than 0.8 t ha\(^{-1}\) y\(^{-1}\) [2]. Nonetheless, coffee production in the Lampung area contributes significantly to the economy of the community and the region through trade, processed products, and services related to this commodity.

So far, the coffee cultivation business in Lampung Province is still carried out by the farmers using a conventional way. Farmers tend to apply poor farm management and maintenance, regular plant care, and pay less attention to the sustainability of coffee farming principles. The continued impact of these conditions is the tendency of decreasing coffee production and land degradation in the form of critical land with minimal nutrients. Robusta coffee has superior properties, which is higher productivity than arabica coffee, even though the taste quality is inferior to the arabica. Moreover, robusta coffee is more adaptive in the lowlands compared to arabica coffee. If properly maintained, the potential production of dry coffee production bean can reach 2 t ha\(^{-1}\) y\(^{-1}\) [3].

To produce well, robusta coffee plantation should be carried out good preparation, including making superior seeds and land preparations (such as planting permanent shade plants, temporary shade, making...
planting holes, and providing compost or soil organic matter). Also, coffee plantation needs to be protected from soil erosion by making trenches, terraces, and ground cover crops [4].

Conservation is an effort to manage natural resources wisely based on the principle of sustainability [5]. Soil conservation is an effort to protect the soil so that it can continue to function correctly. Soil conservation treatments are divided into two types, which are vegetative and mechanical (technical) soil conservation. Vegetatively, soil conservation can be done by planting cover crops and shade plants. Technically, land conservation can be conducted by making trenches and terraces [6]. The vegetative soil conservation can be done by rotating crops, replanting, strip cropping, planting animal feed grass, applying organic mulch, and planting the drainage banks with grass [7].

Vegetative conservation by planting shade plants has an additional economic aspect. Apart from being an effort to conserve land, it can also be used to increase land productivity. The selection of appropriate shade plants that have high economic value in the long term will increase land productivity in the form of wood and fruit. A good shade plant must also meet other agronomic requirements, such as not too dense, having small and elongated leaves to allow sunlight sufficiently, not become a host for pests and diseases, and not act as a plant competitor [4].

Technical conservation can be done by making trenches. A trench is a water infiltration hole that has other functions, such as reducing excess surface water, reducing surface water flow rate, improving soil air conditioning, and storing organic matter around the land [8]. It can also reduce soil erosion in the rainy season, especially on sloping area. According to Morgan in Heddy [9], there are three stages of the erosion process that causes land damage, which are the separation of soil particles, transport of soil particles by wind and surface runoff, and deposition of soil particles. Soil erosion causes loss of topsoil and soil nutrients deficiency. In coffee and cacao plants, a trench is an excavation that is made next to the stump of the plant to place organic fertilizer and can serve as a drainage hole. The land trench is one of the standard plantation practices which aims to maintain land, organic matter, and soil and water conservation practices in coffee and cocoa plantations [10].

A previous study showed that low coffee production in the Tanggamus Regency, Lampung Province, because the old trees and has not been rejuvenated, low soil fertility, poor soil structure, and adopted minimal land conservation [11]. Moreover, to improve the existing coffee plantations, with fertilizers application is necessary to provide nutrition to coffee plants and replacing nutrients that are carried away during the harvest. The fertilizers used are organic in the form of manure or compost and inorganic fertilizers (urea, SP36, KCl). The study aimed to evaluate the effect of conservation and fertilization treatment on the performance and production of robusta coffee plants in Air Naningan District, Pringsewu Regency, Tanggamus.

2. Materials and methods
This study was carried out on coffee plantations in the village of Way Harong, Air Naningan District, Tanggamus Regency from 2018 to 2019. The design was a randomized block design with the following treatments: A) The full recommendation package (full fertilizer, trenches, and pruning) and P fertilizer from SP36, B) The complete recommendation package (full fertilizer, land trenches, and pruning) and P fertilizer from Rock Phosphate, C) The semi-recommended cultural package (half fertilizer, land trenches, and pruning) and P fertilizer from SP36, D) The semi-recommended cultural package (half fertilizer, trenches, and pruning) and P fertilizer from Rock Phosphate, and E) Farmer plantation (minimum fertilizer and no conservation). The full recommended package was using land management, including making trenches, applying lime, pruning, organic and inorganic fertilizers. The semi-technology land management package was using half dosage (50%) of fertilizater of the full recommendation package, pruning, and trenches. The existing technology package was entirely carried out based on the farmers’ habits (without conservation and fertilizers). The coffee plantations were made into five blocks according to the above treatment package. The five treatment blocks were attempted to have relatively uniform plants (plant age, stand condition, and plant health). Each treatment block was 0.5 ha or a minimum plant population of 500 plants so that the study area was 2.5 ha or 2,500 plants.
The soil samples were randomly taken based on the diversity of topography in the field. Soil samples analyzed for their nutrients including pH, C-organic, soil N, available P, total P, total K, interchangeable bases, interchangeable Al, interchangeable H, Fe, and Mn. The dosage of lime and other fertilizer was applied based on the recommended dosage by Indonesian Coffee and Cacao Research Institute (ICCRI) (table 1). The application of lime and organic matter was made once (at the end of the rainy season), while fertilizer application was carried out twice, at the beginning and at the end of the rainy season. This activity was carried out at the coffee plantation location owned by farmers in Tanggamus.

The data observed included analysis of plant tissue to determine nutrient uptake and analysis of soil nutrient content after one year of application (carried out in 2nd year). The number of sampling plants was 50 plants per block/treatment or 10% of the treated plant population. Data were analyzed using the LSD test method to compare the effect of treatments on coffee productivity. Other data observed were plant pest and disease incidences, vegetative and generative plant growth scores, and coffee beans yields. The number of plant samples was 250 plants. Plant growth was scored using the following criteria:

1. **Excellent plant** (lush canopy and branching, shiny green leaves, no symptoms of leaf rust attack, no pest attack), and 81 to 100% of coffee beans in branches.
2. **Good** (dense canopy and branching, shiny green leaves, <5% of leaves infected with leaf rust, <5% of stems and branches affected by stem borer), and 61 to 80% of coffee beans in tree branches.
3. **Moderate** (branching and leaves are not dense, leaves are slightly yellowish, leaf rust attack is 5 to 10% and branches/stems are affected by stem borer 5 to 10%), and 41 to 60% of coffee beans in branches.
4. **Bad** (the canopy is not dense and branching rarely leaves 11 to 20% yellow, leaf rust and stem borer 11 to 20%, and 21 to 40% of coffee beans in branches.
5. **Very bad**. The canopy is not very dense, and the plant branches were less than four stems per plant, the leaves were entirely yellow, the attack of leaf rust and stem borer pests is > 20% and 0 to 20% of coffee beans in branches.

| Lime and Fertilizer   | Dosage (g plant⁻¹) |
|----------------------|--------------------|
| Dolomite             | 1,000              |
| SP36                 | 200                |
| Rock Phosphate       | 240                |
| Urea                 | 400                |
| KCl                  | 320                |
| Manure               | 10,000             |

*Source: Indonesian Coffee and Cacao Research Institute (ICCRI) [10].

3. **Results and discussion**

Observations of pests and diseases in coffee plants in the five treatments of robusta coffee cultivation are presented in table 2. The study showed that the presence of trenches, which functions as a water retainer and a place to dispose of coffee leaf litter and other organic materials, could increase the resistance of coffee plants to significant pests and diseases in coffee plants. The trenches around the coffee plant added with recommended dose of half or full fertilizer showed a smaller level of pest and disease attack compared to the cultivation method of farmers (treatment E). Trenches can also be a source of organic material needed by coffee plants to grow better. The study was in agreement with the previous research that disease control could be done by strengthening plant tissue with fertilization.
techniques [12]. The application of NPK fertilizer to rice plants could reduce the intensity of brown leaf spot (leaf blight) disease from 57.81% to 32.05% and striped spot disease from 8.55% to 2.48%. Applying K fertilizer to rice plants can also reduce the intensity of leaf blight by 20 to 30% compared to without K fertilizer [13]. Giving manure can also reduce the disease intensity of stem rot vanilla disease caused by the fungus *Fusarium oxysporum* from 88% to 52% and better than the use of organic pesticides from clove products [14]. The provision of different sources of phosphate elements has not yet shown an effect on observed pests and diseases of coffee plants. The vegetative growth of coffee plants was shown in table 3.

Table 2. The percentage of pest and disease attack on coffee plantation.

| Treatments                          | Pest (%) | Disease (%) |
|------------------------------------|----------|-------------|
|                                    | White flea | Cacao Pod Borer | Branch Borer | Fusarium Leaf blight |
| A (Full recommendation, P-36)      | 0.330 a | 0.033 a | 0.093 a | 0.022 a | 1.767 a |
| B (Full recommendation, rock phosphate) | 0.300 a | 0.033 a | 0.113 a | 0.016 a | 1.700 a |
| C (Half recommendation, P-36)      | 0.200 a | 0.067 a | 0.059 a | 0.004 a | 1.167 a |
| D (Half recommendation, rock phosphate) | 0.300 a | 0.067 a | 0.154 a | 0.011 a | 1.967 a |
| E (farmer)                         | 0.467 b | 1.000 a | 0.281 c | 0.045 b | 1.663 a |

The number in each column followed by the same lowercase letter is not significantly different according to the LSD test at the 5% level.

Table 3. The average result on growth score observation on the vegetative and final generative phase of coffee plants.

| Treatments                          | Growth Score | Productivity (kg ha⁻¹ year⁻¹) |
|------------------------------------|--------------|-------------------------------|
|                                    | Vegetative   | Final Generative              |
| A (Full recommendation, P-36)      | 2.86 a       | 2.80 a | 700 a |
| B (Full recommendation, rock phosphate) | 2.83 a   | 2.83 a | 680 a |
| C (Half recommendation, P-36)      | 3.00 b       | 3.20 b | 380 b |
| D (Half recommendation, rock phosphate) | 3.26 b    | 3.53 b | 370 b |
| E (farmer)                         | 4.70 c       | 4.70 c | 210 c |

The number in each column followed by the same lowercase letter is not significantly different according to the LSD test at the 5% level.

The study showed that coffee plants with A and B treatments, i.e., the full technology package, showed better growth. The recommendation for robusta coffee fertilization that has been issued by the ICCRI [10] is a general recommendation. Theoretically, the type and amount of the fertilizer needed by each type of plant, including for coffee plants, really depends on several important factors such as local environmental characteristics and conditions, varieties or clones used, plant age, and land management [15, 16]. The type and amount of fertilizer applied will interact with the nutrient elements in the soil so that it will affect its availability for plants. The differences in the soil nutrients, acidity, and temperature could be caused by interaction between nutrients [17]. Interactions between nutrients could be synergistic or antagonistic, and the interactions that were antagonistic are at risk of being bad for the process of their availability for plants. From the data above, it could be seen that the fertilizer dosage given is following the specific conditions of the location so that it results in a better plant growth performance compared to the half-recommended treatment or the farmer's method. Observations on the final vegetative and generative phase of the growth score were not significantly different, because the effect
of the treatment applied had been seen starting from the vegetative phase and this was the same until the plants entered the final generative phase.

The coffee plant productivity on the land treated with full or half recommended fertilization and land without fertilizer were shown in table 3. The study showed that the use of land trenches and fertilization produced 700 kg ha\(^{-1}\) y\(^{-1}\) of coffee beans, whereas that treated without the land trenches, and fertilization was lower (210 kg ha\(^{-1}\) y\(^{-1}\) coffee beans). It means that the trenches and fertilization could increase the productivity of the robusta coffee plant by 333%.

The soil analyses of the plots treated with A, B, C, and D are shown in tabel 4.

**Table 4.** Soil analysis results at the end of treatments.

| Treatment | A     | B     | C     | D     | E     |
|-----------|-------|-------|-------|-------|-------|
| pH H\(_2\)O | 4.97 a | 5.05 a | 5.28 a | 5.48 a | 4.72 b |
| KCl       | 4.22 a | 4.31 a | 4.64 a | 4.62 a | 4.20 a |
| % C-organic | 1.71   | 1.90   | 1.65   | 2.19   | 1.55   |
| % Nitrogen | 0.18   | 0.21   | 0.18   | 0.22   | 0.17   |
| Available P\(_2\)O\(_5\) (ppm) | 29.79 | 25.12 | 27.13 | 23.79 | 11.46 |
| Potential P (mg) | 55.81 | 54.37 | 41.23 | 41.34 | 26.53 |
| Potential K (mg) | 12.53 | 15.05 | 17.92 | 16.12 | 10.38 |
| Acidity Al-i | 0.37 | 0.31 | 0.26 | 0.16 | 0.21 |
| Kg H-i | 0.40 | 0.34 | 0.28 | 0.35 | 0.24 |
| K-e | 0.47 | 0.50 | 0.45 | 0.49 | 0.40 |
| Na-e | 0.51 | 0.54 | 0.52 | 0.56 | 0.53 |
| Ca-e (cmol kg\(^{-1}\)) | 4.85 | 5.02 | 4.96 | 5.28 | 4.48 |
| Mg-e | 1.07 | 1.28 | 1.11 | 1.30 | 1.02 |
| CEC | 16.12 | 18.63 | 17.24 | 20.02 | 12.23 |

The soil pH data are similar in both land with and without trenches, either in combination with a full or with half fertilization recommendations, ranged from 4.97 to 5.48. Based on table 3, it can be seen that there are differences in nutrient content between the land using trenches and those without land trenches. The N-total content in the plot treated with land trenches ranged from 0.18 to 0.22% and land without the trenches was 0.17%, whereas the P-available content was higher on the land trenches (23.79 to 29.79 ppm) (land trenches) compared with the none treated (11.46 ppm P). The K-dd elements in the land using trenches ranged from 0.47 to 0.49 me 100 g\(^{-1}\) and on the land without trenches ranged 0.40 me 100 g\(^{-1}\). The study showed that the nutrient content of NPK in the land using trenches was higher than land without the trenches. Loss of nutrients N, P, K, and Ca through surface runoff is generally greater than the losses through erosion [8]. This may be due to the transport selectivity process by surface runoff. Only the nutrients that can be dissolved in the surface runoff water are able to be transported by the slow surface flow rate, but on the land without a higher surface flow rate, it can transport the nutrients suspended in the sediment. This fact illustrates the importance of controlling runoff as early as possible by infiltrating as much rainwater as possible deeper into the soil. These efforts are critical to reduce nutrient loss, as well as to increase the supply and availability of water for increased crop production in dryland agriculture.

The results of the laboratory analysis of coffee leaves showed that there were not significantly different between the treatments (table 5). However, the P element was significantly different between the treatment of trenches and fertilization by farmers. In contrast, the N and K elements were not
significantly different. This was because of the addition of fertilization and the trenches has not been too much absorbed by the leaves. At the same time, there was more P element the leaves because of the results of soil analysis (table 4). It can be seen that the available P elements were higher in the treatment of trenches and fertilization than with the treatment of farmers.

Table 5. Data analysis result on the NPK fertilizer levels from coffee leaves

| Treatment                              | N     | P     | K     |
|----------------------------------------|-------|-------|-------|
| A (Full recommendation, P-36)          | 2.453 a | 0.107 a | 0.99 a |
| B (Full recommendation, rock phosphate) | 2.630 a | 0.113 a | 1.21 a |
| C (Half recommendation, P-36)          | 2.400 a | 0.093 a | 1.10 a |
| D (Half recommendation, rock phosphate) | 2.593 a | 0.097 a | 1.16 a |
| E (farmer)                             | 2.307 a | 0.093 b | 1.01 a |

The number in each column followed by the same lowercase letter is not significantly different according to the LSD test at the 5% level.

The use of trenches by farmers was initially intended to reduce dependence on chemical fertilizers and maximize the use of all parts of the coffee plant as well as soil conservation efforts aimed at increasing soil fertility. The skin of the coffee plant used to be thrown away without being fully utilized. In general, starting from the color of the leaves, it shows the difference between the land using trenches and fertilization and the farmer's method. In the treatment E, yellow leaves reached 20%, although the N content found in the leaves was not significantly different between treatments, likewise with pest attacks and coffee production.

Soil fertility conditions based on the results of the filed study indicate differences between land using trenches and land without trenches, so that it affects land productivity. The production of coffee beans shows differences in the amount, on land that used trenches and fertilizers heavier than farmers' land. This was thought to be due to the influence of high soil moisture content and high NPK fertilizer nutrient content on land using trenches and fertilization, which can be seen in table 4 and table 5. Soil using trenches will be able to maintain soil moisture due to the large amount of organic material applied into the soil in the process. Trenches that have been created can obstruct the flow rate of water so that the amount of water entering the soil increases and minimizes run off so that soil loss due to erosion decreases. Coffee plantation, when equipped with trenches, allow more runoff and soil to be carried off (erosion) into the trenches so that it is avoided from washing and transportation to other places, particularly to water bodies (rivers, reservoirs, etc.). As a result, soil damage due to the transport of topsoil by runoff and erosion is low. Also, the trenches could be filled with litter and coffee pruning leaves, and even fertilizer application can be done through the trenches so that rainwater should avoided and fertilization efficiency increases [19].

The existence of trenches conserved water to be collected and reduces the flow rate so that the infiltration rate increases. The increase in the infiltration rate is also due to the increased infiltration surface because the trench wall is also a place of infiltration. If the surface runoff and erosion are lower, then the infiltration of water that enters the soil using trenches will be higher than without trenches. Water availability in the root zone is influenced by the ability of surface runoff management so that most of the rainwater that falls on the land surface can enter the ground. Trenches conservation technique can collect rainwater and surface runoff so that more rainwater enters the soil. The presence of trenches and mulch cause the water that is stored in the trenches to seep more in-depth into the soil and distribute it into percolation water and flow sideways so that groundwater was stored in the land. This soil conservation technique could reduce the amount of erosion and at the same time reduce the amount of organic matter and nutrients losses by erosion because nutrient loss is directly related to the amount of erosion and is a function of the concentration of C-organic and these nutrients in the sediment [20, 21]. Through the application of adequate soil conservation techniques such as the manufacture of trenches,
which can control erosion as well as control the loss of organic matter and nutrients, especially N. The use of trenches can optimize nutrient absorption in plants so that plants will produce better. There was more nutrient availability on land using trenches, as shown by the results of testing the nutrient levels of N, P, and K in table 4 and table 5. This is presumably due to the role of trenches, which was able to suppress the amount of surface runoff and erosion, and was able to trap or hold topsoil which is rich in nutrients to be carried away by erosion and surface runoff and into the trenches. With the availability of sufficient nutrients and supported by the availability of adequate water, it will help to absorb nutrients more optimally compared to land that does not use trenches. The function of water for plants is the main compound forming protoplasm, as a solvent compound for the entry of minerals from the soil solution to plants and as a solvent for minerals which will be transported from one part of the cell to another [22].

Also, the high level of organic matter in the soil can also keep the soil temperature and the environment from being too high because it has an effect on the ripening period of the fruit; the too high temperature can cause incomplete maturation and prematurely dry fruit. If the environmental temperature is not optimal, there will be a fall of flowers and young fruit so that the final result of coffee plant production was low [23]. High organic matter content in the land could be due to the low carrying capacity of top soil by runoff and erosion and filling of trenches with litter and coffee pruning leaves that are protected from washing rainwater can increase soil pH as shown in table 4. When viewed from the soil pH in the trenches and fertilization treatment, the soil pH is higher than the farmer's treatment, meaning that the better soil pH will facilitate the absorption of nutrients for plants. This shows that trenches and fertilization can increase the productivity of robusta coffee plants because the high content of organic matter and other macroelements in the land causes a more optimum absorption of water and nutrients. Besides, the use of trenches and optimal fertilization can also increase soil fertility by increasing the nutrient content of N, P, K.

4. Conclusions
Conservation and fertilization treatments can improve the soil quality in the coffee plantation (increase the organic matter of nutrients N, P, K and soil pH), so that it can improve the performance of coffee plants, having better growth scores, resistance to pests and diseases and increased production to 333 %. By increasing the coffee production, it is expected to increase coffee farmers' income and support coffee exports, especially in Lampung province.

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