Analysis of the Effect of Several Types of Shade on the Productivity of Robusta Coffee

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Abstract. Coffee is a commodity that plays an important role in economic activity and is Indonesia’s leading export which contributes to foreign exchange for the country. The coffee market opportunity is quite potential due to increased export demand and domestic consumption. But when viewed from the development of the number of coffee productivity per year has decreased every year. The decline in coffee productivity was caused by many factors, one of which was the coffee shade plant. The purpose of this study was to analyze the factors that influence the types of coffee shade plants so that they have an impact on the level of coffee productivity. This study used 25 farmers as respondents in Jember Regency and Banyuwangi Regency. Observations on one of the coffee plantations in the Jember area with four different types of shade. The research variables to be measured include biotic factors, abiotic factors and management and productivity of coffee. Data collection used interviews and direct observations on coffee plantations. The results of this study indicate that different types of shade plants have an effect on coffee productivity. The results of measurement of biotic and abiotic factors present in each shade mostly have different results. With different factor levels, it will affect coffee growth which will affect the number of coffee cherries produced so that each type of shade has a different amount of productivity. For one year Gliricidia sepium has an average productivity yield of 2500 kg / hectare, Carica papaya has an average productivity yield of 1000 kg / hectare, Tectona grandis has an average productivity yield of 700 kg / hectare, and Falcataria mollucana has an average productivity of 450 kg / acres. The conclusion of this study is the use of different shade plants affects coffee productivity.

Keyword : Robusta Coffee, Shade Plant, Coffee Productivity

1. Introduction

Coffee is a commodity that plays an important role in economic activity and is Indonesia's leading export which contributes to foreign exchange for the country. The coffee market opportunity is quite potential because export demand and domestic consumption have increased [1][2]. In Indonesia, two types of coffee are most commonly used, namely Robusta coffee and Arabica coffee. Robusta coffee production reaches 81.96% with an average plantation area of 1.04 million hectares, while the rest is produced from Arabica coffee. Robusta types are more developed in Indonesia compared to Arabica types [3]. Robusta coffee production centers, especially in smallholder plantations from 2013 to 2017, reached 95.6% of Indonesia's total Robusta coffee production. But when viewed from the development
of the number of coffee production per year has decreased every year. According to data from the Directorate General of Plantation, the development of robusta coffee production from 2013 to 2017 tended to decline, with details of production amounting to 645.34 tonnes; 612.87 tons; 602.42 tons; 602.16 tons; 599.90 tons [5][1][3]. In addition to declining coffee productivity, according to the Indonesian Coffee Exporters and Industry Association, the export volume of Indonesian coffee also experienced a sharp decline, especially in 2013 to 2014, amounting to 534,023 tons to 381,816 tons [5][3].

The decrease in coffee productivity is caused by many factors. So far, the decline in coffee productivity tends to be associated with plant pests, nematodes and post-harvest processing. Garcia's research (2019) states that coffee production has decreased significantly due to the presence of nematodes in plantation land. In this case, there are still not many who have conducted research on other factors that cause a decrease in coffee production, namely coffee shade plants. Coffee shade plants can affect the productivity produced by coffee plants. Like the research of [4][6] that coffee shade plants can have a positive or negative effect on coffee productivity. Shade plants have an important function in coffee growth and productivity, because shade plants can control and protect coffee plants against environmental stresses such as high temperatures, bright light and humidity. Shade plants can also create differences in the physiological properties of coffee plants such as the high rate of photosynthesis, leaf area index and the size of the coffee beans produced [7][8]. Shade plants can create a microclimate in coffee plants. The existence of shade plants causes sunlight not to hit directly on coffee plants, because coffee plants are C3 plants that require shade [9][10][11]. C3 plants can be said to be shade-loving plants. This shade serves to increase the concentration of CO2 in the atmosphere. This will make it easier for plants to get CO2 so that it can increase the assimilation process [12]. However, coffee plants require different light intensity levels for each phase [10]. The nursery phase requires less light intensity than the generative phase. The intensity of the incoming light differs according to the characteristics of the shade plants used. The level of sunlight intensity on coffee plants greatly affects the physiology of the plant, so the type of shade plant used will affect the growth and productivity of coffee [15]. Coffee productivity varies according to the type of shade plant used and the type of coffee shade has different impacts on coffee plants [13]. In addition, the spatial distribution of shade can affect coffee growth and productivity. An appropriate distance between the shade and the coffee plant which is about one meter will be more effective for coffee plants [14].

Shade plants used for coffee shade must meet the required characteristics as shade for coffee plants. Plants that have coffee shade requirements include legume trees such as *Leucaena leuecephala* (lamtoro), *Falcataria mollucana* (sengon), *Gliricidia sepium* (gamal), *Cedrella toona* (toona), and *Erythrina lithosperma* (dadap) [17]. Therefore, the use of shade plants and shade maintenance patterns greatly affects the growth and productivity of coffee. With the use of coffee shade that matches the characteristics of coffee shade, coffee growth can be optimal because it will produce an environment that is in accordance with the requirements for growing coffee, especially Robusta coffee. The growth requirements for Robusta coffee plants can be optimal at temperatures between 60 °C to 65 °C. Suitable humidity will also maximize the growth of coffee plants, the relative humidity of Robusta coffee is around 70% to 85% [16]. Based on the explanation above, it is necessary to conduct research on the effect of coffee shade plants on coffee productivity. This study aims to analyze the factors that influence the types of coffee shade plants so that they have an impact on the level of coffee productivity.

2. Methodology

This study uses a mixed method research which combines qualitative and quantitative research. Qualitative research methods, namely methods that aim to examine the natural condition of the object, the key instrument in qualitative research is the researcher himself. Quantitative research methods are methods that aim to test the predetermined provisional answers and examine the relationship between variables in the form of the sample and the study population. This research method using descriptive
method. Descriptive research method aims to analyze and present in the form of systematic and accurate data. Data collection methods used interviews and observations on coffee plantations. Interviews using snowball sampling techniques directly on primary sources. Snowball sampling technique is a sampling technique with the principle of finding information or answers to problems through one informant to another. There is some information needed in this study, including coffee and shade management, fertilization, pests that attack and coffee productivity in the last 3 years. The snowball sampling technique itself is also known as the snowball technique, which is a technique that obtains an unlimited number of samples through a rolling process from first responders to other respondents. This study used a linear snowball sampling technique. The following Figure 1 is a snowball sampling technique carried out in this study.

![Figure 1. Snowball Sampling Technique](image)

Based on Figure 1. The snowball sampling technique carried out in this study consists of several stages, the first stage symbolized by the letter A is conducting interviews with the initial respondents. Furthermore, from the initial respondent's suggestion, the researcher conducted further interviews with the second respondent who was denoted by the letters B and C then so on until it reached the final respondent.

Research respondents were 28 coffee farmers in Jember Regency and Banyuwangi Regency. The research variables to be measured in this study are management to coffee productivity, biotic factors and abiotic factors. Processing to coffee productivity is carried out using the interview method with respondents, namely coffee farmers. Biotic and abiotic factors were carried out by measuring methods on coffee plantations with different shade plants. Each biotic and abiotic factor measurement is carried out 3 times and then the results are averaged, so that accurate measurement results are obtained.
The following Figure 2 shows the various types of measurements of the biotic and abiotic factors of this study.

Based on Figure 2. above, there are several aspects to be observed in coffee plantations. These aspects are grouped into biotic and abiotic factors. The biotic factor consists of 8 aspects, namely (1) The height of the shade plants measured by walking sticks, namely using a simple measurement in the form of a stick of approximately 30-50cm. This measurement uses a geometric principle with a triangle similar to the formula AB = (BCxPQ): QR. (2) The length of the shade is measured by taking a leaf sample and measured using a measuring roller. (3) Shade area or crown area (diameter) is carried out by using a canopy shape projection measured in two parts of the projection using raffia ropes, in addition to that, crown density is carried out by observing the condition of the interlocking crown and the distance between the canopy. (4) The distance between shade and coffee plants is measured using a meter. (5) The morphology of coffee is treated with coffee age, accompanied by information from the farmer. (6) The distance between the coffee and other coffees was measured using a meter and (7) Weeds were observed for the density of weeds on the soil surface and even on the coffee plants. While the abiotic factor consists of 10 aspects, namely (1) the slope of the place is measured using a clinometer. (2) The altitude of the place is measured using an altimeter. (3) Air pressure is measured using a barometer. (4) Air temperature is measured using a thermometer. (5) Air humidity is measured using a hygrometer. (6) soil pH and (7) soil moisture was measured using a soil tester. (8) Light intensity is measured using a luxmeter. (9) Soil litter is measured using a ruler. (10) The characteristics and texture and type of soil are carried out by observation. Biotic and abiotic factors were observed and measured directly on one of the coffee plantations owned by private farmers in Jember Regency.
3. Result

The following are the research results obtained in this study consisting of three aspects, namely biotic factors, abiotic factors and processing and coffee productivity. Measurements of biotic and abiotic factors were carried out on coffee plantations that have four different types of shade plants, namely Gliricidia sepium (*Gamal*), Carica papaya (*Papaya*), Tectona grandis (*Jati*), and Falacataria mollucana (*Sengon*). The following Figure 3. is a coffee plantation and its shade observed in this study.

![Coffee plantations and their shade](image)

(a) Shade of *Gliricidia sepium* (*Gamal*), (b) Shade of *Carica papaya* (*Papaya*), (c) Shade of *Tectona grandis* (*Jati*), (d) Shade of *Falacataria mollucana* (*Sengon*)

3.1 Biotic Factors

The following is Table 1. It is the measurement result of biotic factors in four coffee plantations with different shade as follows.

| No. | Measurement Type     | *Gliricidia sepium* | *Carica papaya* | *Tectona grandis* | *Falacataria mollucana* |
|-----|----------------------|---------------------|-----------------|-------------------|-------------------------|
| 1.  | Shade plant height   | 2 m                 | 3 m             | 10-15 m           | 12-16 m                 |
| 2.  | Leaf length          | ±15 cm              | ± 40 cm         | ± 20 cm           | ± 25 cm                 |
| 3.  | Shade area (diameter)| 1-2 m               | 2.3 m           | 3.5 m             | 2.3 m                   |
4. Shade plant spacing 2.5 m 2.5 m 1 m 0.75 m
6. Coffee plant age 5 tahun 5 tahun 5 tahun 5 tahun
7. Coffee plant height ±1.5 m ±1.5 m ±1.5 m ±1.5 m
8. Coffee spacing 2.5 m 2.5 m 2.5 m 2.5 m
9. Weeds on the ground Not too much (1 cm) Not too much (0.5 cm) Lot (2 cm) Lot (2 cm)

Table 1. Measurement Results of Biotic Factors

Based on table 1, it can be seen that there are several factors that have the same values and conditions. These same values and conditions mean that these factors have no effect on coffee productivity growth. These factors include the age of the coffee, the height of the coffee plants and the spacing of the coffee, all of which have the same measurement results for the four shade plants. Other factors have relatively different measurement results. The height of the shade plants of the four different from the lowest height is Gliricidia sepium. Gliricidia sepium also has a low leaf size yield value of ± 15 cm. The lowest shade area is Gliricidia sepium. But at the lowest spacing were Tectona grandis and Falacataria mollucana with measurement results of 1 m. For the lowest weeds were in the shade of Gliricidia sepium and Carica papaya with a yield value of 2 cm.

3.2 Abiotic Factors

The following is Table 2. It is the measurement results of the abiotic factors in four coffee plantations with different shade as follows.

| No. | Measurement Type       | Gliricidia sepium | Carica papaya | Tectona grandis | Falacataria mollucana |
|-----|------------------------|-------------------|---------------|-----------------|----------------------|
| 1   | Slope of Place         | Flat              | Flat          | Flat            | Flat                 |
| 2   | Altitude Place         | 330 mdpl          | 329 mdpl      | 326 mdpl        | 315 mdpl            |
| 3   | Tekanan udara          | 1009 mb           | 1011 mb       | 1010 mb         | 1010 mb             |
| 4   | Suhu udara             | 32°C              | 30°C          | 35°C            | 35°C                |
| 5   | Air humidity           | 71% RH            | 62% RH        | 61% HR          | 59% HR              |
| 6   | soil pH                | 6.7               | 6.7           | 6.7             | 6.6                  |
| 7   | Soil moisture          | 60%               | 60%           | 30%             | 20%                  |
| 8   | Intensitas cahaya      | 1948 Cd           | 1931 Cd       | 1756 Cd         | 1382 Cd             |
| 9   | Litter on the ground   | 3 cm              | 2 cm          | 5 cm            | 2 cm                 |
| 10  | Soil characteristics   | Organic soil      | Organic soil  | Organic soil    | Organic soil         |
| 11  | Soil texture           | Smooth            | Smooth        | Smooth          | Smooth               |
| 12  | Jenis tanah            | Humus soil        | Humus soil    | Humus soil      | Humus soil           |

Table 2. Measurement Results of Abiotic Factors

Based on Table 2, it can be seen that there are several factors that get the measurement results that are not too different from the four shading, namely altitude, slope, air pressure, humidity, soil pH, soil texture, soil type, soil characteristics. With the same results or not too much different, it means that there is no significant difference between the types of shade and the growth and productivity of coffee. Other factors have different results, for the air temperature that has the lowest value is the Carica papaya shade of 30 °C. A much different difference was also found in the light intensity factor, the shade that got the lowest value was Falacataria mollucana at 1328 Cd.
3.3 Management and Productivity of Coffee

The following Figure 4 is the average result of the interview results for coffee productivity from four different shade, namely Gliricidia sepium, Carica papaya, Tectona grandis, and Falacataria mollucana.

![Coffee Productivity](image)

**Figure 4. Average Coffee Productivity**

Based on Figure 4, it can be seen clearly that the productivity of coffee from each shade has a different amount of production. For one year, Gliricidia sepium has an average productivity yield of 2500 kg/hectare, Carica papaya has an average productivity yield of 1000 kg/hectare, Tectona grandis has an average productivity yield of 700 kg/hectare, and Falacataria mollucana has an average productivity of 450 kg/hectares. From the results of the coffee productivity data above, each type of shade plant has a different amount of coffee productivity. When associated with the results of measurement of biotic and abiotic factors present in each shade, most of them have different results. With different factor levels, it will affect coffee growth which will affect the number of coffee cherries produced so that each type of shade has a different amount of productivity.

The results of the interviews with some of the questions posed to farmers are as follows. The first question "how is the management of coffee plants carried out by farmers?" Most of the farmers' answers were the same, namely pruning the branches of the coffee plant before and after harvesting. The second question "How is fertilization done by farmers?" Most farmers have the answer that fertilization is applied twice a year, but there are some farmers who apply fertilizer once a year. The next question is "how far have shade plants been managed?" For shade plants Gliricidia sepium and Tectona grandis, pruning will be carried out every time it starts the rainy season. Meanwhile, for Carica papaya and Falacataria mollucana no pruning was done. The next question "Pests that attack" for pests that attack on each shade are almost the same, namely mealybugs, stem borer pests and pests that attack the roots of coffee plants.
4. Discussion

Based on the results of research on four types of shade plants for which biotic factors were measured, there were several factors that had the same measurement value and conditions. Factors that have the same value include the age of the coffee, the height of the coffee plants and the spacing of the coffee. From the same results with the same conditions, it can be concluded that these factors have no effect on the growth and productivity of coffee. This is due to the existence of the same value of the four shade so that it has the same impact on coffee growth and productivity. Meanwhile, if viewed from the shading area factor of the four shade plants, they have almost the same shade area (diameter), which is about 2 m on average, but not the same shade area means that it does not affect the growth and productivity of coffee. Even though they have the same shade area, each shade has different characteristics of leaves, branches, and plant height. This will affect the growth and productivity of coffee. With the characteristics of the leaves, branches and different heights will directly affect the level of light intensity on the coffee plant. In addition, each shade also has a different distance from the coffee plant, so it will affect the level of light intensity that enters.

Furthermore, the research results from the measurement of abiotic factors, there are several factors that have the same measurement results and the same conditions, including slope, altitude, air pressure, soil pH, soil characteristics, texture and soil type. These factors have the same results because the research sites are still in the same area, so in this study some of these factors did not affect the growth and productivity of coffee. There are several factors that have differences, one of which is the light intensity with the measurement results of the four different shades. This is due to the existence of different types of shade plants. If the intensity of the incoming light has an optimal value or is in accordance with the requirements for growing coffee, it will have a positive impact on coffee growth and productivity. Likewise with the factors of air humidity, air temperature, soil humidity have different results even though the differences are not too far away. For texture, characteristics, and soil type, because the four shade plants are in the same area, it has no effect, but the litter factor in this soil will greatly affect the growth and productivity of coffee. The difference in the level of litter will affect soil moisture. With differences in soil moisture, it will have an impact on coffee plants, with too much soil conditions there will usually be a lot of nematodes or root pests that attack, and vice versa if the soil moisture is too dry it will result in less than optimal coffee growth.

Based on the results of the interview, the productivity of coffee produced was different from each type of shade. The coffee productivity that gets the highest yield is Gliricidia sepium with coffee productivity of 2500 kg/hectare. When viewed from the characteristics of Gliricidia sepium, this plant has characteristics in accordance with the characteristics of coffee shade plants and the area of shade used is 2m. The result of the factor of 1948 Cd light intensity level, air temperature reached 32 ° C, air humidity 71RH and soil humidity 60%. Of these biotic and abiotic factors as well as the characteristics that suit coffee shade requirements, Gliricidia sepium can make a positive impact on coffee growth and productivity.

5. Conclusion and Recommendation

From the results and data analysis, it can be concluded that the use of shade plants can affect coffee productivity. There are many abiotic and biotic factors that affect the types of shade plants that affect coffee productivity. Biotic factors that influence include shade area, shade height, spacing and leaf length. Abiotic factors that affect, among others, light intensity, air temperature, humidity, soil moisture and soil litter.
Acknowledgments

Thank you for the University of Jember for facilitating this research. Thank you to the 2020 postgraduate research team and the ministry of higher education technology research.

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