Farmers understanding and practices on shading and pruning for Arabica coffee – a survey and analysis on the effects to the yields

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Abstract. This study aimed to identify and formulate the influence and correlation of farmers’ practices and understanding related to the shading and pruning on the yields of their Arabica coffee. The research was carried out in Bolokan Village, Lembang Tiroan Bittuang, Tana Toraja Regency, South Sulawesi-Indonesia. The research was in the form of surveys (study literature, observations, and interviews), with the selection of samples carried out deliberately (purposive sampling). The data was analysed with multiple linear regression using SPSS software. The results showed that the different levels of practices related with shading and pruning management provided significant effect and correlation with the yields of coffee plants. The generated multiple linear regression equation was $Y = 27.983 + 1.131X_1 + 0.591X_2 + 2.575X_3 + 1.050X_4 + 0.820X_5 + 1.967X_6 + 1.185X_7 + 0.313X_8 + 0.823X_9$. Factors from aspects of maintenance techniques related with shading and pruning could increase the production and productivity of Arabica coffee plants. Variables of plant height adjustment, flowering and fruiting stimulation through shading, production pruning, understanding of shade plants benefits and pests and diseases control were stated to have an influence on yields (fruit) of coffee plants, while shade management, pruning time, rejuvenation pruning, and permanent shade plants were declared to have no significant effect.

1. Introduction

The area of coffee plantations in Indonesia in the 1980-2017 period tended to increase. In 1980, the area of Indonesian coffee plantations was 707,464 hectares. Within a period of twenty years, the area of coffee plantations increased by 74.33% to 1,233,294 hectares. Nevertheless the average growth rate of coffee area in Indonesia in the 1980-2017 period was not too high, on average it only increased by 1.61% per year or increased 14,212 Ha / year [1].

South Sulawesi is one coffee production centres in Indonesia with large plantation area. In 1016, the coffee area in this province was 73,429 hectares, however the area slightly declining to 71,473 hectares in 2020 [2]. This province is especially also one of the Arabica coffee plantations centres where smallholder farmers contribute to coffee in Indonesia. Specialty Arabica coffee is found in Enrekang (Kalosi Specialty Coffee) and Tana Toraja (Toraja Specialty Coffee) districts, while grade 1 Arabica coffee is found in Gowa and Bantaeng districts [3].

One of the best types of Arabica coffee in the world that is the one produced in Tana Toraja district. It has been widely known abroad as the specialty of Tana Toraja coffee (Toraja Specialty Coffee) and has obtained a Geographical Indication Certificate (GIS) in 2013. Since a few years ago,
Toraja coffee has been exported to foreign countries at quite high prices, such as Germany, Japan and America. This coffee is preferred for its distinctive taste and aroma [4].

There are two kinds of shade plants for coffee, they are temporary shade and permanent shade. Temporary shading should be tidied at the beginning of the rainy season so it is not overly overgrown. In the permanent shade, the lowest branching should be cultivated 1-2 meters above the coffee tree, therefore trimming should be done sufficiently. There is also a set of pruning so that the branching is arranged in order to maintain air circulation [3].

There are several benefits of shade plants for coffee such as to reduce the intensity of sunlight, to reduce the temperature difference between day and night, to maintain a more stable microclimate, to become source of organic matter, to act as windbreaks and to prevent erosion. The high intensity of sunlight and temperature in coffee plantations have implications for the amount of carbon assimilation, decreased photosynthesis efficiency and stomatal conductivity [5].

Despite the benefits of shading, the practice in the field by farmers is highly dependent on their understanding as well as availability of resources [6]. Therefore, farmers’ knowledge and perception become significant factors to consider before formulating improvement programs and efforts.

2. Methodology
This research was carried out in Bolokan Village, Lembang Tiroan, Bittuang, Tana Toraja Regency, South Sulawesi. Research location is at an altitude of 1,300-1700 m asl, which has a topical climate, with average humidity ranging from 82% - 86%, air temperature of 16° C-26° C, rainfall ranges between 1500mm / year to 9000 mm / year.

This research was in a form of survey which consisted of study literature, field observations, and interviews. The determination of the location of the research was carried out intentionally (purposive sampling) based on the consideration that the location was in Tana Toraja Regency which was one of the centers of coffee development.

The data analysis was multiple linear regression to see the effect of different levels of shade on flowering and fruiting of coffee plants. The form of multiple linear type production functions can be stated as follows

$$Y = a + bX_1 + cX_2 + dX_3 + eX_4 + fX_5 + gX_6 + hX_7 + iX_8 + jX_9$$ (1)

Where:
- $Y$ = Average of fruit yield per plant (output quantity)
- $X_1$ = Plant height
- $X_2$ = Shading arrangement
- $X_3$ = Flowering and fruiting
- $X_4$ = Pruning time
- $X_5$ = Production pruning
- $X_6$ = Rejuvenation pruning
- $X_7$ = Shade plants benefits
- $X_8$ = Permanent shade plants
- $X_9$ = Pest and disease control
- $a$ = Intercept
- $b$ = Regression coefficient for plant height
- $c$ = Regression coefficient for shading arrangement
- $d$ = Regression coefficient for flowering and fruiting
- $e$ = Regression coefficient for Pruning time
- $f$ = Regression coefficient for production pruning
- $g$ = Regression coefficient for rejuvenation pruning
- $h$ = Regression coefficient for shade plants benefits
- $i$ = Regression coefficient for permanent shade plants
- $j$ = Regression coefficient for pest and disease control.
Data obtained from the field were generally qualitative in nature, before being analyzed in multiple linear regression scoring was carried out on the factors of the coffee plant maintenance techniques. Scores are given for each factor maintaining coffee plants based on the results of interviews, library research and observations presented in tabular form. Table 1 shows the scoring for each factor.

Table 1. Weighting criteria for Arabica coffee shading plants and practices

| No | Observation aspects | Farmers practices | Score |
|----|---------------------|-------------------|-------|
| 1  | Shade plant height  | 1 8 metres        | 100   |
|    |                     | 2 6 metres        | 75    |
|    |                     | 3 4 metres        | 50    |
|    |                     | 4 2 metres        | 25    |
|    |                     | 5 Not considered  | 0     |
| 2  | Shading arrangement | 1 High shading coverage | 100 |
|    |                     | 2 Middle shading coverage | 75  |
|    |                     | 3 Low shading coverage | 50  |
|    |                     | 4 No shading       | 25    |
| 3  | Treatments during flowering and fruiting period | 1 Shading reduce | 100 |
|    |                     | 2 Pruning/trimming | 75 |
|    |                     | 3 Fertilizer application | 50 |
|    |                     | 4 Unnecessary branches clearance | 25 |
|    |                     | 5 No treatment     | 0     |
| 4  | Production pruning  | 1 When plants do not yet bear fruit, prune the shape of a single rod and double rod | 100 |
|    |                     | 2 When plants do not yet bear fruit, prune the shape of a single rod or double rod | 75 |
|    |                     | 3 When plants are bearing fruit, prune the shape of a single rod and double rod | 50 |
|    |                     | 4 When plants are bearing fruit, prune the shape of a single rod or double rod | 25 |
|    |                     | 5 Did not perform production pruning | 0 |
| 5  | Rejuvination pruning | 1 Early rainy season and before fertilizer application and before flowering; prune all of the: turning branches, overlapping branches, bud shoots) | 100 |
|    |                     | 2 Early rainy season or before fertilizer application or before flowering; prune all of the: the turning branches, overlapping branches, bud shoots) | 75 |
|    |                     | 3 During dry season or after fertilizer application or during flowering; prune all of the: the turning branches, overlapping branches, bud shoots) | 50 |
|    |                     | 4 During dry season and after fertilizer application and during flowering; prune all of the: the turning branches, overlapping branches, bud shoots) | 25 |
|    |                     | 5 Did not perform rejuvenation pruning | 0 |
| 6  | Farmers understanding regarding pruning | 1 Shade plants form root nodules | 100 |
|    |                     | 2 Planting canopy and architecture | 75 |
|    |                     | 3 High Nitrogen availability | 50 |
|    |                     | 4 Less competition for lights | 25 |
|    |                     | 5 Pruning provide no benefits | 0 |
| 7  | Type of Shade plants | 1 Leucaena (Leucaena leucocephala) | 100 |
|    |                     | 2 Tiger's claw (Erythrina variegata) | 75 |
|    |                     | 3 Albizia (Albizia chinensis) | 50 |
|    |                     | 4 Tephrosia (Albizia chinensis) | 25 |
|    |                     | 5 No shade plants | 0 |
| 8  | Pest and disease control | 1 Mechanical and biological control | 100 |
|    |                     | 2 Mechanical control | 75 |
|    |                     | 3 Control with specific pesticide | 50 |
|    |                     | 4 Control with other chemicals | 25 |
|    |                     | 5 Did not perform pest and disease control | 0 |
3. Result and Discussion

3.1. Shade Aspect
Shade tree species affect the amount of sunlight intensity that can be absorbed by coffee plants. The amount of sunlight will affect the physiological processes of plants. Therefore, the use of various types of shade plants on coffee plants and their management practices will affect the growth, production and quality of the coffee that will be produced [7]. When the coffee plant does not have or lack shade, it could experience overbearing which causes the coffee plant to dry out quickly [8]. Table 2 presents results of shade aspects understood and practised by the surveyed farmers.

| Aspects                  | %   |
|--------------------------|-----|
| Level of shades          |     |
| Low or no shade          | 33.33 |
| Medium shades            | 33.33 |
| High shades              | 33.33 |
| Type of shade plants     |     |
| Leucaena (*Leucaena leucocephala*) | 100.00 |
| Albizia (*Albizia chinensis*) | 0.00 |
| Tephrosia (*Albizia chinensis*) | 0.00 |
| Others                   | 0.00 |
| Pruning frequency        |     |
| 2 times / year           | 100 |
| Once a year              | 0   |
| Never                    | 0   |
| Others                   | 0   |
| Average yields           |     |
| Yields per plant (kg)    | 2.06 |
| Production per hectare (tons) | 2,382.05 |

Primary Data Sources
Permanent shade plants used by all surveyed farmers was Leucaena. The selection of Leucaena as shade plants was due to farmers understanding that this plant had several qualities such as root nodules, easily managed, has a high N content and was resistant to pests infestation. Too dense shading however, might result in poor response of coffee plants to fertilization. Even worse, high humidity conditions will stimulate the development of fruit borer pests. Therefore appropriate selection and use of shade plant could make significant results.

3.2. Multiple regression results
The results of the complete multiple linear regression analysis is summarized and elaborated as seen in table 3.

| Regression Model | Coefficient of Regression Direction | Probability | Information                |
|------------------|--------------------------------------|-------------|----------------------------|
| Constant (intercept) | 27.983                             | 0.829       |                            |
| Plant height     | 1.131                               | 0.002       | Significantly influential (real) |
| Shading arrangement | 0.591                               | 0.644       | Not significantly influential (not real) |
Based on the multiple linear regression, an equation can be formulated based on value shown in table 2. The formula correlates factors of plant height (X1), shading arrangement (X2), flowering and fruiting (X3), pruning time (X4), production pruning (X5), rejuvenation pruning (X6), shade plants benefits (X7), permanent shade plants (X8), and pest and disease control (X9); all were determinat to the average fruit yield per plant. (Y). The equation obtained was:

\[
Y = 27,983 + 1,131X_1 + 0.591X_2 + 2,575X_3 + 1,050X_4 + 0.820X_5 + 1,967X_6 + 1,185X_7 + 0,313X_8 + 0,823X_9
\]

The equation reflects the correlation between each factor with the increase of yield (fruit) formation value. Each value preceding the factor indicates percentage of increase in the value of yield (fruit) formation when the factor in hand is also increased 1 level.

### 3.3. Coefficient of Determination

The coefficient of determination (R^2) is used to measure the extent of the model's ability to explain independent variable variations. The coefficient of determination value is between 0 and 1. A small R^2 (close to 0), means the ability of the independent variable is very limited, and close to 1 means that the independent variable almost gives all the information needed to predict the dependent variable as presented in table 4.

| Model | R Square | R | Adjusted R Square | Std. Error of the Estimate | R Square Change | F Change | df1 | df2 | Sig. F Change |
|-------|----------|---|------------------|---------------------------|-----------------|----------|-----|-----|---------------|
| 1     | 0.992a   | 0.984 | 0.972            | 24.09838                  | 0.948           | 77.439   | 9   | 11  | 0.000         |

Based on the results of calculations using multiple linear regression analysis, the coefficient of determination obtained was an R square value of 0.984, meaning that the influence of shade on coffee fertilization could be explained by controlling pests and diseases, increasing understanding on benefits of shade plants, appropriate pruning time, treatment to stimulate flowering and fruiting, production pruning practice, shade plant height adjustment, treatment for shade management, practice of rejuvenation pruning, permanent shade plants existence. Beyond that, the value was determined by other variables outside the variables used.

### 3.4. Simultaneous Significant Testing (f-Test)

Simultaneous test with the F-test aimed to determine the effect of the dependent variable together on the independent variable. The F-test basically shows whether all the independent variables included in the model have an overall influence on the dependent variable as presented in table 5.
Table 5. F-Test Results for all variables

| Model            | Sum of Squares | df | Mean Square | F     | Sig. |
|------------------|----------------|----|-------------|-------|------|
| Regression       | 404269.949     | 9  | 44918.883   | 77.349| .000*|
| Residual         | 6388.051       | 11 | 580.732     |       |      |
| Total            | 410658.000     | 20 |             |       |      |

a) Dependent Variable: Yield average per plant
b) Predictors: (Constant), all tested factors

Explanation of the multiple linear regression analysis results is that the model was feasible and assumption which stated that the shade factors did not affect the flowering and fruiting of coffee plants (H0) were rejected, since the results showed that the shading factors had an influence on production so the H1 was accepted.

3.5. Significant Testing of Individual Parameters (T Statistical Test)
Partial test with T-test was conducted to determine the magnitude of the influence of each factor independently to the influence of shade on coffee plants. The results is presented in table 6.

Table 6. T-test results for all variables.

| Model                          | Unstandardized Coefficients | Standardized Coefficients | t    | Sig. |
|--------------------------------|-----------------------------|---------------------------|------|------|
|                                | B                           | Std. Error                | Beta |      |
| Constant (intercept)           | 27.983                      | 126.325                   | .222 | .829 |
| Plant height                   | 1.131                       | .289                      | .321 | 3.907| .002 |
| Shading arrangement            | .591                        | 1.241                     | .178 | .476 | .644 |
| Flowering and fruiting         | 2.575                       | .877                      | .241 | 2.938| .014 |
| Pruning time                   | 1.050                       | 1.268                     | .326 | .828 | .425 |
| Production pruning             | .820                        | .307                      | .207 | 2.668| .022 |
| Rejuvenation pruning           | 1.967                       | 1.095                     | .130 | 1.797| .100 |
| Shade plants benefits          | 1.185                       | .318                      | .218 | 3.725| .003 |
| Permanent shade plants         | .313                        | 1.669                     | .011 | .188 | .855 |
| Pest and Disease Control       | .823                        | .208                      | .196 | 3.951| .002 |

T-test results in multiple linear regression analysis showed p-values for each of the factors. If the p value < significant level of 0.05 means the effect of independent variables significantly influencial. The T-test conducted produced the following answers:
- Plant height had a probability value of 0.002 < 0.05 indicating that it was significant. In conclusion, plant height had a significant effect on yields (fruit) of coffee plants.
- The shade arrangement had a value of 0.644 > 0.05 indicating that it was not significant, meaning there was no significant effect of the frequency of treatment for shade management to the yields (fruit) of the coffee plant.
- Flowering and fruiting had a value of 0.014 < 0.05, which means significant, or there was significant effect between the frequency of treatment to stimulate flowering and fruiting through shading to the yields (fruit) of the coffee plants.
- Pruning time had a value of 0.425 > 0.05 which means it was not significant. There was no significant effect between the time of pruning to the yields (fruit) of coffee plants.
- Production pruning had a value of 0.022 > 0.05 which means it was significant. There was a significant influence between production pruning on the yields (fruit) coffee plants.
• Rejuvenation pruning had a probability value of 0.100 > 0.05 which means it was not significant. In conclusion, rejuvenation pruning had no significant effect on the the yields (fruit) of coffee plants.
• Understanding the benefits of shade plants had a probability value of 0.003 > 0.05 which means it was significant. There was significant effect between farmers understanding about the benefits of shade plants on the yields (fruit) coffee plants.
• Existence of permanent shade plants had a probability value of 0.850 > 0.05 which means that it was not significant. There was no significant effect of the permanent shade plants on the yields (fruit) coffee plants.
• Pest and disease control had a probability value of 0.002 < 0.05 which means that it had a significant effect on on the yields (fruit) coffee plants.

4. Conclusion
Several farmers practices had given significant effect on the yiels of Arabica coffee in the study location. These practices such as plant height adjustment, flowering and fruiting stimulation, production pruning, understanding of the benefit of shade plants and pest and diseases control. Whereas shading management, pruning time, rejuvenation pruning and permanent shade plants were declared to have no significant effect on the yield of farmers surveyed coffee plants.

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