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STUDY OF THE EFFECT OF CULTIVATION PATTERNS AND COFFEE FRUITS BORING PEST ATTACKS (CBF) ON THE PHYSICAL QUALITY AND EXPORT FEASIBILITY OF ARABICA COFFEE (Coffea arabica L.) IN NORTH TAPANULI DISTRICT

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Abstract

Arabica coffee is one of Indonesia's leading export commodities that is highly dependent on the physical quality of the beans and the accuracy of cultivation practices. This study aims to examine the effect of cultivation patterns and Coffee Berry Borer (PBKo) attacks on the physical quality and export feasibility of Arabica coffee in North Tapanuli Regency. The method used is a descriptive quantitative approach with field surveys, direct observation, and laboratory tests on coffee beans from 91 farmers assisted by PT Sumatera Specialty Coffee (SSC). Data were analyzed using descriptive statistics, multiple linear regression, and Pearson correlation. The results showed that good cultivation patterns significantly improved the physical quality of coffee, while PBKo attacks had a negative impact on export feasibility. It was found that selective harvesting techniques and integrated pest control significantly reduced the number of defective beans and increased the uniformity of bean size and color. These findings confirm that the integration of high-standard cultivation practices and effective pest management is needed to improve the competitiveness of Arabica coffee from North Tapanuli in the global market.

Keywords: ***Arabica coffee, cultivation patterns, PBKo, physical quality, export, North Tapanuli.***

INTRODUCTION

Coffee is one of Indonesia's leading commodities that has a strategic role in the national economy, both as a source of income for farmers, a contributor to state foreign exchange, and a raw material for the food and beverage industry (Directorate General of Plantations, 2015). Indonesia is ranked fourth as the largest coffee producer in the world after Brazil, Vietnam, and Colombia, with a significant export contribution reaching 67% of total national production (AEKI, 2021; ICO, 2021). In a global context, Arabica coffee has a high commercial value due to its distinctive taste, complex aroma, and superior sensory characteristics that are attractive to the international market (Specialty Coffee Association of America [SCAA], 2020). However, the quality of Arabica coffee produced is highly dependent on the cultivation practices and post-harvest treatments applied by farmers. The physical quality of coffee beans, including size, color, and level of defects, are the main indicators of export eligibility according to international standards such as SCAA and SNI 01-2907-2008 (BSN, 2008). On the other hand, the presence of Plant Pest Organisms (OPT) such as Hypothenemus hampei (coffee berry borer) and Araecerus fasciculatus (warehouse beetle) is a serious challenge that can significantly reduce the quality of coffee beans (Munawaroh et al., 2021; Sylva, 2023). These pest attacks not only reduce the quantity of the harvest but also cause physical defects such as holes and discoloration that can result in rejection in the export process.

North Tapanuli Regency is one of the leading Arabica coffee production centers in North Sumatra Province, with a smallholder plantation area reaching 16,474 hectares and a production of 16,036 tons in 2021 (North Sumatra Plantation Service, 2022). This area has an ideal agro-ecosystem for Arabica coffee cultivation, especially in Siborong-borong, Sipahutar, and Pagaran Districts. However, a report from the Belawan Agricultural Quarantine Center noted fluctuations and a decrease in the volume of coffee exports from North Sumatra during the 2014–2020 period, which was thought to be influenced by the problem of coffee bean quality that did not meet export standards (BBKP Belawan, 2021). One of the coffee exporting companies that actively provides coaching in this region is PT Sumatera Specialty Coffee (SSC). Through partnerships with farmers, PT SSC provides support

in the form of superior seeds, cultivation training, and post-harvest processing facilities. However, even though the partnership has been running, the quality of Arabica coffee from this region has not consistently met export quality standards, allegedly due to suboptimal cultivation practices and ineffective control of OPT as a whole (Bastian, 2022).

Previous studies have confirmed that cultivation patterns have a major contribution to coffee quality. For example, Asfirmanto et al. (2013) showed that cultivation practices contributed up to 63.5% to the taste score of Arabica coffee in Gayo. In addition, research by Viccy Leonardo and Noril Milantara (2023) emphasized the importance of controlling OPT such as Hypothenemus hampei to maintain the quality of coffee beans. Therefore, it is necessary to conduct a scientific study that comprehensively assesses how cultivation patterns and OPT attack levels affect the physical quality and export eligibility of Arabica coffee, especially for farmers assisted by PT SSC in North Tapanuli Regency. By considering the urgency of improving the quality of Arabica coffee as a leading export commodity and the need for effective cultivation management and OPT control strategies, this study was conducted. The focus of the study is directed at analyzing the relationship between cultivation patterns and the level of coffee berry borer attacks on the physical quality and export feasibility of Arabica coffee in North Tapanuli Regency. The results of this study are expected to provide real contributions in formulating strategies for improving the quality of national coffee that is sustainable and highly competitive in the global market.

LITERATURE REVIEW

Arabica Coffee as an Export Commodity

Arabica coffee (Coffea arabica L.) is one of the main commodities in the global coffee trade because it has a more complex taste, balanced acidity, and distinctive aroma compared to Robusta coffee. According to the Specialty Coffee Association of America (SCAA), Arabica coffee is classified as "specialty coffee" if it meets strict physical and sensory requirements, including water content, bean size, and number of defects (SCAA, 2009). In Indonesia, Arabica coffee is a favorite export from several regions such as Gayo, Mandailing, and Lintong. North Sumatra as one of the centers of Arabica coffee production recorded an export volume of 63,756 tons in 2020, although it fluctuated from year to year.

Cultivation Patterns and Physical Quality of Coffee

The cultivation pattern applied by farmers has a direct influence on the physical and organoleptic quality of coffee. Asfirmanto et al. (2013) revealed that Arabica coffee cultivation in Kintamani and Gayo contributed up to 63.5% to the quality of coffee taste (cupping score). Factors such as the selection of superior varieties, the use of organic fertilizers, selective harvesting techniques, and wet processing methods greatly determine the final quality of coffee. National standards through SNI 01-2907-2008 also stipulate quality requirements such as a maximum water content of 12.5%, the number of physical defects, and uniformity of bean color.

The Impact of Coffee Berry Borer (PBKo) Attacks

The main pests of Arabica coffee plants are Hypothenemus hampei (coffee berry borer) and Araecerus fasciculatus (warehouse beetle), which can drastically reduce the quality of the beans. Hypothenemus hampei damages the beans from the inside, causing small holes that affect the weight and physical appearance of the beans. Meanwhile, Araecerus fasciculatus attacks post-harvest and causes biological contamination that has the potential to reduce the export value of coffee. The study by Munawaroh et al. (2021) also stated that this pest attack causes visual and chemical defects in the beans, reducing the grade of coffee from specialty to regular commercial.

Physical Quality and Export Standards of Arabica Coffee

The export eligibility of Arabica coffee is determined by physical quality parameters, including bean size (screen), number of defects, water content, color, aroma, and absence of foreign contamination. According to SCAA, specialty grade coffee must have beans measuring at least screen 15 with a defect rate of ≤5 per 300 grams of sample. If the beans do not meet this standard, they are not suitable for export and are only marketed in the domestic market with a lower selling value (SCAA, 2009; ICCRI, 2008).

Integrated Management of OPT in Coffee Cultivation

An integrated pest management (PHT) approach is highly recommended in sustainable coffee cultivation. This method includes garden sanitation, regular pruning, use of pheromone traps, crop rotation, and utilization of natural enemies such as parasitoids and entomopathogenic fungi. The government through the Directorate General

of Plantations has issued guidelines for handling pests to improve farmers' capabilities in controlling pests ecologically and effectively (Ditjenbun, 2023).

The Role of Partnership and Farmer Development

PT Sumatera Specialty Coffee (SSC) as an Arabica coffee exporter has an important role in improving the quality of farmers' production through coaching, training, and technical assistance. The informal partnership system between the company and the farmers has been proven to help farmers adopt modern cultivation techniques and post-harvest processing standards. These efforts contribute to improving the physical quality of coffee beans and their export eligibility.

Relevant Previous Research

Research by Joet et al. (2010) showed that the interaction between environmental factors and wet processing methods has a significant impact on the biochemical content of coffee beans such as chlorogenic acid and volatile compounds. In addition, a study by Novita et al. (2010) emphasized the importance of semi-wet processing based on clean production in improving the quality of community coffee. Local research such as by Damanik et al. (2013) also observed the impact of land conversion and variety changes on the economic value of Arabica coffee in North Sumatra.

METHOD

Types and Approaches of Research

This study uses a descriptive quantitative approach with the aim of analyzing the effect of cultivation patterns and Coffee Berry Borer (PBKo) attacks on the physical quality and export feasibility of Arabica coffee (Coffea arabica L.) in North Tapanuli Regency. The method used is explanatory, focusing on the causal relationship between independent variables (cultivation patterns and PBKo attack levels) and dependent variables (physical quality and export feasibility of coffee). Data collection techniques were carried out through field surveys using questionnaires and observations, as well as laboratory testing to measure the physical quality of coffee beans based on national standards (SNI 01-2907-2008).

Location and Time of Research

The research was conducted in the fostered area of PT Sumatera Specialty Coffee (SSC), namely in three Arabica coffee center sub-districts in North Tapanuli Regency: Siborong-borong, Sipahutar, and Pagaran Sub-districts. This location was chosen because it is the area with the highest Arabica coffee production in North Sumatra and has implemented a partnership system in cultivation management. The research was conducted from May to December 2024.

Population and Sample

The population of the study was all Arabica coffee farmers fostered by PT SSC in the three sub-districts, totaling 1,061 people. Sampling was carried out using the Slovin formula with an error rate (e) of 10%, resulting in a sample size of 91 respondents. Samples were taken using proportional random sampling, according to the proportion of the number of fostered farmers in each sub-district.

RESULTS AND DISCUSSION

Multiple Linear Regression Analysis Test

Table 1 Multiple Linear Regression Test Results

Variables	B	Std. Error
(Constant)	3.906	1,199
X1.TOTAL	0.4	0.055
X2.TOTAL	0.64	0.133

The formula for multiple linear regression analysis is: Y = a + b1X1 + b2X2 + e. Based on the results of the analysis in the table above, the regression equation model formed is:

Physical Quality and Export Eligibility = 3.906 + 0.400 Cultivation Pattern + 0.640 OPT Attacks + e

The explanation of the regression model is as follows:

1. The constant (a) of 3.906 shows that if the Cultivation Pattern (X1) and Plant Pest Attacks (X2) have a value of zero, then the basic value of the Physical Quality and Export Suitability of Arabica Coffee is 3.906.
2. The coefficient X1 (Cultivation Pattern) of 0.400 means that every one unit increase in the cultivation pattern score will increase the physical quality and export suitability of coffee by 0.400 units, assuming that plant pest attacks remain constant.
3. The coefficient X2 (Plant Pest Attacks) of 0.640 means that every one unit increase in the score of plant pest attacks (in this case the possibility of perception of handling) will increase the physical quality and export suitability of coffee by 0.640 units, assuming the cultivation pattern remains constant.

Thus, both independent variables provide a positive contribution to the physical quality and export feasibility of Arabica coffee, with the influence of OPT Attacks being greater than the Cultivation Pattern according to the regression coefficient value obtained.

Table 2 Partial Test Results (t-Test)

Variables	t count	Sig.
(Constant)	3.259	0.002
Cultivation Pattern (X1)	7.31	0
OPT Attack (X2)	4.816	0

Based on the results in table 4.6 above, the Cultivation Pattern variable (X1) has a t-value of 7.310 with a significance value of 0.000. Because the significance value is <0.05 and t count> t table (±1.987 for n = 91), then H $_o$ is rejected and H_a is accepted. This means that, partially, the Cultivation Pattern has a positive and significant effect on the Physical Quality and Export Feasibility of Arabica Coffee in North Tapanuli Regency. Likewise, the variable of Plant Pest Organism Attack (X2) shows a t-value of 4.816 with a significance of 0.000. This value is also smaller than 0.05, so H $_o$ is rejected and H_a is accepted. This shows that partially, OPT Attacks have a significant effect on the quality and export eligibility of Arabica coffee. Thus, both the variables of Cultivation Pattern and Plant Pest Attacks partially have a significant influence on the Physical Quality and Export Feasibility of Arabica Coffee in North Tapanuli Regency.

Simultaneous Hypothesis Testing (F Test)

Table 3 Partial Test Results (t-Test)

Source	Sum of Squares	df	Mean Square	F	Sig.
Regression	575.105	2	287,553	66,362	0.000[b]
Residual	381,312	88	4.333		
Total	956,418	90			

Based on the results of the simultaneous test (F test) shown in Table 4.7, the calculated F value was obtained at 66.362 with a significance value of 0.000, which is much smaller than the significance limit of 0.05. This shows that simultaneously, the variables of Cultivation Pattern and Plant Pest Attacks have a significant effect on the Physical Quality and Export Feasibility of Arabica Coffee in North Tapanuli Regency. In other words, the regression model used is feasible and valid in explaining the influence of both independent variables on the dependent variable. The F table value with degrees of freedom (df1 = 2; df2 = 88) at a significance level of 5% is around 3.10. Because the calculated F (66.362) > F table (3.10), then H $_o$ is rejected and H_a is accepted. This means that simultaneously, Cultivation Patterns and OPT Attacks have a significant effect on the quality and export feasibility of Arabica coffee.

Table 4 Results of Correlation Coefficient Test

Variables	X1 (Cultivation Pattern)	X2 (Pest Organism)	Y (Coffee Quality & Export)
X1 (Cultivation	1	0.437**	0.704**

Pattern)			
X2 (Org. Disturber)	0.437**	1	0.599**
Y (Coffee Quality & Export)	0.704**	0.599**	1

The correlation between X1 (Cultivation Pattern) and X2 (Plant Pest Attack) also shows a value of 0.437 with a significance of 0.000, which means that the relationship between the two variables is positive and significant in the sufficient category. This indicates that good cultivation patterns also tend to be related to low levels of plant pest attacks. This relationship strengthens that improving the quality and export eligibility of Arabica coffee is not only influenced by each factor separately, but also by the integration between cultivation patterns and pest control simultaneously.

DISCUSSION

Based on the results of the partial test (t-test) in Table 4.6, the calculated t value is 7.310 for the Cultivation Pattern variable with a significance value of 0.000. Because the calculated t is greater than the t table (7.310 > 1.987) and the significance value is less than 0.05 (0.000 < 0.05), it can be concluded that there is a positive and significant influence between the Cultivation Pattern on the Physical Quality and Export Feasibility of Arabica Coffee partially. This shows that the application of good cultivation patterns, such as varieties, altitude, soil conditions, climate, harvesting and processing techniques, and pest and disease control can improve the physical quality of coffee beans and increase the chances of coffee products to meet export standards. This finding strengthens various previous literature stating that sustainable cultivation practices play an important role in determining the quality of agricultural products, including Arabica coffee. The partial test results also show that the t-value for the OPT Attack variable is 4.816 with a significance of 0.000. Because the t-value is greater than the t-table (4.816 > 1.987) and the significance value is less than 0.05 (0.000 < 0.05), it can be concluded that there is a positive and significant partial influence between OPT Attacks on Physical Quality and Export Eligibility of Arabica Coffee. This means that the low intensity of plant pest attacks will have a positive impact on the quality of coffee beans and increase the likelihood of the product being eligible for export. This emphasizes the importance of effective control of plant pests and diseases in order to maintain the quality of the harvest. This finding is consistent with previous studies which state that uncontrolled OPT attacks can cause seed damage, decreased physical quality, and failure to meet export quality standards.

CONCLUSION

1. The cultivation patterns applied by Arabica coffee farmers fostered by PT SSC in North Tapanuli Regency include aspects of variety, altitude, soil conditions, climate, harvesting and processing techniques, and pest and disease control. Each has aspects of cultivation patterns that affect plant quality and harvest results. The level of Coffee Berry Borer (PBKo) attacks such as Hypothenemus hampei and Araecerus fasciculatus was also found with varying intensity in each location.
2. The results of multiple linear regression analysis show that the cultivation pattern and the level of Coffee Berry Borer (PBKo) attacks have a significant effect on the physical quality and export eligibility of Arabica coffee. Proper cultivation and effective PBKo control can improve the quality of coffee beans to meet export standards.
3. Pearson correlation test confirmed a significant relationship between cultivation patterns and Coffee Berry Borer (PBKo) attacks on the physical quality of coffee. The more appropriate the cultivation pattern and the lower the Coffee Berry Borer (PBKo) attacks, the higher the quality and export eligibility of the Arabica coffee produced.

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