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ANALYSIS OF COCOA FRUIT ROT AND ECONOMIC LOSSES ON FARMERS

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Abstract

Cocoa fruit rot caused by Phytophthora palmivora *is the main obstacle to smallholder cocoa production in Indonesia because it reduces crop yields, increases control costs, and reduces farmers' income. This study aims to analyze the rate of attack, yield loss, control costs, income changes, and estimated economic losses of farmers in Anreapi sub-district and Polewali Mandar district, West Sulawesi. The study used a descriptive quantitative approach through a survey of 60 farmers grouped according to control practices, accompanied by direct observation of 14,400 cocoa fruits. The attack rate was calculated using the formula of incidence and intensity of the disease, while the economic loss was calculated from the value of yield loss plus the cost of control. The results showed an average incidence of disease of 25.5% with an intensity of 19.0%. Yield loss reached 197.5 kg of dry beans/ha/year or 25.3% of potential production. The average economic loss was Rp13.71 million/ha/year, equivalent to a 36.3% decrease in potential income. The highest losses occurred to farmers without control (Rp17.64 million/ha), while integrated control reduced losses to Rp10.70 million/ha. Cocoa fruit rot caused large economic losses, and proper sanitation, pruning, and fungicide-based control was economically feasible for farmers.*

Keywords: *Cocoa Fruit Rot; Yield Loss; Economic Loss; Farmer Income; Phytophthora palmivora*

1. INTRODUCTION

Cocoa (*Theobroma cacao* L.) is one of the strategic plantation commodities for the Indonesian economy. This commodity is a source of state foreign exchange, raw materials for the processing industry, and the main source of income for millions of farming households. Most of the national cocoa area is cultivated in the form of smallholder plantations with narrow land area, limited capital, and suboptimal cultivation techniques (Directorate General of Plantations, 2023). Sulawesi is the largest cocoa production center in Indonesia, so disruptions to production in this region have a direct impact on the welfare of farmers and the national cocoa supply (Central Statistics Agency, 2024).

The productivity of smallholder cocoa in Indonesia tends to be low and fluctuating. One of the main causes is the attack of plant pest organisms (OPT), especially cocoa borers and fruit rot. Cocoa fruit rot (*black pod disease*) is caused by the oomisetes *of Phytophthora palmivora* (Butler) Butler. This pathogen attacks fruits at all age levels with symptoms of

blackish-brown patches that spread rapidly to the entire surface of the fruit, so that the seeds inside are damaged and cannot be harvested (Semangun, 2000; Wood & Lass, 1985). The development of the disease is greatly influenced by high humidity, rainfall, too close shade, and poor garden sanitation (McMahon & Purwantara, 2004).

Globally, fruit rot is the most detrimental cocoa disease. Guest (2007) reported that this disease causes an annual yield loss of about 20–30% of world production, with much higher losses in plantations with humid conditions and poor management. Ploetz (2016) and Marelli et al. (2019) also place *Phytophthora-induced diseases* as a major threat to the sustainability of cocoa production. In Southeast Asia, *P. palmivora* not only attacks fruits, but also causes stem cancer and leaf blight, so the losses are short-term and long-term (Drenth & Guest, 2004; Afriati et al., 2021).

The impact of fruit rot is not limited to a decrease in physical production. Farmers also bear additional costs for sanitation labor, pruning, the purchase of fungicides, and application equipment. The combination of declining revenues and rising production costs makes farmers' net income decline sharply (Soekartawi, 2006). For smallholders with limited capital, this condition often encourages them to reduce their garden maintenance, which actually worsens the attack in the following season.

Previous research has generally focused on aspects of pathogen biology, epidemiology, and the effectiveness of control techniques (Acebo-Guerrero et al., 2012; Akrofi, 2015). In South Sulawesi, previous research has shown that the resistance of cocoa clones to *P. palmivora* varies (Agustiawan et al., 2021; Musa et al., 2022) and that the biological agent *Trichoderma* sp. is able to suppress the development of rotten spots on cocoa fruits (Hastuti et al., 2025). Several studies have also estimated yield loss on a global or regional scale (Guest, 2007; Hebbar, 2007). However, studies that simultaneously measure the rate of attacks in the field, calculate yield losses, detail the cost of control, and translate them into the value of economic losses at the level of smallholder farming are still limited. This information is important because farmers' decisions to control diseases are largely determined by the ratio between control costs and economic benefits obtained.

Therefore, this study aims to: (1) analyze the rate of cocoa fruit rot disease attack in farmers' gardens; (2) estimate yield loss due to disease; (3) calculate control costs incurred by farmers; (4) analyze changes in farmers' income; and (5) estimate economic losses due to cocoa fruit rot according to control practices. The results of the research are expected to be the basis for farmers, extension workers, and local governments in designing effective and economically viable control strategies.

2. RESEARCH METHODS

Location and time

The research was carried out in Anreapi district, Polewali Mandar district, West Sulawesi, in May and 2026. The location was chosen deliberately (*purposive*) because it is

a community cocoa center with a history of high fruit rot attacks and relatively high rainfall throughout the year.

Types and approaches of research

This research is a descriptive quantitative research with survey and field observation methods. This approach allows direct measurement of the rate of disease attacks in gardens as well as the collection of farming data from farmers (Sugiyono, 2019).

Population and sample

The population is all cocoa farmers in the research site totaling 150 people. The sample was determined as many as 60 farmers with the following criteria: (1) cultivating cocoa for at least five years; (2) the crop has been produced; and (3) willing to be interviewed. The sample was selected in *stratified random sampling* based on control practices, namely: group A, without or with minimal control (18 farmers); group B, control of technical culture in the form of sanitation of sick fruits and pruning (24 farmers); and group C, integrated control in the form of technical culture plus fungicides made of active ingredients of copper (18 farmers).

Data collection techniques

Primary data was collected through (1) direct observation of cocoa fruits on sample trees, (2) structured interviews using questionnaires on production, prices, costs, and control practices, and (3) documentation. In each plantation, 10 sample trees were selected diagonally, and all fruits on the sample trees were observed in four observations, bringing the total number of fruits observed to 14,400 fruits. Secondary data were obtained from BPS, the Plantation Service, and scientific publications.

Variables and indicators of the study.

The variables and indicators used in this study are presented in Table 1.

Table 1 Research Variables and Indicators

Variable	Indicator	Units
Attack rate	Incidence of disease; disease intensity (score 0–4)	%
Loss of yield	Difference between potential production and actual production	kg dried seeds/ha/year
Control costs	Sanitation and pruning workforce, fungicides, tools and applications	Rp/ha/year
Revenue	Receipts, production costs, actual and potential net income	Rp/ha/year
Economic losses	Value of yield loss + control costs	Rp/ha/year

Source: Processed Data, 2026

Attack rate analysis

Disease incidence (*IP*) is calculated as the percentage of fruit attacked against all fruits observed using equation (1).

$$IP = (n / N) \times 100\% \quad (1)$$

with n = number of fruits attacked and N = number of fruits observed. Disease intensity (*IS)* was calculated using the formula of Townsend and Heuberger (1943) in equation (2).

$$IS = [\Sigma(It's \times vi) / (N \times Z)] \times 100\% \quad (2)$$

with ni = the number of fruits on the first score, vi = the attack score value, and Z = the highest score. Attack score: 0 = healthy; 1 = spotting ≤ 25% of the fruit surface; 2 = > 25–50%; 3 = > 50–75%; 4 = > 75% or rotten fruit entirely. Attack categories: mild (< 25%), medium (25–50%), and severe (> 50%).

Yield loss analysis

Potential production (*Yp*) is estimated from the total number of fruits (healthy and sick) multiplied by the value of fruit conversion to dried seeds, while actual production (*Yes*) is the production of dried seeds sold or harvested by farmers. Yield loss (*KH)* is calculated using equations (3) and (4).

$$KH = Yp - Ya \quad (3)$$

$$\%KH = [(Yp - Ya) / Yp] \times 100\% \quad (4)$$

Economic analysis

Income analysis follows the farming approach (Soekartawi, 2006). Revenue (*TR*) = production × price; net income (π) = *TR* − other production costs − control costs. Economic losses (*KE)* are calculated using equation (5).

$$WED = (KH \times P) + BP \quad (5)$$

with P = price of dried cocoa beans at the farmer level and BP = control cost. The feasibility of control was assessed by the marginal benefit-cost ratio (MBCR), i.e. additional revenue divided by the additional control cost compared to group A. Control was assessed as feasible if the MBCR > 1. The difference between groups was tested by one-way variance analysis (ANOVA) or the Kruskal–Wallis test when the data did not spread normally, at a real level of 5%.

3. RESULTS AND DISCUSSION

3.1 Characteristics of Respondents

A total of 60 cocoa farmers were the respondents of the study. The characteristics of the respondents are presented in Table 2.

Table 2 Characteristics of Respondents (n = 60)

Features	Category	Frequency	Percentage (%)
Age	< 40 years old	14	23,3
	40–55 years old	31	51,7
	> 55 years old	15	25,0
Education	SD	22	36,7
	SMP	18	30,0
	High School/equivalent	17	28,3
	Diploma/Bachelor's	3	5,0
Cocoa land area	< 1 ha	21	35,0
	1–2 ha	32	53,3
	> 2 ha	7	11,7
Plant lifespan	< 10 years	12	20,0
	10–20 years	35	58,3
	> 20 years old	13	21,7

Source: *Processed Data, 2026*

The majority of respondents were of productive age (40–55 years; 51.7%) and had primary to secondary education. Most of them cultivated 1–2 ha (average 1.2 ha) with 10–20 year old plants. Plants at this age have tight crowns so that garden moisture is high, conditions that support the development of *P. palmivora* if pruning is not carried out.

3.2 Rate of Fruit Rot Attack

The results of observations of the incidence and intensity of cocoa fruit rot in the three groups of farmers are presented in Table 3.

Table 3 Incidence and Intensity of Cocoa Fruit Rot by Control Practices

Farmer groups	N Farmer	Fruit observed	Fruit infested	Incidence (%)	Intensity (%)	Category
A. Without/minimal control	18	4.320	1.642	38,0	29,6	Medium
B. Sanitation and pruning	24	5.760	1.382	24,0	17,8	Lightweight
C. Integrated control + fungicide	18	4.320	648	15,0	10,2	Lightweight
Average/total	**60**	**14.400**	**3.672**	**25,5**	**19,0**	**Medium**

Source: Processed Data, 2026

The average incidence of disease was 25.5%, meaning that one in four cocoa fruits in the study site was affected by fruit rot. The average disease intensity of 19.0% indicated that most of the affected fruits had suffered further damage. The highest attack rate was found in group A (incidence 38.0%), more than double that of group C (15.0%).

The high incidence in group A is related to the diseased fruit left on the tree or on the ground surface. The fruit is a source of inoculum that spreads through rainwater, insects, and soil splashes (McMahon & Purwantara, 2004). The attack rate in this study was in the global loss range of 20–30% reported by Guest (2007). The decrease in attacks in groups B and C is in line with Acebo-Guerrero et al. (2012), who stated that sanitation and shade management are the basis for control, while copper fungicides are effective when combined with technical culture. Biological control also has the potential to be combined, as *Trichoderma* sp. has been shown to suppress the area *of P. palmivora* patches in cocoa fruits (Hastuti et al., 2025).

3.3 Loss of Production

Potential production, actual production, and yield loss in each group of farmers are presented in Table 4.

Table 4 Potential Production, Actual Production, and Yield Loss (kg dried seeds/ha/year)

Farmer groups	**Potential production**	**Actual production**	**Loss of yield**	**Loss (%)**
A. Without/minimal control	760	471	289	38,0
B. Sanitation and pruning	780	593	187	24,0
C. Integrated control + fungicide	800	680	120	15,0
Weighted average	**780**	**582,5**	**197,5**	**25,3**

Source: Processed Data, 2026

The average yield loss reached 197.5 kg of dry beans/ha/year or 25.3% of potential production. Group A farmers lost 289 kg/ha, leaving the actual production to only 471 kg/ha, well below potential productivity. Integrated control reduced yield loss to 120 kg/ha, or 169 kg/ha lower than group A. These findings support Ploetz (2016) and Marelli et al. (2019) that *Phytophthora disease* is the main cause of the gap between potential and actual cocoa production, especially in smallholder plantations with limited management.

3.4 Control Costs

The cost structure of fruit rot control incurred by farmers in each group is presented in Table 5.

Table 5 Fruit Rot Control Cost Structure (Rp/ha/year)

Cost component	Group A	Group B	Group C
Sanitation and pruning workforce	300.000	1.800.000	1.800.000
Copper fungicide	–	–	1.250.000
Tools and application fees	–	–	450.000
Total control costs	**300.000**	**1.800.000**	**3.500.000**

Source: Processed Data, 2026

Control costs increase with the intensity of the practices applied. The largest component in group B is labor, while in group C almost half of the costs come from fungicides and their applications. These costs are often considered heavy by smallholders, even though the analysis in the next subchapter shows that the benefits far outweigh the costs.

3.5 Changes in Income and Estimated Economic Losses

The price of dried cocoa beans at the farmer level used is Rp60,000/kg, and other production costs outside control (fertilizer, harvest, post-harvest) average Rp9,000,000/ha/year. Farmers' income, income, and economic losses are presented in Table 6.

Table 6 Income, Income, and Economic Losses of Farmers (Rp million/ha/year)

Description	Group A	Group B	Group C	Weighted average
Potential acceptance	45,60	46,80	48,00	46,80
Actual acceptance	28,26	35,58	40,80	34,95
Value of yield loss	17,34	11,22	7,20	11,85
Control costs	0,30	1,80	3,50	1,86
Economic losses	**17,64**	**13,02**	**10,70**	**13,71**
Potential net income	36,60	37,80	39,00	37,80
Actual net income	18,96	24,78	28,30	24,09
Decrease in revenue (%)	48,2	34,4	27,4	36,3

Source: Processed Data, 2026

Fruit rot causes an average economic loss of IDR 13.71 million/ha/year. With an average land area of 1.2 ha, each farmer loses around IDR 16.45 million per year. This loss reduces farmers' net income by 36.3% of their potential income. In group A, almost half of the potential income (48.2%) is lost due to disease.

Control proved to be economically beneficial. Compared to group A, an additional cost of Rp1.50 million in group B resulted in an additional revenue of Rp7.32 million (MBCR = 4.88). An additional cost of Rp3.20 million in group C resulted in an additional revenue of Rp12.54 million (MBCR = 3.92). This means that every Rp1 spent on sanitation and pruning is around Rp4.9, while integrated control provides the highest net income (Rp28.30 million/ha). Sanitation and pruning are the most efficient steps, while the addition of fungicides is still feasible (MBCR C to B = 3.07) for farmers who can afford the initial costs.

These findings are in line with Hebbar (2007) and Marelli et al. (2019), who assert that losses due to cocoa disease depress smallholder incomes and threaten the sustainability of supply. These results also support the recommendations of Keane and Putter (1992) and Acebo-Guerrero et al. (2012) regarding integrated control. The difference is that this study shows quantitatively at the farming level that the greatest losses come from the lost production value, not from the cost of control. Thus, the reluctance of farmers to incur control costs is an economically detrimental decision. Counseling needs to emphasize the calculation of these benefits, not just the technical aspects of control.

4. CONCLUSION

This study analyzes the level of cocoa fruit rot attacks and the economic losses it causes to farmers in Anreapi district, Polewali Mandar Regency, West Sulawesi. Based on the results of the analysis, it can be concluded as follows.

1. The rate of attack of cocoa fruit rot is moderate, with an average incidence of 25.5% and intensity of 19.0%. The highest attacks occur in uncontrolled orchards (38.0% incidence) and lowest in orchards with integrated control (15.0%).
2. The disease causes an average yield loss of 197.5 kg of dried seeds/ha/year or 25.3% of potential production.
3. Control costs range from IDR 0.30 million to IDR 3.50 million/ha/year, depending on the control practices applied.
4. Fruit rot reduced farmers' net income by an average of 36.3% of potential income, and up to 48.2% in uncontrolled farmers.
5. The average economic loss reached Rp13.71 million/ha/year, most of which came from the lost value of production. Control is economically feasible, with MBCR of 4.88 for sanitation and pruning and 3.92 for integrated control.

From a practical perspective, farmers are advised to make sick fruit sanitation and regular pruning a mandatory practice, then add fungicides in a timely manner during the rainy season. Extension workers and local governments need to combine technical control training with the calculation of farm profits, as well as consider assistance with control facilities for small-cap farmers.

This study has limitations. First, the study was conducted at a single location and one season period, so the generalization of the findings was limited. Second, potential production was estimated from the number of fruits, so it could be influenced by factors other than diseases, such as fruit borer pests. Further research is recommended using multi-season data, covering a wider area, and separating the contribution of pests and other diseases to yield loss.

REFERENCES

Acebo-Guerrero, Y., Hernández-Rodríguez, A., Heydrich-Pérez, M., El Jaziri, M., & Hernández-Lauzardo, A. N. (2012). Management of black pod rot in cacao (*Theobroma cacao* L.): A review. *Fruits, 67*(1), 41–48.

Afriati, N., Parawansa, A. K., & Haris, A. (2021). Isolation and morphology of the fungus *Phytopthora palmivora* Butl on cocoa stalks (*Theobromae cacao* L). *AGrotekMAS Indonesian Journal: Journal of Agricultural Sciences, 2*(2), 16–22. https://doi.org/10.33096/agrotekmas.v2i2.187

Agustiawan, P., Parawansa, A. K., & Gani, M. S. (2021). Detached pod test of several cocoa fruit clones against *Phytopthora palmivora* Butler. *AGrotekMAS Indonesian Journal: Journal of Agricultural Sciences, 2*(2), 11–15. https://doi.org/10.33096/agrotekmas.v2i2.186

Akrofi, A. Y. (2015). *Phytophthora megakarya*: A review on its status as a pathogen on cacao in West Africa. *African Crop Science Journal, 23*(1), 67–87.

Central Statistics Agency. (2024). *Indonesian cocoa statistics 2023*. Central Statistics Agency.

Bailey, B. A., & Meinhardt, L. W. (Eds.). (2016). *Cacao diseases: A history of old enemies and new encounters*. Springer.

Directorate General of Plantations. (2023). *National Superior Plantation Statistics 2021–2023*. Ministry of Agriculture.

Drenth, A., & Guest, D. I. (Eds.). (2004). *Diversity and management of Phytophthora in Southeast Asia* (ACIAR Monograph No. 114). Australian Centre for International Agricultural Research.

Guest, D. (2007). Black pod: Diverse pathogens with a global impact on cocoa yield. *Phytopathology, 97*(12), 1650–1653. https://doi.org/10.1094/PHYTO-97-12-1650

Hastuti, A. R., Parawansa, A. K., & Gani, M. S. (2025). Effectiveness of *Trichoderma* sp concentration against (*Phytopthora palmivora* Butl.) on cocoa fruit (*Theobroma cacao* L.). *AGROTEK: Scientific Journal of Agricultural Sciences, 9*(1), 29–34. https://doi.org/10.33096/agrotek.v9i1.708

Hebbar, P. K. (2007). Cacao diseases: A global perspective from an industry point of view. *Phytopathology, 97*(12), 1658–1663. https://doi.org/10.1094/PHYTO-97-12-1658

Keane, P. J., & Putter, C. A. J. (Eds.). (1992). *Cocoa pest and disease management in Southeast Asia and Australasia* (FAO Plant Production and Protection Paper No. 112). Food and Agriculture Organization of the United Nations.

Marelli, J.-P., Guest, D. I., Bailey, B. A., Evans, H. C., Brown, J. K., Junaid, M., Barreto, R. W., Lisboa, D. O., & Puig, A. S. (2019). Chocolate under threat from old and new cacao diseases. *Phytopathology, 109*(8), 1331–1343. https://doi.org/10.1094/PHYTO-12-18-0477-RVW

McMahon, P., & Purwantara, A. (2004). Phytophthora on cocoa. Dalam A. Drenth & D. I. Guest (Eds.), *Diversity and management of Phytophthora in Southeast Asia* (hlm. 104–115). Australian Centre for International Agricultural Research.

Musa, M. A., Parawansa, A. K., & Ralle, A. (2022). Resistance of several cocoa clones (*Theobroma cacao* L.) to stem cancer *Phytopthora palmivora*. *AGrotekMAS Indonesian Journal: Journal of Agricultural Sciences, 3*(2), 18–25. https://doi.org/10.33096/agrotekmas.v3i2.243

Ploetz, R. (2016). The impact of diseases on cacao production: A global overview. Dalam B. A. Bailey & L. W. Meinhardt (Eds.), *Cacao diseases: A history of old enemies and new encounters* (hlm. 33–59). Springer.

Semangun, H. (2000). *Plantation Plant Diseases in Indonesia*. Gadjah Mada University Press.

Soekartawi. (2006). *Agricultural analysis*. UI Press.

Sugiyono. (2019). *Quantitative, qualitative, and R&D research methods*. Alphabet.

Townsend, G. R., & Heuberger, J. W. (1943). Methods for estimating losses caused by diseases in fungicide experiments. *Plant Disease Reporter, 27*, 340–343.

Wood, G. A. R., & Lass, R. A. (1985). *Cocoa* (4th ed.). Longman.