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Correlation Analysis between LOF Dosage from Cassava Peel with Stem Height, Number of Leaves, and Leaf Width on Cocoa Seedlings (*Theobroma cacao* L.)

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Abstract: This study aims to determine the correlation analysis of the liquid organic fertilizer (LOF) dose of cassava peel with stem height, number of leaves, and leaf width on Cocoa Seedlings (*Theobroma cacao* L.). This study was conducted in an experimental garden with a controlled environment managed by the Plantation Management Study Program at the Politeknik Indonesia Venezuela, Aceh Besar Regency. Bivariate correlation analysis tests were conducted to examine the relationship between the LOF dose and growth parameters of stem height, number of leaves, and leaf width. The results of the bivariate correlation analysis showed that the administration of LOF 50-150 mL correlated with plant height and the number of leaves. The variable number of leaves of Cocoa plants was closely related to the variable LOF 200 ml. This is because LOF contains macronutrients (such as N, P, K) and micronutrients (Fe, Zn, Mn, Cu) as well as bioactive compounds such as amino acids, humic acid, and growth hormones (auxins, cytokinins, and gibberellins). Several doses of LOF made from cassava peels showed a positive correlation with the height and number of leaves of cocoa plants. However, there was no correlation between LOF and leaf diameter.

Keywords: Cacao; Cassava peel; Liquid organic fertilizer; Pearson correlations

Introduction

Cocoa, which comes from the *Theobroma cacao* L. tree, originates from the tropical rainforests of the Americas. The most economically important types include Forastero, Criollo, and Trinitario. Forastero is recognized for its intense flavor, while Criollo and Trinitario are valued for their refined and fragrant characteristics (Stojković et al., 2021). Cocoa (*Theobroma cacao* L.) is a perennial crop of significant global economic importance, including in Indonesia. It contributes notably to the national economy by generating foreign exchange, serving as a key income source for farmers, and supporting the growth of domestic agribusiness and agroindustry. Cocoa plantations are widely distributed across the Indonesian archipelago, with Sulawesi as the primary production area. Specifically, Central Sulawesi accounts for 18% of national cocoa output, Southeast Sulawesi 16%, South Sulawesi 15%, West Sulawesi 11%, while the remaining 40% is produced in other regions (FAO, 2021). In terms of annual output, Indonesia produced 658,399 tons of cocoa in 2016. This figure declined to 590,684 tons in 2017 but rose again in 2018 to 767,280 tons. However, production decreased to 734,796 tons in 2019 and continued to fall to 713,378 tons in 2020 (DGPI, 2020; Kasim et al., 2024). The vigor of cocoa seedlings is affected by several factors, including the position of the beans, the variety of the plant, the level of bean maturity, and various environmental conditions (Olaiya, 2016).

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The cocoa plant (*Theobroma cacao* L.) is a plantation crop with significant economic value and is a potential export commodity that can generate foreign exchange for the country. In Indonesia's plantation sector, cocoa holds a prominent position among the primary commodities (Tsaaqifah et al., 2023). In Indonesia, cocoa production ranks third in the plantation subsector, following palm oil and rubber.

Correlation analysis was used to determine the relationship between the dosage of LOF from cassava peel with stem height, number of leaves, and leaf width in cocoa seedlings (*Theobroma cacao* L.). Correlation analysis is employed to identify the direction of the relationship between two or more variables. A correlation exists when a change in one variable is followed by a corresponding linear change in another variable, whether in the same or opposite direction. The degree of this relationship is quantified using a statistical value known as the correlation coefficient (Roflin & Riana, 2022). To determine the correlation value in statistical tests, it is necessary to model the correlation between variables. However, also testing a series of complex correlations simultaneously. The complex correlation can involve one or more dependent variables with one or more independent variables. The dependent and independent variables can be factors (constructs built from several indicator variables). These variables can be single variables that can be measured or variables that can be observed directly. Correlation refers to a numerical value that represents both the direction and strength of the relationship between two or more variables. This relationship is measured using a correlation coefficient, which ranges from -1 to +1. A positive sign indicates a direct (positive) relationship, while a negative sign signifies an inverse (negative) relationship (Yannasari et al., 2024).

Liquid organic fertilizer (LOF) is one of the choices for environmentally friendly fertilization. It is generally used to address the lack of organic matter in the soil and can improve the physical, chemical, and biological characteristics of the planting medium. The advantages of LOF include its ease of application, enhanced nutrient absorption, soil and plant protection, and increased nutrient availability (Gunawan et al., 2024; Phibunwatthanawong & Riddech, 2019). Marwantika (2020), explained that the use of organic fertilizers enhances soil fertility and does not adversely affect crop production, making them safe for human health. According to Oghenejoboh et al. (2021), cassava peel waste is a viable material for composting, as it still contains various nutrients essential for plant growth. According to Fitriani & Ciptandi (2017), every 100 grams of cassava peel waste contains 8.11 grams of protein, 15.20 grams of crude fiber, 0.22 grams of pectin, 1.29 grams of fat, and 0.63 grams of calcium. As reported by Sebayang et al. (2023), cassava peels also have a starch content of 36.5% (Sulistyowati et al., 2023).

Stojković et al. (2021), found that utilizing multivariate analysis tools enables more effective interpretation of VOC (volatile organic compound) data, revealing that pasteurization combined with additives results in a more uniform compound profile during storage in cacao (*Theobroma cacao* L.). Meanwhile, Basri et al. (2023), reported that applying *Gliricidia sepium* leaf-based LOF at varying concentrations did not significantly affect the height or stem diameter of cacao plants. However, it did lead to a significant increase in leaf number. In a separate study, Abdullah et al. (2024), discovered through correlation analysis that plant height, stem diameter, and leaf number in jackfruit seedlings (*Artocarpus heterophyllus* Lamk) are interrelated. However, no significant correlations were found between watering frequency and any of these growth parameters. Specifically, watering every nine days did not significantly influence plant height, stem diameter, or leaf count. The strong reasons for conducting this research are: Cassava peel is an abundant agricultural waste but has the potential to be a source of nutrients (Mohidin et al., 2023), LOF from waste has been shown to affect early plant growth (Dahunsi et al., 2021), the nursery stage determines long-term cocoa quality and productivity (initial vegetative parameters are very important), correlation analysis provides quantitative information on the strength and direction of the dose-response relationship (Arum et al., 2023), and supports sustainable agricultural practices and reduced use of chemical fertilizers (Dahunsi et al., 2021). This study aims to determine the correlation analysis applied to test the relationship between different doses of cassava peel-based liquid organic fertilizer and growth traits such as stem height (SH), number of leaves (NL), and leaf width (LW) in cocoa seedlings (*Theobroma cacao* L.).

Method

The study was carried out in a controlled-environment experimental garden managed by the Plantation Management Study Program at Politeknik Indonesia Venezuela, situated in Cot Suruy Village, Ingin Jaya District, Aceh Besar Regency. This study was completed on July 1, 2025, with the garden temperature maintained between 25 and 28°C.

The parameters observed were: Plant height was measured using a ruler from the soil surface to the tip of the tallest stem. Leaf width was measured vertically using a ruler. The number of leaves counted includes only those that have fully opened. The leaf count was carried out two weeks after planting. Stem diameter measurements were carried out 2 weeks after planting

and then measured once a week for seven weeks. The research utilized a non-factorial Randomized Block Design (RBD), consisting of five treatment groups, each replicated five times. The treatments were arranged as follows: S0 = no application of cassava peel fertilizer, S1 = application of 50 ml of cassava peel LOF, S2 = application of 100 ml of cassava peel LOF, S3 = application of 150 ml of cassava peel LOF, and S4 = application of 200 ml of cassava peel LOF. Each experimental unit consisted of 1 2-month-old Cacao plant seedling, with a total of 25 Cacao plant seedlings. The flow diagram of this research is seen in Figure 1.

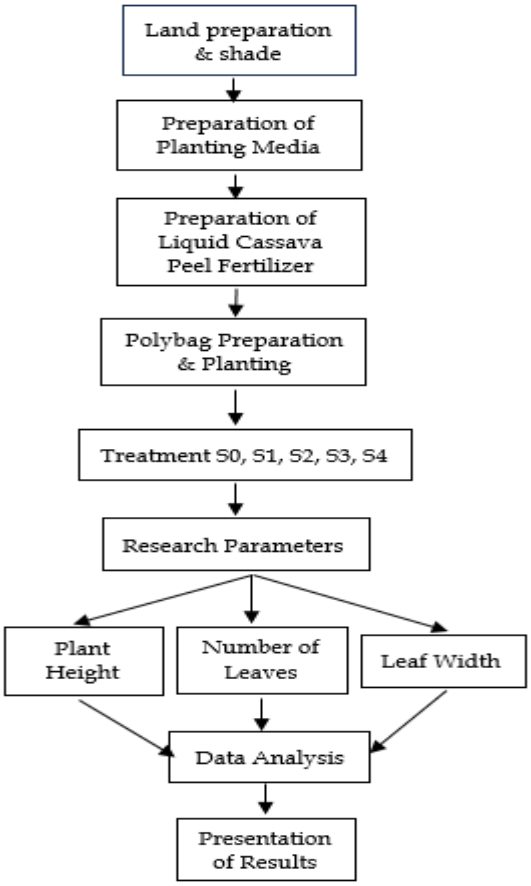

Figure 1. Diagram of this research

To see the correlation analysis between LOF, Stem Height, Number of Leaves, and Leaf Width in Cacao Plant Seedlings (*Theobroma cacao* L.), bivariate correlation analysis was used (Khriswanti et al., 2022; Triadiawarman et al., 2022; Afifah et al., 2024; Kim et al., 2023; Windra et al., 2022). The degree of association between variables is commonly expressed through the correlation coefficient, denoted by the symbol "r". If the value of the change in Sig. F < 0.05 then:

$$r = \frac{n\sum XY - (\sum X)(\sum Y)}{\sqrt{\left(n\sum X^2 - (\sum X)^2\right)\left(n\sum Y^2 - (\sum Y)^2\right)}} \quad (1)$$

This is the Pearson correlation coefficient formula, which measures the strength and direction of a linear relationship between two variables X and Y. Where n = number of data pairs, $\sum XY$ = sum of products of X and Y, $\sum X$, $\sum Y$ = sum of each variable, and $\sum X^2$, $\sum Y^2$ = sum of squared values. The criteria for analyzing the correlation test are presented in Table 1 (Abdullah et al., 2024).

Table 1. Criteria analysis test correlation

Correlation Value	Information
0	There is no correlation between the two variables
> 0 – 0.25	The correlation is very weak
> 0.25 – 0.5	Correlation enough
> 0.50 – 0.75	Strong correlation
> 0.75 – 0.99	The correlation is very strong
= 1	The perfect correlation is positive
= -1	Negative perfect correlation

The data obtained from the field were then tested with a normality test (Tsagris & Pandis, 2021; Tsagris et al., 2020;) and a homogeneity test (Zhou et al., 2023; Kédagni & Mourifié, 2020; Sandrini & Camargo, 2022; Yozgatligil & Yazici, 2016). Then, if the data were normally distributed and homogeneous, it continued to the correlation statistical analysis.

Result and Discussion

The results of this study, which aimed at correlation analysis applied to test the relationship between different doses of cassava peel-based LOF on the growth characteristics of stem height (SH), number of leaves (NL), and leaf width (LW) in cocoa seedlings (*Theobroma cacao* L.) can be seen in Table 2-6.

In Table 2, the control treatment (S0) reveals a high correlation between the NL variable and the LOF variable (indicated by the ** sign). The NL variable is very strongly related to the LOF variable (Sig. F change value 0.00 < 0.05, H_0 is rejected, so there is a significant relationship) (Wahyono, 2014; Dharta et al., 2024). This indicates that without the provision of LOF, the NL of cacao plants increases with the development of cacao plants in general. Cocoa plants (*Theobroma cacao* L.) naturally have vegetative growth phases, including the formation of new leaves in response to environmental factors such as the availability of water, sunlight, and soil conditions containing sufficient basic nutrients (macronutrients and micronutrients), even though they do not come from additional fertilizers. Even without the application of LOF, cocoa plants can still experience an increase in the NL because the soil where the plant grows generally has nutrient reserves that can support the initial growth of the plant (Craswell & Lefroy, 2001; Carter & Steward, 2020). Plant adaptability: Cocoa is a

plant that is adaptive in various types of tropical soils, and in the early stages of vegetative growth, this plant relies on nutrient reserves in seeds and soil (Wood & Lass, 2008). Photosynthesis mechanism and internal growth hormones: plants physiologically produce growth hormones such as auxins and cytokinins internally, which play a role in the formation of shoots and leaves (Taiz et al., 2015). With the support of sufficient sunlight and humidity, the leaves can still grow naturally.

Table 2. Results of CA without LOF, with SH, LW, and NL

		Correlations			
		LOF 0 ml	PH	LW	NL
LOF 0 ml	PC	1	0.057	-0.031	0.817**
	Sig. (2-tailed)		0.786	0.883	0.000
	N	25	25	25	25
PH	PC	0.057	1	-0.054	0.007
	Sig. (2-tailed)	0.786		0.797	0.973
	N	25	25	25	25
LW	PC	-0.031	-0.054	1	-0.081
	Sig. (2-tailed)	0.883	0.797		0.699
	N	25	25	25	25
NL	PC	0.817**	0.007	-0.081	1
	Sig. (2-tailed)	0.000	0.973	0.699	
	N	25	25	25	25

**. Correlation is significant at the 0.01 level (2-tailed).
Pearson Correlation: PC.

Table 3. Results of CA of 50 ml LOF with SH, LW, and NL

		Correlations			
		LOF 50 ml	PH	LW	NL
LOF 50 ml	PC	1	0.792**	0.348	0.644**
	Sig. (2-tailed)		0.000	0.089	0.001
	N	25	25	25	25
PH	PC	0.792**	1	0.359	0.457*
	Sig. (2-tailed)	0.000		0.078	0.022
	N	25	25	25	25
LW	PC	0.348	0.359	1	0.116
	Sig. (2-tailed)	0.089	0.078		0.581
	N	25	25	25	25
NL	PC	0.644**	0.457*	0.116	1
	Sig. (2-tailed)	0.001	0.022	0.581	
	N	25	25	25	25

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
Pearson Correlation: PC.

In Table 3, it is evident that PH and the NL are highly correlated with the 50 ml LOF variable (as indicated by the ** sign). The variables of PH and NL are very strongly correlated with the variable of 50 ml of liquid organic fertilizer. The NL is strongly correlated with PH (Sig. F change value 0.00 < 0.05, H0 is rejected, indicating a significant relationship). LOF contains macronutrients (such as N, P, K) and micronutrients (Fe, Zn, Mn, Cu) as well as bioactive compounds such as amino acids, humic acid, and growth hormones (auxins, cytokinins, and gibberellins). When given at optimal doses (e.g., 50 ml), this fertilizer can: increase plant physiological activities, including photosynthesis and cell division (Akande et al., 2018; Bandera, 2020). Encourages the growth of meristematic tissue, thus supporting an increase in PH, and stimulates the formation of new leaves, mainly due to the content of cytokinins and nitrogen, which are important in the development of vegetative organs (Taiz et al., 2015; Afza et al., 2023). The NL and PH are important indicators in the vegetative growth phase. Both physiologically support each other because leaves are the main organs for photosynthesis, producing energy for the growth of stems and other tissues. Stem growth (PH) requires photosynthetic products produced from leaf activity, so the healthier the leaves, the higher the plant's ability to grow vertically.

In Table 4, it is evident that PH and the NL are highly correlated with the 100 ml LOF variable (as indicated by the ** sign). The variables of PH and the NL are very strongly related to the variable of 100 ml of liquid organic fertilizer. The NL and LW are very strongly related to PH (the value of change in Sig. F 0.00 < 0.05, H_0 is rejected, so there is a significant relationship). Fermented cassava peel contains significant amounts of macronutrients (N, P, K), micronutrients, and is rich in organic matter that enhances nutrient availability and soil microbiome activity (Adiaha, 2017). Studies show that applying cassava peel–based biofertilizer to maize significantly increased both PH and LN at $p < 0.05$. At application rates equivalent to 12 t/ha, maize achieved ~95 cm in height and ~6.5 leaves compared to ~54 cm and ~4 leaves in control plants. By analogy, cassava peel fertilizer at 100 ml applied to cacao provides a concentrated dose of nutrients and bioactive compounds (e.g., hormones, amino acids) that stimulate stem elongation (height) and leaf production, consistent with mechanisms seen in other LOF (Hassan et al., 2020). More and wider leaves increase the photosynthetic surface and thus energy (carbohydrate) production, fueling stem growth and cell elongation. Statistically robust ANOVA analyses (Sig F < 0.05) confirm these traits are highly correlated, showing a clear biological feedback loop: greater foliage → more energy → more vertical growth.

In Table 5, it is evident that the variables of cacao PH and NL are highly correlated with the application of 150 ml of LOF derived from cassava peel. LW and NL are highly related to PH (can be seen with the ** sign). The variables of PH and NL are highly related to the application of 150 ml of LOF derived from cassava peel. The variables of LOF 150 ml cassava peel, LW, and NL are highly related to plant height. Leaf width is highly related to PH and the NL. The NL is strongly related to LOF 150 ml cassava peel, pH, and LW (Sig. F change value 0.00 < 0.05; H0 is rejected, indicating a significant relationship). The strong and significant relationships shown in Table 5 between the variables of 150 ml cassava peel LOF and cacao plant growth (height, number of leaves, and leaf width) are due to the high concentration of nutrients and bioactive compounds in the cassava peel. Fermented cassava peel is rich in nitrogen, phosphorus, potassium, calcium, and plant growth hormones (such as auxins and cytokinins), which collectively enhance photosynthesis, cell elongation, and leaf development (Abduh et al., 2020; Dieudonne et al., 2021). The positive correlations among LW, NL, and PH reflect the biological mechanism where increased leaf area supports greater light capture and energy production, directly contributing to plant elongation. The Sig. F change value of 0.00 (< 0.05) confirms these variables are significantly interrelated and not due to random variation.

In Table 6, it is evident that the NL on Cacao plants is highly correlated with the 200 ml LOF variable (as indicated by the ** sign). The height of Cacao plants is highly related to the variable NL (as indicated by the * sign). The variable NL is highly related to the variables 200 ml LOF and Cacao PH (Sig. F change value 0.00 < 0.05, H0 is rejected, indicating a significant relationship). The strong positive correlation between the NL of cocoa plants and 200 ml LOF, as well as the significant relationship between PH and the NL, suggests that applying LOF in this volume can significantly enhance the vegetative growth process. LOF from fermented cassava peels contains macronutrients (N, P, K), micronutrients, and bioactive compounds (such as auxin and cytokinin) that encourage the formation of new shoots and leaves. An application with a dose of 200 ml provides a relatively high availability of nutrients, thus triggering a significant increase in the number of leaves. Leaves play a crucial role in photosynthesis, producing energy and carbohydrate compounds necessary for vertical plant growth (stem elongation). Therefore, the more leaves formed, the higher the potential for plant growth upwards (Stefanie & Wally, 2022; Ji et al., 2017; Pangaribuan et al., 2019; Ranasinghe et al., 2019). A Sig. F value of 0.00 (< 0.05) indicates that the relationship between these variables is statistically significant. This means that this relationship is not due to chance, and H_0 (no relationship) is rejected.

Leaf width variables were not correlated with LOF from cassava peels at doses of 50, 100, 150, and 200 mL. This was caused by doses that did not trigger specific nutritional responses to leaf width (suboptimal or limited), environmental or genetic limiting factors, and lack of availability or absorption of essential nutrients that affect leaf width. Research by Rusdiyana et al. (2022), showed that LOF doses affected spinach leaf width, but this occurred at different doses and under different conditions.

The results of the study showed that PH was not correlated with the application of LOF made from cassava peels at a dose of 200 mL. This condition can be explained by several factors. First, the response of PH growth to LOF is generally non-linear and dose-specific, with a certain optimal point before the effect decreases or becomes insignificant (Shaik et al., 2022). At a dose of 200 mL, the available nutrient content, particularly nitrogen, which plays a crucial role in stem growth, may be insufficient or unbalanced to stimulate PH increase (Zhao et al., 2021). Furthermore, environmental factors and plant genetic traits can be significant limitations that mask the effects of fertilizer application, so that additional nutrients do not directly impact height growth (Goss et al., 2013). The quality of LOF can also

vary depending on the cassava peel fermentation process; the presence of secondary compounds with phytotoxic properties can temporarily reduce the effectiveness of fertilizer (Nahrisah et al., 2020). Thus, the absence of correlation at a dose of 200 mL indicates that this dose is not yet suitable as an optimum point for increasing PH. However, other growth parameters may still show a positive response.

Table 4. Results of CA of 100 ml LOF with SH, LW, and NL

		Correlations			
		LOF 100 ml	PH	LW	NL
LOF 100 ml	PC	1	0.476*	0.177	0.721**
	Sig. (2-tailed)		0.016	0.397	0.000
	N	25	25	25	25
PH	PC	0.476*	1	0.489*	0.830**
	Sig. (2-tailed)	0.016		0.013	0.000
	N	25	25	25	25
LW	PC	0.177	0.489*	1	0.374
	Sig. (2-tailed)	0.397	0.013		0.066
	N	25	25	25	25
NL	PC	0.721**	0.830**	0.374	1
	Sig. (2-tailed)	0.000	0.000	0.066	
	N	25	25	25	25

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).
Pearson Correlation: PC.

Table 5. Results of CA of 150 ml LOF with SH, LW, and NL

		Correlations			
		LOF 150 ml	PH	LW	NL
LOF 150 ml	PC	1	0.621**	0.263	0.812**
	Sig. (2-tailed)		0.001	0.204	0.000
	N	25	25	25	25
PH	PC	0.621**	1	0.667**	0.796**
	Sig. (2-tailed)	0.001		0.000	0.000
	N	25	25	25	25
LW	PC	0.263	0.667**	1	0.621**
	Sig. (2-tailed)	0.204	0.000		0.001
	N	25	25	25	25
NL	PC	0.812**	0.796**	0.621**	1
	Sig. (2-tailed)	0.000	0.000	0.001	
	N	25	25	25	25

**. Correlation is significant at the 0.01 level (2-tailed).
Pearson Correlation: PC.

Table 6. Results of CA of 200 ml LOF with SH, LW, and NL

		Correlations			
		LOF 200 ml	PH	LW	NL
LOF 200 ml	PC	1	0.268	0.062	0.739**
	Sig. (2-tailed)		0.196	0.768	0.000
	N	25	25	25	25
PH	PC	0.268	1	0.300	0.455*
	Sig. (2-tailed)	0.196		0.145	0.022
	N	25	25	25	25
LW	PC	0.062	0.300	1	0.395
	Sig. (2-tailed)	0.768	0.145		0.051
	N	25	25	25	25
NL	PC	0.739**	0.455*	0.395	1
	Sig. (2-tailed)	0.000	0.022	0.051	
	N	25	25	25	25

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
Pearson Correlation: PC

Conclusion

Several doses of LOF made from cassava peel showed strong (*) and very strong (**) correlations with cocoa plant height and leaf number. However, there was no correlation between LOF and cocoa plant leaf diameter.

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Author Contributions
Conceptualization and design of research work, U.H.A.; implementation of field/laboratory experiments and data collection, U.H. and L.M.; manuscript preparation, data analysis and interpretation, U.H., L.M., & T.J.S.

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Conflicts of Interest
The authors declare no conflict of interest.

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