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The Effect of Fermentation Duration of Cocoa Pulp Waste Bioherbicide (*Theobroma cacao* L.) on the Mortality Rate of Sweet Potato Weeds (*Borreria latifolia*)

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ABSTRACT

A substantial population of weeds represents a significant threat to human well-being, thus necessitating measures for their regulation and management. As public consciousness regarding the significance of environmental sustainability grows, there is a corresponding rise in the public's call for farming methods that are environmentally conscious and for agricultural products that are safer for consumption. An alternate approach to managing agricultural and plantation weed growth involves the utilization of bioherbicides derived from the liquid waste of cocoa pulp (*Theobroma cacao* L.). In this research, a Non-Factorial, Completely Randomized Design (CRD) was utilized to investigate the impact of varying fermentation times on different Cocoa Pulp Liquid Waste. The treatments included F0 as the control, F1 with 1 week of fermentation, F2 with 2 weeks of fermentation, F3 with 3 weeks of fermentation, and F4 with 4 weeks of fermentation, each with 6 replications. A total of 30 treatment units were observed, each containing 5 plants, resulting in 150 polybags of potato weeds (Borreria latifolia) being utilized in the study. The observational data were subjected to analysis through the Kruskal-Wallis method. In instances where the test yielded significant outcomes, the analysis proceeded with the Duncan Multiple Range Test (DMRT) at a significance level of $\alpha = 5\%$. The assessment of weed poisoning levels was conducted visually daily over fourteen days following the application of Cocoa Pulp Bioherbicide. This assessment utilized a scoring system based on percentage estimates as outlined by the Pesticide Commission (2000), categorized as follows: 0 = No poisoning; 0-5% exhibiting abnormal leaf shape or color; 1 = Mild poisoning, 5-10% abnormal leaf shape or color; 2 = Moderate poisoning, 10-20% abnormal leaf shape or color; 3 = Severe poisoning, 20-50% abnormal leaf shape or color; 4 = Very severe poisoning, exceeding 50% abnormal leaf shape or color, leading to drying, leaf drop, and eventual plant death. The findings indicated that the fermentation period for the Bioherbicide Liquid Waste derived from Cocoa Pulp (*Theobroma cacao* L.) was three weeks, which significantly enhanced the mortality rate of Potato weeds (Borreria latifolia), achieving a maximum death rate of 20% (classified as moderate) and demonstrating effectiveness at seven days post-application (HSA).

Keywords: *Bioherbicide, Borreria latifolia, Cocoa Pulp, Fermentation, Weeds*

1. INTRODUCTION

Weeds are defined as plants that thrive in various environments, ranging from those with low nutrient availability to those that are nutrient-rich. This adaptability sets weeds apart from cultivated species. Notably, perennial weeds exhibit a remarkable capacity for regeneration. Furthermore, weeds can produce a substantial number of seeds, facilitating their rapid reproduction (Madusar, 2017). The prevalence of weeds can lead to significant economic losses for humans, necessitating effective control measures. The extent of competition posed by weeds is influenced by several factors, including soil fertility, the types of cultivated plants, the species of weeds present, moisture levels in the soil, land management practices, the application of fertilizers, the growth stages of the plants, and the density of the weed population. Favorable environmental conditions contribute to the suitability of the habitat for plant growth (Hartono et al., 2022). The robust growth of weeds can adversely impact the development and yield of cultivated crops as they compete for essential resources such as nutrients and light, ultimately hindering optimal growth and productivity. Various methods for weed control are available, including preventive measures, manual removal, cultural techniques, biological approaches, integrated strategies, and chemical treatments utilizing herbicides.

Chemical herbicides are commonly used for weed control, particularly in large agricultural areas. The rationale for this lies in the fact that chemical herbicides have the capability to manage weeds prior to their interference effectively, control weed infestation in oil palm crops, mitigate the potential damage to oil palm plants, exhibit greater efficacy in eradicating annual weeds and undergrowth, and ultimately enhance oil palm yields when compared to conventional methods of weeding (Sumekar Y, 2022).

As public awareness regarding the significance of environmental sustainability continues to grow, there is a corresponding increase in the demand for eco-friendly agricultural practices and safer food products. Chemical pest control involves the application of synthetic pesticides to mitigate pest populations that threaten cultivated crops. The repercussions of pesticide use extend beyond environmental concerns, directly affecting human health. Pesticide residue that remain on crops, mainly fruits and vegetables, pose health risks when ingested, as continuous application leads to plant accumulation (Inayah and Nirmala, 2020). An alternative approach to managing weeds in agriculture and plantations is the utilization of bioherbicides. These are herbicides derived from natural organisms. This study explores the potential of utilizing waste from cocoa plants as a source of bioherbicides. The cocoa plant (*Theobroma cacao* L.) represents Indonesia's significant non-oil and gas export commodity, serving as a vital source of income for farmers and contributing to the nation's foreign exchange earnings from the agricultural sector. Traditionally, cocoa has been employed as a flavoring agent in various products, including food, confections, beverages, cosmetics, and as a source of vegetable fat (Kaab et al., 2020).

Weed management involves taking measures to halt the ongoing proliferation of undesirable plants. This measure is implemented because weeds, plant species that proliferate around cultivated plants, vie for resources with the cultivated plants (Sabtu et al., 2023). Weeds are plant species that thrive in various environments, ranging from low-nutrient to high-nutrient locations. This particular trait is the factor that sets weeds apart from cultivated plants. Perennial weeds exhibit a high capacity for regeneration, particularly in comparison to other weed varieties. Weeds can thrive in competition with cultivated plants due to their ability to modify their leaves and other parts, allowing them to spread widely. Moreover, weeds can produce a significant number of seeds, facilitating their rapid proliferation (Mustafa et al., 2019).

The proliferation of weeds, characterized by a significant population density, results in substantial economic losses for humans, necessitating effective management strategies. The application of chemical herbicides is increasingly favored, particularly in extensive agricultural settings, due to their efficacy in preemptively controlling weed growth and managing weeds in oil palm cultivation. Furthermore, allelochemical compounds derived from certain plant species have potential as bioherbicides (Muningsih and Chandra, 2024). Motmainna et al. (2021) noted that secondary metabolites such as flavonoids, phenols, terpenoids, and tannins serve as bioherbicides. Among the invasive plant species, those containing secondary metabolites have demonstrated effectiveness in mitigating damage to oil palm plants, outperforming traditional weeding methods by effectively eliminating annual weeds and shrubs while simultaneously enhancing oil palm yields

This research investigates the potential of cocoa plant waste as a source of bioherbicides. Specifically, the study focuses on using cocoa pulp waste to develop natural bioherbicides, which are advantageous as eco-friendly alternatives to conventional herbicides. The primary objective of this investigation is to assess how varying fermentation durations of cocoa pulp liquid waste bioherbicides influence the mortality rate of potato weeds (Borreria latifolia).

2. MATERIAL AND METHODS

Sei Putih Garden, located in the Galang District of Deli Serdang Regency, will be operational for three months, specifically from June 2024 to August 2024. Its geographical coordinates are N: 98° 0' 22.85", E: 02° 0' 34.44", with an elevation of 38 meters above sea level.

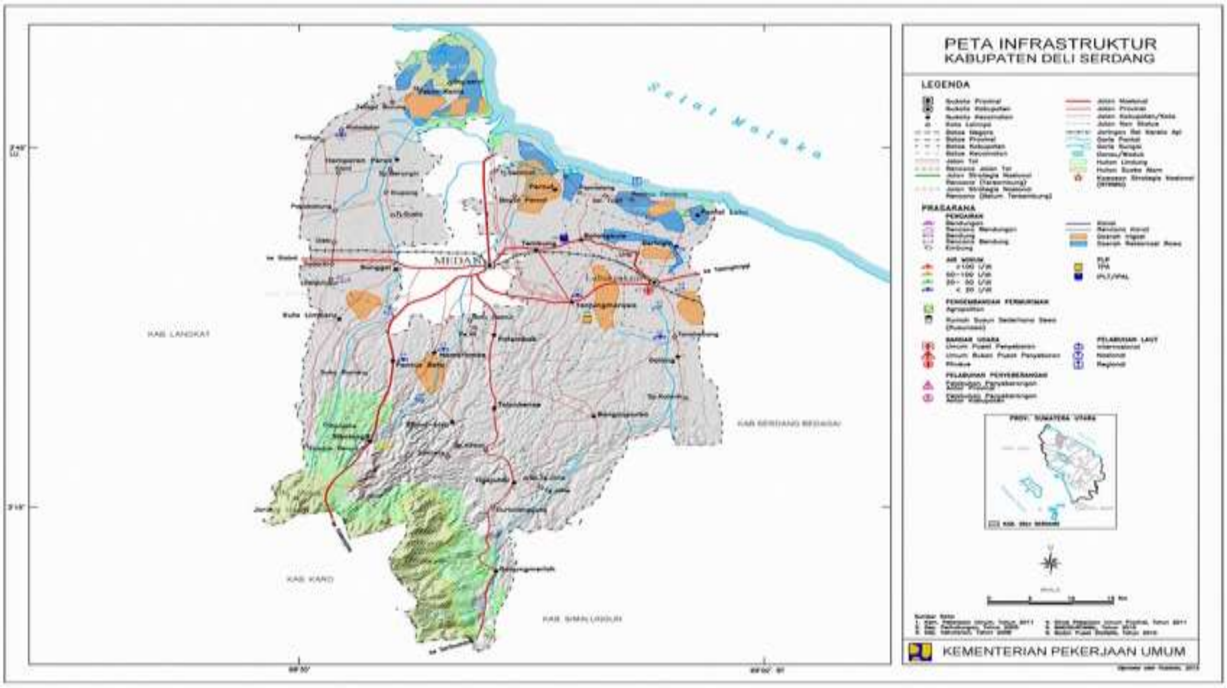

Figure 1. Administrative Map Deli Serdang Regency, Galang District

The materials used in this study include fermented cocoa pulp liquid aged 1 week, 2 weeks, 3 weeks, and 4 weeks, along with potato weed (Borerria latifolia). The planting medium in the polybags consists of soil, chicken manure at a 1:1 ratio, and Furadan 3GR containing 3% carbofuran as the active ingredient. The tools include a hand sprayer, hoe, polybags sized 15 x 30 cm/1000 g, buckets, gloves, and a measuring cup.

This research employed a Non-Factorial, Completely Randomized Design (CRD) to investigate the effects of varying fermentation durations of cocoa pulp liquid waste across different treatments. The fermentation periods were designated as follows: F0 served as the control group; F1 represented one week of fermentation; F2 indicated two weeks; F3 denoted three weeks; and F4 corresponded to four weeks of fermentation. Each treatment was replicated six times, resulting in 30 treatment units. Each unit comprised five plants, culminating in 150 polybags of potato weeds (Borreria latifolia). The data collected from observations were analyzed using the Kruskal-Wallis method, and in instances where significant differences were identified, the analysis proceeded with the Duncan Multiple Range Test (DMRT) at a significance level of $\alpha = 5\%$. The assessment of weed toxicity was conducted visually daily over fourteen days following the application of the cocoa pulp bioherbicide, utilizing a scoring system based on percentage estimates as outlined by the Pesticide Commission (2000). The scoring criteria were as follows: 0 indicated no poisoning with 0-5% of leaves exhibiting abnormal shape or color; 1 represented mild poisoning with 5-10% abnormality; 2 indicated moderate poisoning with 10-20% abnormality; 3 denoted severe poisoning with 20-50% abnormality; and 4 signified very severe poisoning with over 50% abnormality, leading to wilting, leaf drop, and eventual plant death. The indicators for observation included the physical condition of the weeds post-application of the bioherbicide, where surviving weeds appeared fresh, while those affected by poisoning exhibited signs of distress, characterized by yellowing or brownish-yellow coloration. The process of obtaining the cocoa pulp bioherbicide commenced with harvesting cocoa fruits from fields deemed ready for harvest. The harvested cocoa fruit is gathered in a clean and dry environment. Subsequently, the fruit is carefully broken or split to extract the cocoa beans, ensuring that the beans remain uninjured and undamaged during this process. This breaking can be accomplished using either a wooden mallet or a knife. Once the cocoa beans are extracted, they are placed into a clean burlap sack while any adhering pith is discarded. After all beans have been collected, the burlap sack is securely tied, suspended, and covered with plastic to facilitate the drainage of cocoa pulp liquid into the plastic. This liquid is then transferred into a tightly sealed jerrycan for natural fermentation. The collection of the fermented cocoa liquid occurs three times weekly. Additionally, bioherbicide was applied once during the study, targeting weeds that were two weeks old after being transferred to a 15 x 30 cm polybag arranged in a 3 m² area (1.5 x 2 m). The spraying, performed with a hand sprayer, was executed directly above the weeds to ensure complete coverage, aiming for a spray volume of 10 ml. This application took place in the morning between 07:00 and 09:00.

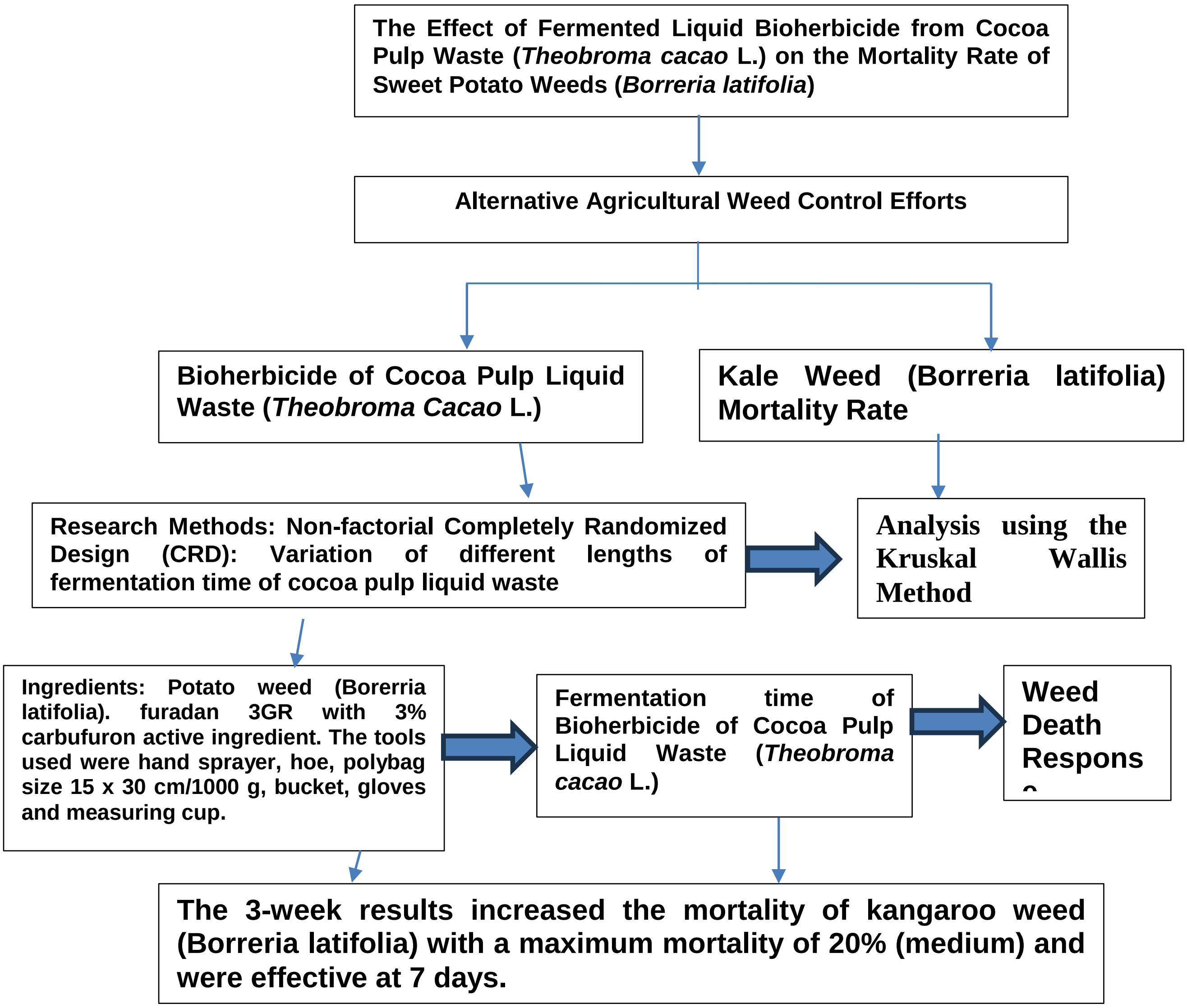

Figure 2. Flowchart in Research on the Length of Fermentation of Bioherbicide of Cocoa Pulp Liquid Waste (*Theobroma cacao* L.) on the Death Rate of Kentangan Weed (*Borreria latifolia*)

3. RESULT AND DISCUSSION

3.1 Growth Power(%)

The results of the research on the mortality rate of the observed weeds over 14 Days After Application (DAA) can be seen in Table 1 and Figure 3 below.

The findings presented in Table 1 indicate that the Control Treatment (F0) did not significantly impact the mortality rate of potato weeds (Borreria latifolia) in the absence of bioherbicide application. As noted by Ulfa (2018), the inherent characteristics of weeds contribute to their resistance to control measures. In agricultural settings, chemical methods, particularly herbicides, are often favored for weed management due to their efficiency in large-scale applications and relative cost-effectiveness under specific conditions (Munthe and Dahang, 2018). While low-dose herbicides can effectively eliminate certain weed species without harming other plants, the data illustrated in Figure 3 reveals that high doses administered over 14 days can eradicate all plant parts and species. However, the regrowth of weeds is attributed to only removing the aerial portions, leaving the roots intact. Consequently, as the duration of observation extends, the total dry weight of the weeds increases. This result suggests that manual weeding is insufficient in curbing weed proliferation, as it merely displaces the upper sections of the weeds while the subterranean parts remain viable for growth and reproduction into new weed populations (Sitohang and Tyasmoro, 2019).

Table 1. Average Weed Mortality Rate from Day 1 to Day 14 HSA

Treatment	Days						
	1	2	3	4	5	6	7
F0	0,00 ± 0,43 c	0,07 ± 0,43 c	0,07 ± 0,43 c	0,07 ± 0,43 c	0,07 ± 0,43 c	0,17 ± 0,43 c	0,13± 0,43 d
F1	0,43±0,03 bc	0,50 ± 0,03 bc	0,90 ± 0,43 b	1,03 ± 0,43 b	1,07 ± 0,43 b	0,97 ± 0,43b	0,97 ± 0,43 c
F2	0,73 ± 0,43 b	0,80 ±0,03 b	1,00 ± 0,43 a	1,30 ±0,03 b	1,20 ± 0,43 b	1,20 ± 0,43b	1,37 ± 0,43 b
F3	1,30 ± 0,43 a	1,87 ±0,03 a	2,17 ± 0,43 a	2,33 ± 0,43 a	2,33 ± 0,43 a	2,37 ± 0,43 a	2,20 ± 0,43 a
F4	0,60 b ± 0,43	0,57 ±0,03 bc	0,57	0,93 b ± 0,43	0,90 b ± 0,43	0,83 ± 0,43 b	0,93 ± 0,43 c
Mean	0,61	0,76	0,94	1,13	1,11	1,11	1,1 2
kw (H)	18,52	18,46	22,95	21,52	23,72	21,5	24,77
Significance	*	*	*	*	*	*	*

Treatment	Days						
	8	9	10	11	12	13	14
F0	0,13 ± 0,43 c	0,13± 0,43 c	0,17± 0,43c	0,10 ± 0,43 c	0,10 ± 0,43 c	0,10 ± 0,43 c	0,10 ± 0,43 c
F1	1,00 ± 0,43 b	1,03 ± 0,43 b	0,67 ± 0,03 bc	0,63 ± 0,03 bc	0,97 ± 0,43 b	0,87 ± 0,43 b	0,71 ± 0,43 b
F2	1,50 ± 0,43 b	1,33 ± 0,43 b	0,97 ± 0,43 b	1,03 ± 0,43 b	0,87 ± 0,43 b	1,07 ± 0,43 b	1,03 ± 0,43 b
F3	2,33 ± 0,43 c	2,40 ± 0,43 a	2,20 ± 0,43a	2,23± 0,43 a	2,03 ± 0,43 a	2,20 ± 0,43 a	2,07 ± 0,43 a
F4	0,30 ± 0,43 c	0,17 ± 0,43 c	0,57 ± 0,03 bc	0,20 ± 0,43 c	0,50± 0,03 bc	0,83 ± 0,43 b	0,47 ± 0,03 bc
Mean	1,05	1,01	0,91	0,84	0,89	1,01	0,88
kw (H)	21,68	19,86	20,07	21,49	21,26	22,11	22,19
Significance	*	*	*	*	*	*	*

Notes: According to Duncan's Distance Test with α = 5%, the same letter in the same column is not significant

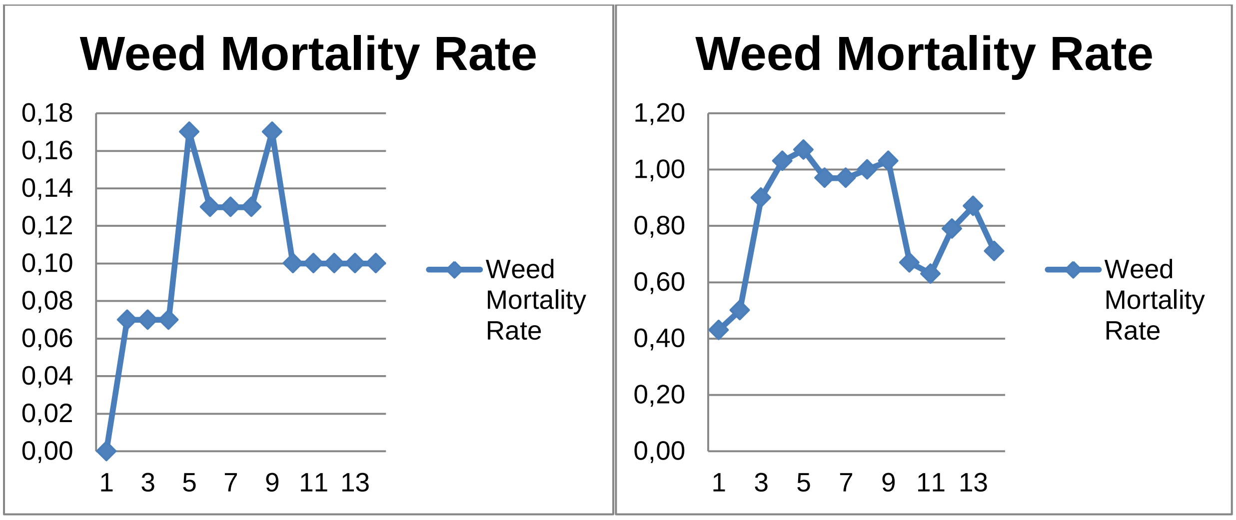

Figure 3. Relationship between weed mortality rate and control (F0) and F1 for 14 HSA

The results of the variance analysis indicate that the herbicide paraquat was only effective in controlling weeds during the early observation period, precisely 10 days after sowing (DAS). This result is evidenced by the findings in treatment F1, which show a response in the death rate of the Kentangan weed from day 1 to day 8 DAS when exposed to the fermentation duration of 1 week of liquid cocoa pulp bioherbicide (F1), as presented in Figure 3. Similarly, treatment F2 indicates a response in the death rate of the Kentangan weed from day 1 to day 8 DAS concerning the fermentation duration of 2 weeks of liquid cocoa pulp bioherbicide (F2), and as observed in treatment F3, the same death rate response was noted over 14 DAS for the 3-week fermentation of the liquid cocoa pulp bioherbicide (F3). These findings align with those reported by Ulfa, W.D. (2018), who stated that the fermentation of cocoa pulp impacts the toxicity against the weeds Ageratum conyzoides, Axonopus compressus, Borreria latifolia, Cyperus kylingia, and Paspalum conjugated. Effectiveness was noted particularly in F3. The results depicted in Figure 4 demonstrate the relationship between weed death rates and the effectiveness of the 2-week fermentation duration of the liquid cocoa pulp bioherbicide (F2), as well as the relationship between weed death rates and the 3-week fermentation duration (F3) over 14 DAS. The findings suggest that a fermentation duration of 3 weeks leads to significant effects on the length of the thorny spinach roots. This result is suspected to be due to the presence of allelopathic compounds in the liquid cocoa pulp bioherbicide, which may inhibit plant nutrient absorption, thus restricting the root length of the thorny spinach weeds. The allelopathic content in babadotan can reduce cell membrane permeability, resulting in impaired plant ability to absorb nutrients and dissolved water (Zainuddin et al., 2018).

The data presented in F4 indicates a measurable response in potato weed mortality from day 1 HSA to day 8 HSA during the fermentation of Cocoa Pulp Liquid Waste Bioherbicide, which spans four weeks (F4). Notably, the efficacy of the cocoa pulp liquid waste fermentation for three weeks demonstrates a significant impact within the initial seven days post-application. Research by Murtilaksono et al. (2020) has shown that liquid organic fertilizers derived from babadotan plants can effectively suppress the growth of hanjeli plant roots. This suppression is attributed to the allelopathic properties of babadotan, which hinder the development of hanjeli roots. The allelopathic compounds in babadotan leaves can diminish cell membrane permeability, disrupting the plant's capacity to absorb water and essential nutrients. This finding aligns with the observations of Adilla et al. (2024), who noted that a 3% concentration of herbicide solution resulted in a more rapid weed mortality rate compared to 1% and 2% concentrations, averaging eight days post-application. Overall, the effectiveness of the Cocoa Pulp Liquid Waste Bioherbicide fermentation period declines from the 8th to the 14th day, leading to a lighter dry weight of weeds at various dosage levels compared to manual weeding. This phenomenon can be attributed to the fact that broadleaf weeds are typically classified as annual weeds. Perianto et al. (2016) have indicated that while annual weeds are generally easier to manage, they exhibit rapid growth and prolific seed production, unlike perennial weeds, which have a life cycle exceeding two years and demonstrate greater environmental adaptability.

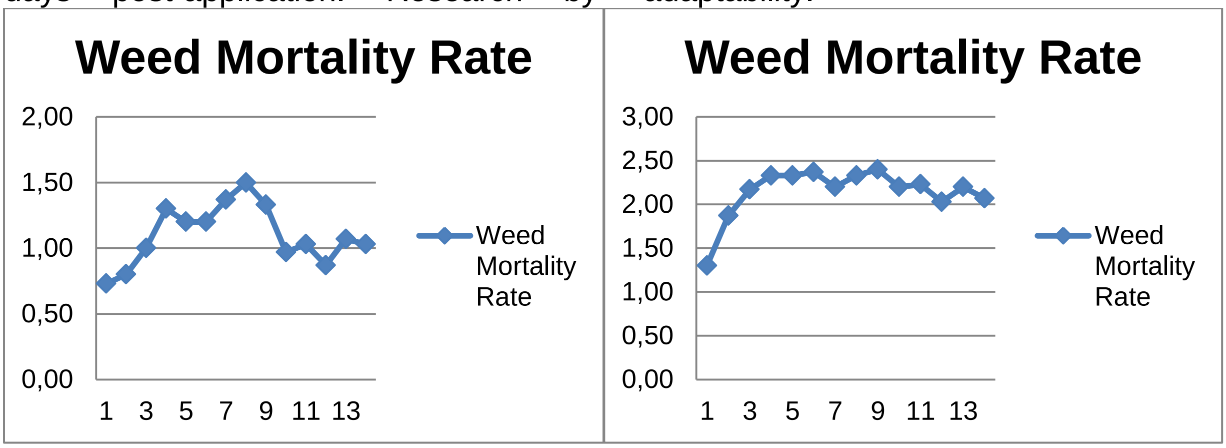

Figure 4. The relationship between weed mortality rates and the effectiveness of a two-week fermentation period of cocoa pulp wastewater bioherbicide (F2) and the relationship between weed mortality rates and the effectiveness of a

three-week fermentation period of cocoa pulp wastewater bioherbicide (F3) over 14 days after sowing (DAS).

4. CONCLUSION

The duration of fermentation for Bioherbicide Liquid Waste derived from Cocoa Pulp (*Theobroma cacao* L.) is three weeks, leading to a notable rise in the mortality of Potato weeds (Borreria latifolia) with a peak mortality rate of 20% (moderate), proving to be effective at 7 Days After Application (DAP).

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