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Optimization of Cocoa Rootstock Seedling Growth (*Theobroma cacao* L.) MCC-02 Clone Using KoHeA+MF Organic Fertilizer Application

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Abstract

Cocoa (*Theobroma cacao*) is a significant plantation crop with considerable economic importance. The beans derived from cocoa are abundant in antioxidants, which play a crucial role in cellular protection and the enhancement of endorphin levels. Given the increasing demand and favorable pricing, the future of cocoa cultivation appears promising. A critical factor influencing cocoa production is the quality of seedlings, particularly the rootstock. The growth of cocoa seedlings is affected by various elements, among which soil fertility stands out as a vital component of the planting medium. The necessary properties for optimal growth can be sourced from organic materials. One such organic amendment is KoHeA + MF organic fertilizer, which has demonstrated effective growth and yield improvements in pak choi. This study aims to formulate recommendations for an optimal planting medium composition that incorporates KoHeA + MF organic fertilizer for the nursery of cocoa rootstocks, ultimately producing high-quality seedlings. The research was conducted over a six-month period, from May to October 2024, at the experimental garden of the Payakumbuh State Agricultural Polytechnic, situated at an elevation of approximately 500 meters above sea level. The observed variables included leaf count, plant height, leaf length, and leaf width. The findings indicate that the most effective combination for cultivating the cocoa variety MCC-02 is a soil to KoHeA + MF ratio of 3:1.

Keywords: Cocoa, KoHeA + MF, MCC-02, Organic Fertilizer, Rootstock

1. Introduction

Cocoa (*Theobroma cacao*) is a significant plantation crop with considerable economic implications. As noted by Matatula, Mahulette, and Tanasale (2022), the origins of the cocoa plant can be traced back to the tropical rainforests of South America, and it is not indigenous to Indonesia. The introduction of cocoa to Indonesia occurred in 1560, facilitated by the Spanish via Sulawesi (Minahasa). Since the 1930s, cocoa has emerged as a vital plantation commodity within the Indonesian economy, contributing to employment opportunities, income generation, and foreign exchange earnings. The fruit of the cocoa plant serves as a fundamental ingredient in a variety of food, medicinal, and cosmetic products, thereby supporting the livelihoods of farming families and enhancing the nation’s foreign exchange reserves. According to the Kew Royal Botanical Garden (2024), the utilization of cocoa dates back to ancient civilizations, with the Maya and Aztecs incorporating chocolate into engagement and wedding ceremonies as well as religious rituals. Initially, cocoa was consumed in Central and South America as a spiced liquid food, often combined with ingredients like chili and vanilla. The flesh of the cocoa fruit possesses a tropical flavor reminiscent of passion fruit and mango, while the beans are abundant in antioxidants, which are beneficial for cellular protection and the enhancement of endorphin levels.

Cocoa exhibits a favorable outlook due to its significant demand and elevated market prices. As reported by the Agricultural Instrument Standard Information Center, BSIP (2023), cocoa plants represent a plantation

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commodity with considerable potential, thriving in Indonesia's tropical climate. In 2020, Indonesia's cocoa production reached 659.7 thousand tons, with Sulawesi Island contributing the majority, accounting for approximately 75% of the nation's total output. Key regions for cocoa cultivation include Central Sulawesi, Southeast Sulawesi, South Sulawesi, West Sulawesi, Lampung, Aceh, West Sumatra, and North Sumatra. The combination of high production levels and robust demand for cocoa beans underscores the necessity for enhancing the quality of cocoa seedlings. Strong and resilient rootstock cocoa seedlings, characterized by extensive root systems, are essential for fostering healthy, vigorous trees that yield high production. The application of organic fertilizer KoHeA + MF, an environmentally friendly product made from readily available materials, is pivotal for producing quality and sustainable cocoa seedlings. Currently, many cocoa farmers have not adopted superior seed varieties, and the maintenance of plants remains suboptimal. Most farmers do not engage in intensive care and rejuvenation practices for their cocoa plants. Furthermore, the fertilizers used often do not align with recommended guidelines, primarily due to challenges in obtaining fertilizers, which are limited in distribution and relatively costly.

Cocoa production in 2022 was notably high, with BSIP (2023) reporting an output of 667.3 thousand tons. This figure, while substantial, is still below the peak production of 740.5 thousand tons achieved in 2012. Following this peak, cocoa production experienced a decline, despite indications of potential recovery. From 2009 to 2013, the Indonesian government, through the Directorate General of Plantations, initiated the National Movement Program for Increasing Cocoa Production and Quality (Gernas Cocoa). This initiative aimed at rejuvenating, rehabilitating, and intensifying cocoa cultivation. As a result of Gernas Cocoa, the area dedicated to cocoa farming in Indonesia expanded by 11.36%, with community plantations seeing an increase of 12.44%. During this timeframe, Indonesia significantly boosted its cocoa production and successfully exported to markets in Malaysia, the United States, the Netherlands, and China. Despite facing various challenges, the growth of Indonesia's cocoa sector underscores the resilience of domestic plantations and highlights the potential for future expansion. However, cocoa production has seen a decline. According to BSIP (2023), productivity was recorded at 0.77 tons per hectare in 2009, which fell to 0.61 tons per hectare by 2018. This reduction in cocoa production has had far-reaching consequences, impacting not only the export of cocoa beans but also the supply for the domestic processing industry. Consequently, the government has been compelled to allow imports of cocoa beans to satisfy the demands of the domestic cocoa processing sector.

According to the findings of BSIP (2023), the factors influencing the endeavors to augment cocoa production can be categorized into several domains. These include, but are not limited to, the waning capacity of human resources in the management of cocoa plantations, the emergence of soil conditions exhibiting signs of "tiredness" (soil fatigue), the aging of cocoa plants, incidences of attacks by cocoa fruit borer pests (PBK), and the occurrence of vascular stroke dieback (VSD). A salient issue is the underutilization of fertilizers, with some farmers opting against the application of fertilizers to cocoa plants. Furthermore, the quality of the seeds utilized in cocoa cultivation is of paramount importance.

Efforts to enhance cocoa production can take various forms. As reported by BSIP (2023), one effective strategy involves the utilization of superior cocoa variety seeds, a practice that was successfully adopted in Southeast Sulawesi in 2020. Indah, Agustien, and Mulyadi (2014) emphasize that high-quality cocoa seeds are essential for achieving profitability in cocoa cultivation. The advantages of superior cocoa seeds can extend for as long as 37 years, indicating that errors in seed selection can lead to enduring adverse effects.

The growth of cocoa seedlings is influenced by multiple factors, with soil fertility being a critical component of the planting medium. Optimal soil fertility is determined by the physical, chemical, and biological characteristics of the soil. Favorable physical properties are indicated by a well-structured, loose soil composition. Furthermore, the chemical properties, including nutrient adequacy and balance, soil pH, and cation exchange capacity, play a significant role in determining soil fertility. The enhancement of these properties can be achieved through the application of organic materials. One such organic material is KoHeA + MF organic fertilizer, which has demonstrated effective growth and production outcomes in pakcoy cultivation.

The high levels of cocoa production coupled with a significant demand for cocoa beans necessitate enhancements in the quality of cocoa seedlings. Strong and robust cocoa rootstock seedlings, characterized by an extensive root system, are essential for fostering the growth and development of healthy, productive trees. The application of organic fertilizer KoHeA + MF, recognized as an environmentally sustainable product, is advantageous due to its accessibility and ease of preparation, thereby contributing to the cultivation of quality and sustainable cocoa seedlings. Currently, many cocoa farmers have not adopted the superior seed varieties that are in demand, and the maintenance of existing plants remains suboptimal. Most farmers do not engage in intensive care or rejuvenation practices for their cocoa plants. Furthermore, the fertilizers utilized by many farmers often do not align with recommended guidelines, primarily due to the challenges in sourcing fertilizers that are both limited in availability and relatively costly. Consequently, the introduction of organic fertilizer KoHeA + MF, which utilizes locally sourced materials such as banana stem mole activators and abundant chicken manure, presents a viable solution for producing quality cocoa seedlings at a lower cost while also promoting environmental sustainability.

This study aims to assess the necessity of organic fertilizer KoHeA + MF for cocoa rootstock seedlings and to evaluate the growth rate of these seedlings when treated with the organic fertilizer. The findings of this research are anticipated to yield recommendations regarding the appropriate dosage of KoHeA + MF organic fertilizer for cocoa rootstock nurseries, ultimately leading to the production of high-quality cocoa rootstock seedlings.

2. Material and Methods

This study was carried out between May and October 2024 at the experimental garden of the Payakumbuh State Agricultural Polytechnic, situated at an elevation of approximately 500 meters above sea level, with geographic coordinates of -0°10'9.8184" S and 100°39'51.7464" E (0.169394° S, 100.664374° E). The materials utilized in this research included MCC-02 cocoa beans, topsoil, KoHeA+MF fertilizer, NPK fertilizer, polybags, insecticides, and fungicides. The tools employed comprised hoes, machetes, carts, buckets, construction materials for shelters, scales, and knapsack sprayers. The experimental design implemented was a 3x5 Factorial Completely Randomized Design (CRD) with three replications. The primary factor examined was the location of the seed source, categorized as A1 = Base, A2 = Middle, and A3 = Tip. The secondary factor involved the composition of the planting media, defined as B1 = 100% soil, B2 = soil: KoHeA + MF ratio of 4: 1, B3 = soil: KoHeA + MF ratio of 3: 1, B4 = soil: KoHeA + MF ratio of 2: 1, and B5 = soil: KoHeA + MF ratio of 1: 1. The study's variables included plant height (cm), leaf length (cm), leaf width (cm), and the number of leaves (blades). The data collected were subjected to statistical analysis using the F test at a 5% significance level, followed by the Duncan Multiple Range Test (DMRT) at the same level.

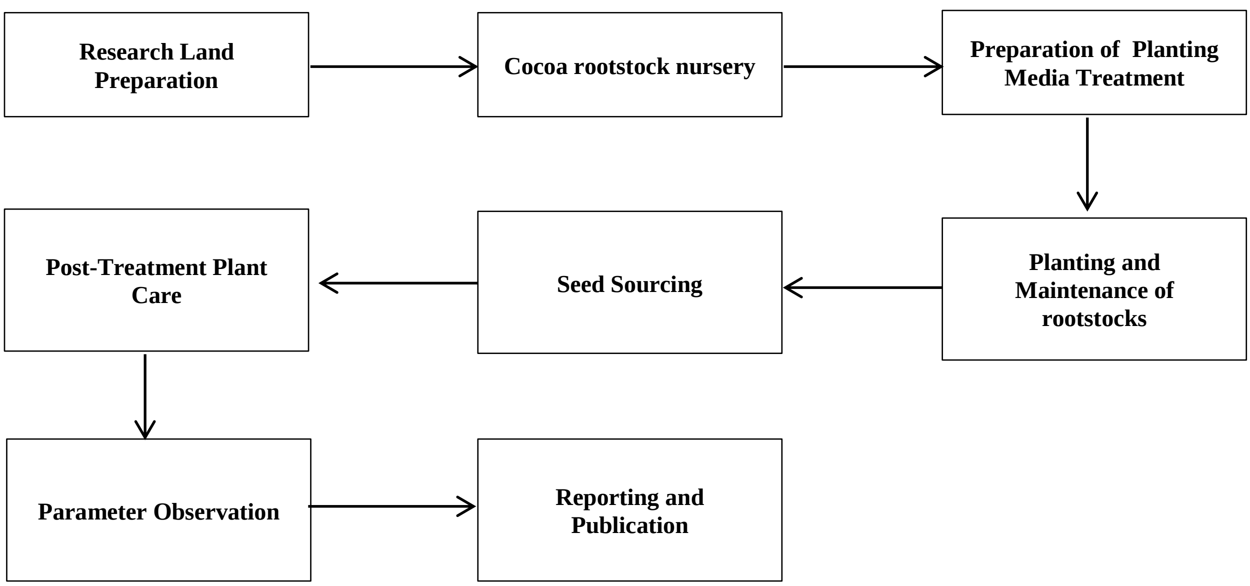

Figure 1. Research flow diagram

3. Results and Discussion

3.1. Number of leaves

The results of observations on the number of leaves in the study of the effect of planting media composition on the growth of cocoa seeds can be seen in Table 1.

The application of KoHeA+MF fertilizer at a soil to KoHeA+MF ratio of 3:1 across all cocoa seed positions yielded the most favorable outcomes regarding the number of seedling leaves. This phenomenon is likely attributed to the enhanced formation of auxins facilitated by this specific composition. The optimal ratio of 75% soil to 25% KoHeA+MF fertilizer effectively maximizes ion exchange processes, thereby improving nutrient absorption in the vicinity of the roots.

Table 1. Number of Cocoa Leaves

Seed Position	Komposisi Media Tanam				
	Soil 100%	Soil:Fertilizer (4:1)	Soil:Fertilizer (3:1)	Soil:Fertilizer (2:1)	Soil:Fertilizer (1:1)
Base	9.83 ± 2.08 a AB	7.83 ± 0.76 b B	9.17 ± 1.53 a AB	7.33 ± 0.76 a B	11.66 ± 1.61 a A
Middle	10.50 ± 0.87 a A	6.50 ± 1.80 b B	10.00 ± 0.50 a A	10.00 ± 1.73 a A	7.67 ± 2.84 b AB
Edge	9.67 ± 0.76 a A	11.00 ± 0.87 a A	10.17 ± 2.89 a A	9.17 ± 1.15 a A	9.50 ± 0.50 ab A

Numbers followed by the same lowercase letter in a column and the same uppercase letter in a row indicate no significant difference based on the DMRT test (α = 5%).

The substantial application of KoHeA+MF fertilizer at the 3:1 ratio correlates with increased plant height, as taller plants typically exhibit a greater number of shoots from the stem nodes, leading to an increase in leaf count, which is associated with nitrogen uptake. This observation aligns with Jumin's assertion (2001) that leaf development is positively correlated with nitrogen availability. Nitrogen is crucial for amino acid synthesis, which in turn is essential for protein formation (Lakitan, 2000). Consequently, the presence of adequate protein contributes to both leaf proliferation and enhanced plant height. Furthermore, Hakim (2007) emphasizes that effective seeding is contingent upon the quality of the planting medium and its maintenance. As noted by Supriyanto et al. (1986) in Purbiati et al. (1994), a superior planting medium fosters optimal root development, ultimately leading to improved overall plant growth.

3.2. Plant Height

The findings of the observations conducted on the impact of varying planting media compositions on cocoa seed growth are presented in Table 2.

The composition of the planting medium significantly influences plant growth, as it directly impacts the root zone and, consequently, the efficiency of nutrient absorption. Muryaningsih et al. (1995), as cited in Wahyuni et al. (2018), emphasize the critical role of organic media in developing the root system. Ideally, the growing medium should possess characteristics such as being lightweight, homogeneous, cost-effective, and conducive to optimal seedling development. This assertion is further corroborated by research conducted by Wulantika et al. (2023), which indicates that the combination of KoHeA and MF fertilizers, both organic in nature, enhances the number of shoots in rice plants as well as in pak choy.

Table 2. Plant Height

Seed Position	Komposisi Media Tanam				
	Soil 100%	Tanah:Pupuk (4:1)	Soil 100%	Tanah:Pupuk (2:1)	Soil 100%
Base	22,96 ± 0,64	22,75 ± 1,95	24,25 ± 1,52	23,32 ± 1,15	23,22 ± 4,85
Middle	24,92 ± 2,67	20,25 ± 0,66	25,75 ± 2,14	24,28 ± 1,99	22.30 ± 1.87
Edge	23,43 ± 1,84	22,18 ± 0,81	23,17 ± 4,14	24,83 ± 2,50	20,92 ± 1,04

3.3. Leaf Length

The findings concerning the impact of planting media composition on cocoa seed growth, as observed in this study, are presented in Table 3.

Cocoa plants, as noted by Soedidjanto (1983), thrive in loose substrates that possess adequate water retention and nutrient content. Nyakpa et al. (1988) emphasized the critical role of nutrients, particularly Nitrogen and Phosphate, in the leaf development process, which is intrinsically linked to the nutrient availability in the planting medium. These nutrients are essential for the synthesis of new cells and constitute vital components of organic compounds in plants, including amino acids, nucleic acids, chlorophyll, ADP, and ATP. A deficiency in either of these nutrients can disrupt the plant's metabolic functions, thereby impeding leaf formation. Furthermore, Darmawan and Baharsyah (1983) highlighted that the presence of sufficient and balanced nutrients is crucial for the metabolic processes within plant tissues. Djuarnani et al. (2005) also reported that the application of compost enhances soil structure, leading to improved soil aggregation and stabilization, which in turn benefits aeration, drainage, heat retention, and the soil's capacity to absorb air, while also aiding in the prevention of air stagnation.

Table 3. Length of cocoa leaves

Seed Position	Planting Media Composition				
	Soil 100%	Soil:Fertilizer (4:1)	Soil:Fertilizer (3:1)	Soil:Fertilizer (2:1)	Soil:Fertilizer (1:1)
Base	17,78 ± 1,67	17,59 ± 1,76	19,93 ± 3,00	20,37 ± 1,21	18,38 ± 0,63
Middle	15,73 ± 2,58	14,35 ± 0,56	21,23 ± 3,74	19,10 ± 2,95	18,80 ± 1,29
Edge	18,90 ± 0,13	17,22 ± 3,02	16,67 ± 1,98	17,88 ± 2,93	16,98 ± 2,25

3.4. Leaf Width

The results of observations of leaf width in the study of the effect of planting media composition on cocoa seed growth can be seen in Table 4.

Table 4 illustrates the relationship between the composition of planting media and the positioning of seeds concerning leaf width. The application of KoHeA+MF fertilizer at a 3:1 ratio across all cocoa seed positions yielded the most favorable outcomes in terms of leaf width. This can be attributed to the enhanced soil structure resulting from the incorporation of suitable organic fertilizers, which in turn promotes optimal soil aeration and drainage. Supporting this observation, Sarief (1986) noted that robust root development in plants correlates with the overall growth of other plant parts, as well-developed roots are more effective in absorbing essential air and nutrients. Furthermore, Haikal (2000) emphasized that compost, derived from the decomposition of plant or animal matter mixed with naturally occurring minerals, serves as a valuable organic material. Compost is particularly advantageous as an alternative planting medium due to its abundance and accessibility as a waste product.

Table 4. Cocoa leaf width

Seed Position	Planting Media Composition				
	Soil 100%	Soil 100%	Soil 100%	Soil 100%	Soil 100%
Base	7.32 ± 0.81 a A	7.27 ± 0.53 a A	8.05 ± 1.35 a A	7.80 ± 0.15 a A	7.03 ± 0.48 a A
Middle	6.37 ± 0.55 a AB	5.67 ± 0.30 b B	7.63 ± 0.84 ab A	7.65 ± 1.26 a A	7.52 ± 0.71 a A
Edge	7.63 ± 0.95 a A	7.73 ± 0.90 a A	6.75 ± 0.40 b AB	6.27 ± 0.38 b B	6.50 ± 0.31 a AB

Numbers followed by the same lowercase letter in a column and the same uppercase letter in a row indicate no significant difference based on the DMRT test ($\alpha = 5\%$).

4. Conclusion

The experiment's findings indicate that the optimal soil-to-organic-fertilizer ratio for fostering cocoa seedlings' growth is 3:1, employing the proprietary blend known as KoHeA+MF. The findings of the present study indicate the necessity for further research, encompassing diverse soil types and alternative media compositions that can be utilized in conjunction with organic fertilizer KoHeA+MF.

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