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Enhancement of Cocoa (Theobroma cacao L.) Seed Viability Using Various Types of Organic Storage Media and Storage Durations

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Abstract

Cocoa (*Theobroma cacao* L.) is a recalcitrant seed that has a short shelf life and is susceptible to decreased viability during storage. This study aims to determine the effect of the type of organic storage media and storage duration on the viability of cocoa seeds. The experiment used a factorial Completely Randomized Design (CRD) with two factors, namely the type of storage media (cocopeat, rice husk charcoal, and sawdust) and storage duration (7, 14, 21, and 28 days), plus one control treatment (direct sowing). Data were analyzed using ANOVA, and when significant effects were observed, the BNJ test was performed at the 5% level. Observed variables included germination power, maximum growth potential, fresh weight of sprouts, and sprout length. The combination of storage media type and storage duration did not provide significant interactions with any of the observed variables. Cocopeat storage media produced the best values for all parameters compared with rice husk charcoal and sawdust, with 67% germination power and a maximum growth potential of 86%. A 7-day storage period gave the best results compared to other storage treatments. The control treatment consistently produced the highest values for all variables. The advantage of this study is the information obtained regarding effective organic storage media for maintaining cocoa seed viability during storage. It was concluded that cocopeat storage media with a 7-day storage period was the best combination in maintaining cocoa seed viability. Therefore, the use of cocopeat with a maximum storage period of 7 days is recommended for farmers, seed breeders, and cocoa cultivators to maintain seed quality before planting.

Keywords: Cocopeat, Rice Husk Charcoal, Sawdust, Seeds Cocoa, Seed Recalcitrant

1. Introduction

Cocoa (*Theobroma cacao* L.) is an important plantation commodity in Indonesia, boosting the economy of farmers and generating foreign exchange through exports. Cocoa has high economic value due to its increasing demand. One important factor supporting the success and growth of cocoa production is the availability of high-quality seeds that can thrive in the field (Tambunsaribu *et al*., 2017).

One of the important obstacles in providing quality cocoa seeds is their recalcitrant nature. Recalcitrant seeds *have* a distinctive characteristic that distinguishes them from orthodox seeds, namely that recalcitrant seeds are generally relatively larger in size with a water content of 30-70%. Recalcitrant seeds are highly sensitive to drying, so that if the water content decreases, viability also decreases, thus reducing germination power (Sudrajat et al., 2015). Recalcitrant seeds will die if they are in critical water conditions. Cocoa seeds are included among recalcitrant seeds that have a short shelf life and are difficult to store for long periods due to their high water content.

Cocoa seeds are recalcitrant seeds with high sensitivity and a short shelf life, making them difficult to store for long periods because of their high water content. Therefore, proper treatment and storage techniques are required to maintain seed viability and vigor throughout the shelf life and prevent the seeds from losing their ability to germinate. (Fatchurrohman et al., 2025) . According to Yudiawati et al. (2022), storing cocoa seeds for too long causes seed

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degradation, decreased water content, and low germination due to respiration. Anita-sari et al. (2018) showed that the percentage of stored cocoa seed germination decreased with the Length of storage. At 3-4 weeks of storage, seed germination dropped below 60%, and inappropriate storage conditions can reduce viability to below 50%. The use of this type of storage medium can be applied in storing recalcitrant seeds, because it can maintain seed moisture content for a longer period of time (Triani, 2021).

Storage media can be used to maintain the viability of cocoa seeds and so that cocoa seeds that initially cannot be stored for a long time can have their shelf life extended for use in the next planting period (Nengsih et al., 2020). Selecting the right storage media to maintain the humidity of cocoa seeds during storage is an important effort to maintain germination and seed growth strength. Research by Wahyudi & Marlina (2024) shows that the longer cocoa seeds are stored, the more germination and seed vigor decrease due to seed deterioration. However, that study only examined the effect of storage time. In contrast, this study has a novelty in the form of testing the interaction of various organic storage media (cocopeat, rice husk charcoal, and sawdust) with storage time to obtain the best combination in maintaining viability and extending the shelf life of MCC 02 variety cocoa seeds.

Seed storage media can absorb and bind water to maintain humidity, thereby maintaining seed moisture content and maintaining seed viability, and extending storage time (Syaiful et al., 2007 in Nengsih et al., 2020). Some types of organic storage media commonly used include sawdust, *cocopeat*, and rice husk charcoal. Research by Yuniarti and Djaman (2015) showed that treating cardboard boxes filled with *cocopeat with a storage period of 15 days can produce* seed germination values. mangrove of 93% with a seed water content of 51.44%, compared to the cardboard box storage medium without *cocopeat*, which had a germination value of 75% and a water content of 47.42%.

Storage media is expected to be able to extend the storage period of recalcitrant cocoa seeds by maintaining the quality of the seeds; therefore, research is needed to determine the best storage media and storage period that can maintain the viability and initial growth of seedlings in recalcitrant cocoa seeds (*Theobroma cacao* L.). This research is expected to provide benefits in cocoa cultivation to produce optimal and sustainable results.

2. Material and Methods

2.1. Time and Place

This research was conducted in January- April 2026 in Glindah Village, Kedamean District, Gresik Regency. The location coordinates are -7.3106362, 112.4974288, with an altitude of 10 - 25 meters above sea level, temperatures between 24°C - 33°C, average rainfall of 276 mm/month with humidity between 50% - 95%.

2.2. Tools and Materials

The tools used in this study were analytical scales, ovens, trowels, scoops, watering cans, measuring tapes, and rulers. The materials used in this study were cocoa seeds, *cocopeat*, rice husk charcoal, sawdust, *Dithane* M-45 fungicide, 15x22 cm aluminum foil, germination trays, sterile sand, label paper, cardboard, and water.

2.3. Research Design

This research is a factorial experiment designed using a Completely Randomized Design (CRD) consisting of two factors. The first factor is the type of organic storage media, consisting of 3 types: cocopeat, husk charcoal, and sawdust. F second factor is the storage period, consisting of 4 levels: 7 days, 14 days, 21 days, and 28 days. The combination of the two treatment factors resulted in 12 treatment combinations and 1 control (no treatment; direct sowing) for comparison in the study; the treatment was repeated three times.

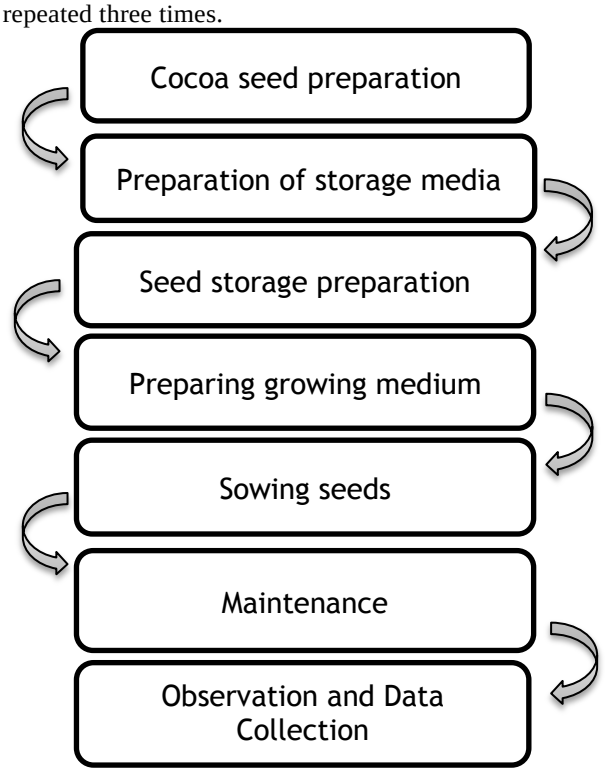


Figure 1. Research Implementation

2.4. Data Analysis

An ANOVA test was used to determine the effect of the treatment. If the effect was significant or very significant, it was followed up with a 5% honestly significant difference (HSD) test. Data analysis was done using Microsoft Excel 2019. The observed variables were:

2.4.1. Seed germination power

The germination rate of cocoa seeds was tested at 14 days after sowing by calculating the percentage of normal

germination. The germination rate test used 50 seeds, which was then calculated using the following formula:

$$\%DB=\frac{Number\ of\ normally\ germinated\ seeds}{Number\ of\ seeds\ germinated}X\ 100\%$$

2.4.2. b). Maximum growth potential

Maximum growth potential was calculated on the last day of observation, based on the total number of seeds showing signs of growth, whether normal or abnormal. Maximum growth potential (MGP) was observed on the 14th day to determine the seeds' germination ability. The formula for maximum growth potential (MGP) is:

$$\%PTM=\frac{Number\ of\ seeds\ that\ germinated}{Number\ of\ Seeds\ Planted}X\ 100\%$$

2.4.3. Fresh weight of sprouts

The fresh weight of the sprouts was measured at the end of the observation period (14 days after sowing) by selecting normal sprouts and cleaning them of the germination medium. They were then weighed using an analytical balance.

2.4.4. Length of sprouts

The Length of the sprouts was measured 14 days after planting by observing normal sprouts. Measurements were taken from the base of the sprout to the tip of the longest root using a ruler.

3. Results and Discussion

3.1. Seed Germination Rate (%)

The analysis of variance showed that the combination of storage media type and storage duration did not significantly affect seed germination percentage. The single factors of storage media type and storage duration each showed a highly significant effect.

Table 1 shows that the results of a single treatment of storage media type on the percentage of germination power are very significantly different, with the highest average in the treatment of *cocopeat storage media type* of 67%, which is significantly different from the storage media of rice husk charcoal 52.83% and sawdust 35.17%. The results of a single treatment of storage time are very significantly different in the percentage of germination power, with the highest average in the treatment of 7 days storage time, namely 64.44%, which is significantly different from the treatments of 14 days, 21 days, and 28 days with values of 51.11%, 51.11%, and 40%, respectively. The treatment of 14 days of storage time shows no significant difference from the storage time of 21 days, which obtained the same value of 51.11%. The control treatment gave the highest germination percentage, 89.33%, compared with the single factors of storage media type and storage time. The Length of seed storage has a direct effect on the decrease in seed viability and vigor, which in turn has an impact on the initial growth of seedlings. The longer the seeds are stored, the greater the possibility of damage to the cell membrane and a decrease in food reserves, which results in low germination power and non-uniform seedling growth (Jatmiko et al., 2025) .

The combination of storage media treatment and storage duration for normal sprouts in the control treatment gave the highest value, namely 89.33% of all treatment combinations. This occurred because the cocoa seeds in the control treatment were directly planted in sand planting media, so the seeds were in good quality. They did not deteriorate during storage. The combination of cocopeat storage media types performed better than the rice husk charcoal and sawdust media types at storage periods of 7, 14, 21, and 28 days. This is thought to be due to the nature of cocopeat, which can absorb and store more water, so that the seeds will absorb water around them in an effort to achieve balance with the surrounding environment. Moist seed storage media has a higher water content compared to the water content of the seeds, so the seeds will imbibe, which causes the water content of the seeds to increase (Dewi, 2016 *in* Nurhayani and Wulandari, 2019)

Cocoa seeds stored in cocopeat media showed the highest germination rate (Table 1). Cocopeat storage media has the optimum humidity required for cocoa seeds to maintain seed viability, so storage activities do not reduce the germination rate of cocoa seeds. According to Lodong & Tambing (2015), proper storage techniques create a good spatial ecosystem for seeds. Humid storage media ensures that the seeds' water needs are met until the end of storage, so the storage period does not reduce the seeds' ability to germinate.

Decreased germination is a physiological indication of seed deterioration (Triani, 2021). Decreased germination during storage results from damage to embryonic tissue, which causes seed death and disrupts germination (Taini et al., 2019). Stored cocoa seeds undergo a deterioration process characterized by decreased viability and vigor. (Wahyudi & Marlina, 2024) reported that cocoa seeds planted directly had a germination rate of 97.56%, while increased storage time decreased the seed's ability to germinate. This condition indicates that storage management is an important factor in maintaining the physiological quality of cocoa seeds.

Proper storage techniques create a favorable spatial ecosystem for seeds. A moist storage medium ensures the seeds' water needs are met until the end of storage, so the storage period does not reduce the seeds' ability to germinate (Lodong & Tambing, 2015).

The average value of the percentage of cocoa seed germination power in single factors of the treatment of storage media type and seed storage duration is presented in Table 1.

3.2. Maximum Growth Potential (%)

The results of the analysis of variance that has been carried out show that a combination of types of organic storage media and storage time does not provide a

significant interaction on the percentage of maximum seed growth potential. The single factor is the type of organic storage media. Moreover, the storage time of each showed very significant results.

Table 2 shows that every single treatment of storage time and storage media (organic fertilizers) has a very significant effect on the maximum growth potential of cocoa seeds. The results of a single treatment of storage media: The highest average effect of organic fertilizer on the percentage of germination was found in the cocopeat storage media treatment, which was 86%, showing a significant difference compared to the rice husk charcoal storage media treatment of 74.83% and sawdust of 57%. The high maximum growth potential in the cocopeat treatment compared to other media is thought to be closely related to cocopeat's ability to maintain humidity. Cocopeat has the property of easily absorbing and storing water and has pores that facilitate air exchange. This property makes cocopeat able to maintain the water content of cocoa seeds above the critical point during storage. This result is in line with the research of Tambunsaribu et al. (2017), which states that storage media affect the viability and growth of cocoa seedlings, where media with better water retention capacity are proven to be more effective in maintaining the viability of recalcitrant seeds.

The results of a single treatment of seed storage duration on the maximum growth potential of seeds with the highest average yield in the 7-day storage treatment, namely 83.78%, which is significantly different from the 28-day storage treatment, namely 61.11%, but not significantly different from the 14-day storage period (73.56%) and 21-day storage period (72%). The average value of the control treatment on maximum growth potential shows the best value of all treatments, namely 94%. This is in line with Yazid's (2020) research, which shows that the storage period of rubber seeds for 0 days, or without storage, is significantly different from the storage period of 10 and 20 days, where the average at the beginning of germination is 62.67%, decreasing to 28.99% in the 10-day storage period and decreasing again with an average of 15.96% in the 20-day storage period. This occurs because germination is influenced by the water content of the seeds with storage duration without storage. This pattern of decreasing viability with increasing storage duration is in line with the recalcitrant nature of cocoa seeds. Cocoa seeds that have been removed from the fruit will germinate quickly if stored without special treatment for a period of 3-4 days, so that their viability and vigor will decrease drastically during storage (Amalia et al., 2024).

The average percentage value of the maximum growth potential of cocoa seeds in a single-factor treatment of organic storage media type and seed storage time is presented in Table 2.

3.3. Fresh weight of sprouts (grams)

The results of the analysis of variance that has been carried out show that a combination of types of organic storage media and storage time did not provide a significant interaction on the fresh weight of cocoa sprouts. The only significant factor was the type of storage medium. Organic fertilizers had no significant effect, and storage time had no significant effect on the fresh weight of the sprouts. The average values of the percentage of fresh weight of cocoa sprouts in a single-factor analysis of the storage media type treatment, organic matter, and seed storage time are presented in Table 3.

Table 4.3 shows the single factors of storage media treatment. Organic matter did not significantly affect the fresh weight of cocoa sprouts; for storage media alone of organic matter and storage duration showed no significant differences among treatments. The results of the control treatment showed a higher fresh weight of sprouts compared to the storage media and storage duration treatments. Sawdust storage media and a storage duration of 28 days tended to reduce the fresh weight of sprouts.

Table 1. Power sprouts Seed Cocoa consequence Storage Media Treatment Organic and Storage Time

Treatment	Seed Germination Rate (%)
Control	89.33 ± 1.33
Storage Media Organic	
Cocopeat	67.00 ± 6.52 c
Rice Husk Charcoal	52.83 ± 5.13 b
Sawdust	35.17 ± 6.43 a
BNJ 5%	4.68
Storage Period	
7 days	64.44 ± 8.83 c
14 days	51.11 ± 8.29 b
21 days	51.11 ± 8.19 b
28 days	40.00 ± 8.93 a
BNJ 5%	6.54

Description: Numbers accompanied by the same letter in the same treatment show no significant difference in the 5% BNJ test.



Figure 2. The shape of the sprouts from stored cocoa seeds. M_1: Cocopeat, M_2: Rice Husk Charcoal, M_3: Sawdust, L_1: 7 days, L_2: 14 days, L_3: 21 days, L_4: 28 days. a: Normal sprouts, b: Abnormal sprouts.

Table 2. Potential Maximum Growth of Cocoa consequence Storage Media Treatment Organic and Storage Period.

Treatment	Maximum Growth Potential (%)
Control	94.00 ± 2.00
Storage Media Organic	
Cocopeat	86.00 ± 4.49 c
Rice Husk Charcoal	74.83 ± 5.13 b
Sawdust	57.00 ± 7.28 a
BNJ 5%	7.65
Storage Period	
7 days	83.78 ± 6.23 b
14 days	73.56 ± 8.06 b
21 days	72.00 ± 7.3 ab
28 days	61.11 ± 9.83 a
BNJ 5%	12.33

Description: Numbers accompanied by the same letter in the same treatment show no significant difference in the 5% BNJ test.

Table 3. Fresh Weight of Sprouts of Cocoa consequence Storage Media Treatment Organic and Storage Period.

Treatment	Fresh Weight of Sprouts (grams)
Control	5.57 ± 0.50
Storage Media Organic	
Cocopeat	5.29 ± 0.37
Rice Husk Charcoal	5.08 ± 0.52
Sawdust	4.82 ± 0.32
BNJ 5%	Mr.
Storage Period	
7 days	5.25 ± 0.52
14 days	5.00 ± 0.3
21 days	5.14 ± 0.48
28 days	4.87 ± 0.37
BNJ 5%	tn.

Description: tn= not significantly different.

The higher fresh weight of sprouts in the control treatment, compared with all storage media and storage duration treatments, indicates that fresh seeds without storage treatment still maintain better physiological integrity. This is closely related to the optimal seed moisture content at the initial stage. Maintaining seed moisture content within the optimal range will support the success of the imbibition process, ensuring the embryo receives sufficient water to activate metabolic reactions and form substantial seed tissue. (Nengsih et al., 2020) .

The results of this study showed that the fresh weight of sprouts in a single storage media factor was highest in *cocopeat media* at 5.29 g, while the research of Toyyib et al. (2017) showed that the wet weight of sprouts was highest in 100% rice husk charcoal media at 8.70 g. This value is 3.41 g higher, or around 64.46%, than the results of this study. However, both studies showed the same trend that storage media that can maintain moisture produce higher sprout biomass.

3.4. Length of sprout (cm)

The results of the analysis of variance that has been carried out show that a combination of storage media types, organic matter, and storage time did not provide a significant interaction on the Length of the cocoa sprouts. For the single-factor type of storage media type, organic matter had no significant effect, while storage time showed a very significant effect. Table of presents the average cocoa sprout length for the single-factor treatments of storage media type, organic matter, and seed storage time are presented in Table 4.

The results of the study showed that the single treatment of storage media and organic fertilizers had no significant effect on the Length of cocoa sprouts. Meanwhile, the results of the single treatment of storage time had a significant effect on sprout length. The control treatment had a value of 29.5 cm higher than the single treatment of storage media type—organic matter and storage duration. The results of a single treatment of storage duration with the highest average yield were in the 7-day storage duration treatment, namely 26.37 cm, which was significantly different from the 14-day, 21-day, and 28-day storage durations, namely at values of 24.63 cm, 23.07 cm, and 22.65 cm.

The results of the observations show that the longer the storage, the lower the germination rate. This occurs because sprouting ability is influenced by factors such as seed moisture content and germination rate. This result aligns with research by Nurhayati et al. (2015), which showed that storing rubber seeds for 2 weeks resulted in the highest

average wet weight of 33.60 g, which was then followed by a decrease in gross weight in the 0-8 week period. The Length of the sprout is influenced by the Length of the root and the number of roots that function in absorbing water and nutrients in the planting medium, which encourages sprout growth. Germination energy is the result of the assimilation of materials such as carbohydrates, fats, and proteins, which are then translocated to the growing point, resulting in germination and growth. (Hayati & Setiono, 2021).

Table 4. Long Sprouts Cocoa consequence Storage Media Treatment Organic and Storage Period.

Treatment	Sprouts Length (cm)
Control	29.50 ± 1.44
Storage Media Organic	
Cocopeat	25.82 ± 1.99
Rice Husk Charcoal	23.21 ± 1.7
Sawdust	23.51 ± 1.44
BNJ 5%	Mr.
Storage Period	
7 days	26.37 ± 1.69 b
14 days	24.63 ± 1.13 ab
21 days	23.07 ± 1.77 a
28 days	22.65 ± 1.95 a
BNJ 5%	2.81

Description: Numbers accompanied by the same letter in the same treatment show no significant difference in the 5% BNJ test ; tn : no real difference.

4. Conclusion

The combination of storage media types and storage time did not show any significant interaction with the observation variables. The best results were obtained in the control treatment (direct sowing) produced the best results, with the highest values of all observation parameters.

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