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Research Paper

Response of Germination of Cocoa (*Theobroma Cacao* L.) Seeds to Types of Storage Media and Various Storage Times

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Abstract
Cocoa plants are plantation crops, one of the export commodities that can contribute to efforts to increase Indonesia's foreign exchange. This research aims to determine the type of storage media, storage time and treatment interactions on the germination response of cocoa seeds. The research was carried out in Madang Village, Sumber Harta District, Musi Rawas Regency from February-March 2024. The research method used a Completely Randomized Factorial Design, the observation data was analyzed using R-Studio software. If the results of the variance test are significant at the 5% level, mean that the treatment shows a significant or very significant effect, then it will be continued with high significancy different test (HSD). The first factor consists of the type of storage media: without treatment (M0), sawdust storage media (M1), wood charcoal powder storage media (M2), and rice husk storage media (M3), the second factor is length of storage time: without treatment (W0), stored for 5 days (W1), stored for 10 days (W2), stored for 15 days (W3) and repeated 3 times. Based on the results of the research, sawdust storage media treatment had a significant effect on: germination at age 1-10 days and 11-20 days, root length, leaf length and leaf area; without storage treatment had a significant effect on: at age 1-10 days and 11-20 days, root length, leaf length, and leaf area.

Keywords
Cocoa seeds, Media, Storage, Time

1. INTRODUCTION

Cocoa plantations in Indonesia have experienced quite large developments in the last 20 years. The development of cocoa today is seen from the addition of well-developed areas, especially smallholder cocoa plantations and private plantations. Cocoa is one of the non-oil and gas export commodities that has quite bright prospects, because domestic demand is also increasing with the development of the agro-industrial sector. Total cocoa production from 2020 to 2023 reached 2,782,868 tons or reached 72.33% of the total target (Directorate General Of Plantations, 2023). Production can reach its maximum, apart from that, we urge farmers to provide fertilizer to producing plants and also provide education to overcome pests and diseases that can attack cocoa plants, so that production can be maximized.

The factor that really supports the success and increase in cocoa production is the availability of quality seeds that are able to grow well in the field (Directorate General Of Plantations, 2023). Cocoa seeds are seeds are classified as recalcitrant seeds, do not have a dormancy period (easily germinate) and are very sensitive to low temperature and humidity, and sensitive to drought below critical water levels. The main obstacle facing cocoa cultivation is seed viability. Cocoa is a plant whose seeds recalcitrant and cannot be stored for long time. The viability of recalcitrant seeds can only be maintained for a few weeks or months, even if stored under optimum conditions (Karjunita and Kuswandi, 2022).

Efforts to improve the quality of cocoa seeds, which easily deteriorate during storage, can be done by maintaining seed viability. One effort to maintain optimal seed viability is to store seeds in containers with high humidity using moist storage media. By giving sawdust to rubber seeds, it can maintain the moisture of the seeds in the storage medium, the seeds are fresh, the flesh does not change color, the germination percentage is high, and the germination rate is faster (Loso et al., 2024). According to Gunawan et al. (2018); Ardi et al. (2021) cocoa seeds that use sawdust have the best effect on germination, germination rate and vegetative growth of cocoa seedlings.

Seed storage is carried out to maintain germination or seed viability during storage. The storage time and seed

treatment have a significant effect on the vigor index and root length of cocoa seeds. The duration of storage was two weeks, the root growth of cocoa seeds appeared to be longer during storage and after four weeks of storage the seeds significantly decreased the vigor index, germination capacity compared to newly harvested seeds (Indriana and Budiasih, 2017). The purpose of storage is as an effort to keep the seeds in good condition (maintain high viability), and to obtain the availability of seeds that have high germination capacity, within a certain period until they are needed for planting. According to Yudiawati et al. (2022), cocoa seeds that are stored too long will result in seed deterioration, decreased water content, seeds experiencing low germination respiration. Seed storage is required for a long time because not all seeds are planted immediately, and can be available in the planting area, therefore storage time is needed to continue testing the viability of the seeds so that the results are optimal. Based on the description above, it is necessary to conduct research with the title: "Response of Germination of Cocoa Seeds (*Theobroma Cacao L.*) to Types of Storage Media and Various Storage Times". The aim of this research was to determine the type of storage media and various storage times on the germination of cocoa seeds.

2. EXPERIMENTAL SECTION

2.1 Research Location

The research was conducted for 2 months starting from February to March 2024. The research location was in Madang Village, Sumber Harta District, Musi Rawas Regency at an altitude of 97 m above sea level.

2.2 Material and Methods

The research tools used include; stationery, camera, label paper, scissors, saw, machete, shovel, analytical scale, hand sprayer, ruler, plastic bucket. The research materials used include; cocoa seeds of Sulawesi 1 variety, sawdust, wood charcoal powder, rice husks, Dithane M-45, bamboo, cardboard box. This research used a factorially randomized block design (FRBD) consisting of 2 treatment factors with three replications. The first factor of storage media type consists of: without treatment (M0), treated sawdust storage media (M1), wood charcoal powder storage media (M2), and rice husk storage media (M3), the second factor of storage time consists of; without storage (W0), stored for 5 days (W1), stored for 10 days (W2), and stored for 15 days. Placement of treatments in experimental plots was carried out randomly. There were 50 cocoa seeds in one experimental treatment.

2.3 Research Implementation

Storage Media Preparation. The storage media used in this research were sawdust, wood charcoal powder, and rice husks. Then, before use, store the media in a plastic bag measuring 30 cm x 30 cm. Seed Preparation. The seeds are taken from the product garden with the Sulawesi 1 variety, the cocoa pod carefully broken using wood. The seeds are removed from the cocoa pod, the three parts at the base and tip are removed, the seeds are kneaded using kitchen ash and then washed with clean water. The seeds are air-dried, choose seeds that are healthy, not wrinkled, not attacked by pests and diseases, place them in a plastic bowl and the seeds are ready to be treated. Seed Treatment. Cocoa seeds, storage boxes and storage media that have been prepared, experimental treatments are in accordance with those tried. Seed storage, at the bottom of the box, 2.5 cm thick media is given. The seeds are arranged on top of the media, then given more media until the seeds are arranged completely. Arrangement is carried out according to the storage media tested, the box is stored in a safe place. Planting Seeds. Cocoa seeds are planted in seedling beds according to the length of time treatment tested. Without treatment, the seeds are planted directly in the seedling bed, as well as with other treatments. Seed Maintenance. Seeds that have been planted in seedling beds are maintained, consisting of: watering twice a day, namely: morning and evening and watering using hand spray, control of pests such as ants, earthworms and armyworms. Pest and disease control is carried out chemically.

2.4 The Variables Observed are :

1. Seed Germination Time 1-10 days after sowing (DAS_, 11-20 DAS, and 21-30 DAS (%). Observation of germinating seeds was carried out at 4 days, by looking at the seeds that grew in each treatment. Seeds that have grown for 10 days are marked with bamboo, while 11-20 DAS and 21-30 DAS observations are the same. Observations were carried out in the morning. The germination ability formula

$$= \frac{Number\ of\ germinated\ seeds}{Number\ of seeds\ sown} \times 100\%$$

2. Root Length (cm)
   Observation of Root Lengh were carried out at the age of 35 DAS, the cocoa seeds that grew in each treatment were observed. This is done by, before the seeds are removed, the seedling bed is doused with water, then the roots of the sample plants are removed and washed with water. Select the longest root, measure using a ruler starting from the base to the tip of the root.
3. Leaf Length (cm)
   Observations of cocoa plant seedlings leaf length were carried out at the end of the research by selecting leaves that opened completely. Measuring the length of the leaves using a ruler (ruler) is carried out in the morning or evening.
4. Leaf Area (cm)
   Observation of the leaf area of cocoa seedlings using the millimeter paper method. Measurements were

carried out in the afternoon, by selecting leaves that had completely opened and then drawing leaf samples on millimeter paper.

3. RESULTS AND DISCUSSION

3.1 Germination ability (%)

The percentage of germination ability of cocoa seeds at 0-10 days after sowing (DAS) can be seen in Table 1. The highest average percentage of the germination ability (GA) obtained by the sawdust storage media (M1) treatment was 17.67%, significantly different from the rice husk storage media treatment (M3) 11.00% and without treatment (M0) 7.83% and not significantly different from the treatment. storage medium for wood charcoal powder (M2) 13.17%. The lowest average percentage of the seed do not germination was obtained from the sawdust storage media (M1) treatment of 82.33%, significantly different from the rice husk storage media treatment (M3) 89.00% and without treatment (M0) 92.17% and not significantly different from processing media for storing wood charcoal powder (M2) 86.83%.

This shows that the storage media affects of the germination ability the age of 0-10 DAS in cocoa seeds. This is because cocoa seeds are stored in sawdust storage media (M1), at the age of 0-10 DAS he cocoa seeds germinate so that the storage media is used for storing which can maintain water content, provide good conditions for maintaining humidity in the storage media, and being able to maintain seed freshness will affect the percentage of seed germination at the age of 0-10 DAS.

Based on the results of analysis of variance in the percentage of the germination ability at the age of 11-20 DAS the highest average of growing seeds was obtained by the sawdust storage media (M1) treatment, namely 21.50%, significantly different from the wood charcoal powder storage media (M2) treatment of 13.33% , rice husk (M3) 13.17% and without treatment (M0) 10.67% while other treatments showed no significant difference. The results of analysis of variance for the lowest percentage of the seed do not germination were obtained by the sawdust treatment (M1) at 60.83%, which was significantly different from the charcoal dust treatment (M2) 73.50%, rice husk (M3) 75.83% and without treatment (M0) 81.50% while other treatments were not significantly different.

Observations of the germination ability (GA) and the seed do not germination (SDG) aged 21-30 DAP are in Table 1. The highest average percentage of Germination ability (GA), obtained from the sawdust storage medium (M1) treatment, was 8.67%, not significantly different from the wood charcoal powder (M1) treatment of 7.00%, rice husk (M3) 6.67% and significantly different from without treatment (M0) 6.33%. The lowest observation of the seed do not germination SDG) in the sawdust storage medium (M1) was 52.17%, showing a significant difference to the wood charcoal powder storage media treatment (M2) 66.50%, rice husk (M3) 69.17%, and without treatment (M0) 75.17%.

Observation data on the the germination ability (GA) and the seed do not germination (NGS) at the ages of 1-10 DAS, 11-20 DAS, and 21-30 DAS, showed the best results at the ages of 11-20 DAS. This means that the type of storage media used has different abilities in determining he germination ability (GA) and the seed do not germination (SDG) , which can be seen from the cocoa seeds that are sown. begins to actively reorganize the food reserves contained in the seeds to be used for growth. Sawdust storage media is the best variable for he germanition ability (GA) and the lowest for the seed do not germination (SDG) at all age levels. Sawdust is a storage medium that can maintain the moisture of the seeds in the storage medium, and the cocoa seeds are stored in fresh condition without any damage due to attack by fungi resulting in the seeds rotting or the seeds hardening due to lack of water. Water plays a role in activating enzymes in seeds, initiating embryo growth, and helping the seeds crack and sprouts emerge (Darma et al., 2019). The results of this research are in line with (Loso et al., 2024) that the reduction in water content in rubber seeds can still be maintained, namely by storing using sawdust with the aim of maintaining humidity, with the aim of water content or preventing respiration from entering to prevent rapid growth. dormancy.

The length of seed storage time for the variables 1-10 DAS, 11-20 DAS, and 21-30 DAS the germination ability (GA) and the seed do not germination (SDG) (NGS) can be seen in Table 1 . Cocoa seeds that were not treated with storage obtained the best results, compared with storage for 5 days, 10 days and 15 days. This shows that the longer the seeds are stored, the smaller the seed do not germination (SDG) and the larger the seed do not germination (SDG) Cocoa seeds that are stored for a long time will experience a decrease in water content, water is an essential ingredient for the metabolic process to break down chemicals that are ready to be used for the germination process. This may be closely related to the nature of cocoa seeds which are recalcitrant seeds, which have the property that if stored for a long time their germination will decrease. Seeds that are not stored at seed age are 1-10 days, begin to germinate at 7 DAS, seeding age is 11-20 days, The germination ability of seed increases at the age of seeds days to 16 days, on the 17th day it decreases, on the 17th day it decreased, at the age 24 days until the end of the research there were perminated seeds.

According to Loso et al. (2024) stated that water is a basic need for germination, the function of water is to soften the seed coat so that the embryo and endosperm swell which causes the seed coat to crack, allows gas exchange so that the supply of oxygen in the seed occurs, dilutes the protoplasm so that the process occurs. – metabolic processes in seeds and translocate food reserves to the required growing point. According to Ningsih et al. (2021), cocoa seeds that

Table 1. Research variables and their measuring techniques

Treatment	0-10 DAS		11-20 DAS		21-30 DAS	
	GS	NGS	GS	NGS	GS	NGS
Media						
M0	7.83c	92.17a	10.67b	81.50a	6.33b	75.17a
M1	17.67a	82.33c	21.50a	60.83b	8.67a	52.17b
M2	13.17ab	86.83bc	13.33b	73.50a	7.00ab	66.50a
M3	11.00 bc	89.00 ab	13.17 b	75.83 a	6.67 ab	69.17 a
Time						
W0	18.00 a	82.00 b	20.17 a	61.83 b	10.83 a	51.00 c
W1	15.67 a	84.33 b	17.00 ab	67.33 b	8.17 b	59.17 c
W2	10.33 b	89.67 a	13.00 bc	76.67 a	5.50 c	71.17 b
W3	5.67 b	94.33 a	8.50 c	85.83 a	4.17 c	81.67 a

Note: Numbers followed by the same letter indicate that they are not significantly different based on the High Significancy Different (HSD) test at the α = 5% level. M0 = without storage media treatment, M1 = treatment with sawdust storage media, M2 = treatment with wood charcoal powder storage media, M3 = treatment with rice husk storage media, W0 = control (without storage treatment), W1 = stored for 5 days, W2 = stored for 10 days, W3 = stored for 15 days. DAS = days after sowing, GA = the germination ability (GA) (%), SDG = the seed do not germination (%).

are stored for 15 days experience a decrease in germination, because the seeds experience high respiration during storage, causing the internal water content to decrease. Cocoa seeds that are stored for 21 days (3 weeks) still have good viability, supported by storage media that can maintain humidity and water content in the seeds (Kusmiah, 2018; Umroh et al., 2022)

3.2 Root Length of Cocoa Seedling (cm)

Table 2 shows the effect of storage media and storage time on the root length of cocoa seedlings. The results of the analysis of variations in storage media (M) on the root length of cocoa plant seedlings, the highest average was obtained from the sawdust storage media (M1) treatment of 14.60 cm, showing a significant difference to the wood charcoal powder (M2) treatment of 13.41 cm, rice husk (M3).) 13.13 cm and without treatment (M0) 12.67 cm, other treatments showed no significant difference. This shows that the type of storage media used affects the length of the roots formed, sawdust storage media produces the longest root length and indicates that the growth of cocoa seedlings is good. Seed viability will decrease, affecting root length and shorter roots and poor cocoa seed germination growth. The main obstacle in storage is the rapid deterioration of seeds during storage because the media used cannot maintain the freshness of the seeds, the water content in the seeds. The results of this research are in line with Ardi et al. (2021),Yudiawati et al. (2022) which states that the root length of cocoa seedlings depends on the speed of seed growth, because seeds stored in different media will affect the speed of seed growth.

The average longes cacao seedling root was obtained from the treatment without storage (W0) was 15.37 cm, indicating a significant difference to the treatment stored for

Table 2. Effect of storage media and storage time on the root length of cocoa seedlings (cm)

Treatment	Root length(cm)				
	W0	W1	W2	W3	Average
M0	14.59	13.11	12.13	10.86	12.67 b
M1	16.58	14.97	14.32	12.53	14.60 a
M2	14.86	13.88	12.77	11.52	13.41 b
M3	14.86	13.28	12.84	11.54	13.13 b
Average	15.37 a	13.81 b	13.02 b	11.61 c	(-)

Note: Numbers followed by the same letter indicate that they are not significantly different based on the High Significancy Different (HSD) test at the α = 5% level. M0 = without storage media treatment, M1 = treatment with sawdust storage media, M2 = treatment with wood charcoal powder storage media, M3 = treatment with rice husk storage media, W0 = control (without storage treatment), W1 = stored for 5 days , W2 = saved

5 days (W1) was 13.81 cm, stored for 10 days (W2) was 13.02 cm , and stored for 15 days (W3) was 11.54 cm. The treatment stored for 5 days was not significantly different from the treatment stored for 10 days (W2), and was significantly different from the treatment stored for 15 days. This shows that the longer the cocoa seeds are stored, there will be a decrease in the length of the roots formed on the cocoa seedlings because the roots function to absorb nutrients from the soil, it is also possible that the food reserves in the fast growing seeds are still available so that they can support the extension of the roots before they grow. serves to absorb elements in the soil. The length of time you store seeds will affect the condition of the seeds. The rapid dete-

rioration of cocoa seeds is mainly caused by high seed damage, long storage time, storage environmental conditions, and high humidity. According to Triani (2021), recalcitrant seeds show that long storage treatment has a very significant effect on physiological changes in seeds, such as the rate of seed germination, which causes a decrease in seed viability and will affect plant vegetative growth such as plant height, number of leaves and root length. The results of this research are in line with research Loso et al. (2024) that rubber seeds that are stored for a long time, during storage will experience physiological processes, especially evaporation, which causes water loss in the seeds, which will affect the germination rate, germination percentage, and the growth of the vegetative parts of the plant.

3.3 The Leaf Length of cacao seedling (cm)

The results of the analysis of variance and honest significant difference test (BNJ) at the 5% level, the effect of storage media (M) on leaf length can be seen in Table 3. The average of the longest leaf on the the cacao seedling obtaines from sawdust treatment (M!) 13.01 cm, showing a significant difference from the wood charcoal powder treatment (M2) was 11.93 cm, rice husks was 11.04 cm, and without treatment (M0) was 10.68 cm. The wood charcoal powder treatment (M2) was significantly different from the rice husk treatment (M3) and without treatment (M0), while the rice husk treatment (M3) was not significantly different from the treatment without treatment (M0). The type of storage media influences the length of the leaves produced, and without treatment with the storage media the length of the resulting leaves is shortened. This can be seen as a medium for storing sawdust which has the longest leaf length. Sawdust is an organic waste that comes from sawing various types of wood and also has the ability to retain different levels of water and humidity. Cocoa seeds that are stored in sawdust storage media do not lose much water, the seeds are still fresh, their germination capacity and germination rate will affect the root length, plant height, number of leaves and leaf length of cocoa plant seeds.

The results of the analysis of variance in the length of storage time (W) on the length of the leaves of cocoa seedlings, The average of longest leaf on cacao seedling obtained from sawdust treatment (M1) was 13.18 cm, indicating a significant difference from the 5 day storage treatment (W1) was 12.29 cm, stored for 10 days (W2) was 11.12 cm and storage (W3) was 10.07 cm, other treatments showed significant differences between treatments. The longer the seeds are stored, the freshness of the seeds will decrease and will affect the ability of the seeds to provide food reserves before the roots can function to absorb nutrients in the soil, thus affecting the growth and development of the vegetative parts of cocoa plant seeds. This can be seen from the results of long storage times which produce shorter leaf lengths, compared to not storing them which produce longer leaf lengths. According to Miftakhurrohmat and Widiyanti (2016) stated in their research that the longer the seeds are stored, the length of the leaves formed decreases.

Table 3. Effect of storage media and storage time on the length of cocoa seedlings leaves

Treatment	Leaf Length (cm)				
	W0	W1	W2	W3	Average
M0	12.56	11.30	9.56	9.30	10.68 c
M1	14.37	13.96	12.48	11.22	13.01 a
M2	13.19	12.48	11.55	10.50	11.93 b
M3	12.59	11.40	10.90	9.28	11.04 c
Average	13.18 a	12.29 b	11.12 c	10.07 d	(-)

Note: Numbers followed by the same letter indicate that they are not significantly different based on the High Significancy Different (HSD) test at the α = 5% level. M0 = without storage media treatment, M1 = treatment with sawdust storage media, M2 = treatment with wood charcoal powder storage media, M3 = treatment with rice husk storage media, W0 = control (without storage treatment), W1 = stored for 5 days , W2 = stored for 10 days, W3 = stored for 15 days, (-) = no interaction.

3.4 The leaf Area of Cacao Seedling (cm)

Table 4 shows the effect of storage media and storage time on the leaf area of cocoa plant seeds. The results of the analysis of variations in storage media (M) on the leaf area of cocoa seedlings, The average of the longest leaf on cacao seedling obtained from sawdust treatment (M1) 3.72 cm2, showing a significant difference to the wood charcoal powder (M2) treatment was 3.35 cm2, rice husk (M3).) was 3.20 cm2 and without treatment (M0) was 3.13 cm2, other treatments showed no significant difference. This is because sawdust storage media has the best influence on The maximum germination potential the cocoa seeds that germinate quickly will affect the number of roots, seedling height and number of leaves. The root arena functions as a tool for taking up nutrients from the soil, while the leaves are a place for the photosynthesis process to take place which will produce photosynthesis which is translocated to the parts that need it, for growth and development in the leaf meristem tissue so that the number and area of the leaves increases. The increase in leaf area is also influenced by the availability of the N nutrient in the soil and supporting environmental factors. The results of this research are in line with Loso (2022) the growth and development of leaves of cocoa seedlings, supported by the type of planting media used and the need for sufficient nutrients. According to Loso et al. (2024) that through seed storage technology, recalcitrant seeds that were previously only stored for a short time and even those that could not be stored, can maintain their viability with good storage technology.

The observing of the long storage time treatment (W) on

Table 4. Effect of storage media and storage time on the length of cocoa seedlings leaves

Treatment	Leaf Area (cm^2)				
	W0	W1	W2	W3	Average
M0	3.76	3.36	2.87	2.53	3.13 b
M1	4.51	4.08	3.43	2.84	3.72 a
M2	3.93	3.54	3.21	2.72	3.35 b
M3	3.77	3.52	3.00	2.51	3.20 b
Average	3.99 a	3.62 b	3.13 c	2.65 d	(-)

Note: : Numbers followed by the same letter indicate that they are not significantly different based on the High Significancy Different (HSD) test at the α = 5% level. M0 = without storage media treatment, M1 = treatment with sawdust storage media, M2 = treatment with wood charcoal powder storage media, M3 = treatment with husk storage media rice, W0 = control (no storage treatment), W1 = stored for 5 days, W2 = stored for 10 days, W3 = stored for 15 days, (-) = no interaction.

the leaf area of cocoa seedlings, the average of the longes leaf on cacao seedlings obtained from a treatment without storage time (W0) was 3.99 cm2, showing a significant difference from the 5 day storage treatment (W1) was 3.62 cm2, 10 day storage treatment (W2) was 3.13 cm2 , and 15 days storage (W3) was 2.65 cm2. while others showed significant differences between treatments. This shows that the length of storage time affects the leaf area of the cocoa seedling, a low life area . The cocoa seeds that are stored for a long time have a physiological process, namely the process of evaporation during storage so that the water reserves in the seeds decrease, thereby affecting the growth and development of the vegetative parts of the plant. The growth and development of the vegetative parts (leaf area, number of leaves, plant height, number of roots, and root length) of cocoa seedlings depends on the availability of sufficient water in the seeds and in the seedling media. The results of this research are in line with Anjarwati et al. (2020) factors that influence the viability of seeds during storage, namely internal factors, which consist of the genetic characteristics of the seeds, their growth capacity and vigor, freshness and initial water content of the seeds, while the factors external, which consists of the seed storage medium, temperature, composition of gases, and humidity in the storage room. According to Irawati et al. (2019), during storage the seeds will experience respiration, the respiration that occurs in recalcitrant seeds can result in more use of food reserves, namely carbohydrates, fats and proteins. Continuous active respiration will produce alcohol which can cause damage to cell membranes and decreased seed viability.

4. CONCLUSION AND SUGGESTION

Based on the discussion described, it can be concluded that the storage media treatment provided the best influence on the variables of: the germination ability seed at 1-10 days, 11-21 days, and 21-30 days, root length, leaf length, and leaf area. The long storage time treatment had the best effect the germination ability seed at 1-10 days, 11-21 days, and 21-30 days, root length, leaf length, and leaf area.

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