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Growth of Two Cocoa (*Theobroma cacao* L.) Planting Materials on Three Growing Media Composition

Zahrul Fuadi Mubaroq[1)], Indah Anita-Sari[2*)], Nurman Abdul Hakim[1)], Nazirman[1)], Ari Wibowo[2)], and Bayu Setyawan[2)]

[1)]Lampung State Polytechnic, Jl. Soekarno Hatta No.10, Rajabasa Raya, Kota Bandar Lampung 35141, Indonesia
[2)]Indonesian Coffee and Cocoa Research Institute, Jl. PB Sudirman No. 90, Jember 68118, Indonesia
[*)]Corresponding author: indah.anitasari@gmail.com
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Abstract

Seed growth and uniformity are keys in producing high quality and yield of cocoa (*Theobroma cacao* L.). Plant growth is influenced by internal factors (genetics) and external factors, including planting media. This study aimed to determine the effect of cocoa planting material types and planting media of cocoa seedlings. The research was conducted at Kaliwining Experimental Station, Indonesian Coffee and Cocoa Research Institute (ICCRI), Jember, Indonesia, using a split-plot group randomized design. The main plot was the planting media consisting of topsoil, topsoil and rice husk, and topsoil and manure. The subplots consisted of two types of cocoa planting material: hybrid seeds ICCRI 08H and half-sib Sulawesi 1. Each treatment was replicated three times. The results showed that the media influenced on seedling growth uniformity, plant height, stem diameter, and number of leaves. Genetic factors affect plant height and stem diameter. The interaction of media and the type of planting material affect the stem diameter and number of leaves. Cocoa seedling growth with the best plant height and stem diameter was shown in topsoil and manure media, while the response to the number of leaves showed differences between ages and planting media used. ICCRI 08H hybrid cocoa planting material showed the highest plant height and stem diameter compared to Sulawesi 1 half-sib.

Keywords: Half-sib, hybrids, media, seed quality, growth

INTRODUCTION

Cocoa is an important commodity for Indonesia, aside from being a foreign exchange source, it is also a commodity that people widely developed. The main problems faced in cocoa development in Indonesia are including climate change, pests and diseases, and the high number of aged plants. Some efforts that can be conducted to increase cocoa production are rejuvenation, intensification, and rehabilitation programs. In the cocoa replanting program, good quality of superior planting materials are vital for resulting good seedling growth performance.

Cocoa plant nursery development in Indonesia generally uses the generative propagation method, such as grafted with scions (Susilo, 2018; Zasari *et al*., 2020; Asman *et al*., 2021). This propagation method is also commonly developed in Malaysia and the Philippines (Yin, 2004). Propagation methods using grafting techniques require two types of planting material, i.e. rootstock and scion. Rootstocks are usually selected from genotypes that have strong roots and are tolerant to abiotic stresses, while scions usually have superior characteristics such as high productivity and resistance to biotic stresses (Zasari *et al*., 2020).

Genetic factor is one of the internal factors that affect the growth of cocoa plants in nursery. These internal factors are related to seed resistance to biotic and abiotic stresses, ability to grow, and uniformity of plant growth (Ratnasari *et al*., 2015). These traits will affect plant growth in the field. Genetically, seeds with good growth will produce good-quality seedlings with uniform growth. The selection of genotypes as rootstocks is critical because it greatly affects nutrient absorption, plant resistance to environmental stress, and plant growth performance (Susilo *et al*., 2005). The development of cocoa planting material as a source of rootstock in Indonesia leads to hybrid seeds, where the origin of the two elders of the cross can be known so that the superior character of the plant can be predicted, while the cocoa farming community still uses rootstock types sourced from half-sib planting material. Half-sib offspring are genotypes only known to one of the parents (Kinho *et al*., 2015). The consequence of not knowing one of the elders makes it difficult for farmers to predict the level of segregation of their offspring. Using superior and certified rootstocks is highly recommended to minimize production failures in cocoa farming. In the production of clonal seeds, the desired rootstock is a seed with excellent and uniform growth of stem diameter to facilitate the determination of simultaneous grafting time.

External factors that affect seed growth include planting media (Ratnasari *et al*., 2015). A good planting medium can provide adequate amounts of water and nutrients available for plant growth. This can be found in soil with good air circulation, suitable aggregates, good water-holding capacity, and enough space for rooting (Puslitkoka, 2011). The composition of planting media affects plant height, stem diameter, shoot fresh weight, and shoot dry weight of cocoa (Simorangkir *et al*., 2016). Based on research by Hendrata & Sutardi (2010), the media type can increase seedling height, number of leaves, and stem diameter.

So far, seedling producers have relied on topsoil media as the primary media in cocoa plant nurseries because it has sufficient nutrient availability. However, the continuous production of seedlings due to commercial cocoa seedling activities has depleted topsoil media availability. The continuous use of topsoil can also damage the environment and make the seedling polybags heavier for long-distance transportation during field planting (Anthonio *et al*., 2018; Quaye *et al*., 2019). Therefore, new media compositions are needed to reduce the use of topsoil as the primary media for cocoa plant nurseries. To solve this problem, one of the ways to maintain the availability of cocoa seedling growing media is to use modified nursery media composition. This study aims to determine the growth response of cocoa seedlings from two different types of planting material sources, namely from half-sib and hybrid seeds to the combination of planting media used in nurseries. The results of this study are expected to be a source of reference to conduct a further study on the effect of clone types and media composition on the is growth of cocoa seedlings in the nursery.

MATERIALS AND METHODS

Study area and genetic materials

The research was conducted at Kaliwining Experimental Station of the Indonesian Coffee and Cocoa Research Institute (ICCRI), Jember, Indonesia from July 2022 to October 2022. The research used a split-plot design with a randomized complete block design. In this study, the main plot was the combination of planting media used, and the subplot was planting meterial. There were three planting media used, namely topsoil, topsoils

with rice husk (1:1), and topsoil with manure (1:1). Chemical composition of the growing media were as follow topsoil with pH 6.7, C 7.1 g kg^{-1}, N 1.0 g kg^{-1}, C/N 7.5, top-soil with rice husk pH 5.5, C 28.7 g kg^{-1}, N 2.3 g kg^{-1}, C/N 13.0, topsoil with manure pH 7.1, C 40.2 g kg^{-1}, N 3.8 g kg^{-1}, C/N 10.5. Meanwhile the cocoa planting materials were seeds derived from Sulawesi 1 half-sib and ICCRI 08H hybrid, Sulawesi 1 is moderate resistant to cocoa pod borer, and resistant to VSD (Kepmentan, 2008). Cocoa hybrid ICCRI 08H is resulted from a cross between cocoa KEE 2 and Sulawesi 1 (Kepmentan, 2017). ICCRI 08H has the advantages of high yield (2.5 tons ha^{-1} $year^{-1}$), resistant to pod rot, and resistant to the VSD. This variety also has a robust root system.

Maximum growth potential

The maximum growth potential (MGP) of cocoa seeds was obtained by calculating the ability of normal and abnormal seeds to germinate until day 14 days after sowing (DAS). The formula used to calculate the maximum growth potential is as follows:

$$(\%)\ \mathrm{MGP} = \frac{\text{number of seed sprouted}}{\text{number of seeds sown}} \times 100$$

Seed growth rate

The growth rate of cocoa seed (KcT) seedling was calculated from when the seeds sprouted normally until the 14th DAS. Seed growth rate is determined from the percentage of normal sprouts per day. To determine the growth rate of seedling following formula was used:

$$(\%)\ \mathrm{KcT} = \frac{N1}{D1} + \frac{N2}{D2} \ldots + \frac{Nn}{Dn}$$

Seed germination uniformity

Seed germination uniformity (KsT) is determined between the first observation day (first counting) and the second observation day (final counting). The first observation is conducted on the 4th DAS and the final observation on the 10th DAS. Therefore, the uniformity of cocoa seed growth (KsT) is done on the 7th DAS by the formula:

$$(\%)\mathrm{Kst} = \frac{\text{Number of strong normal sprouts on day 7}}{\text{Number of germinated seeds}} \times 100\ \%$$

Plant height

Plant height observations were done at the age of 30, 60, and 90 DAS. Measurements on day 30 and 60 were only taken 5 plant samples in each treatment per replicate, while on day 90 the whole plant samples were measured. Measurement of plant height was carried out using a ruler measured from the surface of the seedling media to the growing point of the plant.

Stem diameter

Observations of stem diameter were made using an automatic vernier, observations were made when the plants had reached the 30th, 60th, and 90th DAS. Measurements on day 30 and day 60 were only taken 5 plant samples in each treatment per replication, while on day 90 the whole plant samples were measured. Measurement of stem diameter was done above the stem basal, the distance between the basal to the point of measurement ranges from 2–5 cm.

Number of leaves

Observations of the number of leaves were made at the age of 30, 60, and 90 DAS. Measurements on day 30 and day 60 were only taken 5 plant samples in each treatment per replicate, while on day 90 the whole plant

samples were measured. This observation was done by counting all number of leaves.

Data Analysis

Data were analyzed using analysis of variance and further tests using Duncan multiple range test. The software used in the analysis was Microsoft Excel 2019, Mintab, and R-Studio for multiple regression analysis and dendrogram.

RESULTS AND DISCUSSION

The results showed that the planting media significantly influenced the quality of cocoa seedling growth uniformity but did not significantly influenced the growth rate and maximum growth potential. The results also showed that the planting media significantly influenced plant height at 90 DAS, stem diameter at 60 and 90 DAS, and number of leaves at 60 and 90 DAS. Different types of planting media will provide different space for roots to develop (Anthonio *et al.,* 2018), so crown growth will also be different. Purwantoro (2016) also reported that different types of planting media significantly affected the germination and growth of *Aganope heptaphylla* seedlings. Meanwhile, the planting material type showed a significant effect on the plant height and stem diameter at all testing ages. The interaction between the planting media composition and the plant materials type showed a significant effect on stem diameter at 60 DAS and the number of leaves at 90 DAS (Table 1).

Seedling Germination

Different types of planting media and types of planting materials did not significantly affect the maximum growth potential and growth rate of cocoa seeds. Different types of planting media had a significant effect on the uniformity of cocoa seedling growth. The best sprouting rate was observed in the media with the composition of topsoil manure and topsoil, while media with topsoil and rice husk composition showed the lowest seedling germination (Table 2). Rice husk charcoal has a good drainage rate, is lightweight, contains potassium, has high water holding capacity, has a high air-circulation rate, has good porosity, and is sterile (Handayani & Yuzammi, 2019), so it is widely used as a nursery media. Different properties are possessed by rice husks that have not undergone the combustion process. The drainage system of raw husk is lower than husk charcoal, and it is not as sterile as husk charcoal.

Table 1. Analysis of variance of treatments of media, planting materials, and their interactions

Observation parameters		Media factor	Planting material factor	Interaction
Maximum growth potential (%)		ns	ns	ns
Seed growth rate (%)		ns	ns	ns
Seed growth uniformity (%)		*	ns	ns
Plant height (cm)	30 DAS	ns	*	ns
	60 DAS	ns	*	ns
	90 DAS	*	*	ns
Stem diameter (mm)	30 DAS	ns	*	ns
	60 DAS	*	*	*
	90 DAS	*	*	ns
Number of leaves	30 DAS	ns	ns	ns
	60 DAS	*	ns	ns
	90 DAS	*	ns	*

Notes: (*) = Significant; (ns) = Nonsignificant; DAS = days after sowing.

Plant height growth of cocoa seedlings in several planting media is shown in Table 3. The analysis showed that the type of planting media did not influence the initial growth of cocoa seedling height at 30 DAS. The planting media factor began to show a significantly different effect on plant height after the seedlings were 60 days old. The composition of planting media in the form of topsoil and manure gives the best performance to the height of cocoa seedlings aged 60 DAS and 90 DAS. The addition of manure to the topsoil planting media is able to provide better plant height growth than other planting media compositions. Similar results were also reported by Anthonio *et al.* (2018) that topsoil media added with organic matter from river sand showed better cocoa seedling height growth than planting media in the form of 100% topsoil and 100% clay. Quaye *et al.* (2019) also reported that topsoil and rice husk planting media added with compost provided better growth of cocoa seedlings than cocopeat and sawdust media. Optimum growth in seedling height and the highest number of leaves found on media that have a high organic matter content (Mahmoud *et al.*, 2019). Organic fertilizer is a natural source of soil nitrogen (N). Manure can restore essential macro-nutrients and some micro-nutrients to the soil to maintain its fertility (Khaitov *et al.,* 2019).

Meanwhile, the cocoa planting material factor showed a significantly different effect on plant height since 30 DAS. ICCRI 08H cocoa planting material showed significantly higher plant height than Sulawesi 1. The difference in the cocoa planting material type significantly affected plant height growth in the seedling phase. Sulawesi 1 half-sib seedlings used in this study came from generative propagation which is the result of crossing two elders and only the female elder clone is known. Cocoa plants are predominantly cross-pollinated so that there will be a phenomenon of heterosis from crosses of different elders, and vice versa if taken from seeds sourced from selfing, there will be inbreeding depression. In this case, the planting material from the Sulawesi 1 half-sib is only known to have female elders and the male elders as pollinators are unknown. ICCRI 08H cocoa seedlings are planting material derived from hybrid crosses where the genotypes of the female and male elders are known. In hybrid cocoa planting material, the offspring will experience heterosis effects with better vigor than the two elders. In the seedling phase, cocoa derived from ICCRI 08H hybrid seeds has better plant height growth than Sulawesi 1 half-sib seed although, genetically, Sulawesi 1 genotype has strong roots and heavy biomass at 1.5 months after planting in the nursery (Zakariyya, 2017). ICCRI 08H planting material, the offspring of the cross of KEE 2 and Sulawesi 1 (Kepmentan, 2017), has better plant height performance in the seedling phase than Sulawesi 1 half-sib.

The interaction of planting material type and planting media is shown in Table 3. Topsoil and manure planting media combined with the ICCRI 08H hybrid gave the highest plant height performance at all seedling ages. However, the plant height response of ICCRI 08H in all three combinations of planting media also showed better performance than the Sulawesi 1 half-sib.

Topsoil and manure media performed best in stem diameter compared to the other planting media compositions at all ages (Table 4). The diameter of cocoa seedlings in topsoil + manure media at 30, 60, and 90 DAS were 2.88 mm, 4.09 mm, and 5.69 mm, respectively. Cocoa seedlings can develop well on topsoil media added with organic matter in the form of manure. Anthonio *et al*. (2018) also reported that cocoa seedlings developed well on river sand media mixed

Table 2. Uniformity of cocoa seed germination on several growing media

Treatment	KsT (%)
Media	
Topsoil	97.78 a
Topsoil and rice husk	91.11 b
Topsoil and manure	98.89 a

Notes: KsT = Seedling germination; numbers followed by different letters in the same column indicate significantly different values at the α = 5% level.

Table 3. Effect of media, planting materials, and their imteractions on plant height of cocoa seedlings

Treatment	Plant height (cm)		
	30 DAS	60 DAS	90 DAS
Media			
Topsoil	22.8 a	27.1 b	31.8 b
Topsoil and rice husk	22.6 a	26.8 b	29.7 b
Topsoil and manure	23.6 a	31.1 a	41.8 a
Planting material			
Sulawesi 1	21.6 b	26.6 b	32.5 b
ICCRI 08H	24.3 a	30.0 a	36.4 a
Media x Planting material interaction			
Topsoil - Sulawesi 1	20.6 b	25.3 c	30.0 c
Topsoil - ICCRI 08H	25.1 a	28.9 abc	33.7 bc
Topsoil + rice husk - Sulawesi 1	22.1 ab	25.1 c	28.0 c
Topsoil + rice husk - ICCRI 08H	23.0 ab	28.5 bc	31.4 c
Topsoil + manure - Sulawesi 1	22.4 ab	29.5 ab	39.4 ab
Topsoil + manure - ICCRI 08H	24.7 ab	32.6 a	44.2 a

Notes: DAS = days after sowing; numbers followed by different letters in the same column indicate significantly different values at the α = 5% level.

with sawdust and topsoil media added with organic matter when the cocoa seedlings were 30, 60, and 120 days after planting.

ICCRI 08 planting material performed better stem diameter than Sulawesi 1 half-sib at all observation ages. The development of stem diameter is positively correlated with root volume and lateral root length (Susilo *et al*., 2005). Based on the stem diameter performance, it is possible that ICCRI 08H hybrid cocoa has stronger and have more roots than Sulawesi 1 half-sib. Meanwhile, the best interaction of media composition and type of planting material was shown in topsoil + manure fertilizer with ICCRI 08H planting material. Although, this result was not significantly different from the interaction of topsoil with ICCRI 08H and topsoil + husk with ICCRI 08H. These results also showed that ICCRI 08H showed stable and better performance than Sulawesi 1 half-sib in all combinations of planting media.

Topsoil and manure media gave the best results on the uniformity of growth, plant height, stem diameter, and number of leaves of cocoa seedlings. At the beginning of seedling growth (30 DAS), topsoil and manure media have not shown a significant effect but after 60 and 90 DAS, topsoil and manure media have a significant effect on plant height, stem diameter, and number of leaves of cocoa seedlings. Adding organic matter has a positive effect on the growth of cocoa seedlings, although the real effect occurs after 60 days of age. Organic matter provides nutrients available to cocoa seedlings for a long period. In contrast to the rice husk mixed media, although rice husk is lightweight and very effective in improving drainage, rice husk has poor nutrient availability (Kaushal &

Kumari, 2020). Adding organic matter can increase the content of Ca, K, Mg, Na, total P, and N. This also affects the uptake of nutrients into plant roots (Khaitov *et al*., 2019).

A suitable growing medium has important functions for plants, such as providing nutrients, providing space for aeration and plant roots to respire, and maintaining water availability for plants (Anthonio *et al*., 2018). In the nursery phase, the growing medium must provide adequate plant support, good gas exchange circulation, and be a reservoir of nutrients and water (Mahmoud *et al*., 2019). The quantity of growing media in the nursery is minimal, so the appropriate growing media can support the growth of seedlings in the nursery. The more vigorous the seedling growth in the nursery, the higher the planting success rate in the field.

The growth of ICCRI 08H hybrid cocoa seedlings was better than Sulawesi 1 half-sib in plant height, stem diameter, and number

Table 4. Effect of media, planting materials and their interaction on stem diameter of cocoa seedlings

Treatment	Stem diameter (mm)		
	30 DAS	60 DAS	90 DAS
Media			
Topsoil	2.62 b	3.77 b	5.33 ab
Topsoil and rice husk	2.79 ab	3.83 b	5.09 b
Topsoil and manure	2.88 a	4.09 a	5.69 a
Planting material			
Sulawesi 1	2.65 b	3.64 b	4.85 b
ICCRI 08H	2.87 a	4.14 a	5.89 a
Media x planting material interaction			
Topsoil - Sulawesi 1	2.43 b	3.46 b	4.61 c
Topsoil - ICCRI 09H	2.81 a	4.07 a	6.05 a
Topsoil + rice husk - Sulawesi 1	2.70 a	3.46 b	4.56 c
Topsoil + rice husk - ICCRI 08H	2.88 a	4.19 a	5.63 ab
Topsoil + manure - Sulawesi 1	2.83 a	4.02 a	5.40 b
Topsoil + manure - ICCRI 08H	2.92 a	4.16 a	5.99 a

Notes: DAS = days after sowing; numbers followed by different letters in the same column indicate significantly different values at the $\alpha = 5\%$ level.

Table 5. Effect of media, planting material and their interaction on leaf number

Treatment	Number of leaves		
	30 DAS	60 DAS	90 DAS
Media			
Topsoil	4.40 a	7.63 ab	9.43 b
Topsoil and rice husk	4.43 a	7.10 b	7.77 c
Topsoil and manure	4.70 a	8.06 a	11.10 a
Planting material			
Sulawesi 1	4.58 a	7.69 a	9.29 a
ICCRI 08H	4.44 a	7.51 a	9.58 a
Media x planting material interaction			
Topsoil - Sulawesi 1	4.20 b	7.53 b	8.93 cd
Topsoil - ICCRI 09H	4.60 ab	7.73 ab	9.93 bc
Topsoil + rice husk - Sulawesi 1	4.60 ab	7.07 b	7.27 e
Topsoil + rice husk - ICCRI 08H	4.27 b	7.13 b	8.27 de
Topsoil + manure - Sulawesi 1	4.93 a	8.47 a	11.67 a
Topsoil + manure - ICCRI 08H	4.47 ab	7.67 b	10.53 ab

Notes: DAS = days after sowing; numbers followed by different letters in the same column indicate significantly different values at the $\alpha = 5\%$ level.

of leaves at all seedling ages (30, 60, and 90 DAS). Planting material derived from hybrid crosses showed the best growth performance. Cocoa hybrid ICCRI 08H is a cross between KEE 2 and Sulawesi 1 (Kepmentan, 2017) with strong roots and vigorous growth. In accordance with its description, ICCRI 08H planting material is recommended as a source of rootstock. This is supported by the test results of Susilo (2018), which showed that ICCRI 08H cocoa hybrids could adapt well to dry areas. The results of this study are in accordance with Susilo *et al*. (2005), who stated that cocoa planting material derived from controlled crosses and not from free crosses has the best seedling growth.

CONCLUSIONS

ICCRI 08H as planting root stock showed the best growth in growth uniformity, plant height growth, stem diameter, and the number of leaves at 90 days after planting. Planting media combination of topsoil and manure showed the best seedlings growth, as indicated by the highest uniformity of seedlings growth, plant height, stem diameter and number of leaves at 90 days after sowing. The interaction of topsoil and manure media treatment with ICCRI 08H hybrid cocoa planting material showed the best growt results, which were indicated by highest stem diameter at 90 days after sowing and number of leaves.

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