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Growth Response of Cocoa (*Theobroma cacao* L.) Seedlings on Various Planting Media Administration

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Abstract **Original Research Article**

Growth response of cocoa (*Theobroma cacao* L.) seedlings on various planting media administration. This research aimed to determine the growth response of cocoa seedling plants with the application of various compost media. The purpose of this research was to provide information regarding the type of compost combination that was suitable for the growth of cocoa seedlings. This research was conducted in Sugihwaras Village, Wonomulyo Subdistrict, Polewali Mandar Regency, West Sulawesi, Indonesia from October 2020 to January 2021. The analytical method used in this research was the Randomized Block Design (RBD) with 8 treatments: 1) 1:1:1 (Soil + Cow Manure + Sand), 2) 2:1:1 (Soil + Cow Manure + Sand), 3) 1:1:1 (Soil + Tofu Dregs + Sand), 4) 2:1:1 (Soil + Tofu Dregs + Sand), 5) 1:1:1 (Soil + Vermicompost + Sand), 6) 1:1:1 (Vermicompost + Cow Manure + Tofu Dregs), 7) 2:1:1 (Soil + Vermicompost + Cow Manure), 8) 2:1:1 (Soil + Cow Manure + Tofu Dregs). Each treatment was repeated three times, so that the number of samples was 72 plants. This study indicated that the treatment of Soil + Cow Manure + Sand media with a ratio of 2:1:1 gave the best effect on the plant height, plant weight, and root length of cocoa seedlings.

Keywords: Seedlings**,** Compost, Tofu Dregs, Fertilizer, plant height.

INTRODUCTION

Indonesia is an agricultural country with a large population making a living in agriculture. As a country with a tropical climate, Indonesia has a geographical advantage with only two seasons, i.e., the rainy and dry seasons, which will greatly support plant growth. Plantations in Indonesia play an important role both in the economic and social fields because it can generate a large foreign exchange to build the Indonesian nation and state. Cocoa (*Theobroma cacao* L.) is one of the export commodities that can contribute to efforts in increasing Indonesia's foreign exchange. The cocoa commodity ranks third in the plantation sector's exports in contributing to foreign exchange, after CPO and rubber commodities. Cocoa also has a fairly stable market and relatively expensive prices (Obeng *et al.,* 2020,Hoffmann *et al.,* 2020).

Total cocoa exports in the last five years have fluctuated up and down, increasing from 6.78 to 7.53% per year, while the decline reached 19.4%. In 2018, the total exports increased by 7.31%. In 2014, the total export volume reached 333.68 thousand tonnes with a total value of US$ 1.24 billion, then increased to 380.83 thousand tonnes in 2018 with a total value of US$ 1.25 billion. Most of Indonesia's cocoa production is exported to foreign countries and the rest is marketed domestically. Indonesia's cocoa exports reach five continents, i.e., Asia, America, Europe, Africa, and Australia with the main share in Asia.

Indonesia is the third largest cocoa producer in the world after the Ivory Coast and Ghana with a production of 777,500 tonnes in 2013. Sulawesi Island holds the position of the largest plantation with an area of 857,757 Ha and production of 538,059 tonnes in 2013. Meanwhile, the province of West Sulawesi ranks 5th in cocoa production in Indonesia within the 2020 national level, and the 4th position in island-level cocoa production. The success of cocoa development is determined by the availability of seeds in sufficient quantities and attention to the cultivation (Becerra *et al.,* 2023). One of the important actions of cocoa cultivation is the provision of quality seedlings (Farghal *et al.,* 2022). Seedling quality determines the growth and productivity of cocoa (Essah *et al.,* 2022). Key efforts to obtain quality seedlings is through the nursery process (Barišić *et al.,* 2023).

Nurseries require actions such as the fertilizers administration which aim to improve soil fertility and to

add certain nutrients to the soil. The fertilizer given can be in the form of organic fertilizer. The benefits of organic matter physically improve the structure and increase the capacity of the soil to store water, chemically increase the buffering capacity of the soil against changes in pH; and biologically (Jaja & Barber, 2017), it is a source of energy for soil microorganisms which play an important role in the process of decomposition and release of nutrients in the soil ecosystem (Lal, 2020). There are several types of organic fertilizers derived from nature, i.e., manure, green manure, compost, humus, biological fertilizers (Naghdi *et al.*, 2022), and agroindustrial waste (Fuentes *et al.*, 2021).

Compost is the result of partial/incomplete decomposition of a mixture of organic materials which can be accelerated artificially by a population of various types of microbes in warm, humid, and aerobic or anaerobic environmental conditions. Meanwhile, composting is a process in which organic matter undergoes biological decomposition, especially by microbes that utilize organic matter as an energy source. Making good compost is regulating and controlling this natural process, so that compost can be formed more quickly (Qian *et al.*, 2023). This process includes making a balanced mixture of ingredients, providing sufficient water, setting aeration, and adding composting activators (de Nijs *et al.*, 2023);Lin *et al.*, 2023). Therefore, this study was conducted to investigate the best growth response of cocoa seedling plants by providing various planting media.

MATERIALS AND METHODS

Location and Time

This research was conducted in Sugihwaras Village, Wonomulyo Subdistrict, Polewali Mandar Regency, West Sulawesi, Indonesia from October 2020 to January 2021.

Tools and Materials

The tools used in this study were hoes, plastic tubs, stationery, measuring cups, scales, rulers, and a camera. The materials used were cocoa seeds, polybags, cow dung compost, tofu dregs compost, vermicompost fertilizer, soil, sand, and water.

Research Methods

This research was conducted using the Randomized Block Design (RBD) method which consisted of 8 treatments as follows: P1 = 400 gr soil + 300 gr cow manure + 300 gr sand / polybag, P2 = 600 g soil + 200 gr cow manure + 200 gr sand / polybag, P3 = 400 gr soil + 300 gr tofu dregs + 300 g sand / polybag, P4 = 600 gr soil + 200 gr tofu dregs + 200 gr sand / polybag, P5 = 400 gr soil + 300 gr vermicompost + 300 gr sand / polybag, P6 = 400 gr vermicompost + 300 gr cow manure + 300 gr tofu dregs / polybag, P7 = 600 gr soil + 200 gr vermicompost + 200 gr cow manure / polybag, P8 = 600 gr soil + 200 gr cow manure + 200 gr tofu dregs / polybag. Each treatment was repeated 3 times, so that 24 experimental units were obtained with 5 plants per experimental unit. The total number was 120 plants, and 3 plants were taken as samples per experimental unit, so that 72 plant samples were obtained.

Research Implementation

Preparation of Cocoa Seeding Sites

After the planting materials or seeds were ready, the next step was to prepare the seeds beds and shades. Beds and shades were made in areas that met the requirements of good nursery areas, e.g., close to water sources, flat and level ground, close with affordable distance, and safe from various disturbances.

Nursery beds size was 1 x 8 m in a north-south direction. The land was cleared of weeds and root debris, then the soil was loosened to a depth of 15 cm, then leveled. Sands of 3-5 cm thick were added to make it easier during the process of transferring the seeds to the polybags.

Shades were then provided on the beds to protect the seeds from the hot sunlight or direct raindrops. The shade of the beds can be in the form of coconut leaves, sugarcane leaves, or woven reed leaves. The shade was made with a pole height of 1.5 meters on the east and 1.2 meters on the west.

Seeding

After the seeds and nursery beds were established, the next stage of the nursery was to sow the seeds. Prior to seeding, the cocoa beans that had been cleaned of mucus were soaked using a fungicide to prevent the seeds from becoming moldy during sowing. The soaking time was about 120 minutes in the container. After soaking, the seeds were drained in place in a sieve. The seeds were then placed in a layer of sand with the flat side facing down. The seeds were pressed into the sand layer, so that about a third of the seeds were immersed in the sand medium. Seeds were sown in rows with a distance of 2.5 x 5 cm.

Treatments Application

Preparation of planting media for cocoa seedlings consisted of 8 treatments using soil, sand, cow manure, tofu dregs compost, and vermicompost. The treatments used are as follows: Treatment 1 = 400 gr soil + 300 gr cow manure + 300 gr sand / polybag, Treatment 2 = 600 gr soil + 200 gr cow manure + 200 gr sand / polybag, Treatment 3 = 400 gr soil + 300 gr tofu dregs + 300 gr sand / polybag, treatment 4 = 600 gr soil + 200 gr tofu dregs + 200 gr sand / polybag, Treatment 5 = 400 gr soil + 300 gr vermicompost + 300 gr sand / polybag, treatment 6 = 400 gr vermicompost + 300 gr cow manure + 300 gr tofu dregs / polybag, Treatment 7 = 600 gr soil + 200 gr vermicompost + 200

gr cow manure / polybag Treatment 8 = 600 gr soil + 200 gr cow manure + 200 gr tofu dregs / polybag

After each combination of media was mixed, it was then placed in a 10 x 15 cm polybag. Polybags that had been filled with planting media were then arranged under the shades that were prepared. The shade for the polybag nursery was similar to the shade for the seeding. The polybag arrangement model was one row. The distance between rows was tight, while the distance between rows of polybags was 50 cm.

Transfer of Sprouts

After 4-5 days in the nursery, the cocoa seeds started to germinate, and they must be immediately transferred to the prepared polybags. In this case, the selection of sprouts was performed to obtain quality seedlings. Transfer of sprouts was performed carefully, so that the taproot was not cut off. Sprouts collection was conducted using bamboo. The sprouts that had been removed were then planted in the planting media in polybags that had been perforated as deep as the forefinger, so that the taproot of the sprout can stand straight in the hole as much as possible. Then, the hole was closed and left until it can adapt to its new environment.

Seedling Maintenance

Cocoa seedlings in polybags must be properly maintained, so that they grow strong and healthy. Seedling maintenance activities included watering, fertilizing, and pest and disease control. Watering is necessary, so that the seedlings do not dry out. During the dry season, watering was applied 2 times a day in the morning and evening; while during the rainy season, watering was adjusted to the condition of the growing media in polybags.

Fertilization on cocoa seedlings was performed every 14 days until the seeds reached 3 months old. Fertilization was applied with LOF (liquid organic fertilizer) “biotani” at a dose of 10 mL/10 L which had been dissolved in water. Control of pests and diseases in cocoa seedling nurseries was carried out depending on the attack conditions. If pests and diseases such as mealybugs, aphis, small beetles, or rotting fungi attacked the seeds, control was performed by applying insecticides according to the dose.

Observation Parameters

Measured parameters for seedlings growth were Plant Height (cm). Plant height was measured from the soil surface to the highest growing point. Measurements were made from plants aged 15, 30, 45, 60, 75, and 90 days after planting (DAP). Number of Leaves (strands). Number of leaves was observed when the plants aged 15, 30, 45, 60, 75, and 90 DAP. Leaf Area (cm^2). Leaf area was measured by the millimeter paper method. Leaves were drawn on millimeter paper which was easily done by placing the leaf on millimeter paper and following the leaf pattern. The leaf area was estimated based on the number of squares in the leaf pattern. Measurements were made at 90 DAP. Plant Weight (gr). Plant Weight was obtained by weighing when the plants had been removed from the polybag and cleaned of soil residues, then the fresh plant weight was weighed per treatment unit. Measurements were made at 90 DAP. Root Length (cm). The length of the stem root was measured from the base of the stem to the tip of the single root of the cocoa seedling plant. Measurements were made at 90 DAP. Root Volume (mL). Root Volume was measured by immersing the roots in the measuring cup and observing the increase in water volume when immersing the roots in the measuring cup. Measurements were made at 90 DAP.

RESEARCH RESULTS

Plant Height (cm)

The observation and ANOVA results of the average seedling plant height at 90 DAP are presented in Figure 1, respectively. The ANOVA and Tukey's honestly significant difference (HSD) results showed that the treatment of various combinations of growing media at the age of 90 DAP had a very significant effect on the height of the cocoa seedling plants. Numbers followed by different letters show significantly different results at the α level of 0.05 = 2.91. The results in Figure 1 showed that the P2 treatment was significantly different from the P3 treatment, but not significantly different from the P8, P1, P4, P5, P7, P6, and P3 treatments. The P8 treatment was significantly different from the P3 treatment, but not significantly different from the P1, P4, P5, P7, P6, and P3 treatments. Meanwhile, the P1 treatment was significantly different from the P3 treatment, but not significantly different from the P4, P5, P7, P6, and P3 treatments. The P4 treatment was significantly different from the P3 treatment, but not significantly different from the P5, P7, P6, and P3 treatments. The P5 treatment was significantly different from the P3 treatment, but not significantly different from the P7, P6, and P3 treatments.

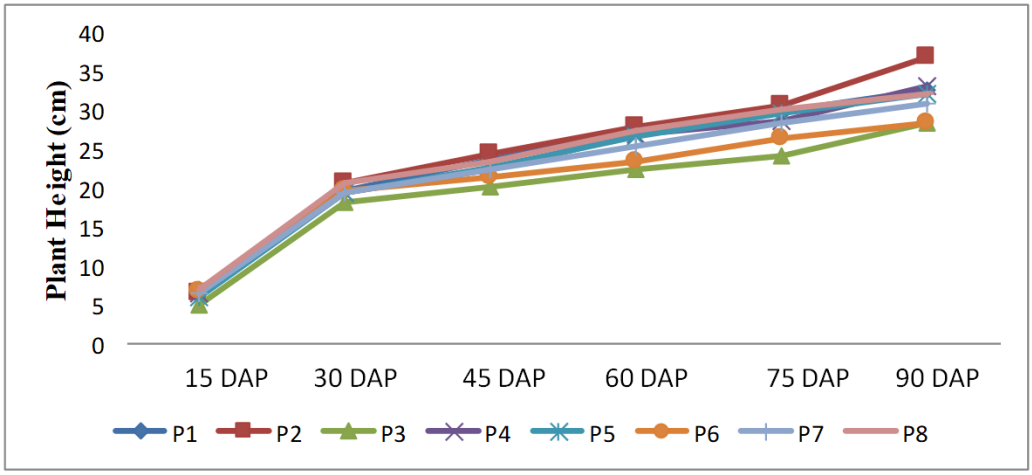

Figure 1: Average Growth Rate of Cocoa Seedling Plant Height

The observation results on the average growth rate of cocoa seedling plant height in Figure 1 showed that the P2 treatment achieved the best results with an average growth rate of 6.55 cm at 1-15 DAP, 14 cm at 15-30 DAP, 3.72 cm at 30-45 DAP, 3.5 cm at 45-60 DAP, 2.95 cm at 60-75 DAP, and 6.11 cm at 75-90 DAP. Meanwhile, the P3 treatment showed the lowest average growth rate of plant height of 5.05 cm at 1-15 DAP, 13 cm at 15-30 DAP, 2.17 cm at 30-45 DAP, 1.12 cm at 45-60 DAP, 1.87 cm at 60-75 DAP, and 4.12 cm at 75-90 DAP.

Number of Leaves (strands)

The ANOVA results showed that the treatment of various combinations of planting media at the age of 90 DAP had no significant effect on the number of leaves of cocoa seedlings. Figure 2 on the number of leaves aged 90 DAP shows that the P7 treatment tends to be better than the P5, P1, P6, P2, P8, P4, and P3 treatments.

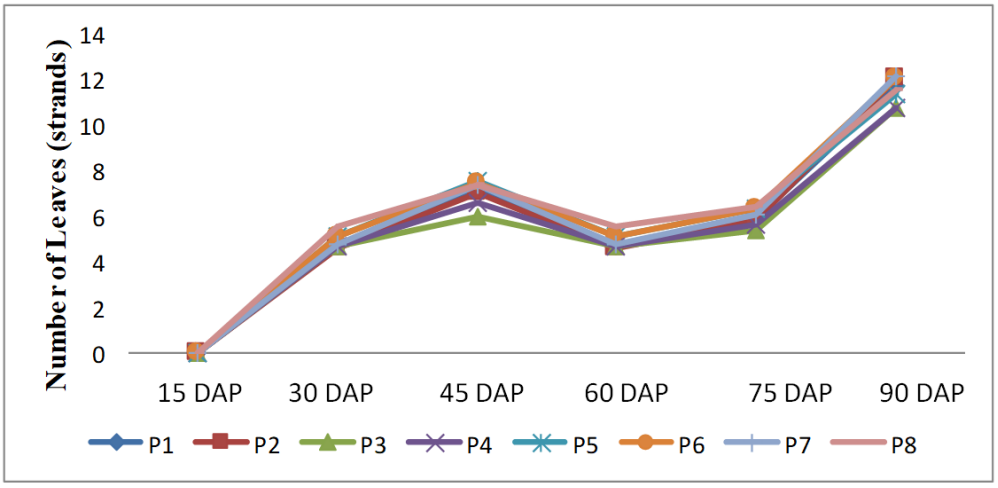

Figure 2: Average Growth Rate of Cocoa Seedling Number of Leaves at 90 DAP

The observation results on the average growth rate of the number of leaves of cocoa seedlings in Figure 2 showed that the P7 treatment achieved the best results with an average growth rate of 0 strand at 1-15 DAP, 4.77 strands at 15-30 DAP, 2.56 strands at 30-45 DAP, 1.55 strands at 45-60 DAP, 1.56 strands at 60-75 DAP, and 1.66 strands at 75-90 DAP. Meanwhile, the P3 treatment showed the lowest average growth rate of the number of leaves as much as 0 strand at 1-15 DAP, 4.66 strands at 15-30 DAP, 1.33 strands at 30-45 DAP, 1.78 strands at 45-60 DAP, 1.44 strands at 60-75 DAP, and 1.56 strands at 75-90 DAP.

Plant Weight (gr)

The observation and ANOVA results of the average plant weight at 90 DAP are presented in Appendix Tables 1, respectively. The ANOVA and Tukey's HSD results showed that the treatment of various combinations of planting media at the age of 90 DAP had a significant effect on the plant weight of cocoa seedlings.

Table 1: Average Weight of Cocoa Seedlings (90 DAP)

TREATMENT	AVERAGE	HSD at α 0.05
P2	15.66 [a]	5,19.
P5	14.55 [ab]	
P1	14.33 [ab]	
P6	12.66 [ab]	
Q7	12.44 [ab]	
Q8	12.10 [ab]	
P4	11.00 [a.b]	
P3	10,11b [-]	

Note: Numbers followed by different letters show significantly different results at the α level of 0.05.

The HSD test results at level α 0.05 in Table 1 showed that the P2 treatment was significantly different from the P3 treatment, but not significantly different from the P5, P1, P6, P7, P8, P4, and P3 treatments on the weight of cocoa seedlings at 90 DAP.

Root Length (cm)

The observation and ANOVA results of the average root length at 90 DAP are presented in Figure 3. The ANOVA and Tukey's HSD showed that the treatment of various combinations of planting media at the age of 90 DAP had no significant effect on the root length of cocoa seedlings.

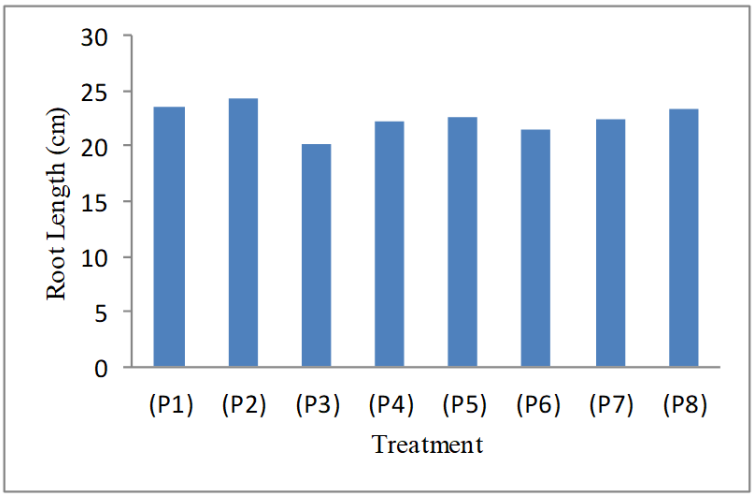

Figure 3: Average Root Length of Cocoa Seedlings at 90 DAP

Figure 3 on the root length aged 90 DAP shows that P2 treatment tends to be better than the P1, P8, P5, P7, P4, P6, and P3 treatments.

Root Volume (mL)

The observation and ANOVA results of the average root length at 90 DAP are presented in Table 2, respectively. The ANOVA and Tukey's HSD showed that the treatment of various combinations of planting media at the age of 90 DAP had a very significant effect on the root volume of cocoa seedlings.

Table 2: Average Root Volume of Cocoa Seedlings (90 DAP)

TREATMENT	AVERAGE	HSD at α 0.05
P1	0.30a	0.1
P2	0.24 [ab]	
P5	0.24 [ab]	
P6	0.23 [ab]	
P3	0.18b	
P4	0.18b	
Q8	0.17b	
Q7	0.14b	

Note: Numbers followed by different letters show significantly different results at the α level of 0.05.

The HSD test results at level α 0.05 in Table 2 showed that the P1 treatment was significantly different from the P3, P4, P8, P7 treatments, but not significantly different from the P2, P5, and P6 treatments on the root volume of cocoa seedlings at 90 DAP.

DISCUSSION

Plant Height

Plant height is a plant growth variable that is easily observed as a parameter to determine the effect of the environment or treatments on plants. The increase in plant height shows the vegetative growth activity of a plant. The results of observations and ANOVA showed that the treatments had a very significant effect on the parameter of plant height of cocoa seedlings. The highest average plant height (24.44 cm) was obtained in the P2 treatment (Soil + Cow Manure + Sand), while the lowest average plant height (19.7 cm) was found in the P3 treatment (Soil + Tofu Dregs + Sand).

According to Andi (2015), applying compost can improve soil chemical properties, pH, and C-organic soil (Xiao *et al.,* 2022);(Magdich *et al.,* 2022). Furthermore, (Kuroda *et al.,* 2023) and (Fidelis & Rajashekhar Rao, 2017) reported that the application of soil enhancer affects field capacity and plant growth including plant height, plant wet weight, dry weight, and number of leaves. Organic matter can improve the properties of regosol soil which has porosity, so that the soil can maintain the availability of moisture for fertilizer nutrient absorption. Observation of plant height was carried out to determine the plant growth rate.

Number of Leaves

The leaf is a plant organ that functions as a place for photosynthesis to take place which produces photosynthate. With the help of sunlight, water and carbon dioxide are converted by chlorophyll into organic compounds, carbohydrates, and oxygen. The nutrients resulting from photosynthesis are used for plant needs as well as for food reserves.

The results of observations and ANOVA showed that the treatments had no significant effect on the number of leaves of cocoa seedlings. The highest average number of leaves (8.7) was found in the P7 treatment (Soil + Vermicompost + Cow Manure), while the lowest average number of leaves (7.68) was obtained in the P3 treatment (Soil + Tofu Dregs + Sand). The results were not significantly different within treatments. It is suspected that the various compost media tested have the same nutrient content and can meet the needs of seedlings in all treatments.

Plants with more leaves will have faster growth (Tosto *et al.,* 2023). The number of leaves is the main determinant of the plant growth rate (Notaro *et al.,* 2021). The more the number of leaves on the plant, the higher the photosynthetic results, so the plants will grow well.

Leaf Area

Plant leaf area is one of the parameters that indicates whether the plants have good growth or not. The wider the leaf size indicates that the plant has better growth. The results of observations and ANOVA showed that the treatments had no significant effect on the parameter of leaf area of cocoa seedlings. The highest average leaf area (108.7 cm) was obtained in the P5 treatment (Soil + Vermicompost + Sand), while the lowest average leaf area (82.48 cm) was found in the P1 treatment (Soil + Cow Manure + Sand). The results were not significantly different within treatments. It is apparently that the various compost media tested have the same nutrient content and can meet the needs of seedlings in all treatments

Leaf area is a parameter to determine the photosynthetic growth rate per unit dominant plant which is determined by leaf area. The plant growth rate is influenced by the net assimilation rate and leaf area. A high net assimilation rate and optimum leaf area can increase plant growth (Weraduwage *et al.,* 2015**).** The formation of leaves in plants is affected by genetic factors and also influenced by environmental factors. The availability of nutrients in the soil, especially N, can affect the formation of leaf area and number of leaves in plants.

Plant Weight

Plant weight is a parameter to determine the plant biomass and growth. Plant biomass is a measure of the plant growth resulting from biochemical reactions that begin with the formation of cells that will form tissues and then build organs and eventually form the plant body. The results of observations and ANOVA showed that the treatments had a significant effect on the weight of cocoa seedlings. The highest average plant weight (15.66 g) was found in the P2 treatment (Soil + Cow Manure + Sand), while the lowest average plant weight (10.11 gr) was obtained in the P3 treatment (Soil + Tofu Dregs + Sand).

Nutrient N plays a role in stimulating overall plant growth, so plant weight also increases. Increasing the amount of nutrients absorbed by plants will indirectly increase photosynthetic yields. An increase in photosynthate results causes an increase in the materials to be stored in the stem and leaf tissues, and this result can then increase the wet weight of the plant canopy.

Root Length

Root length measurement was carried out in a fresh root condition and clean from soil impurities. Measurements were not made on root hairs. Root length

measurement was performed according to root structure in the root system based on the classification. The results of observations and ANOVA showed that the treatments had no significant effect on the root length of cocoa seedlings. The highest average root length (24.27 cm) was found in the P2 treatment (Soil + Cow Manure + Sand), while the lowest average root length (20.22 cm) was obtained in the P3 treatment (Soil + Tofu Dregs + Sand). The treatments were not significantly different within treatments. It is suspected that the various compost media tested have the same nutrient content and can meet the needs of seedlings in all treatments.

Root development is strongly influenced by soil structure, water and drainage in the soil which are highly dependent on soil organic matter. Plant roots develop well, the growth of other plant parts will also be good because the roots are able to absorb water and nutrients needed by plants.

Root Volume

The root volume measurement aims to investigate the ability of roots to reach or obtain nutrients and water. The results of observations and ANOVA showed that the treatments had a very significant effect on the root volume of cocoa seedlings. The highest average root volume (0.3 mL) was obtained in the P1 treatment (Soil + Cow Manure + Sand), while the lowest average root volume (0.14 mL) was found in the P7 treatment (Soil + Vermicompost + Cow Manure).

According to (Zhang *et al.*, 2020) the application of organic fertilizers or organic matter with sufficient N content when planting can maintain a good start of plant growth, so that it can increase the large number of roots. If the number of roots in a plant is large, it will support the plant growth itself. This is because basically the root is one of the plant organs that is used to store water and biomass from the soil which will then be distributed to plants and later be used for metabolic processes in the plants.

CONCLUSIONS

This research concluded that the combination treatment of Soil + Cow Manure + Sand media with a ratio of 600:200:200 gr affected and tended to be very good on the plant height, plant weight, and root length of cocoa seedlings. However, the treatments did not significantly affect the number of leaves, leaf area, and root volume of cocoa seedlings. Therefore, the medium of Soil + Cow Manure + Sand with a ratio of 600:200:200 gr was determined as the best medium for cocoa nursery. From the results of this study, there are several recommendations that need to be made in the future as follows to obtain good growth of cocoa seedlings, it is better to use a combination of soil, cow manure, and sand as a planting medium. Further research is needed using different dosages of treatments and combinations of fertilizers on the growth of cocoa seedlings, as scientific materials and consideration in cultivating cocoa seedlings using compost media. In research using a combination of compost media, it is necessary to consider the type of compost to be used to obtain more efficient results.

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