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Response of Cocoa (*Theobroma cacao* L.) Seedling Growth on Various Growing Media and Organic Plant Supplements

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Abstract

Cocoa (*Theobroma Cacao* L.) as a plantation crop which success is determined by healthy and quality seedlings. The use of planting media with a mixture of manure and plant organic supplements may result in healthy soil because it contains soil microorganisms that are beneficial and may support the growth of cocoa seedlings. Purpose of this study was to determine the initial growth response of cocoa seedlings on various growing media and dosages of an organic plant supplement as liquid organic fertilizer. The research was conducted in February–September 2022 in a nursery located in Kradenan, Purwoharjo, Banyuwangi Regency and in Agricultural Laboratory of University of Jember, Bondowoso Campus, Bondowoso Regency. Study was carried out in a 4 x 4 factorial using a randomized block design with three replications. The first factor was planting media which consisted of four levels of treatment, namely soil + chicken manure, soil + goat manure, soil + cow manure, and soil + rabbit manure. The second factor was dose of organic plant supplement which consisted of 4 levels, namely the control treatment of 0, 50, 100, and 150 mL polybag^{-1}. Data were analyzed using analysis of variance and follow-up tests using Duncan's multiple range test at 5% level. Variables observed included seedling height, number of leaves, stem diameter, leaf length, leaf width, number of roots, root length, fresh weight, and dry weight of seedlings. The results showed that there was an interaction effect on all parameters except seedling height, number of leaves, and number of roots. The conclusion of the study showed that there was an effect of interaction treatment with the best treatment combination planting media using cow manure and organic plant supplement dose of 50 mL polybag^{-1}.

Keywo rds: Cocoa seeds, growing media, plant organic supplement dosage, organic

INTRODUCTION

Cocoa plantation area in Indonesian declined as much as 3.93% year^{-1} (BPS, 2020). The data indicates a decrease in the cocoa plantation area from 1,611,014 ha in 2018 with the production of 767,280 tons to 1,528,382 ha in 2020 with production of 713,378 tons.

One of the efforts to increase cocoa production may be started from nursery. Cocoa seedlings will have good quality depending on the selection of seeds of which may have a major impact in long-term (Iskandar *et al.*, 2015). Activities in nurseries that must be paid attention are the selection of nursery location, selection of planting materials, polybags, planting media, seeds, as well as activities of seed planting, shelter, watering, weeding and control of pests and diseases. Proper nursery management may produce good seedlings (Fadillah *et al.*, 2019; Karmawati *et al.*, 2010).

According to Mulyani *et al*. (2018) seed quality affects growth and development of cocoa plants. Efforts to increase the quality of cocoa can be carried out by improving planting media and providing plant supplement. The planting media used plays an important role in achieving healthy plant growth because it affects the process of absorption of nutrients by plant roots (Lismawati *et al*., 2021; Mulyani *et al*., 2018).

Fertilization is important because it will provides nutrients needed by plants to grow and develop. Liquid organic fertilizer may improve physical, chemical, and biological properties of soil which eventually increase crop production and quality. Therefore, fertilization dosage used for cocoa plant in nurseries must be considered (Aji, 2016; Siregar, 2021).

The planting medium in cocoa nurseries must be able to provide good fertility for plants so that a mixture of organic matter such as manure (Widyastuti *et al*., 2021; Nora *et al*., 2015) will be able to provide good soil physical and chemical properties. Generally, a good planting medium is able to maintain optimal humidity in the area around the roots, provide sufficient oxygen, and fulfill sufficient nutrients for the growth of seedlings. Sufficient availability of nutrients, water and oxygen in planting medium can be provided by organic fertilizers. Top soil as a medium can be used in cocoa nurseries because it has sufficient nutrient content.

The best growing media are soil and manure with a composition of 2:1 for cocoa plant nurseries. Several types of manure are used as a growth medium for plants such as chicken manure, goat manure, cow manure, rabbit manure, and so on (Fadillah *et al*., 2019; Loss *et al*., 2019; Lubis *et al*., 2019). The results of several studies indicate that the application of manure to the planting medium will affect the response of plants (Rangkuti, 2019; Sitompul *et al*., 2014; Tarigan *et al*., 2014; Widyastuti *et al*., 2021). Well decomposed manure will provide good nutrient content. Criteria for mature composting has a brown to black brown color and has an earthy or musty smell caused by actinomycetes (Agus *et al*., 2014).

The early growth of cocoa plant seeds requires supplements to grow and develop properly. One of the supplements is organic plant supplement which used as a fertilizer because it contains soil microorganisms that are beneficial to plants. According to Wicaksono *et al*. (2015) soil microorganisms have a major role in the decomposition of organic matter into nutrients required by plants (Wicaksono *et al*., 2015).

The precise dosage of organic plant supplements used for cocoa plant nurseries needs to be known. The use of liquid organic fertilizer can increase cocoa plant growth if the dosage given is sufficient for the plant's needs due to the macro and micro nutrients contained in the organic fertilizer (Lismawati *et al*., 2021; Nugroho *et al*., 2021). The research results of Fadillah *et al*. (2019) showed that the combination of manure and liquid organic fertilizer on planting media resulted in a significant interaction on the leaf number of cocoa seedlings. Therefore, understanding the interaction and influence of planting media and organic plant supplement were the aims of this study.

MATERIALS AND METHODS

The research was carried out in a nursery located in Kradenan, Purwoharjo, Banyuwangi for growing of cocoa seedlings and the Agriculture Laboratory of Jember University, Bondowoso Campus, Bondowoso for analysis of several parameters, from February 2022 to September 2022. Organic plant supplement was used as liquid fertilizers that contained macronutrients (N, P, K, Ca, Mg, and S),

micronutrients (Mn, Mo, Fe, Bo, Co, Zn) and soil microorganisms. Manure treatments were manures of chicken, goat, cow, and rabbit which have been decomposed naturally for two months. The C/N ratio of chicken, goat, cow, and rabbit manures were 21.8, 30.5, 33.9 and 17.8, respectively. NPK composition of the manures and organic plant supplement used in this study, namely, chicken manure (1.00% N, 0.80% P, 0.39% K); goat manure (1.44% N, 0.50% P, 1.21% K); cow manure (0.57% N, 0.23% P, 0.62% K); rabbit manure (2.40% N, 1.40 % P, 0.60% K); and organic plant supplement (12.98% N, 5.12% P, 14.20% K).

The experiment was carried out in a 4 x 4 factorial using a randomized block design with three replications resulted in 48 experimental units. The first factor was planting media which consists of four levels, namely: top soil mixed with manures of chicken, goat, cow and rabbit. Ratio between top soil and manures was 3:1. The second factor was organic plant supplement doses which consist of four levels, namely 0 mL, 50 mL, 100 mL, and 150 mL polybag^{-1}.

The size of nursery area used was 3 m x 4 m, and cleaned from weeds and rubbish. The nursery was shaded using UV plastic and paranet. The size of polybag containers used in this experiment were 20 cm x 30 cm with the capacity of 4 kg was filled with the planting media of 3.5 kg.

Cocoa seeds of ICCRI 08 H hybrid were sown using fine sand and watered every morning and afternoon. The selected cocoa seeds are of normal size and free from pests and diseases. Selected and healthy two leaf seedlings were transferred to polybags containing planting media 10 days after sowing (DAS). The transfer was carried out simultaneously on the same day.

Plant maintenance was carried out by daily watering adjusting soil moisture conditions. Inferior plant replacement using similar age seedlings, continued with routine weeding and pest control using pesticides when needed.

Manure was applied before planting cocoa seedlings by evenly mixing with soil as planting medium. The organic plant supplement application was carried out after the plants were three weeks old after planting in polybags until they were three months old with an interval of two weeks. Application was done in the morning by pouring a predetermined dose as treatment around the plant after being diluted with water, namely 10 mL in 5 L of water. After being diluted, the solution was applied according to the treatment dose, namely 50 mL, 100 mL, and 150 mL polybag^{-1} by pouring it around the plants.

Parameters of growth were observed at three weeks after transplanting until the age of three months. Data collection included plant height, leaf number, stem diameter, leaf length, leaf width, root number, root length, fresh, and dry weight of cocoa seedlings.

In the last week of observation the cocoa seedlings were removed and cleaned from soil attached to the roots using water to reduce the potential for the roots to break off from the plants. The root length of cocoa seedlings was measured from the base of the stem to the tip of the root. Root number was measured by counting number of main secondary roots in the soil according to Rao & Ito (1998). The fresh weight of cocoa seedlings was determined by weighing all parts of the plant. The dry weight of cocoa seedlings was determined after being dried using an oven at 65 ^{0}C until reached a constant weight. Measurements were made in the last week. Observed data obtained were analyzed using analysis of variance and follow-up tests using Duncan's multiple range test at the 95% significant level.

RESULTS AND DISCUSSION

Summary of Analysis of variance for all observed variables was presented in Table 1. Based on that results, there are interaction of planting media and organic plant supplement on growth cocoa seedlings except for plant height, leaf number, and root number. Type of planting media affected all observed variables, while organic plant supplement also affected all variables except leaf number

Treatment Interaction

Interaction between growing media and organic plant supplement resulted in a significant effect on growth of cocoa seedlings in every observed variable except for plant height, leaf number, and root number. Use of planting media in the form of manure and use of organic plant supplement provided different responses to the growth of cocoa seedlings due to the content of these two materials as needed by plant growth. The significant interaction effect on seedling diameter, leaf length, leaf width, root length, fresh weight, and dry weight of cocoa indicated that the nutrients needed by the plants are available in sufficient quantities. The availability of sufficient nutrients will trigger an increase in plant metabolism and performance in managing the food it gets so that it will eventually increase plant growth and development (Marpaung, 2013).

Figure 1 showed that the best interaction in term of plant diameter was found in planting media with cow manure combined with 50 mL polybag^{-1} of organic plant supplement. Similarly, leaf length (Figure 2) shows the best interaction of combination of cow manure with a dose of 50 mL polybag^{-1} organic plant supplement. Also, for leaf width (Figure 3) shows the best interaction of combination of cow manure with a dose of 50 mL polybag^{-1} organic plant supplement as well. Meanwhile, the size of stomata was positively correlated with number of leaf stomata which are needed by plants in the process of photosynthesis as a means of entering and leaving CO in plants. Rosniawaty *et al*. (2015) stated that the amount of CO_2 that enters, automatically produces more photosynthate and the photosynthate results will be used for the growth of other plant organs.

Related with plant root length, the best interaction is shown by combination of goat manure with 150 mL polybag^{-1} of organic plant supplement. This is in line with the research of Prayogo *et al*. (2020) that soil combined with goat manure can increase soil moisture by 40.7%, soil porosity by 56.4%, organic C content by 2.97%, and N content by 0.47% which support growth of the root of cocoa seedlings. Combination of cow manure media and 50 mL polybag^{-1} of organic plant supplement result in the highest fresh weight (Figure 5) and dry weight (Figure 6) of cocoa seedlings (Figure 6). The increase in growth

Table 1. Analysis of variance (F-count) summary of all observed variables

Observational variables	F-count		
	Manure type (M)	Liquid fertilizer dosage (LF)	Interaction (M x LF)
Plant height	10.472 **	4.069 *	2.189 ns
Leaf number	7.707 **	0.414 ns	1.119 ns
Stem diameter	13.435 **	13.749 **	14.798 **
Leaf length	8.061 **	5.794 **	2.581 *
Leaf width	36.461 **	3.876 *	3.176 *
Root number	3.685 *	3.990 *	1.945 ns
Root length	3.567 *	6.982 **	2.771 *
Fresh weight	15.682 **	10.165 **	9.297 **
Dry weight	22.872 **	6.284 **	6.571 **

Notes: ** = very significant, * = significant, ns= not significant.

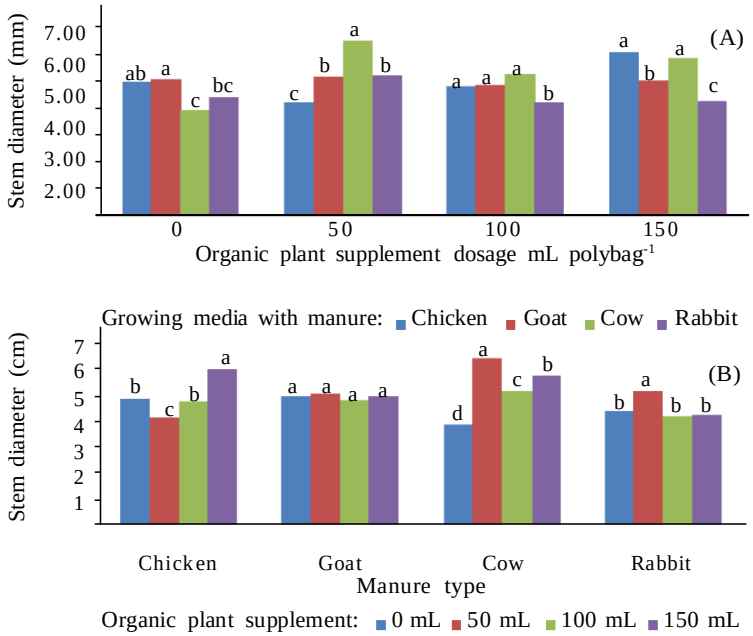

Figure 1 . Interaction of the simple effect of growing media at the same organic plant supplement dose (A) and the simple effect of organic plant supplement dose on same growing media (B) on stem diameter. Bars followed by different letter show significant differences at 0.05.

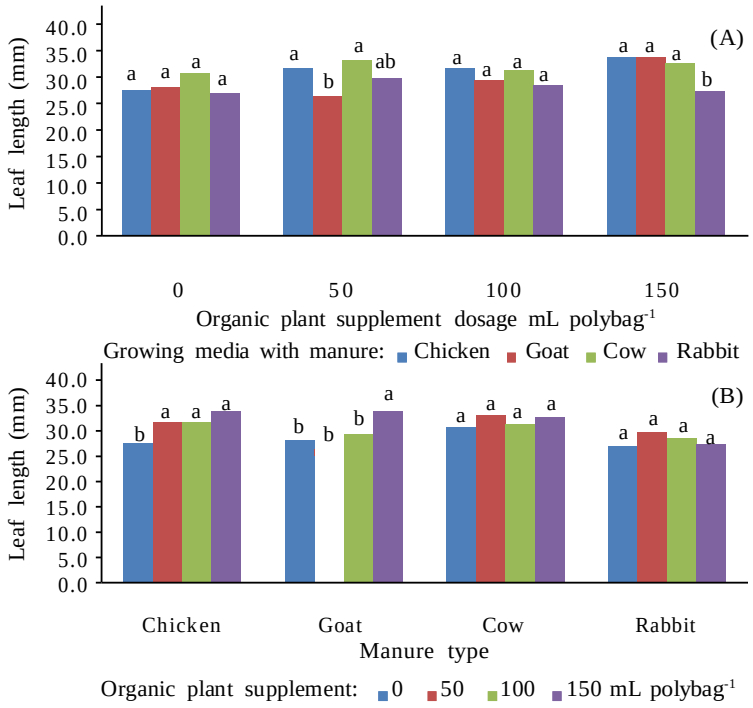

Figure 2. Interaction of the simple effect of growing media at the same organic plant supplement dosage (A) and the simple effect of organic plant supplement dose on the same growing media (B) on leaf length. Bars followed by different letter show significant differences at α 0.05.

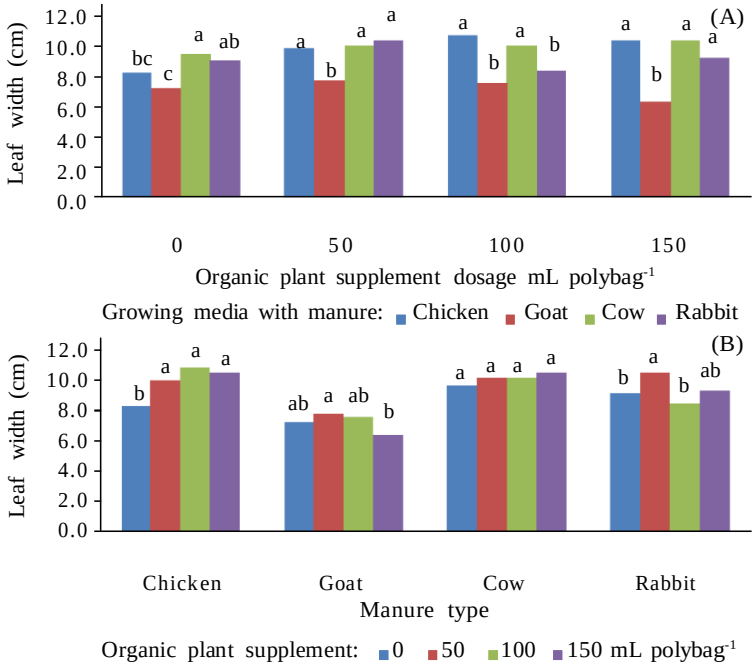

Figure 3 . Interaction of the simple effect of growing media at the same organic plant supplement dose (A) and the simple effect of organic plant supplement dose on the same growing media (B) on leaf width. Bars followed by different letter show significant differences at 0.05.

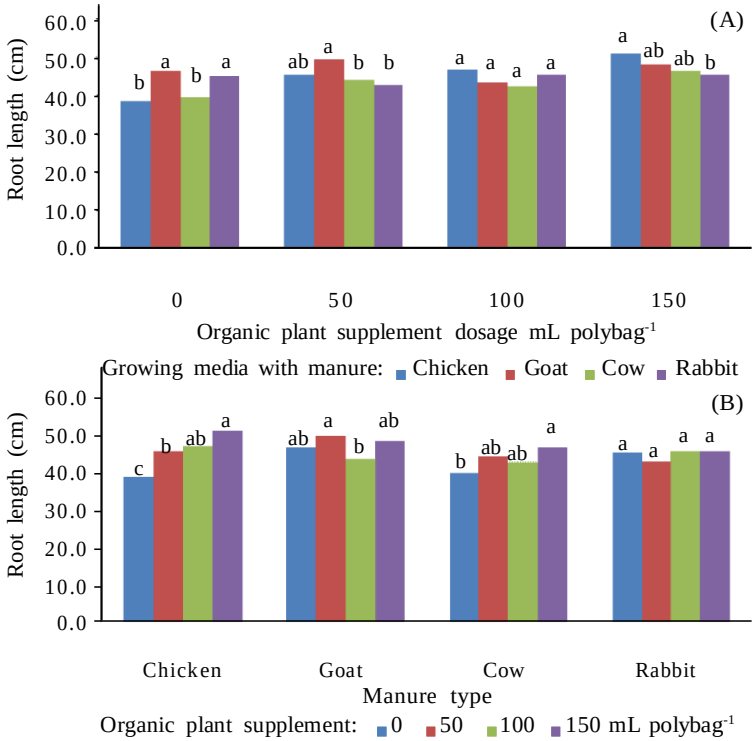

Figure 4. Interaction of the simple effect of growing media at the same organic plant supplement dosage (A) and of the simple effect of organic plant supplement dose at the same growing media (B) on root length. Bars followed by different letter show significant differences at 0.05.

and development of cocoa seedlings is thought to be due to the availability of essential macro and micro nutrients in the manures and organic plant supplement. Combination of cow manure planting medium with organic plant supplement of 50 mL polybag^{-1} to obtain stem diameter, leaf width and length, fresh and dry weight of cocoa seedlings is considered to be due to the content of macroelement such as N, P, K, S, Ca, and Mg as well as micro-elements such as Fe, Mo, Zn, and Cu which are naturally contained in cow manure and can be optimized by application of organic plant supplement. Yusuf *et al.* (2018) described the interaction between the two treatment factors triggering actions and reactions between the two factors that will affect plant growth.

Low availability of N, P, and K nutrient in cow manure can be triggered by the addition of organic plant supplement which content of those nutrients was relatively high. These elements according to Widyastuti *et al.* (2021) have a role in stimulating vegetative growth. This statement was supported by the work of Hasiholan *et al.* (2017) that N is needed for vegetative growth of plants especially the formation of chlorophyll which plays a role in the process of photosynthesis. Nutrient P is also needed and plays a role in the formation of ATP. Cell activity which includes cell elongation, cell division, and cell enlargement requires ATP for plant growth and development. Rosniawaty *et al.* (2015) stated that the content of element K can increase cell size and volume in cocoa seedlings because

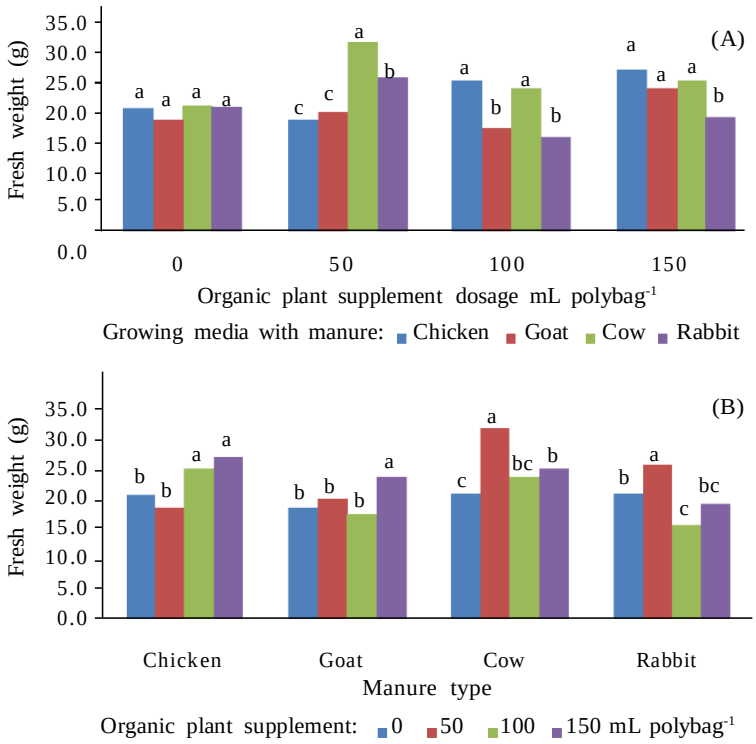

Figure 5. Interaction of the simple effect of growing media at the same level organic plant supplement dosage (A) and the simple effect of organic plant supplement dose at the same growing media (B) on fresh weight of seedlings. Bars followed by different letter show significant differences at 0.05.

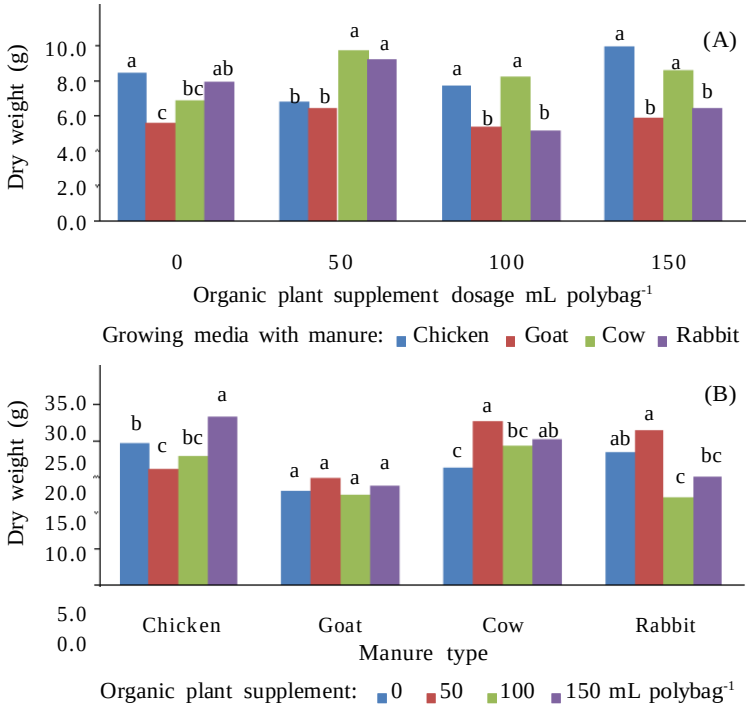

Figure 6. Interaction of the simple effect of growing media at the same level organic plant supplement dose (A) and the simple effect of organic plant supplement dose at the same growing media (B) on dry weight of seedlings. Bars followed by different letter show significant differences at 0.05.

element K acts as a cofactor in the process of protein synthesis, regulation of water balance, and stomata movement (Hasiholan *et al*., 2017; Rosniawaty *et al*., 2015; Widyastuti *et al*., 2021).

Combination of planting medium of goat manure and organic plant supplement 150 mL polybag^{-1} was the best to obtain seedling root length. The better root growth might be related with the availability of complete nutri- ents in goat manure which may maximize plant root length. Meanwhile, N content in goat manure combined with organic plant supplement 150 mL polybag^{-1} might have more influence on root length growth compared to other manures. The organic material contained in goat manure was thought to contribute more total pore space so that the porous conditions created make it easier for roots to penetrate the soil and develop roots properly (Widyastuti *et al*., 2021). Consid- ering that N content in goat manure was rela- tively low, therefore there are other assump- tions that affected this growth, such as the presence of plant growth promotor. Yusuf *et al*. (2018) stated that the type, nature, and structure of the planting medium greatly determine the success of plant growth so that it is possible that the planting medium with a mixture of goat manure is better used for growing root length than other manure applications. The insignificant interaction effect on the variables of plant height, leaf number, and root number in this study may be due to the nutrients absorbed by the plants was not adequate to support those growth variables.

Growing Media Effect

Growth response of cocoa seedlings to manures in planting medium was significantly different to all observed variables, because naturally manure can also provide nutrients needed by plants. Widyastuti *et al*. (2021) stated that nutrient uptake in the form of N, P, and K nutrients in cow manure can trigger plant growth. Manures applied, in general, can increase humus content in planting medium, increase soil fertility, improve soil structures, and trigger the activity of microorganisms in the soil to increase the availability of nutrients (Widyastuti *et al*., 2021).

There were three observed variables that were significantly affected by planting media, namely, plant height, leaf number, and root number. However, there was interaction between treatments. Table 2 shows that the largest plant height and root number were found in growing media mixed with cow manure. The difference in the effect of the type of planting media in terms of number of leaves was greater in growing media mixed with goat manure. Based on these results, the better growth response of cocoa seedlings was found in cow manure mixed growing media which might be due to the content of cow manure was more quickly absorbed by plants than other manures. Better growth in cow manure application was thought to be due to well natural decomposition process that occurs in cow manure than in other manures. The decomposition process in manure produces toxic gases, such as ammonia. Agus *et al.* (2014) stated that the ammonia content is not easily utilized by plants and poisonous to
plants. Actually, ammonia content in naturally decomposed cow manure has lower levels of ammonia, and therefore no toxic to plants (Agus *et al*., 2014).

Organic Plant Supplement Effect

Organic plant supplement showed a significant effect on growth of cocoa seedlings on all observed variables except for leaf number. Yusuf *et al.* (2018) revealed that the influence of a more dominant factor would result in closed reactions from other factors, therefore organic plant supplement dose treatment gave no effect.

Although there was significant effect of organic plant supplement, but there was interaction on the variables of seedling height and root number. Higher value of plant seedling height was obtained by application of organic plant supplement with a dose of 100 mL polybag^{-1}, however, it was not significantly different compared to dose of 50 mL polybag^{-1}. Therefore, optimal dose for using organic plant supplement fertilizer was 50 mL polybag^{-1}. The better effect of application 50 mL polybag^{-1} compared to other doses was due to the fact that the needs of the plants have been met with an additional dose of 50 mL polybag^{-1}. Adequate nutritional supply could optimize the growth of cocoa seedlings. Hutabarat *et al*. (2016) explained that excess nutrients tended to result in less optimal plant growth because these nutrients cannot be utilized properly by plants. This study showed that organic plant supplement doses showed an increase in the growth of cocoa plant seedlings in each variable compared to control (without organic plant supplement).

Table 2. Effects of manures in growing media on seedling height, leaf number, root number

Growing media (Top soil + manures of)	Seedling height (cm)	Leaf number	Root number
Chicken manure	42.2 b	13.1 b	101.3 ab
Goat manure	38.0 c	15.3 a	94.4 b
Cow manure	45.3 a	13.7 b	104.5 a
Rabbit manure	41.1 b	13.5 b	94.4 b

Note: Numbers followed by the same letter in the same column show no significant difference based on the 5% DMRT test.

Table 2. Effect of organic plant supplement on height, leaf number, and root number of cocoa seedling

Organic plant supplement dosage (mL polybag $^{-1}$)	Seedling height (cm)	Leaf number	Root number
0	40.0 b	13.8 a	91.1 b
50	43.0 a	14.2 a	102.7 a
100	43.5 a	14.0 a	101.8 a
150	40.0 b	13.7 a	99.1 ab

Note: Numbers followed by the same letter in the same column show no significant difference based on the 5% DMRT test.

CONCLUSIONS

There was an interaction between treatments on growth response of cocoa seedlings except for seedling height, leaf number, and root number parameters with the best combination was growing media of cow manure and organic plant supplement dose of 50 mL polybag^{-1}. Planting media with different types of manure affected the response of cocoa seedling growth in all observed variables. The best planting media as shown in all treat- ments was cow manure. Organic plant supplement in the planting medium affected the initial growth response of cocoa plant seedlings in all observed variables except leaf number. The best treatment of organic plant supplement was found in dose of 50 mL polybag^{-1}.

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