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Research Article

Impact of Cocoa Biochar Application Techniques and its Types of Fertilizers on Cocoa Plant Production (*Theobroma cacao* L.)

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Abstract

Background and Objective: Organic approaches, including biochar, can increase cocoa production synergistically. The concept of biochar in cocoa plants requires several optimization techniques that can support cocoa production. Therefore, this research aimed to learn the effect of cocoa biochar application techniques and the type of fertilizer used in cocoa production and determine the best biochar dosage and different fertilizers for cocoa growth and production. **Materials and Methods:** The research was conducted from July, 2021 to January, 2022 in Batupanga Village, Luyo District, Polewali Mandar Regency, West Sulawesi. This research was conducted using an experiment with a split-plot design. The main plot is the biochar application technique, while subplots contain the type of fertilizer consisting of 3 levels with four replications. Observation data were focus on several leaf characteristics and agronomy analyzed by analysis of variance and least significant difference (LSD) test 0.05 to significant traits. **Results:** The results of this research showed that the interaction between the application technique of cocoa biochar biopore system and chicken manure 2.7 kg/tree contributed the best effect on the number of pods assumed to survive (23.50 pods), number of harvested pods (18.75 pods), dry weight of 100 beans (127.98 g), dry beans production per tree (692.38 g) and dry beans production per hectare (771.46 kg). **Conclusion:** The application technique of cocoa biochar biopore system and chicken manure 2.7 kg/tree were recommended as part of the cacao cultivation.

Key words: Biopore, biochar application, cocoa biochar, fertilizer package, *Theobroma cacao*

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Cocoa (*Theobroma cacao* L.) is one of the commodities plantations that have an essential role in the Indonesian economy, namely as a source of income for farmers, a foreign exchange earner and the creation of employment for the community¹. Cocoa has the potential to continue developing. Indonesia then became one of the countries that could compete in an international economy due to cocoa commodities. It can be seen from the level of Indonesian cocoa production, which is projected to continue to increase from a total production of 713,378 thousand tons in 2020 to 728,046 thousand tons in 2021, with a production growth of 4.23% per year².

The problem cocoa farmers face today is a large amount of land cocoa being replaced by other commodities and decreasing soil fertility and production quality. This is due to the use of chemicals and the excessive use of inorganic fertilizers³. Other factors leading to decreased crop productivity include land degradation, reduction of organic matter and loss of nutrients around the roots due to harvesting, leaching and denitrification, all of which contribute to soil degradation on cocoa farms. Nutrients N, P and K lost through 1 ton of cocoa beans are equivalent to 42-50 kg of urea, 43-48 kg of TSP and 34-43 kg of KCl, while nutrient losses through fruit shells are equivalent to 32-37 kg of urea, 20-25 kg of TSP, 249-310 kg of KCl and 22 kg of kieserite⁴.

Facing these problems, using biochar can be a solution to increasing water storage in the soil so plants can be used to their full potential. Biochar is black charcoal obtained from biomass heating in a state of limited or without oxygen. This biochar raw material is selected based on the residual production of abundant and untapped plants⁵.

Biochar can be applied properly, so pay attention to the application technique because it can affect the percentage of nutrients that plant roots can absorb. One of the biochar application techniques that can be done is biopore. The Biopore is a hole made to accommodate or absorb water into the soil and can also be used to make compost. Biopori can also be maximized when applying fertilizers for plantation crops because the soil is drilled as deep as 10-30 cm into the ground, making it easier and closer for the roots to absorb nutrients from fertilizers⁶.

The combination of cocoa biochar application technique and type of fertilizer is expected to improve the cocoa problems that occurred in planting in the field. The application technique of cocoa biochar in a biopore manner can directly provide a root supply of nutrients that can support growth and crop production even more with the help of biochar,

which can absorb and keep water longer in the soil so that the supply of nutrients and plants is sufficient⁷. Likewise, with the addition of fertilizer, whether it's fertilizer NPK or manure containing macronutrients when combined with great biochar and application techniques, growth and production plants will do very well. Based on the description above, it is necessary to carry out this research to determine the optimum dose of cocoa husk biochar and the type of fertilizer that can increase the production of cocoa plants.

MATERIALS AND METHODS

Experimental design: This research was conducted in Batupanga Village, Luyo District, Polewali Mandar Regency, West Sulawesi Province, from July, 2021 to January, 2022. This research was conducted using an experiment with a split-plot design. The main plot is the 5 kg biochar application technique, which consists of the following:

- **b1:** Broadcast/dish system
- **b2:** Biopore system

Sub-plots are a type of fertilizer that consists of:

- **p0:** Without fertilizer (control)
- **p1:** NPK 350 g/tree
- **p2:** Chicken manure 2.7 kg/tree

Thus, there are six treatment combinations: b1p0, b1p1, b1p2, b2p0, b2p1 and b2p2. Every combination repeated four times, so there are 24 experimental units. Each unit consists of 4 plant samples.

Research procedure: The cocoa plant used in this research is a Sulawesi cocoa clone after a side graft aged 2.5 years. Before experimenting, plants were selected for the main plot and then the subplots were chosen for the main plot. Biochar is made using ingredients from skins, cocoa husk, plant litter and twigs from cocoa pruning; combustion is carried out using a Kon-Tiki kiln, Kiln-production of biochar fertilizers, mixing biochar with manure and NPK fertilizers.

Make a biopore hole on the edge of the cocoa plant and make the dish. Biochar is applied to cocoa plants that are suitable for treatment that has been determined by following the biopore holes made with a depth of 50 cm and a width of 15 cm, as well as for the depth of the dish application technique is 5 cm and a width of 1.5 m from the stem. Biochar applied to plants is covered with soil around the cocoa plantations.

Table 1: Standard formulas for measuring chlorophyll concentration

Parameter	$y = a + b (CCI)^c$		
	a	b	c
Chl a	-421.35	375.02	0.1863
Chl b	38.23	4.03	0.88
Chl tot	-283.2	269.96	0.277

Source: de Carvalho Gonçalves *et al.*⁸

Data observation and analysis: In this research, observations were made on several leaf characteristics and production. On leaf characteristics, stomata density and stomatal opening area were observed using nail polish methods in a microscope Nikon Eclipse E100, New York, USA at 400- and 1000-times magnification. Chlorophyll a, b and total ($\mu\text{mol}/\text{m}^2$) using Content Chlorophyll Meter 200+(CCM 200+) based on the formula $y = a + b (CCI)^c$, where a, b and c are constants (Table 1) and CCI is the value that is reading at CCM. The same leaf sample was then observed for the light reception character consisting of absorption light, reflection light and transmission light (%), using the Miniature Spectrophotometer CI-710/720. The production parameters observed were the number of Cherelle formed (Cherelle), the number of pods assumed to survive with length >10 cm, dry weight of 100 beans at WC 8% (g) and dry weight beans per tree (g).

Statistical analysis: The ANOVA will analyze observational data at the 95% confidence level. If the treatment has a significant effect, further tests will be carried out with the least significant difference (LSD) test 0.05.

RESULTS

Leaf stomata: Statistical analysis showed that biochar application technique, a combination of biochar and other fertilizers and interaction had no significant effect on leaf stomata density. Still, a combination of biochar and other fertilizers considerably impacts the stomata opening area. Table 2 showed that the highest stomata density was found in biopore methods with a fertilizer combination of biochar 5 kg and chicken manure 2.7 kg/tree (b2p2). The BNT test in Table 2 showed that the combination of biochar 5 kg and chicken manure 2.7 kg/tree (p2) contributed to wider stomata opening area and was significantly different than biochar 5 kg/tree (p0) and the combination of biochar 5 kg and NPK 350 g/tree (p1).

Leaf chlorophyll content: Statistical analysis showed that biochar application technique, combination of biochar and other fertilizers and interaction had no significant effect on

chlorophyll a, b or total. Figure 1(a-b) showed that biopore methods with biochar 5 kg+chicken manure 2.7 kg (b2p2) contributed the highest chlorophyll a by 234.52 mol/m^2 and chlorophyll b by 99.06 mol/m^2 (2A) and also the highest chlorophyll total of 48.89 mol/m^2 (2B). The lowest chlorophyll a was 217.60 mol/m^2 , the lowest chlorophyll b was 89.12 mol/m^2 and the lowest chlorophyll total was 313.72 mol/m^2 on disc methods with biochar 5 kg (b1p0).

Light absorption, reflection and transmission: Statistical analysis showed that the biochar application technique, combination of biochar and other fertilizers and interaction had no significant effect on light absorption, reflection and transmission. Figure 2(a-b) showed that biopore methods with biochar 5 kg+350 g NPK/tree (b2p1) contributed the highest light absorption by 8.05%. Then, disc methods with biochar 5 kg/tree (b1p0) contributed the lowest light absorption by 7.29% (3A). Biopore methods with biochar of 5 kg/tree contributed the highest light reflection by 20.54% and the highest light transmission by 18.83%. Disc methods with biochar 5 kg/tree (b1p0) contributed the lowest light reflection by 16.52% and the lowest light transmission by 15.76 % (3B).

Several Cherelle formed: Statistical analysis showed that combining biochar and other fertilizers significantly affected the number of Cherelle formed. Still, biochar application technique and interaction did not significantly affect the number of Cherelle formed. The BNT test α 0.05 on Table 3 showed that the combination of biochar 5 kg+chicken manure 2.7 kg/tree (p2) contributed the highest number of Cherelle formed and significantly different than biochar 5 kg/tree (p0), but not significantly different than the combination of biochar 5 kg+NPK 350 g/tree (p1).

Number of survival pods: Statistical analysis showed that the interaction of application technique and combination of biochar and other fertilizers significantly affected many survival pods. The BNT test α 0.05 on Table 4 showed that biopore methods with biochar 5 kg+chicken manure 2.7 kg (b2p2) contributed the highest average number of

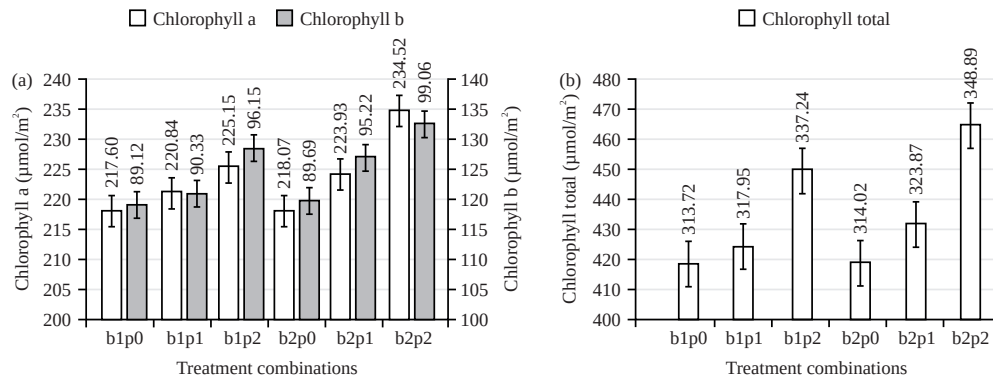


Fig. 1(a-b): Graph of the average levels of (a) Chlorophyll a, chlorophyll b and (b) Chlorophyll total in various combinations of biochar application techniques with fertilization

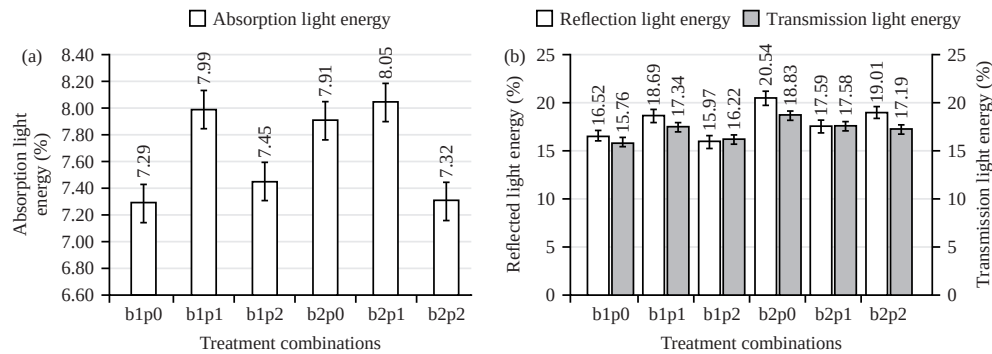


Fig. 2(a-b): Average percentage of (a) Light absorption and (b) Light reflection and light transmission in various combinations of application techniques and types of fertilization

Table 2: Stomatal parameter to biochar treatment application and types of fertilizer

Stomata parameter	Biochar application technique (b)	Type of fertilizer (p)		
		Biochar 5 kg (p0)	Biochar 5 kg+NPK 350 g (p1)	Biochar 5 kg+chicken manure 2.7 kg (p2)
Stomata density (stomata/mm ²)	Disc (b1)	403.45	439.76	452.26
	Biopore (b2)	409.52	447.62	463.45
	Rata-Rata	406.49	443.69	457.86
	NP BNT	Non significant (ns)		
Stomata opening area (µm ²)	Disc (b1)	70.39	70.65	75.88
	Biopore (b2)	76.10	77.19	102.05
	Rata-Rata	73.24 ^a	73.92 ^a	88.97 ^p
	NP BNT 0.05	11.42		

Mean values with different letters in rows (p, q, r) are significantly different at BNT α 0.05

Table 3: Average number of Cherelle formed in various combinations of application techniques and types of fertilization

Biochar application technique (b)	Type of fertilizer (p)		
	Biochar 5 kg (p0)	Biochar 5 kg+NPK 350 g (p1)	Biochar 5 kg+chicken manure 2.7 kg (p2)
Broat/disc (b1)	28.56	31.25	33.25
Biopore (b2)	48.75	61.56	65.50
Average	38.66 ^b	46.41 ^a	49.38 ^a
NP BNT α 0.05	3.20		

Mean values with different letters in rows (a, b) are significantly different at BNT α 0.05

Table 4: Average number of pods survival on biochar application techniques and types of fertilizers after treatment

Biochar application technique (b)	Type of fertilizer (p)			NP BNT
	Biochar 5 kg (p0)	Biochar 5 kg+NPK 350 g (p1)	Biochar 5 kg+chicken manure 2.7 kg (p2)	
Broat/disc (b1)	10.50 ^b _q	19.75 ^a _p	22.25 ^a _p	3.32
Biopore (b2)	17.00 ^a _r	20.25 ^a _q	23.50 ^a _p	
NP BNT α 0.05	2.50			

Mean values with different letters in rows (a, b) and columns (p, q, r) are significantly different at BNT α 0.05

Table 5: Average number of harvested pods on biochar application techniques and types of fertilizers after treatment

Biochar application technique (b)	Type of fertilizer (p)			NP BNT
	Biochar 5 kg (p0)	Biochar 5 kg+NPK 350 g (p1)	Biochar 5 kg+chicken manure 2.7 kg (p2)	
Broat/disc (b1)	7.50 ^b _q	16.50 ^a _p	15.75 ^b _p	1.84
Biopore (b2)	14.50 ^a _r	16.25 ^a _q	18.75 ^a _p	
NP BNT α 0.05	1.70			

Mean values with different letters in rows (a, b) and columns (p, q, r) are significantly different at BNT α 0.05

Table 6: Average dry weight of 100 beans at WC 8% (g) on biochar application techniques and type of fertilizer after treatment

Biochar application technique (b)	Type of fertilizer (p)			NP BNT
	Biochar 5 kg (p0)	Biochar 5 kg+NPK 350 g (p1)	Biochar 5 kg+chicken manure 2.7 kg (p2)	
Broat/disc (b1)	106.88 ^a _r	115.08 ^b _q	125.03 ^a _p	7.13
Biopore (b2)	107.70 ^a _q	125.93 ^a _p	127.98 ^a _p	
NP BNT α 0.05	5.06			

Mean values with different letters in rows (a, b) and columns (p, q, r) are significantly different at BNT α 0.05

survival pods by 23.50 pods but not significantly different than disc methods. The results of the BNT test α 0.05 showed that the combination of biochar 5+2.7 kg chicken manure using biopore methods contributed to the highest average number of survival pods by 23.50 pods, which was significantly different from other treatments.

Number of harvested pods: Statistical analysis showed that the interaction of application technique and combination of biochar and other fertilizers significantly affected the number of harvested pods. The BNT test 0.05 on Table 5 showed that bio pore methods with biochar 5 kg+chicken manure 2.7 kg (b2p2) contributed the highest average number of harvested pods by 18.75 pods and significantly differed from disc methods. The results of the BNT test 0.05 showed that the combination of biochar 5 kg+2.7 kg chicken manure on biopore methods contributed to the highest average number of harvested pods by 18.75 pods, significantly different from other treatments.

Average dry weight of 100 beans at WC 8%: Statistical analysis showed that the interaction of application technique and combination of biochar and other fertilizers significantly affected the average dry weight of 100 beans at WC 8%. The

BNT test α 0.05 on Table 6 showed that biopore methods with a combination of biochar 5 kg+chicken manure 2.7 kg (b2p2) contributed the highest average dry weight of 100 beans by 127.98 g and were not significantly different from disc methods (b1). The results of BNT test 0.05 showed that the combination of biochar 5 +2.7 kg chicken manure on biopore methods contributed the highest average dry weight of 100 beans by 127.98 g but was not significantly different than the combination of biochar 5 kg+NPK 350 g (p1) and significantly different than biochar 5 kg (p0).

Average dry weight beans production at WC 8% per tree:

Statistical analysis showed that the interaction of application technique and combination of biochar and other fertilizers significantly affected average dry-weight bean production at WC 8% per tree. The BNT test α 0.05 on Table 7 showed that biopore methods with a combination of biochar 5 kg+chicken manure 2.7 kg (b2p2) contributed the highest dry beans production per tree by 694.38 g and were significantly different from disc methods. The results of the BNT test α 0.05 showed that the combination of biochar 5+2.7 kg chicken manure using biopore methods contributed to the highest average dry bean production per tree by 127.98 g, significantly different from the other treatments.

Table 7: Average dry weight beans at WC 8 % per tree based on treatment combinations

Biochar application technique (b)	Type of fertilizer (p)			NP BNT
	Biochar 5 kg (p0)	Biochar 5 kg+ NPK 350 g (p1)	Biochar 5 kg+chicken manure 2.7 kg (p2)	
Broat/disc (b1)	217.14 ^b _q	522.24 ^a _p	558.05 ^b _p	72.36
Biopore (b2)	433.31 ^a _r	574.58 ^a _q	694.38 ^a _p	
NP BNT α 0.05	60.55			

Mean values with different letters in rows (a, b) and columns (p, q, r) are significantly different at BNT α 0.05

DISCUSSION

The results showed that there was an interaction in biopore methods with a combination of biochar and chicken manure 2.7 kg/tree (b2p2), which showed the best results on the number of survival pods (Table 1), the number of harvested pods (Table 2), dry weight of 100 beans (Table 3), dry beans production per tree (Table 4) and dry beans production per ha (Table 5). This is caused by application technique, which is very important in placing or giving organic matter and fertilizers on plants to produce the best plant. This shows that using the application method of different fertilizers on cocoa plants gives different development results, where the fertilizer provided by the method or technique results in nutrients being in direct contact with the root surface and making it easier for plants to absorb. This was in line with study of Lehman and Joseph⁹, plants can absorb new nutrients if these nutrients are near the root surface. According to Barłóg *et al.*¹⁰, in addition to the fertilizer dose, the fertilization method also greatly determines the level of success of a fertilization goal. When fertilizers are placed by making a hole in the active roots, the fertilization benefits plants.

As previously explained, the biopore biochar technique, which is accompanied by the provision of chicken manure, can increase soil fertility; this is supported by the results of soil analysis, which show that there was an increase in pH and CEC after being given cocoa biochar and chicken manure. Adding cocoa biochar and chicken manure into the soil is believed to improve fertility and nutrients in the soil so that it has a good influence on the root conditions of plants, even more so by using a biopore technique that can absorb and store enough water for plants. Ratmini¹¹ states that adding biochar can increase the cation exchange capacity (CEC) and the pH value of the soil. Therefore, it can minimize the risk of leaching of nutrients to soil and plants. Biochar application technique in biopore produces the development of the flower bud into a nipple, the nipple into more fruit compared to other application techniques and produces a large number of the highest yield of fruit because the biopore application

technique can increase the availability of water in the soil so that the roots plant more easily absorbs nutrients. The biopore holes formed can prevent the occurrence of runoff and organic matter contained in the biopore holes can be used by plants as additional fertilizer that can help optimize plant reproductive growth. The results showed that chicken manure 2.7 kg gives the best influence on the parameter number of harvested fruits (Table 1), dry weight of 100 seeds (Table 2), dry seed production per tree (Table 3), dry seed production per hectare (Table 5) and opening area stomata (Table 6). This is because chicken manure tends to be able to increase crop production. In this case, chicken manure has been widely used as organic fertilizer to increase soil productivity and crop production. Chicken manure is believed to be able to provide nutrients for plants. This is due to the provision of materials. Organic fertilizer in the form of chicken manure will improve the soil's physical structure, improving plants' root area and rooting. Good plants will increase the rate of nutrient absorption in plants. This is because chicken manure has the necessary nutrients for plants, such as N, P and K and micronutrients in Zn, Fe and Mo. According to Yafizham and Sumarsono¹², chicken manure contains N: 1.5%, P₂O₅: 1.3% and K₂O: 0.8%. This was also the opinion of Silalahi *et al.*¹³, who stated that the use of organic materials in the form of fertilizers chicken coops as a supplier of soil nutrients and increases water retention; if the soil water content increases, the process of overhauling organic matter will increase produce a lot of organic acids, the anions of organic acids can force the phosphate bound by Fe and Al so that the phosphate is available at the plant.

Based on the overall results of this research, providing biochar using the biopore system is very effective in stimulating the development of cocoa plants. This is increasingly effective through a combination of manure at a 2.7 kg/ha dose. This combination will increase the number of fruits that can be harvested, thus having implications for increasing cocoa productivity. Therefore, a combination of biopore technology on biochar and the application of chicken manure is recommended in cocoa cultivation. However, this research must be optimized with effective manure doses and

types adjusted to availability in the farmer's area. Apart from that, the application of this technology needs to be disseminated to several farmers in several regions so that the evaluation results become more comprehensive. This topic can be used for future research to stimulate increased cocoa productivity.

CONCLUSION

It can be concluded that the interaction between the biopore system cocoa biochar application technique and chicken manure 2.7 kg/tree gave the best effect on most growth parameters. Cocoa biochar application technique in biopore technique has the best impact on the most flower clusters and the highest number of harvested fruits. Chicken manure 2.7 kg/tree has the best effect and is the best dosage for cacao growth. Therefore, a biopore utilization system and 2.7 kg chicken manure/tree are recommended to increase the sustainable potential of cocoa.

SIGNIFICANCE STATEMENT

This research focuses on the interaction between biochar and chicken manure use on cocoa plants. Based on this study, the interaction between the biopore system cocoa biochar application technique and chicken manure 2.7 kg/tree gave the best effect on the highest number of surviving fruit, the highest number of harvested fruit, the highest dry weight of 100 seeds, seed production highest dry yield per tree and dry seed production per hectare highest. Therefore, combining the biopore system in the application of biochar with a dose of chicken manure of 2.7 kg/tree can be a recommendation for increasing cocoa production, especially in South Sulawesi.

REFERENCES

1. Fahmid, I.M., Wahyudi, D. Salman, I.K. Kariyasa and M.M. Fahmid *et al.*, 2022. "Downstreaming" policy supporting the competitiveness of Indonesian cocoa in the global market. *Front. Sustainable Food Syst.*, Vol. 6. 10.3389/fsufs.2022.821330.
2. BPSSI, 2023. Indonesian Cocoa Statistics 2022 Volume 7. BPS-Statistics Indonesia, Jakarta, Indonesia, Pages: 73.
3. Ferry, Y., M. Herman, E.B. Tarigan and D. Pranowo, 2022. Improvements of soil quality and cocoa productivity with agricultural waste biochar. *IOP Conf. Ser.: Earth Environ. Sci.*, Vol. 974. 10.1088/1755-1315/974/1/012045.
4. Muhtar, Nasaruddin, B. Rasyid and Kurniawan, 2022. Application of special formula NPK fertilizer and compost to increasing cocoa (*Theobroma cacao* L.) production and productivity. *Syntax Literate: J. Ilmiah Indonesia*, 7: 15793-15803.
5. Demirbas, A., 2004. Effects of temperature and particle size on bio-char yield from pyrolysis of agricultural residues. *J. Anal. Appl. Pyrol.*, 72: 243-248.
6. Karna, N.P.I.S., N.L. Suriani, I.K. Muksin, A.A.I.S. Wiadnyani, T.S. Ho, Rusdianasari and Mariani, 2023. Utilization of liquid organic fertilizer to increase growth and production of mustard plants (*Brassica juncea* L.). *East. J. Agric. Biol. Sci.*, 3: 52-62.
7. Drewer, J.M.Z., M. Köster, I. Abdulai, R.P. Rötter, N. Hagemann and H.P. Schmidt, 2022. Impact of different methods of root-zone application of biochar-based fertilizers on young cocoa plants: Insights from a pot-trial. *Horticulturae*, Vol. 8. 10.3390/horticulturae8040328.
8. de Carvalho Gonçalves, J.F., U.M. dos Santos Junior and E.A. da Silva, 2008. Evaluation of a portable chlorophyll meter to estimate chlorophyll concentrations in leaves of tropical wood species from Amazonian Forest. *Hoehnea*, 35: 185-188.
9. Lehmann, J. and S. Joseph, 2015. Biochar for Environmental Management: An introduction. In: *Biochar for Environmental Management: Science, Technology and Implementation*, Lehmann, J. and S. Joseph (Eds.), Routledge, Abingdon, Oxfordshire, ISBN: 9780203762264, pp: 1-13.
10. Bartóg, P., W. Grzebisz and R. Łukowiak, 2022. Fertilizers and fertilization strategies mitigating soil factors constraining efficiency of nitrogen in plant production. *Plants*, Vol. 11. 10.3390/plants11141855.
11. Ratmini, N.P.S., 2012. Characteristics and management of peatland for agricultural development. *J. Suboptimal Lands*, 1: 197-206.
12. Yafizham and Sumarsono, 2020. Effect of bio-slurry fertilizer and chicken manure on growth and yield of green bean in latosol. *IOP Conf. Ser.: Earth Environ. Sci.*, Vol. 518. 10.1088/1755-1315/518/1/012045.
13. Silalahi, M.J., A. Rumambi, M.M. Telleng and W.B. Kaunang, 2018. The effect of providing chicken manure on the growth of sorghum plants as feed [In Indonesian]. *Zootec*, 38: 286-295.