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"Journal of Agriculture Based on Ecosystem Balance"
http://e-journal.unmas.ac.id/index.php/agrimeta
Vol 16 No 1 (APRIL, 2026) hal 15-25 e-ISSN : 2721-2556 ; p-ISSN : 2088-2531
DOI : https://doi.org/10.36733/agrimeta.v16i1.13972

EFFECTS OF BIOCHAR DOSE AND MEDIA MOISTURE CONTENT ON THE GROWTH OF LOCAL EBAN COFFEE SEEDLINGS IN AGROFORESTRY SYSTEMS

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Abstract

According to BPS data (2021), the North Central Timor Regency has a potential coffee production of 210.00 tons, with a planting area reaching nearly 1,152 ha, predominantly distributed in the West Miomaffo region. Water availability and soil fertility levels are the primary limiting factors in coffee cultivation practices. This study aims to determine the effect of biochar dosage and soil moisture levels on the growth of coffee seedlings (*Coffea sp.*).
This research utilized a Split Plot Design with two factors and three replications. The results showed that a higher watering discharge significantly increased soil temperature. An application of 40 g of biochar significantly increased plant height at 84 DAP (Days after Planting) and stem diameter across all observation periods. While the combination of 60 g biochar and a watering discharge of 4 mL/second produced the tallest plants at each observation, the 40 g biochar dosage was sufficiently influential and not significantly different from the 60 g dosage across all watering levels. The application of biochar dosage is closely related to the increase in soil organic carbon content, which subsequently influences the increase in plant height, stem diameter at 70 DAP, and 84 DAP. The treatment of 60 g biochar and 4 mL/second watering was found to be the most optimal in enhancing the growth of coffee seedlings.

Keywords: *Biochar, Eban Coffee, Soil Moisture, Agroforestry. Timor*

Introduction

Geographically, North Central Timor (TTU) Regency covers an area of 2,669.70 km^2, or approximately 5.48 % of the total land area of East Nusa Tenggara (NTT) Province. Administratively, TTU Regency consists of 24 districts and 193 villages/sub-districts (BPS North Central Timor 2015, cited in Damasius, 2017). The topography of TTU Regency is generally undulating and hilly with varying elevations: 1) 177.60 km^2 (6.63%) at less than 100 meters above sea level (mdpl); 2) 1,499.45 km^2 (56.17%) at 100–500 mdpl; and 3) 993.19 km^2 (37.20%) at more than 500 mdpl (Sasi, 2017).

Coffee production in TTU Regency reached 210.00 tons in 2021, with a plantation area of 1,152 hectares (BPS East Nusa Tenggara Province, 2021). Noepesu Village is one of the 13 coffee-producing villages in the West Miomaffo District. Farmers in this region often practice conventional farming, including coffee cultivation that relies solely on natural regeneration by "dictating nature." Noepesu Village is located in a highland area ranging from 600 - 1,200 mdpl (BPS TTU, 2018), with an average temperature of 18°C. The topography is predominantly hilly, with most land having a slope of ± 45°, utilized as fields planted once a year during the rainy season with various food crops such as maize, rice, cassava, long beans, red beans, peanuts, garlic, carrots, and other horticultural crops. The rainy season is typically very short, lasting only four months. Given the constraints of dryland conditions, farming activities are mostly limited to land preparation just before the rainy season.

Consequently, the primary obstacles faced by coffee farmers in Noepesu Village are limited water availability and low rainfall (drought), resulting in low production and productivity. Besides drought, soil moisture levels significantly influence the growth and yield of coffee plants. Soil moisture refers to the water filling part or all of the soil pores. Therefore, one effort to overcome water shortages and increase soil moisture is through the use of biochar as a soil amendment. The application of biochar is expected to maintain soil and environmental productivity, preserve soil humidity, enhance soil moisture, and promote the growth of coffee seedlings.

Biochar is an emerging and prospective agricultural cultivation technology for dryland applications, serving as an innovation to mitigate the effects of drought on plant growth and yield. Biochar technology involves managing
agricultural waste—such as rice husks, straw, furniture waste (sawdust), and other dry organic materials—through a process of incomplete combustion with limited oxygen (pyrolysis), ensuring the final product is charcoal rather than ash. The production of biochar can be carried out traditionally, and the resulting charcoal is used as a soil conditioner (*Agu et al.,* 2025). Coffee planting is conducted within an agroforestry scheme. Agroforestry, known as *"Wanatani"* in Indonesian, combines agricultural and forestry sciences through intensive land

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use, integrating forest trees with agricultural crops to increase economic, environmental, and socio-cultural benefits (Agu et al., 2025). Based on the background described above, the research problem is formulated as follows: *How does the application of biochar dosage affect the medium moisture levels within a coffee-based agroforestry scheme?*

Materials and Methods

This research was conducted in Noepesu Village, West Miomaffo District , North Central Timor Regency from August 2025 to November 2025

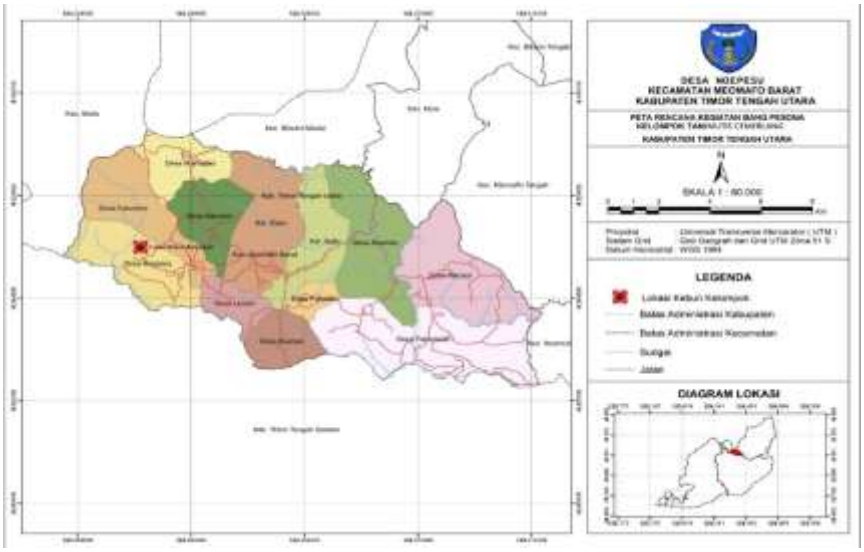

Figure 1 Research Location Map

This research was conducted using a split plot design method *with 2* factors . Observations and data processing were carried out once every 7 days when the plants were 7 days after planting to 84 days after planting .

Growth Observation

1. Plant Height (cm)
   Plant height was measured using a ruler on each plant, from the soil surface to the growing point. Measurements were taken every two weeks from 14 to 84 days after planting.
2. Bar Diameter (mm)
   Stem diameter was measured using a vernier caliper by clamping the stem (1 cm above the base of the stem) of each plant. Measurements were carried out every 2 weeks until the plant was 84 days after planting. Number of leaves (Sheets)
3. Number of leaves (blades)
   The number of leaves was counted every two weeks while measuring plant height and stem diameter until the plants were 84 days after planting. Leaves counted were those that were fully open and not yellow or dry.

Environmental Observation

1. Moisture Content (%)
   Measurements were made by taking soil samples in the form of lumps of soil at a depth of 10 cm in the research area and then weighing them to obtain the wet weight (BB) of the soil, then oven-dried at 150°C for 24 hours and then weighed using an analytical balance to obtain the dry weight (BK) of the soil. According to the 2005 Soil Research Center, moisture content can be calculated using the formula:

   $$KL(\%) = \frac{BB - BK}{BK} \times 100\%$$

   Description: KL = Soil moisture content, BK = Dry weight of soil (oven) BB = Wet weight of soil
2. Soil Temperature (ºC)
   Soil temperature measurements using a thermometer measuring instrument are carried out every 7 days after planting until the plants are 84 days old.
3. DHL Land (mS)
   Take a 10 gram soil sample and weigh it, then put it in a shaker bottle, and add 30 mL of distilled water, then record the results listed on the shaker bottle.
4. Cation Exchange Capacity (CEC) (me/100g)

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Take a soil sample and analyze it in the laboratory. Then calculate it using the formula:
CEC (me/100 grams) = ml. blank – ml. sample x N. NaOH x 100 x Fka.

5. C- Organic (%)
Take soil samples at a depth of 0-10 cm, then air dry them. After drying, crush them and sieve them with a 2 mm sieve. Take the soil that passes through the sieve and is ready to be analyzed in the laboratory. According to Ohorella *et al.,* (2011) C-organic is calculated using the Walkey and Black method with the formula:

$$\text{Organic C content (\%)} = \frac{(mek2cr207 - mefeSO4)x0{,}0003xF}{BKM} \text{ X } 100\%$$

Information:
- *f = 1.33>C which is oxidized 77% = 100/77 = 1.03*
- *me = N x V*
- *N = Normality*
- *V = Volume*
- *BKM = absolute dry weight 105°C*
- *00.003 = valence of oxidized Cr = 3 x 0.001 (mg to grams)*
- *% B – organic = %C organic x 1.724.*

Data analysis

The observation data were then analyzed using a split -*plot analysis of variance (ANOVA*) . The treatment averages were then further tested using *the Duncan Multiple Range t -Test* (DMRT) with a significance level of 5%, as directed by Gomez and Gomez (2010). Data analysis used the SAS 9.1 program.

Results and Discussion

Results

1. Soil Temperature

The results of the analysis of variance showed that the interaction between biochar dosage treatment and irrigation discharge did not occur in soil temperature observations at 14, 28, 42, 56, 70, and 84 days after planting (DAP). The single effect of biochar treatment showed that soil temperature was not significantly different in observations at 14, 56, 70, and 84 days after planting, but was significantly different in observations at 28 and 42 days after planting and the lowest soil temperature occurred in plants treated with 20 g of biochar.

The single effect of irrigation discharge treatment showed that the soil temperature was not significantly different in the 70 HST observation, but was significantly different in the 14, 28, 42, 56, and 84 HST observations, the lowest soil temperature occurred in plants given the irrigation discharge treatment of 2 ml/second.

Table 1. Effect of biochar dosage and irrigation flow rate on soil temperature

Time Observation (HST)	Dose Biochar (grams)	Irrigation Debit (ml/sec)		Average
		2	4	
14	0	24.34	24.33	24.33a
	20	23.67	25.50	24.59a
	40	24.00	25.50	24.75a
	60	24.34	25.34	24.84a
	Average	24.09b	25.17a	(–)
28	0	23.67	23.67	23.67bc
	20	22.50	23.84	23.17c
	40	23.17	25.17	24.17ab
	60	24.17	25.34	24.75a
	Average	23.38b	24.50a	(–)
42	0	24.17	25.34	24.75a
	20	23.50	24.84	24.17b
	40	24.50	25.67	25.08a
	60	24.34	25.67	25.00a
	Average	24.13b	25.38a	(–)
56	0	22.50	24.83	23.67a
	20	22.84	25.34	24.09a

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	40	24.00	25.00	24.50a
	60	23.67	24.84	24.25a
	Average	23.25b	25.00a	(–)
	0	24.34	24.83	24.58a
	20	24.00	24.34	24.17a
70	40	24.50	24.83	24.67a
	60	24.50	24.67	24.58a
	Average	24.33a	24.67a	(–)
	0	24.00	25.17	24.59a
	2h0	24.33	24.84	24.58a
84	40	23.84	24.67	24.25a
	60	24.17	25.00	24.59a
	Average	24.08b	24.92a	(–)

Description: Numbers in the same row and column followed by the same letter indicate no difference at the 5% real level (α) according to the DMRT test, (–) there is no interaction between factors.

2. Plant Height (cm)

The results of the analysis of variance showed that the interaction between the biochar dose treatment and the watering rate occurred at each observation time of plant height. The application of a biochar dose treatment of 60 g with a watering rate of 4 ml/second produced the tallest plants at each observation time and was significantly different from other treatment combinations where at 14 HST observations the combination gave a coffee plant height value of 18.49 cm, becoming 18.60 cm at 28 HST observations and then increasing to 19.10 cm at 42 HST observations, 19.60 cm at 56 HST observations, 20.30 cm at 70 HST observations and 21.09 cm at the end of the observation (84 HST). Based on the research data, the growth of coffee plant height at each observation time increased.

Table 2. Effect of biochar dosage and irrigation flow on coffee plant height

Time Observation (HST)	Dose Biochar (grams)	Irrigation Debit (ml/sec)		Average
		2	4	
	0	14.47abc	12.09bc	13.28
	20	12.34bc	12.97bc	12.65
14	40	16.35ab	15.77ab	16.06
	60	11.70c	18.49a	15.09
	Average	13.71	14.83	(+)
	0	14.09abc	13.00bc	13.54
	20	12.62bc	13.19bc	12.90
28	40	16.50ab	16.07ab	16.28
	60	11.90c	18.60a	15.25
	Average	13.78	15.21	(+)
	0	14.33abc	13.20bc	13.77
	20	12.84bc	13.45bc	13.14
42	40	16.79ab	16.52ab	16.65
	60	12.15c	19.10a	15.63
	Average	14.03	15.57	(+)
	0	14.70abc	13.52bc	14.11
	20	13.12bc	13.87bc	13.49
56	40	17.08ab	16.75ab	16.92
	60	12:43c	19.60a	16.02
	Average	14.33	15.93	(+)
70	0	15.52abc	14.20bc	14.86
	20	13.88bc	14.60bc	14.24

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	40	17.73ab	17.57ab	17.65
	60	13.07c	20.30a	16.68
	Average	15.05	16.67	(+)
	0	16.37abc	14.92bc	15.64
	20	14.82bc	15.85abc	15.34
84	40	18.62ab	18.47ab	18.54
	60	13.78c	21.09a	17.43
	Average	15.90	17.58	(+)

Description: Numbers in the same row and column followed by the same letter indicate no difference at the 5% real level (α) according to the DMRT test, (+) there is interaction between factors.

2. Number of leaves (strands)

The results of the analysis of variance showed that the interaction between the biochar dose treatment and the watering rate did not occur on the number of leaves at each observation time. The single effect of each treatment was also not significantly different at each observation time, the results of the DMRT further test showed that at the level of the 40 gram biochar dose treatment gave the highest number of leaves, namely 5.67 strands at the observation time of 14 HST, then in other observations the 20 gram biochar dose treatment gave the highest number of coffee leaves until the end of the observation and was significantly different at the observation of 70 HST and very significantly different at the observation of 84 HST. At the level of the 2 ml/second watering rate treatment, the highest number of coffee leaves was given at each observation time to give the highest number of leaves at the end of the observation, namely 7.54 strands and was significantly different from the level of the 4 ml/second watering rate treatment.

Table 3. Effect of biochar dosage and irrigation flow rate on the number of leaves

Time Observation (HST)	Dose Biochar (grams)	Irrigation Debit (ml/sec)		Average
		2	4	
	0	5.00	5.67	5.34a
	20	5.67	4.34	5.00a
14	40	5.67	5.67	5.67a
	60	4.67	4.50	4.58a
	Average	5.25a	5.04a	(–)
	0	6.33	5.83	6.08a
	20	8.50	6.33	7.42a
28	40	5.50	6.17	5.84a
	60	5.67	5.50	5.59a
	Average	6.50a	5.96a	(–)
	0	6.67	5.84	6.25a
	20	9.34	7.50	8.42a
42	40	7.00	8.34	7.67a
	60	6.33	6.17	6.25
	Average	7.33a	6.96a	(–)
	0	5.34	6.67	6.00a
	20	8.50	7.00	7.75a
56	40	7.17	7.67	7.42a
	60	6.50	6.00	6.25a
	Average	6.88a	6.83a	(–)
	0	6.50	6.33	6.42b
70	20	9.17	7.50	8.33a
	40	7.34	8.00	7.67a

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	60	6.50	6.33	6.42b
	Average	7.38a	7.04a	(–)
84	0	6.34	6.00	6.17c
	20	9.17	7.17	8.17a
	40	8.00	6.67	7.33ab
	60	6.67	6.00	6.34bc
	Average	7.54a	6.46b	(–)

Description: Numbers in the same row and column followed by the same letter indicate no difference at the 5% level of significance (α) according to the DMRT test, (–) there is no interaction between factors.

3 Bar Diameter (mm)

The results of the analysis of variance showed that there was no interaction between the biochar dosage treatment and the irrigation discharge on the stem diameter parameter. The results of the DMRT further test showed that the application of the 40 gram and 60 gram biochar dosage treatment provided the widest stem diameter value of 0.25 mm at the observation time of 14 HST, then in other observations, the 60 gram biochar dosage treatment provided the widest coffee stem diameter value until the end of the observation and was significantly different at each observation time. The application of the 2 ml/second and 4 ml/second irrigation discharge treatment provided the widest coffee stem diameter value at the observation time of 14 HST. Furthermore, in other observations, the 4 ml/second irrigation discharge treatment provided the widest coffee stem diameter value until the end with a value of 0.31 mm.

Table 4. Effect of biochar dosage and irrigation flow rate on coffee stem diameter.

Time Observation (HST)	Dose Biochar (grams)	Irrigation Debit (ml/sec)		Average
		2	4	
14	0	0.25	0.23	0.24ab
	20	0.20	0.23	0.22b
	40	0.27	0.24	0.25a
	60	0.24	0.27	0.25a
	Average	0.24a	0.24a	(–)
28	0	0.24	0.25	0.24b
	20	0.25	0.29	0.27ab
	40	0.29	0.25	0.27ab
	60	0.25	0.34	0.29a
	Average	0.26a	0.28a	(–)
42	0	0.25	0.25	0.25b
	20	0.25	0.29	0.27ab
	40	0.29	0.25	0.27ab
	60	0.25	0.35	0.30a
	Average	0.26a	0.28a	(–)
56	0	0.25	0.25	0.25b
	20	0.25	0.29	0.27ab
	40	0.29	0.25	0.27ab
	60	0.25	0.35	0.30a
	Average	0.26a	0.28a	(–)
70	0	0.28	0.30	0.29ab
	20	0.27	0.30	0.29ab
	40	0.29	0.28	0.28b
	60	0.30	0.37	0.34a
	Average	0.28a	0.31a	(–)

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	0	0.28	0.30	0.29ab
	20	0.27	0.30	0.29ab
84	40	0.29	0.28	0.28b
	60	0.30	0.37	0.34a
	Average	0.28a	0.31a	(–)

Description: Numbers in rows and columns followed by the same letter indicate a difference at the 5% level of significance (α) according to the DMRT test, (–) there is no interaction between factors.

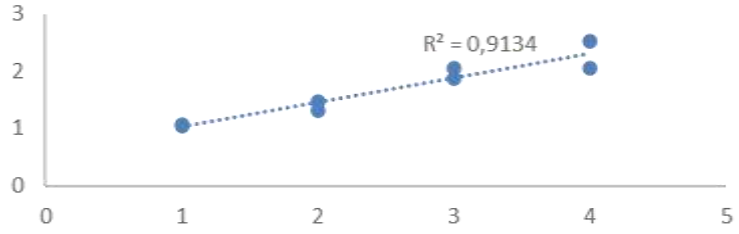
Discussion.

Correlation analysis is a statistical term commonly used to study the relationship between variables. The purpose of this analysis technique is to identify patterns and the closeness or strength of the relationship between two or more variables, expressed by the correlation coefficient. The correlation coefficient in regression analysis is a measure of the strength of the linear relationship between the independent variable (X) and the dependent variable (Y). This correlation coefficient is symbolized by *r* . Its values vary from -1 to +1. A correlation coefficient of -1 indicates a perfect negative correlation, while +1 indicates a perfect positive correlation. Using the correlation regression analysis approach, the results of this study can be described as follows: When the increasing biochar application data is correlated with the organic C content in the medium, it shows that biochar application is closely related to the increase in organic C content in the medium. The square root of R2 = 0.9134 is 0.96, proving that the application of biochar in this study increased organic C in the medium. Organic C is useful for helping the sustainability of soil fertility and water related to the nutrient cycle, thus increasing plant growth.

Table 5. Biochar dosage data (g), water irrigation flow rate (ml/sec) and C organic (%)

Treatment		C Organic (%)
Biochar Dosage (g)	Water irrigation discharge (ml/sec)	
0	2	1.04
	4	1.07
20	2	1.30
	4	1.47
40	2	2.05
	4	1.87
60	2	2.04
	4	2.52

Figure 2. Relationship between Biochar and organic C



Information :
Horizontal line: Biochar variable
Vertical Line: C-Organic Variable

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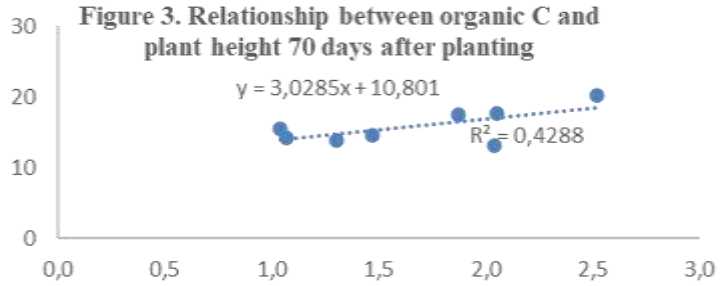
When the organic C content data in the media is correlated with the plant height data, it shows that the organic C content in the media is closely related to the increase in plant height 70 HST. The square root of R^2 = 0.4288 is = 0.655 proving that the increase in organic C in the media plays a role in increasing plant height in the 70 HST observation.

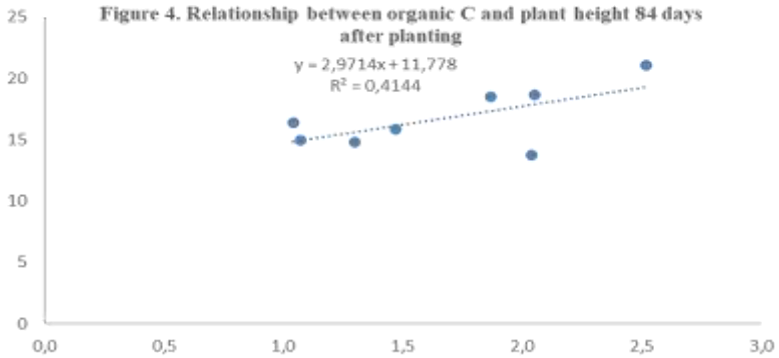
Table 6 Data on biochar dosage (g), water irrigation flow (ml/second) and organic C (%), plant height 70 HST and 84 HST (cm)

Treatment		C Organic (%)	Tall Plants 70 HST (cm)	Plant height 84 HST (cm)
Biochar Content (g)	Water spraying rate (ml/second)			
0	2	1.04	15.52	16.37
	4	1.07	14.20	14.92
20	2	1.30	13.88	14.82
	4	1.47	14.60	15.85
40	2	2.05	17.73	18.62
	4	1.87	17.57	18.47
60	2	2.04	13.07	13.78
	4	2.52	20.30	21.09



Information :
Horizontal Line: Variable C-organi
Vertical Line: Variable Plant Height 70 HST

When the organic C content data in the media is correlated with plant height data, it shows that the organic C content in the media is closely related to the increase in plant height 84 HST. The square root of R^2 = 0.4144 is = 0.644 proving that the increase in organic C in the media plays a role in increasing plant height in the 84 HST observation.



Information :
Horizontal Line: C-organic Variable

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Vertical Line: Variable Plant Height 84 HST

When the organic C content data in the media is correlated with the plant stem diameter data, it shows that the organic C content in the media is closely related to the increase in plant stem diameter at 70 HST. The square root of R^2 = 0.3742 is = 0.612 proving that the increase in organic C in the media plays a role in increasing the plant stem diameter at 70 HST observations.

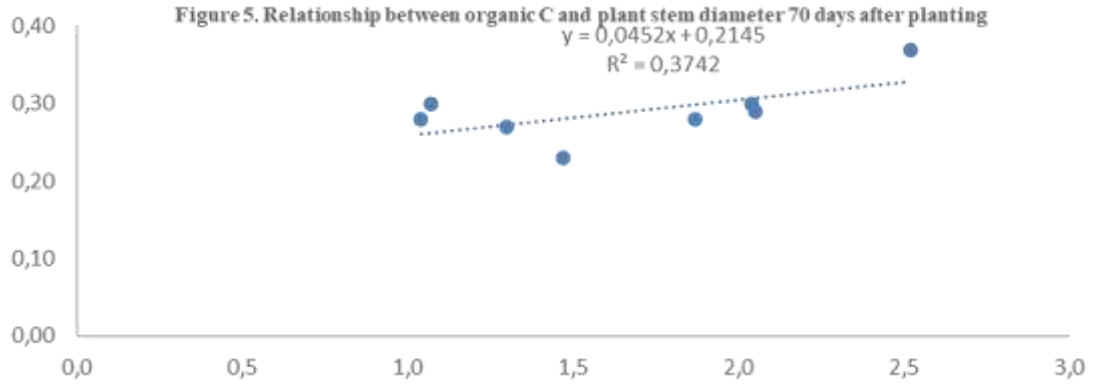

Figure 5. Relationship between organic C and plant stem diameter 70 days after planting

Table 7 Data on biochar dosage (g), water irrigation flow rate (ml/second) and Organic C (%), stem diameter 70 HST and 84 HST (cm)

Treatment		C Organic (%)	Stem diameter 70 HST (mm)	Stem diameter 84 HST (mm)
Biochar Dosage (g)	Water spraying rate (ml/second)			
0	2	1.04	0.28	0.28
	4	1.07	0.30	0.30
20	2	1.30	0.27	0.27
	4	1.47	0.23	0.30
40	2	2.05	0.29	0.28
	4	1.87	0.28	0.29
60	2	2.04	0.30	0.30
	4	2.52	0.37	0.37

Information :*Horizontal Line : C- organic*, *Vertical Line: Variable stem diameter 70 HST.*

When the organic C content data in the media is correlated with the plant stem diameter data, it shows that the organic C content in the media is closely related to the increase in plant stem diameter 84 HST. The square root of R^2 = 0.3719 is = 0.640 proving that the increase in organic C in the media plays a role in increasing the plant stem diameter in the 84 HST observation.

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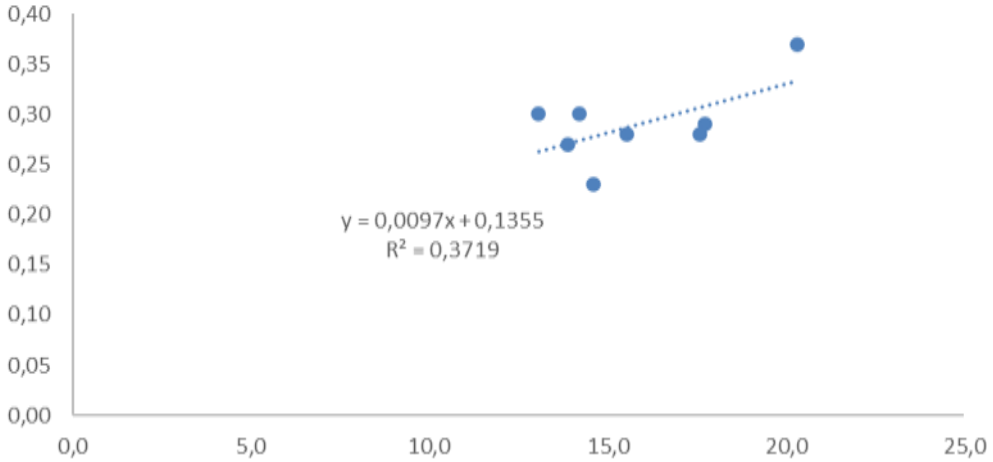
DOI : https://doi.org/10.36733/agrimeta.v16i1.13972

Figure 6. Relationship between Plant Height and Plant Stem Diameter 84 HST



Information:
Horizontal Line: Variable Plant Height 84 HST
Vertical Line: Stem Diameter Variable 84 HST

Conclusion and Recommendation

The results of this study conclude that:

1. The highest irrigation discharge had a significant effect on increasing soil temperature at each observation time.
2. The administration of a biochar dose of 40 g had a significant effect on increasing plant height growth at 84 HST and stem diameter at each observation time.
3. The application of a biochar dose treatment of 60 g with a watering flow rate of 4 ml/second produced the highest plants at each observation time.
4. The application of a biochar dose of 40 g had a significant effect at all levels of irrigation discharge to increase the growth of coffee seedlings and was not significantly different from the biochar dose of 60 g at all levels of irrigation discharge.
5. The application of biochar dose treatment is closely related to increasing soil organic C content, increasing plant height and stem diameter at 70 HST and 84 HST.

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A G R I M E T A
"Journal of Agriculture Based on Ecosystem Balance"
http://e-journal.unmas.ac.id/index.php/agrimeta
Vol 16 No 1 (APRIL, 2026) hal 15-25 e-ISSN : 2721-2556 ; p-ISSN : 2088-2531

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