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Application of Compost and Biochar from Cow, Goat, and Chicken Manure to Restore Soil Fertility and Yield of Red Chili

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***Abstract* — The application of compost and biochar derived from locally produced livestock waste has been shown to provide agricultural and environmental benefits. The study aimed to test the best combination of compost and biochar from various livestock wastes to increase red chili yields and restore soil fertility. A factorial randomized block design was used in this study. The first factor consists of 4 levels of compost, namely without compost, cow compost, goat manure compost, and chicken manure compost. The second factor consists of 4 levels: no biochar, cow biochar, goat manure biochar, and chicken manure biochar. Observations on all soil properties variables obtained a significant effect from the interaction of various types of compost and biochar in the content of sand, dust, clay, pH, fulvic acid, humic acid, N, P, CEC, and base saturation. The application of chicken compost, goat compost, and cow compost gave the highest fresh weight of chilies per ha, each increased by 37.73%, 27.40%, and 20.15% compared to without compost. The application of chicken biochar, goat biochar, and cow biochar produced the highest fresh weight of chili per ha. which increased by 27.04%, 16.18%, and 9.97%, respectively compared without biochar. Increased yield of chilies and restoration of soil fertility due to the interaction between compost and biochar can be proven by finding a significant correlation between the fresh weight of chilies and the total pore space, pH, C-organic, N-total, P-available, K-available, ratio C/N, and base saturation.**

Keywords— Manure; compost; biochar; soil fertility; red chilies.

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I. INTRODUCTION

Red Chili Plant (*Capsicum annuum* L.) is a herbaceous plant with a spicy fruit taste caused by the capsaicin content. In general, chilies contain nutrients, such as carbohydrates, protein, fat, calcium, vitamins (A, B1, B2, and C), fiber, iron, calcium, phosphorus, and niacin [1]. The production of red chili in Bali in the last three years (2017-2019) is still fluctuating. Production of red chilies in Bali in 2018 (45,155 tons) increased by 2.24% compared to production in 2017 (44,164 tons). However, the production of red chili in 2019 (38,844 tons) decreased by 13.98% compared to chili production in 2018. Likewise, the production of red chili in Badung Regency for the last three years (2017-2019) is still fluctuating were in 2017 (1,701 tons) increased by 22.81% from 2018 (2,089 tons), on the other hand, the production of red chili in 2019 (1,956 tons) down 6.37% from 2018 [2]. The decline in chili production can be overcome by improving agricultural cultivation and optimizing land use for agriculture.

Agricultural land in Bali has not fully used organic fertilizers derived from livestock manure. This source of organic matter produced from the livestock environment is available in very abundant quantities. In simple terms, livestock manure can be processed into organic fertilizers such as compost and biochar soil repairer, which are useful for improving soil physical properties. The utilization of livestock waste as compost and biochar can also overcome environmental pollution while restoring soil fertility and increasing sustainable agricultural production.

Compost results in the fermentation of various organic mixtures with the addition of microbes (fermenters). Organic material is broken down from the remains of plants and animals through the breakdown of microorganisms into compost, which functions as a soil constituent, increasing soil fertility, including physical, biological, and chemical soil. Compost can loosen the soil, improve water and air systems, has the power to retain nutrients and water, accelerates the weathering of mineral materials, and can provide complete nutrients in the soil, and provide foodstuff availability for microbes. Compost can improve soil quality because compost is rich in minerals, contains humic substances, heavy metals, and endogenous microorganisms [3]. Some soil ameliorant materials such as compost and biochar derived from plant residues and livestock waste can be used to overcome soil fertility, water scarcity, and soil pH in dryland [4]. The positive effects of combining compost with biochar to improve soil fertility and crop yields suggest that compost is the best way to overcome inherited biochar deficiencies, as well as improve nutrient cycling [5].

Biochar is black charcoal grains that contain a lot of carbon resulting from heating or burning biomass in a closed space and with little oxygen. Biochar can also be produced through incomplete combustion by charcoal [6] from agricultural biomass derived from plant waste or livestock waste, producing charcoal or biochar. The treatment of biochar can restore soil fertility and by increasing soil acidity (soil pH), increasing the association of beneficial microbes and fungi, maintaining nutrients, and increasing soil CEC. The application of biochar is useful in improving soil structure, holding water and soil from erosion due to a larger surface area, enriching organic carbon in the soil, and increasing soil pH. Biochar used in nutrient-poor soils can effectively increase soil fertility, growth, and crop biomass yield [7], [8].

There is a lot of research evidence that the use of biochar can increase crop yields, such as tomatoes, cauliflower, and chilies [9]. Several studies have been conducted, such as Situmeang[10], showing that compost 20 tons ha per ha and biochar 10 tonnes per ha can increase the growth of maize yields in the dry land. In Jaya [11], a mixed treatment of 5 tons of biochar per hectare and 15 tons of manure per hectare showed a significant increase in plant height, fruit count, and fruit weight of red chilies mixed treatment of 15 tonnes. biochar and 5 tons of manure per hectare. In one study [12], coconut shell biochar and compost of 30 tons per ha significantly increased the weight of red chilies. Research by Situmeang [6], used compost, biochar, and poschar from chicken manure as much as 15 tons per hectare resulted in the highest weight of red chili, which increased respectively by 39.16, 41.72, and 46.48 % compared without compost and biochar.

Biochar can function to improve the humification and quality of compost. The quality of good compost is characterized by an increase in humic acid content (humic and fulvic). Compost formulated with biochar as a bulking agent when applied to the soil will further increase nutrient chelation by fulvic and humic acids to become more available to plants. Observing livestock waste, which often pollutes the environment and its great potential and benefits, it is necessary to research to obtain the best combination of compost and biochar from various livestock wastes in increasing soil fertility and yield of red chilies.

II. Materials and Method

A. Time and Place

This research was conducted on former rice fields in Blahkiuh Village. Abian Semal District, Badung Regency, Bali. The research took place from February to August 2020. The research stages in the form of a flow chart can be seen in Figure 1.

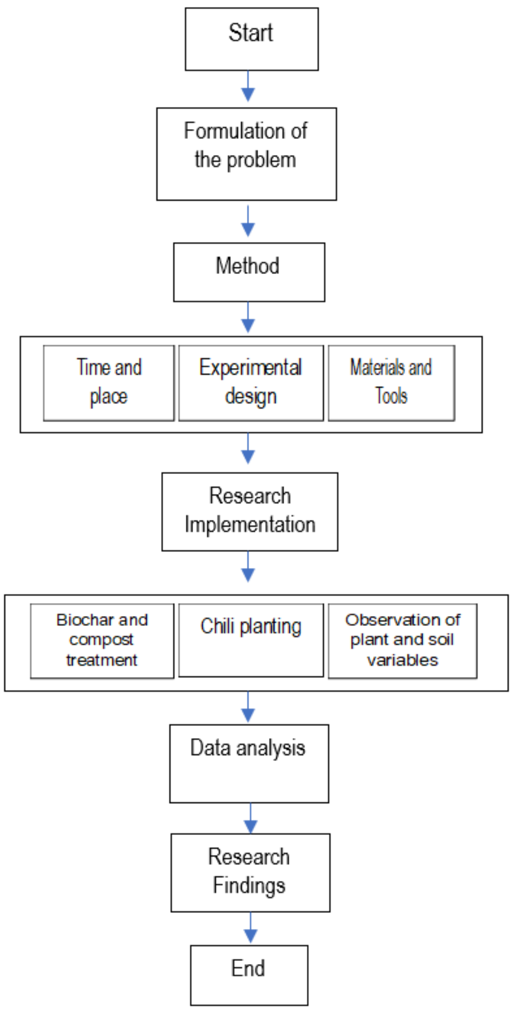


Fig. 1 Research Stages Flow Chart

B. Materials and Tools

This study uses fertilizer materials from the results of previous studies, namely compost and biochar products from cow, goat, and chicken manure, whose effects have been tested on red chili plants in greenhouses. From the results of trials in the greenhouse, the authors used a recommended dose of 15 tonnes ha-1 of various types of compost and biochar from cow, goat, and chicken manure [6].

C. Experimental Design

A factorial randomized block design was selected for this field experiment. The compost type treatment is the first factor (4 levels) consisting of without compost (C0), cow manure compost (C1), goat manure compost (C2), chicken manure compost (C3). The type of biochar treatment is the second factor (4 levels) consisting of: no biochar (B0), cow manure biochar (B1), goat manure biochar (B2), chicken manure biochar (B3). If the above treatment arrangement (16 treatment combinations) is repeated three times, then 48 experimental plots (experimental units) are obtained.

D. Research Variable

Plant parameters observed included the number of leaves, plant height, stem diameter, number of chilies, the weight of fresh and oven-dry of the roots, plant stover, and chilies. The soil properties variables observed were soil moisture content, soil texture, bulk density (BD), total pore space (porosity), pH, humic acid (HA), fulvic acid (FA), C, N, C/N ratio, P, K, CEC, and Base Saturation (BS).

E. Statistical Analysis

Analysis of variance (ANOVA) was used to process data statistically. If there is a significant effect on one treatment (compost or biochar), it can be continued using the LSD test at the 5% level, whereas if the combination treatment has a significant effect, continue using the Duncan test at the 5% level.

III. RESULTS AND DISCUSSION

A. Soil Fertility Due to Compost and Biochar Applications

1) Soil physical: Providing compost and biochar on soil physical properties such as water content, BD, porosity (Total Pore Space), as well as sand, dust, and clay content are presented in Table 1. From Table 1, it can be seen that the treatment of various types of compost and biochar was not significantly different in soil water content. Whereas in the application without compost (0.92 g cm^{-3}) and biochar (0.91 g cm3), the highest soil bulk density was significantly different from compost and biochar treatments from cow, goat, and other chickens manure. In comparison, the highest soil porosity was obtained in the treatment of chicken compost (69.74%) and chicken biochar (68.93%) which were significantly different when compared without compost (65.16%) and biochar (65.64%).

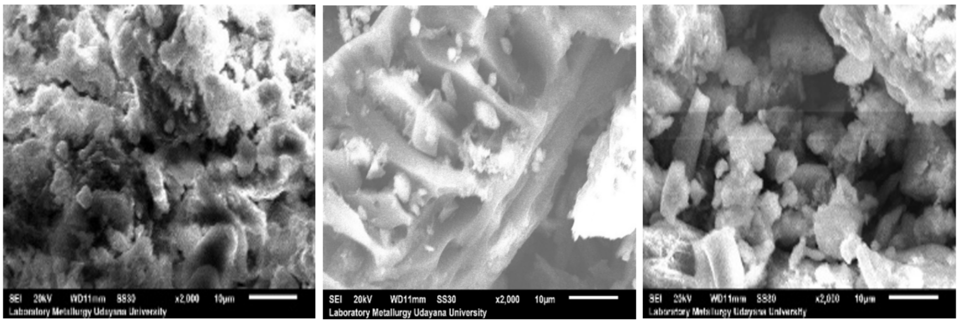
The interaction between compost types and biochar types (Table 1) has not shown any significant differences in moisture content, density, porosity, or total pore space (TPS). Meanwhile, the variables of sand, dust, and clay that formed the soil texture gave the highest percentage value of interaction in the C1B3, C2B2, and C1B1 treatments of 38.68; 47.04; and 55.19% experienced an increase of 129.66; 21.02; and 24.58% compared without treatment (C0B0) respectively 16.84%, 38.87%, and 44.30%. Before the study on physical properties such as soil texture, the results of soil analysis showed that the experimental land had a dusty clay texture class that turned into clay to dusty clay after the study. Provision of compost and biochar from cow, goat, and chicken manure causing soil properties to change for the better where soil density decreases. On the contrary, the total pore space or soil porosity, the content of sand, dust, and clay in the soil increases. This is supported by the appearance of micropore distribution on the surface morphology of compost and biochar, which is known through the *Scanning Electron Microscope* (SEM). SEM analysis results with a magnification of 2000 times show the pore arrangement and surface area of the particles of various types of compost and biochar, as shown in Figures 2 and 3.

TABLE I

PHYSICAL PROPERTIES OF SOIL DUE TO THE INFLUENCE OF COMPOST AND BIOCHAR AND ITS INTERACTIONS

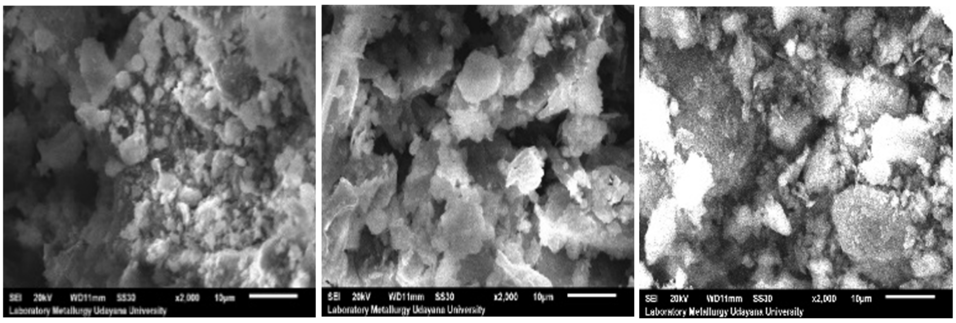
Treatment	Water Content (%)	Bulk Density (g/cm^3)	Porosity (%)	Sand (%)	Dust (%)	Clay (%)
C0	23.97 a	0.92 a	65.16 b	19.57 a	35.35 ab	45.08 a
C1	24.37 a	0.85 b	68.02 a	23.54 a	31.31 b	45.15 a
C2	24.11 a	0.84 b	68.32 a	23.34 a	38.29 a	38.36 b
C3	23.44 a	0.80 b	69.74 a	23.07 a	34.01 b	40.20 b
LSD 5%	-	*0.06*	*2.22*	-	*3.71*	*4.35*
BO	23.93 a	0.91 a	65.64 b	18.65 c	37.32 a	44.04 a
B1	23.70 a	0.83 b	68.52 a	22.28 b	33.01 a	44.70 a
B2	24.36 a	0.84 b	68.16 a	22.40 b	35.80 a	40.55 a
B3	23.90 a	0.82 b	68.93 a	26.19 a	32.83 a	39.50 a
LSD 5%	-	-	*2.22*	*3.27*	-	-
C0B0	22.65 a	1.01 a	61.77 a	16.84 d	38.87 b	44.30 bcd
C0B1	23.64 a	0.90 a	65.93 a	20.51 cd	36.56 bc	42.94 bcde
C0B2	24.37 a	0.89 a	66.52 a	21.65 bcd	32.30 bcd	46.06 bcd
C0B3	25.21 a	0.89 a	66.42 a	19.29 cd	33.68 bcd	47.04 ab
C1Bo	23.40 a	0.88 a	66.74 a	18.46 d	34.95 bcd	46.59 abc
C1B1	24.94 a	0.82 a	69.09 a	16.97 d	27.80 d	55.19 a
C1B2	26.50 a	0.86 a	67.63 a	20.05 cd	33.42 bcd	46.54 abc
C1B3	22.66 a	0.83 a	68.62 a	38.68 a	29.07 cd	32.27 f
C2B0	26.10 a	0.88 a	66.67 a	19.34 cd	35.46 bcd	45.21 bcd
C2B1	22.95 a	0.82 a	68.87 a	28.20 ab	34.90 bcd	36.85 def
C2B2	23.03 a	0.82 a	69.21 a	19.46 cd	47.04 a	33.51 ef
C2B3	24.36 a	0.83 a	68.55 a	26.36 abc	35.77 bcd	37.87 cdef
C3B0	23.56 a	0.86 a	67.36 a	19.95 cd	40.00 ab	40.06 bcdef
C3B1	23.27 a	0.79 a	70.18 a	23.44 abcd	32.76 bcd	43.81 bcd
C3B2	23.57 a	0.81 a	69.29 a	28.46 ab	30.45 cd	36.10 def

Lowercase notation in the same column is no different for LSD testing at the 5% level LSD testing at the 5% level for a single treatment and Duncan's 5%



Chicken compost Goat compost Cow compost

Fig. 2 *Scanning Electron Microscope* (magnification 2000 times) compost from chickens, goats, and cows



Chicken biochar Goat biochar Cow biochar

Fig. 3 *Scanning Electron Microscope* (magnification 2000 times) biochar from chickens, goats, and cows

Based on Figures 2 and 3, it can be seen that the SEM analysis results (magnification 2000 times) of compost and biochar from cow, goat, and chicken manure show surface morphology with different arrangements and sizes of pores and surface areas. From Figures 2 and 3, the SEM analysis results of chicken compost and chicken biochar show that the pore structure is better than compost and biochar from cow and goat manure. These pores are a place to exchange or circulation of air, water, and nutrients in the soil. Compost and biochar pores also play a role in holding water and nutrients and being a good habitat for microorganisms in the soil. Apart from being influenced by the biomass's source, shape, and hardness, the biochar is also influenced by the optimal combustion temperature and pressure during the manufacturing process. Due to the large variety of biochar characteristics such as surface heterogeneity and high porosity due to different types of raw materials used, various efforts were made to optimize pores and surface area benefits by modifying the appropriate biochar manufacturing process [13].

2) Soil chemical properties: Soil chemical properties (Table 2) such as pH, humic acid (HA), fulvic acid (FA), C, N, P, K, C/N, CEC, and base saturation due to the use of compost and biochar. Table 2 shows that the highest pH was obtained in the interaction of chicken compost with goat biochar (C2B2), namely 6.66, which was significantly different from the lowest pH obtained in the interaction without compost and biochar (C0B0), namely pH 5.99. The highest average of humic acid was obtained in the interaction of goat compost and goat biochar (C2B1), namely 1.20%, and the lowest in the interaction without compost and biochar (C0B0), namely 0.79%. However, the highest fulvic acid was obtained in the interaction cow compost and cow biochar (C1B1), which was 38.89%, which was significantly different from the lowest fulvic acid obtained in the interaction without compost and biochar (C0B0), namely 30.36%.

Organic C content in the types of compost and biochar gave the best effect compared to control (without treatment). The N-total content in chicken and goat compost gave the best results significantly different from that without compost. However, the best results of total N were found in cow and goat biochar compared to without biochar. The highest total N was obtained from the interaction of chicken compost with cow biochar (C3B1) 0.54%, and the lowest N-total was obtained in the interaction without compost and biochar (C0B0) of 0.24%. While the C/N ratio in compost types was not significantly different, but real biochar of chicken gave the highest yield than other types of biochar.

The highest available soil P content was obtained from the interaction of cow compost with chicken biochar (C1B3), namely 1051.16 ppm, which was significantly different from the lowest P-available soil obtained in the interaction without compost and without biochar (C0B0) which is 106.02 ppm. The highest average K-available soil was obtained in the treatment of chicken compost (401.32 ppm), goat compost (371.34 ppm), and the lowest yield was in the treatment without compost (294.76 ppm). In comparison, the highest K-available was in the treatment of cow biochar (361.79 ppm), goat biochar (378.74 ppm), and chicken biochar (349.25 ppm) which were significantly different compared to treatment without biochar (297.58 ppm). The highest average soil cation exchange capacity (CEC) was obtained in the interaction of goat compost with no biochar (C2B0), namely 40.50 me/100g, and the lowest CEC was obtained at the interaction without compost and biochar (C0B0), namely 35.80 me/100g. However, the highest soil base saturation (BS) was obtained in the interaction of chicken compost treatment with no biochar (C3B0), namely 98.96%, and the lowest result of base saturation was obtained in the interaction without compost and biochar (C0B0), namely 80.83%.

Soil chemical properties (Table 2) on the interaction of compost and biochar have not shown real differences with C, K, and C/N. From the interaction compost and biochar types, it can be seen that the highest and most significant yields compared to C0B0 are pH at C3B2 (increased by 11.28%), fulvic acid at C1B1 (increased by 28.10%), humic acid at C2B1 (increased 51.25%), N at C3B1 (increased 127.66%), P at C1B3 (increased by 891.52%), CEC at C2B0 (increased 13.13%), and BS at C3B0 (increased 22.42%). Changes in chemical properties after the experiment prove that the application of compost and biochar still leaves high residues in the soil or causes the soil to become more fertile so that it will be profitable for subsequent planting. The high nitrogen of the soil treated with biochar causes the absorption of negative charges originating from carboxyl and phenolic groups in the biochar, thereby reducing nitrogen losses due to leaching [14]. In carbonate compounds, oxygen that contains functional groups and silicates in biochar is the main component that improves acidic soils and holds soil acidity [15].

Combining compost with biochar can improve the humification process, which is characterized by increasing humic and fulvic acid content. Compost combined with biochar will further increase the chelation of nutrients by humic acid to become more available to plants. The highly porous biochar structure contains many extractable substances such as humate and fulvic. Humin compounds consist of humic acid and fulvic acid, an important part of soil organic matter closely related to C and N in the soil. Changes in the ratio of carbon to soil nitrogen indicate that biochar treatment increases nitrogen mineralization of the original soil organic matter [16]. High levels of biochar and compost after six years of application can recover soil characteristics (pH and CEC) that support the agroecosystem's sustainability [17].

TABLE II
SOIL CHEMICAL PROPERTIES OF COMPOST AND BIOCHAR TYPES

Treatment	pH	FA (%)	HA (%)	C (%)	N-total (%)	P (ppm)	K (ppm)	C/N ratio	CEC me/100g	BS (%)
C0	6.11 c	33.19 b	0.86 c	3.06 b	0.26 c	219.60 c	294.76 b	12.37 a	35.54 b	87.86 b
C1	6.17 c	34.81 a	0.94 b	3.88 a	0.33 b	581.04 b	319.94 b	12.80 a	37.11 a	92.01 a
C2	6.29 b	34.68 a	1.03 a	4.34 a	0.38 ab	585.44 b	371.34 a	11.64 a	37.80 a	93.65 a
C3	6.42 a	31.72 c	0.79 d	4.25 a	0.39 a	775.65 a	401.32 a	11.78 a	34.84 b	93.45 a
LSD 5%	*0.10*	*0.37*	*0.03*	*0.50*	*0.06*	*129.38*	*47.38*	-	*0.95*	*2.96*
B0	6.15 b	30.88 c	0.82 c	3.38 b	0.32 b	349.25 c	297.58 b	11.05 b	36.99 ab	90.64 a
B1	6.26 a	35.03 a	1.04 a	4.07 ab	0.39 a	585.64 ab	361.79 a	11.60 b	36.12 b	90.93 a
B2	6.28 a	33.81 b	0.87 b	4.22 a	0.38 ab	524.41 b	378.74 a	11.40 b	37.73 a	93.44 a
B3	6.31 a	34.68 a	0.90 b	3.86 a	0.27 b	702.45 a	349.25 a	14.54 a	34.45 c	91.96 a
LSD 5%	*0.10*	*0.37*	*0.03*	*0.50*	*0.06*	*129.38*	*47.38*	*2.06*	*0.95*	-
C0B0	5.99 f	30.36 l	0.79 g	2.08 a	0.24 ef	106.02 h	267.01 a	8.87 a	35.80 cdef	80.83 f
C0B1	6.13 def	33.68 fg	0.93 cde	3.36 a	0.23 ef	312.72 fgh	297.75 a	14.89 a	35.24 efgh	91.23 bcde
C0B2	6.08 ef	32.14 i	0.80 fg	3.88 a	0.37 bc	324.20 efgh	299.03 a	10.76 a	36.81 cde	94.70 abc
C0B3	6.25 bcde	36.56 b	0.94 cde	2.94 a	0.20 f	135.46 fg	315.28 a	14.96 a	34.31 fgh	84.67 ef
C1Bo	6.08 ef	30.64 kl	0.78 gh	3.85 a	0.40 bc	348.67 efgh	324.03 a	11.66 a	36.23 cdefg	88.20 cdef
C1B1	6.15 cdef	38.89 a	1.13 b	3.90 a	0.33 cde	560.27 def	321.73 a	12.03 a	37.59 bcd	92.59 bcd
C1B2	6.14 cdef	35.18 de	0.96 cde	3.95 a	0.32 cdef	364.07 efg	323.16 a	12.55 a	38.18 bc	91.94 bcd
C1B3	6.33 bcd	34.52 e	0.90 e	3.82 a	0.26 def	1051.16 a	310.86 a	14.97 a	36.46 cdef	95.33 ab
C2B0	6.24 bcde	32.42 hi	0.98 c	4.18 a	0.35 bcd	326.50 efgh	279.32 a	11.94 a	40.50 a	94.58 abc
C2B1	6.34 bcd	36.18 bc	1.20 a	4.32 a	0.47 ab	851.25 abc	408.85 a	9.01 a	37.13 cde	92.81 bcd
C2B2	6.24 bcde	34.47 ef	0.98 c	4.73 a	0.40 bc	417.03 efg	464.23 a	11.92 a	39.50 ab	92.27 bcd
C2B3	6.36 cdef	35.67 cd	0.97 cd	4.12 a	0.31 cdef	747.00 bcd	332.97 a	13.70 a	34.09 gh	94.97 ab
C3B0	6.29 bcde	30.08 l	0.72 h	3.40 a	0.29 cdef	615.80 cde	319.97 a	11.72 a	35.46 efg	98.96 a
C3B1	6.43 bc	31.39 jk	0.92 de	4.70 a	0.54 a	618.32 cde	418.86 a	10.49 a	34.52 fgh	87.12 def
C3B2	6.66 a	33.46 g	0.76 gh	4.34 a	0.42 bc	992.33 ab	428.55 a	10.39 a	36.45 cdef	94.84 ab
C3B3	6.30 bcde	31.97 ij	0.78 gh	4.55 a	0.32 cdef	876.17 abc	437.90 a	14.53 a	32.94 h	92.88 bc

Lowercase notation in the same column is no different for LSD testing at the 5% level (for a single treatment), and Duncan's 5% test (for interaction treatment).

B. The Plant Growth and Yield in Compost and Biochar

Based on Table 3, in the treatment of goat compost and chicken compost, the best results were found, respectively, plant height as high as 99.75 cm and 98.19 cm. While the plant height yield in various biochar treatments showed no significant differences, but there was a tendency for goat biochar treatment to give higher yields than other biochar. The highest number of leaves was found in chicken compost (118.54 strands), which was significantly different from that without compost (97.71 strands). While the number of leaves in various biochar treatments showed insignificant differences, there was a tendency for chicken biochar treatment to give higher yields than other biochar treatments. Applications of chicken compost and chicken biochar gave the highest yields of stem diameter per plant with values of 15.23 mm and 14.83 mm, respectively.

Based on Table 3, the application of chicken compost and chicken biochar produced the highest fresh root weight per plant of 24.93 g and 24.84 g, respectively. Likewise, chicken compost and goat biochar treatment gave the highest weight of plant stover 326.61 g and 327.77 g, respectively. The results showed that the highest root oven-dry weight (21.14 g) was obtained in chicken compost, while the highest root oven-dry weight (20.73 g) was obtained in goat biochar. The chicken compost and chicken biochar treatment produced the highest oven-dried fruit per hectare, respectively 9.56 tons and 9.76 tons.

Application of chicken compost and chicken biochar gave the highest number of chilies per plant, namely 93.21 pieces and 89.77 pieces, respectively. The highest fresh weight of chilies per ha was obtained in chicken compost (55.83 tons), goat compost (51.65 tons), and cow compost (48.71 tons), respectively increasing by 37.73, 27.40, and 20.15% when compared to without compost (40.54 tons). Compost treatment gave chili fresh weight yield ranging from 48.71-55.83 tons per ha, an increase of 99.96-106.78% when compared with the yield potential of large chili varieties, namely 24.36-27.00 tons per ha. The increase in fresh weight of chilies per ha in the type of chicken compost treatment (C3) is thought to be because chicken compost can provide macro and micronutrients needed by plants and contains humic and fulvic acids, which can increase soil cation exchange and increase soil microorganism activity. Chicken manure decomposes relatively quickly and has sufficient nutrient content compared to the same number of units compared to other manure.

Chicken manure gives a positive response to plant growth because of N's better availability in the soil. Apart from its high nutrient content, chicken manure can also increase the availability of phosphorus [18]. The improvement of soil fertility due to this compost will increase nutrient uptake by plant roots for plant growth. This can be seen from the growth of the highest vegetative parts of chili plants found in compost applications. The increased vegetative growth of this plant is caused by increased interception of sunlight on the leaves or green parts of the plant to produce photosynthate, which plants in the metabolic process will actively use so that plant growth and development will be better, and overall will encourage an increase in the yield of fresh fruit weight.

Organic fertilizers are better for soil amendments than artificial fertilizers, although in general organic fertilizers contain low levels of macronutrients N, P, and K but contain sufficient amounts of micronutrients which are very necessary for plant growth. According to [19], the increase in the height of chili plants is caused by the application of organic fertilizers because organic fertilizers can provide nitrogen, phosphorus, and potassium elements needed by plants. The nitrogen element in organic fertilizers helps synthesize chlorophyll, protein, and enzymes to increase photosynthesis and plant growth rates [20]. Giving biochar to fresh weight of chilies per ha obtained the highest yield in chicken biochar which was significantly different compared to goat biochar, cow biochar, and without biochar. Figure 3 shows the relationship between compost and biochar treatment with fresh chili weight per ha.

TABLE III
GROWTH AND RESULTS OF RED CHILI DUE TO THE INFLUENCE OF SOME TYPES OF COMPOST AND BIOCHAR

Treatment	Plant height	Number of leaves	Rod diameter per plant	Root fresh weight per plant	Stover fresh weight per plant	Number of fruits per plant	Fruit fresh weight per ha	Root oven-dry weight per ton	Stover oven-dry weight per ton	Oven dry weight of fruit per ha
	(cm)	(strands)	(mm)	(g)	(g)	(fruit)	(ton)	(g)	(g)	(ton)
No Compost	90.72 b	97.71 b	13.17 c	21.30 b	254.07 b	67.98 c	40.54 b	16.93 c	66.64 c	7.29 b
Cow Compost	93.53 b	106.10 ab	13.94 bc	24.11 a	305.67 a	82.28 b	48.71 a	19.53 b	84.61 b	8.23 ab
Goat Compost	99.75 a	107.69 ab	14.23 b	24.58 a	309.00 a	84.00 b	51.65 a	20.42 ab	87.14 ab	9.20 a
Chicken Compost	98.19 ab	118.54 a	15.23 a	24.93 a	326.61 a	93.21 a	55.83 a	21.14 a	95.20 a	9.56 a
LSD 5%	*5.02*	*12.74*	*0.83*	*1.95*	*28.80*	*7.60*	*3.64*	*1.54*	*10.26*	*1.03*
No Biochar	93.03 a	102.17 a	13.27 b	21.50 b	269.68 b	75.44 b	43.41 c	17.30 b	73.16 b	7.91 b
Cow Biochar	94.77 a	109.08 a	14.31 a	24.19 a	290.50 b	78.67 b	47.74 b	19.57 a	80.81 ab	8.19 b
Goat Biochar	97.65 a	106.48 a	14.16 a	24.39 a	322.77 a	83.58 ab	50.43 b	20.73 a	90.85 a	8.42 b
Chicken Biochar	96.74 a	112.31 a	14.83 a	24.84 a	312.40 ab	89.77 a	55.15 a	20.43 a	88.78 a	9.76 a
LSD 5%	-	-	*0.83*	*1.95*	*28.80*	*7.60*	*3.64*	*1.54*	*10.26*	*1.03*

The lowercase letters in the same column are no different for LSD testing at the 5% level (for a single treatment)

Based on Figure 4 and Table 3, it can be seen that the highest weight of chili fruit per ha is obtained in chicken biochar (55.15 tons), goat biochar (50.43 tons), and cow biochar (47.74 tons), respectively 27.04, 16.18, and 9.97% when compared without biochar (43.41 tons). Likewise, the application of biochar gave fresh chili yields ranging from 47.74 to 55.15 tons per ha, an increase of 95.98-104.26% when compared to the potential yield of large chili varieties, namely 24.36-27.00 tons per ha. The increase in fresh weight of chilies per ha in the type of chicken biochar treatment (B3) was caused by the biochar reinforcing porous soil which was able to hold nutrients and water and could be a good place for decomposing microbes in the soil. The absorption of nutrients and water by biochar in the soil causes nutrients and water to become more available, the soil becomes looser, and the life of soil microorganisms increases so that overall, it will increase soil fertility and plant production. In line with [21], porous biochar can improve soil quality because of its ability to hold nutrients and water firmly. Nutrient and water retention can also add nutrients and maintain soil moisture. Besides, biochar can also reduce soil hardness, increase porosity, and soil microorganisms. The above statement is supported by [22] that biochar is a very porous fibrous and charcoal material, which can hold nutrients, water, and store carbon in the soil for a long time.

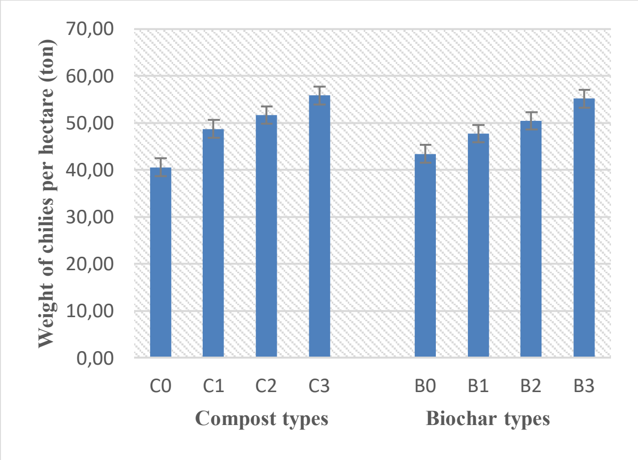


Fig. 4 The relationship histogram of compost and biochar treatment with a weight of chilies per hectare

C. Soil Fertility and Yield of Chilies due to the Effect of Compost and Biochar

The closeness of the relationship between soil variables and crop yield can illustrate how soil properties can increase crop yield chili. The high fresh weight of chilies in the interaction treatment between compost types and biochar types is supported by a significant correlation to the observed variables such as total pore space (0.84**), pH (0.81**), C-organic (0.69**), N-total (0.30*), P-available (0.75**), K-available (0.63**), C/N ratio (0.31*), and base saturation (0.51**). This correlation analysis proves that the combination of compost with biochar has resulted in improving soil fertility and yields of red chilies. As organic fertilizers, compost and biochar have different characteristics in their weathering process. Generally, compost in the soil rots faster than biochar. The biochar-compost mixture offers nutritional benefits [23], and the application of a combination of biochar with compost to the soil has high agricultural performance and value [24].

This porous and carbon-rich biochar is usually more resistant to weathering and stability, so it lasts longer to maintain soil moisture. Also, in line with the weathering process in the soil, compost and biochar can slowly provide macro and micronutrients that can increase soil fertility and crop yields. This highly porous surface structure of biochar can improve air exchange systems, water, and chemical reactions in the soil. Biochar has higher stability to weathering and can absorb nutrients and water well than other organic materials due to its larger surface area. The use of biochar can store carbon in the long term stably, reduce nutrient leaching and soil acidity, increase soil moisture content, availability of P and K, CEC, and crop yields so that biochar as a whole can restore soil fertility (physical, biological, and chemical).

The closeness of the relationship between chili production and soil fertility can also be proven by the significant correlation between the weight of chilies and the total pore space, pH, C, N, P, K, C/N, and base saturation. The growth and yield of red chilies are supported by an increase in the soil's total pore space (porosity) followed by a decrease in soil weight. The decrease in soil weight and increase in soil porosity is caused by the formation of soil aggregates and the presence of aromatic and carboxylate functional groups in biochar which are related to their surface area. Dissolved nutrients obtained from complex reactions during composting via capillary action are first introduced into the biochar pores along a concentration gradient followed by absorption and surface retention processes that block the biochar pores to produce nutrient-rich organic mineral deposits (plaque) [25].

Increasing soil pH and electrical conductivity due to biochar application also results in improved aggregate stability and micronutrient content [26]. In this regard, biochar can assist in controlling the acidity and salinity of unsuitable soils and restoring polluted soils while increasing carbon sequestration, water content, and crop yields [27]. Improvement of soil physical properties with increasing total pore space causes air and water circulation that supports the weathering process, which slowly provides macronutrients N, P, K, and micronutrients which are absorbed by plant roots for plant metabolic processes. Improvement of soil properties as evidenced by increasing the total pore space or soil porosity due to the treatment of compost and biochar is also supported by the results of SEM analysis which shows the surface morphology of the particles with micropore structures (Figure 3). Changes in pore space among particles and the addition of pores that are part of biochar will promote improved air circulation in the soil [28]. The porous features of biochar are very unique, due to their large surface area, stable structure, and carbon-rich [29].

IV. Conclusion

The use of compost and biochar from chicken, goat, and cow manure has provided tangible results in restoring soil fertility, as evidenced by the improvement of soil properties, both physical and chemical, and increased production of chilies. The highest fresh weight of chilies per ha was found in the treatment of chicken compost, goat compost, and cow compost, each increasing by 37.73, 27.40, and 20.15% from without compost. Meanwhile, the highest weight of chilies per hectare was obtained in the application of biochar from chicken, goat, and cow dung, which respectively increased by 27.04, 16.18, and 9.97% from without biochar. The findings of this study are expected to inspire other researchers to use livestock manure as compost and biochar to restore soil fertility and support sustainable agricultural production in the future.

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References

[1] A. Harpenas and R. Dermawan, *Budi Daya Cabai Unggul*. PT Niaga Swadaya, 2011.

[2] BPS-Bali, “Produksi cabe menurut Kabupaten/Kota, 2017-2019,” 2020.

[3] U. De Corato, “Agricultural waste recycling in horticultural intensive farming systems by on-farm composting and compost-based tea application improves soil quality and plant health: A review under the perspective of a circular economy,” *Sci. Total Environ.*, vol. 738, p. 139840, 2020, doi: 10.1016/j.scitotenv.2020.139840.

[4] S. Bahri, D. Budianta, and M. Munandar, “Perubahan karakteristik

beberapa sifat kimia tanah dengan pemberian biochar dan pupuk kandang ayam pada tanah Ultisol," *Klorofil J. Penelit. Ilmu-Ilmu Pertan.*, vol. 11, no. 2, pp. 77–84, 2016.

[5] H. Schulz, G. Dunst, and B. Glaser, "Positive effects of composted biochar on plant growth and soil fertility," *Agron. Sustain. Dev.*, vol. 33, no. 4, pp. 817–827, 2013, doi: 10.1007/s13593-013-0150-0.

[6] Y. P. Situmeang, I. D. N. Sudita, and M. Suarta, "Manure utilization from cows, goats, and chickens as compost, biochar, and poschar in increasing the red chili yield," *Int. J. Adv. Sci. Eng. Inf. Technol.*, vol. 9, no. 6, pp. 2088–2095, 2019, doi: 10.18517/ijaseit.9.6.10345.

[7] D. Trupiano *et al.*, "The effects of biochar and its combination with compost on lettuce (Lactuca sativa L.) growth, soil properties, and soil microbial activity and abundance," *Int. J. Agron.*, vol. 2017, 2017, doi: 10.1155/2017/3158207.

[8] Y. P. Situmeang, I. M. Adnyana, I. N. N. Subadiyasa, and I. N. Merit, "Effectiveness of Bamboo Biochar combined with compost and NPK fertilizer to improved soil quality and corn yield," *Int. J. Adv. Sci. Eng. Inf. Technol.*, vol. 8, no. 5, pp. 2241–2248, 2018, doi: 10.18517/ijaseit.8.5.2179.

[9] M. R. Karim, "Biochar for Promoting Sustainable Agriculture," W. Leal Filho, A. M. Azul, L. Brandli, P. G. Özuyar, and T. Wall, Eds. Cham: Springer International Publishing, 2020, pp. 1–8.

[10] Y. P. Situmeang, I. Made Adnyana, I. Nengah Netera Subadiyasa, and I. Nyoman Merit, "Effect of dose biochar bamboo, compost, and phonska on growth of maize (Zea mays L.) in Dryland," *Int. J. Adv. Sci. Eng. Inf. Technol.*, vol. 5, no. 6, pp. 433–439, 2015, doi: 10.18517/ijaseit.5.6.609.

[11] R. U. W. Jaya, I. Kusnarta, and Sukartono, "Aplikasi Biochar, Pupuk Kandang dan Campuran Keduanya pada Bedeng Permanen yang Ditanami Cabai Merah (Capsicum annum L.)," *Crop Agro*, vol. 10, no. 2, pp. 148–156, 2017.

[12] H. D. D. R. Amaral, Y. P. Situmeang, and M. Suarta, "The effects of compost and biochar on the growth and yield of red chili plants," in *Journal of Physics: Conference Series*, 2019, vol. 1402, no. 3, doi: 10.1088/1742-6596/1402/3/033057.

[13] Z. Jiang, F. Lian, Z. Wang, and B. Xing, "The role of biochars in sustainable crop production and soil resiliency," *J. Exp. Bot.*, vol. 71, no. 2, pp. 520–542, 2020, doi: 10.1093/jxb/erz301.

[14] W. H. Utomo, L. A. Soehono, and B. Guritno, "Effect of biochar on the Release and Loss of Nitrogen from Urea Fertilization," *J. Agric. Food. Tech*, vol. 1, no. 7, pp. 127–132, 2011.

[15] R. yong SHI, J. yu LI, N. NI, and R. kou XU, "Understanding the biochar's role in ameliorating soil acidity," *Journal of Integrative Agriculture*, vol. 18, no. 7. 2019, doi: 10.1016/S2095-3119(18)62148-3.

[16] T. Kätterer *et al.*, "Biochar addition persistently increased soil fertility and yields in maize-soybean rotations over 10 years in sub-humid regions of Kenya," *F. Crop. Res.*, vol. 235, 2019, doi: 10.1016/j.fcr.2019.02.015.

[17] J. Cooper *et al.*, "Effect of biochar and compost on soil properties and organic matter in aggregate size fractions under field conditions," *Agric. Ecosyst. Environ.*, vol. 295, p. 106882, 2020, doi: 10.1016/j.agee.2020.106882.

[18] R. Safrianto, S. Syafruddin, and R. Sriwati, "Pertumbuhan dan hasil cabai merah (Capsicum annuum L) pada Andisol dengan pemberian berbagai sumber pupuk organik dan jenis endomikoriza," *J. Floratek*, vol. 10, no. 2, pp. 34–43, 2015.

[19] M. Moneruzzaman Khandaker, F. Rohani, T. Dalorima, and N. Mat, "Effects of Different Organic Fertilizers on Growth, Yield and Quality of Capsicum Annuum L. Var. Kulai (Red Chilli Kulai)," *Biosci. Biotechnol. Res. Asia*, vol. 14, no. 1, pp. 185–192, 2017, doi: 10.13005/bbra/2434.

[20] H. H. Alhrout, "Response of Growth and Yield Components of Sweet Pepper to Tow Different Kinds of Fertilizers under Green House Conditions in Jordan," *J. Agric. Sci.*, vol. 9, no. 10, p. 265, 2017, doi: 10.5539/jas.v9n10p265.

[21] Y. P. Situmeang, "Soil quality in corn cultivation using bamboo biochar, compost, and phonska," in *MATEC Web of Conferences*, 2018, vol. 197, doi: 10.1051/matecconf/201819713001.

[22] C. J. Atkinson, J. D. Fitzgerald, and N. A. Hipps, "Potential mechanisms for achieving agricultural benefits from biochar application to temperate soils: A review," *Plant Soil*, vol. 337, no. 1, pp. 1–18, 2010, doi: 10.1007/s11104-010-0464-5.

[23] T. L. Oldfield, N. Sikirica, C. Mondini, G. López, P. J. Kuikman, and N. M. Holden, "Biochar, compost and biochar-compost blend as options to recover nutrients and sequester carbon," *J. Environ. Manage.*, vol. 218, 2018, doi: 10.1016/j.jenvman.2018.04.061.

[24] X. xia Guo, H. tao Liu, and J. Zhang, "The role of biochar in organic waste composting and soil improvement: A review," *Waste Management*, vol. 102. 2020, doi: 10.1016/j.wasman.2019.12.003.

[25] S. Joseph *et al.*, "Microstructural and associated chemical changes during the composting of a high temperature biochar: Mechanisms for nitrate, phosphate and other nutrient retention and release," *Sci. Total Environ.*, vol. 618, 2018, doi: 10.1016/j.scitotenv.2017.09.200.

[26] P. Randolph *et al.*, "Effect of biochars produced from solid organic municipal waste on soil quality parameters," *J. Environ. Manage.*, vol. 192, 2017, doi: 10.1016/j.jenvman.2017.01.061.

[27] K. N. Palansooriya *et al.*, "Impacts of biochar application on upland agriculture: A review," *J. Environ. Manage.*, vol. 234, 2019, doi: 10.1016/j.jenvman.2018.12.085.

[28] Z. Liu *et al.*, "Biochar particle size, shape, and porosity act together to influence soil water properties," *PLoS One*, vol. 12, no. 6, 2017, doi: 10.1371/journal.pone.0179079.

[29] J. Wang and S. Wang, "Preparation, modification and environmental application of biochar: A review," *Journal of Cleaner Production*, vol. 227. 2019, doi: 10.1016/j.jclepro.2019.04.282.