Research Article

Response of Katokkon Chilli to Coconut Husk Biochar and Liquid Organic Fertilizer: Implications for Sustainable Agriculture in Toraja, Indonesia

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Abstract | Chilli (Capsicum spp.) is a high-value horticultural crop in Indonesia. Among the various types, katokkon chilli (Capsicum chinense Jacq.) is a local variety of Toraja, which is known for its distinctive aroma and spiciness. Despite the high demand for daily cooking, local production often fails to meet market needs because of limited yield and suboptimal cultivation practices. This study aimed to evaluate the growth and yield performance of katokkon chilli in response to the application of coconut husk biochar and liquid organic fertilizer (LOF). A factorial experiment was conducted using a randomized block design with two factors: coconut husk biochar (0, 1.5, and 3 kg plot^{-1}) and liquid organic fertilizer (0, 3.5, and 7 mL L^{-1}). The observed parameters included fruit diameter, number of fruits per plant, fruit weight per plant, yield per hectare, and vitamin C content. Based on these results, the application of coconut husk biochar at 3 kg plot^{-1} significantly increased fruit size, number of fruits per plant, fruit weight per plant, and yield, producing the highest yield of 9.21 t ha^{-1}. Liquid organic fertilizer applied at 7 mL L^{-1} also improved fruit size and yield. The highest vitamin C content (616.97 mg g^{-1}) was obtained from the combined application of 1.5 kg plot^{-1} biochar and 3.5 mL L^{-1} of liquid organic fertilizer. Yield and quality traits exhibited a quadratic response to increasing input rates, with no further improvement beyond the optimum level. No significant interaction between biochar and liquid organic fertilizer was observed for most traits, indicating independent additive effects. Overall, coconut husk biochar and liquid organic fertilizer effectively enhanced the yield and fruit quality of katokkon chilli, supporting their use as sustainable inputs in highland production systems in Toraja, Indonesia.

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Introduction

Chilli peppers (*Capsicum spp.*) are a significant horticultural commodity in Indonesia and have substantial economic and social value. They are extensively utilized as everyday culinary spices and raw materials in both food and pharmaceutical industries (Cahya and Bangun, 2020). As members of the Solanaceae family, Chilli peppers are second only to tomatoes in global importance and are cultivated as both vegetables and spice crops (Islam *et al*., 2020). Among the various species, katokkon Chilli *(Capsicum chinense Jacq.)* is distinguished by its strong aroma and spicy flavor. This Chilli, originating from the highlands of Toraja, South Sulawesi, has cultural and economic significance, although its cultivation is constrained by challenges related to adaptation and low productivity (Bandaso, 2022). In North Toraja, the production of katokkon Chilli declined despite high local demand. Farmers report yields of up to 28 t ha^{-1} under optimal conditions; however, official data indicate significant fluctuations: in 2021, large chilli production reached 837.9 t from 129 ha, but decreased to only 3.1 t from 3 ha in 2022 (Statistics Indonesia in South Sulawesi Province, 2023). This decline was attributed to pest and disease pressures, decreased soil fertility, and limited access to high-quality seeds. As chili consumption and industrial demand continue to rise (Nur *et al*., 2023), enhancing productivity through sustainable cultivation practices has become increasingly imperative.

Sustainable land use and excessive reliance on inorganic fertilizers have degraded the soil structure and nutrient balance, thereby reducing productivity. Climate change has worsened soil health and yield instability (Mondal, 2021). Therefore, sustainable soil management practices are essential to restore fertility and maintain productivity. Organic farming is one of the best alternatives for improving soil health and ecological balance, while reducing chemical inputs (Dhiman, 2020). Integrating organic amendments with appropriate technologies has been proven to increase crop yields, while supporting long-term sustainability (Gamage *et al*., 2023).

Biochar, a carbon-rich product derived from the pyrolysis of organic biomass, has gained attention as an effective soil amendment agent. Its high porosity and surface area improve the soil structure, nutrient retention, and microbial activity, resulting in better water and nutrient use efficiency (Ceccherini *et al*., 2019). The quality of biochar depends on the raw materials and production conditions, such as the temperature and residence time (Tripathi *et al*., 2016). Coconut husk, one of the main agricultural wastes in Indonesia, is an abundant but underutilized source of biochar. Indonesia produced 2.75 million t of coconuts by 2022, including 65,316 t in South Sulawesi (Directorate General of Plantations of Indonesia, 2022). Converting coconut husk waste into biochar can help reduce environmental pollution and improve soil quality (Ramadhani and Puspitawati, 2023).

Research has shown that the application of biochar improves the physical and chemical properties of soil, leading to enhanced plant growth and yield. For example, Sunanryani and Nasaruddin (2023) found significant increases in plant height, number of fruits, and yield in Chilli plants treated with biochar. However, biochar alone cannot supply sufficient nutrients, and its combination with nutrient sources is necessary for optimal plant performance (Evizal and Prasmatiwi, 2023).

Liquid organic fertilizer (LOF) is a supplementary source of nutrients that enhances plant growth. It is produced through the fermentation of agricultural or industrial organic waste and contains macro- and micronutrients as well as beneficial microorganisms (Phibunwatthanawong *et al*., 2019). LOF nutrients are easily absorbed because organic materials are already decomposed. Application via foliar spraying or soil drenching can quickly boost plant vigor and nutrient uptake (Fauziah *et al*., 2023). Research has shown that LOF improves root growth, stem elongation, and leaf development in Chilli peppers (Karim *et al*., 2019).

Combining biochar and liquid organic fertilizers offers a promising approach for synergistically enhancing soil fertility and crop productivity. Biochar improves soil structure and nutrient retention, whereas liquid organic fertilizers provide readily available nutrients and stimulate microbial activity. This integrated organic approach can enhance root development, nutrient uptake, and yield stability, particularly in degraded soil. Therefore, this study aimed to evaluate the growth and yield of katokkon Chilli (Capsicum chinense Jacq.). with the application of coconut shell biochar and liquid organic fertilizer. These findings are expected to provide insights into effective organic-based management strategies for improving soil productivity and supporting sustainable Chilli cultivation systems in the highlands of Toraja, Indonesia.

Materials and Methods

This study was conducted in Pangli Selatan Village, Sesean District, North Toraja Regency, and South Sulawesi. This study was conducted from June to

December 2023. Materials used on this study were Katokkon chilli seeds, water, liquid organic fertilizer, coconut husk biochar, manure, clear cuttings, clear tape, and label paper were used in this study. The tools used in this study were hoes, shovels, trays, stakes, treatment boards, ropes, buckets, measuring cups, sprayers, scales, mulch, CCM 200+, prep glass, microscopes, rulers, meters, cellphones, vectors, and writing instruments.

This study was conducted as an experiment using a 2-factor factorial design with a randomized complete block design (RCBD) as the environmental design.

The first factor is the coconut husk biochar (b), which consists of three levels:
- b0 : 0 kg plot^{-1} (control)
- b1 : 1.5 kg plot^{-1}
- b2 : 3 kg plot^{-1}

The second factor is liquid organic fertilizer (p), which consists of three levels:

- p0 : 0 mL L^{-1} (control)
- p1 : 3.5 mL L^{-1}
- p2 : 7 mL L^{-1}

Thus, the nine treatment combinations were repeated thrice, resulting in 27 treatment combination units. Each experimental plot consisted of 16 plants; thus, the total number of plants was 432.

Research implementation

Preparation of coconut husk biochar

To produce biochar, old coconut husks are dried in the sun to reduce their water content. The husks were then placed in a furnace. Biochar combustion occurs through pyrolysis in a container that produces incomplete combustion without oxygen. The burning was performed in a closed furnace at 350ºC-400ºC for 1 h to avoid ash. After charcoal formation, the fire was extinguished, and the furnace was cooled. Finally, the coconut-husk charcoal was placed in a grinding machine for mashing.

Land preparation

The land was cleared of plant debris, hilled, and beds were made. The land was divided into plots with a length of 2 m and a width of 2 m, with a distance between plots of 30 cm, a distance between replicates of 40 cm, and a bed height of 30 cm.

Nursery and preparation

Before planting, the seeds were soaked in warm water. The floating seeds were discarded. Seeds were planted in a mixture of soil, firewood husks, and chicken manure in equal proportions. The seedlings were watered every morning and evening or as needed. After 14 days, the seedlings were transferred to bags containing equal amounts of soil and chicken manure. At 35 days, the plants were ready to be moved to the beds.

Four-week-old seedlings with 4-6 leaves were selected for being healthy and strong. The seedlings grew evenly and well. Manure was used as the base fertilizer. It was applied once, two weeks before moving the plants. The manure was mixed with the soil using a hoe. Coconut husk biochar was added a week before moving the plants. The amounts were none (b0), 1.5 kg per plot (b1), and 3 kg per plot (b2), respectively. Biochar was mixed evenly with the soil in each plot. Black and silver plastic mulches were used, with black on the bottom and silver on top. It was installed during the day to obtain the best results. After installing the mulch, planting holes and distances were set. The distance was 50 × 60 cm in size. Holes were marked with raffia ropes after being made using a tool.

Planting and maintenance

The initial procedure involved creating a 5 cm planting hole. The selected chilli seedlings exhibited robust growth. Four-week-old Katokkon chilli seedlings with 4-6 leaves were ready for transplantation. The seedlings were then planted in the designated holes. Planting occurred after 3 pm to reduce plant stress from solar heat exposure. After transplantation, the seedlings were irrigated until the soil was moist. Application of Liquid Organic Fertilizer: Liquid organic fertilizer was sprayed onto the plants at specified dosages: p0 = 0 mL (control), p1 = 1 mL, and p2 = 7 mL. The treatments were applied 15, 30, and 45 days after planting. The maintenance of Katokkon Chilli included watering, replanting, staking, and weeding. Watering occurred in the morning and evening until the soil was adequately moist or as needed. Replanting was performed if plants showed mortality or poor growth after seven days. Upright stakes were installed for each plant one month after transplantation to support the plants and fruit. Weeding was performed manually by removing weeds around plants to prevent nutrient competition and pest habitats.

Harvesting

Chilli katokkon harvesting is performed on fruits that are characterized by physiological maturity characteristics such as dense fruit and reddish color. Harvesting is performed by picking the fruit with the stalk so that katokkon chilli can be stored for a longer duration. Harvesting was carried out at the age of 76 days after transplanting and was carried out eight times considering that the plant had experienced aging, with an interval of seven days from the previous harvest.

Observation parameters

The observation parameters used in this study were as follows:

Fruit diameter

Fruit diameter was measured by measuring the largest part of the fruit using calipers. Measurements were conducted for each harvest.

Number of fruit per plants

This observation was made when the plants began to be harvested by counting the entire harvest of each sample plant during harvesting. The measurements were taken from the first harvest until the last harvest.

Fruit weight per plant

Fruit weight was calculated as the weight of the fruit per sample plant from the first to the last harvest.

Production per hectare

This calculation was performed at the end of the observation period by converting the production of katokkon chilli plants per plot (m^2) into the amount of production per hectare (t/ha). Production per hectare can be calculated using the following formula:

(Area (ha))/(Area (plot)) x Fruit Weight per Plot

Vitamin C test

The methods of analyzing vitamin C included when analyzed in the second harvests: Weigh 200-300 g, and then it was weighed and then crushed in a waiting blender until a slurry was obtained. Then, 10-30 g of slurry was weighed and placed in a 100 mL measuring flask, and distilled water was added to the mark. The mixture was filtered through a Krush Goach or centrifuged to separate the filtrate. Take 5-25 mL of filtrate was collected using a pipette and placed in a 125 mL Erlenmeyer flask. Then, 2 mL of 1% amylum solution (soluble starch) and 20 mL of distilled water were added, if necessary. Titrate with 0.01 N standard iodine.

Data analysis

All data were analyzed using analysis of variance. Significant data were tested with least square distance (LSD) for qualitative data and regression for quantitative data and qualitative-quantitative interactions (orthogonal-polynomial). All data analyses were performed using Microsoft Excel 365 software.

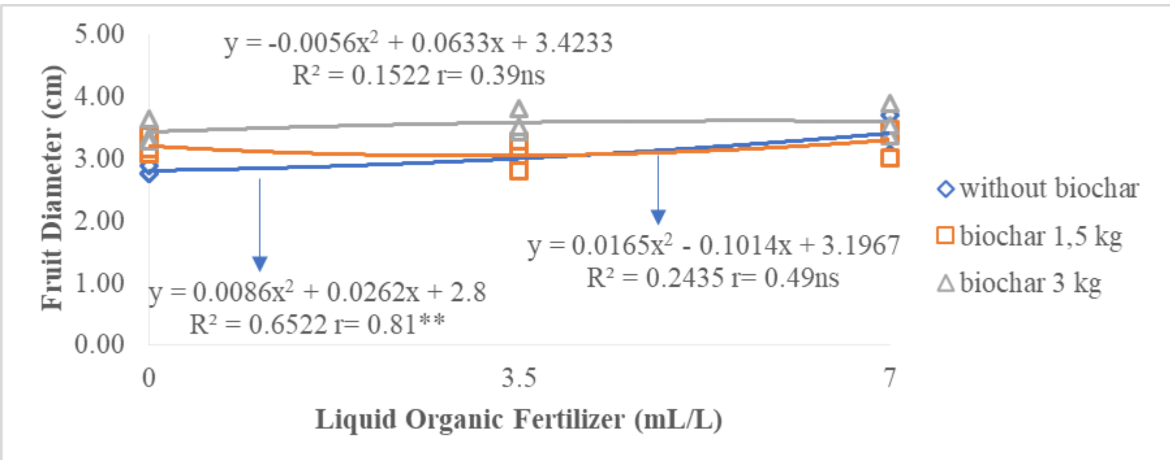

Figure 1: *Graph of bivariate correlation of fruit diameter with the application of coconut husk biochar and liquid organic fertilizer.*

**Indicated significant on 5% error level, ** indicated significant on 1% error level, ns indicated no significant, at least r is significant in 5% error level is 0.67.*

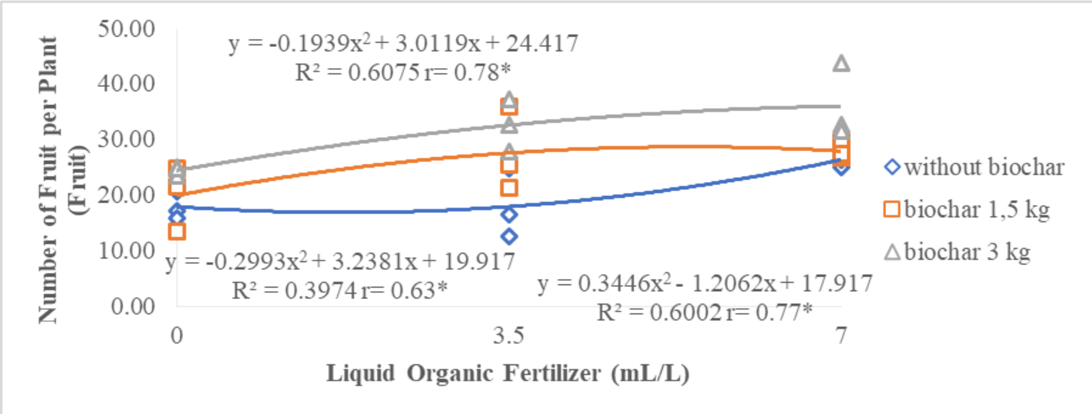

Figure 2: *Graph of bivariate correlation between the number of fruits per plant and the application of coconut husk biochar and liquid organic fertilizer.*

** Indicated significant on 5% error level, ** indicated significant on 1% error level, ns indicated no significant, at least r is significant in 5% error level is 0.67.*

Results

Fruit diameter

The analysis presented in Figure 1 indicates that the application of liquid organic fertilizer, in the absence of coconut husk biochar, influenced fruit size. An increase in fertilizer application resulted in larger fruits, achieving a maximum size of 2.86 at 1.51 mL L^{-1}. Beyond this threshold, further addition of fertilizer resulted in a reduction in fruit size by 0.0086 for every 3.5 mL L^{-1} increment, as represented by the equation $y=0.0086x^2 + 0.0262x + 2.8$, with $R^2 = 0.6522$ and r = 0.81**. When liquid organic fertilizer was combined with 1.5 kg of coconut husk biochar, fruit size was similarly affected, although the correlation with fruit size was not robust. The fruit size increased with additional fertilizer, reaching 3.66 at 3.07 mL L^{-1}. Beyond this point, further fertilizer application resulted in a decrease in fruit size by 0.0165 for every 3.5 mL L^{-1} added, as described by the equation $y=0.0165x^2 - 0.1014x + 3.1967$, with $R^2 = 0.2435$ and r = 0.49. Similarly, the use of liquid organic fertilizer with 3 kg of coconut husk biochar resulted in changes in fruit size without a strong correlation. The fruit size increased with increasing fertilizer, reaching 3.96 at 5.65 mL L^{-1}. Additional fertilizer beyond this point led to a reduction in fruit size by 0.0056 for every 3.5 mL L^{-1} added, as indicated by the equation $y = 0.0056x^2 + 0.0633x + 3.4233$, with $R^2 = 0.1522$ and r = 0.39.

Number of fruit per plant

Figure 2 illustrates the impact of liquid organic fertilizer application, in the absence of coconut husk biochar, on fruit yield per plant. An increase in fertilizer concentration correlated with an increase in fruit number, peaking at 20.13 fruits at a concentration of 1.75. Beyond this concentration, the fruit yield declines by 0.3446 for every 3.5 mL increment in fertilizer, as represented by the equation $y=0.3446x^2 - 1.2062x + 17.917$, with $R^2 = 0.6002$ and r = 0.77*. When 1.5 kg of coconut husk biochar was incorporated with the liquid organic fertilizer, the fruit yield similarly increased with higher fertilizer concentrations, reaching a maximum of 46.19 fruits at a concentration of 5.41. Further increases in fertilizer concentration result in a reduction of fruit yield by 0.2993 for every 3.5 mL increase, as indicated by the equation $y=0.2993x^2 + 3.2381x + 19.917$, with $R^2 = 0.3974$ and r = 0.63. A comparable trend was observed when 3 kg of coconut husk biochar was used. The fruit yield increased with higher fertilizer concentrations, achieving a peak of 59.51 fruits at a concentration of 7.77. Subsequent increases in fertilizer concentration led to a decrease in fruit yield by 0.1939 for every 3.5 mL increase, as described by the equation $y=0.1939x^2 + 3.0119x + 24.417$, with $R^2 = 0.3974$ and r = 0.63.

Fruit weight per plant

Figure 2 depicts the effect of liquid organic fertilizer application on fruit yield per plant in the absence of coconut husk biochar. An increase in fertilizer concentration was associated with an increase in fruit number, reaching a maximum of 20.13 fruits at a concentration of 1.75. Beyond this concentration, fruit yield decreased by 0.3446 for every 3.5 mL increment in fertilizer, as represented by the equation $y=0.3446x^2 - 1.2062x + 17.917$, with $R^2 = 0.6002$ and r = 0.77*. When 1.5 kg of coconut husk biochar was combined with the liquid organic fertilizer, fruit yield similarly increased with higher fertilizer concentrations, peaking at 46.19 fruits at a concentration of 5.41. Further increases in fertilizer concentration result in a reduction of fruit yield by 0.2993 for every 3.5 mL increase, as indicated by the equation $y=0.2993x^2 + 3.2381x + 19.917$, with $R^2 = 0.3974$ and r = 0.63. A similar pattern was observed when 3 kg of coconut husk biochar was used. The fruit yield increased with higher fertilizer concentrations, achieving a peak of 59.51 fruits at a concentration of 7.77. Subsequent increases in fertilizer concentration led to a decrease in fruit yield by 0.1939 for every 3.5 mL increase, as described by the equation $y=0.1939x^2 + 3.0119x + 24.417$, with $R^2 = 0.3974$ and r = 0.63.

Table 1: *Average production per hectare (t ha^{-1})*

Biochar (kg/plot)	Liquid organic fertilizer (mL/L)			Average	NP BNJ$_{\alpha=0,05}$
	0 (p0)	3.5 (p1)	7 (p2)		
0 (b0)	6.44	5.62	8.17	6.74b	2.15
1.5 (b1)	7.09	8.62	7.45	7.72ab	
3 (b2)	7.56	10.03	10.03	9.21a	

Notes: Numbers followed by the same letter in columns (a,b) are not significantly different in the Tukey's HSD test $_{\alpha= 0,05}$.

Table 2: *Vitamin C content in cili katokkon (mg 100g^{-1})*

No	Treatment	Vitamin C (mg 100g^{-1})
1.	b0p0	505.17
2.	b0p1	519.95
3.	b0p2	564.00
4.	b1p0	524.43
5.	b1p1	616.97
6.	b1p2	587.32
7.	b2p0	487.23
8.	b2p1	556.01
9.	b2p2	52181

Source: Feed chemistry laboratory, faculty of animal husbandry, hasanuddin university, 2023.

Production per hectare

Analysis of variance showed that using coconut husk biochar alone had a significant impact on fruit production per hectare. However, the use of liquid organic fertilizer or its combination with biochar did not have a significant effect. According to the Tukey HSD test at $\alpha = 0.05$ in Table 1, the highest average fruit production per hectare was observed with 3 kg of coconut husk biochar per plot (b2), which was 9.21 t ha^{-1}. This was not much different from using 1.5 kg per plot (b1), but was significantly more than using no biochar (b0). Bivariate analysis showed that coconut husk biochar had a linear response and was strongly linked to production per hectare (Figure 3). As the amount of biochar increased, the production per hectare also increased until it reached a maximum at an optimal dose of 0.95 kg. After this point, increasing the dose reduced production by 0.1133 for every 1.5 kg increase in biochar per plot, following the equation $y = 0.8206x + 6.6588$, with a determination coefficient $R^2 = 0.506$, and a correlation coefficient r = 0.71*.

Vitamin C content

The observed data on the vitamin C content in Chilli katokkon are shown in Table 2. Based on this table, the treatment of 1.5 kg coconut husk biochar and 3.5 mL L^{-1} liquid organic fertilizer (b1p1) tended to produce the highest vitamin C at 616.97 mg 100g^{-1}, while the treatment without 3 kg coconut husk biochar and without liquid organic fertilizer (b2p0) tended to produce the lowest vitamin C at 487.23 mg 100g^{-1}.

Discussion

Analysis of variance showed no significant interaction between coconut husk biochar and liquid organic fertilizer on any observed parameter. This indicates that both treatments independently influenced the growth and yield components of Capsicum chinense. The limited synergistic response may be attributed to the low availability of nutrients in the soil, as only manure was used as a basal fertilizer without inorganic supplementation. Ardianti *et al.* (2022) emphasized that adequate soil fertility is essential for maintaining optimal plant growth and productivity. The environmental conditions during the study limited plant development. Prolonged drought occurs during the vegetative stage, causing water stress and suppressing growth and fruit initiation. Katokkon Chilli, In particular, requires sufficient moisture for robust vegetative growth (Flowrenzhy and Harijati, 2017). Water scarcity can lead to reduced humidity, increased temperatures, and plant stress, as highlighted by Moeksan and Laksminiwati (2011), who noted that water availability is crucial for early growth, flowering, and fruiting. Drought during this phase can drastically reduce yields, whereas excessive moisture increases disease vulnerability. Similarly, Widowati *et al.* (2023) reported that unsuitable planting seasons in relation to rainfall patterns can

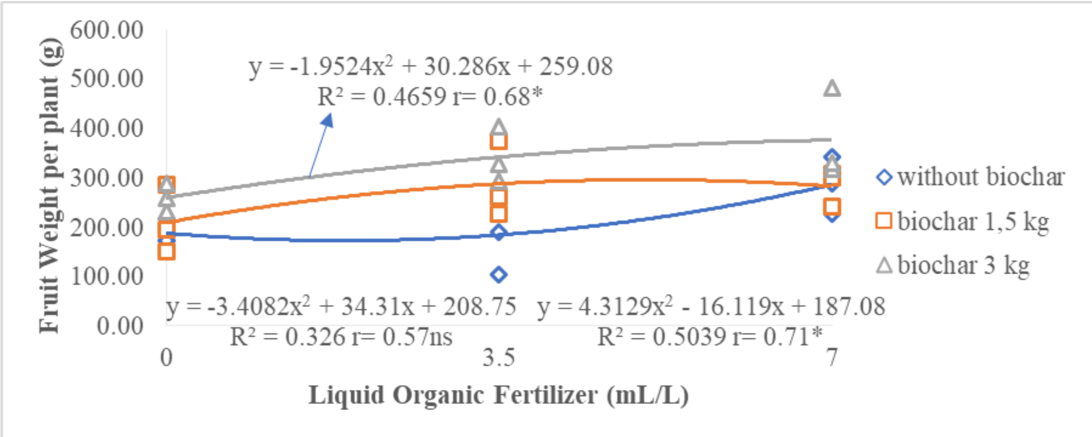

Figure 3: *Graph of bivariate correlation between fruit weight per plant and application of coconut husk biochar and liquid organic fertilizer.*
** Indicated significant on 5% error level, ** indicated significant on 1% error level, ns indicated no significant, at least r is significant in 5% error level is 0.67.*

lead to pest and disease outbreaks, thereby reducing production.
The results obtained in this study were substantially lower than those achieved by farmers (up to 28 t ha^{-1}). This difference reflects the inherently lower nutrient supply from organic fertilizers and the absence of synthetic inputs, which is consistent with the principles underlying organic farming. The main goal of organic farming goes beyond maximizing yield to include the health of soil, water, and ecosystems, ensuring sustainability and food security. According to Siregar (2023), organic farming contributes to environmental preservation, reduces pollution, and improves human health by decreasing exposure to chemical residues. Interestingly, the combination of 1.5 kg coconut husk biochar and 3.5 mL L^{-1} liquid organic fertilizer resulted in the highest vitamin C content in the leaves. This is likely due to sufficient, but not excessive, nitrogen availability, as balanced nitrogen encourages ascorbic acid synthesis, whereas excessive nitrogen can reduce it (Natanael and Banjarnahor, 2021). Vitamin C content is also influenced by fruit ripeness and the harvest stage (Soeparjono and Khasanah, 2023). Overripe fruits tend to have lower vitamin C levels because of the oxidative degradation of diketogulonic acid (Level *et al*., 2019). Storage duration also affects vitamin C retention, as noted by Oktaviana *et al*. (2012), who found that prolonged storage accelerated vitamin C loss through respiration and aging. Environmental factors, such as light intensity, also modulate vitamin C (Paciolla *et al*., 2019).

The application of coconut husk biochar significantly influenced fruit diameter, number of fruits per plant, fruit weight per plant, and yield per hectare. The treatment involving 3 kg plot^{-1} of biochar yielded the highest production at 9.21 t ha^{-1}, which was statistically superior to that of the control group. This enhancement is likely attributable to the increased availability of soil phosphorus (P) and potassium (K), as confirmed by soil analysis. These nutrients are crucial for fruit development and yield (Sihombing *et al*., 2023). Biochar has been demonstrated to augment available P by up to 45% (Gao *et al*., 2019), whereas P and K are vital for root growth, flowering, and fruit set (Marlina *et al*., 2015; Azzahra, 2023). The advantageous effects of biochar are ascribed to its capacity to enhance soil carbon content, water retention, and nutrient-holding capacity (Panataria, 2020). However, its impact may vary depending on the feedstock, pyrolysis conditions, soil type, and environmental factors (Moreno and Ghneim, 2020; Joseph *et al*., 2021). In this study, the application of biochar improved soil carbon, organic matter, and cation exchange capacity (CEC), which is consistent with the findings of Akmal and Bistok (2019) and Justang *et al*. (2021), who reported that biochar enhances soil fertility and cation concentrations, thereby promoting the productivity of plants.

The application of liquid organic fertilizer significantly influenced fruit diameter, number of fruits per plant, and fruit weight per plant. Optimal outcomes were achieved with a concentration of 7 mL L^{-1}, which yielded the highest number of fruits and fruit weight per plant. This treatment effectively provided nutrients essential for fruit development, as fruit weight is positively correlated with both the number and diameter of fruits (Lukmana *et al*., 2023;

Said and Fatiha, 2015). The nutrient composition of the liquid organic fertilizer, comprising 3.69% N, 3.43% P_2O_3, 3.58% K_2O, and micronutrients such as Fe, Mn, Zn, Cu, and B, supports this finding. These nutrients are readily available in liquid form, facilitating rapid absorption through the roots and leaves (Rahmawati *et al*., 2020; Martinez-Alcantara *et al*., 2016). However, for certain parameters, the liquid organic fertilizer had no significant effect, potentially due to suboptimal nutrient dosage or environmental constraints affecting nutrient uptake. Junaidi (2021) and Rehatta *et al*. (2024) observed that both nutrient deficiency and excess can impede plant growth, whereas an appropriate concentration and application timing are crucial (Kahar *et al*., 2022). Variations in soil pH, texture, and climate may also affect fertilizer efficacy.

Conclusions and Recommendations

The present study demonstrated that both coconut husk biochar and liquid organic fertilizer independently enhanced the growth of Katokkon Chilli (*Capsicum chinense* Jacq.) However, their combined application did not yield additional benefits. The application of 3 kg of coconut husk biochar per plot improved soil conditions, resulting in larger fruits and a yield of 9.21 t ha^{-1}. This improvement was attributed to the ability of biochar to increase soil phosphorus and potassium levels, which are essential for plant growth and fruit production. The use of 7 mL of liquid organic fertilizer per liter of water was optimal for achieving the highest fruit number and weight, indicating effective nutrient supply. Higher concentrations did not enhance the yield, suggesting a limit to nutrient uptake. The combination of 1.5 kg of biochar with 3.5 mL of liquid fertilizer per liter resulted in the highest vitamin C content, indicating that moderate nutrient levels improved fruit quality. These findings suggest that organic materials can significantly enhance the growth and quality of Katokkon Chilli. To achieve better yields while maintaining sustainability, it is recommended to use 3 kg of biochar and 7 mL of liquid fertilizer per liter.

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Novelty Statement

This study revealed the independent effects of coconut husk biochar and liquid organic fertilizer on Capsicum chinense (Katokkon chilli) growth under limited inputs. The findings showed that without significant interaction, each factor produced distinct optimal responses. Coconut husk biochar at 3 kg plot^{-1} improved fruit yield (9.21 t ha^{-1}) through enhanced soil nutrients, while liquid organic fertilizer showed quadratic relationships with fruit characteristics. The combination of 1.5 kg plot^{-1} biochar and 3.5 mL L^{-1} fertilizer produced the maximum vitamin C content (616.97 mg 100g^{-1}). This research establishes quantitative models linking fertilizer and biochar levels with yield and nutrition in Katokkon chilli, providing basis for organic production optimization under drought conditions.

Author Contributions

Nurlina Kasim: Conceptualisation, Methodology, Validation, Formal analysis, Data Curation, Original draft was written, Visualisation, Funding acquisition.
Nuniek Widiayani: Conceptualisation, Methodology, Data Curation, Visualisation.
Nataria Sallao: Conceptualisation, Methodology, Formal analysis, Investigation, Visualisation.
Muhammad Fuad Anshori: Validation, Data Curation.

Generative AI and AI-assisted technology statement
The authors declare that no generative AI and AI assisted technology was used in the creation of this manuscript.

Conflict of interest
The authors have declared no conflict of interest.

References

Akmal, S. and H.S. Bistok. 2019. Effect of Biochar Application on Growth and Yield of Pakchoy Mustard (*Brassica rapa* Subsp. Chinensis). AGRILAND J. Agric. Sci., 7(2): 168-174. https://doi.org/10.30743/agr.v7i2.2025

Ardianti, A.A., F.N.F. Athallah, R. Wulansari and K.S.Wicaksono. 2022. Relationship between soil chemical properties and nutrient uptake of tea plants in PTPN VI Jambi. J. Soil Land Resour., 9(1): 181-191. https://doi.

org/10.21776/ub.jtsl.2022.009.1.20

Arsita, Y. and B.Z. Haryati. 2021. Effect of Several Types of Organic Pesticides on the Attack of Pests and Important Diseases of Katokkon Chilli Plants (*Capsicum frutescens* L.). Agrosaint Scient. J., 12(2): 76-82. https://doi.org/10.47178/15pya038

Ayu, D.P., E.R. Putri, P.R. Izza and Z. Nurkhamamah. 2021. Processing Coconut Coir Waste into Cocopeat and Cocofiber Planting Media in Pepen Hamlet. J. Soc. Praxis Dedicat. (JPDS), 4(2): 92-100. http://dx.doi.org/10.17977/um032v4i2p93-100

Azzahra, A., G. Guniarti and F.D. Dewanti. 2023. Effect of Planting Media Composition and Concentration of Kepok Banana Peel Liquid Organic Fertilizer on the Production of Cayenne Pepper (*Capsicum frutescens* L.). Agro Bali: Agric. J., 6(1): 82-92. https://doi.org/10.37637/ab.v6i1.1076

South Sulawesi Central Bureau of Statistics. South Sulawesi Province in Figures 2023. South Sulawesi Province in Figures 2023. https://sulsel.bps.go.id/en/ publication/2023/02/28/3ea69ff21d346fa74bb816b9 /provinsi-sulawesi -selatan-dalam-angka-2023.html

Bandaso, T.S., A. Rauf and I.S. Madauna. 2022. Response of Katokkon Chilli (Capsium chinense Jacq.) to Organic Fertilizer Application. Agrotekbis: E-J. Agric. Sci., 10(4): 508-520.

Cahya, A.A. and R.H.B. Bangun. 2020. Farmer Characteristics and Feasibility of Large Chilli (*Capsicum annum* L.) and Raw Chilli (*Capsicum frutescens* L.) Farms in North Sumatra. Agricore: Unpad J. Agribus. Agric. Socio-Econ., 5(1): 49-58. https://doi.org/10.24198/agricore.v5i1.27139

Ceccherini, M.T., S.M. Rahul and I.P. Shamina. 2019. Carbon and Nitrogen Cycling in Soil. Springer Nature Singapore. Singapore. https://link.springer.com/book/10.1007/978-981-13-7264-3

Dhiman, V. 2020. Organic Farming for Sustainable Environment: Review of Existed Policies and Suggestions for Improvement. Int. J. Res. Rev., 7(2): 22-31. www.ijrrjournal.com

Ding, Y., Y. Liu, S. Liu, X. Tan, X. Huang and B. Zheng, B. 2016. Biochar to Improve Soil Fertility. A Review. Agron. Sustain. Develop., 36: 1-18. https://doi.org/10.1007/s13593-016-0372-z

Directorate General of Plantations. 2022. National leading plantation statistics 2020-2022. Secretariat of the Directorate General of Plantations. Jakarta. https://ditjenbun.pertanian.go.id/ ?publikasi=buku-statistik-perkebunan-2020-2022

Evizal, R. and F.E. Prasmatiwi 2023. Biochar: Utilisation and Practical Applications. J. Agrotrop., 22(1): 1-12. 10.23960/ja.v22i1.7151

Fauziah, L., D. Setyorini, D.P. Saraswati, A. Krismawati, Z. Arifin and N. Istiqomah. 2023. Liquid Organic Fertilizer (LOF) as a Substitute for Nitrogen Fertilizer in Rice on Acid Soils. In IOP Conference Series: Earth Environ. Sci., 1172(1): 1-8. https://doi.org/10.1088/1755-1315/1172/1/012011

Flowrenzhy, D. and N. Harijati. 2017. Growth and Productivity of Katokkon Chilli (Capsicum chinense Jacq.) at 600 Metres and 1,200 Metres Above Sea Level. Biotropika: J. Trop. Biol., 5(2): 44-53. https://doi.org/10.21776/ub.biotropika.2017.005.02.2

Gamage, A., G. Ruchira, G. Jeewan, J. Nepali, K. Nathasha, S. Piumali and M. Othamane. 2023. Role of Organic Farming for Achieving Sustainability in Agriculture. J. Farm. Sys., 1(1): 1-14. https://doi.org/10.1016/j.farsys.2023.100005

Gao, S., T.H. Deluca and C.C. Cleveland. 2019. Biochar Additions Alter Phosphorus and Nitrogen Availability in Agricultural Ecosystems: A Meta-Analysis. Sci. Tot. Environ., 654: 463-472. https://doi.org/10.1016/j.scitotenv.2018.11.124

Hanisah, R., F. Evizal and Y. Sugiatno. 2020. Effect of Biochar Formulation and Coffee Peel Waste on Coffee Seedling Growth. J. Agrotrop., 19(2): 102-109. https://doi.org/10.23960/JA.V19I2.4544

Islam, M.S., N. Akter and S. Jui. 2020. Variability of Chilli (*Capsicum annum* L.) Genotypes for Yield and Yield Attributes. Asian J. Res. Bot., 3(4): 33-37.

Joseph, S., A.L. Cowie, L. Van Zwieten, N. Bolan, A. Budai, W. Buss and J. Lehmann. 2021. How Biochar Works, and When it Doesn't: A Review of Mechanisms Controlling Soil and Plant Responses to Biochar. Global Chan. Biol. Bioener., 13(11): 1731-1764. http://www.sdiarticle4.com/review-history/56776

Junaidi. 2021. Utilisation of Coconut Coir Using MOL as Liquid Organic Fertilizer for Growth and Yield of Gelatik Eggplant (*Solanum melongena* L.) J. Res. Innov., 1(2): 2263-2270. 10.47492/jip.v1i11.473

Justang, J., I. Rahim and N. Ilmi. 2021. Application of Various Types of Biochar on the Growth and Production of Large Chilli (*Capsicum annum* L.). In Proceed. Nation. Semin. Multidiscip. Syner. Sci. Technol., 4(1): 236-245.

Kahar, K., F. Ahmad and M. Mustamin. 2022. Effect of Liquid Organic Fertilizer on Plant Growth and Yield of Green Bean (*Vigna radiata* L.). Cendekia Eksakta., 7(1): 1-7.

Karim, H., A.I. Suryani, Y. Yusuf and N.A. Khaer Fatah. 2019. Growth of Cayenne Pepper (*Capsicum frutescens* L.) plants on the application of liquid organic fertilizer of kepok banana waste. Indones. J. Fundamen. Sci., 5(2): 89-101. https://doi.org/10.36378/juatika.v6i2.3603

Level, M., M.B. Kalase, D.K. Walanda and M. Napitupulu. 2019. Analysis of Vitamin C and Calcium in Jongi (Dillenia serrata thunb) Fruit Based on the Level of Maturity. Academ. Chem. J., 8(3): 147-152. https://doi.org/10.22487/j24775185.2019.v8.i3.pp147-152

Lukmana, M., S. Supian, I. Indriani, L. Rahmawati, H. Iswahyudi and M.H. Abdillah. 2023. Growth and Yield of Large Chilli (*Capsicum annum* L.) in Mineral Swamp Soil with Rice Husk Treatment. J. Agrisist., 19(1): 1-8. https://doi.org/10.52625/j-agr.v19i1.255

Makmur, M. and M. Magfirah. 2018. Response to the Application of various Doses of Liquid Organic Fertilizer on the Growth and Development of Red Chillies. J. Galung Trop., 7(1): 1-10. https://doi.org/10.31850/jgt.v7i1.321

Mansyur, N.I, H.P. Eko and M. Aditya. 2021. Fertilizer and Fertilization. Syiah Kuala University Press. Banda Aceh. https://unsyiahpress.id

Marlina, N., N. Gofar and A. Halim. 2015. Application of Low Dose Inorganic Fertilizer Types on Rice Plants in Tidal Soil. Proceed. Nation. Seminar Supoptimal Land. http://doi.org/10.17503/agrivita.v36i1.300

Martinez-Alcantara, B., M.R. Martinez-Cuenca, C. Fernandez, F. Legaz and A. Quinones. 2016. Production of 15 N-Labelled Liquid Organic Fertilizers Based on Manure and Crop Residue for Use in Fertigation Studies. Plos One., 11(3): 1-12. https://doi.org/10.1371/journal.pone.0150851

Moeksan, T.K. and P. Laksminiwati. 2011. Red Chilli Cultivation under Shade to Suppress Pest and Disease Attacks. Yayasan Bina Tani Sejahtera. Lembang.

Mondal, S. 2021. Impact Climate Change on Soil Fertility. Climate Change and the Microbiome: Susten. Ecosphere., 551-569. https://doi.org/10.1007/978-3-030-76863-8_28

Moreno, R.S. and H.T. Ghneim. 2020. Impact of Biochar Use on Agricultural Production and Climate Change. A Review. Agron. Colomb., 38(3): 367-381. https://doi.org/10.15446/agron.colomb.v38n3.87398

Natanael, J. and D.R.V. Banjarnahor. 2021. Growth, Yield and Vitamin C Content of Organic Kale (Brassica oleracea Var Acephala) Plants in Several Treatments of Liquid Compost Mixtures Made from Rabbit Urine, Fresh Cow's Milk, and Hens' Eggs. J. Appl. Agric. Res., 21(2): 158-166. https://doi.org/10.25181/jppt.v21i2.2094

Noor, A. 2020. Benefits of Liquid Organic Fertilizer. CV Embrio Multi Agro Research and Development. Cirebon. https://repo.unand.ac.id/32018/1/C.2.a.4%2810%29.pdf

Nur, K., L.M. Baga and A.F. Falatehan. 2023. Red Chilli Development Strategy on Productive Land Around the Ciliwung Watershed, Bogor Regency. J. Region. Develop. Manage., 15(2): 54-63.

Oktoviana, Y., S. Aminah and J. Sakung. 2012. Effect of Storage Duration and Sodium Benzoate Concentration on Vitamin C Level of Red Chilli (*Capsicum annum* L.) J. Chem. Acad., 1(4): 193-199. https://media.neliti.com/media/publications/224214-pengaruh-lama-penyimpanan-dan-konsentras.pdf

Paciolla, C., S. Fortunato, N. Dipierro, A. Paradiso, S. De Leonardis, L. Mastropasqua, and M.C. De Pinto. 2019. Vitamin C in Plants: from Functions to Biofortification. Antioxid., 8(11): 1-26.

Panataria, L.R. 2020. Effect of biochar and poc application on growth and production of pakcoy (*Brasssica rapa* L.) on Ultisol Soil. Rhizobia Scient. J., 2(1): 1-14. https://jurnal.usi.ac.id/index.php/rhizobia/en/article/view/635

Panwar, N.L., Pawar, A. and B.L. Salvi. 2019. Comprehensive Review on Production and Utilization of Biochar. SN Appl. Sci., 1: 1-19. https://doi.org/10.1007/s42452-019-0172-6

Panzaru, R.L., D. Firoiu, G.H. Ionescu, A. Ciobanu, D.M. Medelete and R. Pîrvu. 2023. Organic Agriculture in the Context of 2030 Agenda Implementation in European Union Countries. Sustain., 15(13): 1-31. https://doi.org/10.3390/su151310582

Phibunwatthanawong, T. and N. Riddech. 2019. Liquid Organic Fertilizer Production for Growing Vegetables Under Hydroponic Condition. Int. J. Recycl. Organ. Waste. Agric., 8: 369-380. https://doi.org/10.1007/s40093-019-0257-7

Rahmawati, T.I. and A. Asryani. 2020. Potassium Content and C/N Ratio of Liquid Organic Fertiliser (LOF) Made from Leaves and Goat Urine with the Addition of Tape Yeast Bioactivator (*Saccharomyces cerevisiae*). Bullet. Anim. Nutrit. Food., 14(2): 51-60. https://doi.org/10.20956/bnmt.v14i2.12553

Ramadhani, A. and M.D. Puspitawati. 2023. Coconut Coir and Tofu Dregs Mixture for Germination Planting Media to Support Organic Agriculture. J. Bioindus., 5(2): 96-107.

Rehatta, H., D.A. Marasabessy and M.S. Gea. 2024. Effect of Concentration and Frequency of Liquid Organic Fertiliser Application on Plant Growth and Production of Samhong Mustard (*Brassica juncea* L.). J. Agric. Cultivat., 20(1): 40-53. http://creativecommons.org/licenses/by-sa/4.0

Said, E.M. and H. Fatiha. 2015. Genotypic Variation in Fruit Characters in Some Genotypes of Watermelon Cultivated in Morocco. Int. J. Agron. Agric. Res. (IJAAR)., 6(4): 130-137. http://www.innspub.net

Sihombing, A.R., S. Ulpah and R. Baharuddin. 2023. Effect of Mulch Type and KNO3 Fertiliser on Growth and Yield of Tomato (Lycopersicum esculentum Mill.). J. Agric. Dynam., 38(3): 251-258. https://doi.org/10.25299/dp.2022.vol38(3).11902

Siregar, M.A.R. 2023. The Role of Organic Agriculture in Realising Environmental Sustainability and Public Health. 1-11. https://doi.org/10.51470/ABF.2023.2.2.29

Soeparjono, S. and U. Khasanah. 2023. Application of Planting Distance and Dosage of NPK Fertiliser on Yield and Quality of Red Chilli (*Capsicum annum* L.). In Proceed. Nation. Semin. Indones. Hortic. Associat., 1(1): 1-11.

Sunanryani, C.F. and Nasaruddin. 2023. Response on Growth and Production of Cayenne Pepper (*Capsicum frutescens* L.) Due to Application of Bio-Slurry and Biochar. In IOP Conference Series: Earth Environ. Sci., 1230(1): 1-6. https://doi.org/10.1088/1755-1315/1230/1/012198

Statistics Indonesia in South Sulawesi Province. 2022. Statistik harga produsen pertanian Sulawesi Selatan 2022. Statistics Indonesia in South Sulawesi Province, Makassar, Indonesia. https://sulsel.bps.go.id/id/publication/2023/07/13/f91fcb3 dbf4c4d28fe9e774b/statistik-harga-produsen –pertanian -provinsi-sulawesi- selatan-2022.html

Syukur, M., Y. Rahmi and D. Rahmansyah. 2016. Successful Chilli Harvest Every Day. Penebar Swadaya Group. Jakarta.

Tripathi, M., J.N. Sahu and P. Ganesan, P. 2016. Effect of Process Parameters on Production of Biochar from Biomass Waste Through Pyrolisis: A Review. Renew. Sustain. Ener. Rev., 55: 467-481. https://doi.org/10.1016/j.rser.2015.10.122

Widowati, I., A. Dhamira, H. Anggrasari and R.N. Seleky. 2023. Climatic Factors and Its Effect on Chilli Production: One Step Forward Combating Climate Change. In BIO Web Confer., 69: 1-7. https://doi.org/10.1051/bioconf/20236904001