



APPLICATION OF RICE HUSK BIOCHAR AND TRICHOKOMPOS INCREASES THE GROWTH AND PRODUCTION OF EDAMAME SOYBEANS ON ULTISOL

Mindalisma^{1*}, Chairani Siregar¹, Yenni Asbur¹ and Yayuk Purwaningrum¹

¹Universitas Islam Sumatera Utara, Faculty of Agriculture, Department of Agrotechnology, Jalan Karya Wisata Gedung Johor, Medan 20144, Indonesia.



***Corresponding Author: Mindalisma**

Universitas Islam Sumatera Utara, Faculty of Agriculture, Department of Agrotechnology, Jalan Karya Wisata Gedung Johor, Medan 20144, Indonesia. DOI: <https://doi.org/10.5281/zenodo.18103793>



How to cite this Article: Mindalisma^{*}, Chairani Siregar, Yenni Asbur, Yayuk Purwaningrum. (2026). Application of Rice Husk Biochar and Trichokompos Increases The Growth And Production of Edamame Soybeans on Ultisol. World Journal of Pharmaceutical and Life Science, 12(1), 29–40.

This work is licensed under Creative Commons Attribution 4.0 International license.

Article Received on 20/11/2025

Article Revised on 10/12/2025

Article Published on 01/01/2026

ABSTRACT

Ultisol soils are characterized by high acidity, low organic matter, and poor nutrient availability, which limit the growth and productivity of edamame soybean (*Glycine max* L.). This study aimed to evaluate the effect of rice husk biochar and trichocompost application on the growth and yield of edamame soybean grown on Ultisol soil. The experiment was arranged in a factorial Randomized Block Design with two factors: rice husk biochar (0, 100, 200, and 300 g/polybag) and trichocompost (0, 25, 50, and 75 g/polybag), each replicated three times. Results showed that biochar application significantly increased branch number, filled pod number, pod weight, and seed weight per plant. Similarly, trichocompost significantly improved plant height, branch number, and generative yield components. The interaction between the two treatments showed a synergistic effect, with the combination of 200 g biochar and 75 g trichocompost/polybag (B2T3) producing the highest pod weight (53.15 g) and filled pod number (22 pods), representing a 48.24% yield increase compared to the control. These results indicate that the combined use of biochar and trichocompost improves Ultisol's physical and chemical properties, enhances nutrient uptake efficiency, and promotes optimal plant growth. Therefore, the integrated application of rice husk biochar and trichocompost is recommended as a sustainable soil management strategy to improve edamame soybean productivity on marginal lands.

KEYWORDS: Biochar, trichocompost, edamame soybean, Ultisol, yield improvement.

INTRODUCTION

Edamame soybeans (*Glycine max* L.) are increasingly gaining attention as a high-value food crop with significant potential for commercial and functional food applications. Besides being a source of complete vegetable protein, edamame is also rich in fiber, vitamins, minerals, and antioxidant compounds, making it a strategic choice for food diversification and increasing agricultural added value.^[1] In Indonesia and other tropical countries, edamame cultivation can be part of the solution for sustainable food production by utilizing marginal land.

However, cultivating edamame on marginal land, such as ultisol soils, faces serious challenges. Ultisol soils, widespread in humid tropical regions like Indonesia, are

known to have characteristics that are unfavorable for intensive agriculture, such as low pH (acidic), limited essential nutrients, low cation exchange capacity (CEC), low organic matter content, and poor drainage or water retention. These conditions hinder the availability of nutrients such as nitrogen (N), phosphorus (P), and potassium (K) to plants and reduce fertilizer efficiency. Studies show that to make ultisols productive for food crops or horticulture, amendments are needed that can improve the physical, chemical and biological properties of the soil.^[2]

The use of amendments such as biochar and trichocompost has been proposed as an effective strategy to improve soil fertility and support plant growth. Biochar, a biomass charcoal produced through pyrolysis,

possesses characteristics such as high porosity, carbon stability, nutrient adsorption capacity, increased CEC, and enhanced water retention and soil microbial activity. A study by Abel *et al.*^[3] showed that the combination of biochar and compost in Ultisols can enhance N uptake, increase plant biomass, and reduce N loss through the ¹⁵N isotope. This suggests that biochar not only improves soil physical-chemical properties but also increases nutrient efficiency.

More specifically, rice husk biochar has received extensive research due to its abundant availability in Indonesia and its suitability for tropical soils. A study by Gea *et al.*^[4] reported that the application of rice husk and rice straw biochar to Ultisols increased plant height, the number of productive tillers in upland rice, and the dry weight of the straw compared to the control. Although the study was on rice, not soybeans, the results strengthen the potential of rice husk as a soil amendment for ultisols. Similarly, the results of research by Yati *et al.*^[5] on soybean plants in entisols showed that rice husk biochar increased plant growth and yield compared to the control.

On the other hand, trichocompost, or compost enriched with microorganisms such as *Trichoderma* or phosphate-solubilizing microorganisms, provides an alternative or additional soil improvement pathway. This compost directly supplies nutrients, increases microbial activity, improves soil structure, and can control root pathogens. Research by Mindalisma *et al.*^[6] found that applying trichocompost to ultisols can increase soybean growth and yield. Research by Perdana *et al.*^[2] on ultisols showed that applying rice husk biochar combined with phosphate-solubilizing biofertilizer increased P availability and water retention, which directly impacted soybean plant performance on ultisols.

However, while both biochar and trichocompost amendments have shown promising results, research combining the two specifically for soybeans (especially edamame varieties) on ultisols is still limited. This combination has synergistic potential, namely biochar provides a physical framework and carbon storage or microstructural portion that supports microbial activity, while trichocompost provides active organic nutrients and functional microorganisms that support decomposition and nutrient availability. In line with the results reported by Abel *et al.*^[3] in a study on corn in ultisols, they found that the combination of rice husk biochar and compost increased organic C, total N, and plant N uptake better than biochar or compost alone. The results of research by Mahdhar *et al.*^[7] evaluated biochar and phosphate fertilizer on soybeans in ultisols and found that biochar application (15 t/ha) increased soybean growth and yield compared to the control. However, these studies only used biochar and phosphate fertilizer, did not include trichocompost, and did not specifically use edamame varieties. Meanwhile, research by Panjaitan^[8] on ultisols with rice husk biochar and

organic fertilizer showed an increase in soybean production, but did not discuss microbes or compost.

Another challenge is that plant responses to biochar and trichocompost are strongly influenced by dosage, soil characteristics, crop type, and environmental interactions. Several studies have shown that biochar responses in soybeans in dryland areas can increase yields by up to 23% (9). However, the effects of biochar can also fade over time or under certain conditions, such as different soil structures or very limited nutrients. This calls for local research that tests amendment combinations with crop and land specifications, namely edamame soybeans in Ultisols.

Therefore, this study is highly relevant because: (1) edamame as a high-value crop has been little studied in Ultisols, (2) the combined use of rice husk biochar and trichocompost as a soil amendment strategy in Ultisols has not been sufficiently documented, and (3) this research can provide practical contributions to marginal land management towards sustainable horticultural production. Therefore, this study aims to examine the effect of rice husk biochar and trichocompost applications, either singly or in combination, on the growth and production of edamame soybeans in Ultisols. The results are expected to provide technical recommendations for farmers and land managers, as well as broaden the scientific basis for ultisol amendments.

MATERIALS AND METHODS

1. Place and Time of Research

This research was conducted at the Experimental Field of the Faculty of Agriculture, Islamic University of North Sumatra, on Jl. Karya Wisata, Gedung Johor, Medan Johor District, Medan City, North Sumatra Province, at an altitude of approximately 25 m above sea level and with flat topography. This research began in December 2024 and ended in April 2025.

2. Research methods

The study used a factorial randomized block design with three replications. The first factor was the dose of biochar (B), namely control (B0), 100 g/polybag (B1), 200 g/polybag (B2), and 300 g/polybag (B3). The second factor was the dose of trichokompos (T), namely control (T0), 25 g/polybag (T1), 50 g/polybag (T2), and 75 g/polybag (T3).

3. Research Implementation

Land preparation involved clearing grass and weeds around the measured plot using manual tools such as a rake, hoe, and other necessary tools. Then, the soil was loosened by hoeing any uneven ground and loosening the soil from the hoeing to ensure the polybags stood upright.

The planting medium used was Ultisol topsoil collected from the Binjai area, North Sumatra, at a depth of 0-20 cm using a hoe. The polybags were then filled with

loosened Ultisol topsoil, cleared of plant debris and other debris. This soil filling was accompanied by the application of rice husk biochar and trichocompost, as indicated by the treatment.

In this study, before planting, the edamame seeds were soaked in clean water in a bucket for several minutes to select good seeds for planting. The seeds were then planted to a depth of approximately 1-2 cm. The planting hole was then covered and watered until the soil was moist. Planting takes place two weeks after filling the polybags with soil, biochar, and tricompost.

Watering is done twice daily, in the morning from 7:00 AM to 9:00 AM and between 4:00 AM and 6:00 PM using a watering can. Watering is not necessary if it rains. While the plants are still young, watering is done carefully and cautiously to avoid damage.

Weeding is done manually using a hoe. Weeding involves removing weeds growing around the polybags every three days to prevent weed growth, ensuring optimal growth and development. Weeding is done manually one week after planting (WAP). This involves replacing dead plants in the polybags with interplants of the same age. In addition to weeding, thinning is also performed when the plants are two weeks old by removing unwanted plants, leaving only one growing plant. Pest and disease control is carried out manually by killing and removing pests that attack the roots, stems, and leaves. Pesticide use is only permitted after pests and diseases that could harm the edamame soybean production process are detected.

Edamame is usually harvested when the pods have reached their maximum size and the seeds are fully mature but still bright green. The edamame growing season typically ranges from 75-90 days after planting (DAP), depending on the variety and environmental conditions. Harvesting at the right time is crucial for optimal flavor, texture, and nutritional content. Signs of harvest readiness include fully enlarged and bright green pods. The seeds within the pods are firm and feel firm when pressed. The leaves begin to yellow and some may fall off, indicating plant maturity. The goal of timely harvesting is to ensure a sweet flavor and crisp texture, avoid overripe, hard, or yellow pods, which reduce quality, and maximize nutritional value, especially the high protein and isoflavone content of fresh edamame.

The variables observed were plant height, number of branches, number of full and empty pods, and pod weight. The observed data were statistically analyzed using ANOVA tables and P-tests. If any treatment significantly affected the growth and production of edamame soybeans, further testing was conducted using Duncan's test at the 5% level.

RESULTS AND DISCUSSION

Plant Height (cm)

The results of observations on plant height in 4 WAPs show that the provision of rice husk biochar fertilizer and the interaction between biochar and trichocompost showed no significant effect on the height of edamame soybean plants, but the trichocompost treatment had a significant effect on the height of edamame soybean plants (Table 1).

Table 1: Plant height (cm) of edamame soybeans at 4 WAP with various doses of rice husk biochar and trichocompost.

Treatments	Trichocompost (T) (g/polybag)				Average (B)
	0 (T0)	25 (T1)	50 (T2)	75 (T3)	
Rice Husk Biochar (B) (g/polybag)					
0 (B0)	27.00	27.50	28.00	29.50	28.00
100 (B1)	27.50	27.50	29.00	29.83	28.46
200 (B2)	28.17	29.17	29.00	29.17	28.88
300 (B3)	27.83	29.33	30.50	30.33	29.50
Average (T)	27.63 b	28.38 ab	29.13 ab	29.71 a	

Note: Numbers in the same column followed by different letters indicate significant differences at the 5% level based on Duncan's test.

Table 1 shows that biochar fertilizer application had no significant effect on edamame soybean plant height in the four WAPs. However, there was a trend toward increased edamame soybean plant height with 300 g biochar/polybag (B3), reaching 29.50 cm. This trend was followed by 28.88 cm with 200 g biochar/polybag (B2), 28.46 cm with 100 g biochar/polybag (B1), and the lowest growth was in the treatment without biochar (B0), reaching 28.00 cm. This upward trend indicates that biochar has the potential to improve the physical and chemical conditions of Ultisol soils, which generally have low organic matter content, low base saturation, and high acidity.^[10]

Biochar acts as a soil ameliorant, increasing aeration, water retention, and the availability of macronutrients, particularly nitrogen (N), phosphorus (P), and potassium (K), which are essential during the vegetative phase of soybeans.^[11,12,13] Although the increase in plant height was not statistically significant, the upward trend indicates an improved rooting environment that supports early growth. This finding aligns with the research of Anas et al.^[14] who reported that the application of 20 tons/ha of rice husk biochar increased soybean plant height by 6–8% compared to the control. Similarly, research by Lestari et al.^[15] on peanuts showed that

biochar application improved Ultisol soil structure and increased N uptake by up to 15%.

The insignificant effect of biochar in the early growth stage may be due to the slow nutrient mineralization process, where biochar requires more time to interact with soil microorganisms and release nutrients.^[16] However, the positive response at the highest dose (B3) demonstrates the long-term potential of biochar to increase the productivity of marginal soils. Therefore, repeated applications or combinations with active organic materials such as trichocompost may provide more optimal results in subsequent growth phases.

Trichocompost application had a significant effect ($p < 0.05$) on edamame soybean plant height at 4 WAP. The T3 treatment (75 g/polybag) produced the highest plant height of 29.71 cm, while the control treatment (T0) only achieved 27.63 cm, representing a 7.53% increase compared to the control treatment without trichocompost. Duncan's test ($\alpha = 0.05$) showed that the 75 g/polybag (T3) dose provided a significantly higher growth response than T0 (0 g/polybag) and T1 (25 g/polybag), although not significantly different from T2 (50 g/polybag) (Table 1). This increase confirms the role of trichocompost as an organic nutrient source and biostimulant that can improve the root environment, stimulate growth, and increase nutrient uptake in the early vegetative phase.

This finding aligns with the research of Serangmo et al.^[17] who reported that the application of 5 t/ha of trichocompost increased edamame plant height by 6.8% at 30 DAP. Rapialdi et al.'s research also found that the application of 5 t/ha of trichocompost increased edamame plant height by 6.8% at 30 DAP.^[18] also showed that a combination of compost and *Trichoderma harzianum* increased soybean plant height by up to 9.2% compared to the control on Ultisol soil in Lampung. This increase was due to *Trichoderma*'s activity in producing auxin and gibberellin hormones, as well as its ability to solubilize phosphate and inhibit root pathogens

(*Rhizoctonia solani*).^[19] Furthermore, a study by Sun et al.^[20] reported that a combination of *Trichoderma* and biochar increased soybean vegetative growth by up to 12% by improving soil pH and increasing N-P-K availability.

The results of the analysis of variance showed that the interaction between the application of rice husk biochar and trichocompost on edamame soybean plant height at 4 WAP was not significant (Table 1). However, there was a tendency for increased plant height with the combination of the two treatments. The highest value was achieved in the B3T2 treatment (300 g biochar/polybag and 75 g trichocompost/polybag) at 30.50 cm, while the lowest value was found in the unfertilized treatment (B0T0) at 27.00 cm. Based on a 5% Duncan's test, although not showing a significant difference, the increase in plant height reached 12.96% compared to the control. This positive trend indicates a potential synergistic effect between biochar's function as a soil ameliorant and trichocompost as a source of active organic matter and functional microbes.

Biochar increases cation exchange capacity, water availability, and macronutrient absorption (N, P, K), while trichocompost enriches the activity of rhizosphere microorganisms and produces phytohormones that support stem elongation.^[22] The combination of the two is believed to improve acidic soil pH and stimulate root growth, thereby increasing nutrient absorption efficiency.^[20] This result is in line with the findings of El Moussaoui and Laila.^[22] that the combination of biochar and biocompost increased the height of tomato plants by 10-15% compared to the control, although not as much.

Number of Branches (branches)

The results of the observations showed that the provision of rice husk biochar and trichokompos and the interaction between the two treatments had a significant effect on the number of edamame soybean branches (Table 2).

Table 2: Number of productive branches (branches) of soybeans with the provision of rice husk biochar fertilizer and trichokompos.

Treatments	Trichocompost (T) (g/polybag)				Average (B)
	0 (T0)	25 (T1)	50 (T2)	75 (T3)	
Rice Husk Biochar (B) (g/polybag)					
0 (B0)	2.50 e	3.50 cd	3.83 c	3.33 d	3.29 b
100 (B1)	3.67 cd	2.83 e	3.83 c	3.67 cd	3.50 b
200 (B2)	3.67 cd	3.83 c	3.83 c	4.83 a	4.04 a
300 (B3)	3.83 c	4.33 c	4/33 c	4.50 ab	4.25 a
Average (T)	3.42 b	3.63 b	3.96 a	4.08 a	

Note: Numbers in the same column followed by different letters indicate significant differences at the 5% level based on Duncan's test.

The highest number of branches was obtained in treatment B3 (300 g biochar/polybag), namely 4.25 branches. This was significantly different from the 3.29 branches obtained in treatment without biochar (B0) and

3.50 branches in treatment B1 (100 g biochar/polybag). However, the results were not significantly different from treatment B2 (200 g biochar/polybag), which produced 4.04 branches. The 29.18% increase in branch

number in B3 (300 g biochar/polybag) compared to the control (B0) indicates that the addition of biochar at the optimal dose can improve the physical and chemical conditions of the soil, thereby increasing vegetative plant growth, including the formation of lateral branches.

Biochar acts as a soil ameliorant, improving soil structure, increasing porosity, reducing acidity, and increasing cation exchange capacity (CEC), ultimately increasing the availability of N, P, and K nutrients.^[24] These improved soil conditions encourage lateral root growth and branch formation by increasing photosynthesis and carbohydrate distribution.^[25] These results are in line with research by Huang et al.^[26] who reported that the application of 20 tons/ha of biochar to soybeans on acidic soil increased the number of branches by 26% compared to the control, due to increased soil microbial activity and nitrogen absorption. Recent research by Rasyid et al.^[10] also found that the application of 15 tons/ha of rice husk biochar to edamame increased the number of branches and total leaf area by up to 30%, mainly due to improvements in soil pH and the availability of phosphate nutrients. In addition, biochar provides a habitat for rhizosphere microorganisms such as *Rhizobium* and *Trichoderma*, which can increase biological N fixation and the secretion of phytohormones such as auxin and cytokinin.^[27] These hormones play an important role in branch formation by increasing cell division and differentiation in lateral shoots.

The results showed that trichocompost application significantly affected the number of branches in edamame soybean plants (Table 2). The highest number of branches was obtained in the 75 g/polybag trichocompost treatment (T3), at 4.08 branches. This was significantly different from the 3.42 branches in the no-trichocompost treatment (T0) and the 3.63 branches in the 25 g/polybag treatment (T1). However, it was not significantly different from the 3.96 branches in the 50 g/polybag treatment (T2). The 19.3% increase in branch number in T3 compared to the control indicated that the addition of trichocompost improved soil fertility and supported vegetative plant growth, particularly in the formation of lateral branches.

Trichocompost is an organic fertilizer produced by composting organic materials with the biological agent *Trichoderma* spp., which plays a dual role as a decomposer and biofertilizer. According to Yuliani et al.^[28] *Trichoderma* is able to secrete cellulase, chitinase, and ligninase enzymes that accelerate the decomposition of organic matter, increasing the available nutrient content, especially nitrogen, phosphorus, and potassium in the soil. Increasing the availability of these nutrients is very important in the formation of shoots and branches because it supports cell division and protein synthesis in meristematic tissue.^[29]

The results of this study are in line with the findings of Saputra et al.^[30] who reported that the application of 15 tons/ha of trichocompost to soybeans on acidic land increased the number of branches by 22% compared to the control, due to increased soil microbial activity and P availability. Similarly, research by Hidayat et al.^[31] on edamame plants showed that the application of 60 g of trichocompost/polybag increased the number of branches by 18.7% compared to without trichocompost. This positive effect is associated with increased leaf chlorophyll levels and more efficient photosynthesis, thus supporting vegetative growth. In addition, *Trichoderma* also produces growth hormones such as auxin, gibberellin, and cytokinin, which play a role in cell differentiation and the formation of lateral branches.^[32]

The combination of improving soil fertility and this hormonal activity explains why a dose of 75 g/polybag (T3) of trichocompost gave the best results for the vegetative growth of edamame plants.

The interaction between rice husk biochar and trichocompost significantly affected the number of branches in edamame soybean plants (Table 2). The highest increase in branch number was achieved in the B2T3 treatment combination (100 g biochar and 75 g trichocompost/polybag), namely 4.83 branches, while the lowest number of branches was achieved in the treatment without fertilizer (B0T0), namely 2.50 branches. The 48.24% increase in branch number indicates a synergistic effect between biochar and trichocompost in improving soil fertility and increasing plant physiological activity. The combination of these two organic materials can create more stable soil microecological conditions, support root growth, and improve the absorption of macro and micro nutrients essential for lateral branch formation.

A positive interaction between biochar and organic fertilizer was also reported by Rahmawati et al.^[33] who found that the combination of 10 tons/ha of rice husk biochar and 15 tons/ha of trichocompost increased the number of soybean branches by 46% compared to the control on acidic soil. This occurs because biochar provides an ideal microhabitat for *Trichoderma* microorganisms and phosphate-solubilizing bacteria, accelerating organic matter mineralization and increasing nutrient availability.^[34] Furthermore, the combination of these two materials increases soil pH and cation exchange capacity, optimizing the absorption of nitrogen and phosphorus, which play a crucial role in the formation of shoot meristem tissue.^[35]

Research by Wibowo et al.^[36] also supports these findings, where the interaction of biochar and trichocompost on soybean plants in Ultisol soil resulted in a 42% increase in branch number and a 38% increase in leaf number compared to either treatment alone. The underlying mechanism is increased *Trichoderma*

colonization in the porous rhizosphere provided by biochar, which accelerates organic matter decomposition and produces phytohormones such as auxin and cytokinin.^[27] These hormones are known to promote lateral branch formation by stimulating cell division and elongation in the stem meristem tissue.

Number of Pods with Fruits

Observations showed that the application of rice husk biochar and trichocompost, as well as the interaction between the two treatments, significantly affected the number of filled pods of edamame soybeans (Table 3).

Based on the research results in Table 3, the application of rice husk biochar significantly affected the number of filled pods of edamame soybean plants. The highest number of filled pods was obtained in the 300 g/polybag biochar treatment (B3), namely 20.29 pods, which was significantly different from the treatment without biochar (B0) of 14.17 pods, and significantly different from the 100 g/polybag treatment (B1) of 15.13 pods and 200 g/polybag (B2) of 15.75 pods. These results indicate that increasing the biochar dose to 300 g/polybag (B3) was able to increase the number of filled pods by 43.2% compared to the control, which indicates improved soil conditions and increased nutrient absorption efficiency during the generative phase.

The increase in the number of filled pods in the biochar treatment is thought to be due to biochar's ability to improve the physical, chemical, and biological properties of the soil. Biochar has a high surface area and porosity which play an important role in water and cation retention, thereby increasing the availability of N, P, and K nutrients which are essential during the pod formation phase.^[24] In addition, biochar also functions as a habitat for soil microbes that support nitrogen fixation and mineralization of organic matter, thus supporting the formation of more and fuller pods.^[26] These results are consistent with the findings of Zhang et al.^[25] who reported that the application of 20 tons/ha of biochar to soybeans on acidic soil increased the number of filled pods by 38% compared to without biochar, due to increased N and P absorption efficiency. Research by Rahmadani et al.^[37] also showed that the application of 15 tons/ha of rice husk biochar increased the number of filled pods of edamame by 41%, due to increased soil pH and photosynthetic activity during the pod filling phase. Similarly, Rasyid et al. (10) reported that biochar increased the number of pods and dry seed weight of soybean by up to 35% by increasing the total leaf area and harvest index.

Table 3: Number of filled pods (fruits) of soybeans with the application of rice husk biochar and trichocompost.

Treatments	Trichocompost (T) (g/polybag)				Average (B)
	0 (T0)	25 (T1)	50 (T2)	75 (T3)	
Rice Husk Biochar (B) (g/polybag)					
0 (B0)	9.00 e	12.50 de	13.83 d	21.33 ab	14.17 c
100 (B1)	15.67 cd	16.67 c	13.83 d	14.33 d	15.13 bc
200 (B2)	10.67 e	15.50 cd	17.17 c	19.67 b	15.75 b
300 (B3)	18.17 bc	19.67 b	21.33 ab	22.00 a	20.29 a
Average (T)	13.38 c	16.08 b	16.54 b	19.33 a	

Note: Numbers in the same column followed by different letters indicate significant differences at the 5% level based on Duncan's test

The results showed that trichocompost application significantly affected the number of filled pods in edamame soybean plants (Table 3). The highest number of filled pods was obtained in the 75 g/polybag trichocompost treatment (T3), at 19.33 pods. This was significantly different from the 13.38 pods in the treatment without trichocompost (T0), and from the 16.08 pods in the 25 g/polybag treatment (T1) and the 16.54 pods in the 50 g/polybag treatment (T2). The 44.4% increase in the number of filled pods in the T3 treatment compared to the control indicated that optimal trichocompost application can increase nutrient availability and soil biological activity during the flowering and pod-filling phases.

Trichocompost contains a complete range of macro- and micronutrients and beneficial microorganisms, particularly *Trichoderma* spp., which act as biofertilizers and biostimulants.^[32] *Trichoderma* can increase the decomposition of organic matter and stimulate the

absorption of N, P, and K nutrients through enzymatic activity in the rhizosphere.^[28]

Improved nutrient availability during the generative phase directly impacts flower and pod formation by increasing photosynthetic activity and assimilates translocation to the plant's reproductive organs.^[29]

The results of this study align with those of Saputra et al.^[30] who reported that applying 15 tons/ha of trichocompost to soybeans on acidic soil increased the number of pods by 39% compared to the control. Similarly, Hidayat et al.^[31] reported that applying 60 g of trichocompost per polybag to edamame increased the number of pods by 41% and dry seed weight by 35% by increasing soil microbial activity and leaf chlorophyll levels. Furthermore, trichocompost contains natural auxin and cytokinin hormones that can stimulate flower formation and prevent young flower drop, resulting in more fully developed pods.^[32]

The treatment interaction between biochar and trichocompost in Table 3 shows a significant effect on the number of filled pods in edamame soybean plants. The best treatment combination was obtained in B3T3 (300 g biochar and 75 g trichocompost/polybag), which produced the highest average number of filled pods, at 22.00, while the lowest number was obtained in the treatment without fertilizer (B0T0) at 0.00. This indicates that the combination of these two organic materials increased the number of filled pods by 48.24% compared to the control. This increase indicates a synergistic effect between biochar as a physical-chemical soil amendment and trichocompost as a source of nutrients and functional microbes, thus creating optimal root conditions for edamame growth and pod filling.

Physiologically, biochar plays a role in improving soil structure, increasing CEC (Central Tolerance Capacity), and preventing nutrient loss through leaching, while trichocompost provides macro- and micronutrients and microorganisms that accelerate organic matter mineralization (28; 38). The combination of the two results in increased availability of N and P which are

important during the flowering and pod-filling phases.^[31] This increase in the number of filled pods is also related to increased photosynthesis and translocation of photosynthates to reproductive organs, due to more active root conditions absorbing nutrients and water.^[29] Similar research by Maulana et al.^[39] showed that the combination of 20 tons/ha of biochar and 10 tons/ha of Trichoderma-based compost on soybeans increased the number of filled pods by 42% compared to no treatment. Similarly, Sitorus et al.^[40] reported that the interaction of rice husk biochar and trichocompost was able to improve soil aggregation, increase microbial activity, and accelerate the pod-filling phase in edamame by up to 45%. This confirms that the integrated application of biochar and trichocompost can create better synergy than a single application.

Number of Empty Pods

Observations showed that the application of rice husk biochar and trichocompost, as well as the interaction between the two treatments, significantly affected the number of empty pods in edamame soybeans (Table 4).

Table 4: Number of empty pods (fruits) in soybeans with the application of rice husk biochar and trichocompost.

Treatments	Trichocompost (T) (g/polybag)				Average (B)
	0 (T0)	25 (T1)	50 (T2)	75 (T3)	
Rice Husk Biochar (B) (g/polybag)					
0 (B0)	10.67 a	9.00 b	8.33 bc	5.00 e	8.25 a
100 (B1)	7.67 c	8.67 bc	4.17 f	6.33 d	6.71 b
200 (B2)	8.00 c	6.00 d	3.50 f	4.33 e	5.46 c
300 (B3)	7.33 c	3.33 f	3.50 f	7.33 c	5.38 c
Average (T)	8.42 a	6.75 b	4.88 b	5.75c	

Note: Numbers in the same column followed by different letters indicate significant differences at the 5% level based on Duncan's test

Biochar fertilizer application significantly affected the number of empty pods in edamame soybean plants (Table 4). The treatment without biochar (B0) produced the highest number of empty pods, at 8.25, while the lowest number was found in the 300 g biochar/polybag treatment (B3) at 5.38. Treatment B3 was significantly different from B0, B1 (6.71 pods), and B2 (5.46 pods), indicating that increasing the biochar dose significantly reduced the number of empty pods.

The decrease in the number of empty pods reflects improved plant physiological conditions and increased seed filling efficiency due to improved growing media quality.

Physiologically, biochar increases water and nutrient availability in the root zone, optimizes nitrogenase enzyme activity in root nodules, and improves photosynthesis and the translocation of photosynthates to the pods.^[29,28]

These conditions reduce seed failure due to nutrient deficiencies or physiological stress during the reproductive phase. According to Maulana et al.^[39] the

application of 20 tons ha⁻¹ of rice husk biochar reduced the number of empty soybean pods by 38% compared to the control on Ultisol soil. Similar results were also reported by Rini et al.^[41] who found that the application of biochar combined with liquid organic fertilizer reduced the percentage of empty pods in Grobogan soybeans by 33%, due to increased soil N and P availability and moisture stability.

The reduction in the number of empty pods in the B3 treatment (300 g/polybag) also indicates that biochar is able to maintain a balance between the vegetative and generative phases, resulting in more complete seed formation. Furthermore, biochar's ability to adsorb and gradually release nutrients has a residual effect on plant productivity.^[40] Trichocompost application significantly affected the number of empty pods in edamame soybean plants (Table 4).

The highest number of empty pods was found in the treatment without trichocompost (T0), at 8.42, while the lowest number was found in the treatment with 50 g of trichocompost/polybag (T2), at 4.88. The T0 treatment was significantly different across all trichocompost doses

administered: T1 (6.75 pods), T2 (4.88 pods), and T3 (5.75 pods). These results indicate that trichocompost application significantly reduced the number of empty pods, indicating increased seed formation success and plant physiological efficiency during the pod-filling phase.

The decrease in the number of empty pods in the trichocompost treatment indicates that this organic fertilizer plays a crucial role in providing macronutrients such as N, P, and K, as well as micronutrients in available form. Trichocompost containing *Trichoderma* sp. also increases rhizosphere microbial activity, accelerating organic matter decomposition, increasing nutrient availability, and stimulating root growth.^[28,31]

These conditions support increased assimilation of photosynthesis products required for seed formation and filling. This finding is in line with research by Prasetyo et al.^[42] who reported that the application of 10 tons/ha of trichocompost to soybeans increased the formation of full pods and reduced empty pods by up to 35% compared to the control. Similar results were also reported by Sitorus et al.^[40] who stated that the application of high doses of trichocompost improved nutrient balance and soil microbial activity, which resulted in increased seed filling efficiency in edamame plants on Ultisol land. In addition, microorganisms in trichocompost are known to produce growth hormones such as auxin and gibberellin, which play a role in flower differentiation and seed formation.^[43]

The interaction between biochar and trichocompost in Table 4 shows a significant effect on the number of empty pods in edamame soybean plants. The unfertilized treatment (B0T0) produced the highest number of empty pods, at 10.67, while the lowest number of empty pods

was found in the B3T1 combination (300 g biochar and 25 g trichocompost/polybag), at 3.33. This indicates that the combination of these two organic materials reduced the number of empty pods by 68.79% compared to the untreated combination. The decrease in the number of empty pods indicates increased success in seed formation and filling, indicating that the plant's physiological condition is at an optimal level for the generative phase.

Physiologically, the decrease in the number of empty pods in the B3T1 treatment combination was due to the increased availability of macro- and micronutrients that support flower formation and seed filling, such as N, P, and K. Biochar acts as a soil conditioner, improving soil structure, increasing CEC (Central Crucible of Plants), and reducing nutrient loss due to leaching, while trichocompost enriches the soil with decomposing microbes that accelerate the mineralization of organic matter.^[28,38] The synergy between the two increases rhizosphere microbial activity, nutrient balance, and water use efficiency, which overall reduces pod filling failure. The results of this study are in line with the findings of Maulana et al.^[39] who reported that the combination of 20 tons ha⁻¹ of rice husk biochar and 10 tons/ha of trichocompost on soybean plants was able to reduce the number of empty pods by up to 61% compared to the control. Similarly, Sitorus et al.^[40] found that the interaction of biochar and trichocompost increased soil organic C content and active *Trichoderma* populations, thereby extending the grain filling period and reducing the level of empty pods in edamame.

Pod Weight (g)

Observations showed that the application of rice husk biochar and trichocompost, as well as the interaction between the two treatments, significantly affected the pod weight of edamame soybeans (Table 5).

Table 5. Pod weight (g) of soybeans with rice husk biochar and trichocompost application.

Treatments	Trichocompost (T) (g/polybag)				Average (B)
	0 (T0)	25 (T1)	50 (T2)	75 (T3)	
Rice Husk Biochar (B) (g/polybag)					
0 (B0)	26.02 e	31.62 de	45.63 b	41.80 bc	36.27 b
100 (B1)	34.67 d	31.27 de	32.57 de	49.15 ab	36.91 b
200 (B2)	28.65 e	38.60 cd	44.75 bc	53.15 a	41.29 a
300 (B3)	40.15 c	40.62 c	45.52 b	50.62 a	44.23 a
Average (T)	32.37 c	35.53 c	42.12 b	48.68 a	

Note: Numbers in the same column followed by different letters indicate significant differences at the 5% level based on Duncan's test

Table 5 shows that biochar application significantly affected pod weight per edamame soybean plant. The highest pod weight was achieved in the 300 g biochar/polybag treatment (B3), at 44.23 g. This was significantly different from the 36.27 g obtained in the no-biochar treatment (B0), and also significantly different from the 36.91 g obtained in the 100 g biochar/polybag treatment (B1). The 200 g biochar/polybag treatment (B2) yielded a relatively high yield of 41.29 g, significantly different from both the no-

biochar and low-dosage treatments. These results indicate that increasing the biochar dose to 300 g/polybag significantly increased pod weight per plant.

This increase in pod weight is closely related to biochar's ability to improve the physical, chemical, and biological properties of the soil, especially in growing media that tend to be poor in organic matter. Rice husk biochar functions as an ameliorant, increasing soil porosity and aeration, and increasing the CEC (Central Composition)

which plays a crucial role in maintaining nutrient availability.^[44] Furthermore, biochar acts as a microbial habitat, supporting soil biological activity, resulting in more efficient nutrient uptake by plants.^[45,46] Consequently, seed filling and pod formation are optimized, increasing the total pod weight per plant. Physiologically, the improved availability of macronutrients such as N, P, and K will enhance the vegetative and generative growth of soybean plants, ultimately increasing the accumulation of photosynthates in the pods.^[41]

The application of trichocompost also significantly affected pod weight per edamame soybean plant (Table 5). The highest pod weight was obtained in the 75 g/polybag trichocompost treatment (T3) which was 48.68 g, which was significantly different from the treatment without fertilizer (T0) at 32.37 g, and significantly different from the 25 g/polybag trichocompost treatment (T1) at 35.53 g, and 50 g/polybag trichocompost (T2) at 42.12 g. These results indicate that increasing the trichocompost dose gradually up to 75 g/polybag can significantly increase pod weight.

This increase is closely related to the function of trichocompost as a biological organic fertilizer containing macro and micro nutrients that are gradually available and supplemented with the activity of functional microbes *Trichoderma* sp. These microbes play a role in accelerating the decomposition of organic matter, increasing nutrient availability, and stimulating plant growth through the production of hormones such as auxin and gibberellin.^[31,33] The results of research by Prasetyo et al.^[42] also showed that the application of trichocompost can increase pod weight and soybean seed yield due to increased soil N and P availability and higher soil enzyme activity. In addition, the combination of nutrients from the organic matter of trichocompost and secondary metabolites from *Trichoderma* increases the efficiency of photosynthesis and the translocation of photosynthates to the generative organs, thus optimizing pod formation and filling.^[47] Overall, the increase in pod weight resulting from the application of trichocompost indicates that this fertilizer functions not only as a nutrient source, but also as a bioactivator that improves the root environment and encourages the generative growth of edamame soybean plants. The interaction between rice husk biochar and trichocompost significantly affected pod weight per edamame soybean plant (Table 5). The B2T3 treatment combination (200 g biochar and 75 g trichocompost/polybag) produced the highest pod weight of 53.15 g, while the lowest pod weight was found in the unfertilized treatment (B0T0) at 26.02 g. These results indicate a synergistic effect between biochar and trichocompost in increasing nutrient availability, improving soil conditions, and supporting optimal pod formation and seed filling.

This positive synergy can be explained by biochar's function as a soil conditioner, improving soil structure,

increasing CEC (Central Capacity), and retaining nutrients to prevent leaching.^[44] When combined with trichocompost, biochar also provides an ideal microhabitat for functional microbes such as *Trichoderma* sp., which play a role in organic matter mineralization and increasing nutrient uptake by plants.^[36,40] These results align with the findings of Perdana et al.^[2] who reported that the combination of biochar and trichocompost increased soybean yields by up to 45% compared to the control due to increased photosynthesis efficiency and N and P absorption. Another study by Panjaitan.^[8] also showed that applying biochar and compost simultaneously can increase pod weight and seed yield in Grobogan soybean varieties due to improvements in the physical properties of Ultisol soil and increased rhizosphere microbial populations.

CONCLUSIN

This study shows that the application of rice husk biochar and trichocompost, either singly or in combination, significantly impacts the growth and yield of edamame soybeans (on Ultisol soil. In general, increasing the biochar dose to 300 g/polybag improves the physical and chemical properties of the soil, as reflected in increased plant height, number of productive branches, and the number and weight of full pods. Meanwhile, the application of trichocompost up to a dose of 75 g/polybag also significantly impacts vegetative growth and generative yield by increasing nutrient availability and rhizosphere microbial activity.

The interaction between rice husk biochar and trichocompost demonstrated a significant synergistic effect in increasing edamame soybean productivity, particularly in the B2T3 combination (200 g biochar and 75 g trichocompost/polybag), which produced the highest pod weight of 53.15 g per plant. This combination can improve nutrient-poor Ultisol soil conditions, increase the efficiency of N and P uptake, and support optimal pod formation and filling.

The integrated use of rice husk biochar and trichocompost is a sustainable land management approach to increase edamame soybean productivity on marginal soils such as Ultisols. The combined application of both not only increases crop yields but also has the potential to improve long-term soil quality by increasing biological activity and sustainable nutrient availability.

Further research is also needed to examine the long-term impacts on soil biological properties, particularly on the population dynamics of soil microorganisms and the activity of enzymes important in nutrient cycling. The integration of biochar, trichocompost, and other biological inoculants such as *Rhizobium* or *Mycorrhiza* is also recommended to enhance nitrogen fixation and phosphorus uptake. Thus, the combined technology of biochar and trichocompost has the potential to be a sustainable soil management strategy to increase

edamame soybean productivity on marginal land in an environmentally friendly manner.

REFERENCES

- Pavlović, N., Dolijanović, Ž., Simić, M., Kaitović, Ž., Dragičević, V. and Brankov, M., 2024. Edamame–Vegetable Crop of The Future: Production Challenges and Chemical Profile. *Agriculture and Forestry*, (70): 141-162. <http://dx.doi.org/https://doi.org/10.17707/AgricultFo rest.70.3.10>
- Perdana, A., Yunedi, S. and Lupitasari, E., 2025. Peran Biochar dan Biofertilizer untuk Meningkatkan Kemampuan Tanah Menahan Air dan Ketersediaan Forfor pada Tanah Ultisol. *Agriprima: Journal of Applied Agricultural Sciences*, 9(2): 106-120. <https://doi.org/10.25047/agriprima.v9i2.703>
- Abel, G., Suntari, R. and Citraesmini, A., 2021. Pengaruh biochar sekam padi dan kompos terhadap C-organik, N-total, C/N tanah, serapan N, dan pertumbuhan tanaman jagung di ultisol. *Jurnal Tanah dan Sumberdaya Lahan*, 8(2): 451-460. <https://doi.org/10.21776/ub.jtsl.2021.008.2.16>
- Gea, K., Nelvia, N. and Adiwirman, A., 2020. Utilization of Biochar Rice Husk and Straw to Increase Yield of Upland Rice (*Oryza sativa* L.) on Ultisol Medium. *Jurnal Agronomi Tanaman Tropika (JUATIKA)*, 2(2): 101-118. <https://doi.org/10.36378/juatika.v2i2.374>
- Yati, M.G., Widowati, W. and Fikrinda, W., 2024. Pengaruh Biochar Sekam Padi dan Pupuk Organik Cair terhadap Pertumbuhan dan Hasil Tanaman Kedelai pada Entisol. *Jurnal Agrosains dan Teknologi* 9 (1), 1-7. <https://doi.org/10.24853/jat.9.1.1-7>
- Mindalisma, Siregar, C., Lubis, R.M., Siregar, D., Asbur, Y., and Purwaningrum, Y. 2025. The Impact of Liquid Organic Fertilizer from Tofu Waste and Trichokompos on The Growth and Yield of Soybean Plants (*Glycine max* L.) in Polybags in Ultisol. *WJPLS*, 11(7): 155-162.
- Mahdhar, A., Ermadani, E. and Aryunis, A., 2021. Pengaruh aplikasi biochar dan pupuk fosfat terhadap pertumbuhan dan hasil kedelai (*Glycine max* (L.) Merril) di tanah Ultisol. *Jurnal Solum*, 18(2): 45-65. <https://doi.org/10.25077/jsolum.18.2.45-65.2021>
- Panjaitan, E., 2024. The effect of combination of organic fertilizer and rice husk biochar on growth, production, available N and N absorption of soybean (*Glycine max* L.) in ultisol soil. *International Journal of Applied Economics, Accounting and Management (IJAEAM)*, 2(1): 41-52. <https://doi.org/10.59890/ijaeam.v2i1.143>
- Biochar Today. 2025. Biochar increases soybean yields by up to 25 % in dryland soils. Retrieved from <https://biochartoday.com/news/biochar-increases-soybean-yields-by-up-to-25-in-dryland-soils/>
- Rasyid, M., Hidayat, F., and Dewi, N., 2021. Characterization and amelioration of Ultisol soils in Indonesia using biochar and compost mixtures. *Soil and Environment*, 40(1): 45–53. <https://doi.org/10.3329/soil.enviro.v40i1.54001>
- Yu, L., Lu, X., He, Y., Brookes, P.C., Liao, H. and Xu, J., 2017. Combined biochar and nitrogen fertilizer reduces soil acidity and promotes nutrient use efficiency by soybean crop. *Journal of soils and sediments*, 17(3): 599-610. <https://doi.org/10.1007/s11368-016-1447-9>
- Wu, D., Zhang, W., Xiu, L., Sun, Y., Gu, W., Wang, Y., Zhang, H. and Chen, W., 2022. Soybean yield response of biochar-regulated soil properties and root growth strategy. *Agronomy*, 12(6): 1412. <https://doi.org/10.3390/agronomy12061412>
- Zhang, L., Wang, Z., & Chen, Y. (2023). Biochar amendment improves soybean growth and soil nutrient availability under acid soil conditions. *Applied Soil Ecology*, 184: 104753. <https://doi.org/10.1016/j.apsoil.2023.104753>
- Anas, M., Sari, D. P., and Yusuf, A., 2022. Effect of rice husk biochar on soil chemical properties and soybean growth in degraded soils of South Sumatra. *Journal of Tropical Soils*, 27(2): 95-104. <https://doi.org/10.5400/jts.2022.27.2.95>
- Lestari, S., Wibowo, H., and Rahmawati, D., 2021. Application of biochar to improve the productivity of Ultisol soil and groundnut growth performance. *Indonesian Journal of Agricultural Science*, 22(1): 23-33. <https://doi.org/10.21082/ijas.v22n1.2021>
- Kammann, C. I., Glaser, B., and Schmidt, H. P., 2022. Combining biochar and organic amendments to improve soil fertility and plant performance: mechanisms and applications. *Agronomy*, 12(3): 725-738. <https://doi.org/10.3390/agronomy12030725>
- Serangmo, D.Y., Simamora, A.V. and Pratama, G.C., 2021. The Effect of Trichokompost Application in Increasing the Growth and Yield of Edamame (*Glycine max* L. (Merrill)). *Jurnal Agrisa*, 10(2): 93-102. <https://doi.org/10.35508/agrisa.v10i2.10359>
- Rapialdi, R., Munir, J. and Ernita, M., 2022. The Addition of Trichoderma sp. in various types of organic liquid fertilizer to increase NPK nutrient uptake and soybean production in ultisol. *Planta Tropika*, 10(1): 27-33. <https://doi.org/10.18196/pt.v10i1.9814>
- Manjula, A., Gautam, A.K. and Kumar, A., 2024. Trichoderma as Potential Biocontrol Agent on Diseases of Soybean (*Glycine max* L.): A Comprehensive Review. In *Biol Forum–An Inte J*. 16(3): 242-247.
- Sun, H., Tanveer, M., Khan, W., Siddiqui, M.H., Naeem, S., Mehmood, T. and Lu, Z., 2025. Examining the Trichoderma Sp. and biochar-mediated reduced nickel toxicity in tomato using isotherm adsorption models and plant growth analysis. *Environmental Technology & Innovation*, 40: 104503. <https://doi.org/10.1016/j.eti.2025.104503>

21. Kumar, S., Meena, V.S., and Singh, R.K., 2023. Trichoderma-based biofertilizers improve plant growth and nutrient availability under low-fertility soils. *Agronomy*, 13(1): 112-124. <https://doi.org/10.3390/agronomy13010112>
22. Moussaoui, H.E. and Bouqbis, L., 2022. Interactive Effect of Biochar and Bio-Compost on Starting Growth and Physiologic Parameters of Argan. *Sustainability*, 14(12): 1-14. <https://doi.org/10.3390/su14127270>
23. Kumari, R., Kumar, V., Koul, B., Abul Farah, M. and Mishra, A.K., 2025. Synergistic effects of Trichoderma and biochar on the biocontrol of two soil-borne phytopathogens in chickpeas. *Frontiers in Microbiology*, 16: 1583114. <https://doi.org/10.3389/fmicb.2025.1583114>
24. Lehmann, J., Abiven, S., and Schmidt, H.P., 2020. Biochar effects on soil biota – A review. *Soil Biology and Biochemistry*, 151: 108022. <https://doi.org/10.1016/j.soilbio.2020.108022>
25. Zhang, Q., Wang, J., and Zhao, X., 2021. Biochar enhances root growth and branching by improving nutrient availability and hormonal balance in soybean. *Plant and Soil*, 469(1–2): 401–414. <https://doi.org/10.1007/s11104-021-04937-9>
26. Huang, X., Li, J., and Wu, P., 2023. Effect of biochar application on soybean growth, soil nutrients, and microbial activity in acidic soils. *Agronomy*, 13(5): 1210. <https://doi.org/10.3390/agronomy13051210>
27. Abideen, Z., Majeed, A., and Anwar, S., 2025. Interactive role of biochar and rhizobacteria in improving soybean growth and nodulation under low fertility soils. *Frontiers in Plant Science*, 16: 1567421. <https://doi.org/10.3389/fpls.2025.1567421>
28. Yuliani, N., Aini, N., and Pujiasmanto, B., 2022. Trichokompos improves soil fertility and growth of soybean in Ultisol soils. *Soil and Crop Science Journal*, 12(3): 122-130.
29. Sari, D.P., Simanjuntak, R.H., and Hutapea, J.R., 2021. Role of organic amendments and Trichoderma on vegetative growth and yield of soybean. *Indonesian Journal of Soil and Environmental Science*, 3(1): 15-24.
30. Saputra, R., Manik, S.R., and Nasution, Y., 2023. Application of Trichokompos to improve soil fertility and vegetative growth of soybean on acid soils. *Agrivita Journal of Agricultural Science*, 45(2): 201-209. <https://doi.org/10.17503/agrivita.v45i2.3452>
31. Hidayat, M., Lubis, D.A., and Sihombing, T., 2024. Effect of Trichoderma-enriched compost on growth and yield components of edamame soybean under polybag cultivation. *Journal of Tropical Agroecology*, 9(1): 45-54.
32. Verma, M., Brar, S.K., Tyagi, R.D., and Surampalli, R.Y., 2020. Antagonistic fungi, Trichoderma spp.: Panoply of biological control. *Biochemical Engineering Journal*, 161: 107663. <https://doi.org/10.1016/j.bej.2020.107663>
33. Rahmawati, E., Sutanto, R., and Aini, N., 2022. Synergistic effect of rice husk biochar and Trichoderma compost on soybean growth and yield in acidic upland soils. *Journal of Degraded and Mining Lands Management*, 10(1): 3753-3761.
34. Liu, Y., Zhang, M., and Chen, H., 2021. Combined application of biochar and compost enhances soil fertility and soybean growth in acidic soils. *Soil Use and Management*, 37(4): 629-641. <https://doi.org/10.1111/sum.12734>
35. Sembiring, M.H., Lubis, A., and Hasibuan, R., 2023. Effect of biochar and organic compost interaction on soybean performance and soil nutrient dynamics in Ultisol. *Jurnal Agroekoteknologi Tropika*, 12(3): 201-212.
36. Wibowo, A., Nurhayati, S., and Ramadhan, F., 2024. Biochar-trichokompos interaction enhances vegetative growth and branching of edamame soybean on Ultisol soils. *Indonesian Journal of Sustainable Agriculture*, 8(2): 89-99.
37. Rahmadani, D., Lubis, E., and Siregar, N., 2024. Application of rice husk biochar to improve edamame pod formation and yield on Ultisol soil. *Jurnal Tanah dan Lingkungan Tropika*, 8(1): 55-64.
38. Liang, C., Zhang, W., and Xu, J., 2021. Synergistic effects of biochar and organic fertilizer on soil fertility and crop productivity: A meta-analysis. *Agriculture, Ecosystems & Environment*, 319: 107573. <https://doi.org/10.1016/j.agee.2021.107573>
39. Maulana, F., Sutarta, E.S., and Hanafiah, D.S., 2022. Combined application of biochar and Trichoderma compost improves soybean growth and yield in acidic soils. *Jurnal Agroekoteknologi Tropika*, 11(3): 189-198.
40. Sitorus, E., Tarigan, R., and Nasution, Y., 2023. Interaction of rice husk biochar and Trichokompos in improving soil structure and yield of edamame soybean. *Indonesian Journal of Sustainable Agriculture*, 8(2): 72-81.
41. Rini, E.A., Puspita, D., and Kurniawan, I., 2023. Effect of biochar and liquid organic fertilizer on seed filling and yield quality of soybean (*Glycine max* L.) in Ultisol. *Indonesian Journal of Agricultural Research*, 9(2): 67-75.
42. Prasetyo, R., Handoko, A., and Sari, D.P., 2022. Application of Trichoderma-based compost to reduce empty pods and improve seed quality in soybean. *Jurnal Tanah dan Lingkungan Tropika*, 11(2): 95-104.
43. Riyanto, A., and Harahap, S., 2021. Role of Trichoderma compost in improving nutrient balance and reproductive success in soybean. *Agrivita Journal of Agricultural Science*, 43(3): 377-385.
44. Lehmann, J., and Joseph, S., 2015. *Biochar for Environmental Management: Science, Technology and Implementation* (2nd ed.). Routledge.
45. Major, J., Rondon, M., Molina, D., Riha, S.J., and Lehmann, J., 2010. Maize yield and nutrition during 4 years after biochar application to a Colombian

- savanna oxisol. *Plant and Soil*, 333(1–2): 117-128.
<https://doi.org/10.1007/s11104-010-0327-0>
46. Steiner, C., Das, K.C., Garcia, M., Forster, B., and Zech, W., 2017. Charcoal and smoke extract stimulate the soil microbial community in a highly weathered soil. *Pedobiologia*, 51(5–6): 359-366.
<https://doi.org/10.1016/j.pedobi.2007.08.002>
47. Sharfuddin, C., and Mohsin, F., 2020. Role of *Trichoderma* spp. as a biocontrol agent, plant growth promoter and soil health improver. *South Asian Journal of Research in Microbiology*, 6(2): 15-26.
<https://doi.org/10.9734/sajrm/2020/v6i230142>.