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Research Article

Enhancing Sweet Corn Growth and Yield through the Integrated Application of Bioneensis Biofertilizer and Rice Husk Biochar

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Abstract: Sweet corn is an essential agricultural product in Indonesia and contributes to national food security. Consequently, numerous strategies can be implemented to increase the yield of sweet corn, such as intensified fertilization. While organic fertilizers like biofertilizers and biochar have shown potential to enhance crop growth, their combined effects on sweet corn, particularly under Indonesian conditions, are understudied. This study seeks to assess the synergistic impact of biogenesis biofertilizer and rice husk biochar on the growth and production of sweet corn in an Indonesian agroecological context. In this study, two treatment parameters were compromised by the factorial Randomized Block Design (RBD): 1. Bioneensis biofertilizer, which was formulated into four distinct levels. B0 = No Bioneensis Biofertilizer (served as a control), B1 = Bioneensis Biofertilizer 571 kg/ha (10 g/planting holes), B2 = Bioneensis Biofertilizer 1,142 tons/ha (20 g/planting holes), B3 = Bioneensis Biofertilizer 1,713 ton/ha (30 g/planting holes); and 2. The dosage factor of rice husk biochar (P) comprises four values, specifically: P0 = No Biochar (0 kg/plot), P1 = Biochar 5 tonnes/ha (0.5 kg/plot), P2 = Biochar 10 tonnes/ha (1 kg/plot), P3 = Biochar 15 tonnes/ha (1.5 kg/plot). The findings of this research indicate that the use of biogenesis biological fertilizers significantly affects plant height and stem diameter. However, the utilization of this fertilizer does not produce a noticeable effect on leaf quantity, leaf colour, cob weight with husks per sample, cob weight per plot, cob weight without husks per sample, or cob weight without husks per plot. Conversely, the utilization of rice husk biochar markedly affected the growth and yield of sweet corn, including parameters such as plant height, stem diameter, leaf quantity, cob weight with husks per plot and cob weight without husks per plot. Nonetheless, it did not substantially influence leaf colour, cob weight with husks per sample, or cob weight without husks per sample. Hence, this study suggests that integrating biogenesis biofertilizer and rice husk biochar holds promise for improving sweet corn productivity.

Keywords: Sweet Corn, Bioneensis, Biochar Technology, Sustainable Agriculture Systems

Introduction

The use of inorganic fertilizers can enhance the productivity of sweet corn fields, but it cannot maintain soil fertility over time (Bilong *et al*., 2022; Enesi *et al*., 2022). The persistent application of inorganic fertilizers without appropriate dosage can result in soil fertility degradation and alterations in the physical, chemical and biological aspects of the soil (Ilahi *et al*., 2020; Kumar Bhatt *et al*., 2019). Plant productivity is decreased as a result of the soil's decreased capacity to absorb water and increased acidity. Therefore, organic fertilizers may be employed as an alternative method to enhance soil fertility and nutrient availability.

Organic fertilizer employs microorganisms that supply nutrients and promote plant growth by effectively capturing atmospheric nitrogen and enhancing phosphorus availability in the soil (Abass Hussein, 2021; Daniel *et al*., 2022). In particular, potassium, nitrogen, and phosphorus are essential for sweet corn plants to yield good crops. The integration of organic elements like manure, compost and biochar technology increases soil carbon and nitrogen levels, boosts soil biological activity and improves crop yield (Abass Hussein, 2021; Daniel *et al*., 2022; Sanchez-Monedero *et al*., 2018). Plant growth and soil fertility are contingent upon the quantity of organic matter in the soil, which can be enhanced through the application of manure, compost and biochar. Reducing the decomposition rate can also be achieved with cover crops through the provision of organic matter that decomposes at a slower rate (Adetunji *et al*., 2020; Koudahe *et al*., 2022). However, the amount of organic matter that is applied to the soil is restricted in humid tropical regions like Indonesia (Jantamenchai *et al*., 2022; Mendham & White, 2019; Minasny *et al*., 2020). Organic matter, when incorporated into the soil, undergoes rapid decomposition and necessitates reapplication each growing season to maintain soil fertility and productivity.

Bioneensis is a biological fertilizer that can be used to improve nutrient deficiencies in the soil. Bioneensis biological fertilizer contains microorganisms that act as decomposers of soil organic matter, enhancing nutrient availability for plants (Ahmed *et al*., 2023). It will result in good plant growth and yields. Bioneensis biological fertilizer contains a variety of microorganisms, including bacteria that make indole acetic acid, Bacillus species, Pseudomonas species, Azospirillium species and Azotobacter species. Bioneensis is a biological fertilizer resulting from innovative research by PPKS researchers, which has many benefits, one of which is its role in increasing the production of plantation crops and horticultural crops (Sari Lubis & Napitupulu, 2023). When compared to applying only chemical fertilizer, the use of bioneensis promotes the growth of corn plants and results in 30-50% more corn dry biomass (PPKS, 2019).

In addition, the application of "biochar," or charcoal produced from organic sources, to the soil can enhance soil fertility and crop yields (Diatta *et al*., 2020; Kapoor *et al*., 2022; Singh Yadav *et al*., 2023). In agriculture, biochar has long been recognized as a tool for boosting soil productivity. Pyrolysis is the process by which biochar is generated. This process involves the thermal decomposition of organic materials, including wood chips, leaf litter and decayed vegetation, in an oxygen-deficient environment. Plant growth is facilitated by biochar's high Cation Exchange Capacity (CEC), which allows it to hold onto soil cations (Alkharabsheh *et al*., 2021; Allohverdi *et al*., 2021; Singh Yadav *et al*., 2023). Apart from that, biochar is intended to enhance soil fertility and retain moisture in the soil (Nepal *et al*., 2023). A benefit of integrating charcoal into the soil is its capacity to improve water and air circulation within the substrate (Johan *et al*., 2021). These soil amendments can affect soil aggregates, affecting plant growth and yield.

While organic fertilizers and biochar have shown promise, numerous studies have typically demonstrated the individual benefits of these materials in various agricultural contexts. The specific conditions of Indonesia, such as its tropical climate, soil types and prevalent farming practices, also introduce unique aspects that require further investigation. This gap in knowledge emphasizes the need for a comprehensive investigation to assess the complementary impacts of biochar and organic fertilizers on the development, yield and quality of sweet corn in Indonesian settings. Consequently, this investigation endeavours to address this knowledge gap by evaluating the cumulative impact of these organic inputs on sweet corn. This investigation offers a novel approach because it delves into the unique properties of these two inputs and their potential interactions in promoting sweet corn growth and development in Indonesia. The findings will provide valuable insights into optimizing organic input management for corn farmers, which enables them to enhance crop productivity, protect the environment and improve their livelihoods. Ultimately, this study is expected to contribute significantly to sustainable agriculture.

Materials and Methods

This current study took place in Barung Kersap Village, Munte District, Karo Regency, North Sumatra. It is located between 716 and 1,242 meters above sea level. The study was conducted between January and April of 2024. Some of the tools needed in this research include:

1) Hoe which functions for tilling the land
2) Measuring Tape
3) Machete as a cutter
4) Rakes which function for cleaning weeds
5) Watering can
6) Scales as a tool for measuring weight
7) Pyrolysis Tubes as a medium for biochar production
8) Lighter as an ignition source
9) Ruler and
10) Report Book

Moreover, the materials used in the research are:

1) Bonanza F1
2) Sweet corn seeds
3) Bioneensis biological fertilizer
4) Rice husks
5) Water
6) Soil
7) Plastic samples
8) White paper label stickers

A factorial Randomized Block Design (RBD) approach with two treatment components was used in this study: (1) Bioneensis biofertilizer had four levels: B0 = No Bioneensis Biofertilizer (0 kg/plot), B1 = Bioneensis Biofertilizer 571 kg/ha (10 g/planting hole), B2 = Bioneensis Biofertilizer 1,142 tons/ha (20 g/planting hole), B3 = Bioneensis Biofertilizer 1,713 tons/ha (30 g/planting hole); and (2) There are four levels in the dosage component of rice husk biochar (P) as well: P0 = No Biochar (0 kg/plot), P1 = Biochar 5 tonnes/ha (0.5 kg/plot), P2 = Biochar 10 tonnes/ ha (1 kg/plot), P3 = Biochar 15 tonnes/ha (1.5 kg/plot). Based on the quantity of treatment used, it is obtained 4'4 = 16. The following illustrates the mix of treatments.

A factorial Randomized Block Design (RBD) was employed to replicate each treatment in accordance with the minimum repetition calculation from these 16 combinations, using the following formula:

(t-1) (r-1)	≥	15
(16-1) (r-1)	≥	15
15 (r-1)	≥	15
15r-15	≥	15
15r	≥	15+15
15r	≥	30
r	≥	30/15 = 2
r	≥	2 Repetitions

Details

Repetitions performed: 2 Repetitions
Quantity of research plots: 32 Plot
Dimensions of research plot: 100'210
Distance between plots: 50 cm
Distance between repetitions: 100 cm
Sweet corn planting distance: 70'25 cm
Total plants in each plot: 12 Plants
Quantity of samples per plot: 5 Plants
Total quantity of plants: 384 Plants
Total quantity of sample plants: 160 Plants

Table 1 illustrates the sixteen treatment combinations used in the experiment. Each cell in the table represents a unique combination of Bioneensis biofertilizer (B) and rice husk biochar (P) dosages.

Table 1: Synergistic effects of bioneensis biofertilizer application and rice husk biochar dosage

B0P0	B1P0	B2P0	B3P0
B0P1	B1P1	B2P1	B3P1
B0P2	B1P2	B2P2	B3P2
B0P3	B1P3	B2P3	B3P3

The notation "B#P#" indicates the specific levels used for each treatment. For example:

1. B0P0: Represents the control group with no Bioneensis biofertilizer and no rice husk biochar
2. B1P0: Represents the treatment with 571 kg/ha of Bioneensis biofertilizer and no rice husk biochar
3. B0P1: Represents the treatment with no Bioneensis biofertilizer and 5 tonnes/ha of rice husk biochar
4. B2P2: Represents the treatment with 1,142 tons/ha of Bioneensis biofertilizer and 10 tonnes/ha of rice husk biochar

By using this table, researchers can easily identify and compare the effects of different combinations of Bioneensis biofertilizer and rice husk biochar on the growth and yield of sweet corn.

Research Design

This research began with making biochar from 120 kg of rice husk. The procedure was executed in two phases: The raw material's carbonation and the activation process. Rice husks were initially sun-dried for three days to diminish their moisture content, facilitating the production process. A pyrolysis tube, modified for high-temperature combustion or carbonation processes, was utilized to perform the carbonation of raw materials (Rice Husks). The duration of this process was two hours. Subsequently, the procedure continued with sorting (Selecting) the ingredients that had completely turned into charcoal. Hydrochloric acid (HCl) at a 10% concentration was then used to complete the activation procedure. After soaking for a full day, the charcoal was then rinsed with distilled water or clean running water until it reached a neutral pH. The next step was draining and drying the charcoal under the sun, followed by grinding the charcoal using a mortar and filtering with a sieve measuring ±20 mesh that could pass biochar particles. Afterwards, rice husk biochar was generated by milling the activated rice husk charcoal.

Subsequently, land preparation was carried out by clearing the land of weeds, twigs, woody plants and other unwanted plants. After that, plot measurements were taken with dimensions of 100'210 cm; plot measurements were made with the following dimensions: 100'210 cm, 30 cm for plot height, 50 cm for sub-plots, 100 cm for major plots and 150 cm between repeats. One day after land preparation, the next step was to apply basic fertilizer. Basic fertilizer was provided by making a hole right next to the seed site in a row of plants with a distance of 7-10 cm and a depth of 3 cm. The basic fertilizer dose used during the research was 50% of the recommendation, and if calculated in a plot measuring 100'210 cm, then the basic fertilizer dose given was Urea 45.67 g/plot, TSP 35.17 g/plot and KCL as much as 26.25 g/plot. This basic fertilization aimed to provide sweet corn seeds with sufficient nutrients to develop.

Bioneensis biofertilizer and rice husk biochar were administered when planting sweet corn by creating a circular hole about ten centimetres away from the planting hole according to the level of treatment. It was then sprinkled around the hole that had been made. After that, the hole was closed again using soil. Next, the Bonanza F1 variety of sweet corn was planted. The seeds were selected by soaking them in water for fifteen minutes prior to sowing. There was no utilization of the seeds that were suspended above the water. Later on, each hole was filled with two seeds to a depth of 3 cm. It was done to minimize seeds that failed to grow. This planting was carried out with a spacing of 70'25 cm.

Furthermore, plant maintenance was carried out in several ways, such as watering, clearing, replanting, thinning space between sprouts and controlling pests and diseases. Watering was carried out at intervals of 2 times a day, in the morning starting at 08.00-09.00 AM and in the afternoon starting at 04.00-05.00 PM. Plants were watered every day except when it rained. The clearing was done once a week, starting one week after planting. The clearing was only done in the space between sub-plots, the space between the main plot and the space between replications. Then, replanting and thinning between sprouts was also done one week after the planting period. Replanting was carried out if sweet corn seeds failed to grow and were replaced with sprouts taken from the addition plot. On the other hand, thinning is carried out in holes where all the seeds have grown, so only one sprout is retained, which meets the same plant criteria as other plants for good corn growth. Ultimately, pest and disease control were carried out manually by handpicking. It is because the pests that infected sweet corn plants of the Bonanza F1 variety at the time of the research were leaf-eating caterpillars, namely.

Spodoptera frugiferda and Spodoptera litura

Lastly, harvesting was done when the corn looked ready to harvest, as indicated by the leaves that were starting to dry (Yellowish Husks and Brown Cob Hairs) and the cobs were completely full. Harvesting was done by breaking corn cobs. The harvest results were then observed by paying attention to the cob weight with husks per sample and per plot, as well as the cob weight without husks per sample and per plot. Additionally, the investigation encompassed numerous variables, including leaf count, leaf colour, stem diameter and plant height. Each of these tasks was executed at a one-week interval beginning two weeks after the planting.

Data Analysis

Data analysis will be conducted using a Factorial Randomized Group Design (RGD) following the acquisition of research data. Additional testing will be performed with the Duncan distance measure if the findings of this research yield a significant effect (Montgomery, 2009; Pane *et al*., 2023).

Results

Plant Height

The results of the analysis concerning the height growth differences of sweet corn plants resulting from the application of Bioneensis and rice husk biochar are displayed in Table (2).

Table (2) indicates that the application of bioneensis did not show a real effect at 2 WAP until 5 WAP but had a very real influence at 6 WAP on plant height growth. Similarly, the incorporation of rice husk biochar significantly influenced outcomes at 6 WAP but did not exhibit any notable effects from 2-5 WAP. The combined treatment of bioneensis and rice husk biochar exhibited no significant effect from 2 WAP to 5 WAP but demonstrated a pronounced influence on plant height growth at 6 WAP.

Field observations indicated that the application of 20 grams of bioneensis per planting hole (B2) resulted in a statistically significant enhancement in the height growth of sweet corn plants at 6 WAP, with a confidence level of 99%. The soil analysis conducted at the PPKS Laboratory indicates an N content of 0.24%, Organic C 1.02%, P_2O5 9.21 ppm and K_2O 0.18%. The results of the study also suggest that the addition of 10 tons/ha (P2) of rice husk biochar resulted in a highly significant difference in comparison to treatments P1 and P3, but it did not significantly differ from treatment P0. The P2 treatment showed increased soil organic carbon, as revealed by the PPKS laboratory analysis, the biochar's organic C content was 10.12%. Moreover, a significant difference in the height growth of sweet corn plants was seen when bioneensis was coupled with rice husk biochar. The combo treatment of B2 and P0 markedly differs from, with a confidence level of 99%.

Table 2: Growth results for plant height from 2-6 Weeks After Planting (WAP) provision of bioneensis and rice husk biochar

SK	Measurement of plant height at 2 weeks after planting 6 weeks after planting									
	2 WAP		3 WAP		4 WAP		5 WAP		6 WAP	
B	2.74	nr	0.72	nr	0.43	nr	1.21	nr	15.69	**
P	0.34	nr	0.88	nr	0.94	nr	1.87	nr	20.19	**
BP	0.82	nr	1.77	nr	0.98	nr	1.80	nr	24.94	**

Note: NR = Not Real, ** = very real at the 99% level. WAP = Week After Planting

Stem Diameter

The results of the investigation into the variations in sweet corn stem diameter development caused by the application of rice husk charcoal and Bioneensis are displayed in Table (3).

Table (3) displays the identical results for plant height growth. The incorporation of rice husk biochar, bioneensis biofertilizer and their combination did not exhibit a significant effect from 2 WAP to 5 MST, but it did have a highly significant effect at 6 WAP. Additionally, the observational data indicated that treatment B1 exhibited a highly significant difference from treatments B2 and B3, although it showed a minimal difference from treatment B0. In addition, the rice husk biochar treatment P2 showed noticeably different results from the other treatments. For the combination treatment of bioneensis biofertilizer and rice.

husk biochar, the P1B2 combination treatment showed a very significant difference from the other treatments but was not much different from the B3P2, B2P0, B0P1, B0P2 treatments. The soil analysis in this investigation contained 9.21% phosphorus.

Leaf Quantity

The effects of applying rice husk biochar and Bioneensis on the quantity of leaves on sweet corn plants are compiled in Table (4).

The table suggests that the leaf count of corn plants did not experience a substantial change from 2 WAP to 6 WAP as a result of the application of bioneensis biological fertilizer. Furthermore, the administration of rice husk biochar did not exhibit a tangible impact between 2 and 5 WAP; however, it had a substantial impact at 6 WAP.

Then, at the age of 5 to 6 WAP, the combination treatment of rice husk biochar and bioneensis biofertilizer demonstrated a very noticeable impact. Conversely, sweet corn plants' leaf development did not significantly change between treatments when bioneensis fertilizer was applied. In comparison to alternative treatments, the application of rice husk biochar, specifically the P3 treatment, exhibited a significant alteration at a 95% confidence level. In addition, the combination of biofertilizer and rice husk biochar treatments showed a very significant difference at 6 WAP. The B1P2 treatment combination showed a very significant difference from the other treatments but was not much different from the B0P3, B3P0 and B2P1 treatment combinations.

Leaves Color

The results of the analysis of variations in sweet corn leaf colour growth due to the application of Bioneensis and rice husk biochar are presented in Table (5).

According to the information in Table (5), there was no discernible difference between 2 WAP and 6 WAP when biogenesis biofertilizer, rice husk biochar and their combination were used. In all observation week ranges, the utilization of bioneensis biological fertilizer did not exhibit any appreciable variations across the treatments.

Table 3: Growth results for plant stem diameter from 2-6 Weeks After Planting (WAP) provision of bioneensis and rice husk biochar

SK	Measurement of stem diameter at 2 weeks after planting and 6 weeks after planting									
	2 WAP		3 WAP		4 WAP		5 WAP		6 WAP	
B	0.16	nr	1.93	nr	0.30	nr	1.32	nr	19.44	**
P	1.26	nr	0.33	nr	0.27	nr	0.45	nr	23.02	**
BP	0.87	nr	0.47	nr	1.46	nr	2.70	nr	22.01	**

Note: NR = Not Real, ** = very real at the 99% level. WAP = Week After Planting

Table 4: Growth results for leaves from 2 to 6 Weeks After Planting (WAP) provision of bioneensis and rice husk biochar

SK	Measurement of leaf quantity at 2 weeks after planting - 6 weeks after planting									
	2 WAP		3 WAP		4 WAP		5 WAP		6 WAP	
B	0.30	nr	0.44	nr	0.23	nr	1.15	nr	1.56	**
P	2.14	nr	1.39	nr	0.78	nr	2.50	nr	3.33	**
BP	0.24	nr	1.28	nr	0.45	nr	4.29	nr	4.80	**

Note: NR = Not Real, ** = very real at the 99% level. WAP = Week After Planting

Table 5: Leaf colour changes observed between 2 and 6 weeks after planting with bioneensis and rice husk biochar treatments

SK	Measurement of leaf colour changes 2 weeks after planting - 6 weeks after planting									
	2 WAP		3 WAP		4 WAP		5 WAP		6 WAP	
B	0.55	nr	0.42	nr	0.80	nr	0.99	nr	0.46	**
P	0.23	nr	2.70	nr	0.63	nr	2.23	nr	0.90	**
BP	2.03	nr	1.72	nr	1.77	nr	1.16	nr	0.77	**

Note: nr = not real, ** = very real at the 99% level. WAP = Week After Planting

The soil analysis results from the PPKS laboratory indicated that the nitrogen content was merely 0.24%. Moreover, in all observations, the incorporation of rice husk biochar did not reveal any appreciable variations in the colour of the leaves of sweet corn plants. The total of N elements in rice husk biochar is only 2.88%.

Cob Weight with Husk Per Sample

The impact of Bioneensis and rice husk biochar treatments on the variation in cob weight (including husks) of sweet corn samples is summarized in Table (6).

According to the table, using rice husk biochar, bioneensis biofertilizer, or both had no discernible effects on the weight of cobs with husks per sample. Upon the application of bioneensis biological fertilizer, there were no significant differences in the weight of cobs with husks per sweet corn sample among the various treatments. The analysis conducted in the PPKS laboratory indicates that the K2O element is present at a concentration of only 0.18%. Also, when rice husk biochar was used, there were no discernible variations in the weight of cobs with husks per sample across treatments. The K_2O content of rice husk biochar is only 1.23%.

Cob Weight with Husk Per Plot

The effects of Bioneensis and rice husk biochar on sweet corn cob weight with husks are shown in Table (7).

According to the data in the table, the weight of cobs with husks per plot was not significantly affected by the application of bioneensis biofertilizer or its combination with rice husk biochar. However, there was a noticeable difference in the weight of cobs with husks per plot when rice husk biochar was used. The application of bioneensis biological fertilizer did not significantly alter the weight of cobs with husks per sample across treatments. In contrast, the application of rice husk biochar resulted in significant differences in each treatment. In comparison to the other treatments, the rice husk treatment at P1 demonstrated a significant difference with a 95% confidence level.

Cob Weight without Husk Per Sample

The impact of Bioneensis and rice husk biochar treatments on the weight of sweet corn cobs (excluding husks) is summarized in Table (8).

Table 6: Results of cob weight with husk per sample due to provision of bioneensis and rice husk biochar

SK	Calculation of cob weight with husk per sample	
B	0.65	nr
P	0.40	nr
BP	0.51	nr

Note: NR = Not Real

Table 7: Results of cob weight with husk per plot due to provision of bioneensis and rice husk biochar

SK	Calculation of cob weight with husk per plot	
B	0.64	nr
P	4.10	*
BP	1.35	nr

Note: NR = Not Real, * = real at the 95% level

Table 8: Results of cob weight without husk per sample due to provision of bioneensis and rice husk biochar

SK	Calculation of cob weight without husk per sample	
B	0.34	nr
P	1.73	nr
BP	1.33	nr

Note: NR = Not Real

Based on the table, just like the cob weight with husk per sample, there was no discernible difference in the weight of cobs without husks per sample when bioneensis biofertilizer, rice husk biochar, or a combination of the two were applied. The testing conducted at the PPKS laboratory indicated that the K_2O element was present at a concentration of only 0.18%. The cob weight per sweet corn sample without husk did not significantly change with the application of bioneensis biofertilizer in any treatment. Subsequently, the application of rice husk biochar did not result in a significant change in the weight of cobs without husks per sample.

Cob Weight without Husk Per Plot

The impact of Bioneensis biochar and rice husk applications on sweet corn cob weight (excluding husks) is summarized in Table (9).

Similar to the previous results, the aforementioned table demonstrates that the weight of cobs without husks per plot was not significantly impacted by the use of biogenesis biofertilizer or a combination of biogenesis biofertilizer and rice husk biochar. However, the weight of cobs without husks per plot was impacted by the use of rice husk biochar itself. When bioneensis biofertilizer was applied, there were no appreciable variations in cob weight per plot without husk between treatments. Lastly, applying rice husk biochar caused a considerable variation in the weight of cobs without husks per plot. At a confidence level of 95%, the treatment P1 of rice husk biochar demonstrated a substantial difference from the other treatments.

Table 9: Results of cob weight without husk per plot due to provision of bioneensis and rice husk biochar

SK	Calculation of cob weight without husk per plot	
B	0.64	nr
P	4.10	*
BP	1.35	nr

Note: NR = Not Real, * = real at the 95% level

Discussion

The application of both bioneensis and rice husk biochar demonstrated a delayed but significant impact on plant height, noticeable at 6 WAP. It is because bioneensis is a biological fertilizer, so microorganisms need time to penetrate plant roots (Fertahi *et al*., 2021; Verma *et al*., 2020). Dias Santos *et al*. (2023) further emphasize this point, explaining that the microorganisms in bioneensis fertilizer need time to penetrate plant roots to help absorb nutrients. Similarly, Kapoor *et al*. (2022) also clarify that biochar needs time to improve the soil fertility. Consequently, the delayed effects of both treatments are attributed to the inherent time needed for biological and organic processes to influence plant growth.

At 6 WAP, significant enhancements in plant height were observed with specific treatments: 20 grams of Bioneensis per planting hole (B2), 10 tons/ha of rice husk biochar (P2), and the combined treatment of B2 and P0. These improvements are attributed to rhizobacteria in Bioneensis aiding nutrient absorption, as indicated by soil analysis. This suggest that the applied Bioneensis effectively augmented the available nutrients. It is consistent with the assertions made by Dias Santos *et al*. (2023). Wang *et al*. (2024a) also stated that the application of bioneensis biological fertilizer made from active ingredients from living organisms' functions to fix N nutrients, making it available to plants. Increasing plant access to nutrients, such as via arbuscular mycorrhizal fungi, dissolution by phosphate solubilizing microbes, or decomposition by fungi, actinomycetes or earthworms, can help make these nutrients more available (Adewara *et al*., 2024). It is also influenced by the increased soil organic carbon from biochar. Study by Rahayu *et al*. (2022) claimed that the soil's organic C content increased with increasing biochar dosage. Taisa *et al*. (2019) and Lumbantobing *et al*. (2020) have also shown that biochar application to ultisol soil can raise organic C- hence boosting corn plant development.

Subsequently, synergistic effect of the B2P0 combination further underscores the complementary roles of these treatments in maximizing plant growth. This result is attributed to the effective role of biological fertilizer and rice husk biochar in the soil (Mon *et al*., 2024). Both Bioneensis and rice husk biochar facilitate the absorption of nutrients from the soil. This validates the results of studies by Ndoung *et al*. (2021) and Shirzad *et al*. (2024), which found that giving sweet corn plants a soil amendment of biochar enhanced with biological fertilizer will maximize their growth.

Similarly, the effects of Bioneensis biofertilizer, rice husk biochar, and their combination on stem diameter were delayed, becoming significant at 6 WAP. Once again, this delay is attributed to the time required for Bioneensis microbes to penetrate roots and enhance nutrient absorption. As Dwipa *et al*. (2019) explained, the microorganisms in Bioneensis need time to establish

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themselves in the roots to assist with nutrient uptake and hormone production. In this way, soil that was previously poor in nutrients becomes richer. Notably, treatment B1 showed a highly significant difference in stem diameter. This is likely because the IAA produced by rhizobacteria. They provide differences in each treatment due to the number of colonies (Alemneh *et al*., 2022; Ganesh *et al*., 2024). Dwipa *et al*. (2019), demonstrated that the interaction of manure with rhizobacteria isolates had no effect on the IAA level of red potatoes, suggesting that the IAA production is not affected by the concurrent application of rhizobacteria and manure. The ability of rhizobacteria to establish colonies in the rhizosphere is necessary for their generation of IAA (Bhadrecha *et al*., 2023). Rhizobacteria's capacity to produce growth hormones, including gibberellin, indole acetate and indole butyric acid I, is directly linked to their capacity to boost the weight of plants and the crop's yield (Sun *et al*., 2024).

There was also a noticeable difference in stem diameter with rice husk biochar. This is because biochar, which is amphoteric, contains carboxyl groups that behave acidically and amino groups that behave wetly (depending on soil conditions) can be positively or negatively charged (Sarma *et al*., 2024). It is in line with the opinion of Barlow and Raval (2008) that aminos change form to anions in wet environments, and in acidic environments, they change to cation forms. On the other hand, the outcome in combination of P1B2 treatment is attributed to the high phosphorus level in the soil, as indicated by the soil analysis, which enhances the growth of sweet corn plants (McDowell *et al*., 2024). Phosphorus contributes to the development of seeds, roots, blooms and fruit (Grzebisz *et al*., 2024). The impact on the roots enhances the root architecture, hence facilitating improved absorption of plant nutrients (Khan *et al*., 2023).

In contrast to stem diameter, the leaf quantity of corn plants did not show substantial changes from 2 WAP to 6 WAP with Bioneensis, suggesting its limited immediate effect. This is because the microorganisms in biogenesis fertilizer require sufficient nutrients so that the microorganisms can absorb more nutrients. This validates the results of Dwipa *et al*. (2019) and Puspitasari *et al*. (2022), who claimed that the microorganisms in bioneensis biofertilizer would work optimally if the soil conditions contained the nutrients available in it. Biochar, however, showed a real influence at 6 WAP, attributed to its ability to improve degraded soil conditions over time (Guo *et al*., 2020; KC & Mahat, 2024). This is consistent with the claims made by Das *et al*. (2021) and Qi *et al*. (2024) that biochar is an organic soil improvement so that degraded soil conditions can be improved. Apart from that, biochar is a material that has a high organic C content that will maximize nutrient absorption so that nutrients are not easily lost due to the washing and evaporation of rainwater (Zhao *et al*., 2022; Zhou *et al*., 2020).

Subsequently, the lack of significant change in leaf development with Bioneensis despite significant changes with biochar is attributed to the limited soil nutrient content. The findings indicate that the effective functioning of biological fertilizer in nutrient fixation is hindered by a lack of soil nutrient content. Available nutrients are those that can be assimilated by plants; in the absence of nutrients, plant growth would be impeded (Brown *et al*., 2022). It reinforces the study by Hidayatullah *et al*. (2018) and Husna *et al*. (2023), who stated that bioneensis biofertilizer would not work optimally if the soil lacked nutrients.

Nonetheless, the significant alteration observed with the P3 treatment of rice husk biochar, as compared to alternative treatments. The elevated organic C content in rice husk biochar is likely responsible for this outcome, as it affects the soil's high CEC and reduces nutrient loss during fertilization (Wachira *et al*., 2024). These findings correspond with the viewpoint of Safaa *et al*. (2024), Aprile and Lorandi (2012), and Jarecki *et al*. (2005), who stated that high levels of organic C in the soil would be followed by an increase in the CEC value. This is because soil containing organic C generally contains organic colloids, which are able to increase cations (Ye *et al*., 2024). It proves that giving biochar can increase CEC after incubation for 21 days. CEC increases along with increasing soil Organic C content (Rehman *et al*., 2021). At last, the B1P2 combination treatment showed a very significant difference at 6 WAP. Bioneensis fertilizer contains rhizobacteria capable of synthesizing the hormone IAA, hence contributing to enhanced plant development (de Andrade *et al*., 2023; Harahap *et al*., 2022). This result supports the assertion made by Dwipa *et al*. (2019) that the ability of rhizobacteria to establish colonies in the rhizosphere is a prerequisite for their production of IAA (Silva *et al*., 2020; Khatun *et al*., 2021). The ability of rhizobacteria to increase plant growth and yield is intimately linked to their capacity to generate growth hormones, such as gibberellin, indole acetate and indole butyric acid (Ajinde *et al*., 2024).

Similar to leaf quantity, the observation revealed no discernible difference in leaf color between 2 WAP and 6 WAP when Bioneensis biofertilizer, rice husk biochar, and their combination were used. This is most likely because these treatments lack the N element crucial for enhancing leaf chlorophyll so that they can produce more photosynthate (Fathi, 2022; Shah *et al*., 2024; Zhang *et al*., 2024; Zhu *et al*., 2024). In plants, this element is involved in the formation of cells and tissues, including roots, stems, leaves and the initial development of blossoms (Wang *et al*., 2024). With the presence of nitrogen, leaves will carry out their function well in the photosynthesis process (Xin *et al*., 2024). Perfect photosynthesis will have an impact on leaf growth; the number of leaves will be greater, the leaves will become wider, and the leaves will look shiny (Ahmad *et al*., 2022; Pessarakli, 2024). Consequently, applying fertilizer containing N below optimal will reduce the quality of leaf colour (Singh *et al*., 2021). A lack of the element N will cause plant leaves to turn yellow and will reduce the results of plant photosynthesis (Brekalo *et al*., 2024; Zewide and Sherefu, 2021). Charcoal typically lacks the N element which is required to improve plant leaf color, thus the application of bioneensis biofertilizer and biochar did not have a significant impact (Bhatt & Kunal, 2024; Dubey & Ojha, 2024).

Moving from leaf color to cob weight, the use of rice husk biochar, Bioneensis biofertilizer, or their combination had no discernible effects on the weight of cobs with husks per sample. This is because there is no additional support for plant production, such as the need for fertilizer in this research. Providing additional fertilizer is very necessary for plants when they enter the generative phase so that the plants can produce maximum fruit (Soetriono *et al*., 2023). This corresponds with research by Singh *et al*. (2014) and Szulc *et al*. (2023), who stated that it is essential to fertilize plants before they enter the generative phase. The fertilizer treated is K fertilizer, which is responsible for facilitating the transit of assimilation from leaves to fruit (Daoud *et al*., 2020). The low K2O content in the soil and biochar, as indicated by the PPKS laboratory analysis, further hindered the translocation of assimilates to corn cobs. The K2O element plays a role in the translocation of assimilates produced by leaves to corn cobs (Peng *et al*., 2023). If the K2O element is not sufficient, it will inhibit the translocation of assimilate in corn (Kumar *et al*., 2020). Additionally, it may result in a less-than-ideal function for the biological fertilizer bioneensis in aiding soil nitrogen absorption.

In the same way, the weight of cobs with husks per plot was not significantly affected by the application of Bioneensis biofertilizer or its combination with rice husk biochar. This is thought to be due to low microbial respiration in biological fertilizers, which is contingent upon the soil's nutrient composition (Wang *et al*., 2023). Kotroczó and Fekete (2020) stated that soil respiration can produce quantitative biological activity in the soil and soil microbial populations. An increase in CO_2 levels from the final results of soil respiration analysis indicates a corresponding rise in microbial activity within the soil (Kuzyakov *et al*., 2019). However, biochar alone resulted in significant differences in cob weight per plot in each treatment. The incorporation of organic material into the soil enhances its quality, thereby promoting improved vegetative growth in plants (Hidayat *et al*., 2024). Good vegetative plant growth will have an impact on sweet corn production. This is consistent with the study conducted by Wei *et al*. (2024), who indicated that the soil structure that is created by the microorganisms in fertilizer improves soil structure and water retention. Biochar has advantages compared to other organic materials, namely that it is more persistent in the soil so that all benefits related to increasing soil fertility can be utilized more optimally; meanwhile, organic fertilizer decomposes and releases gas in the form of methane (Samoraj *et al*., 2022). These biochar properties give it a high nutrient retention capacity so that it can reduce nutrient leakage (Tang *et al*., 2023).

In case of cob weight without husk per sample, there was no discernible difference when Bioneensis biofertilizer, rice husk biochar, or a combination of the two were applied. Again, it is attributed to the low K2O content in the soil as it prevents photosynthetic compounds from moving from the corn plants' to their corn cobs (Qin *et al*., 2024; Xu *et al*., 2023). It prevented bioneensis biological fertilizer from playing its best role in promoting soil nutrient absorption. This aligns with the findings of Singh *et al*. (2014) and Cakmak and Rengel (2024), who indicated that potassium is essential for regulating stomatal opening and closing as well as for enabling the flow of assimilates from the source (leaves) to the storage structures (sinks). Biochar's primary role in enhancing soil conditions and nutrient absorption, rather than direct nutrient supply, further explains the lack of impact as noted by Chen *et al*. (2021), Khan *et al*. (2024), and Ng *et al*., 2024. Cob weight without husks per plot also showed no appreciable variations with Bioneensis. It was believed to be due to low microbial respiration of the biofertilizer, which was influenced by the nutrients contained within the soil (Sinha *et al*., 2024). This is consistent with the opinion of Kotroczó and Fekete (2020), who stated that quantitative soil respiration can indicate the existence of biological activity in the soil and soil microbial populations.

Nevertheless, rice husk biochar caused a considerable variation in the weight of cobs without husks per plot. Specifically, at a confidence level of 95%, the treatment P1 of rice husk biochar demonstrated a substantial difference from the other treatments. This is attributed to its role in improving soil quality and promoting vegetative growth. The quality of the soil is improved by adding organic matter, hence promoting superior vegetative growth in plants (Karlen & Cambardella, 2020; Wen *et al*., 2024). As previously mentioned, biochar's persistence in soil and capacity to enhance nutrient retention and reduce leakage contribute to these beneficial effects.

In summary, the utilization of bioneensis biofertilizer and rice husk biochar significantly influenced specific parameters of sweet corn growth and yield, including plant height, stem diameter and leaf count. Nevertheless, the treatments did not significantly affect the leaves' colour or cob weight. This research advances our knowledge of the effects of various treatments on sweet corn. However, this study has limitations, including its brief duration, absence of data regarding environmental conditions and limited scope of application. Future research could explore long-term effects, environmental impacts and scalable application techniques to support sustainable agriculture.

Conclusion

The utilization of biogenesis biological fertilizer significantly influenced plant height and stem diameter; however, it did not substantially affect leaf quantity, leaf colouration, cob weight with husks per sample and per plot, or cob weight without husks per sample and per plot. Meanwhile, the use of rice husk biochar had a notable impact on sweet corn growth and yield, as measured by plant height, stem diameter, number of leaves and the weight of the cobs with and without husks per plot. However, it had no discernible impact on the colour of the leaves and the weight of the cobs with and without husks per sample. Ultimately, the development of plant height, stem diameter and leaf count were all significantly impacted by the combination of rice husk biochar and bioneensis biofertilizer. Yet, it did not have a meaningful impact on the colour of the leaves, the weight of the cob with husks per sample and per plot, or the weight of the cob without husks per sample and per plot.

This study offers a substantial contribution to the comprehension of the impact of sweet corn growth and yields on the application of biogenesis biofertilizer and rice husk biochar. This research also compares the effects of using bioneensis biofertilizer, rice husk biochar and a combination of both on each component studied. Nevertheless, this research has notable limitations, specifically the brief duration of the study, which spanned merely three months, the lack of data concerning the variability of environmental conditions, and the extensive applicability of this method across diverse soil and climate types. Future study opportunities encompass investigating the long-term effects of bioneensis biofertilizer, rice husk biochar and their combination, as well as their influence on various environmental factors, including greenhouse gas emissions. Additionally, the advancement of techniques applicable on a broader and more efficient scale to promote sustainable agriculture is necessary.

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Rita Hayati and Loso Judijanto: Contributed valuable insights by revising the text, expanding the reference list and making other improvements to strengthen the overall quality of the work.

Ethics

This original article comprises unpublished material. The corresponding author affirms that all co-authors have reviewed and endorsed the work and that there are no ethical concerns present.

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