Sustainable Jack Bean (*Canavalia ensiformis* (L.) DC.) Production through Cocoa Pod Biochar and Effective Microorganism Ratios

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Abstract. Agriculture plays a dual role in climate change, acting both as a source and a potential sink for greenhouse gas emissions. Achieving net zero emissions requires innovative farming practices that not only sustain crop productivity but also enhance carbon sequestration. This study investigates the effects of different rates of biochar (5%, 10%, 15%) and EM (1%, 3%, 5%) on the growth and yield of Jack Bean (*Canavalia ensiformis* (L.) DC.) cultivated in topsoil amended with EFB compost (4:1 ratio). Growth and yield parameters, including plant height, number of leaves, branches, flowers, and pods, were measured. These findings reveal that biochar, particularly at a 10% concentration, significantly improves plant height (up to 177.20 cm), number of leaves (40.03), number of branches (13.00), and number of pods (3.13). These enhancements demonstrate biochar's potential to boost crop yields while simultaneously contributing to carbon sequestration in soil, thereby reducing atmospheric carbon and supporting climate mitigation efforts. Similarly, EM applications, especially at 5%, stimulated vegetative growth, resulting in a significant increase in the number of leaves (39.83), branches (15.30), and flowers (7.93). While EM did not significantly impact pod formation, its marked effect on plant vigor suggests its role in promoting plant health and potentially reducing reliance on synthetic agrochemicals. This aligns with sustainable agricultural practices that aim to minimize the use of energy and application of conventional fertilizers, thereby decreasing greenhouse gas emissions. The results demonstrate that both biochar and EM can serve as valuable amendments in agricultural systems. Integrating these sustainable biological and material inputs represents a promising approach towards achieving higher agricultural output within a net-zero emission framework.

Keywords: Cocoa pod biochar, Effective microorganism, Jack Bean, *Canavalia ensiformis*, Sustainable, Growth and yield.

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1 Introduction

Jack Bean (*Canavalia ensiformis* (L.) DC.) is a leguminous crop that has received relatively little attention in research and agricultural development, as it is often overshadowed by more commercially important crops such as soybean. A study on the physicochemical properties of Jack Bean revealed a protein content of approximately 25.2%, a high carbohydrate level of 58.4%, and a low-fat content of 5.21%.[1]. Despite these benefits, the cultivation of Jack Beans is not widely practiced compared to other legume crops like soybeans or cowpeas. One of the limiting factors is the lack of agronomic research addressing its unique growing requirements. In Malaysia, soybeans are among the primary crops used in the formulation of chicken feed. Due to Malaysia's high temperatures and humidity, the environment is generally unsuitable for soybean cultivation. The optimal temperature range for soybean growth is between 22°C and 35°C, and temperatures exceeding this range can lead to reduced yields [2]. The rising cost of soybeans, a key protein source in chicken feed, has led to higher chicken meat prices.

As a nitrogen-fixing legume, Jack Bean significantly enhances soil fertility and minimizes the reliance on chemical fertilizers. These amendments improve nutrient availability and stimulate microbial activity in the soil, thereby promoting better plant growth and higher yields [3]. Jack Bean is particularly suitable for sustainable farming systems because it demonstrates remarkable adaptability and even flourishes on highly leached, infertile tropical soils, including acidic and degraded conditions [4]. To boost agricultural productivity, biochar plays a crucial role in restoring degraded soils and improving land resistance under conditions of water stress. Biochar, an organic soil enhancer made to improve fertility and increase crop yields, offers a more sustainable and cost-effective alternative to conventional chemical fertilizers. Biochar enhances soil health and sustainability while enabling the production of nutritious crops. Furthermore, biochar's high surface area and cation exchange capacity contribute to improved nutrient availability and retention, which can support the nutrient-demanding growth stages of Jack Bean. Effective Microorganisms (EM) consist of a blend of beneficial microorganisms that enhance both soil health and plant growth. EM facilitates nutrient cycling by breaking down organic matter and converting essential nutrients such as nitrogen (N), phosphorus (P), and potassium (K) into forms readily available for plant uptake [5].

According to [6], the research has highlighted the durability and adaptability of Jack Bean, along with its potential applications in sustainable agriculture, thereby enhancing its possibilities for broader production and utilization. Therefore, highlighting the potential of Jack Bean as an alternative to soybeans in diverse food products, whether for human consumption or as poultry feeds, depending on the processing of the harvest, is in need. The objective of this study was to evaluate the growth performance and yield of Jack Bean under different rates of biochar and effective microorganisms (EM) applied to topsoil amended with EFB compost, with the broader aim of exploring low-emission, sustainable soil management practices that contribute to net-zero agriculture.

2 Materials and Method

2.1 Experimental Site and Crop Establishment

The experiment was conducted in a net-shaded house at the Farm Unit, Universiti Teknologi MARA (UiTM), Sarawak Branch. Prior to planting, seeds of Jack Bean were germinated to select viable and uniform seedlings for 21 days. These seedlings were then transplanted into polybags 16 x 16 inch. The polybags were arranged with a spacing of 60 cm × 40 cm to allow adequate space for plant development. To mitigate the potential effects of intense heat and heavy rain on data collection and processing, the experimental setup was implemented in a sheltered area. Weed control was carried out manually, and watering was performed regularly to maintain optimal soil moisture.

2.2 Experimental Design

The study was arranged using a factorial experiment with two factors within a Completely Randomized Design (CRD) comprising six replicates. Two types of inputs were assessed, which were biochar and EM. Biochar was derived from cocoa pod, and commercial EM (EM-1) was used in this study. Each consisted of three levels represented by percentage, such as control, 5%, 10% and 15% for biochar. EM represented by Control, 1%, 3% and 5% concentrations of EM-1 were prepared as the treatment for this study. The EM solutions must be activated by combining molasses (as a carbon source), EM-1 (the microbial inoculant), and clean water in specific ratios to obtain a total volume of 1 liter per treatment.

2.3 Data Collection and Analysis

Data collection focused on two main categories: growth performance and yield components. Growth parameters included plant height, number of leaves and number of branches were recorded from 2 to 12 weeks after while yield parameters included the number of flowers and number of pods per plant were recorded. All collected data were subjected to statistical analysis using analysis of variance (ANOVA), performed using R Studio software version 4.3.2, to determine the effects of the treatments and their interactions. Where significant differences were detected, Tukey's Honest Significant Difference (HSD) test was used to separate treatment means at the 5% significance level ($p \leq 0.05$).

3 Materials and Method

This study explored the influence of various concentrations of biochar and EM on growth and yield parameters, including plant height, number of leaves, number of branches, number of flowers, and number of pods.

Table 1. The square analysis of variance for the parameters of Jack Bean under different treatments.

SOV	DF	Plant Height	No. of Leaves	No. of Branches	No. of Flowers	No. of Pods
Week	4	359109 ***	8873***	1189***	953.1***	116.27***
Treatment	7	20015***	809***	76.3***	64***	28.81***
Week:Treatment	28	1944***	619***	15.4***	75.5***	3.61***
Residuals	200	92	9	1.8	0.6	0.28

The ANOVA results in Table 1 indicate that plant growth parameters, including plant height, number of leaves, branches, flowers, and pods, were highly significantly influenced by the factor week and treatment, and the interaction between week and treatment ($P < 0.001$). The strong effect of the week highlights the natural progression of plant development over time. The significant treatment effect confirms that both biochar and EM applications had a measurable impact on plant morphology and yield. Furthermore, the highly significant week and treatment interaction demonstrates that the effects of these amendments were not static but varied depending on the specific week of observation, suggesting complex and dynamic responses of the plants to the treatments throughout their growth cycle.

Table 2. The square analysis of variance for the parameters of Jack Bean under different treatments.

Treatment	Plant Height	No. of Leaves	No. of Branches	No. of Flowers	No. of Pods
Biochar					
Control	155.70b	33.13cd	10.70ef	3.17e	1.63c
5%	157.53b	36.00b	11.77cd	4.27d	2.37b
10%	177.20a	40.03a	13.00b	4.67cd	3.13a
%	163.00b	35.20bc	11.73cde	5.13c	2.73ab
Effective Microorganism					
Control	115.53c	25.33f	10.23f	4.43d	0.63d
1%	116.91c	28.17e	11.17def	5.17c	0.83d
3%	116.40c	32.07d	12.57bc	6.47b	0.97d
5%	117.32c	39.83a	15.30a	7.93a	0.83d

The results shown in Table 2 reveal that the effects depend on the type of amendment used and the plant parameter measured. From the results, biochar application generally led to positive and significant improvements across most plant growth parameters, with the 10% concentration often yielding the best results.

The 10% biochar treatment significantly improved plant height (177.20) compared to its control (155.70) and other concentrations. This aligns with research indicating that biochar enhances plant growth, including height, by improving soil physiochemical properties [7],[8],[9]. Similarly, the 10% biochar application resulted in the highest number of leaves (40.03), significantly more than the control (33.13). The increases in leaf production contribute to overall plant biomass and photosynthetic capacity [10], and it also led to a significant increase in the number of branches (13.00) compared to its control (10.70). Enhanced branching can lead to more flowering and fruiting sites. While the 15% biochar showed the highest number of flowers (5.13), the 10% biochar treatment still demonstrated a notable increase (4.67) compared to the control (3.17), indicating that biochar can promote reproductive development. The 10% biochar treatment significantly increased the number of pods (3.13), demonstrating its beneficial impact on final yield compared to the control (1.63).

The consistently positive effects observed at the 10% biochar application rate suggest that this may be the optimal concentration for maximizing its benefits. This improvement is largely due to biochar's ability to enhance soil structure, as its porous nature reduces bulk density, increases porosity and aggregation, and ultimately improves aeration and root penetration [11]. In addition, biochar helps soils retain more water, ensuring that plants have a more reliable moisture supply [11],[12]. It can also adjust soil pH, making essential nutrients more readily available, while providing a favourable habitat for beneficial soil microorganisms that drive nutrient cycling [13]. The improvements can also be attributed to the physicochemical properties of cocoa pod biochar, which enhances soil structure and fertility by soil pH, cation exchange capacity (CEC), and nutrient availability. Cocoa pod husk biochar is typically characterized by a moderately alkaline pH, high CEC, and substantial carbon content. The alkaline nature of the biochar helps neutralize soil acidity, improving nutrient availability, particularly P, K, and Ca, which is important for plant uptake [14]. The high CEC enables greater nutrient retention and exchange, reducing nutrient leaching losses while maintaining a steady nutrient supply to the root zone. Its high carbon content and porous structure contribute to improving soil aggregation, aeration, and water-holding capacity [15],[16]. For legumes, biochar has the added advantage of improving symbiosis with rhizobia, which enhances nitrogen fixation [17]. Biochar stimulates microbial activity by creating a supportive environment for microbial growth, further strengthening nutrient cycling and overall soil health [18].

In contrast to biochar, EM application showed a more selective impact on plant parameters. The results indicate that EM application did not significantly affect plant height across the tested concentrations. Plant heights for all EM treatments (ranging from 115.53 for the control to 117.32 for 5%) were statistically similar. A significant increase in the number of leaves was observed with EM application. The 5% EM concentration resulted in the highest number of leaves (39.83), which was significantly greater than the EM control (25.33). The application of EM also significantly promoted branching. The 5% EM treatment yielded the highest number of branches (15.30), significantly outperforming the EM control (10.23) and other EM concentrations. The 3%

EM treatment also showed a significant increase. The EM application significantly increased the number of flowers. The 5% EM concentration produced the most flowers (7.93), which was statistically superior to all other treatments. The 1% and 3% EM treatments also showed significantly higher flower counts compared to the control (4.43). However, the EM application did not lead to a statistically significant increase in the number of pods. All EM concentrations resulted in almost similar numbers of pods to their respective control.

Effective Microorganisms (EM) are a consortium of beneficial microbes that can improve soil health and plant development [19]. However, their effects on specific growth traits can vary depending on formulation, plant genotype, and environmental conditions [20]. This variability may explain why EM did not significantly influence plant height in this study, as EM may not consistently act as a direct promoter of stem elongation across different systems. The significant increase in leaf number under EM application suggests improved nutrient assimilation and overall plant vigor. Beneficial microorganisms within EM enhance nutrient availability and produce plant growth-regulating substances, which stimulate vegetative development [19],[21]. These mechanisms likely explain the higher leaf counts observed, particularly at 5% concentration. Branching also responded positively to EM, especially at 3% and 5% concentrations. This effect may be attributed to enhanced biological soil activity and improved nitrogen availability, which is crucial for vegetative growth. EM contains microbes such as lactic acid bacteria, photosynthetic bacteria, actinomycetes, and yeast, which can produce auxins and cytokinins that stimulate both apical and lateral bud development [22].

Similar trends have been reported in legumes, where EM significantly increased the number of primary and secondary branches [23]. The improvement in flowering indicates that EM also contributes to reproductive development. Microbial associations in legumes are known to enhance nutrient cycling and soil microbial activity, which promote floral initiation and development [24]. The absence of such microbial partners often restricts nutrient uptake and impairs reproductive physiology. Previous research has shown that beneficial microbes stimulate reproductive traits such as flowering through enhanced nutrient supply and hormonal regulation [19]. Interestingly, while vegetative and floral traits improved, pod number was not significantly affected by EM. This outcome suggests that increased flowering does not necessarily translate into higher pod set. Previous findings confirm that although EM can enhance plant growth and flowering, its effect on yield components such as pods may be inconsistent [25].

4 Conclusion

This study effectively demonstrates the significant potential of both biochar and EM as sustainable amendments to enhance agricultural productivity, aligning directly with global efforts toward net-zero emissions. The findings demonstrate that applying biochar, especially at a 10% concentration, markedly improved essential growth traits of the plants, including height, leaf formation, branching, and pod yield. Concurrently, EM application, especially at 5%, significantly stimulated vegetative growth, leading to a marked increase in the number of leaves, branches, and flowers. While its direct impact on pod production in this study was not statistically significant, the observed promotion of overall plant vigor and health by EM is highly valuable for sustainable agriculture. Encouraging cultivation using sustainable and environmentally friendly practices supports long-term agricultural productivity to reduce reliance on the importation of protein source crops.

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