AGROTECH–FOOD SCIENCE, TECHNOLOGY AND ENVIRONMENT VOL. 2 NO. 1 (2023) P.48-52

AGROTECH
ISSN: 2773-4870 **eISSN:** 2821-3106
DOI: https://doi.org/10.53797/agrotech.v2i1.6.2023

Improving Yield Through Biochar Application in Kailan (*Brassica oleracea* var. alboglabra) Cultivation

Hamidon, Azimah[1]* & Tajidin, Elliza[2]

[1]Faculty of Fisheries and Food Science, University Malaysia Terengganu, 21030, Kuala Terengganu, Terengganu, MALAYSIA

[2]Department of Crop Science, Faculty of Agriculture, Universiti Putra Malaysia, Serdang 43400, Selangor, MALAYSIA

*Corresponding author: azimahhamidon@gmail.com

Received 15 March 2023; Accepted 12 May 2023; Available online 18 June 2023

Abstract: The increasing demand for leafy vegetables in Malaysia necessitates sustainable agricultural innovations to improve soil health and crop yield. This study evaluates the effects of rice husk biochar application at different rates (0, 10, and 20 t/ha) on the growth and yield of Kailan (Brassica oleracea var. alboglabra). A field experiment using randomized complete block design with four replications was conducted, assessing plant height, diameter, number of leaves, fresh weight, and total yield. Results demonstrated significant improvements in all growth parameters and yield with increasing biochar rates. These findings reinforce the potential of biochar as a sustainable amendment for enhancing vegetable production.

Keywords: biochar, kailan, rice husk, sustainable agriculture, vegetable yield, Brassica.

1. Introduction

The rising demand for vegetables, particularly leafy greens, has placed significant pressure on agricultural systems to enhance productivity while maintaining sustainability. In Malaysia, the increasing awareness of health and nutrition has led to greater consumption of vegetables such as Kailan (*Brassica oleracea* var. *alboglabra*), a popular member of the Brassicaceae family known for its high content of vitamins A, C, and K, dietary fiber, and antioxidant compounds (Zainol et al., 2021). As vegetable consumption grows, so does the challenge of ensuring high-yield production without compromising environmental integrity.

Conventional agricultural practices often rely heavily on synthetic fertilizers and intensive land use, which can lead to soil degradation, reduced microbial diversity, and water contamination (Lal, 2020). These issues have prompted researchers and farmers alike to explore more sustainable alternatives for improving soil fertility and crop yields. One such promising solution is the application of biochar, a stable carbon-rich material produced through pyrolysis of organic biomass under limited oxygen conditions (Lehmann & Joseph, 2015).

Biochar has gained attention for its multifunctional role in agriculture. It improves soil structure, increases water retention, enhances cation exchange capacity (CEC), and supports beneficial microbial activity (Glaser et al., 2002; Agegnehu et al., 2017). These properties contribute to improved nutrient use efficiency and reduced leaching of nitrogen and phosphorus. Furthermore, biochar has been reported to act as a liming agent, helping to neutralize soil acidity, which is a common issue in many tropical soils including those in Southeast Asia (El-Naggar et al., 2019). The positive effects of biochar are influenced by its source material and pyrolysis conditions; among the most effective feedstocks in Asia is rice husk, which is abundant, cost-effective, and rich in silica and other beneficial minerals (Milla et al., 2013).

Recent studies have shown that rice husk biochar can significantly improve the growth performance of various crops, including rice, spinach, maize, and leafy vegetables (Vinh et al., 2014; Zhou et al., 2022). However, there remains a gap in literature concerning its application in Kailan cultivation under Malaysian agroecological conditions. Understanding the specific effects of different application rates of biochar on Kailan growth parameters such as plant height, stem diameter, leaf number, and overall yield is essential for developing effective fertilization strategies that align with sustainable agriculture goals.

Therefore, this study aims to assess the impact of rice husk biochar at varying application rates (0, 10, and 20 tons per hectare) on the growth and yield of Kailan. The outcomes of this study are expected to provide insights into

*Corresponding author: azimahhamidon@gmail.com

practical biochar use for enhancing productivity in leafy vegetable cultivation and promoting environmentally sound farming practices in Malaysia.

2. Materials and Methods

2.1 Study Site and Experimental Design

The field experiment was conducted on a cultivated plot measuring 14 m × 17 m. The soil at the site was a sandy loam with moderate fertility and slightly acidic pH (5.8–6.2). Prior to the experiment, the site was plowed, leveled, and raised beds were constructed to improve drainage. The climate during the experimental period was tropical, with average daytime temperatures ranging between 28°C and 33°C and relative humidity between 75% and 85%.

The experiment adopted a Randomized Complete Block Design (RCBD) arranged in a split-plot format with four replications. The main plot factor was biochar application rate, with three treatment levels:

- B_0: Control (0 t/ha)
- B_1: 10 t/ha
- B_2: 20 t/ha

Each replication consisted of three treatment plots, with each plot measuring 3 m × 3 m. A buffer zone of 0.5 m was maintained between plots and replications to prevent treatment interference. The RCBD design was selected to minimize variability due to soil heterogeneity.

2.2 Biochar Preparation and Application

The biochar used in this study was produced from rice husks, collected from a local rice mill. The rice husks were pyrolyzed at a temperature of approximately 400–500°C for 2 hours in a low-oxygen environment using a metal drum kiln. The resulting biochar was allowed to cool, crushed to <5 mm particle size, and sieved to ensure uniformity.
Before incorporation, the biochar was preconditioned by moistening it with water to improve microbial colonization and facilitate mixing with soil. Biochar was applied uniformly by hand and incorporated into the top 15 cm of soil using a hand hoe one week prior to transplanting.

2.3 Crop Establishment and Management

Kailan (*Brassica oleracea* var. *alboglabra*) seedlings were first raised in a nursery using a soil and compost mixture until they reached the appropriate transplanting stage at 21 days after sowing. Transplanting was carried out in the prepared field plots, with each seedling spaced 30 cm apart within rows and 20 cm between rows to ensure adequate growing space and reduce intra-plant competition. Each plot consisted of 50 plants, and only healthy, uniform seedlings were selected for uniformity across treatments. During the cultivation period, standard crop management practices were implemented uniformly across all plots. Manual irrigation was applied twice daily once in the morning and once in the evening using watering cans to ensure consistent soil moisture levels, especially during the early growth stages. Fertilizer was applied in two split doses using a balanced compound fertilizer formulation (NPK 15:15:15). The first application was done at 14 days after transplanting (DAT), followed by a second application at 28 DAT, at a cumulative rate equivalent to 200 kg/ha. Weeding was conducted manually every 7–10 days or as needed to minimize competition for nutrients and water. Pest and disease incidence was minimal during the trial period; however, botanical insecticides were applied as a preventive measure to deter common pests such as flea beetles and aphids. No synthetic pesticides or herbicides were used throughout the study to eliminate potential interference with biochar treatments. These management practices were maintained consistently to ensure that the effects observed in plant performance could be attributed primarily to the biochar treatments.

2.4 Data Collection

Data collection was conducted systematically to assess the influence of different biochar application rates on Kailan growth and yield. Measurements began one week after transplanting and continued weekly until the end of the growing cycle, which lasted approximately six weeks. For consistency, five representative plants were randomly selected and tagged in the central area of each plot to avoid border effects.

These plants were measured repeatedly throughout the study period. Plant height was measured from the soil surface to the tip of the central shoot using a measuring ruler. Stem diameter was recorded using a digital caliper, with measurements taken approximately 2 cm above the soil surface to ensure consistency. The number of fully expanded leaves was manually counted, excluding emerging or damaged leaves to maintain accuracy.

At the end of the growing cycle (approximately 45 days after transplanting), yield-related parameters were recorded. Fresh weight per plant was determined by harvesting individual plants at the soil line and weighing them immediately using a digital balance. The total yield per plot was then calculated by summing the fresh weights of all plants within a plot and converting the value to tons per hectare. These growth and yield metrics were selected based on their relevance in evaluating vegetative performance and marketable yield in leafy vegetable production systems.

2.5 Statistical Analysis

All data were subjected to Analysis of Variance (ANOVA) using SPSS Version 26.0. Treatment means were compared using the Least Significant Difference (LSD) test at a 5% significance level ($p \leq 0.05$) to determine differences among biochar rates.

To evaluate the interaction effects between biochar rates and weeks after planting, regression analysis was conducted using Microsoft Excel. Growth trends were modeled using quadratic and linear regression equations where applicable, and coefficients of determination (R^2) were calculated to assess the goodness-of-fit. Data were presented graphically to illustrate growth trajectories and yield responses across treatments.

3. Results and Discussion

3.1 Growth Performance

The application of biochar significantly influenced the vegetative growth of Kailan, with notable interaction effects observed between biochar application rates and the number of weeks after transplanting for all measured parameters: plant height, stem diameter, and number of leaves. A quadratic growth pattern was evident in plant height, where the tallest plants were consistently found in the 20 t/ha treatment group across the six-week growth period (Figure 1a). This suggests that higher biochar levels may have sustained a gradual but accelerated vegetative response as the plants matured. The enhanced height gain observed under biochar treatment may be attributed to improved soil aeration and nutrient availability, particularly nitrogen and potassium, which are essential for cell elongation and photosynthetic efficiency during early growth stages (Lehmann et al., 2011).

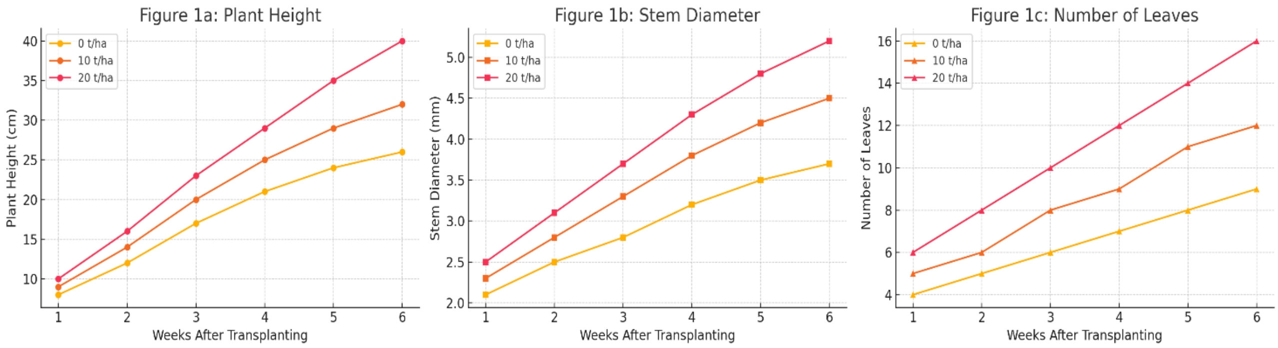

Fig. 1: Growth parameters of kailan under different biochar application rates

In terms of stem diameter, a strong linear relationship was found between the duration of growth and stem thickening, particularly under the 20 t/ha biochar treatment (Figure 1b). Stem diameter is a vital parameter in leafy vegetables like Kailan, as thicker stems often correlate with higher mechanical strength, improved water transport capacity, and greater nutrient translocation to expanding leaves (Agegnehu et al., 2017). The positive response under biochar treatments may be explained by biochar's porous matrix, which facilitates root expansion and microbial colonization, both of which are crucial for nutrient uptake.

Similarly, the number of leaves showed a quadratic increase over time, with significantly more leaves observed in the biochar-treated plots, especially in the 20 t/ha application rate (Figure 1c). Leaf production in leafy vegetables is closely linked to both nutrient availability and hormonal balance within the plant. Biochar has been reported to stimulate soil microbial activity, which enhances the mineralization of nitrogen and phosphorus and releases plant growth-promoting substances such as auxins and cytokinins (El-Naggar et al., 2019; Glaser et al., 2002). Moreover, rice husk biochar is known for its high silica content, which strengthens cell walls and may indirectly support the formation and expansion of new leaves (Sun et al., 2014). Collectively, these factors likely contributed to improved photosynthetic leaf area and biomass accumulation during the vegetative stage.

These findings corroborate those from similar studies in leafy vegetable cultivation. For instance, Agegnehu et al. (2016) and Vinh et al. (2014) reported substantial gains in growth parameters across several vegetable species following biochar application, emphasizing its potential as a sustainable amendment in tropical and subtropical regions. The consistency in positive responses across parameters in this study further supports the hypothesis that biochar enhances early-stage plant vigor by creating a more favorable rhizosphere environment.

3.2 Yield and Biomass

At final harvest, biochar-amended plots demonstrated statistically significant improvements in both total yield and fresh biomass compared to the control (0 t/ha), with the 20 t/ha treatment yielding the highest results (Figure 2a & 2b). The total yield, expressed in tons per hectare, increased proportionally with the rate of biochar application, underscoring its cumulative effects over the crop cycle. Fresh weight per plant also showed similar trends, suggesting that biochar not only increased the number of marketable leaves but also contributed to their size and succulence.

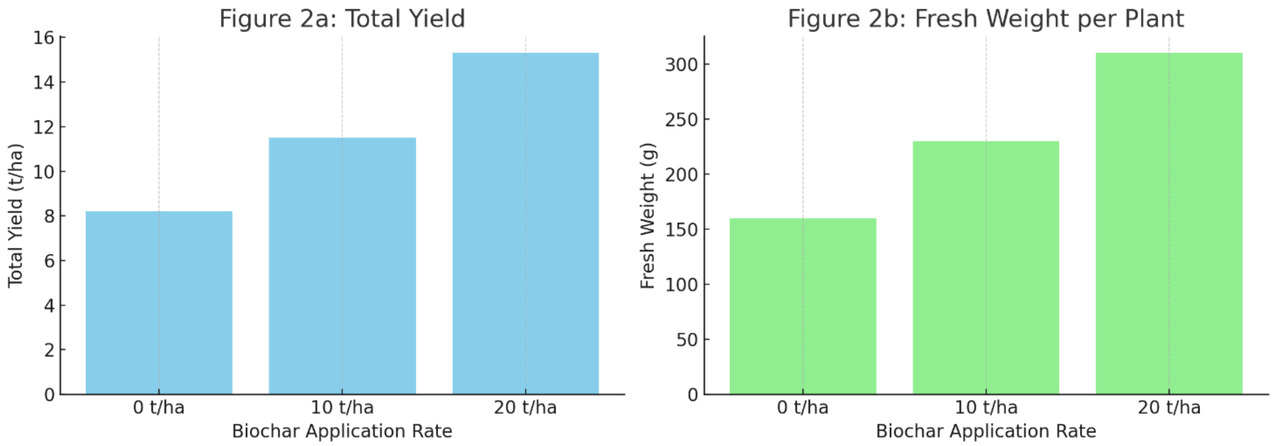

Fig 2: Yield and biomass of Kailan at different biochar application rates

These outcomes are in agreement with previous studies indicating that biochar enhances nutrient use efficiency and plant productivity. The yield boost can largely be attributed to improved nutrient retention in the root zone. Biochar's high surface area and cation exchange capacity (CEC) enable it to adsorb and gradually release macronutrients like nitrogen, phosphorus, and potassium, which are critical for biomass production in leafy vegetables (Laird et al., 2010). Furthermore, the liming effect of biochar helps neutralize soil acidity, thus creating a more favorable pH environment for root growth and microbial activity (El-Naggar et al., 2019).

Additionally, the rice husk biochar used in this study is rich in silica, a micronutrient that plays a functional role in enhancing plant resistance to abiotic stress, strengthening epidermal cell walls, and improving plant water relations (Sun et al., 2014). These attributes are particularly valuable under tropical field conditions where high rainfall and temperature fluctuations can stress plants and compromise yield quality.

Overall, the consistent improvement in both vegetative parameters and final yield confirms that biochar can serve as an effective and eco-friendly amendment for smallholder and commercial vegetable production systems. Its role in improving soil physical and chemical characteristics, combined with increased crop productivity, highlights its potential contribution to sustainable agriculture and food security strategies in Malaysia and similar agroecological zones.

5. Conclusion

This study demonstrates that rice husk biochar application significantly enhances the growth and yield of Kailan (*Brassica oleracea* var. *alboglabra*), particularly at the highest rate of 20 t/ha. Biochar-treated plots showed improved plant height, stem diameter, leaf production, total yield, and fresh biomass compared to the control. The observed enhancements can be attributed to biochar's positive effects on soil structure, nutrient retention, pH buffering, and microbial activity. These findings confirm the potential of rice husk biochar as a sustainable and effective soil amendment for improving the productivity of leafy vegetables in tropical agroecosystems. Future studies should focus on evaluating long-term soil health impacts, economic feasibility, and the integration of biochar with other organic amendments under different climatic and soil conditions to optimize its use in sustainable agricultural practices.

Based on the results of this study, it is recommended that rice husk biochar be adopted as a soil amendment in leafy vegetable production systems, especially at a rate of 20 t/ha for optimal growth and yield performance. For practical implementation, farmers should consider incorporating biochar into existing fertilization regimes to reduce dependency on synthetic inputs. Additionally, pre-conditioning biochar with compost or organic fertilizers prior to application may further enhance its effectiveness. To support wider adoption, future research should investigate the cost-benefit analysis of biochar production and application at the farm level, as well as its long-term effects on soil fertility, microbial diversity, and crop quality. Pilot studies and field trials across diverse agroecological zones in Malaysia and Southeast Asia would also help refine region-specific biochar recommendations for sustainable vegetable cultivation.

Acknowledgement
The authors would like to express their gratitude to the Universiti Malaysia Terengganu for their support in providing both facilities and financial assistance for this research.

Conflict of Interest
The authors declare no conflicts of interest.

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