

Effect of Bokashi and Water Deficiency on the Growth of Kailan (*Brassica Oleracea* Var. *Acephala*) in East Nusa Tenggara, Indonesia

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Abstract: Water scarcity poses a critical challenge to vegetable production in semi-arid regions such as East Nusa Tenggara, Indonesia, where sustainable soil amendment strategies are essential for maintaining crop productivity. This study investigated the interaction between water stress and coconut coir charcoal bokashi application on the growth and yield of kailan (*Brassica oleracea* var. *alboglabra*). The experiment was conducted at the State Agricultural Polytechnic of Kupang, East Nusa Tenggara, using a factorial Randomized Block Design (RBD) with three replications. Two factors were examined: water stress at three levels (no stress, 1-day stress, and 3-day stress) and bokashi dosage at four levels (0 g control, 75 g, 100 g, and 125 g per plant), yielding 12 treatment combinations. Data were analyzed using analysis of variance (ANOVA), and significant treatment differences were determined using Tukey's Honest Significant Difference (HSD) test at the 5% significance level. Both water stress and bokashi dosage significantly affected plant height at 15 and 45 days after planting (DAP). The combination of 3-day water stress with 125 g bokashi per plant produced the best overall growth performance, including the greatest plant height, leaf number, fresh weight, and dry weight per plant. These results suggest that appropriate bokashi amendment can partially compensate for the negative effects of water stress on kailan growth, offering a practical and sustainable strategy for vegetable production under water-limited conditions in East Nusa Tenggara.

Keywords: Kailan, *Brassica oleracea*, Bokashi, Water stress, Coconut coir charcoal, Vegetable production, East Nusa Tenggara

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Introduction

Kailan (*Brassica oleracea* var. *acephala*) holds significant potential for development in East Nusa Tenggara (ENT), Indonesia. This leafy vegetable offers numerous nutritional, economic, and environmental benefits that can contribute to local food security and rural livelihoods. Kailan is known for its high nutritional value, containing essential vitamins and minerals such as vitamin A, vitamin C, calcium, and iron [1]. These nutrients are vital for maintaining good health, supporting immune function, bone strength, and overall metabolic processes. Cultivating kailan can therefore help improve the availability of nutritious food in ENT, especially as public awareness of the importance of healthy diets continues to increase.

Economically, kailan presents an opportunity for farmers in ENT to diversify their agricultural activities and improve their livelihoods. With the rising demand for nutrient-rich vegetables, kailan cultivation can serve as an alternative source of income that contributes to local economic growth. Integrating kailan into existing farming systems also promotes agricultural diversification, reducing farmers' dependence on a single crop and strengthening their resilience to climate and market fluctuations. At the household level, growing kailan can help families reduce their expenses on purchasing vegetables from the market, leading to greater economic self-sufficiency and improved financial stability.

From a public health perspective, regular consumption of nutrient-dense kailan can help reduce the risk of malnutrition and diet-related diseases. This, in turn, supports the development of a healthier and more productive population. Furthermore, if kailan cultivation in ENT achieves high productivity and meets quality standards, it has the potential to expand beyond local markets to regional or even international markets. Such expansion could open new export opportunities, stimulate agribusiness development, and increase regional income. Environmentally, kailan cultivation can make efficient use of local resources such as land and water, contributing to sustainable agricultural practices and minimizing negative impacts on the ecosystem.

Despite its promising potential, kailan cultivation in ENT faces several challenges. The most critical issue is water scarcity, as the region's predominantly dry climate often leads to inadequate water availability for agricultural purposes. Limited rainfall and insufficient irrigation infrastructure make it difficult for farmers to meet the water needs of kailan throughout its growth period. In addition, agricultural infrastructure in ENT remains underdeveloped, with restricted access to irrigation technology, water storage facilities, and other essential farming inputs, which hinders productivity. Another major challenge is the selection of kailan varieties that are suitable for the local environment. Since not all kailan varieties can tolerate dry conditions, choosing or developing drought-resistant cultivars is essential to ensure successful cultivation in ENT. Addressing these challenges through improved irrigation management, infrastructure development, and varietal selection could enhance the success and sustainability of kailan production in the region.

According to data from the Central Bureau of Statistics (BPS, 2015), the productivity of cabbage, including kailan, in Indonesia from 2011 to 2014 was recorded at 1.36 million tons, 1.45 million tons, 1.48 million tons, and 1.43 million tons, respectively. The data indicate that cabbage production experienced a steady increase from 2011 to 2013; however, there was a decline in 2014. This decrease in production was likely caused by the limited application of proper cultivation techniques, particularly among smallholder farmers who may lack access to adequate agricultural training, inputs, and technology.

The success of cauliflower cultivation can be influenced by environmental factors such as the need for water and fertilizer. Water plays a key role in plant growth, and development as it is an essential component of various physiological processes [2–6]. The presentation of water requirements for plants is 70–90%. The need for water in plants greatly affects the yield and quality of crop production. Water must be supplied in the right amount and at the appropriate time according to the plant's growth stage and physiological needs [7–12].

According to Dewi, the total water requirement of cauliflower plants during the growing season is approximately 135 mm, equivalent to 135 L/m² [13]. This consists of an estimated 28.6 mm (28.6 L/m² per day) during the initial growth phase, 64.5 mm (64.5 L/m² per day) during the mid-growth phase, and 41.9 mm (41.9 L/m² per day) during the late growth phase. Providing less water than required can cause plants to experience drought stress, leading to leaf wilting and, eventually, plant death. Conversely, excessive water application may result in root rot, which can further lead to plant mortality [14–17].

The results of Asona's study showed that watering at two-day intervals produced greater plant height, number of leaves, fresh weight, and dry weight in spinach plants compared to other irrigation intervals [18]. Similarly, Remitana reported that daily watering resulted in higher lettuce yields than less frequent irrigation treatments [19].

The East Nusa Tenggara (ENT) region is characterized by a dry climate, making water availability a major limiting factor in crop cultivation. Therefore, in crop cultivation, it is essential to understand the level of plant tolerance to water deficiency, particularly in relation to the volume and frequency of water supply. This understanding enables the development of appropriate strategies to manage soil moisture under limited water conditions while simultaneously ensuring the availability of nutrients for plant growth. Water deficiency, also known as plant drought stress, occurs when the amount of available water in the plant's environment is insufficient to meet its hydration requirements and maintain normal physiological processes. The solution that can be done to maintain water conditions in the soil and at the same time be able to provide nutrients for plants is to apply organic materials such as manure, compost, bokashi and agricultural waste.

Bokashi is compost produced from the fermentation process of organic matter using EM4 (Effective Microorganisms 4) technology. The advantage of using EM4 technology is that organic fertilizer (compost) can be produced in a relatively short time compared to conventional methods. EM4 itself contains *Azotobacter* sp. *Lactobacillus* sp. yeast. photosynthetic bacteria. and cellulose-decomposing fungi.

These microbes can work effectively in improving the physical. chemical and biological properties of soil, providing nutrients for plants, and increasing crop production. The role of bokashi is to provide macro and micro nutrients for plants. loosen the soil, improve soil texture and structure. Organic matter can also improve soil porosity, aeration, and microbial composition, thereby enhancing root growth and increasing the soil's water-holding capacity. As a result, soils with higher organic matter content are better able to retain moisture and support plants in withstanding drought stress conditions [20].

There are several types of bokashi, classified based on the main raw materials used. These include straw bokashi, manure bokashi, soil-manure bokashi, husk charcoal bokashi, and coconut fiber charcoal. Coconut coir can be utilized as a raw material for producing bokashi fertilizer. In addition to being inexpensive and readily available, coconut coir contains essential nutrients required for plant growth, including calcium (Ca), Magnesium (Mg), potassium (K), and Phosphorus (P). Coconut coir is beneficial for plant development both as a planting medium and as an organic soil amendment. It possesses a high water absorption and retention capacity, which helps maintain soil moisture and improves soil structure, keeping it loose and well-aerated.

The results of laboratory analysis of the nutrient content in coconut fiber show that it contains 0.946% Nitrogen (N), 0.142% phosphorus (P), and 1.316% potassium (K) [21]. Based on these findings, coconut coir can be utilized as an organic material for producing bokashi fertilizer, as it provides various essential nutrients required for plant growth. The use of coconut coir in bokashi production can be carried out either by applying it directly or by first processing it into coconut coir charcoal.

According to Haruna et al. the application of goat manure bokashi fertilizer at a rate of 40 tons per hectare can increase the fresh weight of spinach plants [22]. Similarly, Sangadji reported that the addition of rice husk charcoal bokashi at the same rate resulted in a higher fresh weight of mustard plants compared to other treatments [23]. Furthermore, Mooy et al. (2019) stated that for vegetable cultivation, coconut coir bokashi can be applied at a rate of 4 kg/m², which is equivalent to 40 tons per hectare. Based on these findings, it is important to conduct a study entitled "The Effect of Bokashi and Water Deficiency on the Growth of Kailan (*Brassica oleracea* var. *acephala*) in East Nusa Tenggara, Indonesia".

Methods

Place and Time of Research

The experiment was conducted from June to August 2024 in a greenhouse at the Department of Food Crops and Horticulture, State Agricultural Polytechnic of Kupang, Indonesia.

Tools and Materials

The tools used in this study included buckets, meters, measuring cups, a camera, an oven, knives, analytical scales, thermometers, and hygrometers. The materials used consisted of soil, polybags measuring 15 × 30 cm, water, coconut fiber, bran, manure, sugar, EM4, labels, and kailan (*Brassica oleracea* var. *acephala*) seeds of the Winsa variety.

Experimental Design and Procedure

This study employed a two-factor Randomized Block Design (RBD) with three replications. Factor C (water stress level) consisted of three treatments: C0 = control (no stress). C1 = one-day stress. and C2 = three-day stress. Factor D (coconut coir charcoal bokashi) consisted of four treatments: D0 = control (no bokashi). D1 = 30 t ha⁻¹ (equivalent to 15 g kg⁻¹ soil). D2 = 40 t ha⁻¹ (20 g kg⁻¹ soil). and D3 = 50 t ha⁻¹ (25 g kg⁻¹ soil).

The experiment resulted in 36 treatment combinations (3 × 4 factorial × 3 replications). Each treatment unit consisted of five plants, yielding a total of 180 experimental polybags. Treatments were randomly assigned within each replication following the randomized block design

Data Analysis Models

The data were analyzed using a factorial Randomized Block Design (RBD) model as described by Gaspersz (1995), which can be expressed as follows:

Y_{ijk}

$$= \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \gamma_k + \epsilon_{ijk}$$

Where:

Y_{ijk} = The results of observations for the drought stress factor (C) level i , the dose factor of coconut coir charcoal bokashi (D) level j in the k th group – k

μ = general mean value

α_i = The effect of factor C on level i ($i = 1, 2, 3, 4$)

β_j = The effect of factor D on level j ($j = 1, 2, 3$)

$(\alpha\beta)_{ij}$ = Effect of CD interaction on level i (from factor C), and level j (from factor D).

γ_k = Group influence to – k ($k = 1, 2, 3$)

ϵ_{ijk} = Random effect (trial error) on the i th level (factor C), j th level (factor D), the i th and j th CDI interactions – j

The research data were analyzed using analysis of variance (ANOVA). When significant differences were found among treatments, the means were further compared using the Honest Significant Difference (HSD) test at the 5% significance level.

Results and Discussion

Overview of the Research

The kailan (*Brassica oleracea* var. *acephala*) seeds used in this study were of the Winsa variety. The seeds were sown in trays and began germinating two days after sowing. At one week after sowing, the seedlings had developed two to three leaves and were then transplanted into seedling containers. After an additional week, the seedlings had produced four to five leaves and were subsequently transferred into polybags. The polybags used in this study measured 15 × 30 cm.

The seedlings selected for planting were those that exhibited normal and uniform growth, and were free from pests and diseases. Before planting the kailan seeds, it is essential to prepare the soil medium and fertilizer properly. The fertilizer used in this study was coconut coir charcoal bokashi, which contained 39.46% organic carbon (C-organic), 2.13% nitrogen (N), 1.08% phosphorus (P), 2.62% potassium (K), and had a pH of 6.73. These nutrient components play a vital role in supporting plant growth and development, as well as influencing the yield produced. The fertilizer functions as a source of essential nutrients to meet plant requirements, improve soil structure, and enhance nutrient retention.

The kailan seedlings were planted in polybags that had been filled with a soil medium mixed with coconut coir charcoal bokashi according to the respective treatment levels. After planting, the seedlings were watered every morning and evening for seven days using a uniform volume of 300 mL per day. Beginning on the eighth day, watering was carried out according to the assigned treatments, namely: daily watering (no stress), one-day water stress, and three-day water stress. The volume of water applied during each watering was adjusted to the plants' water requirements. The kailan plants were ready for harvest at 45 days after planting. At this stage, the plants were characterized by dark green leaves with uneven and wavy leaf margins, indicating optimal vegetative growth and maturity.

Supporting Variables

Supporting variables measured include.

Preliminary Soil Analysis

The results of the initial soil analysis for pH, C-organic, N, P, and K were obtained from the Soil Chemistry Laboratory, Faculty of Agriculture, University of Nusa Cendana, as presented in Table 1.

Table 1: Nutrient Content in Soil Prior to Experiment

Parameters	Content (%)	Soil Analysis Results and Assessment Criteria
pH	7.11	Neutral
C-organik (%)	2.24	Medium
N-total (%)	0.21	Medium
P ² O ⁵ (ppm)	43.87	Very high
K (ppm)	2.21	Very high

Source: Results of Soil Chemistry Laboratory Analysis, Faculty of Agriculture, University of Nusa Cendana. 2024

Nutrient Analysis of Coconut Coir Bokashi Fertilizer

The results of the analysis of coconut coir charcoal bokashi, including C-organic, macronutrient, and micronutrient contents, were obtained from the Soil Chemistry Laboratory, Faculty of Agriculture, University of Nusa Cendana, as presented in Table 2.

Table 2: Nutrients and pH of Coconut Coir Bokashi Fertilizer

Parameters	Content	Quality Standards
Ph	6.37	4-9
C-organik (%)	39.46	minimum 15
N (%)	2.13	
P (%)	1.08	N+P+K = 2-6
N (%)	2.62	

Source: Results of Soil Chemistry Laboratory Analysis. Faculty of Agriculture. University of Nusa Cendana. 2024

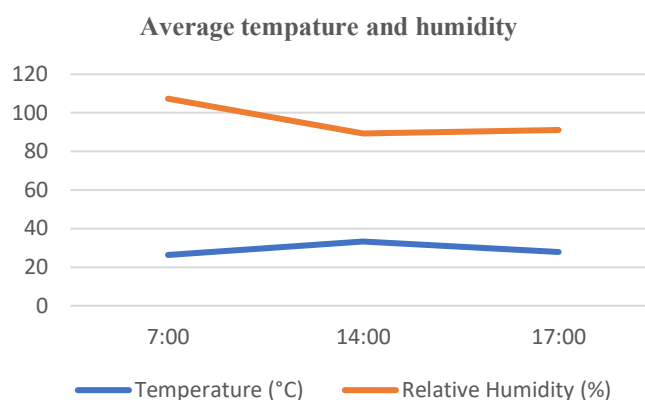
Table 2 shows that the pH of the coconut coir charcoal bokashi was 6.37, which is considered suitable for the cultivation of kailan plants. According to the minimum technical requirements for solid organic fertilizers, an acceptable pH range is 4–9, indicating that the bokashi used in this study meets the required standard.

The C-organic content of the coconut coir charcoal bokashi was 39.46%, which meets the requirements for solid organic fertilizer as stipulated in the Minister of Agriculture Regulation No. 261/KPTS/SR.310/M/4/2019, with a minimum standard of 15%. A high C-organic content in the soil plays an important role in improving soil quality by enhancing its ability to retain water, thereby reducing evaporation and maintaining soil moisture to support plant water needs. In addition, soils with high organic carbon content can serve as a source of nutrients and improve nutrient-holding capacity, preventing nutrient loss through leaching during watering or rainfall.

The total nutrient content of N, P, and K in the coconut coir charcoal bokashi was 5.83%, which meets the minimum technical requirements for solid organic fertilizer, set at a minimum of 2%. This condition has a positive impact on the growth and productivity of kailan plants. In terms of nutrient function, Nitrogen (N) supports vegetative growth by promoting the formation of new leaves and increasing plant height. Phosphorus (P) plays an essential role in stimulating root development, enabling plants to absorb water and nutrients effectively from the soil. In addition, phosphorus contributes to the synthesis of specific proteins and assists in the assimilation processes involved in plant respiration and energy transfer. The potassium (K) element plays a crucial role in regulating the water balance within plant tissues. It enhances the plant's ability to absorb soil moisture and retain water, thereby increasing resistance to drought stress.

Temperature and Air Humidity

Based on observations of temperature and humidity in the kailan plants grown in the screen house, the data are presented in Figure 1. Measurements of temperature and humidity conducted during the experimental period from May to July 2020 showed that throughout the growth phase (45 days after planting), the average air temperature ranged from 26.35°C in the morning, 33.32°C in the afternoon, and 28.02°C in the evening. Meanwhile, the average relative humidity was 81% in the morning, 56% in the afternoon, and 63% in the evening.



Source: Research Observation Data (2024)

Figure 1: Air Temperature and Humidity During Research in May-June 2024.

Figure 1 shows that the average air temperature during the study ranged from 26.35°C to 33.32°C. This range is still within the optimal temperature limits for kailan growth (23–35°C) as reported by Samadi [24]. However, temperatures approaching the upper threshold may cause mild heat stress, which can adversely affect plant physiological processes. Elevated temperatures tend to increase transpiration rates, reduce water absorption, and disrupt cellular respiration due to an imbalance between water loss and water availability within plant tissues.

According to Lehar et al., high environmental temperatures significantly accelerate evaporation rates, thereby intensifying plant stress [25]. Under extreme conditions, this may result in tissue damage, especially when water absorption by roots cannot match the rate of water loss through transpiration. In leafy vegetables such as kailan, the effects of heat stress are particularly evident in reduced leaf area, delayed cell division, and inhibited leaf expansion, all of which contribute to lower leaf yield, the primary economic part of the plant.

Moreover, excessive temperature can suppress enzymatic activity crucial for photosynthesis, thereby slowing biomass accumulation in leaves. Over time, this directly reduces both the quantity and quality of kailan yields. Therefore, as emphasized by Lehar et al., maintaining an optimal growing environment is essential to sustain plant physiological performance and productivity [26].

Figure 1 also indicates that the relative humidity during the study ranged between 56% and 81%. This condition falls below the ideal humidity requirement for kailan growth (80–90%) as stated by Sunarjono (2004). Low humidity levels tend to increase transpiration and water absorption, which may enhance nutrient availability. In contrast, excessive humidity reduces transpiration and nutrient uptake, thereby limiting nutrient availability and potentially leading to stunted growth. Furthermore, high humidity favors fungal development that can damage or rot plant roots, while low humidity may increase pest incidence, causing additional damage.

In addition to the average values, Figure 1 illustrates the diurnal pattern of air temperature and humidity. At around 14:00, temperature peaked while humidity decreased, whereas at 07:00 and 17:00, temperature was lower and humidity higher. This pattern corresponds with solar radiation dynamics, where midday radiation intensifies air temperature and decreases humidity, while early morning and late afternoon radiation is lower, resulting in cooler air temperatures and higher humidity levels.

Principal Variables

Plant Height

The results of the Analysis of Variance (ANOVA) indicated that there was no interaction effect between drought stress and coconut coir charcoal bokashi dosage on kailan plant height at 15 and 45 Days After Planting (DAP). However, at 30 DAP, a significant interaction effect was observed between the two factors. At 15 and 30 DAP, the bokashi dosage treatment showed a highly significant single-factor effect on plant height, while at 45 DAP, the drought stress treatment exhibited a significant effect (Appendix 5.1a and 5.1c).T.

The height of kailan plants at 30 DAP showed a significant interaction effect between drought stress and the dosage of coconut coir charcoal bokashi, as indicated by the analysis of variance (Appendix 5.1b). The average height of kailan plants at 15, 30, and 45 DAP is presented in Table 3.

Table 3: Average Plant Height (cm) of Kailan Due to Drought Stress Treatment and Dosage of Bokashi Coconut Coir Charcoal at 15, 30 and 45 DAP

Treatment	Plant Height (cm) Kailan 15 DAP			
	Without Stress	1 Day Stress	2 Days Stress	Mean values of Bokashi Dose
D0= Control	11.71 ^{ns}	13.22 ^{ns}	11.81 ^{ns}	12.24 ^a
D1= Dosag 75 g	16.47 ^{ns}	19.20 ^{ns}	18.00 ^{ns}	17.89 ^b
D2= Dosag 100 g	17.99 ^{ns}	19.05 ^{ns}	21.15 ^{ns}	19.39 ^b
D3= Dosag 125 g	16.52 ^{ns}	18.33 ^{ns}	21.96 ^{ns}	19.59 ^b
HSD (5%) for bokashi dose 3.23				
Treatment	Plant Height (cm) Kailan 30 DAP			
	Without Stress	1 Day Stress	2 Days Stress	
D0= Control	16.01 ^a	19.52 ^{abc}	18.56 ^{ab}	
D1= Dosag 75 g	22.24 ^{bcd}	26.31 ^{de}	24.43 ^{cd}	
D2= Dosag 100 g	23.09 ^{bcd}	25.53 ^{de}	27.56 ^{de}	
D3= Dosag 125 g	22.82 ^{bcd}	24.46 ^{cd}	30.95 ^e	
HSD (5%) for interaction (water stress × bokashi dose) 43.47				
Treatment	Plant Height (cm) Kailan 45 DAP			
	Without Stress	1 Day Stress	2 Days Stress	Mean values of Bokashi Dose
D0= Control	27.27 ^{ns}	27.73 ^{ns}	27.42 ^{ns}	27.47 ^a
D1= Dosag 75 g	29.32 ^{ns}	32.09 ^{ns}	31.21 ^{ns}	30.87 ^b
D2= Dosag 100 g	30.13 ^{ns}	31.95 ^{ns}	32.54 ^{ns}	31.54 ^b
D3= Dosag 125 g	29.73 ^{ns}	31.47 ^{ns}	34.81 ^{ns}	32.00 ^b
Mean Water Stress				
Treatments	29.11 ^a	30.81 ^{ab}	31.49 ^b	
Value HSD 5% Water Stress =2.28 and Dosage Bokashi = 2.92				

Note: Numbers followed by the same letter in the same column are not significantly different on the 5% HSD test.

The HSD 5% post hoc test indicated that at 15 and 45 Days After Planting (DAP), the highest plant height was recorded in the treatment receiving 125 g of coconut coir charcoal bokashi (D3). This treatment differed significantly from the control but not from the other bokashi doses. The improved growth performance at this level may be attributed to the 2.13% nitrogen (N) content in the bokashi, which effectively supplemented the initial soil N level of 0.21%, thereby enhancing early vegetative development and increasing plant height.

In contrast, the control (without bokashi) produced significantly shorter kailan plants. This result was likely due to limited nitrogen availability, as the only N source came from the soil, which contained a moderate N level of 0.21%. Considering that leafy vegetables such as kailan require high nitrogen levels for optimal growth, this limitation likely restricted vegetative development and resulted in stunted plant height.

At 45 DAP, the HSD 5% results (Table 3) showed that plants subjected to three days of water stress exhibited significantly greater height than those in the non-stress treatment, although the difference was not significant compared with the one-day stress treatment. The increased height under three-day stress conditions may be associated with the plant's developmental phase between 30 and 45 DAP, during which the water requirement naturally decreases as kailan approaches harvest maturity. Consequently, plants could tolerate temporary drought stress and sustain vegetative growth effectively.

Conversely, daily watering under non-stress conditions may have caused excessive soil moisture, reducing soil aeration and oxygen exchange. Such conditions can inhibit cell elongation, leading to shorter plants. Table 3 further indicates that the

combination of no bokashi and no water stress (C0D0) resulted in the shortest plant height, which differed significantly from most treatments, except for the one- and three-day stress treatments without bokashi (C1D0 and C2D0).

This outcome may be attributed to the initial soil organic carbon (C-organic) content of 2.24%, which was insufficient to improve water retention under stress conditions. Conversely, the 125 g bokashi treatment containing 39.46% organic carbon likely improved soil structure and water-holding capacity, allowing plants to maintain turgor pressure and sustain cell elongation despite higher temperatures (average 29.83 °C in the fourth week, Figure 3.1).

These results are consistent with previous studies showing that nitrogen plays a crucial role in shoot development, promoting greater plant height [19,25,27–31]. Plant growth depends on cell division and elongation, which require sufficient organic and inorganic compounds for protoplasm and cell wall synthesis [18]. Furthermore, Asona emphasized that these processes are highly dependent on adequate water uptake; limited absorption can hinder growth and lead to stunted development [18].

Total Leaves

The Analysis of Variance (ANOVA) showed that at 15 DAP, the number of kailan leaves was not significantly affected by the interaction between water stress and bokashi dose, but a significant main effect was observed for bokashi application (Appendix 5.2a).

At 30 and 45 DAP, ANOVA results revealed a highly significant interaction effect between water stress and bokashi dose (Appendix 5.2b and 5.2c). The mean number of kailan leaves at 15, 30, and 45 DAP is presented in Table 4.

Table 4: Average Number of Leaves (strands) of Kailan Plant Due to Treatment of Drought Stress and Bokashi Coconut Coir Charcoal at Age 15, 30 and 45 DAP

Treatment	Number of Leaves (strands) of Kailan Plant 15 DAP			
	Without Stress	1 Day Stress	2 Days Stress	Mean values of Bokashi Dose
D0= Control	6.11 ^{ns}	6.67 ^{ns}	6.67 ^{ns}	6.48 ^a
D1= Dosag 75 g	6.78 ^{ns}	7.56 ^{ns}	7.11 ^{ns}	7.15 ^{ab}
D2= Dosag 100 g	7.00 ^{ns}	7.45 ^{ns}	7.67 ^{ns}	7.37 ^{ab}
D3= Dosag 125 g	6.89 ^{ns}	7.34 ^{ns}	8.22 ^{ns}	7.48 ^b

Value HSD 5% Dosage Bokashi 0.97

Treatment	Number of Leaves (strands) of Kailan Plant 30 DAP		
	Without Stress	1 Day Stress	2 Days Stress
D0= control	7.67 ^a	8.22 ^{ab}	7.89 ^a
D1= Dosage 75 g	8.33 ^{ab}	9.44 ^{ab}	8.67 ^{ab}
D2= Dosage 100 g	8.55 ^{ab}	9.22 ^{ab}	10.67 ^{bc}
D3= Dosage 125 g	8.44 ^{ab}	8.78 ^{ab}	12.22 ^c

Value HSD 5% Interaction of Water Stress and Dosage of Bokashi = 2.65

Treatment	Number of Leaves (strands) of Kailan Plant 45 DAP		
	Without Stress	1 Day Stress	2 Days Stress
D0= control	11.00 ^a	11.89 ^{ab}	11.33 ^a
D1= Dosage 75 g	12.00 ^{ab}	14.56 ^{bcd}	12.89 ^{abc}
D2= Dosage 100 g	12.34 ^{ab}	13.89 ^{abc}	15.67 ^{cd}
D3= Dosage 125 g	12.11 ^{ab}	13.00 ^{abc}	16.34 ^d

Value HSD 5% Interaction of Water Stress and Dosage of Bokashi = 3.04

Note: Numbers followed by the same letter in the same column are not significantly different on the 5% HSD test

The treatment without the addition of coconut coir charcoal bokashi produced fewer leaves and was significantly different from the treatment with 125 g of coconut coir charcoal bokashi, but not significantly different from the other treatments. The lower number of leaves observed in the control treatment was likely due to the absence or minimal addition of phosphorus (P) in the soil, which reduced the availability of this essential nutrient. Although the total P content in the soil was relatively

high (43.87 ppm, Table 4), a large portion of it was in a form unavailable to plants, thereby limiting root development. Insufficient root growth, in turn, restricted water and nutrient uptake, ultimately inhibiting leaf formation.

The role of phosphorus (P) in plants is to support root formation, thereby enabling efficient absorption of water and nutrients. Adequate phosphorus availability promotes normal physiological processes and contributes to improved plant growth and development. Conversely, if the soil lacks the element P, the growth of plant roots becomes stunted and has an impact on the limited absorption of water and nutrients. This can result in limited plant growth and development [32–39].

Conversely, when the soil is deficient in P element, root growth becomes stunted, which limits the plant's ability to absorb water and nutrients. This nutrient deficiency can consequently restrict overall plant growth and development [32–39].

Lehar et al. emphasized that in leafy horticultural crops such as kailan, Phosphorus (P) plays a vital role not only in root formation but also in accelerating cell division and differentiation at the plant's growing points [40]. This process supports the development of vegetative organs, particularly the leaves, which serve as the primary photosynthetic structures and represent the main economic yield of the crop. When phosphorus availability is adequate, plants tend to develop deeper and more extensive root systems, enabling more efficient absorption of water and nutrients during active growth phases and providing greater tolerance to short-term drought stress. Conversely, phosphorus deficiency leads to shallow and poorly branched roots, thereby reducing the number and size of leaves the primary economically valuable organ of kailan. Table 4 shows that at 30 and 45 Days after Planting (DAP), the highest number of leaves was observed in the 3-day drought stress treatment with a 125 g dose of coconut coir charcoal bokashi (C2D3). This treatment was significantly different from the control but not significantly different from the 3-day stress with a 100 g dose (C2D2) or the 1-day stress with a 100 g dose (C1D2).

The higher number of leaves under these treatments may be attributed to the application of coconut coir charcoal bokashi under relatively dry soil conditions and air humidity ranging from 56% to 81% (Figure 3.1). Such conditions likely enhanced the mineralization process, thereby increasing the availability of Phosphorus (P) in the soil. The absorbed phosphorus was then utilized for cell division and expansion in leaf tissues, resulting in a greater number of leaves in kailan plants.

The number of leaves of kailan plants at 30 Days After Planting (DAP), based on the results of the 5% HSD follow-up test, showed that the treatment without drought stress and without the application of bokashi coconut coir charcoal produced fewer leaves and was significantly different from the 3-day drought stress treatment with a 125 g dose of bokashi coconut coir charcoal, but not significantly different from the other treatments. At 45 DAP, the treatment without drought stress with no dose of bokashi coconut coir charcoal gave fewer leaves and was significantly different from the 3-day drought stress treatment with a dose of 100 and 125 g and the 1-day drought stress treatment with a 75 g dose. The small number of leaves produced was likely due to the absence of drought stress and the lack of bokashi coconut coir charcoal application, which caused the Phosphorus (P) nutrients in the soil most of which are water-soluble to dissolve slowly. Consequently, the absorption of P by the roots was limited, slowing down the leaf formation process and resulting in a small number of leaves produced.

The influence of organic matter on Phosphorus (P) availability can occur either directly through the process of mineralization or indirectly by facilitating the release of P nutrients that are bound to soil particles. The results of the decomposition form chelation bonds with Al and Fe ions so that they can reduce the solubility of Al and Fe ions, thereby increasing the availability of P. Organic matter can also release bound Phosphorus (P), thereby increasing its availability in the soil [26].

Lehar et al. further emphasized that microbial activity resulting from the decomposition of organic matter plays a crucial role in mobilizing macronutrients, particularly phosphorus, through the secretion of organic acids and phosphatase enzymes [26]. According to Simanungkalit, Dotaniya and Meena, Zarei et al., and Zhang et al., the solubility of phosphorus in soil is generally low, especially under conditions of excessive soil moisture or waterlogging, which hinders its absorption by plant roots and ultimately reduces shoot development [32,41–43].

The growth and development of kailan plants requires air humidity of 80-90%. Low air humidity can result in the increase rate of evaporation or transpiration and the absorption of water and mineral substances. This process can enhance the availability of nutrients essential for plant growth. Conversely, high air humidity can reduce the rate of transpiration, which in turn may limit the absorption of nutrients by the plant. This condition reduces the availability of nutrients for plant growth, potentially resulting in stunted development. In addition, high humidity can promote the growth of fungi, which may damage or rot plant roots. Conversely, low humidity can encourage the emergence of pests that harm plants [44–47].

Plant Fresh Weight

The Analysis of Variance (ANOVA) results showed that the fresh weight of kailan plants at 45 days after planting (DAP) was significantly influenced by the interaction between drought stress and coconut coir charcoal bokashi dose (Appendix 5.3). The mean fresh weight of kailan plants at 45 DAP is presented in Table 5.

Table 5: Average fresh weight (g) of kailan plants as affected by the interaction between drought stress and coconut coir charcoal bokashi doses at 45 DAP

Treatment	Average Fresh Weight (g) of Plants Kailan		
	Without Stress	1 Day Stress	2 Days Stress
D0= control	145.04 ^a	174.18 ^{abc}	168.31 ^{ab}
D1= Dosage 75 g	182.71 ^{abcd}	239.10 ^e	212.54 ^{cde}
D2= Dosage 100 g	210.21 ^{bode}	226.17 ^{de}	244.31 ^e
D3= Dosage 125 g	200.91 ^{bode}	221.31 ^{de}	288.41 ^f

Value HSD 5% 43.47

Note: Numbers followed by the same letter in the same column are not significantly different on the 5% HSD test

Table 5 shows that the three-day drought stress treatment combined with 125 g of coconut coir charcoal bokashi produced the highest fresh weight of kailan plants, reaching 288.41 g per plant. This value was significantly different from other treatments based on the 5% HSD test and exceeded the varietal standard of 250 g per plant.

This increase in fresh weight was closely associated with superior plant morphology, as reflected in greater plant height and number of leaves (30.95 cm and 16.34 leaves, respectively). Since fresh weight represents the accumulation of biomass from all physiologically active plant parts, improvements in these morphological traits contributed substantially to the total fresh weight.

Furthermore, the role of bokashi as an organic fertilizer containing 2.62% potassium (K), with a soil K content of 2.21 ppm, was instrumental in maintaining soil moisture under drought conditions. Potassium plays a vital role in sustaining turgor pressure, photosynthetic efficiency, and enzymatic activity related to plant metabolism. These functions enabled the roots to continue absorbing water and nutrients effectively, even under stress. Consequently, optimal biomass accumulation during the vegetative stage directly translated into a significant increase in the fresh weight of kailan plants.

Table 5 also indicates that the treatment without drought stress and without bokashi application produced a significantly lower fresh weight (145.04 g per plant) compared to most other treatments, although it was not significantly different from the 1-day and 3-day drought stress treatments without bokashi or with 75 g of bokashi. This value was considerably lower than the varietal standard of 250 g per plant.

The reduced fresh weight can be attributed to lower values in key morphological traits such as plant height and number of leaves (Table 5). These limitations significantly affected biomass accumulation, resulting in reduced plant weight. Furthermore, the absence of bokashi under drought stress conditions meant that the soil potassium content (2.21 ppm) was insufficient to maintain adequate soil moisture, likely impairing root function in water and nutrient absorption and leading to lower overall plant mass.

Organic matter plays a crucial role in mitigating drought stress by enhancing the soil's water-holding capacity. Under conditions of high evapotranspiration and limited water availability, soils enriched with organic inputs can retain sufficient moisture to support optimal plant growth [25].

Moreover, the function of organic matter extends beyond physical properties to include physiological benefits. Its essential nutrient content improves soil structure, stimulates microbial activity, and promotes the development of a healthy and active root environment. Efficient photosynthetic processes supported by adequate water and nutrient availability stimulate the accumulation of carbohydrates and proteins, which directly enhance plant fresh weight, a key indicator of total biomass accumulation [26,40].

According to Lehar et al., organic matter such as compost or bokashi not only enhances the soil's water retention capacity but also strengthens plant resilience against extreme environmental fluctuations, including short-term drought stress [40]. This approach is both agronomically relevant and a sustainable strategy for crop production systems in dry and semi-arid regions.

Plant Dry Weight

The Analysis of Variance (ANOVA) results revealed that the dry weight of kailan plants at 45 Days After Planting (DAP) was significantly influenced by the interaction between drought stress and the dose of coconut coir charcoal bokashi (Appendix 5.3). The mean dry weight of kailan plants at 45 DAP is presented in Table 6.

Table 6 shows that, based on the 5% HSD test, the three-day drought stress treatment combined with 125 g of coconut coir charcoal bokashi produced the highest plant dry weight (28.38 g), which was significantly different from other treatments. The higher dry weight observed under this treatment was associated with improved growth and yield parameters, including plant height and leaf number, which contributed to greater total biomass accumulation. As plant tissues underwent drying, the accumulated biomass resulted in increased dry matter content.

Table 6: Average dry weight (g) of kailan plants as affected by the interaction between drought stress and coconut coir charcoal bokashi doses at 45 DAP

Treatment	45 DAP		
	Without Stress	1 Day Stress	2 Days Stress
D0= control	12.05 ^a	13.47 ^{ab}	12.79 ^{ab}
D1= Dosage 75 g	13.67 ^{ab}	18.92 ^{bc}	15.97 ^{abc}
D2= Dosage 100 g	15.24 ^{abc}	17.44 ^{abc}	20.64 ^c
D3= Dosage 125 g	14.28 ^{abc}	16.23 ^{abc}	28.38 ^d

Value HSD 5% 6.74

Note: Numbers followed by the same letter in the same column are not significantly different on the 5% HSD test

The non-stress treatment without the application of coconut coir charcoal bokashi, as presented in Table 6, resulted in a lower plant dry weight. This value was significantly different from most other treatments but not from the 1-day and 3-day drought stress treatments without bokashi or from the 75 g bokashi dose under non-stress conditions.

This reduction is likely related to lower values in key morphological traits, including plant height (16.01 cm), number of leaves (11.00), and fresh weight (145.04 g) at 45 Days After Planting (DAP), all of which contributed to decreased dry matter accumulation.

Plant dry weight represents the total accumulation of photosynthetic assimilates mainly carbohydrates, proteins, and lipids and reflects the plant's overall growth and development throughout its life cycle. A higher dry weight generally indicates greater nutrient absorption and metabolic efficiency. According to Jumin, dry weight also reflects the accumulation of photosynthates stored within the roots, stems, and leaves, serving as an integrative indicator of plant productivity [44].

Conclusion

Based on the findings of this study, it can be concluded that drought stress had a significant influence on the growth performance of kailan plants. The highest plant height (31.49 cm) was observed under drought stress at 45 Days After Planting (DAP). The application of coconut coir charcoal bokashi also significantly affected plant height (32.00 cm) and the number of leaves (16.34) at 45 DAP.

The interaction between two-day drought stress and a 125 g dose of coconut coir charcoal bokashi produced the best vegetative growth, as indicated by plant height at 30 DAP (30.95 cm), number of leaves at 30 DAP (12.22) and 45 DAP (16.34), fresh weight (288.41 g), and dry weight (28.38 g) per plant. These results indicate that bokashi can improve the physiological resilience and growth of kailan under short-term drought stress.

Suggestions

It is recommended that further studies explore similar treatments under different environmental conditions or soil types. For optimal results in drought-prone areas, cultivating kailan using 125 g of coconut coir charcoal bokashi per plant is suggested, as it enhances plant tolerance to short-term (2-day) drought stress.

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Author's Contributions

All authors contributed equally to the conception, design, data collection, analysis, and preparation of the manuscript

Ethics

This article is original and has not been published elsewhere. All authors have read and approved the final version of the manuscript, and no ethical issues are involved.

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