Bokashi as a KCl Substitute: Effects on Sweet Corn Growth and Yield Under Different Application Times

Nanik Setyowati [1*], Mony Novelindah Purba [2], Zainal Muktamar [3], Fahrurrozi [4], Putri Mian Hairani [5], Uswatun Nurjanah [6]
[1-2, 4-6] Departement of Crop Production, University of Bengkulu, Indonesia
[3] Departement of Soil Science, University of Bengkulu, Indonesia

* Corresponding Author: **Nanik Setyowati**

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Abstract
Sweet corn productivity is closely related to effective nutrient management, particularly potassium supply, while excessive reliance on inorganic fertilizers may reduce soil sustainability. This study aimed to evaluate the effectiveness of bokashi as a partial substitute for KCl applied at different times on the growth and yield of sweet corn. The experiment was conducted from April to July 2023 in Bengkulu City, Indonesia, using a randomized complete block design with two factors: bokashi application timing (at planting, 7 days before planting, and 14 days before planting) and combinations of bokashi and KCl doses (5 ton ha^{-1} + 50 kg ha^{-1} KCl, 7.5 ton ha^{-1} + 75 kg ha^{-1} KCl, and 10 ton ha^{-1} + 100 kg ha^{-1} KCl). Growth and yield parameters were analyzed using ANOVA followed by Duncan's Multiple Range Test at 5%. The results showed that bokashi application timing did not significantly affect growth and yield variables. Bokashi–KCl dosage significantly influenced shoot fresh weight, with the highest value obtained from 7.5 ton ha^{-1} bokashi combined with 75 kg ha^{-1} KCl applied seven days before planting. Other growth and yield parameters were not significantly affected by bokashi dosage. In conclusion, bokashi can partially substitute KCl without reducing sweet corn performance, with moderate doses applied before planting providing optimal biomass. This finding highlights the potential of bokashi-based fertilization to support more sustainable sweet corn production.

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Keywords: Nutrient Management, Organic Amendment, Potassium Availability, Crop Performance, Soil Health

1. Introduction

Sweet corn (Zea mays saccharata) is a high-value horticultural crop that is widely grown and consumed for its pleasant sweetness, rich nutritional value, and significant economic contribution. It is utilized as fresh food, livestock feed, and raw material for agro-industry in accros regions. Despite its strong economic potential, sweet corn productivity often below optimal levels, largely due to poor soil fertility and inadequate nutrient management practices (Abbas *et al*., 2024) [1]. Adequate and balanced nutrient availability is essential to support vegetative growth, cob development, and kernel quality, making fertilization a critical factor in sweet corn production systems (Wulansari *et al*., 2022) [21].

Conventional sweet corn cultivation relies heavily on synthetic fertilizers to supply essential nutrients, including potassium (K), which plays a fundamental role in photosynthesis, enzyme activation, assimilate translocation, stomatal regulation, and plant tolerance to biotic and abiotic stresses. Potassium deficiency has been associated with reduced biomass accumulation, impaired carbohydrate transport, and lower yield quality in maize crops (Zhang *et al*., 2023) [26]. Consequently, potassium chloride (KCl) is widely applied as the primary K source. However, continuous dependence on synthetic fertilizers may negatively affect soil health by reducing soil organic matter, disturbing microbial activity, and increasing the risk of nutrient imbalance

(Xing *et al*., 2025; Abudurezike *et al*., 2025) [22, 2], particularly under acidic soil conditions.

Organic fertilizers and soil amendments have gained increase attention as sustainable alternatives or complements to synthetic fertilization. Previous studies confirmed that organic fertilizer including weed-based compost (Suci *et al*., 2025; Muktamar *et al*., 2022) [19, 14], vermicompost (Muktamar *et al*., 2025) [16] and liquid organic fertilizer (Muktamar *et al*., 2024) [15] enhances soil properties as well as growth and yield of horticultural crops (Khoirya *et al*., 2025; Yuliana *et al*., 2025; Mario *et al*., 2025; Setyowati *et al*., 2024; Fahrurrozi, *et al*., 2024; Setyowati *et al*., 2023) [11, 24, 13, 17, 8, 18]. This amendment improves soil physical properties by enhancing aggregation, porosity, and water-holding capacity, while also increasing soil organic matter and nutrient retention (Liu *et al*., 2024) [12]. In addition, organic materials contribute to improved soil chemical properties, including higher cation exchange capacity (CEC) and increased availability of macro- and micronutrients (Awwal *et al*., 2025; Xue *et al*., 2022) [5, 23]. These improvements generate a more favorable soil environment for root development and nutrient uptake, ultimately supporting crop growth and productivity (Awwal *et al*., 2025) [5].

Despite these benefits, nutrients in organic fertilizers are predominantly present in organic forms and must undergo microbial mineralization before they become available to plants. Consequently, nutrient release from organic amendments is lower and may not always align with crop nutrient requirements during critical growth stages when used alone. Therefore, integrating organic fertilizers with synthetic nutrient sources has been proposed as a more efficient strategy to synchronize nutrient supply with plant demand while maintaining soil fertility and sustainability.

Bokashi, a fermented organic fertilizer produced through microbial decomposition of organic materials, has been reported to enhance nutrient availability more rapidly than conventional organic amendments. The fermentation process reduces the carbon-to-nitrogen ratio and increases microbial activity, thereby accelerating nutrient mineralization. Bokashi has also been shown to improve soil physical properties, increase microbial populations, and supply essential nutrients, including potassium, making it a potential partial substitute for synthetic K fertilizers (Ginting, 2019) [9].

The effectiveness of bokashi as a substitute or complement to KCl depends on application rate and timing, since these factors influence nutrient mineralization and how well nutrient availability matches crop demand. However, information on how bokashi application timing interacts with partial KCl substitution, particularly in acidic soils, is still limited. Understanding these interactions is essential for optimizing fertilizer management strategies that enhance crop performance while reducing reliance on synthetic fertilizers.

The aim of this study was to evaluate the effects of bokashi as a partial substitute for KCl, applied at different times, on the sweet corn growth and yield, to identify the optimal combination of bokashi and KCl application rates, determine the most suitable timing of bokashi application, and assess their combined effect on sweet corn performance. The findings of this study are expected to contribute to the development of more sustainable and efficient nutrient management practices for sweet corn production.

2. Materials and Methods

2.1 Study Site and Soil Sampling

The study was carried out from April to July 2023 in Kandang Limun Village, Muara Bangkahulu District, Bengkulu City, Indonesia, at approximately ±10 m above sea level. Before establishing the experiment, composite soil samples were collected from a 0–20 cm depth using a grid sampling method. The samples were then air-dried, ground, sieved, and analyzed to determine initial soil chemical properties. Bokashi was also analyzed to assess its nutrient composition.

2.2. Experimental Design and Treatments

The experiment was arranged in a randomized complete block design (RCBD) with two factors. The first factor was the timing of bokashi application, and the second factor was the combination of bokashi rate and potassium chloride (KCl) fertilizer dose. Each treatment combination was replicated three times. Bokashi application timing included three levels: application at planting, 7 days before planting, and 14 days before planting. The bokashi–KCl combination factor also comprised three levels: 5 ton ha^{-1} bokashi with 50 kg ha^{-1} KCl, 7.5 ton ha^{-1} bokashi with 75 kg ha^{-1} KCl, and 10 ton ha^{-1} bokashi with 100 kg ha^{-1} KCl.

2.3. Field Preparation and Crop Management

Land preparation followed standard cultivation practices, including soil tillage and plot arrangement in accordance with the experimental design. Bokashi was applied according to the designated treatment timing and uniformly incorporated into the soil. Sweet corn seeds were then planted following local agronomic recommendations. Basal fertilizers were applied uniformly to all plots, except for potassium fertilizer, which was adjusted based on the treatment combinations. Crop management practices such as regular irrigation, thinning, replanting, manual weed control, and integrated pest and disease management were implemented to support optimal crop growth throughout the growing period.

2.4. Observed Variables

Growth and yield parameters were recorded throughout the experiment. Vegetative growth was evaluated using plant height, number of leaves per plant, stem diameter, and leaf area. Biomass production was assessed through fresh and dry weights of shoots and roots. Yield components included cob length, cob diameter, and the weights of husked and unhusked cobs. Kernel quality was determined by measuring total soluble solids (°Brix). Dry weights were recorded after oven-drying plant samples at a constant temperature until a constant weight was reached, while sweetness was measured using a refractometer.

2.5. Statistical Analysis

All collected data were subjected to analysis of variance (ANOVA) at a 5% significance level to evaluate the effects of bokashi application timing, bokashi–KCl dosage combinations, and their interactions. When significant treatment effects were detected, mean separation was performed using Duncan's Multiple Range Test (DMRT) at the 5% probability level. Statistical analyses were conducted using standard SAS statistical software.

3. Results and Discussion

3.1. Analysis of Variance of Sweet Corn Growth and Yield at Different Application Times and Doses of Bokashi

The results indicated that bokashi application timing did not significantly affect any growth or yield parameters of sweet corn. In contrast, the combined bokashi–KCl application rate significantly influenced shoot fresh weight, whereas other growth and yield variables remained unaffected. A significant interaction between application timing and dosage was observed only for shoot fresh weight (Table 1).

Table 1: Analysis of variance of growth and yield of sweet corn

	F-calculated 5%			
Variables	**Application times (M)**	**Bokashi dose (W)**	**Interaction (M x W)**	**Coefficient Variation (CV) (%)**
Plant height	1.26^{ns}	1.16^{ns}	2.63^{ns}	12.03
Leaves number	0.45^{ns}	0.19^{ns}	2.8^{ns}	9.40
Stem diameter	0.53^{ns}	2.46^{ns}	2.56^{ns}	11.06
Leaf area	0.06^{ns}	0.31^{ns}	2.15^{ns}	9.00
Shoot fresh weight	0.14^{ns}	5.56*	4.2*	17.95
Root fresh weight	2.00^{ns}	1.21^{ns}	0.22^{ns}	29.66
Shoot dry weight	0.23^{ns}	0.85^{ns}	2.03^{ns}	21.10
Root dry weight	0.48^{ns}	1.44^{ns}	0.27^{ns}	31.73
Husked cob weight	0.11^{ns}	1.11^{ns}	0.96^{ns}	20.41
Unhusked cob weight	0.19^{ns}	0.85^{ns}	0.86^{ns}	20.97
Husked cob length	0.11^{ns}	1.19^{ns}	0.75^{ns}	7.05
Unhusked cob length	0.17^{ns}	2.14^{ns}	1.13^{ns}	8.26
Husked cob diameter	0.03^{ns}	0.59^{ns}	0.56^{ns}	8.24
Unhusked cob diameter	0.09^{ns}	0.64^{ns}	0.32^{ns}	8.54
Corn sweetness	0.23^{ns}	0.71^{ns}	0.34^{ns}	17.00

Note: ns = no significant effect, * = significant effect at the 5% level, CV = coefficient of variation

The uniform response of sweet corn growth and yield to different bokashi application times suggests that the bokashi was well decomposed, allowing nutrients to be readily available regardless of application timing. This is supported by the low C/N ratio of bokashi, which promotes rapid and consistent nutrient release.

3.2. The Effect of Bokashi Application Time on Sweet Corn Growth and Yield

Bokashi application timing (at planting, 7 days before planting, and 14 days before planting) had no significant effect on vegetative growth parameters, including plant height, leaf number, stem diameter, leaf area, and shoot and root biomass (Table 2). Similarly, yield components such as cob length, cob diameter, cob weight, and sweetness level were not significantly influenced by application timing (Table 3).

Table 2: Effect of Bokashi Application Time on Sweet Corn Growth

Application time	PH (cm)	LN	SD (mm)	LA (cm^2)	SFW (g)	RFW (g)	SDW (g)	RDW (g)
M0	175.50	10.24	22.83	103.56	337.37	53.17	103.7	12.22
M1	176.82	9.87	23.91	104.80	339.04	52.17	97.39	12.78
M2	162.79	9.89	22.77	103.40	351.80	40.88	102.86	11.04

Note: M0= bokashi applied at planting time, M1=7 days before planting, M2= 14 days before planting, Plant height (PH), Leaves number (LN), Stem diameter (SD), Leaf area (LA), Shoot fresh weight (SFW), Root fresh weight (RFW), Shoot dry weight (SDW), Root dry weight (RDW)

Table 3: Effect of Bokashi Application Time on Sweet Corn Yields

Application time	HCL (cm)	UCL (cm)	HCD (mm)	UCD (mm)	HCW (g)	UCW (g)	CS (brix)
M0	29.08	18.77	52.56	45.76	261.51	186.06	9.68
M1	28.72	19.20	53.10	46.50	269.09	191.47	10.22
M2	29.14	18.93	52.79	45.76	273.57	197.98	9.68

Note: Treatment descriptions as in Table 2., Husked cob length (HCL), Unhusked cob length (UCL), Husked cob diameter (HCD), Unhusked cob diameter (UCD), Husked cob weight (HCW), Unhusked cob weight (UCW), Corn sweetness (CS)

These results indicate that bokashi nutrients were sufficiently available across all application times, likely due to the fermented nature of bokashi, which promotes relatively stable nutrient release. Consequently, differences in application timing did not result in measurable differences in plant growth or yield responses.

In general, organic amendments can improve soil properties by increasing organic matter and soil physical properties, thus increasing nutrient availability to plants throughout the growth phase (Abbas *et al*., 2024; Haider *et al*., 2021) [1, 7]. Research shows that organic matter application significantly increases soil organic matter content and nutrient concentrations available to plants, although specific growth responses may vary depending on the type and dosage of organic matter used (Abbas *et al*., 2024) [1].

In addition to organic amendments, corn growth can be influenced by the enriched soil microorganism through the application of organic fertilizer. Bio-organic fertilization, which combines organic fertilizer and beneficial microbes, can significantly increase corn productivity by improving soil enzyme activity and microbial diversity, which supports sustainable nutrient cycling (Tang *et al.*, 2025) [20]. This suggests that the timing of application, once the bokashi is mature, has a smaller impact than the presence and quality of the organic matter itself.

3.3. The Effect of Bokashi Dosage on Sweet Corn Growth and Yield

Different combinations of bokashi and KCl significantly affected shoot fresh weight but did not influence other growth or yield parameters (Table 4). The highest shoot fresh weight was observed at the intermediate bokashi–KCl dose (7.5 ton ha⁻¹ bokashi + 75 kg ha⁻¹ KCl), whereas the highest dose did not further increase biomass.

Table 4: Effect of Bokashi Dose on Sweet Corn Growth

Bokashi dose	PH (cm)	LN	SD (mm)	LA (cm^2)	SFW (g)	RFW (g)	SDW (g)	RDW (g)
W0	163.64	9.89	22.71	105.82	349.87 ab	49.01	98.17	12.81
W1	176.61	10.16	24.71	103.60	387.15 a	53.92	108.89	12.98
W2	175.40	9.96	22.16	102.34	291.19 b	43.29	96.92	10.25

Note: W0= 5 ton ha⁻¹ bokashi + 50 kg ha⁻¹ KCl; W1=7.5 ton ha⁻¹ bokashi + 75 kg ha⁻¹ KCl, W2= 10 ton ha⁻¹ bokashi +100 kg ha⁻¹ KCl, Plant height (PH), Leaves number (LN), Stem diameter (SD), Leaf area (LA), Shoot fresh weight (SFW), Root fresh weight (RFW), Shoot dry weight (SDW), Root dry weight (RDW)

Table 5: Effect of Bokashi Dose on Sweet Corn Yield

Bokashi dose	HCL (cm)	UCL (cm)	HCD (mm)	UCD (mm)	HCW (g)	UCW (g)	CS (brix)
W_0	25.25	18.58	52.44	45.47	257.79	190.08	10.34
W_1	28.96	19.85	54.08	47.25	283.57	204.76	10.03
W_2	29.74	18.47	51.93	45.76	254.39	180.08	9.41

Note: Treatment descriptions as in Table 4., Husked cob length (HCL), Unhusked cob length (UCL), Husked cob diameter (HCD), Unhusked cob diameter (UCD), Husked cob weight (HCW), Unhusked cob weight (UCW), Corn sweetness (CS)

The absence of significant differences in most yield components suggests that sweet corn yield was relatively stable across bokashi–KCl dosage treatments. This indicates that partial substitution of KCl with bokashi did not negatively affect yield performance within the tested dosage range.

As an essential element, potassium plays a crucial role in plant physiological processes, including stomatal regulation, photoassimilate translocation, and increased resistance to environmental stress. Studies combining potassium fertilizer with organic sources have reported that the addition of potassium along with organic fertilizers can improve vegetative growth and corn biomass by stimulating root growth and nutrient utilization efficiency (Al-khalifa *et al.*, 2024; Al-Sheikh *et al.*, 2025) [3, 4]. Other studies have also shown that the combination of synthetic and organic fertilizers generally provides the highest yield increases compared to single application, as it improves soil fertility and overall crop productivity (Jiang *et al.*, 2024) [10].

The higher fresh shoot weight response at certain doses of bokashi and KCl in this study was due to organic fertilizers stimulating soil microbial activity, which affects sustainable nutrient availability. Bio-organic fertilizers enriched with microbes such as Bacillus spp. have been reported to improve the efficiency of potassium and NPK fertilization in corn by increasing micronutrient availability and soil enzyme activity that plays a role in nutrient mineralization (Tang *et al.*, 2025) [20].

However, increasing the bokashi dosage to the highest level does not always result in increased yields. This is likely related to acidic soil conditions and the limited availability of certain nutrients due to nutrient fixation at low pH. Furthermore, the slow-release nature of bokashi means some nutrients are not fully available during the critical phase of cob formation.

Based on soil analysis results at the research site, the soil pH used in the study was 4.58 (acidic) and the availability of macronutrients was also low. Low soil pH also reduces nutrient availability and inhibits organic decomposition, thereby reducing soil fertility (Brady & Weil, 2016) [6]. Nutrients are easily absorbed by plant roots at a neutral pH. At this pH, most nutrients are readily soluble in water, but in acidic soils, P is bound to Al and cannot be absorbed by plants. If the pH is too low or too high, the decomposition of organic matter will be hampered, thus inhibiting the release of nutrients from organic matter.

3.4. Combined Effect of Bokashi Application Time and Dosage on Shoot Fresh Weight

A significant interaction between bokashi application timing and dosage was resulted only for shoot fresh weight (Table 6). The combination of 7.5 ton ha⁻¹ bokashi and 75 kg ha⁻¹ KCl applied seven days before planting produced the highest shoot fresh weight. In contrast, increasing bokashi dosage to 10 ton ha⁻¹ combined with higher KCl rates did not improve biomass accumulation, particularly when applied earlier.

Table 6: Interaction of application time and bokashi dose on fresh weight of corn shoots

Application time	Bokashi dose (ton ha^{-1}) + KCl (kg ha^{-1})		
	5 ton + 50 kg	7.5 ton + 75 kg	10 ton + 100 kg
At planting date	376.21 AB	307.55 B	328.35 A
	a	a	a
7 days before planting	277.19 AB	455.48 A	284.46 AB
	b	a	ab
14 days before planting	396.22 A	398.41 AB	260.76 B
	a	a	b

Overall, these results suggest that moderate bokashi–KCl combinations applied shortly before planting optimize vegetative biomass production, while higher doses do not necessarily enhance plant performance.

The results of this study indicate that high bokashi doses do not always increase yields, which can be attributed to soil properties. In acidic or low-organic soils, the dynamics of nutrient release from organic matter can be delayed or inhibited by nutrient fixation if the soil pH is not optimal. Other studies have shown that soil physical-chemical conditions significantly influence the response of organic and synthetic fertilizers to plant growth. Soils with improved structure through organic amendments tend to exhibit more stable productive responses over the long term compared to those with synthetic fertilizers alone (Zhang *et al*., 2022) [25]. The use of organic materials such as bokashi also increases soil organic carbon content, improves porosity, and improves soil microbial activity, all of which are important indicators of the sustainability of corn agroecosystems. These soil properties improve crop production, although the dose effect only affects certain vegetative parameters but not all yield parameters directly within a single crop growth cycle (Abbas *et al*., 2024) [1].

4. Conclusion

The highest fresh biomass of sweet corn was obtained from the application of 7.5 ton ha^{-1} bokashi combined with 75 kg ha^{-1} KCl applied seven days before planting. Bokashi application timing had similar effects on sweet corn growth and yield, and different bokashi rates substituting KCl showed no significant influence on most growth and yield parameters.

5. Conflicts of interest

The authors declare no conflict of interest

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