



Effectiveness of Ameliorant and Potassium Fertilizer Applications on the Vegetative Growth of Sugarcane (*Saccharum officinarum* L.) Var. Bululawang

Boby Akbar Faris¹, Sudiarso^{1*}, Nur Edy Suminarti¹, Subiyakto²

(Received September 2025/Accepted January 2026)

ABSTRACT

Sugarcane (*Saccharum officinarum* L.) is a strategic crop in Indonesia's sugar industry, but its productivity fell from 87.40 t/ha in 2022 to 86.40 t/ha in 2023, remaining below the potential yield of the Bululawang variety (94.3 t/ha). This decline was attributed to unsustainable agriculture practices and climate change, which resulted in decreased soil fertility. The purpose of this study was to examine the effects of ameliorant and potassium fertilizer combinations on the vegetative growth of sugarcane (Bululawang variety) and identify which treatment was more beneficial. The treatments included seven combinations: P1 (no ameliorant and no K₂O), P2 (4 L/ha ameliorant + 388.8 kg K₂O), P3 (4 L/ha ameliorant + 259.2 kg K₂O), and P4 (4 L/ha ameliorant + 129.6 kg K₂O), P5 (8 L/ha + 388.8 kg K₂O/ha), P6 (8 L/ha + 259.2 kg K₂O/ha), and P7 (8 L/ha + 129.6 kg K₂O/ha) were duplicated four times. The findings revealed that the combination of ameliorant and potassium fertilizer greatly promoted vegetative development, as evidenced by increased root length, root dry weight, number of leaves, plant height, leaf area, number of tillers, stem diameter, and total plant biomass. Treatment P5 provided the highest values for several parameters, however treatment P6 had no significant difference from P5 for certain features, indicating more efficient potassium usage.

Keywords: ameliorant, Bululawang Variety, potassium fertilizer, sugarcane, vegetative growth

INTRODUCTION

Sugarcane (*Saccharum officinarum* L.) is a valuable plantation crop that plays an important part in the sugar industry. It is characterized by extensive environmental adaptability, efficient water use, and high biomass production capability (Waclawovsky *et al.* 2010). In addition to being an essential food source, sugarcane is used to make a variety of industrial goods, including bioethanol (Pratiti *et al.* 2023). Indonesia, as one of Southeast Asia's top sugar producers, relies heavily on this commodity to provide national food security and industry (Tian 2017). However, national sugarcane productivity has decreased from 87.40 t/ha in 2022 to 86.40 t/ha in 2023 (Pusat Data dan Sistem Informasi Pertanian 2023), despite the Bululawang variety's potential yield of up to 94.3 t/ha (P3GI). This loss is linked to unsustainable agricultural techniques, particularly the continuous use of inorganic fertilizers, which impair soil physical, chemical, and biological qualities (Andriyani *et al.* 2023; Nurnawati *et al.* 2022; Prasetyo & Evizal 2021; Sesanti *et al.* 2021).

Despite substantial study on sugarcane farming, most studies focus on the specific impacts of ameliorants or potassium fertilizers. Few research have examined their combined impact on vegetative development, notably for the Bululawang cultivar in the field. Furthermore, the processes governing the interaction of soil amelioration and potassium availability throughout early physiological and morphological development are mainly unknown. Addressing these gaps is critical to making evidence-based recommendations for sustainable agricultural practices.

A viable technique for improving sustainable farming is the use of both ameliorants and potassium fertilizers. Ameliorants help to improve soil fertility by increasing organic carbon content, cation exchange capacity (CEC), and soil porosity, all of which help water and air travel through the soil (Uswanti 2023). Meanwhile, potassium, an essential macronutrient, plays an important physiological role in sugarcane growth by acting as a cofactor for over 40 enzymes and participating in processes such as photosynthesis, protein synthesis, and carbohydrate and protein metabolism. Previous research suggests that this combination can significantly improve soil conditions and agricultural output (Mulyati *et al.* 2022; Hazra *et al.* 2021; Haryati *et al.* 2020; Agustin *et al.* 2020; Hidayat *et al.* 2020), as well as improve photosynthesis and water-use efficiency in sugarcane (Puspitasari 2023; Diana *et al.* 2016). Nonetheless, most of the previous

¹ Agronomy Study Program, Faculty of Agriculture, Brawijaya University, Malang 65145, Indonesia

² Center for Horticulture and Plantation Research, National Research and Innovation Agency, West Java 16911, Indonesia

* Corresponding Author: Email: sudiarso1105@gmail.com

studies has concentrated on the individual impacts of ameliorants or potassium fertilizers, with few studies addressing their synergistic influence on sugarcane vegetative growth, particularly for the Bululawang type in the field. The mechanisms governing the interplay between soil improvement and potassium availability throughout early physiological and morphological development are likewise insufficiently explored. Therefore, the purpose of this study was to see how combining ameliorants and potassium fertilizers affected the vegetative growth of the Bululawang sugarcane variety. This study aimed to bridge a knowledge gap by providing scientific insights as well as practical solutions to promote more sustainable sugarcane cultivation through enhanced soil and nutrient management.

METHODS

The study was carried out from September 2024 to March 2025 on a sugarcane farmer's field in Pringu Village, Bululawang Subdistrict, Malang Regency, East Java, Indonesia. The site is located at 8.10° S and 112.68° E, with an elevation of 406 m above sea level. During the study period, the minimum temperature was 18.15–21.24 °C, the maximum temperature was 29.72–31.30 °C, the relative humidity ranged from 63.45% to 81.65%, the annual rainfall was 1,512.1 mm, and the daily sunlight time ranged from 18.82 to 37.72%.

An initial soil analysis was conducted at the UPT Agribusiness Development Laboratory for Food Crops and Horticulture in Bedali-Lawang to evaluate baseline soil fertility status, which included total N, accessible P, exchangeable K, organic C, soil texture, pH, and CEC. Mid-term and final soil studies were performed for three- and six-months following ratooning, using incubated soil samples devoid of plants, to assess changes in nutrient availability throughout the experiment.

The field trial adopted a Randomized Complete Block Design (RCBD) with 7 treatment combinations. Treatments included a combination of ameliorant doses (4 and 8 L/ha) and potassium (K₂O) fertilizer rates (129.6, 259.2, and 388.8 kg/ha), as well as a control treatment without either. In total, 28 experimental units were established. Sugarcane from the Bululawang variety at the first ratoon stage was used as planting material. Each treatment combination was reproduced four times, for a total of 28 experimental units. The plots measured 34.125 m in length and 2.35 m in width, with an area of 80.19 m². Each plot contained two planting beds separated by drainage strips. Each bed measured 34.125 m in length and 0.6 m in breadth, and included 46 plants, for a total of 92 plants per plot.

Land preparation consisted of identifying the 2,252.25 m² trial area, cleaning weeds, and preparing 56 planting ridges. Crop management techniques included irrigation, fertilization, weeding, hilling-up, leaf stripping, and integrated pest management (IPM). The ameliorant (24.44% organic C) was applied 21 days after low cutting (DALC) by dissolving it in 500 L water/ha. SP-36 fertilizer was applied completely at 7 DALC, whereas urea was applied twice. Potassium chloride was applied alongside the second urea application 1.5–3 months after low cutting (MALC). All fertilizers were placed 5 cm from the stalk, with a soil depth of 7 cm. Hilling-up was done at 3 MALC, followed by leaf stripping at 3 and 6 months to increase light penetration and air circulation.

The observations comprised morphological and physiological characteristics such as root length, root dry-weight, plant height, number of internodes, number of tillers, number of leaves, leaf area, plant fresh weight, stem fresh weight, stem diameter, plant dry weight, and crop growth rate. The data were evaluated using analysis of variance (ANOVA) with a 5% significance level. When treatment effects were significant, the Honestly Significant Difference (HSD) test at the 5% level was used to separate treatment responses.

RESULTS AND DISCUSSION

The study's findings revealed that the combination of ameliorant and potassium treatments had a significant impact on all examined parameters, including the vegetative phase, biomass accumulation, and yield quality.

Root Length (cm/clump)

A statistical examination of root length revealed a substantial effect of the combination of ameliorant and potassium fertilizer treatments from 1 to 6 months after low cutting (MALC), as shown in Table 1. P2 and P5 consistently produced the longest roots, whereas P1 and P4 were typically the shortest. Although most treatments did not differ substantially from the control at particular points in time, P2 and P5 demonstrated the most consistent improvements.

Root length was assessed to reflect soil exploration capacity and nutrient-water uptake, which supports the study's goal of determining how ameliorant and potassium improve soil conditions for ratoon regrowth. Ameliorant application increased root elongation by increasing sand and silt while reducing clay, particularly at 8 L/ha, resulting in improved structure, porosity, and aeration, lowering mechanical resistance. Potassium fertilizer stimulated root development through osmotic regulation, enzyme activation, and photosynthetic transport, while improved soil structure increased potassium retention and uptake. At 8 L/ha, the ameliorant reduced clay to 59–62% and increased

sand and silt by 9–10% and 29–30%, respectively, while also increasing soil organic carbon and CEC, hence improving nutrient retention and aggregate stability (Gu *et al.* 2023; Li *et al.* 2022). Potassium-induced turgor promoted cell proliferation (Nanda *et al.* 2022; Respatie *et al.* 2020), and root length was greatest in P5.

Root Dry-weight (g/clump)

Table 2 shows the combination of ameliorant and potassium fertilizer had a substantial effect on root dry-weight ranging from 1 to 6 MALC. Observations revealed that the combination of ameliorant and potassium fertilizer greatly enhanced the root dry weight of Bululawang sugarcane at all stages (1–6 MALC). Treatments P2, P5, and P6 consistently gave higher results, indicating early stimulation of a stronger root system. Ameliorants improved soil structure, porosity, and water retention (Amelya & Syarovy 2024), whereas potassium promoted cell division, osmotic control, and biomass production (Sopiana *et al.* 2024; Pramukyana *et al.* 2021).

Treatments P2, P5, and P6 had the highest root dry-weights at all stages. Ameliorants reduced nutrient leaching and increased potassium absorption, hence promoting biomass buildup. Setyaji *et al.* (2024) discovered that ameliorant-potassium combinations promote microbial colonization and subterranean

biomass. At 6 MALC, P5, P6, and P7 had the highest values, indicating continuous increases in soil condition and nutrient efficiency. This is comparable with *Solihin et al.* (2019), who observed up to a 38% increase in root biomass under combined ameliorant and potassium treatment.

Plant Height (cm)

The investigation revealed that the combination of ameliorant and potassium fertilizer had a significant effect on plant height ranging from 1 to 6 MALC, as shown in Table 3. Plant height in Bululawang sugarcane grew dramatically from 1 to 6 MALC with the combined application of ameliorant and potassium fertilizer, with P5 exhibiting the greatest growth. Ameliorants increased soil structure and water retention, allowing for vegetative development even under suboptimal conditions, as reported by Tando (2017) and Aziza *et al.* (2021). Mid-season soil study revealed that 8 L/ha ameliorant enhanced total nitrogen, which promotes cell division, elongation, and photosynthesis (Jin *et al.* 2024; Mao *et al.* 2024; Anwar *et al.* 2021).

Potassium also increased stem elongation by increasing photosynthetic transport, chlorophyll production, and enzyme activity (Hafizah *et al.* 2022). The combination of ameliorant and potassium provided excellent and maintained vertical growth. Ameliorants

Table 1 The average root length of sugarcane plants under the combination treatment of ameliorant and potassium fertilizer at all observation ages

Treatment	Mean root length (cm/clump) at each observation period (MALC)					
	1	2	3	4	5	6
P1	10.00 ^a	15.50 ^a	25.00 ^a	30.25 ^a	34.00 ^a	39.50 ^a
P2	15.75 ^{cd}	22.00 ^d	33.75 ^{bc}	39.00 ^b	45.50 ^{bc}	52.00 ^{cd}
P3	14.00 ^{bc}	19.50 ^{bc}	29.75 ^{abc}	36.25 ^{ab}	43.00 ^{abc}	46.75 ^{bc}
P4	12.25 ^{ab}	17.25 ^{ab}	28.00 ^{ab}	35.25 ^{ab}	36.50 ^{ab}	43.75 ^{ab}
P5	17.75 ^d	25.00 ^e	35.75 ^c	40.75 ^b	49.25 ^c	56.75 ^d
P6	16.25 ^{cd}	21.75 ^{cd}	32.00 ^{abc}	38.75 ^b	43.50 ^{abc}	55.00 ^d
P7	14.25 ^{bc}	19.50 ^{bc}	28.25 ^{ab}	35.75 ^{ab}	40.75 ^{abc}	51.25 ^{cd}
HSD (5%)	2.46	2.43	7.38	6.55	10.28	7.10
CV (%)	7.35	5.19	10.41	7.66	10.53	6.17

Remarks: Data are presented as the mean of 4 replicates \pm SD; Different superscripts in the same column indicate a significant difference ($\alpha < 0.05$); MALC = months after low cutting; CV = coefficient of variation.

Table 2 The average root dry weight of sugarcane plants under the combination treatment of ameliorant and potassium fertilizer at all observation ages

Treatment	Mean root dry weight (g/clump) at each observation period (MALC)					
	1	2	3	4	5	6
P1	23.08 ^a	38.00 ^a	132.40 ^a	209.18 ^a	347.33 ^a	572.71 ^a
P2	29.95 ^{bc}	57.68 ^{bc}	153.45 ^{bcd}	264.53 ^{cd}	617.00 ^b	849.19 ^c
P3	27.90 ^{ab}	52.88 ^{abc}	141.33 ^{abc}	254.15 ^{bcd}	510.55 ^{ab}	761.55 ^{bc}
P4	25.20 ^{ab}	51.58 ^{ab}	137.65 ^{abc}	219.95 ^{ab}	557.18 ^{ab}	679.27 ^{ab}
P5	35.65 ^c	70.65 ^c	164.60 ^{bd}	267.33 ^d	704.10 ^b	868.93 ^c
P6	35.08 ^c	63.85 ^{bc}	160.55 ^{cd}	248.28 ^{abcd}	614.08 ^b	840.64 ^c
P7	29.45 ^{bc}	59.35 ^{bc}	151.30 ^{abcd}	225.45 ^{abc}	571.58 ^{ab}	740.93 ^{bc}
HSD (5%)	6.31	18.05	19.79	41.21	237.84	155.62
CV (%)	9.16	13.72	5.69	7.31	18.17	8.77

Remarks: Data are presented as the mean of 4 replicates \pm SD; Different superscripts in the same column indicate a significant difference ($\alpha < 0.05$); MALC = months after low cutting; CV = coefficient of variation.

increased potassium retention and decreased leaching. Harini *et al.* (2021) found that this combination increased vegetative growth by up to 25% as compared to single applications. Such synergy is critical in tropical systems like Indonesia for effective input usage and increased yield (Anam *et al.* 2023).

Number of Internodes

The investigation revealed that the combination of ameliorant and potassium fertilizer had a substantial influence on the number of internodes between 2 and 6 MALC, with no effect at 1 MALC, as shown in Table 4. The number of internodes is an important morphological characteristic that influences sugarcane output because internodes are the primary locations of sucrose accumulation. Their creation is dependent on active cell division and extension in stem meristems, which are affected by plant physiology and nutrient supply. The treatments P2–P7 yielded the highest internode numbers. Potassium is the most important nutrient in this process, as it promotes photosynthate transport, enzyme activity, and turgor pressure, all of which promote stem growth and internode formation (Hafizah *et al.* 2022). Nitrogen also aids vegetative development.

Ameliorants improve soil physical and chemical qualities such as structure, water content, and CEC, resulting in increased root nutrient uptake and more

active stem and internode development. Increased organic carbon facilitates progressive N and K release. Mid- and late-season soil analysis revealed that 8 L/ha ameliorant consistently improved soil quality, resulting in higher K and N total levels, particularly when combined with 388.8 kg/ha potassium fertilizer (Kurnianto *et al.* 2023). This treatment also enhanced soil texture by lowering clay content and increasing sand and silt fractions, leading in more stable soil moisture and better root-zone conditions.

Potassium improved glucose translocation, photosynthesis, enzyme activity, and stem strength (Ahanger *et al.* 2015; Liu *et al.* 2011), resulting in larger and healthier internodes (Wang *et al.* 2013). The best results were obtained with 8 L/ha ameliorant and 388.8 kg/ha potassium fertilizer, which enhanced nutrient availability and uptake, promoting active cell division and elongation and significantly boosting internode number (Prayitno 2017).

Number of Tillers

The investigation revealed that the combination of ameliorant and potassium fertilizer significantly increased the number of tillers from 1 to 6 MALC, as shown in Table 5. The use of ameliorant and potassium fertilizer improved the number of tillers in Bululawang sugarcane from 1 to 6 MALC, with treatment P5 yielding the most tillers. This demonstrates a good

Table 3 The average plant height of sugarcane plants under the combination treatment of ameliorant and potassium fertilizer at all observation ages

Treatment	Mean plant height (cm) at each observation period (MALC)					
	1	2	3	4	5	6
P1	18.13 ^a	44.25 ^a	131.00 ^a	157.50 ^a	180.25 ^a	226.55 ^a
P2	24.00 ^b	59.50 ^{bc}	157.00 ^b	193.00 ^b	216.75 ^b	289.13 ^{bc}
P3	22.63 ^b	57.00 ^{abc}	151.00 ^{ab}	183.00 ^{ab}	203.50 ^{ab}	280.05 ^{bc}
P4	21.50 ^{ab}	50.25 ^{ab}	142.00 ^{ab}	175.75 ^{ab}	209.75 ^{ab}	251.00 ^{ab}
P5	24.88 ^b	64.00 ^c	162.50 ^b	194.75 ^b	227.25 ^b	319.30 ^c
P6	24.00 ^b	56.50 ^{abc}	156.50 ^b	183.25 ^{ab}	217.75 ^b	294.75 ^{bc}
P7	22.63 ^b	54.25 ^{abc}	150.50 ^{ab}	181.25 ^{ab}	213.25 ^{ab}	277.50 ^{abc}
HSD (5%)	3.91	12.95	22.50	27.75	39.11	53.07
CV (%)	7.43	10.06	6.42	6.55	7.98	8.20

Remarks: Data are presented as the mean of 4 replicates \pm SD; Different superscripts in the same column indicate a significant difference ($\alpha < 0.05$); MALC = months after low cutting; CV = coefficient of variation.

Table 4 The average number of internodes of sugarcane plants under the combination treatment of ameliorant and potassium fertilizer at all observation ages

Treatment	Mean number of internode at each observation period (MALC)					
	1	2	3	4	5	6
P1	2.75	3.50 ^a	4.75 ^a	6.75 ^a	9.50 ^a	13.25 ^a
P2	3.25	6.50 ^b	8.75 ^b	13.50 ^b	17.75 ^{bc}	22.00 ^b
P3	3.25	5.75 ^b	8.25 ^b	12.50 ^b	17.00 ^{bc}	21.25 ^b
P4	3.00	5.50 ^{ab}	8.00 ^b	11.75 ^b	15.75 ^b	20.75 ^b
P5	4.00	6.75 ^b	9.75 ^b	14.50 ^b	18.50 ^c	22.75 ^b
P6	3.75	6.50 ^b	9.00 ^b	13.00 ^b	17.00 ^{bc}	22.00 ^b
P7	3.50	5.75 ^b	8.50 ^b	11.50 ^b	15.50 ^b	21.25 ^b
HSD (5%)	ns	2.03	2.60	3.82	2.71	4.69
CV (%)	16.14	15.10	13.66	13.72	7.31	9.81

Remarks: Data are presented as the mean of 4 replicates \pm SD; Different superscripts in the same column indicate a significant difference ($\alpha < 0.05$); MALC = months after low cutting; CV = coefficient of variation; ns = Non-significant.

physiological response to increased soil conditions and nutrient availability. According to Anggraeni *et al.* (2022), adequate nutrition and good soil porosity promote early tiller development.

Ameliorants promoted tillering by increasing soil texture and regulating water retention. Although the short-term soil texture classification remained similar, adding 4–8 L/ha of ameliorant resulted in an increase in sand and silt content and a decrease in clay. These alterations enhance porosity, aeration, and water availability in the root zone. Ameliorants also aided bud sprouting by boosting accessible nitrogen and dissolved carbon levels after dormancy break (Kusumastuti *et al.* 2022). Soil study revealed that 8 L/ha of ameliorant produced the most total nitrogen (N-total), promoting vegetative tissue and tiller production (Uge *et al.* 2021; Kurniawati & Priyadi 2021). Nitrogen is required for protein and enzyme production, which promotes axillary bud formation (Hikmah *et al.* 2021). Potassium also plays an important function in photosynthesizing transport and activating enzymes involved in axillary bud elongation (Widyati 2020). Marwanto *et al.* (2021) found that the appropriate potassium dosage enhances tiller production by up to 35% relative to untreated controls.

Number of Leaves (blade/clump)

The investigation revealed that the combination of ameliorant and potassium fertilizer significantly increased the number of leaves from 1 to 6 MALC, as shown in Table 6. Treatment P5 generated more leaves than the control because the ameliorant increased nitrogen availability and encouraged microbial activity, promoting early leaf formation (Septiningrum & Hardiani 2016). Leaf number represents photosynthetic capacity and productivity (Raksun *et al.* 2020), demonstrating that increasing soil nitrogen promotes early leaf growth. Mid-season soil study revealed that plots treated with ameliorant had higher total nitrogen levels. The 8 L/ha dose increased soil physical, chemical, and biological parameters such as pH, structure, and microbial activity, promoting organic matter decomposition and nitrogen mineralization (Setiawati *et al.* 2023). Nitrogen promotes chlorophyll, amino acid, and protein synthesis, which stimulates cell division and leaf expansion (Astiko *et al.* 2025).

The study's findings indicate that the ameliorant and potassium have a synergistic effect on canopy growth. Potassium reinforces cell walls, improves nutrient transport, regulates turgor, and stimulates photosynthesis and stomatal activity, encouraging leaf

Table 5 The average number of tillers of sugarcane plants under the combination treatment of ameliorant and potassium fertilizer at all observation ages

Treatment	Mean number of tillers at each observation period (MALC)					
	1	2	3	4	5	6
P1	2.50 ^a	2.75 ^a	4.00 ^a	4.25 ^a	4.50 ^a	5.00 ^a
P2	3.50 ^{ab}	5.00 ^{cd}	6.75 ^{bc}	7.50 ^{cd}	8.00 ^{bc}	8.00 ^c
P3	3.25 ^{ab}	4.00 ^{bc}	5.75 ^{abc}	6.25 ^{bc}	7.00 ^{abc}	6.75 ^{bc}
P4	2.75 ^{ab}	3.25 ^{ab}	4.75 ^{abc}	5.00 ^{ab}	5.50 ^{ab}	5.50 ^{ab}
P5	3.75 ^b	5.50 ^d	7.50 ^c	8.00 ^d	8.25 ^c	9.75 ^d
P6	3.25 ^{ab}	4.75 ^{cd}	6.00 ^{abc}	7.25 ^{cd}	7.50 ^{bc}	8.25 ^{cd}
P7	2.75 ^{ab}	4.00 ^{bc}	5.50 ^{abc}	5.50 ^{ab}	6.25 ^{abc}	7.50 ^c
HSD (5%)	1.20	1.25	2.56	1.65	2.68	1.78
CV (%)	16.59	12.79	19.04	11.31	17.07	10.21

Remarks: Data are presented as the mean of 4 replicates \pm SD; Different superscripts in the same column indicate a significant difference ($\alpha < 0.05$); MALC = months after low cutting; CV = coefficient of variation.

Table 6 The average number of leaves of sugarcane plants under the combination treatment of ameliorant and potassium fertilizer at all observation ages

Treatment	Mean numbers of leaves (blade/clump) at each observation period (MALC)					
	1	2	3	4	5	6
P1	14.75 ^a	21.00 ^a	30.75 ^a	34.75 ^a	43.00 ^a	49.75 ^a
P2	18.75 ^{bc}	28.00 ^{ab}	40.50 ^b	44.25 ^{bc}	52.00 ^{bc}	58.50 ^{ab}
P3	17.25 ^{abc}	27.75 ^{ab}	37.00 ^{ab}	41.00 ^{bc}	48.75 ^{abc}	56.25 ^{ab}
P4	15.50 ^{ab}	25.50 ^{ab}	31.00 ^a	39.00 ^{ab}	46.25 ^{ab}	53.50 ^{ab}
P5	20.25 ^c	31.25 ^b	39.25 ^b	46.25 ^c	54.75 ^c	59.75 ^b
P6	18.25 ^{bc}	27.50 ^{ab}	37.50 ^{ab}	43.75 ^{bc}	50.00 ^{bc}	56.50 ^{ab}
P7	16.00 ^{ab}	26.25 ^{ab}	34.00 ^{ab}	40.25 ^b	47.50 ^{ab}	54.00 ^{ab}
HSD (5%)	3.40	8.55	7.97	5.67	6.85	7.48
CV (%)	8.43	13.68	9.55	5.87	5.99	5.77

Remarks: Data are presented as the mean of 4 replicates \pm SD; Different superscripts in the same column indicate a significant difference ($\alpha < 0.05$); MALC = months after low cutting; CV = coefficient of variation.

development (Aziza *et al.* 2021). Ginting (2020) showed a rise in leaf number with potassium and organic matter. The observed leaf growth reflects enhanced nutrient absorption efficiency and soil moisture stability, both of which boost metabolism (Mansyur *et al.* 2021). These results are consistent with those of Oktaviani *et al.* (2020), that potassium–organic matter combinations improved leaf growth and shoot biomass in tropical crops, resulting in more sustainable cultivation.

Leaf Area (cm²/clump)

The analysis of variance on leaf area revealed a significant influence of the combination ameliorant and potassium fertilizer treatments from 1 to 6 MALC, as shown in Table 7, with P5 showing the best response. In comparison to the control, P5 leaf area rose by 16.17%. This finding is consistent with earlier research showing that ameliorants improve soil CEC, moisture retention, and nutrient availability, whereas potassium stimulates leaf growth by improving cell turgor and photosynthetic activity in sugarcane and ratoon systems. The combination improvement in soil characteristics and physiological performance gives a clear explanation for the increased leaf growth seen in this study.

Plant Fresh Weight (g/clump)

The analysis of variance revealed that the combination of ameliorant and potassium fertilizer enhanced the total fresh weight of sugarcane by 1 to 6 MALC, as shown in Table 8. All treatments including ameliorant and potassium (P2–P7) produced more fresh weight than the control (P1), with P5 consistently exhibiting the greatest biomass accumulation. Compared to the control, P5 raised total fresh weight by +49% to +265%, with the highest effect seen at early growth stages (1–2 MALC). These outcomes are consistent with prior research showing that ameliorants improve soil physical characteristics, CEC, moisture retention, and nutrient availability, all of which promote early vegetative growth in sugarcane and ratoon crops. Meanwhile, potassium is well-known for its function in enzyme activation, osmotic regulation, photosynthetic transport, and stalk biomass synthesis, which promotes increased fresh weight accumulation. The synergistic interaction of ameliorant and potassium most likely resulted in more effective N, P, and K absorption, improved water-use efficiency, and increased plant resistance in tropical fields. This is consistent with previous sugarcane research, demonstrating that integrated soil amendments and balanced K fertilization can provide significant practical

Table 7 The average leaf area of sugarcane plants under the combination treatment of ameliorant and potassium fertilizer at all observation ages

Treatment	Mean leaf area (cm ² /clump) at each observation period (MALC)					
	1	2	3	4	5	6
P1	241.18 ^a	714.98 ^a	5241.90 ^a	5529.20 ^a	7287.15 ^a	7661.55 ^a
P2	334.48 ^{cd}	1252.73 ^{bcd}	7756.53 ^{bc}	8397.05 ^{ab}	9393.05 ^{ab}	11762.83 ^{bcd}
P3	298.30 ^{bc}	1078.28 ^b	6878.23 ^{abc}	7288.80 ^{ab}	8905.78 ^{ab}	9915.88 ^{abc}
P4	284.85 ^{ab}	985.20 ^{ab}	5888.98 ^{ab}	6821.90 ^{ab}	8977.55 ^{ab}	9328.13 ^{ab}
P5	354.70 ^d	1435.40 ^d	8159.85 ^c	9375.68 ^b	11285.28 ^b	13826.83 ^d
P6	317.08 ^{bcd}	1317.35 ^{cd}	7440.05 ^{abc}	8390.80 ^{ab}	9452.35 ^{ab}	12623.23 ^{cd}
P7	299.88 ^{bc}	1080.13 ^{bc}	5974.53 ^{abc}	7583.45 ^{ab}	8904.90 ^{ab}	9910.03 ^{abc}
HSD (5%)	44.27	311.74	2243.12	2882.22	3177.20	2809.63
CV (%)	6.23	11.88	14.20	16.17	14.83	11.22

Remarks: Data are presented as the mean of 4 replicates \pm SD; Different superscripts in the same column indicate a significant difference ($\alpha < 0.05$); MALC = months after low cutting; CV = coefficient of variation.

Table 8 The average plant fresh weight of sugarcane plants under the combination treatment of ameliorant and potassium fertilizer at all observation ages

Treatment	Mean plant fresh weight (g/clump) at each observation period (MALC)					
	1	2	3	4	5	6
P1	248.78 ^a	886.48 ^a	1784.73 ^a	2151.15 ^a	2935.73 ^a	3576.90 ^a
P2	774.68 ^{bc}	1598.38 ^b	2599.58 ^b	5068.13 ^b	6326.40 ^b	7138.08 ^b
P3	658.78 ^{bc}	1424.45 ^b	2443.93 ^b	4565.18 ^b	5696.15 ^b	6966.93 ^b
P4	611.08 ^b	1416.20 ^b	2341.10 ^b	4287.03 ^b	5333.90 ^b	6768.90 ^b
P5	907.95 ^c	1622.18 ^b	2650.38 ^b	5550.58 ^b	7182.95 ^b	8293.65 ^b
P6	851.88 ^{bc}	1652.48 ^b	2533.75 ^b	5480.63 ^b	7048.25 ^b	8183.15 ^b
P7	629.95 ^{bc}	1447.18 ^b	2385.63 ^b	4309.53 ^b	5577.53 ^b	6992.13 ^b
HSD (5%)	290.59	413.02	474.80	1753.25	1986.11	2480.44
CV (%)	18.59	12.32	8.50	16.72	14.84	15.51

Remarks: Data are presented as the mean of 4 replicates \pm SD; Different superscripts in the same column indicate a significant difference ($\alpha < 0.05$); MALC = months after low cutting; CV = coefficient of variation.

improvements to ratoon production, promoting more sustainable and strong sugarcane development.

Stem Fresh Weight (g/clump)

The analysis of variance revealed that the combined ameliorant and potassium fertilizer treatments had a significant influence on stem fresh weight from 1 to 6 MALC, as shown in Table 9. The combined application of ameliorant and potassium resulted in a considerable increase in stem fresh weight throughout all observation periods. At 6 MALC, treatments P2–P7 produced more biomass than the control, with P5 recording the highest value (6480.48 g), a 133% increase over P1 (2798.13 g), illustrating the efficacy of integrated soil amendment and potassium management in increasing ratoon productivity. These are consistent with previous research indicating that soil ameliorants increase structure, moisture retention, and CEC, hence promoting efficient nutrient uptake. Potassium improves osmotic regulation, turgor maintenance, and photosynthetic translocation, which promotes stalk thickening and biomass growth. The synergistic connection implies that ameliorant-improved soil conditions maximize potassium availability and consumption, hence increasing stalk growth and physiological performance. Overall, the combined ameliorant potassium method significantly enhances

stem biomass and is consistent with previous sugarcane research.

Stem Diameter (mm)

The analysis of variance on stem diameter revealed a significant effect of the combination of ameliorant and potassium fertilizer treatments from 1 to 6 MALC, as shown in Table 10. Observation uncovered that the combination of ameliorant and potassium fertilizer considerably enhanced the stem diameter of Bululawang sugarcane. At 6 MALC, treatment P5 consistently had the highest stem diameter. Stem diameter is an important indication of vegetative growth because it reflects mechanical strength and the ability to transport water and nutrients. This improvement was attributed to increased nutrient availability (particularly N, P, and K) because of ameliorant-induced improvements in soil attributes such as structure, pH, and CEC. The highest nutrient content was obtained by applying ameliorant at a rate of 8 L/ha. Furthermore, potassium fertilizer promoted vascular and structural tissue growth by regulating osmotic pressure, activating enzymes, and facilitating assimilate transport. Several investigations indicated that the combination of ameliorant and potassium increased stem diameter by enhancing nutrient retention, soil moisture, and hormonal stimulation (Imtiyaz & Octavia 2023; Sari *et al.* 2023). The combination of the two inputs resulted in increased cell proliferation and stem

Table 9 The average stem fresh weight of sugarcane plants under the combination treatment of ameliorant and potassium fertilizer at all observation ages

Treatment	Mean stem fresh weight at each observation period (MALC)					
	1	2	3	4	5	6
P1	151.40 ^a	368.90 ^a	1198.60 ^a	1499.00 ^a	2090.25 ^a	2798.13 ^a
P2	400.88 ^{bc}	749.40 ^b	1597.43 ^b	3257.88 ^{bc}	4454.15 ^{bc}	5731.53 ^b
P3	345.10 ^{bc}	672.88 ^b	1550.43 ^b	2965.55 ^{bc}	4018.25 ^b	5534.45 ^b
P4	300.90 ^{ab}	636.10 ^b	1491.85 ^b	2629.80 ^b	3999.75 ^b	5369.30 ^b
P5	503.40 ^c	854.25 ^b	1762.68 ^b	4244.38 ^d	5909.88 ^c	6480.48 ^b
P6	431.90 ^{bc}	806.08 ^b	1610.95 ^b	3728.58 ^{cd}	5789.55 ^c	6367.00 ^b
P7	383.50 ^{bc}	656.68 ^b	1529.98 ^b	2988.83 ^{bc}	4171.98 ^b	5447.38 ^b
HSD (5%)	171.44	249.10	279.30	781.75	1594.77	2119.18
CV (%)	20.41	15.73	7.79	10.99	15.70	16.83

Remarks: Data are presented as the mean of 4 replicates \pm SD; Different superscripts in the same column indicate a significant difference ($\alpha < 0.05$); MALC = months after low cutting; CV = coefficient of variation

Table 10 The average stem diameter of sugarcane plants under the combination treatment of ameliorant and potassium fertilizer at all observation ages

Treatment	Mean stem diameter (mm) at each observation period (MALC)					
	1	2	3	4	5	6
P1	13.30 ^a	15.13 ^a	16.43 ^a	18.83 ^a	20.88 ^a	21.10 ^a
P2	15.68 ^b	17.20 ^{ab}	21.13 ^c	24.85 ^{ab}	26.10 ^{cd}	28.30 ^{cd}
P3	14.95 ^{ab}	16.73 ^{ab}	18.98 ^{abc}	23.20 ^{ab}	24.20 ^{abc}	25.30 ^{abc}
P4	14.20 ^{ab}	16.48 ^{ab}	18.15 ^{abc}	21.58 ^{ab}	22.60 ^{ab}	23.25 ^{ab}
P5	16.40 ^b	19.18 ^b	20.85 ^c	25.25 ^b	27.88 ^d	30.20 ^d
P6	15.90 ^b	18.33 ^{ab}	20.33 ^{bc}	22.73 ^{ab}	25.28 ^{bcd}	26.48 ^{bcd}
P7	15.20 ^{ab}	18.53 ^{ab}	17.65 ^{ab}	21.70 ^{ab}	24.50 ^{bcd}	26.25 ^{bcd}
HSD (5%)	2.22	4.01	3.02	4.40	3.43	4.44
CV (%)	6.28	9.88	6.77	8.33	5.99	7.35

Remarks: Data are presented as the mean of 4 replicates \pm SD; Different superscripts in the same column indicate a significant difference ($\alpha < 0.05$); MALC = months after low cutting; CV = coefficient of variation

biomass accumulation, particularly on deteriorated or sandy soils. This integrated nutrient management technique promotes sustainable intensification and is critical for increasing stalk production and sugar recovery.

Plant Dry Weight (g/clump)

The analysis of variance for the plant's dry weight revealed a significant effect of the combined treatment of ameliorant and potassium fertilizer at 1 to 6 MALC, as shown in Table 11. Observations uncovered that the combination of ameliorant and potassium considerably enhanced the dry weight of Bululawang sugarcane, with P5 yielding the most biomass. At 6 MALC, P5 gained dry weight by 121% compared to the control (P1), indicating higher ratoon productivity. Dry weight indicates an assimilate buildup and increased photosynthetic efficiency. These are consistent with previous research suggesting that ameliorants improve soil texture, aeration, and CEC, hence increasing nutrient retention and root activity in ratoon crops. The 8 L/ha dose certainly improve the availability and uptake of N, P, and K, allowing for ongoing biomass formation.

Potassium's functions in osmotic regulation, enzyme activation, and photosynthetic translocation all contributed to increased dry matter accumulation. Previous studies has found that when sufficient K is paired with improved soil physical conditions, biomass

increases by 30–60%. The synergistic interaction of ameliorant and potassium increased nutrition and water use efficiency while strengthening physiological resilience, resulting in significantly higher biomass within a short growth time. This integrated nutrient management strategy is especially beneficial for sugarcane on marginal soils and promotes sustainable intensification.

Crop Growth Rate (g/m²/day)

The analysis of variance revealed that the combined application of ameliorant and potassium fertilizer had a significant effect on crop growth rate (CGR) across all observation intervals (1–2, 2–3, 3–4, 4–5, and 5–6 MALC), as shown in Table 12. The application of ameliorant and potassium significantly enhanced the CGR of Bululawang sugarcane, with Treatment P5 consistently obtaining the greatest rate from the early vegetative phase to stem elongation. CGR denotes the rate of biomass increase and is influenced by photosynthetic efficiency, nutritional intake, and structural tissue development. Applying 8 L/ha ameliorant improved soil aeration, water retention, and CEC, leading to increased availability of N, P, and K. The addition of 388.8 kg/ha potassium improved glucose translocation, stomatal function, and enzymatic activities, resulting in increased metabolic activity. The synergistic effects of ameliorant and potassium improved root development and nutrient

Table 11 The average plant dry weight of sugarcane plants under the combination treatment of ameliorant and potassium fertilizer at all observation ages

Treatment	Mean plant dry weight at each observation period (MALC)					
	1	2	3	4	5	6
P1	71.86 ^a	194.60 ^a	517.43 ^a	908.03 ^a	1101.48 ^a	1327.74 ^a
P2	103.98 ^b	361.63 ^{bc}	949.08 ^{bc}	1586.07 ^{cd}	2056.45 ^{cd}	2558.28 ^{cd}
P3	96.35 ^{ab}	337.45 ^b	854.48 ^b	1425.00 ^{bc}	1770.70 ^{bc}	2170.30 ^b
P4	90.20 ^{ab}	315.35 ^b	807.33 ^b	1320.15 ^b	1612.05 ^b	1972.03 ^b
P5	137.03 ^c	525.40 ^d	1146.10 ^d	1820.45 ^e	2387.40 ^e	2938.90 ^e
P6	120.15 ^{bc}	463.10 ^{cd}	1018.85 ^{cd}	1676.15 ^{bde}	2213.23 ^{de}	2675.75 ^{de}
P7	99.18 ^{ab}	395.40 ^{bc}	925.15 ^{bc}	1515.13 ^{bcd}	1836.08 ^{bc}	2247.35 ^b
HSD (5%)	31.10	109.34	161.91	206.37	299.49	345.71
CV (%)	12.97	12.63	7.80	6.03	6.91	6.52

Remarks: Data are presented as the mean of 4 replicates \pm SD; Different superscripts in the same column indicate a significant difference ($\alpha < 0.05$); MALC = months after low cutting; CV = coefficient of variation.

Table 12 The average crop growth rate of sugarcane plants under the combination treatment of ameliorant and potassium fertilizer at all observation ages

Treatment	Mean crop growth rate (g/m ² /day) at each observation period (MALC)					
	1	2	3	4	5	6
P1	0.05 ^a	0.13 ^a	0.16 ^a	0.08 ^a	0.09 ^a	0.05 ^a
P2	0.11 ^b	0.24 ^b	0.26 ^b	0.20 ^{bc}	0.21 ^b	0.11 ^b
P3	0.10 ^b	0.21 ^{ab}	0.24 ^{ab}	0.14 ^{ab}	0.17 ^b	0.10 ^b
P4	0.09 ^b	0.20 ^{ab}	0.21 ^{ab}	0.12 ^a	0.15 ^{ab}	0.09 ^b
P5	0.16 ^d	0.26 ^c	0.28 ^b	0.24 ^c	0.23 ^b	0.16 ^d
P6	0.14 ^{cd}	0.23 ^b	0.27 ^b	0.22 ^c	0.19 ^b	0.14 ^{cd}
P7	0.12 ^{bc}	0.22 ^b	0.25 ^b	0.13 ^{ab}	0.17 ^b	0.12 ^{bc}
HSD (5%)	0.04	0.09	0.08	0.07	0.07	0.04
CV (%)	15.99	17.37	14.18	19.57	17.63	15.99

Remarks: Data are presented as the mean of 4 replicates \pm SD; Different superscripts in the same column indicate a significant difference ($\alpha < 0.05$); MALC = months after low cutting; CV = coefficient of variation.

transport, resulting in consistent growth improvements. Treatment P5 demonstrated significant agronomic benefits, validating prior research on enhanced tillering, ratoon vigor, and biomass with appropriate K and soil amendments. This integrated nutrient management enhanced plant growth and soil quality, allowing for more sustainable and productive sugarcane cultivation.

Practically, the panelists' preference for P6 and P5 shows that combining ameliorant and potassium not only boosts agronomic performance but also improves sugarcane sensory quality. Higher acceptance scores suggest sweeter juice, improved stalk freshness, and increased customer attractiveness. This is beneficial to farmers and the sugar industry, as nutritionally balanced treatments such as P5 and P6 can increase yield potential and marketability. Thus, adopting these combinations increases production and adds economic value through higher-quality harvests.

CONCLUSION

This study found that the combination of ameliorant and potassium fertilizer had a substantial effect on major vegetative growth indices of Bululawang sugarcane, such as root length, plant height, number of tillers, number of leaves, leaf area, stem diameter, and total biomass. Treatment P5 (8 L/ha ameliorant + 388.8 kg K₂O/ha) provided the highest values for various metrics ($p < 0.05$). Treatment P6 (8 L/ha ameliorant + 259.2 kg/ha K₂O) showed no significant difference from P5 for several traits ($p > 0.05$), indicating more efficient potassium usage.

ACKNOWLEDGMENTS

Thank you to all contributors and the study team, as well as the Agronomy Study Program, Department of Crop Production, Universitas Brawijaya, for providing facilities and support during the research's implementation.

REFERENCES

- Agustin SN, Zuraida Z, Muyasiir M. 2020. Teknologi ameliorasi dan pemupukan tanah suboptimal serta hubungannya dengan sifat kimia tanah dan pertumbuhan padi galur sikuneng. *Jurnal Ilmiah Mahasiswa Pertanian*. 5(2): 241–249. <https://doi.org/10.17969/jimfp.v5i2.14860>.
- Ahanger MA, Agarwal RM, Tomar NS, Shrivastava MP. 2015. Potassium induces positive changes in nitrogen metabolism and antioxidant system of oat (*Avena Sativa* L Cultivar Kent). *Journal of Plant Interactions*. 10(1): 211–223. <https://doi.org/10.1080/17429145.2015.1056260>.
- Amelya AYS, Syarovy M. 2024. Pemanfaatan berbagai jenis bahan pembenah tanah pada pembibitan kelapa sawit (*Elaeis guineensis* Jacq.). *Warta Pusat Penelitian Kelapa Sawit*. 29(3): 197–207. <https://doi.org/10.22302/iopri.war.warta.v29i3.131>.
- Anam C, Qibtiyah M, Sofyan MM. 2023. Aplikasi asap cair dan pupuk kotoran kelelawar terhadap pertumbuhan dan hasil padi (*Oryza sativa* L.). *Berkala Ilmiah Agroteknologi Plumula*. 11(2): 82–92. <https://doi.org/10.33005/plumula.v11i2.200>.
- Andriyani I, Wahyuningsih S, Novita E, Ernanda H. 2023. Aplikasi pupuk organik untuk memperbaiki kualitas tanah pada lahan pertanian intensif di hulu DAS Bedadung. *Jurnal BETA (Biosistem dan Teknik Pertanian)*. 11(1): 217. <https://doi.org/10.24843/jbeta.2023.v11i01.p22>.
- Anggraeni R, Mahrup M, Kusnarta IGM, Silawibawa P. 2022. Variasi regim lengas dan suhu tanah pada lahan yang mengalami penutupan awan rendah berbasis peta terra modis di pulau lombok. *JSQM*. 1(1): 7–15. <https://doi.org/10.29303/jsqm.v1i1.9>.
- Anwar K, Redjeki ES, Budi S. 2021. Perbedaan pertumbuhan dan hasil tiga klon tanaman tebu (*Saccharum officinarum* L.) pada tanah aluvial di Desa Sambiroto Kecamatan Sooko, Mojokerto. *Tropicrops (Indonesian Journal of Tropical Crops)*. 4(1): 1. <https://doi.org/10.30587/tropicrops.v4i1.2316>.
- Astiko W, Sudirman S, Ernawati NML, Muthahanas I. 2025. Uji efektivitas beberapa sumber amelioran terhadap peningkatan serapan np dan produktivitas jagung manis di tanah pasiran. *Saintek*. 7: 36–46. <https://doi.org/10.29303/saintek.v7i1.3432>.
- Aziza I, Rahayu YS, Dewi SK. 2021. Pengaruh pupuk organik cair dengan penambahan silika dan cekaman air terhadap pertumbuhan tanaman kedelai. *Lenterabio Berkala Ilmiah Biologi*. 11(1): 183–191. <https://doi.org/10.26740/lenterabio.v11n1.p183-191>.
- Batalipu NIR, Darman S, Amelia R. 2023. Serapan hara K pada tanaman cabai merah besar (*Capsicum annum* L.) terhadap pemberian bokasi pada entisols sidera. *Agrotekbis*. 11(3): 707–713. <https://doi.org/10.22487/agrotekbis.v11i3.1744>.
- Diana NE, Supriyadi S, Djumali. 2016. Growth, productivity, and sugar content of plant cane on several fertilizer pockets. *Jurnal Ilmu Pertanian Indonesia*. 21(3): 159–166. <https://doi.org/10.18343/jipi.21.3.159>.
- Ginting EN. 2020. Pentingnya bahan organik untuk meningkatkan efisiensi dan efektivitas pemupukan

- di perkebunan kelapa sawit. *Warta Pusat Penelitian Kelapa Sawit*. 25(3): 139–154. <https://doi.org/10.22302/iopri.war.warta.v25i3.38>.
- Gu B, Qin T, Qiu M, Yu J, Zhang L, Li Y. 2023. Addition of exogenous organic ameliorants mediates soil bacteriome and microbial community carbon source utilization pattern in coastal saline–alkaline soil. *Agriculture*. 14(1): 44. <https://doi.org/10.3390/agriculture14010044>.
- Hafizah N, Jumar J, Saputra RA. 2022. Kualitas kompos limbah solid sawit dengan berbagai biodekomposer. *Jurnal Ilmu-Ilmu Pertanian Indonesia*. 24(2): 109–119. <https://doi.org/10.31186/jipi.24.2.109-119>.
- Harini D, Radian, Sasli I. 2021. Tanggap pertumbuhan dan perkembangan jagung ketan terhadap pemberian amelioran dan pupuk npk pada tanah ultisol. *Jurnal Agronomi Indonesia (Indonesian Journal of Agronomy)*. 49(1): 29–36. <https://doi.org/10.24831/jai.v49i1.34284>.
- Haryati U, Sutono S, Subiksa IGM. 2020. Pengaruh amelioran terhadap perbaikan sifat tanah dan produksi cabai rawit (*Capsicum Frutescens*) pada lahan bekas tambang timah. *Jurnal Tanah dan Iklim*. 43(2): 127. <https://doi.org/10.21082/jti.v43n2.2019.127-138>.
- Hazra F, Syahiddin D, Widyastuti R. 2021. Peran kompos dan mikoriza pada pertumbuhan tanaman tomat (*Solanum lycopersicum*) di tanah berpasir. *Journal of Tropical Agrifood*. 113–122. <https://doi.org/10.35941/jatl.4.2.2022.7003.113-122>.
- Hidayat C, Supriadin A, Huwaida'a F, Rachmawati YS. 2020. Aplikasi bokashi eceng gondok (*Eichhornia crassipes*) dan fungi mikoriza arbuskula untuk perbaikan sifat fisika tanah pascagalian C dan hasil tanaman cabai (*Capsicum frutescens* L.). *Agrosainstek Jurnal Ilmu dan Teknologi Pertanian*. 4(2): 95–102. <https://doi.org/10.33019/agrosainstek.v4i2.124>.
- Hikmah ZM, Sulistyono E, Susanti Z. 2021. Pertumbuhan, hasil dan efisiensi pemakaian air padi Inpari 33 pada perlakuan pupuk anorganik dan organik. *Jurnal Agronomi Indonesia (Indonesian Journal of Agronomy)*. 49(3): 242–250. <https://doi.org/10.24831/jai.v49i3.38323>.
- Imtiyaz AN, Octavia B. 2023. Identifikasi bakteri pada bintil akar aktif dan tidak aktif serta rhizosfer kacang tanah. *Kingdom*. 9(1): 63–74. <https://doi.org/10.21831/kingdom.v9i1.18626>.
- Jin X, Zhu J, Wei X, Xiao Q, Xiao J, Jiang L, Xu D, Cai-Xia S, Liu J, He Z. 2024. Adaptation strategies of seedling root response to nitrogen and phosphorus addition. *Plants*. 13(4): 536. <https://doi.org/10.3390/plants13040536>.
- Kurnianto HA, Limeranto DM, Madyaningrana K. 2023. Pengaruh pemberian pupuk organik cair berbasis kulit buah terhadap pertumbuhan bayam brasil (*Althernanthera sissoo* Hort) dalam sistem hidroponik. *Journal Science of Biodiversity*. 4(2): 41–50. <https://doi.org/10.32938/jsb/vol4i2pp41-50>.
- Kurniawati N, Priyadi P. 2021. Pengaruh aplikasi abu terbang dan pupuk kotoran sapi terhadap populasi mikroorganisme di tanah ultisol. *Agriprima Journal of Applied Agricultural Sciences*. 5(1): 41–49. <https://doi.org/10.25047/agriprima.v5i1.406>.
- Kusumastuti A, Indrawati W, Supriyanto S, Kurniawan A. 2022. Keanekaragaman mesofauna tanah dan aktivitas mikroorganisme tanah pada vegetasi nilam di berbagai dosis biochar dan pupuk majemuk npk. *Agriprima Journal of Applied Agricultural Sciences*. 6(2): <https://doi.org/10.25047/agriprima.v6i2.488>.
- Li S, Zhou H, Chen C, Zeng F, Zheng G, Wang X, Zhang C. 2022. Rhamnolipids amendment improves soil properties and enhances microecological functions in the saline-alkali soil. *Environmental Engineering Research*. 28(4). 220230–220234. <https://doi.org/10.4491/eer.2022.234>.
- Liu Y, Qi H, Bai C, Qi M, Xu C, Hao J, Li Y, Li T. 2011. Grafting helps improve photosynthesis and carbohydrate metabolism in leaves of muskmelon. *International Journal of Biological Sciences*. 7(8): 1161–1170. <https://doi.org/10.7150/ijbs.7.1161>.
- Mansyur NI, Pudjiwati EH, Murtalaksono A. 2021. Pupuk dan pemupukan. <https://doi.org/10.52574/syiahkualaaniversitypress.379>.
- Mao X, Zhang G, Liu Z, Huang F, Yu F. 2024. Combined application of nitrogen and phosphorus promotes the growth and nutrient accumulations of *Cinnamomum camphora* container seedlings. *Agriculture*. 14(2): 280. <https://doi.org/10.3390/agriculture14020280>.
- Marwanto S, Ariani R, Haryati U, Irawan I. 2021. Perbaikan sifat tanah dan hasil kedelai (*Glycine max*) dengan pemberian amelioran biochar dan pupuk kandang di lahan sawah tadah hujan. *Jurnal Tanah dan Iklim*. 45(1): 59. <https://doi.org/10.21082/jti.v45n1.2021.59-67>.
- Mulyati M, Sania A, Priyono J, Baharuddin A, Tejowulani R. 2022. Use of soil ameliorant and inorganic fertilizer to increase soil fertility phosphorous concentrations in plant tissue, growth and yield of shallot in dry land. *Jurnal Penelitian Pendidikan IPA*. 8: 22–29. <https://doi.org/10.29303/jppipa.v8ispecialissue.2498>.

- Nanda CV, Sari VK, Khozin MN. 2022. Respons pertumbuhan tanaman kangkung (*Ipomoea reptans* Poir) pada berbagai dosis pupuk NPK. *Agribios*. 20(2): 295. <https://doi.org/10.36841/agribios.v20i2.1943>.
- Nurnawati AA, Syarifuddin RN, Samsu AK. 2022. Mengurangi dosis pupuk anorganik pada tanaman jagung ungu dengan aplikasi pupuk organik cair. *Agro Bali: Agricultural Journal*. 5(1): 137–143. <https://doi.org/10.37637/ab.v5i1.863>.
- Oktaviani E, Lunggani AT, Ferniah RS. 2020. Karakter Rhizobakteri pelarut fosfat potensial dari rhizosfer tumbuhan mangrove Teluk Awur Kabupaten Jepara secara mikrobiologi. *Jurnal Ilmu Lingkungan*. 18(1): 58–66. <https://doi.org/10.14710/jil.18.1.58-66>.
- Pramukyana L, Restanto DP, Wijaya KA. 2021. Respons tanaman sorgum (*Sorghum bicolor* L.) pada tingkat cekaman salinitas dengan aplikasi kalsium. *Agriprima Journal of Applied Agricultural Sciences*. 5(2): 86–96. <https://doi.org/10.25047/agriprima.v5i2.418>.
- Prasetyo D, Evizal R. 2021. Pembuatan dan upaya peningkatan kualitas pupuk organik cair. *KLOROFIL: Jurnal Ilmu Biologi dan Terapan*. 20(2): 68–80. <https://doi.org/10.30821/kfl:jibt.v3i1.8248>.
- Pratitis WL, Kurniasari K, Fata HAI. 2023. Klasifikasi penyakit pada citra daun tebu menggunakan algoritma convolutional neural network. *JTECS: Jurnal Sistem Telekomunikasi Elektronika Sistem Kontrol Power Sistem dan Komputer*. 3(2): 117. <https://doi.org/10.32503/jtecs.v3i2.3433>.
- Prayitno J. 2017. Ujicoba konsorsium mikroba dalam upaya bioremediasi tanah tercemar minyak dengan menggunakan teknik *landfarming* skala bangku. *Jurnal Teknologi Lingkungan*. 18(2): 208. <https://doi.org/10.29122/jtl.v18i2.2050>.
- Puspitasari AR. 2023. Pertumbuhan dan produksi tebu varietas PSJK 922 pasca-aplikasi pupuk silikat (*Biosilac dan Siabate*). *Indonesian Sugar Research Journal*. 3(2): 56–63. <https://doi.org/10.54256/isrj.v3i2.110>.
- Raksun A, Zulkifli L., Mahrus M. 2020. Pengaruh dosis dan waktu pemberian kompos terhadap pertumbuhan kangkung darat. *Jurnal Pijar MIPA*. 15(2): 171–176. <https://doi.org/10.29303/jpm.v15i2.1516>.
- Respatie DW, Rohman MS, Widiyanto D, Widada J. 2020. Pengaruh kombinasi pupuk anorganik dan vinase diperkaya mikrobia terhadap pertumbuhan dan hasil jagung (*Zea mays* L.). *Vegetalika*. 9(4): 547. <https://doi.org/10.22146/veg.60497>.
- Sari JM, Turnip M, Zakiah Z. 2023. Pengaruh cekaman kekeringan terhadap karakteristik anatomi daun, batang, dan akar tanaman *Nepenthes mirabilis* (Lour.) druce. *Buletin Kebun Raya*. 26(1): 1–10. <https://doi.org/10.55981/bkr.2023.737>.
- Septiningrum K, Hardiani H. 2016. Aplikasi konsorsium mikroba untuk meremediasi tanah terkontaminasi timbal dari limbah proses *deinking* industri kertas. *Jurnal Selulosa*. 1(02). <https://doi.org/10.25269/jsel.v1i02.24>.
- Sesanti RN, Sudrajat D, Ali F, Sari RM. 2021. Potensi cuka bambu PT. Bukit Asam pelabuhan tarahan untuk mengurangi penggunaan pupuk kimia pada budidaya tanaman pakchoy (*Brassica rapa* L.). *Jurnal Penelitian Pertanian Terapan*. 21(2): 184–191. <https://doi.org/10.25181/jppt.v21i2.2159>.
- Setiawati TC, Widinda SA, Hartatik W. 2023. Aplikasi bakteri pemacu tumbuh dan amelioran terhadap ketersediaan hara P dan K di tanah masam serta serapannya pada tanaman padi (*Oryza sativa* L.). *Jurnal Agro*. 10(1): 98–109. <https://doi.org/10.15575/22633>.
- Setyaji K, Sumarni T, Baskara M. 2024. Pengaruh pupuk kandang dan pupuk kalium pada pertumbuhan dan hasil jagung manis (*Zea mays saccharata* Sturt.) varietas Talenta. *Produksi Tanaman*. 12(04): 221–228. <https://doi.org/10.21776/ub.protan.2024.012.04.01>.
- Solihin E, Sudirja R, Kamaludin NN. 2019. Pengaruh dosis pupuk kalium terhadap pertumbuhan dan peningkatan hasil tanaman jagung manis (*Zea mays* L.) pada inceptisol. *Agrikultura*. 30(2): 40. <https://doi.org/10.24198/agrikultura.v30i2.22791>.
- Sopiana S, Ramanda RF, Kurniawan T, Rosmalinda R, Mahruf H. 2024. Aplikasi kompos jerami padi di media gambut untuk meningkatkan pertumbuhan bibit kopi Liberika. *Journal of Agro Plantation (Jap)*. 3(1): 210–218. <https://doi.org/10.58466/jap.v3i1.1517>.
- Tando E. 2017. Review: Peningkatan produktivitas tebu (*Saccharum officinarum* L.) pada lahan kering melalui pemanfaatan bahan organik dan bahan pelembab tanah sintesis. *Biotropika Journal of Tropical Biology*. 5(3): 90–96. <https://doi.org/10.21776/ub.biotropika.2017.005.03.6>.
- Tian XF. 2017. Effects of controlled-release potassium fertilizer on available potassium, photosynthetic performance, and yield of cotton. *Journal of Plant Nutrition and Soil Science*. 180(5): 505–515. <https://doi.org/10.1002/jpln.201700005>.
- Uge I, Afa LO, Nurmas A. 2021. Pengaruh kombinasi pupuk organik dan anorganik terhadap pertumbuhan dan hasil padi gogo lokal Wakawondu (*Oryza sativa* L.) yang diberi rizobakteri pada sistem budi daya berbeda. *Berkala Penelitian Agronomi*.

- 9(2): 55. <https://doi.org/10.33772/bpa.v9i2.21297>.
- Uswanti BP. 2023. Karakteristik kimia dan pertumbuhan kedelai (*Glycine max* L.) akibat pemberian biochar di tanah vertisol pada kondisi rumah kaca. *Agroteksos Agronomi Teknologi Dan Sosial Ekonomi Pertanian*. 33(3): 1105. <https://doi.org/10.29303/agroteksos.v33i3.995>.
- Waclawovsky AJ, Sato PM, Lembke CG, Moore PH, Souza GM. 2010. Sugarcane for bioenergy production: an assessment of yield and regulation of sucrose content. *Plant Biotechnology Journal*. 8(3): 263–276. <https://doi.org/10.1111/j.1467-7652.2009.00491.x>.
- Wang M, Zheng Q, Shen Q, Guo S. 2013. The critical role of potassium in plant stress response. *International Journal of Molecular Sciences*. 14(4): 7370–7390. <https://doi.org/10.3390/ijms14047370>.
- Widyati E. 2020. Intervensi manusia terhadap komunitas rhizosfir: Review (Human disturbance on rhizosphere communities: Review). *Jurnal Manusia dan Lingkungan*. 26(1): 10. <https://doi.org/10.22146/jml.25513>.