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RESEARCH ARTICLE

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Improving soil acidity on peat soil through rice husk ash and rabbit urine biofertilizer application

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Abstract
Low pH and limited nutrient availability in peat soil hinder optimal mustard growth, underscoring the need for effective organic amendments. This study aimed to evaluate the effects of rice husk ash and rabbit urine liquid organic fertilizer (POC) on soil pH and mustard plant growth in peat media. The experiment was conducted using a Completely Randomized Design (CRD) with two factors: rice husk ash (0, 15, 20, and 25 tons/ha) and rabbit urine POC (0, 15, 30, and 45 mL/L), replicated three times for a total of 48 polybag units. Prior to transplanting, rice husk ash was incubated in the soil for one week to increase pH. Mustard seedlings were grown for 28 d, and POC was applied weekly for three weeks as both foliar and soil treatments. Growth parameters measured included plant height, leaf width, leaf number, and fresh biomass. The results showed that both rice husk ash and rabbit urine POC significantly influenced all measured growth parameters. The highest fresh weight (40.22 g) was observed in the P2K1 treatment (20 tons/ha ash + 30 mL/L POC), while the best overall vegetative performance was recorded in P3K2. It can be concluded that the integrated use of rice husk ash and rabbit urine POC can effectively improves peat soil properties and enhances mustard growth. This study highlights the potential of utilizing agricultural waste-based organics to support sustainable crop production in acidic soil environments.

KEYWORDS
Biofertilizer; Soil amelioration; Organic input; Vegetative growth; Sustainable agriculture

1. INTRODUCTION

Peatlands are globally recognized as one of the most challenging yet essential resources for agricultural expansion, especially in tropical regions. In Indonesia alone, peatlands cover approximately 13.43 million hectares, representing about 7% of the country's total land area, with most of these lands exhibiting soil pH levels below 4.5, which is categorized as highly acidic (Shi et al., 2024). Such conditions are accompanied by high organic carbon content (>50%) but critically low levels of available nitrogen (<0.2%) and phosphorus (<5 mg/kg), making peat soils infertile and unsuitable for intensive agriculture (Bhunia et al., 2021). As a result, vegetable yields on unmanaged peatlands are often less than 8–10 t/ha, compared with more than 15 t/ha on mineral soils (Yuwati et al., 2021). Addressing the chemical constraints of peat soil, particularly its low pH and poor nutrient retention, is therefore a critical step to improving soil fertility and promoting sustainable agricultural practices on marginal lands. Technological approaches utilizing organic-based soil amendments, such as rice husk ash and biofertilizers, have gained attention as effective and environmentally friendly solutions to rehabilitate degraded soils. Rice husk ash contains up to 94% silica and base cations (Ca^{2+}, K^{+}, Mg^{2+}), which can neutralize exchangeable acidity and improve soil structure, while rabbit urine is known to contain approximately 1–2% nitrogen, 0.5–1% P_2O_5, 1–2% K_2O, and natural growth regulators that enhance vegetative development (Abelenda & Aiouache, 2022). The integration of such locally available organic resources not only improves soil quality but also supports circular agriculture and waste utilization, offering a sustainable strategy for peatland management in agricultural systems (Widiastuti et al., 2024). Moreover, these practices hold direct socio-economic value for smallholder farmers by reducing dependency on costly chemical inputs, providing affordable nutrient alternatives, and promoting local resource recycling. By strengthening low-cost production systems and improving yields of mustard a key component of household diets this approach contributes not only to farmers' livelihoods but also to broader food security and the resilience of agricultural ecosystems in peatland regions.

Numerous studies have been conducted to improve the productivity of peatlands through various soil amelioration techniques. The application of rice husk ash as a soil amendment has consistently shown positive effects in reducing soil acidity and enhancing nutrient availability. Research by Usman et al. (2023) demonstrated that rice husk ash significantly increases soil pH due to its high content of silica, calcium, and potassium, which are crucial in neutralizing exchangeable acidity, reducing aluminum toxicity, and improving soil structure. Silica further strengthens plant cell walls and enhances stress resistance, while base cations such as Ca^{2+}, Mg^{2+}, and K^{+} improve soil buffering capacity and nutrient balance. Similarly, Usman et al. (2023) confirmed that the addition of rice husk ash not only raises soil pH but also promotes root proliferation and enhances soil water retention. On the other hand, liquid organic fertilizers derived from animal urine, particularly rabbit urine, are known to supply essential nutrients such as nitrogen, phosphorus, and potassium, along with naturally occurring plant growth regulators. Chand et al. (2022) reported that rabbit urine application significantly enhanced vegetative growth and chlorophyll content in leafy vegetables, which was attributed not only to its high nitrogen content but also to growth-promoting compounds such as auxins and cytokinins. Furthermore, rabbit urine biofertilizer represents an eco-friendly and cost-effective alternative to synthetic fertilizers, making it highly relevant for smallholder farmers. Studies integrating organic soil amendments and bio-liquid fertilizers have also indicated synergistic outcomes; for instance, the combined application of rice husk ash and organic fertilizers improved soil fertility and crop growth on mineral soils (Johan et al., 2021). However, despite the extensive research on their individual applications, there is limited research quantifying the interactive effects of rice husk ash and rabbit urine biofertilizer on mustard (*Brassica juncea*) growth performance and soil acidity correction in peatland systems. In particular, the combined influence of silica, base cations, and natural growth hormones on peat soil pH dynamics and mustard productivity remains underexplored, highlighting the need for further investigation to establish sustainable and site-specific soil management strategies for acidic peatlands.

Despite numerous studies demonstrating the benefits of rice husk ash and liquid organic fertilizers, several critical limitations remain unaddressed. For instance, research on rice husk ash has largely focused on soil stabilization in civil engineering contexts, such as peat stabilization for bearing capacity, rather than its agronomic effects on crop growth. Studies by Liu and Hung (2023) reported significant increases in soil pH and bearing strength of peat soils treated with rice husk ash (often combined with calcium additives), yet these works were oriented toward geotechnical outcomes rather than crop performance. In agronomic contexts, studies utilizing the pozzolanic effect of rice husk ash, such as those by Ali and Atemimi (2024) demonstrated pH improvements in mineral soils but did not test these amendments under peatland conditions, where acidity and nutrient leaching are more severe. Similarly, research on animal urine-based fertilizers, including rabbit urine, has primarily focused on enhancing vegetative growth in common vegetables, yet rarely examined their suitability for highly acidic peat soils or their potential interaction with alkaline amendments. Comparable knowledge gaps have also been noted in other tropical peatlands. For example, in Malaysia, peat soils under oil palm cultivation experience severe acidity and nutrient depletion, and although ash and lime have been tested as ameliorants, studies rarely connect these practices with broader implications for food security (Mahmud & Chong, 2022). In the Congo Basin, peatland research has emphasized carbon storage and ecosystem services (Crezee et al., 2022), leaving unanswered questions about how organic amendments can simultaneously improve crop productivity in smallholder farming systems. These limitations highlight the absence of studies that specifically quantify the interactive effects of rice husk ash and rabbit urine biofertilizer on soil pH dynamics and mustard (*Brassica juncea*) growth performance in tropical peat soils.

Therefore, this research aims to evaluate the combined effects of rice husk ash and rabbit urine biofertilizer on soil pH improvement and the growth performance of mustard cultivated in peat soils. More specifically, the study seeks to identify dosage combinations that can effectively reduce soil acidity toward a more favorable pH range, improve nutrient availability, and simultaneously enhance key growth parameters, including plant height, leaf number, leaf width, and fresh biomass. In this study, the treatment combination that achieves the best balance between soil chemical improvement (pH correction and nutrient availability) and crop performance (biomass and vegetative growth). The significance of this research lies in its contribution to scientific understanding of soil chemistry–plant physiology interactions in peatland systems, while also offering a cost-effective and environmentally friendly soil management strategy. By utilizing locally available agricultural waste products, such as rice husk ash and rabbit urine, this study supports sustainable soil rehabilitation, promotes circular agriculture, and provides practical solutions for smallholder farmers working on acidic peat soils.

2. METHODS

2.1 Material

This research was conducted at the polybag-scale experimental garden managed by the Agroecotechnology Department, Faculty of Agriculture, Universitas Kadiri, East Java, Indonesia. The experimental site is geographically located at -7.806946° S and 112.012420° E, with an elevation of approximately 65 m above sea level. The study was carried out over a period of two months, from April to May 2025, covering all phases from land preparation to plant harvest. The local climate during the research period was characterized by tropical humidity with daytime temperatures ranging between 28 °C and 32 °C. The biological material used in this study was mustard green (*Brassica juncea*) of the 'Shinta' variety, selected for its adaptability to tropical environments and rapid vegetative growth. The main soil medium was mature, decomposed peat soil that had previously been used for cultivation. Prior to its use as a growing medium, the soil was analyzed in the laboratory to determine its initial physicochemical characteristics. The peat soil used in this study was collected from Muara Kaman District, East Kalimantan, Indonesia, an area of long-established agricultural peatland. Approximately 20 kg of mature, decomposed peat was excavated from the top 0–20 cm soil layer in April 2025. Soil samples were composited from 5 random points across the site to ensure representative conditions, homogenized, and air-dried prior to use in the polybag experiment. The results of the baseline soil analysis are presented in Table 1. Other materials included rice husk ash obtained from the controlled combustion of clean rice husks at a local rice mill in Kediri, East Java, with a silica (SiO_2) content of approximately 90–94%. Fermented rabbit urine was prepared by collecting fresh urine from local rabbit farms and fermenting it anaerobically in sealed containers for 7 d without any additives, following the method described by (Ananda et al., 2024). Compound NPK fertilizer (15-15-15, Petrokimia Gresik, Indonesia) was applied as a standard supplement when required. A biological insecticide (Turex WP, PT Indo Bio Fertilizer, Indonesia), containing Bacillus thuringiensis spores and crystals, was applied only if pest incidence was detected. The tools and equipment used throughout the experiment included 30 × 30 cm polyethylene polybags (local manufacturer, Kediri), hoes, buckets, and watering cans, along with a digital weighing scale (Camry EK5055, China), a digital pH meter (Hanna Instruments HI98107, Italy), measuring tapes, treatment markers, writing tools, and a digital camera (Canon EOS 3000D, Japan) for documentation.

Table 1. Soil analysis in present study

Properties	Analysis result	Scale
pH H_2O	7.23	High
P	26.82	High
N %	1.92	Very high
P_2O_5 (mg/100g)	74.11	Very high
Ca-dd cmol+/kg	2.12	Low
Mg-dd cmol+/kg	3.34	High
K-dd cmol+/kg	0.13	Low

2.2 Experimental procedure

The experimental design followed a Completely Randomized Design (CRD) with two treatment factors: rice husk ash (P) and rabbit urine POC (K). The rice husk ash factor consisted of four dosage levels: P0 (0), P1 (15), P2 (20), and P3 (25) tons/ha, while the rabbit urine factor consisted of concentrations of K0 (0), K1 (15), K2 (30), and K3 (45) mL/L. The selected dosage ranges were scientifically justified based on their effectiveness in both soil chemistry and plant growth reported in prior studies. Rice husk ash doses between 15–25 tons/ha have been shown to raise peat soil pH from <4.5 to near-neutral levels (pH 5.5–6.0), while also supplying silica, potassium, and calcium that improve soil structure and nutrient retention (Tafonao, 2025). Similarly, rabbit urine applied at concentrations of 15–45 mL/L has been reported to provide bioavailable nitrogen, potassium, and natural growth regulators, significantly enhancing vegetative growth and biomass in leafy vegetables without causing ammonium toxicity when applied within this range (Haryanta & Widya, 2024). Therefore, the chosen treatment levels were intended to capture the response range where soil pH correction and nutrient supply are balanced, allowing the identification of the optimal combination for mustard cultivation on acidic peat soils. The factorial combination of these treatments, each replicated three times, resulted in 48 experimental units. Each polybag was filled with homogenized mature peat soil and thoroughly mixed with the assigned dose of rice husk ash. The mixture was incubated for one week before transplanting to allow for initial chemical stabilization, particularly to increase the soil pH and improve nutrient availability (Saberi Riseh et al., 2023). A paranet shade structure was installed above the experimental area to protect the young seedlings from direct rainfall and physical damage, especially during the early establishment stage.

Mustard green (*Brassica juncea*) seeds of the 'Shinta' variety were soaked in water for 6–8 h to identify and separate viable seeds based on density. The seeds were then sown in seed trays and maintained under partial shade for 14 d until they reached the appropriate size for transplanting. Two healthy and uniform seedlings were transplanted into each polybag in the morning between 07:00 and 09:00. Rabbit urine POC was fermented for 7 d in a closed container prior to use. The fertilizer was applied weekly. During the plant growth period, maintenance practices were routinely conducted, including manual weeding and watering in the morning or afternoon depending on environmental conditions. Pest control was carried out using mechanical methods, specifically handpicking of pest larvae or insects when observed. At 28 days after plant (dap), plants were harvested by uprooting the entire plant, washing off adhering soil particles from the roots, and weighing the fresh biomass immediately using a digital scale to obtain the fresh weight per plant. The timing and method of harvesting followed guidelines described by (Behera et al., 2024) for leafy vegetable experiments in polybag systems.

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2.3 Growth and biomass measurement

Observations of plant growth parameters were conducted at 28 dap. The parameters measured included plant height, number of leaves per plant, and leaf width measured at the widest part of the largest leaf. At harvest, fresh biomass was determined by weighing the whole plant (aboveground portion) without drying. Soil pH was also observed using a digital pH meter before incubation and after one week of rice husk ash application, using a 1:2.5 soil-to-water ratio suspension.

2.4 Data analysis

All collected data were analyzed statistically using Analysis of Variance (ANOVA) to determine the significance of treatment effects. When significant differences were found ($p \leq 0.05$), further analysis was performed using a post-hoc test such as Least Significant Difference (LSD) or Tukey's HSD to compare treatment means. The results were organized and presented in the form of tables and graphs to facilitate interpretation of plant responses to the combined application of rice husk ash and rabbit urine fertilizer on peat soil.

3. RESULT AND FINDING

3.1 Soil properties

The peat soil used in this study was analyzed in the laboratory prior to the application of any treatments to determine its baseline chemical properties (Table 1). The soil exhibited characteristics typical of hemic peat, including a partially decomposed organic matrix, fibrous residue, low bulk density, and a brownish color. Hemic peat is commonly found in topogenic peatlands, which are formed in depressions or basins influenced by stagnant or slowly flowing water, often under tidal or seasonal flooding conditions (Khanday et al., 2021). This type of peat generally has moderate decomposition, which allows it to retain moisture efficiently while still providing some aeration. The pH value of 7.23, categorized as high, is relatively uncommon for peat soils, which typically have acidic pH levels ranging from 3.5 to 5.5 due to the accumulation of organic acids (Ghorbani et al., 2022). The neutral to slightly alkaline reaction observed in this study likely results from previous land management interventions, such as the application of liming agents or base-rich organic materials. Such shifts in pH can indicate long-term anthropogenic input that alters the acid-base balance of peatlands, especially in cultivated lowland areas (Suryani et al., 2019).

Hemic peat is commonly found in topogenic peatlands, which are formed in depressions or basins influenced by stagnant or slowly flowing water, often under tidal or seasonal flooding conditions

The nutrient profile of the peat soil revealed substantial concentrations of certain elements, while others remained limited or deficient. Laboratory results showed that total nitrogen content was 1.92%, which falls into the very high category according to the soil fertility criteria set by (Khan et al., 2023), likely due to the high organic matter inherent in peat and previous fertilization history. The available phosphorus (P) was 26.82 mg/100g, also considered high, and P_2O_5 content reached 74.11 mg/100g, indicating a very high level of phosphorus in mineral form, sufficient to support basic soil fertility needs. In contrast, exchangeable potassium (K-dd) was found at only 0.13 $cmol^+/kg$, and exchangeable calcium (Ca-dd) was 2.12 $cmol^+/kg$, both classified as low, revealing a notable imbalance in base cations. However, exchangeable magnesium (Mg-dd) showed a relatively high value of 3.34 $cmol^+/kg$, indicating a sufficient level of this essential nutrient. Such cation imbalances can influence soil chemical buffering, nutrient retention, and long-term soil quality (Alkharabsheh et al., 2021). Moreover, low levels of potassium and calcium are often characteristic of highly leached peat soils, especially under conditions of high rainfall and poor cation exchange capacity (Wilpert, 2022). Overall, while the soil exhibited high nutrient concentrations in terms of organic nitrogen and phosphorus, the low base saturation in some cations suggests that targeted amendments may still be required to maintain chemical balance and sustain long-term soil health.

Overall, while the soil exhibited high nutrient concentrations in terms of organic nitrogen and phosphorus, the low base saturation in some cations suggests that targeted amendments may still be required to maintain chemical balance and sustain long-term soil health

3.3 Impact on growth

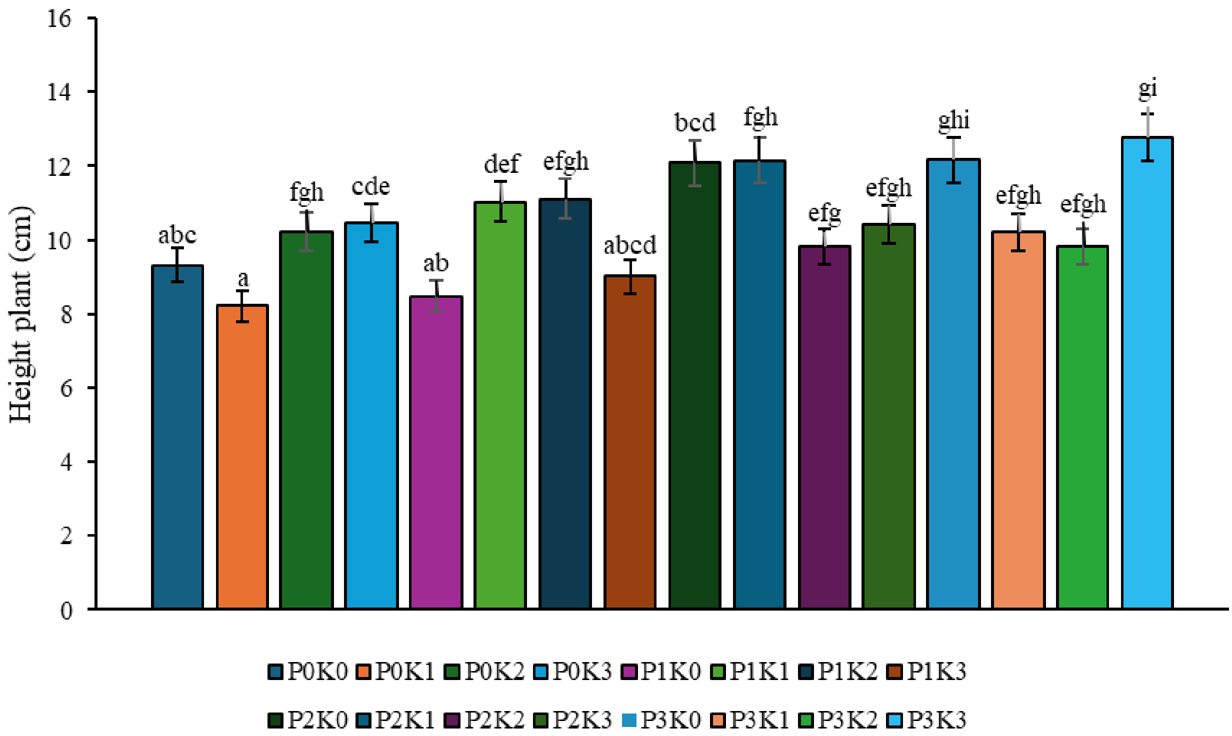

Figure 1. Impact dosage combination rice husk ash and rabbit urine on the plant height

The results of this study demonstrated that the combined application of rice husk ash and rabbit urine POC significantly influenced mustard plant height (Figure 1). The highest plant height was observed in the P3K3 treatment, whereas the lowest was recorded in P0K1, where no ash was applied and only 15 mL/L of POC was used. In general, increasing the dose of rice husk ash tended to improve plant height, especially when paired with higher POC concentrations. However, this trend was not strictly linear. For instance, in the P3 treatments, plant height declined under K1 and K2 before increasing again at K3. This pattern suggests a complex interaction between the two factors, indicating that the growth response of mustard plants depends not solely on the individual effect of each input, but on their synergistic or antagonistic interactions.

The observed pattern can be explained by the chemical properties of the amendments used. Rice husk ash contains alkaline elements such as potassium (K), calcium (Ca), and silica (Si), which can neutralize soil acidity and enhance nutrient availability in peat soils (De la Rosa et al., 2023). Its application likely contributed to an increase in soil pH, improving conditions for nutrient release. On the other hand, rabbit urine POC fermented for seven days supplies readily available nitrogen and beneficial microbes that stimulate vegetative growth. However, when POC is applied excessively or under high ash conditions (as in P3K1 or P3K2), nutrient imbalance or osmotic stress may occur, leading to suboptimal growth. Peat soil's low cation exchange capacity may also cause rapid leaching, particularly under over-irrigation or unbalanced fertilization. Thus, while both inputs can individually promote growth, their combined application must be carefully balanced to avoid diminishing returns or nutrient antagonism.

These findings align with previous studies that reported beneficial effects of rice husk ash in improving soil pH and enhancing nutrient availability. Singh et al. (2024) found that rice husk ash increased mustard growth in acidic soils by raising potassium and calcium availability. Similarly, Yin et al. (2023) observed that rabbit urine-based POC enhanced leafy vegetable height when applied at moderate concentrations. However, unlike those studies, the current results suggest that higher doses do not always lead to better growth, especially under peat soil conditions. This difference highlights the importance of soil-specific considerations particularly for organic soils that are highly sensitive to nutrient inputs. The present study thus reinforces the need for optimization strategies that account for both amendment dose and soil type to maximize plant response effectively.

3.3 Leaf width

Leaf width is a critical morphological indicator of vegetative growth, often linked to nutrient availability and environmental conditions. In this study, leaf width was significantly influenced by the interaction between rice husk ash and rabbit urine POC (Figure 2). The highest leaf width was recorded in P2K1, followed closely by P3K0, P2K3, and P3K2. The lowest value was found in P1K3, indicating a possible negative interaction between moderate ash and high POC concentration. Treatments P0K0 to P0K3 consistently showed lower leaf width values, ranging from 7.92 to 10.23 cm, highlighting the limited effectiveness of rabbit urine alone without pH amelioration from ash application.

Leaf width is a critical morphological indicator of vegetative growth, often linked to nutrient availability and environmental conditions

This pattern can be attributed to the ability of rice husk ash to adjust peat soil pH and improve base cation availability, especially potassium and calcium. Potassium plays a central role in cell enlargement, stomatal regulation, and carbohydrate translocation, while calcium contributes to cell wall stability and membrane integrity, all of which are vital for sustained leaf expansion and development (Liu et al., 2023). The application of POC further supplements macro- and micronutrients, particularly nitrogen, which is essential for chlorophyll synthesis, amino acid formation, and enzymatic activity that enhances photosynthesis efficiency. These mechanisms collectively explain the increased leaf width and number observed under balanced treatments. However, excessive application, such as in P1K3, may have created an osmotic imbalance or intensified microbial competition in the rhizosphere, reducing nutrient uptake efficiency and impairing leaf expansion. The high leaf width values at P2K1 and P3K2 suggest a synergistic effect when ash and POC are combined in balanced doses, simultaneously supporting soil chemical recovery and plant physiological processes. The results are consistent with findings by Qi et al. (2021), who reported that leaf width in leafy vegetables improved significantly with bio-organic amendments on acidic soils. Similarly, fermented rabbit urine enhances vegetative growth by supplying nitrogen and growth hormones that promote leaf expansion and chlorophyll accumulation, particularly when soil pH is within the optimal range (Okonji et al., 2023). In contrast, over-application of organic liquid fertilizers in poorly buffered soils such as peat can trigger osmotic stress, microbial imbalance, and reduced root activity, ultimately constraining vegetative growth (Mandal et al., 2025). Therefore, this study reinforces the importance of precise combination strategies in organic farming, optimizing both ameliorants and nutrient sources in accordance with soil properties and plant physiological requirements.

Potassium plays a central role in cell enlargement, stomatal regulation, and carbohydrate translocation, while calcium contributes to cell wall stability and membrane integrity, all of which are vital for sustained leaf expansion and development

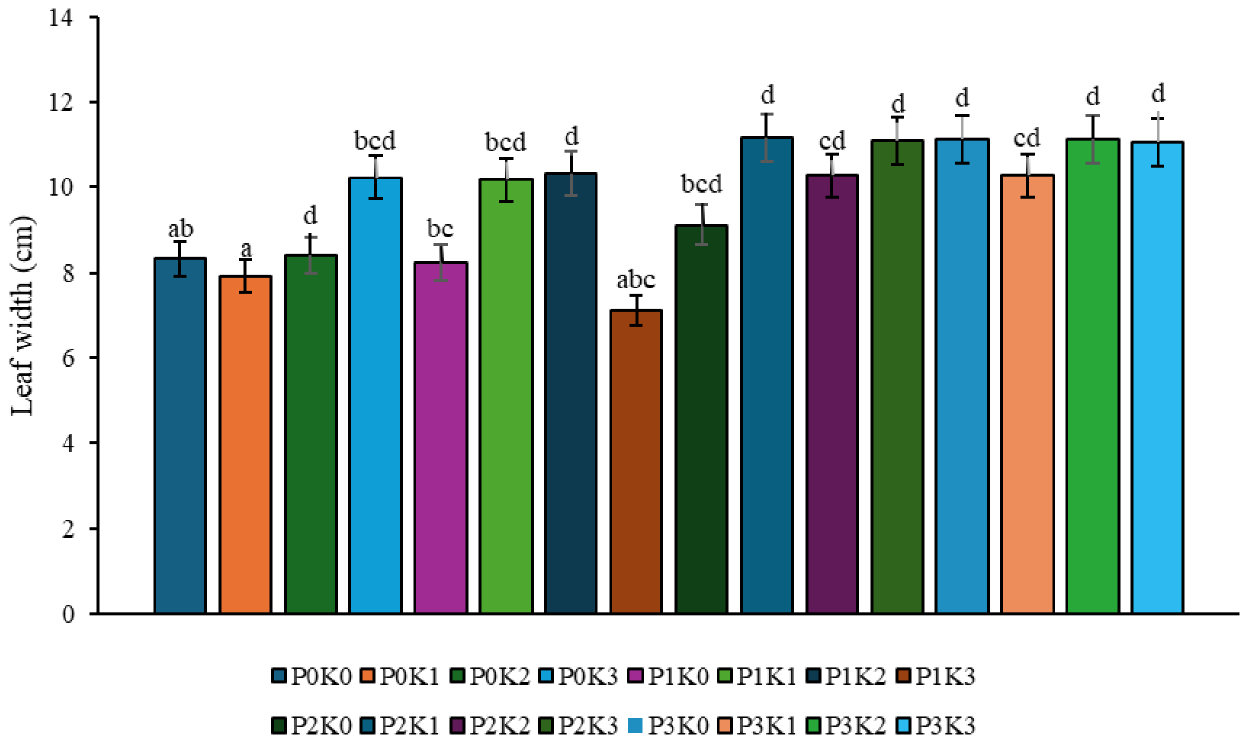

Figure 2. Impact dosage combination rice husk ash and rabbit urine on the leaf width.

3.4 Number of leaves

The number of leaves served as a key indicator of vegetative growth and photosynthetic potential in mustard plants. Results showed that leaf number was significantly influenced by the interaction between rice husk ash and rabbit urine POC (Figure 3). The highest leaf number was obtained in treatments P3K2, P2K1, and P3K1 with values of 9.82, 9.47, and 9.22 leaves/ plant, respectively, while the lowest was recorded in P1K0 with 6.82 leaves. Across the ash treatments, the average number of leaves increased from 7.45 in P1 to 8.76 in P3, indicating that higher doses of rice husk ash promoted leaf development by improving soil pH and enhancing nutrient uptake. Similarly, the application of POC increased leaf number, with the highest average observed at K1 (8.96 leaves), suggesting that moderate doses of rabbit urine optimized nutrient supply and hormonal stimulation, while excessive doses did not further enhance leaf formation. These results demonstrate that the synergy of rice husk ash and rabbit urine, particularly at P3K2, promoted optimal vegetative performance in peat soil conditions.

The variation in leaf number can be attributed to nutrient availability and the improvement of root-zone conditions. Rice husk ash likely played a role in increasing soil pH and reducing acidity related stress in peat soil, thus improving nutrient solubility and uptake efficiency (Bekana et al., 2022). Rabbit urine, rich in nitrogen and other growth-promoting elements, stimulates the synthesis of plant hormones like cytokinins, which promote leaf initiation and expansion. However, low leaf number in treatments like P1K0 or P1K3 may be due to suboptimal synergy between ash and POC, or temporary nutrient imbalances during early growth. The results also highlight that moderate POC concentrations (30 mL/L) in combination with medium-to-high ash dosages produce more consistent vegetative performance.

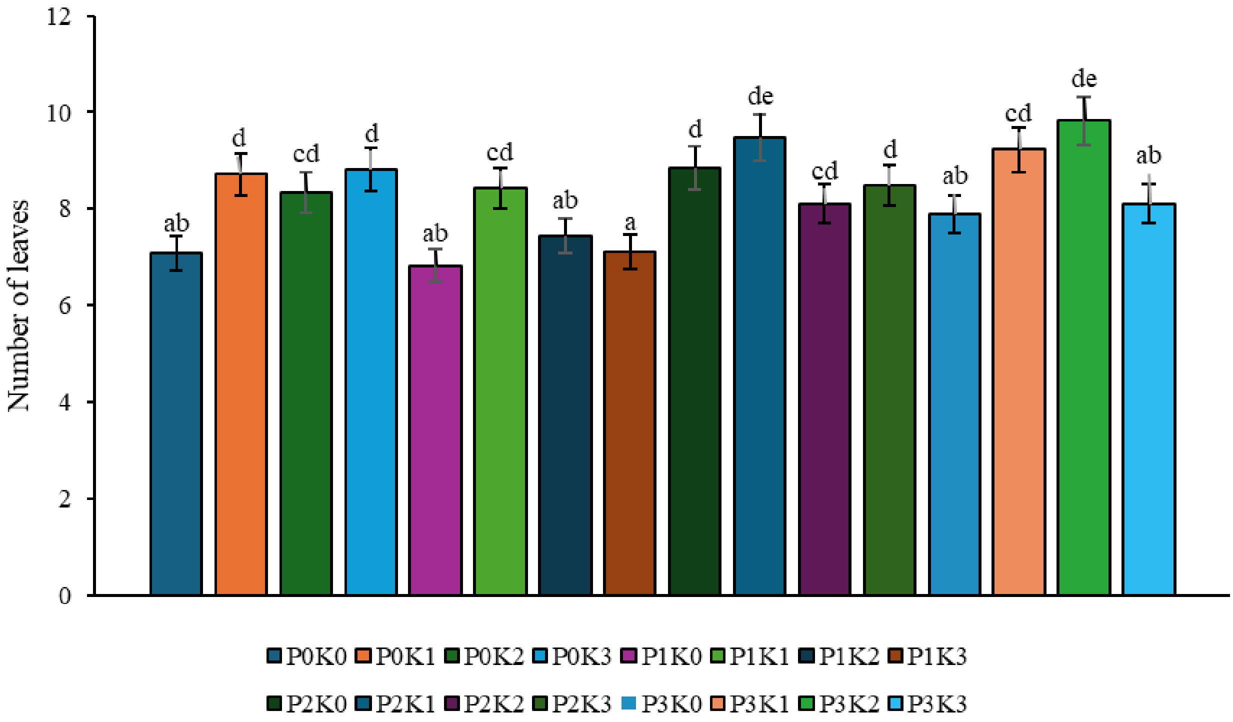

Figure 3. Impact dosage combination rice husk ash and rabbit urine on the number of leaves.

This finding aligns with research by Cardarelli et al. (2023), who found that balanced organic fertilization significantly enhanced leaf number in leafy vegetables, particularly on acidic or degraded soils. Similarly, Addition of rice husk ash improved soil buffering capacity, which in turn increased nutrient availability and led to better leaf proliferation (Yin et al., 2022). However, our results emphasize the importance of optimizing the ratio between ash and POC: excess nitrogen or potassium without proper soil buffering may suppress leaf development. Thus, these findings confirm the necessity of tailored organic fertilization strategies that consider both the chemical condition of the soil and the specific requirements of the crop.

3.5 Fresh weight

Fresh weight, which reflects total biomass accumulation, varied significantly across treatments. The highest fresh weight was obtained in P2K1, P3K2, and P3K1 with values of 40.22, 36.79, and 33.89 g/plant, respectively, while the lowest was recorded in P1K3 and P0K1 with 12.25 and 14.22 g (Figure 4). Treatments combining moderate to high doses of rice husk ash (P2 and P3) with mid-range concentrations of rabbit urine POC (K1 and K2) consistently produced significantly greater biomass compared to other treatments. In contrast, unbalanced applications, such as P1K3 and P0K1, led to markedly reduced fresh weight, suggesting that excessive or insufficient inputs negatively affected plant growth. These findings highlight the synergistic role of ash-induced pH improvement and nutrient supply from POC in optimizing vegetative biomass production on peat soils.

Similarly, Addition of rice husk ash improved soil buffering capacity, which in turn increased nutrient availability and led to better leaf proliferation

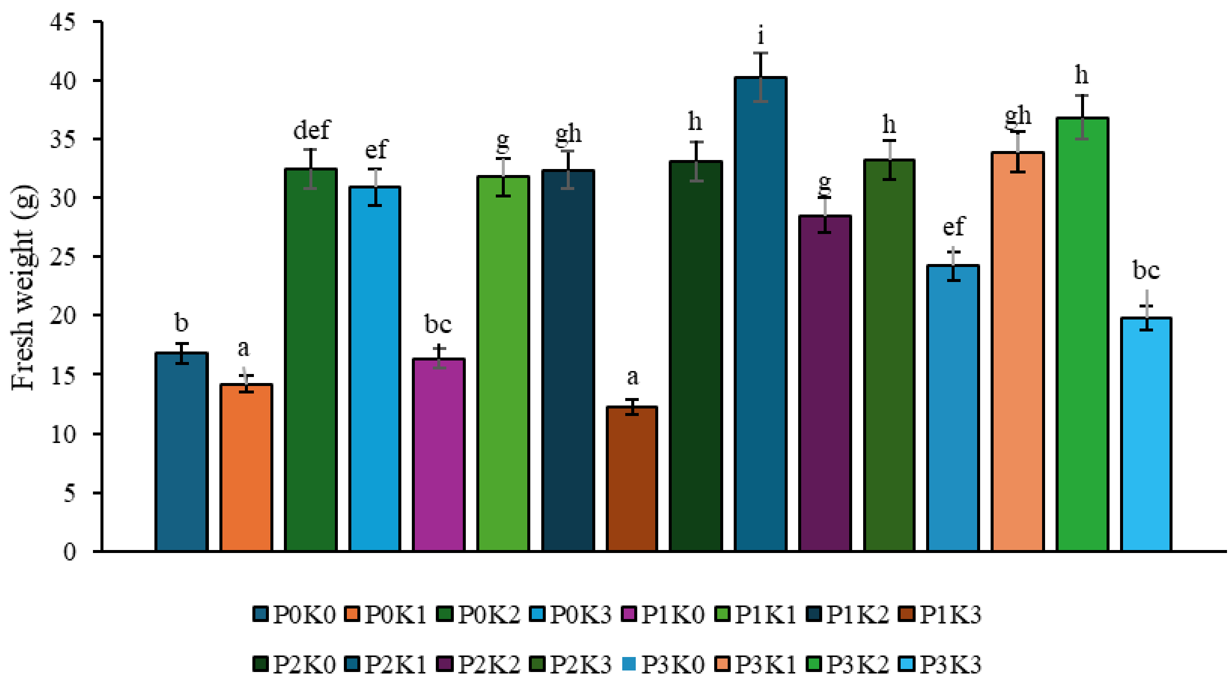

Figure 4. Impact dosage combination rice husk ash and rabbit urine on the fresh weight.

The differences in fresh weight are likely driven by both soil nutrient availability and plant physiological responses. Rice husk ash provides essential minerals such as potassium and calcium, while also raising the pH of acidic peat soils, enhancing nutrient uptake efficiency (Yin et al., 2022). Rabbit urine POC, when applied in balanced doses, supplies bioavailable nitrogen and growth hormones that stimulate photosynthesis and protein synthesis, thereby increasing biomass. However, the significantly reduced weight in treatments like P1K3 and P0K1 may result from nutrient imbalance, excessive ammonium accumulation, or osmotic stress caused by over-application of organic liquids in a poorly buffered soil system. From a soil chemistry perspective, excessive ash input may elevate soil pH beyond the optimal range for mustard growth, leading to reduced availability of micronutrients such as Fe, Mn, and Zn. In parallel, high doses of rabbit urine can increase electrical conductivity, creating osmotic stress and potentially causing ammonium toxicity, both of which impair root function and water uptake. From a plant physiological standpoint, such conditions can disrupt chlorophyll synthesis, enzyme activity, and stomatal regulation, ultimately reducing photosynthetic efficiency and biomass accumulation. This supports the idea that synergy between pH control (from ash) and nutrient availability (from POC) is key to optimizing biomass growth in peat soil environments. These results are consistent with the findings of Chen et al. (2021), that combining alkaline organic amendments with liquid organic fertilizers improved fresh biomass yield of leafy vegetables in acid soils. Similarly, (Cao et al., 2024) emphasized that fresh weight increased significantly when nutrient availability was optimized through pH correction and balanced organic feeding. However, our findings further suggest that while organic inputs individually support growth, their combined application must consider dose compatibility. Excessive doses or improper combinations can reduce effectiveness, as seen in treatments like P1K3. Therefore, this study contributes to a growing body of knowledge that highlights the importance of treatment optimization, particularly in sensitive soils like peat, to achieve maximum productivity.

Rice husk ash provides essential minerals such as potassium and calcium, while also raising the pH of acidic peat soils, enhancing nutrient uptake efficiency

4. CONCLUSION

This study demonstrated that the co-application of rice husk ash and rabbit urine POC significantly improved soil pH and the growth performance of mustard (*Brassica juncea*) cultivated on peat soil. The combination of 20–25 tons/ha rice husk ash with 30–45 mL/L rabbit urine POC produced the most favorable vegetative growth and biomass yield, with P2K1 and P3K2 treatments showing the best performance. Scientifically, these findings contribute new evidence on the synergistic mechanisms by which alkaline organic amendments (silica and base cations from rice husk ash) and nutrient-rich biofertilizers (nitrogen, potassium, phosphorus, and growth regulators from rabbit urine) interact to optimize plant growth under acidic peat conditions. Practically, this research highlights a low-cost and eco-friendly strategy for smallholder farmers to improve soil fertility and crop productivity in peatland regions, thereby supporting sustainable agriculture and local food security.

However, this study has several limitations. The experiment was conducted at polybag scale under short-term conditions, which may not fully capture the long-term dynamics of peat soil chemistry and crop responses under field environments. The analysis also focused primarily on soil pH and plant growth parameters, without examining microbial activity, nutrient cycling, or potential environmental impacts. Therefore, future studies are recommended to evaluate these organic amendments at larger field scales, over multiple cropping cycles, and with more comprehensive soil plant microbe analyses to validate the sustainability and scalability of this approach in diverse agroecological contexts.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

Muhammad Muharram: Writing – original draft, Conceptualization. Tarekegn Yoseph: Conceptualization, Supervision, Methodology. Marchel Putra Garfansa: Data curation.

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ETHICS APPROVAL

No ethical approval was needed for this study.

FUNDING

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CONFLICT OF INTEREST

The author declares no conflicts of interest.

DATA AVAILABILITY STATEMENT

The review did not report any data.

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