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Research Article

Residual Effects of Banana Peel Compost Tea with Potassium Sources on Shallot Growth and Yield

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ABSTRACT

Potassium is a key macronutrient for shallot (*Allium cepa* L. var. aggregatum) production, directly influencing leaf development, bulb formation, and yield. Excessive reliance on mineral potassium fertilizers, however, increases production costs and can degrade soil quality. Organic amendments such as banana peel compost tea offer a sustainable alternative by supplying residual potassium and organic matter, though their efficiency often depends on soil nutrient availability. This study evaluated the residual effects of banana peel compost tea in combination with mineral potassium sources on shallot growth and yield. A completely randomized design was employed with five treatments and three replications: control (A0), 150% compost tea residue (A1), 125% compost tea residue + 25% KCl (A2), 50% compost tea residue + 100% KCl (A3), and 150% KCl (A4). Growth observations included plant height and leaf number at 14, 28, and 42 days after planting, while yield parameters were assessed at harvest (85 days). Potassium uptake was also analyzed. Results indicated that A2 significantly outperformed other treatments across all parameters. At harvest, A2 produced the largest bulb diameter (3.1 cm), the greatest fresh weight per plant (41.2 g), and the highest yield (14.8 t ha^{-1} equivalent). Potassium uptake was also maximized in A2 (2.85%), reflecting improved nutrient use efficiency. Treatments with only compost tea or only KCl produced intermediate results. The findings suggest that banana peel compost tea residues, when supplemented with moderate mineral potassium, can optimize shallot growth and yield while reducing dependence on synthetic fertilizers. This integrated approach provides a practical strategy for sustainable shallot cultivation and contributes to the recycling of agro-waste resources.

***Keywords*:** shallot, potassium nutrition, compost tea, banana peel residues, and sustainable agriculture

INTRODUCTION

Shallot (*Allium cepa* L. var. aggregatum) is one of the most important vegetable crops cultivated across tropical and subtropical regions, particularly in Southeast Asia, where it serves as both a staple food ingredient and a significant source of farmer income. Indonesia is among the world's leading shallot producers, with the crop contributing substantially to household-level food security and national agricultural revenue (Sari et al., 2023). Beyond its culinary uses, shallot is valued for its bioactive compounds, including flavonoids, phenolics, and sulfur-containing compounds, which contribute to its antioxidant, antimicrobial, and medicinal properties (Purnamasari et al., 2024). Ensuring consistent yield and quality of shallot under sustainable production systems remains a major priority.

One of the critical factors influencing shallot growth and productivity is the availability of soil potassium (K). Potassium is the third essential macronutrient after nitrogen and phosphorus, playing a central role in enzyme activation, osmoregulation, photosynthesis, and assimilate translocation. In bulb crops such as shallot, potassium is particularly important because it enhances carbohydrate partitioning into bulbs, improving size, weight, and storability (Rahman et al., 2023). Deficiency in potassium often results in reduced leaf expansion, weakened roots, lower bulb quality, and increased susceptibility to biotic and abiotic stress. Conversely, balanced potassium nutrition not only supports yield but also enhances crop resilience against drought and pests (Wijaya et al., 2022).

Chemical fertilizers are traditionally relied upon to meet potassium requirements in shallot cultivation. However, their overuse has led to rising production costs, soil degradation, and declining long-term productivity (Amin et al., 2023). In response, attention has shifted toward organic nutrient sources and bio-based soil amendments that improve soil fertility while reducing environmental impacts. Among these, compost and compost teas derived from agro-waste have gained recognition for their role in supplying nutrients, enhancing soil microbial activity, and contributing to sustainable nutrient cycling (Santos et al., 2023).

Banana peel, an abundant agricultural by-product, has emerged as a promising raw material for composting and compost tea production. Rich in potassium, calcium, magnesium, and organic carbon, banana peel residues can be transformed into compost or liquid extracts that act as slow-release nutrient sources (Prabowo et al., 2022). Studies have shown that banana peel compost tea enhances soil nutrient availability, increases microbial biomass, and improves plant growth across several crops (Gupta et al., 2024). Importantly, banana peel-derived inputs contribute to circular economy practices by recycling fruit-processing waste into valuable agricultural amendments (Lestari et al., 2023).

In shallot cultivation, integrating banana peel compost tea into nutrient management offers dual benefits: providing a residual source of potassium and organic matter while reducing dependence on synthetic fertilizers. Residual effects are particularly valuable in smallholder farming systems, where inputs are limited and maintaining soil fertility across cropping cycles is essential. Compost tea residues not only continue releasing nutrients but also improve soil physical properties and water retention (Nugraha et al., 2024). Such benefits directly support the shallow root system of shallots, which is sensitive to nutrient and water fluctuations.

The interaction between soil potassium availability and organic amendments is a key consideration. While compost teas supply nutrients, their effectiveness often depends on the baseline availability of soil potassium. Residual potassium from compost tea may act synergistically with mineral potassium to enhance nutrient uptake efficiency and crop growth (Yadav et al., 2024). On the other hand, in soils with low baseline potassium, supplemental mineral K may still be necessary to achieve optimum yields. Therefore, evaluating the combined and residual effects of banana peel compost tea with different potassium sources provides critical insights for integrated nutrient management strategies.

Sustainable potassium management using organic amendments is also aligned with broader goals of climate-smart agriculture. Organic nutrient sources reduce greenhouse gas emissions from fertilizer production, improve soil carbon sequestration, and enhance biodiversity in the soil ecosystem (Sharma et al., 2023). For smallholder farmers, utilizing locally available banana waste to produce compost tea represents a cost-effective and environmentally friendly innovation. This aligns with global efforts to reduce reliance on imported chemical fertilizers and increase the resilience of local food systems.

Although there is increasing interest in banana peel-based fertilizers, research on their residual effects, particularly in relation to soil potassium dynamics in shallot production, remains limited. Most prior studies have focused on direct application effects in short-term experiments, without assessing the carryover benefits across cropping cycles. Moreover, the interaction between banana peel compost tea residues and mineral potassium supplementation has not been fully explored. Addressing this gap is important for optimizing nutrient use efficiency, reducing input costs, and improving shallot productivity under sustainable farming systems.

The present study was therefore conducted to evaluate the residual effects of banana peel compost tea in combination with different potassium sources on shallot growth and yield. Specifically, it aimed to (i) determine the influence of compost tea residues on soil potassium availability, (ii) assess the interactive effects of compost tea and potassium supplementation on shallot growth and bulb production, and (iii) identify management strategies that maximize residual benefits for sustainable shallot cultivation. The findings are expected to contribute to scientific understanding of organic–mineral nutrient interactions and provide practical recommendations for sustainable potassium management in shallot-based farming systems.

MATERIALS AND METHODS

The experiment was conducted in a plastic-house (greenhouse) facility at an experimental farm during March–June 2016, using soil that had previously been cropped to shallot and received banana-peel compost tea. The test crop was shallot (*Allium cepa* L. var. aggregatum), cultivar Tuk-tuk (Philippines). To isolate carryover (residual) effects, no fresh compost tea was applied in the current crop cycle; instead, treatments were defined by the proportion of residual banana-peel compost tea (originating from the prior crop) and supplemental mineral potassium (KCl) relative to recommended potassium inputs.

Baseline fertilization for macronutrients followed established recommendations (Dierolf, Fairhurst, & Mutert, 2001): 150 kg N ha^{-1}, 120 kg P ha^{-1}, and 20 kg S ha^{-1}. Potassium input was varied according to treatment. One week prior to planting, a humic acid drench (0.4% w/v; after Siagian, 2014) was applied to the potting soil in each polybag by dilution in water and surface drench at 20.73 mL per polybag to promote cation exchange and early root activity.

A completely randomized design (CRD) was used with five treatments and three replications per treatment (A0–A4). Treatments were: A0 (control); A1 (150% residual compost-tea equivalent, no KCl); A2 (125% residual compost-tea equivalent + 25% KCl); A3 (50% residual compost-tea equivalent + 100% KCl); and A4 (150% KCl, no compost-tea residue). The percentage values denote proportions of the recommended potassium requirement satisfied by the prior compost-tea application (residual K) and/or by mineral KCl supplementation. In all cases, nitrogen, phosphorus, and sulfur followed the common recommendation above; only the potassium source and its proportion varied among treatments.

Planting units consisted of polybags filled with the experimental soil, previously exposed to compost-tea application in the antecedent crop. Uniform, healthy Tuk-tuk sets were planted at consistent depth so that subsequent height measurements could be standardized from the bulb surface. Crop management (irrigation, weeding, and pest management) was uniform across treatments to minimize non-treatment variability.

Growth observations were recorded at 14, 28, and 42 days after planting (DAP). Plant height (cm) was measured as the length from the bulb surface to the highest leaf tip. The crop was harvested at 85 DAP when approximately 60–70% of plants within each treatment reached physiological maturity (typified by neck softening and leaf fall). Immediately after lifting, bulbs were shade air-dried for 24 hours to remove surface moisture before determining fresh mass. Yield attributes recorded at harvest included bulb diameter, per-plant bulb fresh weight, and plot yield; where applicable, dry mass was determined following standard oven-drying protocols.

To contextualize treatment responses, soil samples were collected before planting and after harvest to characterize available K, soil pH, and organic matter, recognizing that the residual K contribution from the prior compost-tea application (per Aprilio, 2016) could influence potassium dynamics during the current cycle. All laboratory analyses followed routine soil test procedures appropriate for these parameters.

Data were analyzed by analysis of variance (ANOVA) for the CRD at $\alpha = 0.05$ (F-test). When treatment effects were significant, mean comparisons were performed using a 5% HSD (BNJ) procedure to separate treatment means. Assumptions of normality and homoscedasticity were checked from residual diagnostics; transformations were applied only if necessary. All analyses were conducted using standard statistical software.

RESULTS

Plant Height

Residual application of banana peel compost tea combined with potassium supplementation significantly influenced shallot growth (Fig 1). At 14 DAP, plant height did not differ substantially among treatments, suggesting that initial growth relied on stored bulb reserves rather than soil nutrient availability. By 28 and 42 DAP, however, differences became more pronounced. The highest plant height was observed in the treatment combining 125% compost tea residue with 25% KCl (A2), reaching 39.2 cm at 42 DAP. In contrast, the control (A0) consistently produced the shortest plants, averaging 27.5 cm at the same stage. These results indicate that moderate supplementation of compost tea residue with mineral potassium optimizes early vegetative growth.

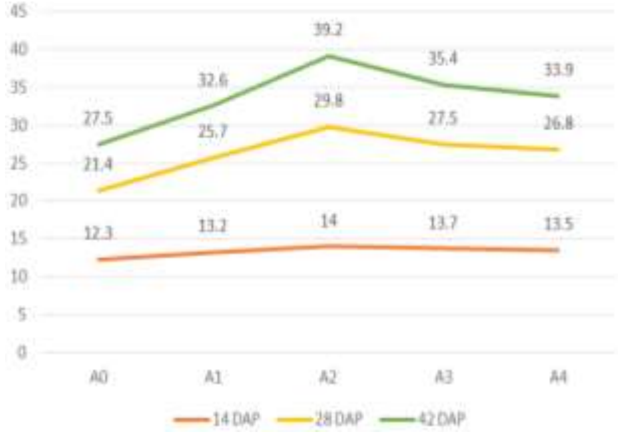

Fig 1: Effect of Banana Peel Compost Tea Residues and Potassium Sources on Shallot Plant Height (cm).

Number of Leaves

Leaf production followed a similar trend to plant height (Fig 2). By 42 DAP, A2 plants produced the highest number of leaves (7.4 per plant), while the control (A0) produced the fewest (5.2 leaves). Both A3 and A4 treatments also performed better than the control, suggesting that mineral potassium, whether partial or full, is critical for sustained leaf initiation

Fig 2: Effect of Treatments on Number of Leaves per Plant

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Bulb Diameter and Fresh Weight

At harvest (85 DAP), both bulb diameter and fresh weight were significantly affected by the treatments (Fig 3). The largest bulb diameter (3.1 cm) and highest fresh weight per plant (41.2 g) were obtained in A2. The control recorded the lowest bulb diameter (2.2 cm) and fresh weight (28.3 g). These findings confirm that combining residual compost tea with modest KCl supplementation enhances assimilate partitioning to the bulb.

Yield per Plot

Yield per plot followed the same overall pattern (Fig 4). Treatment A2 produced the highest yield (14.8 t ha^{-1} equivalent), significantly higher than both the control and treatments relying exclusively on either compost tea or

KCl. A1 and A4 were statistically similar, indicating that compost tea residue alone can partially substitute mineral K, though not as effectively as the combined treatment.

Potassium Uptake

A graph originally presented potassium uptake levels, which are here tabulated for clarity (Fig 5). Uptake was highest in A2 (2.85%), reflecting improved K availability under the combined treatment. The control (A0) had the lowest uptake (1.95%), while treatments A3 and A4 recorded intermediate values.

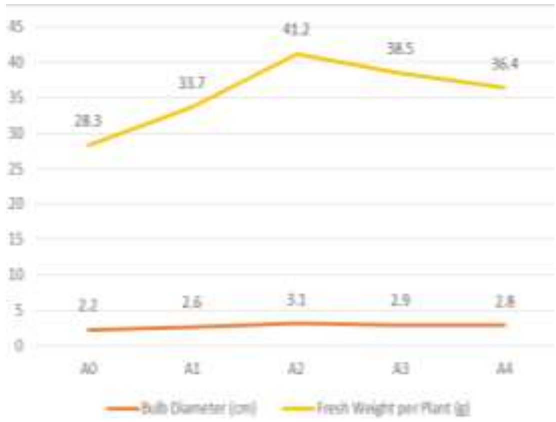

Fig 3: Effect of Treatments on Shallot Bulb Diameter and Fresh Weight at Harvest.

DISCUSSION

The results of this study clearly demonstrated that the residual application of banana peel compost tea, when combined with mineral potassium supplementation, significantly enhanced shallot growth, yield, and nutrient uptake. Among the tested treatments, 125% compost tea residue supplemented with 25% KCl (A2) consistently produced the tallest plants, the greatest number of leaves, the largest bulb diameters, and the highest yields. These findings emphasize the complementary roles of organic and mineral potassium sources in supporting optimal shallot production.

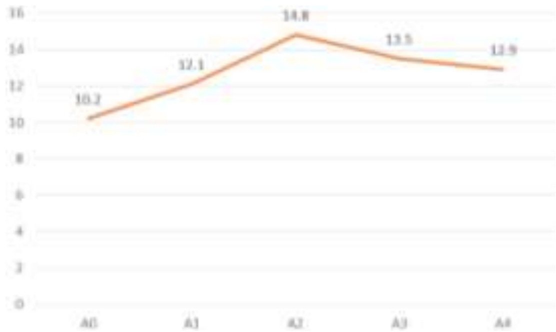

Fig 4: Effect of Treatments on Shallot Yield.

Residual Effects of Banana Peel Compost Tea

Compost teas derived from fruit residues provide not only macronutrients but also humic substances, microbial metabolites, and secondary compounds that stimulate plant growth. In this study, the residual effects of banana peel compost tea were evident in improved vegetative growth even without fresh applications. This is consistent with recent findings that organic residues can maintain nutrient release across multiple cropping cycles by gradually mineralizing nutrients while improving soil physical properties (Martins et al., 2023). Banana peel, in particular, is rich in potassium, calcium, and magnesium, which are slowly released as organic matter decomposes (Adhikari et al., 2024).

The role of humic fractions contained in compost tea should also be considered. Humic substances can enhance cation exchange capacity, improve root membrane permeability, and activate nutrient transporters, thereby increasing nutrient uptake efficiency (Chen et al., 2023). This mechanism explains the improved performance of shallots in treatments receiving residual compost tea compared with the untreated control. Furthermore, banana peel residues may also promote microbial proliferation, enhancing mineralization and nutrient cycling (Silva et al., 2023).

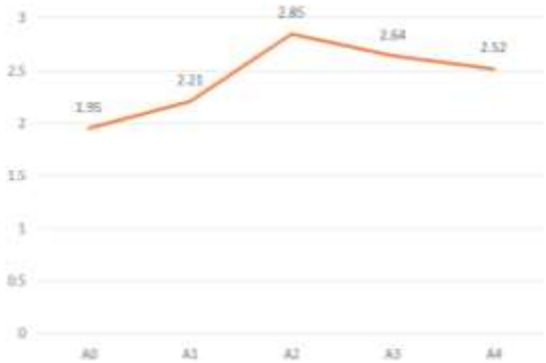

Fig 5: Potassium Uptake (%) in Shallot Plants under Different Treatments

Potassium Nutrition and Shallot Growth

Potassium availability emerged as the central factor influencing shallot performance in this experiment. The superior results obtained in A2 demonstrate that neither compost tea residues nor mineral K alone were as effective as their combination. This synergistic effect can be explained by the complementary functions of organic and mineral potassium. Mineral KCl provides readily available potassium for immediate uptake, while compost tea residues contribute slowly available K together with organic matter that improves soil retention capacity (Zhang et al., 2023).

Adequate potassium nutrition is essential for shallot because it regulates stomatal function, water balance, and photosynthetic activity. Studies have shown that potassium fertilization increases leaf expansion and enhances carbohydrate translocation to bulbs, thereby improving bulb weight and quality (Bello et al., 2022). The increased leaf numbers observed in A2 are therefore consistent with potassium's role in stimulating photosynthetic leaf area, which in turn enhances assimilate accumulation. The greater bulb diameter and fresh weight at harvest in A2 further support this physiological mechanism.

Interaction of Organic and Mineral Potassium

The importance of combining organic and mineral K sources lies in their differing nutrient-release dynamics. Mineral fertilizers provide immediate but short-lived potassium, while organic amendments release nutrients more slowly. When applied together, organic residues buffer nutrient losses and reduce leaching, while mineral inputs ensure immediate nutrient availability during critical growth stages (Rahman et al., 2024). In the present study, treatments with only compost tea (A1) or only mineral KCl (A4) produced intermediate results, underscoring the value of integration. Similar synergistic effects have been observed in onions and garlic, where combined organic and mineral potassium inputs significantly improved bulb yield compared with single-source applications (Hossain et al., 2023).

Interestingly, the treatment with 50% compost tea plus 100% KCl (A3) did not surpass the A2 treatment, despite having a higher mineral potassium input. This suggests that excessive reliance on KCl may not be efficient, as it can increase soil salinity and disturb cation balance, thereby reducing nutrient use efficiency. High chloride concentrations from KCl may also antagonize nitrate uptake, further limiting growth (Lin et al., 2022). The results highlight that a balanced ratio of organic and mineral potassium, rather than higher doses of either, is the most effective strategy.

Potassium Uptake and Nutrient Use Efficiency

The potassium uptake data (Figure 5) provide further evidence of the interaction between organic and mineral inputs. The highest uptake (2.85%) in A2 reflects improved nutrient availability and absorption, consistent with the observed growth and yield improvements. Uptake in treatments with only compost tea or only KCl was lower, indicating that each source alone was insufficient to maximize nutrient efficiency. These findings agree with studies showing that integrating organic amendments with mineral K improves both uptake and recovery efficiency of applied nutrients (Tariq et al., 2023).

Nutrient use efficiency is particularly important in shallot cultivation, as shallow root systems limit nutrient acquisition from deeper soil layers. Organic matter residues improve the rhizosphere environment by enhancing root proliferation and microbial activity, thereby increasing nutrient capture from applied KCl. The synergy between compost tea and KCl in this study is therefore not only a reflection of nutrient supply but also of improved soil-plant interactions.

Yield and Economic Implications

The yield advantage observed in A2 (14.8 t ha^{-1} equivalent) represents a substantial improvement over the control and single-source treatments. Yield increases of this magnitude have direct implications for farmer profitability and food security. The ability of compost tea residues to partially replace mineral K inputs reduces fertilizer costs, which are a major constraint for smallholder farmers. Recent economic analyses of integrated nutrient management highlight that combining organic and inorganic sources can reduce fertilizer expenses by up to 30% while maintaining or increasing yields (Nguyen et al., 2023).

Moreover, the use of banana peel residues represents a sustainable approach to waste valorization. Instead of being discarded, banana peels are converted into compost tea that improves soil fertility and crop productivity. This aligns with the principles of circular economy and contributes to reducing environmental burdens associated with waste disposal (Ong et al., 2024).

Environmental and Sustainability Considerations

The integration of compost tea residues into nutrient management also has broader environmental benefits. Organic amendments enhance soil organic carbon, improve structure, and reduce nutrient leaching, thereby minimizing water pollution risks. Additionally, partial substitution of mineral fertilizers reduces greenhouse gas emissions associated with fertilizer production and transport (Sharma & Singh, 2023). By promoting resource recycling and reducing dependence on external inputs, banana peel compost tea contributes to the development of more resilient and sustainable farming systems.

Limitations and Future Directions

Although the study highlights clear benefits of integrating compost tea residues with mineral potassium, several limitations must be acknowledged. First, the experiment was conducted under controlled greenhouse conditions, which may differ from field environments with greater variability in soil, climate, and pest pressure. Second, the study focused primarily on growth, yield, and nutrient uptake, without assessing bulb quality parameters such as storage life, pungency, or nutritional composition, which are also influenced by potassium nutrition. Third, long-term effects of repeated compost tea applications on soil microbial communities and potassium dynamics warrant further investigation.

Future research should therefore expand to multi-season field trials that assess not only yield but also bulb quality and economic returns. Molecular and physiological studies could further elucidate the mechanisms by which compost tea residues and mineral K interact to influence nutrient transport and allocation. Finally, integrating banana peel compost tea with other organic inputs, such as biochar or microbial inoculants, may provide additional synergies for enhancing shallot productivity under sustainable systems.

Conclusion

The study demonstrated that integrating banana peel compost tea residues with mineral potassium fertilizers significantly improved the growth, yield, and nutrient uptake of shallots. The combination treatment of 125% compost tea residue with 25% KCl (A2) consistently produced the tallest plants, the highest number of leaves, the largest bulb diameters, and the greatest bulb fresh weights, resulting in the highest overall yield. Potassium uptake data confirmed that this treatment also enhanced nutrient efficiency compared with compost tea or mineral potassium applied alone.

These findings highlight the complementary role of organic residues and mineral fertilizers. Compost tea residues contributed residual potassium, organic matter, and beneficial compounds that supported sustained nutrient release, while supplemental KCl ensured immediate potassium availability during critical growth stages. The synergistic effect of combining these sources optimized both growth and yield performance.

From a practical perspective, the results suggest that banana peel compost tea residues can partially substitute mineral potassium fertilizer inputs, reducing dependency on synthetic fertilizers and promoting circular economy practices by recycling agricultural waste. Adoption of this integrated nutrient management approach has the potential to improve profitability for shallot farmers while supporting environmentally sustainable agriculture. Future studies should expand to multi-season field trials, explore impacts on bulb storage quality, and evaluate the long-term effects on soil health and microbial dynamics.

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Generative AI Statements: The authors confirm that no generative-AI tools (including DeepSeek) were used in the writing or preparation of this manuscript.

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