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ORIGINAL RESEARCH ARTICLE

Liquid Organic Fertilizer from Rice-Washing Water and Shallot-Skin Waste Improves Growth and Fresh Yield of Pakchong Grass (*Pennisetum purpureum* cv. Thailand)

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ABSTRACT

Feed is the highest recurring cost in ruminant production, and a continuous supply of low-cost, good-quality forage is a persistent constraint for smallholder farmers. This study evaluated the effect of a liquid organic fertilizer (POC) formulated from two abundant household waste streams — rice-washing water and shallot-skin waste — on the growth and fresh yield of pakchong grass (*Pennisetum purpureum* cv. Thailand). We conducted a 42-day rapid field experiment in Langgongsari Village, Cilongok District, Banyumas Regency, Central Java, Indonesia, using 60 three-node stem cuttings. A completely randomized design with four POC doses (0, 200, 400, and 600 mL m^{-2}, coded P0–P3) and five replications gave 20 experimental units of three cuttings each; POC was diluted to a constant 2,000 mL m^{-2} and applied twice, in the first and second weeks after planting. Plant height, leaf length, tiller number, and fresh yield were recorded and analyzed by analysis of variance followed by the least significant difference test. Increasing POC dose significantly ($P<0.01$) increased plant height (from 101.99 cm at P0 to 116.76 cm at P3), leaf length (from 58.56 to 64.02 cm), and fresh yield (from 7.2 to 8.9 ton ha^{-1}). Tiller number did not differ among treatments ($P>0.05$), ranging from 0 to 0.2 tillers per clump; this near-absence of tillering is attributed to the single-defoliation regime rather than to the fertilizer, and is treated here as a limitation of the design. Overall, POC formulated from rice-washing water and shallot-skin waste, applied at 600 mL m^{-2}, is a promising low-cost organic input for improving pakchong grass productivity. Because the nutrient concentration of the POC and a comparison with an inorganic-fertilizer standard were not established in this study, the magnitude of the substitution benefit should be quantified in future work.

Keywords: *fresh yield; liquid organic fertilizer; pakchong grass; rice-washing water; shallot skin*

INTRODUCTION

The national ruminant population — cattle, buffalo, goats, and sheep — declined from 55,376,019 head in 2020 to 51,822,141 head in 2022 (Badan Pusat Statistik Indonesia, 2022). Feed accounts for 70–80% of total operating costs in ruminant production, and daily feed requirements typically reach 7–12% of body weight, so any shortfall in feed quality directly limits productivity (Budiman et al., 2019). Ensuring a continuous supply of high-quality forage is therefore essential for sustaining and expanding ruminant enterprises, particularly on the limited land available to smallholder farmers.

Among the forage grasses recommended for ruminants, pakchong grass (*Pennisetum purpureum* cv. Thailand), a hybrid of elephant grass (*P. purpureum* × *P. glaucum*) first developed in Thailand, has attracted growing interest because of its rapid growth, high palatability, and fresh-matter yield of up to 100–200 ton ha^{-1} yr^{-1} (Nugraha, 2024). It produces long leaves, a comparatively high number of tillers, and low oxalate content relative to other elephant-grass cultivars, while its dry-matter and crude-protein contents support good animal performance (Dadang Suherman & Herdiawan, 2021; Harianti et al., 2023). Despite these advantages, pakchong cultivation still relies heavily on inorganic fertilizer and a stable water supply, both of which raise production costs, and the crop remains susceptible to armyworm (*Spodoptera frugiperda*) infestation during the early weeks after planting, which can reduce leaf area and fresh yield (Sari et al., 2024; Zuliansyah et al., 2023).

Liquid organic fertilizer (POC) offers a low-cost alternative that can reduce dependence on inorganic inputs while supplying macro- and micronutrients and improving soil biological activity (Hadiyanti, 2021). Rice-washing water, an abundant household waste stream, is reported to contain nitrogen, phosphorus, potassium, and B-vitamins that support vegetative growth (Sulfianti et al., 2021), while shallot-skin waste supplies potassium, magnesium, and iron and contains flavonoid and acetogenin compounds that have been described as having biopesticidal activity against leaf-eating larvae (Hadijah et al., 2022). Combining these two waste streams into a single liquid fertilizer has been attempted for vegetable crops (Hidayat et al., 2024), but its effect on the growth and fresh-yield components of pakchong grass has not been reported. Comparable dose-dependent responses have been documented for related odot and dwarf elephant grass cultivars (*Pennisetum purpureum* cv. Mott), in which urea fertilization increased plant height and fresh production (Didit et al., 2024) and plant growth-promoting rhizobacteria altered tiller number and leaf length (Yandri et al., 2024), suggesting that *Pennisetum* cultivars generally respond strongly to nutrient and biostimulant inputs. This study was therefore conducted to determine the effect of POC from rice-washing water and shallot skin on the plant height, leaf length, tiller number, and fresh yield of pakchong grass.

MATERIALS AND METHODS

Time and place

The experiment was carried out for six weeks (42 days) in Langgongsari Village, Cilongok District, Banyumas Regency, Central Java, Indonesia, a smallholder forage-production area comparable to other Banyumas grass trials reported in this journal (Riyanto et al., 2022). The site is a rainfed lowland field; initial soil properties (texture, pH, and available N, P, and K) and the rainfall and mean temperature recorded over the study period are summarized in Table 1 [values to be completed from field and laboratory records].

Table 1. Site and growing-period characteristics during the experiment [to be completed by the authors].

Parameter	Value / range
Soil texture	[e.g., sandy loam]
Soil pH (H_2O)	[value]
Available N / P / K	[values]
Total rainfall (42 days)	[mm]
Mean air temperature	[°C]

Note: Reporting baseline soil fertility and weather allows the growth response to be interpreted and the trial to be reproduced.

Fertilizer preparation and characterization

POC was prepared 21 days before application by fermenting rice-washing water and shallot-skin waste with EM4 and molasses as a starter culture, following the fermentation procedure recommended for rice-washing-water-based liquid fertilizer (Sulfianti et al., 2021). Before application, a subsample of the finished POC was analyzed for total nitrogen, phosphorus, and potassium, pH, and carbon-to-nitrogen (C:N) ratio (Table 2); the corresponding nutrient loading delivered by each dose is reported so that the treatments can be interpreted in agronomic terms and compared with inorganic-fertilizer studies.

Table 2. Nutrient composition of the liquid organic fertilizer (POC) used in this study [insert measured values].

Parameter	Unit	Value
Total nitrogen (N)	%	[measured]
Total phosphorus (P_2O_5)	%	[measured]
Total potassium (K_2O)	%	[measured]
pH	—	[measured]
C:N ratio	—	[measured]

Note: Laboratory characterization of the POC actually applied is required so that doses can be expressed as nutrient loadings (kg ha^{-1}) rather than volume alone.

Experimental design and data collection

Sixty pakchong stem cuttings, each with three nodes, were used as planting material. The experiment used a completely randomized design (CRD) with a single factor, comprising four POC-dose treatments and five replications, giving 20 experimental units of three cuttings each on 1 m^2 plots (Table 3); this design follows the same experimental logic used in other single-factor *Pennisetum purpureum* fertilization trials (Ressie et al., 2018; Riyanto et al., 2022). Each plot was the experimental unit (n = 5 per treatment); the three cuttings within a plot were measured and averaged as subsamples, so treatment means are based on independent plot values and not on individual plants. POC was diluted with water to a constant total volume of 2,000 mL m^{-2} and applied twice during the vegetative phase, in the first and second weeks after planting.

Plant height, leaf length, and tiller number were measured weekly for six weeks prior to defoliation, following the periodic measurement protocol commonly used for elephant-grass cultivars (Daryatmo et al., 2019; Qisthon et al., 2022); height was measured from the soil surface to the tip of the tallest leaf, and leaf length from the leaf base to the tip, using a measuring tape. Fresh yield was obtained by weighing the harvested biomass of each 1 m^2 plot with a digital scale at the single defoliation performed in the sixth week, and expressed on a per-hectare basis at the plot planting density of three clumps m^{-2} (Anggraini & Yulianto, 2023).

Table 3. Liquid organic fertilizer (POC) dose treatments applied to pakchong grass.

Treatment	POC dose	Water volume	Total volume
P0	0 mL	2,000 mL m^{-2}	2,000 mL m^{-2}
P1	200 mL	1,800 mL m^{-2}	2,000 mL m^{-2}
P2	400 mL	1,600 mL m^{-2}	2,000 mL m^{-2}
P3	600 mL	1,400 mL m^{-2}	2,000 mL m^{-2}

Note: Each treatment was replicated five times, giving 20 experimental units of three cuttings each.

Data analysis

Plant height, leaf length, and fresh yield were analyzed using analysis of variance (ANOVA) appropriate for a completely randomized design, following the model:

$$Yij = \mu + \tau i + \varepsilon ij$$

where Yij is the response of the i-th treatment in the j-th replication, μ is the general mean, τi is the effect of the i-th treatment, and εij is the experimental error. When treatment effects were significant ($P<0.05$), means were separated using the least significant difference (LSD) test, the same follow-up procedure applied in other completely randomized *Pennisetum purpureum* fertilization trials (Didit et al., 2024; Zuliansyah et al., 2023). Tiller counts were very low and near-zero across all treatments; they are therefore summarized descriptively and interpreted with caution rather than treated as a robust quantitative response, because count data of this magnitude do not meet the assumptions of parametric analysis of variance.

RESULTS AND DISCUSSION

Increasing the POC dose produced a consistent, significant improvement in the vegetative growth and fresh yield of pakchong grass. Plant height, leaf length, and fresh yield all rose with dose ($P<0.01$), whereas tiller number remained near zero and did not differ among treatments ($P>0.05$). The treatment means for all four traits are summarized in Table 4, the growth responses are shown in Figure 1, and the fresh-yield response is shown in Figure 2.

Table 4. Mean plant height, leaf length, tiller number, and fresh yield of pakchong grass at different POC doses.

Trait	P0 (0 mL)	P1 (200 mL)	P2 (400 mL)	P3 (600 mL)
Plant height (cm)	101.99^{a}	107.69^{b}	112.96^{c}	116.76^{d}
Leaf length (cm)	58.56^{a}	59.40^{ab}	60.73^{b}	64.02^{c}
Tiller number (per clump)	0.2	0	0.2	0.2
Fresh yield (ton ha^{-1})	7.2^{a}	7.5^{ab}	7.9^{b}	8.9^{c}

Note: Means within the same row followed by different superscripts differ significantly (plant height, $P<0.01$; leaf length and fresh yield, $P<0.05$). Tiller number showed no significant treatment effect ($P>0.05$). Superscript groupings should be confirmed against the final ANOVA/LSD output.

Plant height

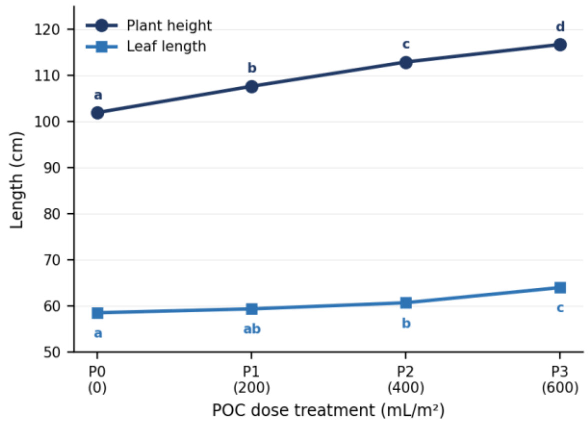

Figure 1. Plant height and leaf length of pakchong grass across POC doses (P0–P3). Means with different letters within a trait differ significantly (P<0.05).

Plant height increased consistently with increasing POC dose, from 101.99 cm at P0 to 116.76 cm at P3, a gain of 14.8 cm across the dose range. Analysis of variance showed a highly significant treatment effect ($P<0.01$), and the LSD test confirmed that all POC-treated groups differed significantly from the untreated control. The largest increment occurred between P0 and P1 (5.7 cm), while increments became progressively smaller at higher doses (5.3 cm for P1–P2 and 3.8 cm for P2–P3), suggesting a diminishing marginal response as nutrient supply approached the plant's uptake capacity during the vegetative stage. This pattern is consistent with the height response reported for pakchong grass fertilized with liquid organic fertilizer derived from biogas slurry, where growth was likewise greatest at the highest dose tested (Ramdhan et al., 2024), and mirrors the significant, dose-dependent increase in plant height obtained with urea fertilization of odot grass (*Pennisetum purpureum* cv. Mott), a closely related cultivar (Didit et al., 2024). The response is most plausibly attributed to the nitrogen and phosphorus supplied by rice-washing water, which support cell elongation and chlorophyll formation during the vegetative phase (Yulianto et al., 2022).

Leaf length

Leaf length followed the same increasing trend as plant height, rising from 58.56 cm at P0 to 64.02 cm at P3 ($P<0.05$). Unlike plant height, the largest increment in leaf length occurred at the highest dose interval, between P2 and P3 (3.3 cm), rather than at the lowest interval, indicating that leaf elongation continued to respond to additional nutrient supply even as height gains slowed. Leaf length is a key determinant of photosynthetic capacity, since longer leaves intercept more light and thereby support greater biomass accumulation. The improvement observed here is consistent with the biogas-slurry POC trial of Ramdhan et al. (2024), in which leaf elongation was likewise greatest at the highest fertilizer dose, and supports the role of the nitrogen and phosphorus supplied by rice-washing water in sustaining vegetative expansion (Yulianto et al., 2022). This significant response contrasts with the dwarf elephant grass trial of Yandri et al. (2024), in which biostimulant application via plant growth-promoting rhizobacteria did not significantly alter leaf length, suggesting that a direct nutrient input such as POC may be more effective than microbial inoculation alone for elongating *Pennisetum* leaves under smallholder field conditions.

Tiller number

Tiller number remained low and statistically indistinguishable across treatments ($P>0.05$), ranging from 0 to 0.2 tillers per clump. This near-absence of tillering is best explained by the defoliation regime rather than by nutrient supply: because the plants were cut only once, at the end of the study, the basal buds that normally give rise to new tillers were not stimulated to break dormancy. Tillering in pakchong and related elephant-grass cultivars is known to depend strongly on repeated cutting, which triggers new shoot emergence from the base of the clump in response to the removal of apical dominance (Sari et al., 2024). A similarly non-significant treatment effect on tiller number was reported for dwarf elephant grass supplemented with plant growth-promoting rhizobacteria (Yandri et al., 2024). The very low and near-zero counts obtained here mean that tiller number could not be evaluated as a robust quantitative response under the present single-defoliation protocol; this is a limitation of the design rather than evidence that the fertilizer was ineffective, and a multi-cut protocol would be required to express treatment differences in tiller production.

Fresh yield

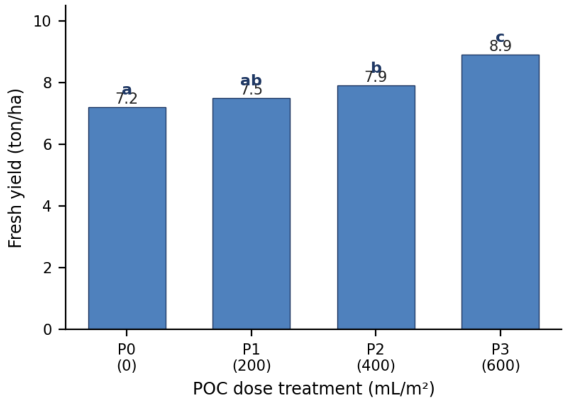

Figure 2. Fresh yield of pakchong grass across POC doses (P0–P3). Bars with different letters differ significantly (P<0.05).

Fresh yield increased significantly with POC dose ($P<0.05$), from 7.2 ton ha^{-1} at P0 to 8.9 ton ha^{-1} at P3, an increase of 1.7 ton ha^{-1}. In contrast to plant height, the yield gains were modest at the lower dose intervals (0.3 ton ha^{-1} for P0–P1 and 0.4 ton ha^{-1} for P1–P2) and largest at the highest interval, between P2 and P3 (1.0 ton ha^{-1}). Because fresh yield integrates the height, leaf area, and overall biomass accumulated by the plant, the yield response broadly mirrors the height and leaf-length results and indicates that POC application translated growth improvements into additional harvestable biomass, with the clearest benefit at the highest dose. A comparable dose-dependent increase in pakchong fresh yield was reported for nitrogen fertilization by Nohong et al. (2023), and the same pattern has been observed for agronomic inputs applied to related *Pennisetum purpureum* cultivars, where urea dose significantly increased the fresh production of odot grass (Didit et al., 2024) and wider plant spacing increased fresh weight per plot in the same cultivar under smallholder grazing-field conditions (Riyanto et al., 2022). The measured fresh yields reflect a single first cut over 42 days at a low planting density of three clumps m^{-2}; they should therefore be read as short-term establishment yields rather than as annual productivity, which for pakchong can reach 100–200 ton ha^{-1} yr^{-1} under multi-cut management.

Taken together, the results show that POC from rice-washing water and shallot-skin waste significantly improved the vegetative growth and first-cut fresh yield of pakchong grass, with the strongest response at 600 mL m^{-2}. Two caveats bound the interpretation. First, because the nutrient concentration of the POC was not established in this study, the doses cannot yet be expressed as nutrient loadings, and the growth response cannot be partitioned between the nitrogen, phosphorus, and potassium of rice-washing water and any contribution from shallot-skin compounds; the biopesticidal role of shallot-skin flavonoids and acetogenin against armyworm is plausible but was not measured here and remains a hypothesis for future work. Second, the absence of an inorganic-fertilizer treatment means the study demonstrates a benefit over an unfertilized control rather than equivalence with a recommended inorganic rate, so claims of substitution should remain provisional until such a comparison is made.

CONCLUSIONS

Application of liquid organic fertilizer (POC) from rice-washing water and shallot-skin waste significantly increased the plant height, leaf length, and fresh yield of pakchong grass, with the greatest response obtained at the highest dose tested, 600 mL m^{-2} (P3). Tiller number was not significantly affected, most likely because only a single defoliation was applied during the 42-day growing period, and this trait could not be evaluated reliably under the present design. POC formulated from these two low-cost household waste streams is therefore a promising organic input for improving the early growth and fresh yield of pakchong grass. To establish it as a practical substitute for inorganic fertilizer, further studies should characterize the nutrient content of the POC and express doses as nutrient loadings, include a recommended inorganic-fertilizer control, test higher POC doses, and apply repeated defoliation cycles to determine whether tillering and multi-cut yield respond under more intensive management.

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