Research Article

The Effectiveness of Cattle Manure-Based Fertilizers Mixed with Different level of Urea on The Growth of *Pennisetum purpureum*

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Abstract | The utilization of the cattle's manure as organic fertilizer represents a key strategy for achieving a sustainable zero waste farming system. This study investigated the effectiveness of organic fertilizers derived from beef cattle manure on the growth of elephant grass (*Pennisetum purpureum*) when combined with different level of urea. A completely randomized design with four treatments (three replications per treatment) was applied. Treatments included: P0 = no fertilizer (control); P1= 100% organic fertilizer; P2= 75% organic fertilizer + 25% urea; P3 = 50% organic fertilizer + 50% urea; P4 = 100% urea. The parameters were plant height (cm), number of tillers, fresh weight (g), leaf width (cm), and leaf-to-stem ratio (%). Results indicated that the treatments significantly ($p<0.05$) affected plant height, with the highest growth observed in the 75% organic fertilizer + 25% urea treatment (P2), reaching 127 cm, which was 19.94% higher than the control. Treatment P2 also significantly increased the number of tillers to 5 and produced a significantly greater leaf width of 2.60 cm. In conclusion, the application of 75% cattle manure-based fertilizer combined with 25% urea effectively enhanced the growth performance of *Pennisetum purpureum*. These findings suggest that integrating cattle manure-based fertilizer and urea at the appropriate ratio may improve forage productivity while supporting sustainable, zero-waste farming practices.

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Introduction

Sustainable agricultural development mainly depends on maintaining soil fertility and optimizing crop productivity through the careful use of fertilizers.

In tropical regions, forage crops play a critical role in supporting ruminant livestock production by providing a continuous source of high-quality feed. *Pennisetum purpureum* commonly known as Elephant grass, is widely cultivated due to its rapid growth, high biomass yield, and nutritional value for cattle (Roni *et al*., 2025). Its ability to produce large quantities of dry matter makes it an essential forage in integrated crop-livestock systems, particularly in smallholder farms in developing country like Indonesia where efficient feed resources are crucial to maintaining livestock productivity. The growth and yield of *P. purpureum* are largely dependent on nutrient availability, particularly nitrogen, which is a key component of proteins and chlorophyll necessary for photosynthesis and biomass accumulation (Hidayat *et al*., 2023). Cattle manure not only provides nitrogen, phosphorus, and potassium but also contributes to long-term soil health by increasing organic matter content and stimulating beneficial microbial populations. Studies have shown that the application of manure improves soil physical properties, enhances nutrient cycling, and reduces the need for excessive chemical fertilizers, aligning with sustainable and environmentally friendly farming practices (Kurniawan *et al*., 2025; Roni *et al*., 2025).

However, the nutrient content of manure alone may be insufficient to meet the rapid nutrient demands of high-yielding forage species like *P. purpureum*. Nitrogen availability from manure is often limited due to its slow mineralization rate, which can restrict plant growth during critical stages of development (Walie *et al*., 2022). To overcome this limitation, supplementation with inorganic nitrogen fertilizers, such as urea, is necessary. Urea is a highly concentrated source of nitrogen that can rapidly supply plants with the nutrients required for optimal growth. However, the optimal combination of cattle manure and urea for maximizing the growth of *P. purpureum* under local tropical conditions remains unclear. Variability in manure quality, soil characteristics, and environmental conditions can influence nutrient availability and plant response, making site-specific evaluation essential. In smallholder farming systems, where resources are limited, understanding the synergistic effects of organic-inorganic fertilizer combinations is particularly important to optimize feed production while minimizing input costs (Ikyume *et al*., 2025). Furthermore, evaluating the effectiveness of different manure-urea ratios can provide practical insights for farmers, enabling them to balance productivity goals with sustainable soil management practices.

Therefore, this study aimed to investigate the effectiveness of cattle manure-based fertilizers mixed with different levels of urea on the growth performance of *P. purpureum*. Specifically, the study evaluates how varying combinations of organic and inorganic nitrogen sources influence plant height and overall forage quality. The findings of this research are expected to provide evidence-based recommendations for optimal fertilizer management in smallholder farms, enhancing forage production, promoting sustainable soil use, and supporting integrated crop-livestock farming systems in tropical regions. By bridging the gap between organic and inorganic nutrient management strategies, this study contributes to the broader goal of sustainable agriculture.

Materials and Methods

The materials used in this study were: bucket (5L sized), spatula, scissors, gloves, shovel, filter, knife, measuring tape, portable digital scale TPE-15 maximum capacity 15kg; water, EM4 (Effective microorganisms 4) (1L), label, molasses (1L), sun-dried cattle feces, middle sized-polybags, cuttings of *Pennisetum purpureum*, rice husks and soil.

Location and study design

This research was conducted from January-April 2025 located in the district of Tanete Riaja, Lempang village, on 119.649071 LS/LU. -4.486865 BT/BB, Barru regency, Province of South Sulawesi, Indonesia. This study was designed using Complete Randomized Design with four treatments and three repetitions for every treatment. The treatments are as follows:

P0 = Control (without fertilizer)
P1 = 100% organic fertilizer
P2 = 75% organic fertilizer + 25% urea
P3 = 50% organic fertilizer + 50% urea
P4 = 100% urea

Organic content analysis

50 g of the organic fertilizer was sampled and stored in the sealed bags then transported to the Laboratory of Biochemistry of Faculty of Animal Science, Hasanuddin University for the organic content analysis: C-organic content, Nitrogen content, Phosphor content and Potassium content.

Based on Table 1, we chose the fermentation time for 28 days for the organic fertilizer before applied it. The parameters of this study:

The height of the plant, which was measured from the base of the stem up to the tip of the leaves after 60 days of planting.

Table 1: *The percentage of C-organic, nitrogen, phosphor pentoxide, potassium oxide from organic fertilizer on the basis of cattle-manure under the different fermentation time.*

Fermentation time	C-organik (%)	N (%)	P_2O_5 (%)	K_2O (%)	C/N ratio
0 day	15.5 ±0.20	0.85 ±0.07	0.40 ±0.03	0.55 ±0.08	18
7 day	18.81 ±0.50^{b}	0.97±0.02	0.72±0.08^{b}	0.63±0.12^{a}	19
14 day	19.10 ± 0.42^{b}	0.96 ±0.01	0.81±0.01^{a}	0.43±0.01^{b}	20
21 day	19.97 ± 0.20^{a}	0.98 ±0.01	0.85±0.05^{a}	0.49±0.05^{b}	20
28 day	19.21±0.38^{a}	0.98 ±0.05	0.77±0.10^{ab}	0.48±0.11^{ab}	20

Note: P0 = 0 day, P1= 7 day, P1=14 day, P2=21 day, P3=28 day. MOL-BS= Local microorganisms isolated from banana stem. Different superscript letters within the same column indicate significant differences.

The number of the tillers of *Pennisetum purpureum*, which was calculated manually at the end of the study (after 60 days). The tillers that already have the fully grown leaves.

- Fresh weigh of *Pennisetum purpureum*
- The leaves width
- The leave-to-stem ratio
- All the measurements were recorded on day 60.

Methods

The organic fertilizer used in this study was prepared using a controlled aerobic composting method. The detailed steps were as follows:

Dried cattle manure was collected directly from the barn; The dried manure was thoroughly mixed with Effective Microorganisms-4 (EM4) and molasses; To correct the naturally low pH of cattle manure, which typically ranges from 4.0 to 4.5, rice husks were added to the mixture; The entire mixture was homogenized and then covered with a tarpaulin. On the third day, the compost was manually turned to ensure proper aeration and maintain high oxygen levels, which are critical for aerobic microbial activity. Turning was performed periodically over a span of 28 days. After compost maturation, the material was sieved to achieve a uniform granule size. The resulting compost was then applied as an organic fertilizer to elephant grass (*Pennisetum purpureum*) for further evaluation.

Selection of seedlings

The seedlings were prepared in the form of the cuttings of *Pennisetum purpureum*. The stems that were approximately 2 months old, with 2–3 nodes were selected. Next, the cuttings of *Pennisetum purpureum* from the larger stem sections with short internodes, ensuring a minimum of 2 nodes or 3 segments.

Planting method

Planting was carried out after the soil and fertilizer are mixed thoroughly, then was placed into the labelled polybags containing 5 kg of soil. Each polybag was filled with one cutting of elephant grass (*Pennisetum purpureum*) with a stem length of 25 cm. The base of the cutting was sliced diagonally and sideways to prevent the cutting from being planted upside down. The prepared cuttings were first adjusted to have the same height then were planted into the polybags.

Statistical analysis

The data was analyzed using analysis of variance (ANOVA) model. If the treatment was significantly affected the measured variables, the statistical analysis would then be continued to the Least Significant Difference test. The statistical model is as follows:

$$Y_{ij} = \mu + \alpha_i + \varepsilon_{ij}$$

Results

The result of the measurements of the organic fertilizer application on *Pennisetum purpureum* with different level of mixture with urea in Table 2.

The application of organic fertilizer had a significant effect ($p<0.05$) on the height of elephant grass (*Pennisetum purpureum*). The LSD test revealed that the combination of 75% organic fertilizer with 25% urea (P2) produced the greatest plant height, reaching 127 cm. This value was 12.86% higher than that observed in plants treated with 100% organic fertilizer derived from cattle manure (P1), and 13.64% higher than those receiving a 50:50 mixture of organic fertilizer and urea (P3).

Fertilizer treatments also influenced the number of tillers ($p<0.05$). The combination treatment P2 consistently resulted in more tillers than other treatments, indicating that moderate supplementation with urea enhanced tillers production. However, when the proportion of urea was increased beyond 25%, the number of tillers tended to reduce.

Table 2: *The average of plant height, the number of pops, the wet weigh, the leaves width and the ratio of leaves and stems with different mixture level of urea.*

Parameters	Treatments				
	P0	**P1**	**P2**	**P3**	**P4**
Plant height (cm)	101.67 ± 5.13^{b}	110.67 ± 6.43^{b}	127.0 ± 2.0^{a}	109.67 ± 5.51^{b}	112.67 ± 8.51^{b}
The number of pops	2.0 ± 5.0^{c}	4.0 ± 1.0^{ab}	5.0 ± 5.77^{a}	4.0 ± 1.0^{b}	3.0 ± 5.0^{ab}
The wet weigh (gr)	61.33 ± 8.09^{b}	130.0 ± 51.89^{a}	158.0 ± 22.87^{a}	113.67 ± 24.42^{a}	141.33±12.90^{a}
The leaves width (cm)	1.47 ± 2.31^{b}	1.60 ± 1.0^{b}	2.60 ± 3.46^{a}	1.63 ± 1.53^{b}	1.60 ± 1.73^{b}
Leave-to-stem ratio (%)	35.11 ± 64.89	21.62 ± 78.38	36.49 ± 63.51	23.75 ± 76.25	25.75 ± 74.25

Note: P0= control (no fertilizer); P1=100% organic fertilizer; P2=75% organic fertilizer + 25% urea; P3=50% organic fertilizer and 50% urea; P4=100% urea. Different superscript letters within the different column indicate significant differences.

Fresh weight of plants varied across treatments, showing a fluctuating pattern. While all fertilized plants performed significantly better (p<0.05) than unfertilized controls, treatment P3 (50% organic fertilizer + 50% urea) resulted in a 12.56% reduction in fresh weight compared with P1. Conversely, the application of 100% urea fertilizer (P4) increased fresh weight by 8.01% compared with 100% organic fertilizer (P1).

Leaf width responded very positively to fertilizer application. Treatment P2 produced a highly significant effect (p<0.05), with leaves that were on average 38.46% wider than those in other treatments. The greatest increase in leaf width was recorded during the third and fourth weeks, with an average expansion of 3–5 cm per week.

Although fertilizer treatments did not significantly affect the leaf-to-stem ratio, there was a tendency for this ratio to increase under the P2 treatment, suggesting improved forage quality when 75% organic fertilizer was combined with 25% urea.

Discussion

Plant height

The best initial growth was observed during the first week, with an average height of 20 cm. In subsequent weeks, the average weekly growth across treatments was approximately 10 cm. This growth pattern is attributable to the balanced application of organic fertilizer combined with urea, which improved soil and plant conditions, thereby enhancing the growth rate of elephant grass. This finding supports the statement of Yeasmin *et al.* (2024), who emphasized that macronutrients such as nitrogen, phosphorus, potassium, calcium, and magnesium are essential for the growth of vegetative plant parts, including roots, stems, and leaves. When both macro- and micronutrient availability is sufficient, plant growth can be significantly improved (Yeasmin *et al.*, 2024).

Post-hoc analysis revealed that P1 was significantly different from P2 (p<0.05) but not significantly different from P3 and P4. This may be attributed to the fact that the 75% organic fertilizer treatment contained 18.25% organic carbon, while the addition of 25% urea contributed to balancing soil pH. Moreover, the 75%:25% ratio of organic fertilizer to urea promoted favourable microbial activity, which further supported the growth of elephant grass. The presence of a comprehensive nutrient profile in organic fertilizer combined with the nitrogen supplied by urea enhanced both plant growth and productivity. Gustiar *et al.* (2020) highlighted that the application of either organic or inorganic fertilizers influences the availability of essential macronutrients such as nitrogen, phosphorus, potassium, calcium, and magnesium in plants. Therefore, the application of fertilizers, when the type, dosage, and technique are appropriately managed, can substantially increase nutrient supply and promote more effective fertilization (Gustiar *et al.*, 2020). Optimal soil management, fertilization, and plant care practices ultimately enhance the productivity of elephant grass.

Conversely, plants that were not treated with manure-based fertilizers showed signs of nutrient deficiency, resulting in suboptimal growth. Rahmawati *et al.* (2020) further emphasized that fertilizer application is crucial for replenishing the essential nutrients required by plants to improve yield and quality (Rahmawati *et al.*, 2020).

The number of tillers

The analysis of variance (ANOVA) demonstrated that the application of organic fertilizer, as well as its combination with urea, tended to produce a greater number of tillers under the treatment combining 75% organic fertilizer and 25% urea (P2). When the proportion of urea was increased, the data revealed a reduction in the number of pops. The highest average number of pops was observed in the fifth week, with two pops per plant. This result is presumably due to the excessive application of urea, which led to soil acidification and consequently inhibited the growth of *Pennisetum purpureum*, thereby reducing the production of pops. This finding is consistent with Asadu *et al.* (2024), who reported that excessive application of urea fertilizer results in soil acidification, which over time degrades soil fertility (Asadu *et al.*, 2024). Acidic soils obstruct nutrient absorption, leading to growth suppression in plants.

The superior performance of the 75% organic fertilizer and 25% urea treatment (P2) is likely attributable to enhanced photosynthetic activity under this condition. Solar radiation influences leaf development, which in turn affects tiller initiation. The number of tillers in plants can vary widely depending on plant species, environmental conditions such as photosynthesis, temperature, humidity, and soil structure, as well as agronomic practices such as weeding (Nguyen *et al.*, 2021). Weeding was carried out manually by removing weeds surrounding the plants, thereby minimizing competition for water and nutrients.

At the ratio of 25% urea to 75% manure, the production of tillers tended to be maximized due to the synchronization of nitrogen (N) availability with the physiological requirements of the initiation and elongation phases of the tiller's development, alongside improvements in the chemical, physical, and biological properties of the soil by organic matter. At this proportion, the urea fraction supplies rapidly available N to stimulate early tiller's initiation, while the dominance of manure provides slow-release Nitrogen and supplementary nutrients (Phosphorus, Potassium, Sulphur, and micronutrients), while simultaneously improving cation exchange capacity (CEC), aggregate stability, water retention, and the activity of decomposer microbes. This stable rhizosphere environment mitigates localized pH spikes around urea granules during hydrolysis, thereby reducing risks of NH_3/biuret toxicity, osmotic stress, and root hair damage. Improved uptake of Nitrogen and Potassium enhances cytokinin biosynthesis in the roots, which is known to increase the tiller's survival (Gonçalves *et al.*, 2024).

Conversely, when the proportion of urea is raised beyond this optimal point, nitrogen supply becomes too rapid and unsynchronized with carbon and other supporting nutrients. This leads to localized accumulation of NH_4^+/NH_3, increased nitrogen volatilization and leaching, a decline in the soil C/N ratio, inhibition of phosphorus mineralization, excessive canopy growth, and self-shading, which ultimately raises the tiller's mortality. Therefore, the composition of 25% urea and 75% manure provides the most balanced nutrient supply and the most favourable soil quality for both the initiation and sustainability of the tiller's production.

The fresh weight

The analysis of variance revealed that the application of organic fertilizer, either alone or in combination with urea, tended to cause fluctuations in the fresh biomass of elephant grass (*Pennisetum purpureum*). When organic fertilizer and urea were applied at equal proportions (50% each, P3), fresh weight decreased by 12.56% compared with P1 (100% organic fertilizer). Conversely, under the P4 treatment (100% urea), fresh biomass was 8.01% higher than in P1. This is attributable to the high nitrogen content of urea (45–46%), which promotes an increase in both the number and size of cells as well as a higher water content, thereby accelerating the growth and development of elephant grass and resulting in optimal fresh weight (Nguyen *et al.*, 2021).

The nitrogen content of urea is crucial for the growth of elephant grass. Urea is synthesized through the reaction between ammonia and carbon dioxide in a process that yields a highly water-soluble compound. As noted by Hartono *et al.* (2021), urea dissolves readily in soil water, making nitrogen immediately available for plant uptake. Various strategies have been developed to reduce the solubility of urea, one of which involves modifying urea with formaldehyde to produce longer polymer chains. The resulting urea–formaldehyde compounds may either consist entirely of modified urea or serve as coatings for conventional urea granules. Such coatings influence the dissolution pattern and nitrogen release dynamics (Hartono *et al.*, 2021). Moreover, the solubility and release rate of urea are strongly affected by external environmental conditions at the site of fertilizer application.

The decline in fresh biomass observed in P3 (50% organic + 50% urea) compared to P1 (100% organic) is primarily associated with asynchronous nutrient supply and nitrogen dynamics in the soil. In P3, urea rapidly releases mineral nitrogen, while the reduced proportion of organic material diminishes improvements to soil chemical properties as well as the gradual supply of Phosphorus, Potassium, and micronutrients. This imbalance increases the likelihood of nitrogen immobilization by microbes decomposing the remaining organic carbon, thereby reducing nitrogen use efficiency (NUE) during early growth stages and constraining fresh biomass accumulation (Aleme *et al*., 2024). Furthermore, urea hydrolysis in soils with diminished organic buffering capacity can create microsites enriched in NH_3/NH_4^+, producing local osmotic stress that negatively affects root hairs, suppresses water uptake, and delays tissue expansion.

By contrast, the increase in fresh biomass in P4 (100% urea) relative to P1 suggests that the immediate and abundant nitrogen supply enhances vegetative growth, leaf expansion, chlorophyll concentration, and cellular osmotic potential. These physiological improvements attract greater water influx into plant tissues, thereby accelerating fresh weight accumulation more effectively than in systems relying on gradual nutrient release (Chaedir *et al*., 2022). In summary, the P3 treatment suffered fresh biomass penalties due to nutrient imbalance and reduced soil quality benefits compared with 100% organic fertilization, while 100% urea (P4) promoted a surge in nitrogen-driven vegetative growth, which was directly reflected in fresh biomass metrics.

The leaves width

The analysis of variance indicated that the combination of 75% organic fertilizer and 25% urea (P2) had a highly significant effect (p<0.05) on the leaf width of elephant grass (*Pennisetum purpureum*). The highest mean leaf width was observed in P2, showing an increase of 38.46%. The best average leaf expansion occurred during the third and fourth weeks, with a weekly increase of 3–5 cm. This effect is likely due to the advantages provided by the 75% organic fertilizer, which not only supplies essential nutrients but also increases the soil's organic matter content. This enhances soil biological metabolism and microbial activity, facilitating decomposition processes. Furthermore, the plant roots gained additional nitrogen from urea, contributing to improved growth.

Follow-up testing revealed that P1 differed significantly from P2 (p<0.05), but did not differ significantly from P3 and P4. This outcome reflects the plant's tolerance threshold to excess urea. Excessive urea application acidifies the soil, eventually reducing fertility and hindering nutrient uptake, which in turn restricts leaf expansion. This is consistent with previous findings that excessive urea application decreases tiller production due to soil acidification. Additional factors influencing leaf width include the availability of light and water. Among environmental factors such as rainfall, temperature, and humidity, water availability is crucial since nearly all physiological processes nutrient absorption, photosynthesis, respiration, carbohydrate synthesis, and translocation depend on sufficient water supply. Sunlight availability is also a critical determinant of growth performance.

The combination of organic fertilizer and urea enhances leaf width in *Pennisetum purpureum* through synergistic effects on nutrient supply and physiological conditions. The application of synthetic fertilizers such as urea together with organic amendments significantly improved vegetative growth parameters, including leaf width, due to the rapid uptake of nitrogen from urea for protein and chlorophyll synthesis, while organic fertilizers enhanced soil structure, water retention, and micronutrient supply (Rahmawati *et al*., 2020). Similarly, Etu *et al*. (2024) demonstrated that combining urea with organic fertilizer significantly increased the leaf width of Telfaria occidentalis, which was associated with improved total nitrogen availability and photosynthetic activity (Etu *et al*., 2024). Moreover, Zhang *et al*. (2025) found that the combined use of organic fertilizer and urea in flue-cured tobacco enhanced maximum leaf area due to joint effects on leaf thickness, nitrogen concentration, and photosynthetic efficiency (Zhang *et al*., 2025). These mechanisms align with the principle that balanced macro- and micronutrient availability, coupled with improvements in soil physicochemical properties, maximizes cell division and enlargement in leaves, ultimately resulting in wider foliage.

Leave to stem ratio

The results of the analysis showed that fertilizer treatments did not significantly affect the leaf-to-stem ratio of Pennisetum purpureum. Nevertheless, a tendency for higher values was observed in the treatment with 75% organic fertilizer and 25% urea (P2). The leaf-to-stem ratio in P2 reached 36.49:63.51%, suggesting that this treatment provided a more balanced and sustainable nutrient supply. Under such conditions, plants tended to allocate a larger proportion of photosynthates toward leaf development rather than stem elongation.

The increased leaf proportion under P2 is explained by the complementary roles of organic and inorganic fertilizers. Urea supplied readily available nitrogen that promoted rapid leaf tissue development and chlorophyll formation during the early growth stage. In parallel, organic fertilizer contributed to the gradual release of nitrogen, improved soil structure, maintained moisture, and enhanced the availability of key micronutrients such as magnesium and iron that are essential for photosynthesis. This stable and continuous nutrient supply allowed for broader leaf development with higher chlorophyll content, thereby increasing photosynthetic efficiency and biomass accumulation in leaves.

The present findings align with Bello and Olaniyi (2024), who demonstrated that integrating organic fertilizer with urea enhanced leaf area and the leaf-to-stem ratio in vegetable crops (Bello and Olaniyi, 2024). Similarly, Pei *et al.* (2025) reported that such combinations increased maximum leaf area and leaf nitrogen content in tobacco, which translated into higher leaf-to-stem ratios (Pei *et al.*, 2025). Furthermore, Gumbeze *et al.* (2024) highlighted that the synergy between organic and inorganic fertilizers not only satisfied nutrient requirements but also improved root-zone conditions, resulting in enhanced vegetative growth.

In contrast, the inhibition of leaf-to-stem ratio is often associated with excessive urea application (Gumbeze *et al.*, 2024). The relatively higher ratio observed in P2 is likely also influenced by environmental conditions, particularly light intensity. Sunlight plays a decisive role in leaf development since leaves act as the primary photosynthetic organs. A greater number of wider leaves facilitates higher photosynthetic capacity, which in turn improves growth quality (Zulkifli *et al.*, 2022). However, precise fertilizer application is essential to prevent toxic effects of over-fertilization that may impair metabolism and reduce leaf formation. From a livestock-feeding perspective, the higher leaf-to-stem ratio observed in P2 has direct implications for forage quality. Leaves generally contain higher crude protein concentrations, lower fiber fractions, and greater digestibility compared to stems. A higher proportion of leaves therefore enhances the nutritive value of elephant grass, improving both its palatability and voluntary intake by ruminants. Consequently, maintaining a balanced nutrient supply through integrated fertilization strategies not only supports agronomic performance but also contributes to better animal productivity by providing a more nutritious feed base.

Overall, the combined application of 75% organic fertilizer and 25% urea provided a dual benefit: an immediate nitrogen supply from urea and a slow-release source from organic matter. This combination also enhanced soil physical, chemical, and biological properties, thereby supporting optimal leaf development. The higher leaf-to-stem ratio achieved under P2 indicates that balanced fertilizer management may improve both forage yield and nutritional quality, thereby strengthening the sustainability of integrated crop-livestock systems.

Conclusions

The integrated application of 75% cattle manure-based organic fertilizer and 25% urea (P2) significantly enhanced the growth and productivity of elephant grass (*Pennisetum purpureum*), outperforming other fertilizer treatments. P2 consistently promoted greater plant height, tiller number, fresh biomass, leaf width, and a higher leaf-to-stem ratio, reflecting balanced nutrient availability, improved soil properties, and optimal rhizosphere conditions. Excessive urea or imbalanced fertilizer ratios negatively affected growth by causing nutrient asynchrony, soil acidification, and reduced tiller survival. The higher leaf proportion under P2 also implies improved forage quality, with greater protein content, digestibility, and palatability for ruminants. Overall, the 75% organic-25% urea combination offers a sustainable and effective strategy to maximize both agronomic performance and nutritive value, supporting integrated crop-livestock systems.

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Novelty Statement

This study provides new insights into the optimal integration of cattle manure-based organic fertilizer with urea for improving the growth of *Pennisetum purpureum*. Unlike previous research that primarily emphasized either organic or inorganic fertilization alone, our findings demonstrate that a 75% organic fertilizer and 25% urea combination not only maximizes plant height and leaf development but also contributes to a sustainable zero-waste farming system. This highlights a novel strategy for enhancing forage productivity while reducing reliance on the synthetic fertilizers through a balanced organic–inorganic fertilization approach.

Author's Contribution

AH: Conducted the research and wrote the original draft of the manuscript. A: Supported in performing the experiment and contributed in drafting the manuscript. Q: Analysed the data and assisted in the experiment. MBP: Supervised the research and supported in reviewing the manuscript. SS: Supported in data collection and contributed in the experiment. S: Facilitated in the field work and data collection.

Generative AI and AI-assisted technology statement
We declare that no Generative AI was used in the creation of this manuscript.

Conflict of interest
The authors have declared no conflict of interest.

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