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Research Article

Efficacy of rabbit urine concentrations as fertilizer on herbage yield and nutritive value of Congo grass (*Brachiaria ruziziensis*)

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Abstract

This study evaluated the efficacy of rabbit urine as a fertilizer on the herbage yield, morphological traits and nutritive value of Congo grass (*Brachiaria ruziziensis*). Rabbit urine was collected and diluted with water at ratios of 1:2.5, 1:5 and 1:7.5. They were applied foliarly on *Brachiaria ruziziensis* plots at 0, 714, 834 and 867 mL/l, arranged in a randomized complete block design with four replicates per treatment. The chemical compositions of urine and Congo grass samples were determined, and agronomic and herbage yield parameters were estimated. The 834 and 867 mL/l had significantly higher ($p < 0.05$) nitrogen, phosphorus, potassium,calcium and magnesium contents than the 714 mL/l. Congo grasses treated with urine concentrations had significantly higher values ($p < 0.05$) for the most agronomic parameters than 0 mL/l. The fresh matter yield and dry matter yield of 867 mL/l were significantly ($p < 0.05$) higher than those of the other treatments. The 867 mL/l (9.78) had significantly highest ($p < 0.05$) crude protein, 0 mL/l (8.05), 714 mL/l (7.18) and 834 mL/l (6.36). The values of crude fibre were significantly higher ($p < 0.05$) in 0 mL/l (34.02) and 834 mL/l (33.96) concentrations than 714 mL/l (31.14) and 867 mL/l (30.15). The metabolisable energy was significantly highest ($p < 0.05$) in 867 mL/l than in 714 and 0 mL/l while 714 mL/l was the least. It could be concluded that rabbit urine at 867 mL/l concentration had better nutrient content which led to improved herbage and agronomic yields as well as crude protein and metabolizable energy contents but lower fibre fractions.

1. Introduction

In recent years, the use of urine as an organic fertilizer has gained increasing attention due to its high content of essential plant nutrients, particularly nitrogen, phosphorus, and potassium, as well as its capacity to support plant growth when properly managed [1]. Its effectiveness in promoting crop growth makes it a viable option [2] as an organic fertilizer for crop production. Rabbit urine is a rich source of nutrients, such as nitrogen and phosphorus, which are essential for plant growth [3]. Fertilization using rabbit urine has been reported to improve soil fertility and increases crop yield [4]. In addition to an organic fertilizer, it is cost-effective and environmentally friendly. Therefore, rabbit urine possesses qualities that promote improved yield and environmental safety.

Brachiaria ruziziensis (Congo grass) is an excellent source of fodder for animals with decent palatability [5]. It exhibits outstanding productive features such as excellent acceptance, effective quick response to fertilization, great fodder quality and feeding value [6], quick establishment, swift growth at the inception of the rainy season, ability to work well in a consortium with legumes, dense flowering, and enormous seed yield [7]. However, despite these noteworthy traits, factors such as poor soil fertility and defective fertilization practices affect the herbage yield and nutritive value of the grass. Meanwhile, the majority of studies on pasture organic fertilization have concentrated primarily on manure from poultry and livestock and limited attention has been paid to microlivestock (rabbit urine) as a potential fertilizer source for pasture crops. Therefore, this study evaluated the efficacy of rabbit urine concentrations as a fertilizer on the herbage yield and nutritive value of Congo grass (*Brachiaria ruziziensis*).

2. Materials and methods

2.1. Experimental location

The research was conducted at the pasture plot of the Department of Animal Science Teaching and Research Farm, College of Agriculture, Ejigbo, Osun State University, Osun State. Nigeria. The experimental site lies within the Derived Guinea Savanna ecological zone of Nigeria with an average annual rainfall of 1330 mm, which covers 6 months of the year and spans April to October. The temperature ranges from 18.88 °C to 33.88 °C and it rarely falls below 15 °C or above 37.22 °C. It has an average elevation of 426 m and latitude of 7.9045 ^{0}N and 4.3025 ^{0}E [8].

2.2. Experimental layout, design and treatment

Existing pasture fields of Congo grass (*Brachiaria ruziziensis)* were used for the experiment. The plots were cut back to a uniform height of 10 cm with the aid of a hand mower. The experiment was laid out in a randomized complete block design with four treatments, replicated four times, resulting in a total of sixteen (16) plots. Each plot measured 8 m × 5 m, with an inter-plot spacing of 1.0 m. Rabbit urine was collected from the rabbit unit of the College of Agricultural Production Teaching and Research Farm, Osun State University and diluted with pipe-borne water in ratios of 1:2.5, 1:5 and 1:7.5. These fertilizer concentrations were applied immediately by foliar application on *Brachiaria ruziziensis* plots; 0, 714, 834 and 867 mL/l.

The concentration of urine in each water-urine mixture was estimated by the following formula as of Harris [9]:

$$\text{Solute volume} = \frac{\text{final volume}}{\text{ratio of urine} + \text{ratio of water}}$$

2.3. Determination of nutrient contents of urine concentrations

The samples of the different urine concentrations used in this study were analysed for nitrogen, phosphorus, potassium, calcium, magnesium, sodium, pH and electrical conductivity according to the standard procedure [10].

2.4. Measurement of agronomic parameters

At ten weeks of age the morphological parameters estimated included plant height, root length, leaf length, leaf width, number of leaves, number of tillers and leaf-stem ratio [11]. Three Congo grass plants were randomly selected from each plot, and the height was measured from the lowest point of the stem up to the apex of the tallest leaf of the grass using a tape rule. Subsequently, the average height was estimated and recorded. Root length was measured using a tape rule from the base of the stem to the tip of the longest root. This was determined by counting the number of tillers of three randomly selected Congo grass plants from each plot. Then, the mean number of tillers was determined and recorded as the number of tillers. Leaf number was determined by counting the number of leaves on three randomly selected plants from each plot. The mean number of leaves per plant was then determined. Three leaves were randomly selected from each plant was carried out. Each leaf was measured from the base of the collar region to the apex of the leaf using a tape rule, by the reported procedure [12]. The leaves and stems of the three sampled plants were separated differently and each part was measured separately using a weighing balance. The ratio of the mass of the leaf to stem was then determined and recorded.

2.5. Determination of herbage yield

The biomass yield was estimated by random tossing of a wooden quadrat measuring 0.5 m^2 [13]. The grass that fell within the quadrat was harvested completely using a sharp matchet, and it was repeated three times on each plot. The herbage was collected, packed into a sack, and measured using a weighing scale. The

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Table 1. The chemical composition of urine concentrations.

Parameters	714 mL/l	834 mL/l	867 mL/l	SEM	P Value
Nitrogen	5.88^b	7.07^a	7.43^a	0.0212	0.28
Phosphorus	0.61^b	0.72^a	0,77a	0.0017	0.02
Potassium	2.77^b	3.29^a	3.42^a	0.0231	0.12
Calcium	0.71^b	0.80^a	0.85^a	0.0008	0.02
Magnessium	0.34^b	0.41^a	0.41^a	0.0206	0.01
Sodium	1.42^c	1.63^b	1.72^a	<0.0001	0.04
pH	7.57^b	7.67^b	8.03^a	0.0328	0.09
Electrical conductivity	12.43^c	14.47^b	15.33^a	0.0002	0.45

weight of each cut was recorded and the average weight was estimated. The results were then interpolated in tons per hectare. The estimated parameters included fresh matter or biomass yield and dry matter yield.

2.6. Determination of dry matter yield

This was achieved by oven-drying 100 g samples from each plot at 65°C for 72 h. The percentage weight loss after drying was then calculated. The product of the percentage weight loss and the fresh sample resulted in the dry matter yield. The results of the dry yield were expressed in tonnes/ha.

2.7. Chemical analysis

The chemical composition of the Congo grass samples from each treatment was analysed using the reported technique [14] technique. The dry matter, crude protein, crude fibre, ether extract, organic matter, and nitrogen-free extract of the stored samples were estimated. The fibre fractions determined were neutral detergent fibre, acid detergent fibre, and acid detergent lignin and were determined in accordance with previous method [15]. Other constituents of fibre, cellulose and hemicellulose were determined using the earlier procedure [16]. Cellulose was estimated by deducting the values of acid detergent lignin from those of acid detergent fibre, and hemicellulose was calculated as the difference between neutral detergent fibre and acid detergent fibres.

2.8. Statistical analysis

Data collected were subjected to two-way analysis of variance (ANOVA) using [17] package and significant means were separated using Duncan's Multiple Range Test at 5% significance level.

3. Results and discussion

3.1. The chemical composition of urine concentrations

There were significant differences in the chemical composition of the urine concentrations used in this study (Table 1). The 834 and 867 mL/l urine concentrations had significantly higher ($p < 0.05$) nitrogen, phosphorus, potassium,calcium and magnesium than the 714 mL/l urine, indicating that a higher dilution rate enhanced nutrient availability, likely driven by improved solubility and reduced precipitation rather than direct mineralization. Furthermore, the sodium content was significantly highest ($p < 0.05$) in 867 mL/l (1.72), followed by 834 mL/l (1.63) and then 714 mL/l (1.42). However, the 714 mL/l 7.57) and 834 mL/l (7.67) groups had significantly lower ($p < 0.05$) than the 867 mL/l (8.03) group. The electrical conductivity had a similar trend to that of the sodium content.

The significant differences observed in the chemical composition of urine indicate that the dilution level strongly influences nutrient availability and ionic behavior within the system. This trend is unlikely to be solely due to increased mineralization; rather, it can be attributed to changes in physicochemical equilibria, particularly improved solubility and reduced precipitation of nutrient-bearing compounds in the soil.

Nutrient elements, such as phosphorus and calcium, are known to undergo precipitation reactions, forming compounds, such as struvite ($MgNH_4PO_4 \cdot 6H_2O$) and calcium phosphates, which reduce their measurable concentrations in solution. Wei et al. [18] demonstrated that high concentrations of nitrogen, phosphorus, and potassium in solution can induce coprecipitation processes that significantly

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Table 2. Herbage and agronomic yields of Congo grass fertilized with rabbit urine.

Parameters	0 mL/l	714 mL/l	834 mL/l	867 mL/l	SEM	P Value
Plant height (cm)	115.95^{d}	150.88^{b}	125.76^{c}	170.05^{a}	4.03	<0.0001
Root length (cm)	29.95^{d}	40.13^{b}	34.60^{c}	55.10^{a}	21.96	<0.0001
Leaf length (cm)	25.00^{c}	31.88^{b}	25.13^{c}	38.05^{a}	1.61	0.0006
Number of leaves	491.50^{b}	472.00^{c}	376.00^{d}	615.00^{a}	2.45	<0.0001
Number of tillers	33.50^{d}	36.75^{c}	43.50^{b}	73.00^{a}	5.48	<0.0001
Leaf/stem ratio	0.87^{d}	1.15^{c}	1.63^{b}	2.35^{a}	0.44	<0.0001
Leaf weight (kg)	2.28	2.23	1.85	2.03	3.69	0.1804

^{abcd} Means with different superscripts are significantly different (p<0.05).

influence nutrient partitioning and their availability. Similarly, it was reported [19] that phosphorus recovery systems are strongly governed by precipitation and dissolution mechanisms, which determine the fraction of nutrients remaining in soluble form. Therefore, the lower nutrient concentrations observed at 714 mL/l may reflect increased precipitation or reduced solubility, whereas the higher concentrations (834 and 867 mL/l) likely favored conditions that maintained nutrients in dissolved and measurable forms. The observed increase in sodium concentration with increasing urine concentration, with the highest value recorded at 867 mL/l, further supports the influence of ionic accumulation. This trend was mirrored by the electrical conductivity, which exhibited a similar pattern. Electrical conductivity is directly related to the total concentration of dissolved ions in a solution, and its increase with sodium content is therefore expected. Santos et al. [20] reported that ionic strength and the presence of coexisting ions significantly influence solution chemistry and nutrient recovery processes, particularly in systems with a high dissolved salt content. The elevated sodium and electrical conductivity levels observed at higher concentrations may indicate increased ionic strength, which can influence nutrient interactions and stability. The significantly higher pH observed in the 867 mL/l treatment suggests enhanced alkalinity at higher concentrations. This increase in pH can be associated with biochemical transformations, such as urea hydrolysis, which leads to the formation of ammonium and ammonia, thereby raising the pH of the solution. Gonçalves, et al. [21] reported that such transformations significantly alter the physicochemical properties of the solution, including the pH and nutrient speciation. However, the relatively moderate pH range observed in this study indicates that these processes may not have been completed, suggesting the presence of buffering mechanisms or incomplete transformation.

3.2. Morphological parameters of Congo grass fertilized with varying concentrations of rabbit urine

Table 2 shows the effects of varying concentrations of rabbit urine on the morphological parameters of *Brachiaria ruziziensis*. Most of the morphological parameters presented a similar trend, as urine concentrations increased, morphological parameters also showed a corresponding increase. All the Congo grasses treated with different concentrations of rabbit urine had significantly higher values ($p < 0.05$) in plant height, root length, leaf length, number of tillers, and leaf/stem ratio than those in the no fertilizer treatment. However, the 867 mL/l concentration was significantly highest ($p < 0.05$) in these parameters. Furthermore, the number of leaves was significantly highest ($p < 0.05$) in 867 mL/l (615.00), followed by 0 mL/l (491.50), 714 mL/l (472.00) and 834 mL/l (376.00). However, there were no significant differences ($p > 0.05$) in leaf weight among of all the different concentrations.

The application of fertilizers has been shown to have significant effects on the morphological parameters of various species. According to Yakubu et al. [22], rabbit urine fertilization results in a notable increase in morphological traits such as plant height and number of leaves, due to the release of nitrogen into the soil. The difference observed in this study could be linked to the disparity in the concentration of rabbit urine. The highly concentrated treatment released more nutrients to the plants than the other treatments with a high dilution ratio. This observation in the

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Table 3. Yields of *Brachiaria ruziziensis* fertilized with varying rabbit urine concentration.

Parameters (Tonne)	0 mL/l	714 mL/l	834 mL/l	867 mL/l	SEM	P value
Fresh matter yield	18.63[d]	25.25[c]	27.75[b]	54.75[a]	0.08	<0.0001
Dry matter yield	5.00[c]	6.82[b]	6.78[b]	9.59[a]	0.15	0.0043

[abc] means of different subscripts are significantly different.

current study is in accordance with Yakubu et al. [22], in which an increase in rabbit urine concentration resulted in a corresponding increase in the height and number of leaves. Similar results were also reported [23, 24], in which the application of organic and inorganic fertilizers caused significant variations ($p < 0.05$) in the morphological traits of *Brachiaria ruziziensis*. However, a contrasting observation was experienced in the study was reported [13], who found that the application of fertilizers had no significant impact on the morphological traits of Congo grass. Since the application at 867 mL/l concentration showed improved morphological traits over other treatments, it should be considered for improved morphological traits to ensure an abundant supply of feed to livestock.

3.3. Fresh and dry matter yield of Brachiaria ruziziensis fertilized with varying concentrations of rabbit urine.

As the concentration of rabbit urine increased, both fresh and dry matter yields increased (Table 3). The values recorded revealed that 867 mL/l had significantly higher ($p < 0.05$) fresh (54.75) and dry matter (9.59) yields than other urine concentrations. Plots fertilized with rabbit urine showed significantly higher values ($p < 0.05$) than the plots with no urine (0 mL/l). The disparity observed in the yields could be attributed to the varying nutrient concentrations in the rabbit urine used for fertilization. According to the report [25], rabbit urine contains nutrients such as nitrogen, phosphorus and potassium, which are essential for plant growth and improved yield. Several studies have verified that the addition of nitrogen increases soil nutrients, thereby resulting in plant growth and consequently, increasing the yield of grass. It is possible that the treatment with the highest concentration enriched the soil with nutrients at a higher rate than the others. The results obtained in this study are similar to those reported data [26], in which varying levels of swine liquid manure were applied to Congo grass. An increase in yield was observed with increasing levels of swine liquid manure. In another similar study [27] was observed that a varying levels of goat manure were used for the fertilization of Congo grass. An increase in yield was also observed with increasing dosage of goat manure. To substantiate this further [28], adopted the foliar application of rabbit urine in crops such as desmodium, oat and spinach. A tremendous increase in the yield of those crops was reported with the use of rabbit urine. However, the best performance was observed in a rabbit-urine mixture at 50:50 [28]. The difference in performance at different mixing ratios may stem from plant species, soil and ecological conditions. Since *Brachiaria ruziziensis* fertilized with 867 mL/l concentration produced more dry matter (9.59 t) than others with lower concentrations. Therefore, application at that rate might provide improved yield for animal feeding, and this could contribute considerably to the availability of forage in dry and wet seasons.

3.4. The nutrient composition of Congo grass fertilized with rabbit urine

The effect of rabbit urine as a fertilizer on the nutrient composition of *Brachiaria ruziziensis* is shown in (Table 4). The results revealed that all parameters estimated were significantly influenced ($p < 0.05$) by varying concentrations of rabbit urine as fertilizer for *Brachiaria ruziziensis*. The dry matter recorded in this study was significantly highest in 0 mL/l (91.13), followed by 867 mL/l (90.65), 834 mL/l (88.75) and 714 mL/l (87.85), as shown in Table 4. The 867 mL/l (9.78) concentration had the highest ($p<0.05$) crude protein content, 0 mL/l (8.05), and 714 mL/l (7.18), while the lowest value was recorded in 834 mL/l (6.36). The values of crude fibre were significantly higher ($p < 0.05$) in 0 mL/l (34.02) and 834 mL/l (33.96) concentrations than 714 mL/l (31.14) and 867 mL/l (30.15). The metabolisable energy was significantly highest ($p < 0.05$) at 867 mL/l (1856.38) than at 714 mL/l (1766.10) and 0 mL/l (1759.28), whereas 714 mL/l

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Table 4. The chemical composition of Congo grass fertilized with rabbit urine.

Parameters (%)	0 mL/l	714 mL/l	834 mL/l	867 mL/l	SEM	P Value
Dry matter	91.13[a]	87.85[c]	88.75[b]	90.65[a]	0.51	0.0008
Crude protein	8.05[b]	7.18[c]	6.36[d]	9.78[a]	0.47	<0.0001
Crude fibre	34.02[a]	31.14[b]	33.96[a]	30.15[b]	0.69	0.0306
Ether extract	1.89[ab]	1.96[a]	1.42[b]	2.25[a]	0.12	0.0397
Ash	10.05[b]	9.28[c]	9.91[b]	10.67[a]	0.19	0.0397
Nitrogen free extract	37.08	38.52	37.09	37.80	0.32	0.4068
Metabolizable energy (MJ/kg)	1759.28[b]	1766.10[b]	1641.63[c]	1856.38[a]	30.56	0.0218
Neutral detergent fibre	43.87[c]	52.90[b]	64.90[a]	40.00[d]	3.62	<0.0001
Acid detergent fibre	25.50bc	26.40[b]	35.35[a]	21.50[c]	1.95	0.0030
Acid detergent lignin	8.95[c]	10.00[b]	14.00[a]	7.70[d]	0.89	<0.0001
Hemicellulose	18.37[b]	26.50[a]	29.55[a]	18.50[b]	1.90	0.0043
Cellulose	16.50[b]	16.40[b]	21.35[a]	13.80[b]	1.10	0.0336

[abcd] Means with different superscripts are significantly different ($p < 0.05$).

(1641.63) was the lowest. However, the Congo grass treated with 834 and 714 mL/l urine concentrations had significantly higher ($p < 0.05$) acid detetrgent fibre, acid detergent lignin, hemicellulose and cellulose contents than 867 and 0 mL/l, which were significantly similar ($p > 0.05$). The increasing crude protein among the treatments with an increasing concentration of urine was similar to that reported data [29]. Nitrogen is a major component of protein. The availability of nitrogen for absorption enhances the formation of protein in plants [30]. The variation in concentration of the urine could have resulted in different quantities of nutrients, such as nitrogen, hence the difference in crude protein across the treatments. The similarity of this observation is found in the previous study [29], in which various doses of swine application resulted in increased crude protein in *Brachiaria ruziziensis* and Mulato II. In the contrary, the results of crude protein obtained in this study showed a disparity to those previous report [31], in which crude protein was not influenced significantly ($p < 0.05$) by fertilizer types. The crude protein content across the treatments was above the recommended crude protein (7%) required for rumen microbial fermentation, except at 834 mL/l (6.36%). Nonetheless, the 867 mL/l concentration contained a crude protein level that could be more beneficial for livestock performance. Neutral detergent fibre, acid detergent fibre and acid detergent lignin are factors that influence intake and digestibility. Previous studies have verified that increased fertilizer dosage augments soil nitrogen, which in turn influences the level of fibre fraction in forage by accumulating in the cell and causing dilution of the cell wall [32]. Rabbits at different concentrations have been proven to possess varying nitrogen content [22]. Therefore, the amount of nitrogen released to the Congo grass could have influenced the crude fibre fraction. The exception in this study was encountered at 834 mL/l, in which the highest values were obtained for the fibre fraction. This discrepancy could be due to the leaching of nitrogen. Most of the results of neutral detergent fibre and acid detergent fibre obtained in this study fall below the range (60-65%) referred to as the critical threshold level for the performance of the animals [33]. These results are in agreement with those revealed by the earlier report [34], where the application of fertilizer diminished the crude fibre content. Consequently, 867 mL/l with the minimum acid detergent fibre and neutral levels considerably favours improved animal performance, as intake and digestibility are imperative factors in the consideration of feed for livestock feeding. The notably varied ($p < 0.05$) acid detergent lignin observed in the current study is in agreement with the previous studies [35,36], in which fertilizer types influenced the acid detergent lignin of various grasses. On the contrary, the previous study [37] revealed that fertilizer type had no effect on the acid detergent lignin content of the forage considered for the study. The acid detergent lignin content recorded in this study was within the value ranged from 5-15%,

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regarded as a critical level for tropical grasses. The differences recorded in various grasses could be attributed to maturity, species and climatic conditions of the area [38]. Forages with low crude fibre were of high quality, therefore, *Brachiaria ruziziensis* grass at 867 mL/l with the lowest crude fibre content had a better nutritive value. Nitrogen-free extract is the fermentable carbohydrate fraction that provides energy (75-80%) by producing volatile fatty acids in the rumen. The values of nitrogen free extract obtained in this study were lower than those obtained [39] but below those reported by Negasu et al. [36].

4. Conclusions

It could be concluded that rabbit urine at 867 mL/l concentration had better nutrient content which led to improved herbage and agronomic yields as well as crude protein and metabolizable energy content but lower fibre fractions. However, Congo grass fertilized with 867 mL/l concentration was optimal for herbage and nutritional value. In addition, the influence of rabbit urine beyond the concentration applied in this study on these parameters should be investigated further in *Brachiaria ruziziensis* and other grass species to establish the actual concentration of rabbit urine required for the optimum performance of various grasses.

Disclaimer (artificial intelligence)

Author(s) hereby state that no generative AI tools such as Large Language Models (ChatGPT, Copilot, etc.) and text-to-image generators were utilized in the preparation or editing of this manuscript.

Authors' contributions

Conceptualization, supervision; fund acquisition, data curation; writing, review and editing, and original draft preparation, S.K.A.; methodology; validation; fund acquisition; formal analysis; software and project administration, S.O.A.; investigation; resources; investigation; fund acquisition and project administration, A.O.O; investigation; resources; investigation; fund acquisition and project administration, F.F.O.

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Availability of data and materials

All data will be made available on request according to the journal policy.

Conflicts of interest

The authors declare no conflict of interest."I have nothing to declare.

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