

Growth Characteristics and Nutritive Value of Congo Grass (*Brachiaria ruziziensis*) as Influenced by Manure Type and Plant Spacing

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ABSTRACT

Adopting the right agronomic practices is crucial for enhancing forage productivity and nutritive value for ruminant feeding. This study investigated the effects of manure type and plant spacing on the growth characteristics and nutritive value of *Brachiaria ruziziensis* at different harvest intervals. A factorial experiment with 3 manure types (no manure, poultry manure, and swine manure) and 3 planting spacing (0.5 m x 0.5 m, 0.5 x 1.0 m, and 1.0 m x 1.0 m) with 3 replications was used. Growth measurements were taken at 4, 6, and 8 weeks after planting (WAP). Growth parameters measured include plant height (PH), leaf length (LL), leaf width (LW), leaf number/plant (LN/plant), and stem girth. For chemical analysis, plant samples from each week of harvest were pooled, oven dried at 60 °C, and analysed for proximate composition, fibre fractions, and mineral contents using standard procedures. Results indicated that manure applications significantly ($P < 0.05$) increased the LL, LW, and LN/plant across harvest periods compared to the control. At 8WAP, swine manure consistently produced the highest values for LL (32.62cm), LW (2.60 cm), and LN/plant (10.78), poultry manure showed comparable lower performance, and the control showed the lowest values for LL (29.35cm), LW (2.40 cm), and LN/ plant (9.5). Row spacing significantly ($P < 0.05$) improved the LW and LN/plant across harvest periods. At 8WAP, the intermediate spacing (0.5 x 1.0m) produced the highest LW (2.55 cm) and LN/plant (10.5). Both manure applications significantly ($P < 0.05$) improved crude protein (CP), Ether extract (EE), and non-fibre carbohydrate (NFC) contents while reducing fibre fractions (neutral detergent fibre -NDF, Acid detergent fibre -ADF, and Acid detergent lignin -ADL) and mineral concentrations. Closer row spacing significantly ($P < 0.05$) improved the dry matter and CP contents and tended to numerically reduce fibre levels and mineral contents. In conclusion, both manure types, especially swine manure with moderate row spacing (0.5 m x 1.0 m), improved the growth characteristics and nutritive value of *B. ruziziensis* for sustainable ruminant production.

Keywords: nutritive value, growth parameter, ruminant feeding, agronomic, manure

INTRODUCTION

The growing need for animal protein by the increasing human population and changing dietary patterns is challenging livestock production systems, especially ruminants in tropical and sub-Saharan areas (Akpensuen et al., 2025). In these regions, natural pastures, which are the major feed for these animals, are often limited and of low nutritional value, which limits the productivity of ruminants, especially during the dry season when feed resources are scarce (Akpensuen et al., 2025). Thus, the need to improve forage production by using well-adapted species and efficient agronomic practices has become imperative for sustainable livestock development.

Brachiaria ruziziensis (Congo grass) is one of the widely cultivated tropical forage grasses available year-round (Oliveira et al., 2020). This grass, over the years, has been investigated because of its high adaptability to harsh environmental conditions, production of high biomass yield, and capability to be used to support soil fertility and nutrient cycling in integrated crop–livestock systems (Prado et al., 2025). The grass is indigenous and can be purposefully managed or improved. However, its productivity and nutritive value are greatly influenced by agronomic management practices, particularly nutrient supply and plant spacing.

Nutrient supply to the soil through organic manure application plays a significant long-term role in improving forage growth and quality (Egbe et al., 2026), they are less expensive, causes no damage to natural vegetation, supports soil physical condition and microbial activity compared to fertilisers (Wang et al., 2024). Among the organic manures used in forage production, poultry and swine manures have a greater impact in improving soil structure, supporting higher microbial activity, and providing a sustained release of nutrients to plants.

In addition, plant spacing is another important factor that regulates the way a plant will use available resources (water, light, and nutrients) for its growth. Obtaining the right spacing prevents competition between plants for resources, thus allowing the plants to grow and establish properly with improved characteristics, yield, and quality (Zemene et al., 2020). It is well established that when closer plant spacing is used, forage quality is often improved through increased leaf production and nitrogen content, while the use of wider spacing promotes individual plant growth, but overall forage productivity per unit area of land is reduced (Yiberkew et al., 2020). Furthermore, forage harvest time has a major influence on its quality, as younger plants are high in soluble nutrients (crude protein and ether extract) and low in insoluble nutrients (fibre and lignin) compared to mature plants (Lee, 2018). Although previous studies have investigated the individual effects of fertilisation, spacing, and harvest intervals, there is still limited information on how these factors combine to influence the growth and nutritional composition of *B. ruziziensis* under field conditions. Therefore, this study was conducted to evaluate the effects of manure type and plant spacing at different harvest intervals and to identify agronomic management practices that can optimise both forage yield and quality for ruminant production systems.

MATERIALS AND METHODS

Study Site Description

The field experiment was conducted at the Teaching and Research farm unit of the Directorate of University Farms (DUFARMS). The location lies within the derived savanna agro-ecological zone in Southwest Nigeria with annual temperature of about 28 to 30°C during the rainy season and average annual precipitation of 1037mm. The relative humidity ranges from 55 - 82% (April-October) in the dry season to 63-96% (November-March) in the wet season, with an average percentage of 82%. (Weather and Climate, 2021).

Treatments and Experimental design

The experiment was a factorial experiment arranged in randomised complete block design with 2 factors (manure type and plant spacing) and 3 replications. Harvesting time was treated as a repeated measure on the same experimental

units. Three manure types (no manure, poultry manure and swine manure) and three plant row spacings (0.5 m x 0.5 m, 0.5 m x 1 m and 1 m x 1 m) were compared at 3 harvesting times (4, 6 and 8 weeks). A total of 9 treatment combinations were evaluated across 3 blocks, resulting in 27 plots. The total experimental area was 299 m² (13 m x 23 m) with an individual plot size of 8 m² (4 m x 2 m). Plots were separated by 0.5 m while blocks were separated by 1.0 m. Prior to plant establishment, composite soil samples were collected for nutrient composition (Table 1) determination. The land was ploughed, cleared of debris and harrowed after 2 weeks before it was demarcated into blocks and plots. The planting material (crown split) of Congo grass was collected from an established pasture at DUFARMS. The source pasture was trimmed to equal height before collection, and the crown was carefully excavated. Planting was carried out in July 2021 by placing the crown splits at a depth of 10-15 cm into the soil according to the designated spacing treatments. Poultry and swine manures were sourced from DUFARM, air-dried to a constant weight, and sub-sampled for chemical analysis. Application rates were determined based on the nitrogen content of the manure, with the manure applied to supply 300 kg N/ha. Weed control was done manually throughout the experimental period to keep the intra- and inter-plot areas weed-free.

Table 1: Initial Physico-chemical properties of the soil samples collected at 0 -15cm depth of the experimental plot

Physico-chemical properties	Values
pH	6.41
Total Nitrogen (%)	0.06
Organic carbon (%)	1.43
Available P (mg/kg)	6.59
Acidity (cmol/kg)	0.08
CEC	4.22
Exchangeable cations (cmol/kg)	
Sodium (Na)	0.33
Potassium (K)	0.22
Calcium (Ca)	10.69
Magnesium (Mg)	1.9
Micro-minerals (mg/kg)	
Manganese (Mn)	2.9
Iron (Fe)	4.85
Copper (Cu)	1.4
Zinc (Zn)	2.26
Particle size (%)	
Sand	89.8
Silt	4.6
Clay	5.6

Data Collection

Growth parameters

Data on the growth characteristics were recorded throughout the experimental period (8 weeks). In each experimental plot, 10 plants were randomly selected at each harvesting time (4, 6 and 8 weeks) to record data on plant height (PH),

leaf length (LL), leaf width (LW), leaf number/plant (LN/plant), and stem girth (SG). The PH (cm) was determined by measuring the plant from the base to the point at which the last leaf on the stem emerges using a metre rule. The LL (cm) was determined by measuring from the tip of the leaf to the collar region base using metre rule. The LW (cm) was measured at the widest middle portion of the leaf using a ruler on 5 leaves on each selected plant. The LN/plant was determined by visually counting the number of fully expanded green leaves per tiller from 6 tillers of each selected plant within each plot, and the average value was recorded. SG (culm diameter) was measured at about 5 cm above ground level using a caliper to measure around the stem on selected plants, and the mean value was recorded (Tilahun et al., 2017; Zemene et al., 2020).

Forage nutrient composition measurements

Fresh herbage samples were randomly collected from each plot and oven-dried at 60°C to a constant weight for dry matter determination. The dried samples were milled to pass through a 1mm sieve and then stored in an airtight, covered plastic container pending chemical analysis. The chemical analysis was conducted at the laboratory of the Department of Pasture and Range Management, Federal University of Agriculture, Abeokuta, Ogun State, Nigeria. The proximate composition, including dry matter (DM), crude protein (CP), ether extract (EE), and ash content (AC) of the samples, was determined according to the standard procedures of AOAC (2002). Non-fibre carbohydrate (NFC) was calculated as $NFC = 100 - (CP + EE + NDF + \text{ash})$. Fibre fractions, including neutral detergent fibre (NDF), acid detergent fibre (ADF), and acid detergent lignin (ADL) of the samples, were analysed using the procedures described by Van Soest et al. (1994). For mineral analysis, sub-samples were further dried in a forced-draught oven at 105°C for 24 hours, followed by wet-digestion using nitric acid and hydrochloric acid mixture (3:1, v/v). The concentration of potassium (K) was measured using a flame photometer, while the concentrations of calcium (Ca), magnesium (Mg), sodium (Na), iron (Fe), manganese (Mn), cobalt (Co), copper (Cu) and zinc (Zn) were determined using absorption spectrophotometry. The concentration of Phosphorus (P) was determined using standard spectrophotometric method (Fritz and Schenk, 1979).

Statistical analysis

All data were analyzed using the General Linear Model (GLM) procedure of SAS (2004) to perform a two-way analysis of variance (ANOVA) to assess the effect of manure type and plant spacing. Treatment means were separated using Duncan's Multiple Range Test. Statistically significant was declared at $P < 0.05$.

RESULTS AND DISCUSSION

Effect of manure type and plant spacing on the growth characteristics of *Brachiaria ruziziensis* at different weeks after planting.

The main effects of manure type and plant spacing on the growth characteristics of *B. ruziziensis* at different harvesting times are presented in Table 2. Growth parameters of *B. ruziziensis* increased consistently with advancing weeks after planting (WAP) irrespective of treatment. Manure application significantly ($P < 0.05$) improved leaf-related parameters (length, width, and number per plant) compared to the control across harvesting periods. At 8WAP, swine manure consistently produced the highest values for LL (32.62 cm), LW (2.60 cm), and LN/plant (10.78); poultry manure showed comparable lower performance; and the control showed the lowest values for LL (29.35 cm), LW (2.40 cm), and LN/plant (9.50). The PH and SG were not influenced by manure type, although numerically higher values were observed in plots treated with manure. The row spacing had a significant ($P < 0.05$) effect on LW and LN/plant but did not influence the PH, LL, and SG. The wider spacing (1.0 x 1.0 m) resulted in the highest numerical SG and the lowest numerical PH, while the intermediate spacing (0.5 x 1.0 m) produced the highest LW and LN/plant and the lowest LL. Closer spacing (0.5 x 0.5 m) produced the lowest LW, LN/plant, and SG, with the highest PH and LL.

Effect of manure type and plant spacing on the chemical composition of *B. ruziziensis*.

Table 3 presents the main effects of manure type and plant spacing on the chemical composition of *B. ruziziensis*. The manure type significantly ($P < 0.05$) influenced most chemical constituents, whereas row spacing had limited effects on forage nutrient composition. The manure types improved the forage quality in terms of CP, EE, and NFC, while the fibre fractions (NDF, ADF, and ADL) were reduced. Swine manure application led to the highest EE (10.11%) and NFC (9.87%) contents as well as the lowest fibre fractions (NDF: 58.22%, ADF: 29.56%, ADL: 9.11%) in the grass. Poultry manure application, however, led to the highest CP (11.48%) content in the grass. The control consistently showed lower nutritive value, with the lowest CP and highest fibre contents. The row spacing had minimal influence on most chemical parameters. However, CP was significantly ($P < 0.05$) affected, with the highest value recorded at 0.5 x 1.0 m spacing. Dry matter (DM) was also slightly higher at 0.5 x 0.5 m and 1.0 x 1.0 m spacings compared to 0.5 x 1.0 m. Fibre fractions were not significantly influenced by spacing.

Effect of manure type and plant spacing on the mineral composition of *B. ruziziensis*.

The main effects of manure type and plant spacing on the mineral composition of *B. ruziziensis* are presented in Table 1. Manure type significantly ($P < 0.05$) influenced both macro- and micro-mineral composition, whereas row spacing showed variable and nutrient-specific effects. The control treatment consistently recorded higher concentrations of the macro minerals (Ca, P, K, and Na) and micro minerals (Cu, Fe, Zn, and Mn) compared to plots treated with manure. Plots treated with poultry manure generally produced intermediate values for most minerals, while those treated with swine manure generally recorded the lowest values for most minerals. The row spacing significantly affected several mineral elements. The intermediate spacing (0.5×1.0 m) recorded the highest calcium (Ca) and magnesium (Mg) concentrations, while closer spacing (0.5×0.5 m) resulted in higher phosphorus (P), potassium (K), and manganese (Mn) contents. Wider spacing (1.0×1.0 m) generally increased sodium (Na), iron (Fe), copper (Cu), and zinc (Zn) concentrations.

Correlation among growth characteristics and nutritional composition of *B. ruziziensis*

The relationships among growth and nutritional parameters of *B. ruziziensis* are shown in Table 5. A strong and significant ($P < 0.05$) relationship was observed among most of the growth and nutritional parameters of *B. ruziziensis*. The growth parameters were highly and positively correlated with each other ($r = 0.73 - 0.99$) and were positively correlated with the soluble nutritional contents, particularly CP ($r = 0.45 - 0.94$), EE ($r = 0.90 - 0.99$), and NFC ($r = 0.77 - 0.998$). In contrast, strong negative correlations were observed between the growth parameters measured and fibre fractions, including NDF, ADF, ADL, HEM, and CELL ($r = -0.87$ to -0.997). DM showed moderate positive correlations with the growth parameters and CP, but reflects a negative relative relationship with fibre fractions. The ash content was negatively correlated with most of the growth parameters but positively correlated with the fibre contents. Strong correlations were observed among the fibre fractions ($r = 0.97 - 1.00$).

Table 2: Growth Characteristics of *Brachairia ruziziensis* at different weeks of planting as influenced by manure type and row spacing

Parameters	WAP	Manure type			SEM	Row spacing (m)			SEM
		Control	Poultry manure	Swine manure		0.5 x 0.5	0.5 x 1	1 x 1	
Plant height (cm)	4	30.37	32.31	30.73	0.76	31.8	30.87	30.74	0.77
	6	46.82	49.26	48.98	0.97	48.91	47.98	48.17	0.97
	8	61.04	62.46	65.08	1.42	63.44	62.72	62.52	1.45
Leaf length (cm)	4	20.73 ^b	21.89 ^a	21.71 ^a	0.34	21.37	21.35	21.63	0.34
	6	26.03 ^b	28.10 ^a	27.58 ^a	0.38	27.35	27.15	27.21	0.39
	8	29.35 ^b	32.35 ^a	32.62 ^a	0.46	31.64	31.31	31.37	0.48
Leaf width (cm)	4	1.33 ^c	1.42 ^b	1.51 ^a	0.03	1.4	1.43	1.42	0.03
	6	2.01 ^b	2.08 ^b	2.21 ^a	0.03	2.01 ^b	2.07 ^{ab}	2.10 ^a	0.03
	8	2.43 ^b	2.53 ^{ab}	2.63 ^a	0.03	2.42 ^b	2.55 ^a	2.48 ^{ab}	0.04
Leaf number/plant	4	4.4	4.54	4.42	0.14	4.27 ^b	4.69 ^a	4.41 ^{ab}	0.14
	6	7.48 ^b	8.10 ^a	8.19 ^a	0.18	7.67 ^b	8.30 ^a	7.80 ^b	0.18
	8	9.52 ^b	10.41 ^a	10.78 ^a	0.21	10.08	10.53	10.1	0.22
Stem girth (cm)	4	2.82	2.88	3.01	0.09	2.76 ^b	2.89 ^{ab}	3.06 ^a	0.1
	6	4.81	5.25	5.12	0.15	4.96	5.04	5.18	0.16
	8	6.4	6.68	6.66	0.19	6.48	6.6	6.66	0.18

a,b,c, Means within the same row with different superscripts are significantly ($P < 0.05$) different. SEM, standard error of means; WAP, weeks after planting

Table 3: Chemical composition of *Brachiaria ruziziensis* at different weeks of planting as influenced by manure type and row spacing

Parameter	Manure type			SEM	Row spacing (m)			SEM
	Control	Poultry manure	Swine manure		0.5 x 0.5	0.5 x 1	1 x 1	
DM	94.94	95.61	95.17	1.73	95.72 ^a	94.33 ^b	95.67 ^a	1.74
CP	8.65 ^c	11.48 ^a	10.35 ^b	0.26	9.96 ^c	10.38 ^a	10.15 ^b	0.28
EE	7.50 ^b	9.11 ^a	10.11 ^a	0.26	8.28	8.72	9.11	0.26
Ash	12.06	11.17	11.44	0.28	11.67	11.67	11.33	0.28
NFC	6.35 ^b	7.80 ^b	9.87 ^a	0.23	7.82	8.68	8.13	0.22
NDF	65.44 ^a	60.44 ^b	58.22 ^c	1.44	61.78	61	61.33	1.46
ADF	33.67 ^a	31.11 ^b	29.56 ^c	0.72	31.67	31.22	31.44	0.74
ADL	10	9.5	9.11	0.24	10	9.83	9.83	0.2
HEM	31.78 ^a	29.33 ^b	28.67 ^b	0.72	29.33	29.89	30.56	0.73
CELL	23.67 ^a	21.61 ^b	20.44 ^b	0.48	21.83	21.61	21.22	0.46

a,b,c, Means within the same row with different superscripts are significantly ($P < 0.05$) different. SEM, standard error of means; DM, dry matter; CP, crude protein; EE, ether extract; NFC, non-fibre carbohydrate; NDF, neutral detergent fibre; ADF, acid detergent fibre; ADL, acid detergent lignin; HEM, hemicellulose; CELL, cellulose.

Table 4: Mineral composition of *Brachiaria ruziziensis* at different weeks of planting as influenced by manure type and row spacing

Parameters	Manure type			SEM	Row spacing (m)			SEM
	Control	Poultry manure	Swine manure		0.5 x 0.5	0.5 x 1	1 x 1	
Macro minerals (g/kg)								
Ca	10.23 ^a	9.76 ^b	8.51 ^c	0.21	8.44 ^c	10.39 ^a	9.67 ^b	0.22
P	12.87 ^a	11.91 ^b	11.12 ^c	0.24	13.33 ^a	11.55 ^b	11.02 ^c	0.25
K	91.44 ^a	84.94 ^c	85.12 ^b	1.68	95.64 ^a	79.75 ^c	86.10 ^b	1.69
Mg	1.76 ^a	1.73 ^b	1.76 ^a	0.02	1.75 ^c	1.77 ^a	1.76 ^b	0.02
Na	3.05 ^a	2.34 ^b	2.22 ^c	0.02	2.42 ^c	2.55 ^b	2.64 ^a	0.04
Micro mineral (mg/kg)								
Fe	4.25 ^a	3.59 ^b	3.50 ^c	0.03	3.45 ^c	3.54 ^b	4.34 ^a	0.08
Cu	2.98 ^a	1.49 ^c	2.15 ^b	0.02	1.26 ^c	2.14 ^b	3.23 ^a	0.04
Zn	5.19 ^a	4.51 ^b	4.45 ^b	0.1	4.44 ^c	4.60 ^b	5.11 ^a	0.09
Mn	14.64 ^a	11.63 ^b	10.29 ^c	0.22	13.07 ^a	10.61 ^c	12.88 ^b	0.22

a,b,c, Means within the same row with different superscripts are significantly ($P < 0.05$) different. SEM, standard error of means

Table 5: Correlation coefficients among growth characteristics and nutritional parameters of *B. ruziziensis*

Predictors	8PH	8LL	8LW	8LN	8SG	DM	CP	EE	Ash	NFC	NDF	ADF	ADL	HEM	CELL
8PH	1	0.814	0.986	0.92	0.727	0.174	0.452	0.954	-0.546	*0.998	-0.925	-0.952	-0.971	-0.882	-0.947
8LL		1	0.901	0.977	0.99	0.713	0.886	0.951	-0.931	0.852	-0.974	-0.953	-0.929	-0.992	-0.958
8LW			1	0.973	0.832	0.338	0.597	0.991	-0.679	0.995	-0.976	-0.99	*-0.997	-0.949	-0.988
8LN				1	0.938	0.547	0.766	0.995	-0.831	0.944	** -1.000	*-0.996	-0.987	*-0.996	*-0.997
8SG					1	0.803	0.941	0.899	-0.972	0.772	-0.933	-0.902	-0.87	-0.965	-0.909
DM						1	0.957	0.461	-0.92	0.241	-0.534	-0.467	-0.404	-0.617	-0.481
CP							1	0.699	-0.994	0.512	-0.757	-0.703	-0.652	-0.819	-0.715
EE								1	-0.771	0.972	*-0.996	** -1.000	*-0.998	-0.983	** -1.000
ASH									1	-0.602	0.822	0.776	0.73	0.876	0.786
NFC										1	-0.949	-0.971	-0.985	-0.912	-0.967
NDF											1	*0.997	0.989	0.995	*0.998
ADF												1	*0.998	0.984	**1.00
ADL													1	0.969	*0.996
HEM														1	0.987

* P < 0.05; **P < 0.01; 8PH, plant height at 8 weeks; 8LL, leaf length at 8 weeks; 8LW, leaf width at 8 weeks; 8LN, leaf number/plant at 8 weeks; 8SG, stem girth at 8 weeks; DM, dry matter; CP, crude protein; EE, ether extract; NFC, non fibre carbohydrate; NDF, neutral detergent fibre; ADF, acid detergent fibre; ADL, acid detergent lignin; HEM, hemicellulose; CELL, cellulose

DISCUSSION

The improvement in the grass growth parameter with an increase in weeks of planting indicates that the grass is undergoing normal vegetative development. The manure application leading to improved LL, LW, and LN/plant, with swine manure producing the highest values at 8 WAP, indicates that more nutrients, especially nitrogen, are available in the soil. This process allows the leaf to expand, produce more tillers, and facilitate the photosynthetic process (Wang et al., 2024; Pan et al., 2025). The comparable performance of poultry manure to that of swine manure further explains the capability of organic manure application in improving soil fertility and eventually plant growth. The plant height and stem girth not being influenced by the manure may be due to their lower sensitivity to short-term nutrient supply in the soil and might be influenced more by factors affecting the genes or the environment (Oliveira et al., 2020). In contrast, the improved leaf properties (LL, LN/plant, and LW) of this study indicate that they are more influenced by nutrient availability in the soil. Row spacing influencing LW and LN/plant, but not PH, LL, or SG, shows that denser plant stands have the capability to regulate the canopy structure. The superior growth performance of intermediate spacing (0.5×1.0 m) suggests an optimal balance between plant density and the use of available resources. The wider spacing (1.0×1.0 m) supporting

greater stem girth might be due to reduced competition. The closer spacing (0.5×0.5 m) resulting in higher PH with reduced leaf development can be attributed to higher plant competition for light and the corresponding responses to avoid shade, leading to stem elongation that increased the height rather than lateral growth (Lemaire et al., 2011).

The increase in the chemical composition of *Brachiaria ruziziensis* after manure application shows that the manure has the potential to release nutrients to the soil capable of improving their nutritive value. The increased CP, EE, and NFC contents and reduced fibre fractions of the grass treated with poultry and swine manure indicate higher nutritive value and digestibility. The comparable CP content of the grass treated with manure indicates a similar rate of absorption of mineralised nitrogen by the grass from the soil (Wang et al., 2024). Similarly, the higher NFC and lower fibre fractions of the grass treated with swine manure suggest higher accumulation of soluble carbohydrates and less deposition of structural carbohydrate in the grass capable of supporting higher feed intake and digestibility (Lee et al., 2018). The control treatment, showing a lower nutritional content characterised by reduced CP and increased fibre fractions, shows that forage grown on soil with inadequate nutrients will support a higher accumulation of structural carbohydrates. This confirms the existing report that planting forages on soil deficient in nutrients will increase fibre deposition and reduce forage quality (Oliveira et al., 2020). Row spacing having less influence on most chemical contents indicates that nutrient availability in the soil has a greater influence on forage quality than plant

density. However, the higher CP content of the grass under intermediate spacing (0.5×1.0 m) may suggest an efficient nitrogen utilisation by the grass when exposed to moderate competition. The spacing that does not influence the fibre fractions of the grass confirms that the accumulation of structural carbohydrates in a plant is more about nutrient availability in the soil and stage of growth than spatial arrangements (Lee et al., 2018; Oliveira et al., 2020).

The manure application potential to influence the mineral composition of *Brachiaria ruziziensis*, with higher mineral composition in the control treatment shows that manure might have produced a nutrient dilution effect. The lowest mineral concentration in plants treated with swine manure than poultry suggests a higher dilution effect with the swine manure treatment. The dilution effect of manure has been linked with rapid vegetative growth and increase biomass production. In addition, when DM accumulates faster in plants grown in soil containing adequate nutrients, the mineral concentration might be reduced per unit DM even when nutrient uptake is high (Darch et al., 2020; Holík et al., 2022). The inconsistent influence of row spacing on mineral compositions might be linked to plant density and resource competition. The intermediate spacing (0.5×1.0 m) supports higher accumulation of calcium and magnesium concentrations in the plant, which might indicate a balance between nutrient uptake and reduced competition among plants. On the contrary, the closer spacing (0.5×0.5 m) supports higher phosphorus, potassium, and manganese accumulation and might reflect a greater demand for nutrients and an efficient nutrient uptake under higher plant density. The wider spacing (1.0×1.0 m) supports higher sodium, iron, copper, and zinc concentrations; accumulation might likely be due to improved root exploration and reduced inter-plant competition for soil nutrients (Lemaire et al., 2011 Yiberkew et al., 2020).

The strong positive correlations observed among the growth indices of *Brachiaria ruziziensis* indicate that the vegetative development is well coordinated in that an improvement in one parameter led to a corresponding increase in another. The positive relationships established between the growth parameters and soluble nutritional components (CP, EE and NFC) suggest that the growth indices increased with an improvement in these components at this vegetative stage of growth investigated. This relationship indicates that at this stage of growth, there is an increased metabolic process and accumulation of more soluble carbohydrates in the plant (Lee et al., 2018). On the other hand, the strong negative correlations between growth parameters and fibre fractions (NDF, ADF, ADL, HEM, and CELL) indicate that an increase in the growth parameters was accompanied by a reduced accumulation of structural carbohydrates at this stage of growth (8 weeks). During the growth periods evaluated in this study, the plants are still in their early vegetative stage, where more leaves are present than stems, tissues are yet to be lignified, and the nutritive quality is high. The negative relationship that existed between the

soluble fractions (CP and EE) and insoluble fractions (NDF, ADF, and ADL) indicates that the higher the soluble fraction, the lower the insoluble fraction and vice versa. This is expected as similar findings have been reported in tropical forage grasses under enhanced nutrient availability (Oliveira et al., 2020). The moderate positive correlations observed between the DM and the growth parameters and with the CP further suggest that the plant-facilitated growth has the potential to produce higher biomass with more soluble fraction accumulation and less fibre deposition at this stage of growth. In contrast, the negative relationship between ash and growth parameters, coupled with its positive association with fibre fractions, may indicate a dilution effect resulting from increased biomass production. The strong positive correlations among fibre fractions confirm the close structural association among cell wall components in forage plants (Wróbel et al., 2025; Tesfaye et al., 2026).

CONCLUSION

The growth characteristics and the nutritive value of *Brachiaria ruziziensis* were improved greatly by the organic manure application and minimally by the plant spacing. Among the organic manure used, swine manure application gave the best performance in terms of enhanced leaf development, increased soluble fractions, and reduced fibre fractions. Among the plant spacing used, the intermediate spacing ($0.5 \text{ m} \times 1.0 \text{ m}$) led to an optimal leaf production and crude protein concentration. Mineral concentrations were generally lower under manure treatments, likely due to dilution effects associated with increased biomass production. Correlation analysis further showed that improved growth was positively associated with soluble nutritional components and negatively associated with fibre fractions. Overall, the combined use of any of the organic manure, especially swine manure, at 0.5 m to 1.0 m spacing can enhance forage productivity and quality for sustainable ruminant production.

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