New Zealand Journal of Agricultural Research

RESEARCH ARTICLE OPEN ACCESS

Forage Biomass and Chemical Composition of Buffelgrass Genotypes in the Semi-Arid Region of Brazil

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Received: 15 August 2025 | **Revised:** 11 December 2025 | **Accepted:** 12 December 2025

Keywords: *Cenchrus ciliaris* | dryland agriculture | forage quality | genotype environment interaction | semi-arid climate

ABSTRACT

Forage improvement in semi-arid regions requires the identification of genotypes capable of maintaining productivity under climatic variability and chronic water scarcity. This study evaluated six buffelgrass (*Cenchrus ciliaris* L.) genotypes over two production years in northern Minas Gerais, Brazil, to characterize their agronomic, morphological, and chemical attributes. The experimental genotypes were Áridus, Buffel 131, Biloela, Common, Grass, and USA. A randomized complete block design with a split-plot arrangement was used, with genotypes assigned to main plots and years to subplots. Main effects of genotype and year were detected for most variables ($p < 0.05$). Productive and morphological traits differed among genotypes (forage dry mass - FDM: $p = 0.0021$; leaf dry mass - LDM: $p = 0.0047$; leaf-to-stem ratio - LSR: $p = 0.0215$). Biloela produced the highest FDM (4615.2 kg ha^{-1} year^{-1}) and LDM, outperforming Buffel 131, Common, Grass, and USA. Grass expressed the greatest LSR. Year effects were pronounced ($p < 0.0001$), with higher biomass accumulation in 2022. Chemical composition also varied among genotypes; notably, Biloela showed the highest acid detergent fiber (383.6 g kg^{-1}), exceeding Buffel 131 by 11.1% ($p < 0.05$), suggesting a trade-off between productivity and fiber concentration. Year influenced crude protein, ash, neutral detergent fiber and acid detergent fiber (all $p < 0.0001$), with improved nutritional attributes in 2023. A genotype × year interaction occurred only for inflorescence proportion ($p < 0.0001$). Overall, Biloela, Áridus, and Buffel 131 exhibited the most favorable combination of forage yield and chemical composition. These genotypes represent promising options for increasing forage resilience and nutritional quality in semi-arid livestock systems.

1 | Introduction

The genetic variability among forage plant genotypes, in conjunction with their adaptive responses to environmental factors, represents a critical determinant in selecting cultivars suited for agronomic deployment in drylands. Tropical arid and semi-arid regions are marked by high temperatures and low rainfall, which restrict ecosystem function and crop performance (Waseem et al. 2021). In the Brazilian semi-arid region, the unfavorable rainfall limits the use of most forage grasses (*Urochloa* spp and *Megathyrsus maximus*) cultivated in the tropics. This region, with an average annual rainfall ranging from 350 to 800 mm, experiences intense and prolonged droughts, which intensify the seasonal nature of pasture productivity and compromise livestock performance indices (Sparacino et al. 2021).

In semi-arid regions of Brazil, forage plants typically exhibit low productivity and high fiber and lignin content, characteristics that negatively impact ruminal fermentation and animal performance (Lee 2018). Originally from Africa and Asia, the species is widely adopted across diverse regions due to its adaptive resilience and agronomic performance under varying climatic

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conditions (Singh et al. 2023). In Brazil, the cultivation of buffelgrass is constrained by the limited availability of high-quality seeds and insufficient number of well-adapted and agronomically competitive cultivars (Bruno et al. 2017).

Forage species with superior adaptive traits are essential for sustaining livestock systems in semi-arid environments. In these regions, forage plants typically exhibit low productivity and high content of fiber and lignin, characteristics that negatively impact ruminal fermentation and animal performance (Lee 2018). Consequently, studies on plant adaptation have emphasized the identification of genotypes with high forage yield, increased leafiness, and desirable chemical profiles, such as elevated crude protein and reduced fibrous fractions (Caradus and Chapman 2025; Chand et al. 2022). Moreover, the assessment of seasonal biomass distribution is fundamental for pasture-based ruminant systems and for guiding sustainable management practices (Chapman et al. 2015).

Although several studies have investigated the adaptability of buffelgrass, most have evaluated isolated traits rather than adopting an integrated, multitrait perspective. For example, Ahmad et al. (2020) focused on morphological and physiological adaptations related to drought and altitude tolerance, while Singh et al. (2023) emphasized nutritional and silage quality traits across global germplasm. Ameer et al. (2023) documented ecotypic variation in structural and physiological characteristics under aridity gradients. These studies consistently identified substantial genetic diversity and highlighted traits associated with productivity, drought tolerance, or nutritive value. However, they did not simultaneously evaluate agronomic, morphological, and chemical traits across multiple genotypes under Brazilian semi-arid conditions, nor did they examine multiyear variability in trait expression. As a result, critical gaps remain regarding which genotypes combine high productivity, favorable morphological structure, and superior nutritional composition when grown under the specific conditions of the tropical semiarid of northern Minas Gerais.

Addressing this knowledge gap requires the evaluation of the existing diversity of buffelgrass materials. In Brazil, Áridus is the only cultivar officially registered, while Biloela, Molopo, and Gayndah originate from Australia. Genotypes such as Grass and Common are naturalized but do not have a known origin, and Buffel 131, grown exclusively in northern Minas Gerais, holds potential for future formal recommendation. The USA cultivar, recently released in Australia, may be considered for introduction pending agronomic validation. Integrating these genotypes into a single comparative framework enables the identification of materials best suited to the climatic and edaphic conditions of the Brazilian semi-arid region.

It is hypothesized that buffelgrass genotypes cultivated in the tropical semi-arid region of northern Minas Gerais exhibit significant variation in forage yield, morphological traits, and chemical composition. Multiyear evaluations are considered essential for accurate identification and recommendation of genotypes, as plant performance may be influenced by interannual variability in environmental conditions.

Given these considerations, the present study evaluates whether these genotypes differ in traits that are agronomically and nutritionally relevant to forage systems exposed to drought, environmental seasonality, and multiannual climatic variability.

2 | Methods

2.1 | Experiment Site and Climate

The experiment was conducted in Montes Claros, Minas Gerais, Brazil, at coordinates 16°40′59″S and 43°50′19″W. The region

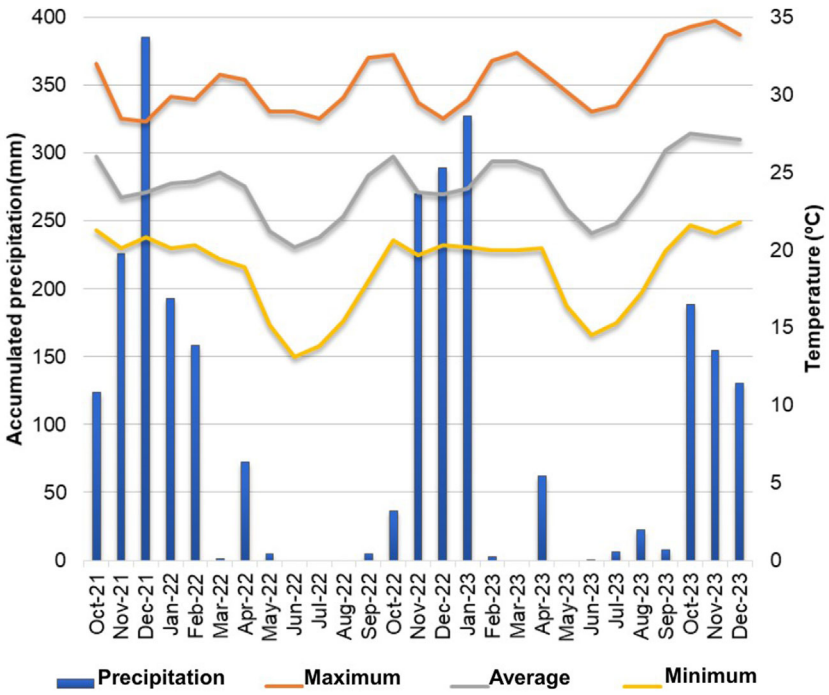


FIGURE 1 | Accumulated precipitation, maximum temperature, minimum temperature, and average temperature during the experimental period - Montes Claros, Minas Gerais, Brazil.

Source: INMET.

has a tropical subhumid and megathermal climate (Aw), with a rainy summer and a prolonged dry winter according to Koppen's classification (Peel et al. 2007). Temperature and precipitation data were recorded throughout the experimental period (Figure 1).

2.2 | Experimental Design

Six buffelgrass genotypes were evaluated: Áridus, Buffel 131, Biloela, Common Grass, and USA. The experimental design was a randomized complete block with six blocks and six replications. A split-plot arrangement over time (6×2) was adopted, where genotypes were assigned to the main plots and the years (2022 and 2023) to the subplots. The experimental blocks were arranged perpendicular to the slope of the field to minimize potential differences in soil moisture and fertility. The experimental area consisted of 36 plots, each measuring 10 m^2 (2×5 m). The experiment was evaluated during a 24-month period.

2.3 | Crop Management

The experimental field soil was classified as eutric cambisol (IUSS Working Group WRB 2022). The soil was analyzed and presented the following characteristics: pH in water = 6.44 (±0.32), pH in $CaCl_2$ = 5.96 (±0.30), organic matter (OM) = 1.79 dag kg^{-1} (±0.09), total organic carbon = 1.04 dag kg^{-1}, potassium (K) = 195.2 mg dm^{-3} (±9.8), phosphorus (P) = 15.64 mg dm^{-3} (±0.78), sulfur (S) = 6.12 mg dm^{-3} (±0.31), calcium (Ca^{2+}) = 8.24 $cmol_c$ dm^{-3} (±0.41), magnesium (Mg^{2+}) = 1.54 $cmol_c$ dm^{-3} (±0.08), and aluminum (Al^{3+}) was practically absent (<0.01 $cmol_c$ dm^{-3}). Potential acidity (H + Al) was 0.83 $cmol_c$ dm^{-3} (±0.04). Regarding granulometric composition, the soil had a clay-loan texture, with 50% clay (±2%), 36% silt (±2%), and 14% sand (±1%). Analyses followed the methods described by Schulte and Hoskins (2011) for organic matter and total organic carbon and by Silva (2009) for the other parameters, according to the Manual for Chemical Analyses of Soils, Plants and Fertilizers.

The soil in the experimental area was conventionally prepared by scarification, tillage, leveling, and homogenization. Forage plots were established with an area of 10 m^2 each. Seeds were manually sown in planting furrows and incorporated by light soil compaction. Each plot consisted of five grass rows, 5 m in length, spaced 0.5 m apart.

Plants were fertilized with the equivalent of 40 kg ha^{-1} of P_2O_5, applied as single superphosphate in the planting furrows. After establishment, they annually received 20 kg ha^{-1} of P_2O_5 (single superphosphate), 50 kg ha^{-1} of N (ammonium sulfate), and 50 kg ha^{-1} of K_2O (potassium chloride) as maintenance fertilization in the beginning of the rainy season.

The experiment was conducted under rainfed conditions, and after the establishment, a uniformity cut was performed at 20 cm above the soil surface to initiate the evaluation period.

2.4 | Sample Collection

Forage production was evaluated through harvests conducted every 30 days during the rainy season and every 90 days during the dry season. Before each harvest, plant height was measured at 10 random points per plot to determine the average canopy height for that evaluation cycle. In this study, the rainy season was defined as November to March and the dry season as April to October. The mean plant height per plot was calculated exclusively from the 6-monthly assessments carried out during the rainy season of each year.

Fresh biomass was estimated by harvesting and weighing accumulated forage from the two central rows of each plot, excluding 0.5 m of border on each row. Thus, 4 m were harvested from each of the two central rows. This sample was weighed and homogenized for further analyses. About 200 g were allocated for plant-part separation, and 200 g for pre-drying and chemical analysis.

Samples for plant-part composition analysis were separated fresh into leaf blades, stems with leaf sheaths, senescent forage, and inflorescences. These were then placed in paper bags and dried separately in a forced-air oven at 55°C for 72 h. With the dry weights, the relative contribution (percentage) of each component (leaf blades, stems with sheaths, dead forage, and inflorescences) was estimated. Leaf and stem weights were used to calculate the leaf-to-stem ratio.

2.5 | Laboratory Analyses

Samples for dry matter (DM) determination were oven-dried at 55°C with forced air until reaching constant weight. After predrying, the samples were ground in a Wiley mill through a 1 mm screen and then oven-dried at 105°C for 24 hr to determine DM content (DM, method 934.01), ash (method 942.05), and crude protein (CP, method 954.01), according to AOAC International (2005). Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined according to Van Soest et al. (1991), using an ANKOM200 fiber analyzer (ANKOM Technology Corporation, Fairport, NY, USA).

The forage used to estimate the chemical composition of each plot was obtained exclusively from samples collected during the rainy season of each year. Subsequently, the predried and ground forage was pooled to form a composite sample, which provided a single value for each trait in each year.

2.6 | Statistical Model and Analysis

The statistical model was:

$$\hat{Y}_{ijk} = \mu + P_i + B_k + E_{ik} + S_j + PS_{ij} + E_{ijk}$$

Y_{ijk}: observed value of the response variable in the i-th plot, j-th block, and k-th observation; μ: Overall mean; P_i: effect of the i-th genotype (plots); B_k: effect of the k-th block; E_{ik}: experimental error associated with plots within blocks; S_j: effect of the year (subplots); PS_{ij}: interaction effect between genotype and year; E_{ijk}: residual error term associated with each observation within the combination of genotype, block, and year.

The data were subjected to analysis of variance (ANOVA), considering the effects of genotype and year of evaluation, with decomposition performed in cases of significant interaction. Genotype means were compared using Tukey's test, while year means were evaluated using the F test, both at the 5% significance level. The same approach was applied when it was

necessary to partition and compare genotypes within years, as well as to assess differences among years for each genotype.

Residual variance-covariance structures were evaluated to model correlated errors from repeated measures. The tested structures included variance components, unstructured model, compound symmetry, autoregressive, and heterogeneous autoregressive. The matrix with the lowest Akaike and Bayesian Information Criterion values was selected. Statistical analyses were performed using R Studio (R Core Team 2024), with the "*EasyAnova*" package (Arnhold 2013).

3 | Results

A significant effect of the genotype factor ($p < 0.05$) was observed for most variables: plant height (PH), forage dry mass (FDM), leaf percentage (%LEAF), stem percentage (%STE), senescent forage percentage (%SEN), leaf dry mass (LDM), leaf to stem ratio (LSR), with emphasis on inflorescence percentage (%INF), and most bromatological variables. The year modified the response of all variables ($p < 0.0001$). The genotype × year controlled only the %INF, suggesting differential responses across years for certain genotypes. Coefficients of variation were acceptable for most variables (Table 1).

The genotypic differences observed in PH have direct practical implications for forage management, as taller plants like Biloela are often associated with higher productivity, while morphological characteristics like LSR directly influence forage quality. Comparison of agronomic trait means among genotypes revealed significant differences in PH, FDM, LDM, and LSR. The Biloela genotype showed the highest values for PH (48.8 cm), FDM (4615.2 kg ha^{-1} year), and LDM (2388.3 kg ha^{-1} year) (Table 2). Conversely, the Grass genotype had the highest LSR (3.0), indicating a greater proportion of leaves relative to stems.

The high PH observed in Biloela was associated with its taller type. Interestingly, the Áridus and Buffel 131 genotypes, considered medium types, did not differ statistically from Biloela (Table 3), likely due to their adaptation to the environment and enhanced vertical growth. Grass, a smaller type, maintained that characteristic in the trial.

TABLE 2 | Agronomic characteristics of buffelgrass forage from six genotypes in the semi-arid region of Minas Gerais, Brazil.

	Variables			
Genotypes	PH (cm)	FDM (kg ha^{-1} year)	LDM (kg ha^{-1} year)	LSR
Áridus	46.4ab	3909.9ab	2125.6ab	2.7ab
Buffel 131	44.9ab	3635.2b	2034.9ab	2.8ab
Biloela	48.8a	4615.2a	2388.3a	2.1b
Common	40.0bc	3599.5b	1797.6b	2.2ab
Grass	38.9bc	3526.7b	1894.8ab	3.0a
USA	35.1c	3417.9b	1693.4b	2.7ab
Mean	34.23	3784.07	1989.10	2.58
SEM	1.67	272.24	167.18	0.28

Note: Means followed by the same letter in the column do not differ according to Tukey's test at the 5% of probability level.
Abbreviation: FDM, Forage dry mass (kg ha^{-1} year); LDM, Leaf dry mass (kg ha^{-1} year); LSR, Leaf to stem ratio; PH: Average plant height of genotypes (cm); SEM, standard error of the mean.

Regarding plant-part composition, Áridus and Buffel 131 had the highest %LEAF values, at 54.8% and 55.0%, respectively. In contrast, the USA genotype had the highest %SEN (26.0%), which was statistically superior ($p < 0.05$) to all other genotypes (Table 3). This elevated %SEN in the USA genotype is indicative of high senescence or low leaf renewal, a characteristic that negatively impacts forage palatability and digestibility for grazing animals.

The genotypic performance was also significantly modulated by environmental conditions. Specifically, the year factor significantly

TABLE 1 | Summary of the analysis of variance and coefficient of variation (CV_a and CV_b) of agronomic and chemical characteristics of six buffelgrass genotypes in the semi-arid region of Minas Gerais, Brazil.

	p value of the source of variation					
Variables	Block	Genotype	Year	Genotype × Year	CV_a (%)	CV_b (%)
PH	<0.0001	0.0002	0.0003	0.2014	11.95	21.67
FDM	<0.0001	0.0021	<0.0001	0.8719	17.63	19.27
LDM	<0.0001	0.0047	<0.0001	0.9498	20.59	20.27
%INFL	0.2273	<0.0001	<0.0001	<0.0001	39.00	32.17
%LEA	0.2446	0.0002	0.0096	0.1189	6.57	7.13
%STE	0.0568	0.0002	<0.0001	0.9185	10.35	12.17
%SEN	0.0060	<0.0001	<0.0001	0.1817	12.56	16.63
LSR	0.5867	0.0215	0.0001	0.1252	26.37	32.19
CP	0.4896	0.0916	<0.0001	0.2541	14.55	12.08
ASH	0.3953	0.0617	<0.0001	0.1208	8.62	8.13
NDF	0.5875	0.0060	<0.0001	0.3304	2.54	2.60
ADF	0.7301	<0.0001	<0.0001	0.2034	3.27	3.89

Abbreviation: ADF, acid detergent fiber; ASH, ash; CP, Crude protein; CVa (%), Coefficient of variation among plots; CVb (%), Coefficient of variation among plots over time; FDM, Forage dry mass; %INF, Percentage of inflorescences; LDM, Leaf dry mass; %LEA, Percentage of leaf blade; LSR, Leaf-to-stem ratio; NDF, neutral detergent fiber; PH: Average canopy height; %SEN, Percentage of senescent forage.

TABLE 3 | Plant-part composition of buffelgrass forage from six genotypes in the semi-arid region of Minas Gerais, Brazil.

	Plant-part composition (%)			
Genotypes	**Leaf blade**	**Stem + sheath**	**Senescent forage**	**Inflorescences***
Áridus	54.81a	24.36abc	18.55b	2.27
Buffel 131	55.03a	23.46bc	20.35b	1.15
Biloela	51.42abc	27.13a	19.88b	1.58
Common	49.46bc	26.29ab	19.50b	4.76
Grass	53.47ab	22.53c	21.81b	2.20
USA	48.86c	22.26c	25.99a	2.89
Mean	52.17	24.34	21.01	2.47
SEM	1.40	1.03	1.08	0.39

Note: Means followed by the same letter in the column do not differ according to Tukey's test at the 5% of probability level. *Inflorescence percentages by genotype × year interaction are shown in Table 7.
Abbreviation: SEM, standard error of the mean.

TABLE 4 | Agronomic characteristics of buffelgrass forage across 2 years of evaluation in the semi-arid region of Minas Gerais, Brazil.

	Variables			
Year	**PH (cm)**	**FDM (kg ha^{-1} year)**	**LDM (kg ha^{-1} year)**	**LSR**
2022	45.2a	4588.6a	2462.0a	3.0a
2023	39.6b	2977.1b	1516.2b	2.2b
Mean	34.2	3782.8	1989.1	2.60
SEM	1.23	121.50	67.20	0.12

Note: Means followed by the same letter in the column do not differ according to F test at the 5% of probability level.
Abbreviation: FDM, Forage dry mass (kg ha^{-1} year); LDM, Leaf dry mass (kg ha^{-1} year); LSR, Leaf to stem ratio; PH: Average plant height of genotypes (cm); SEM, standard error of the mean.

affected the average PH of buffelgrass genotypes during the trial (Table 4). In the first year, PH (45.2 cm), FDM (4588.6 kg ha^{-1} year), LDM (2462.0 kg ha^{-1} year), and LSR (3.0) were all higher compared to the second year, suggesting more favorable edaphoclimatic conditions, which promoted greater biomass accumulation.

The improved conditions in the first year led to greater overall growth, but the second year favored a better structural composition. As for %LEAF, the second year recorded a value 5.1% higher than in the first year (Table 5). Conversely, the %STE component was 33.01% lower in the final year. The %SEN was also notably higher in the first year, with an 81.88% increase over the second year (Table 5).

Despite the general year-to-year differences, the genotype × year interaction modified the %INF of the genotypes (Table 6). The year effect within each genotype indicated a higher inflorescence proportion in year two for all genotypes except Biloela, which maintained stable values across years.

The structural components of the plant, such as fiber, showed a consistent response pattern. The genotype and year of evaluation controlled the NDF and acid ADF contents of forage in buffelgrass genotypes with no interaction (Tables 7 and 8).

During the rainy season, the Biloela genotype exhibited higher NDF concentrations compared to Áridus, Buffel 131, and Grass (Table 7). Following this trend, the variation in ADF content was more pronounced than that observed for NDF, indicating high divergence in the less digestible fiber fractions among the evaluated genotypes (Table 7). Biloela exhibited the highest ADF content, which was accompanied by elevated NDF levels. In contrast, the lowest ADF concentration was observed in the Buffel 131 genotype, which did not differ statistically from Áridus and Common. The increase in ADF content in Biloela compared to Buffel 131 was 11.10%. The genotypes Áridus, Common, Grass, and USA showed intermediate ADF values, with no significant differences among them (Table 7).

The evaluation year influenced the expression of NDF and ADF contents (Table 8). In the first year, forage samples exhibited higher concentrations of NDF (+7.45%) and ADF (+22.48%) compared to the second year, with the ADF increase being more pronounced than that of NDF. These results suggest the first year provided favorable conditions for plant growth, accelerating vegetative development and altering tissue composition. This led to a greater proportion of structural plant components, such as senescent leaves and stems, contributing to both elevated fiber content and increased forage biomass.

Finally, the chemical composition related to animal nutrition also showed interannual variability. The year had a significant effect on CP levels in the genotypes during the rainy season, without genotype or interaction effect. CP content in the second year was 20.35% higher than in the first year (Table 8). Similarly, ash content (ASH) increased by 9.63% in the second year (Table 8). The interannual variability in CP and ASH contents during the

TABLE 5 | Plant-part composition of buffelgrass forage across 2 years of evaluation in the semi-arid region of Minas Gerais, Brazil.

	Plant-part composition (%)			
Year	**Leaf blade**	**Stems + sheath**	**Senescent forage**	**Inflorescences***
2022	50.9b	20.9b	27.1a	1.10
2023	53.5a	27.8a	14.9b	3.80
Mean	52.20	24.35	21.00	2.45
SEM	0.62	0.49	0.58	0.13

Note: Means followed by the same letter in the column do not differ according to F test at the 5% of probability level. *Inflorescence percentages by genotype × year interaction are shown in Table 6.
Abbreviation: SEM, standard error of the mean.

TABLE 6 | Percentage of inflorescences of buffelgrass forage from six genotypes over 2 years in the semi-arid region of Minas Gerais, Brazil.

	Percentage of inflorescences (%)		
Genotype	**2022**	**2023**	**Mean of genotype**
Áridus	0.74Bb	3.80Ab	2.27
Buffel 131	0.27Bb	2.04Ac	1.15
Biloela	1.29Aab	1.86Ac	1.58
Common	2.32Ba	7.20Aa	4.75
Grass	0.39Bb	4.00Ab	2.19
USA	1.63Bab	4.14Ab	2.89
Mean of year	1.11	3.84	
SEM	0.32		

Note: Means followed by the same uppercase letter in the row and the same lowercase letter in the column are not statistically different according to the F test at the 5% probability level.
Abbreviation: SEM, standard error of the mean.

TABLE 7 | Neutral detergent fiber (NDF) and acid detergent fiber (ADF) of buffelgrass forage from six genotypes during the rainy season in the semi-arid region of Minas Gerais, Brazil.

	Content (g kg^{-1})	
Genotypes	**Neutral detergent fiber**	**Acid detergent fiber**
Áridus	626.6b	355.4bc
Buffel 131	628.8b	345.3c
Biloela	653.3a	383.6a
Common	634.1ab	358.4bc
Grass	638.8ab	367.3b
USA	632.3b	362.9b
Mean	635.3	362.1
SEM	6.58	8.12

Note: Means followed by the same letter in the column do not differ according to Tukey's test at the 5% of probability level.
Abbreviation: SEM, standard error of the mean.

TABLE 8 | Crude protein (CP), ash (ASH), neutral detergent fiber (NDF), and acid detergent fiber (ADF) of buffelgrass forage across 2 years of genotype evaluation in the semi-arid region of Minas Gerais, Brazil.

	Content (g kg^{-1})			
Year	**CP**	**ASH**	**NDF**	**ADF**
2022	84.5b	104.9b	658.5a	398.8a
2023	101.7a	115.0a	612.8b	325.6b
Means of year	93.1	109.9	635.6	362.2
SEM	1.87	1.49	2.75	2.04

Note: Means followed by the same letter in the column do not differ according to F test at the 5% probability level.
Abbreviation: SEM, standard error of the mean.

rainy season underscores the substantial influence of edaphoclimatic conditions on the chemical composition of forage (Table 8).

4 | Discussion

These results reinforce the potential of buffelgrass *C. ciliaris* as a prominent forage species for semi-arid environments. Its ability to maintain productivity and nutritive value under water stress conditions is crucial. The evaluation of agronomic, morphological, and bromatological traits revealed consistent differences between genotypes and years, indicating not only significant genetic variation but also a strong interaction with local environmental conditions. The genotype × environment interaction highlights the importance of selecting regionally adapted ecotypes to enhance forage production and quality, tailored to the unique challenges of semi-arid climates (Sánchez-Gutiérrez et al. 2024). This diversity is essential for breeding programs aimed at improving forage crops for these regions (Carloni et al. 2017).

Management practices can be optimized by considering the morphological characteristics of the genotypes. For instance, the Biloela, Buffel 131, and Áridus genotypes, which exhibited high PH and FDM (Table 2), may be best managed at heights near 40 cm to optimize agronomic traits and improve forage nutritive value (Elizondo-Salazar 2017).

Similar trends have been observed in other forage species, where taller cutting heights improve nutritive value by increasing CP and reducing fiber content (Borreani et al. 2006). This occurs because the most fibrous and least digestible parts, typically near the ground, are not harvested at taller cutting heights. This strategy may also shorten the regrowth interval, allowing more harvests during the rainy season (Oliveira et al. 2024).

Regarding leaf composition, as detailed in Table 3, the Áridus and Buffel 131 genotypes recorded the highest %LEAF. Conversely, the USA genotype consistently displayed the highest %SEN across both evaluation years (Table 3), indicating a tendency toward advanced plant maturity or susceptibility to stress factors (Carnevalli et al. 2006).

The consistently high %SEN observed in the USA genotype across years, as detailed in Table 3, may be attributed to advanced plant maturity, as reported in a study on forage accumulation in C4 perennial grass (Carnevalli et al. 2006). Additionally, stress factors such as water deficit or excess (Beloni et al. 2018), nitrogen deficiency, and pest or disease incidence can also contribute to increased senescence. Across both years, all genotypes showed leaf spot symptoms resembling blast (*Magnaporthe grisea*). The USA genotype was the most affected, which may explain its elevated %SEN.

In terms of physiological mechanisms, the high senescence rate in the USA genotype may reflect a biomass investment response that, after reaching a critical leaf area index, leads to intense competition for light and the shading of lower leaves. This shading induces chlorophyll degradation and nutrient translocation, an energy-saving mechanism that manifests as increased %SEN (Macedo et al. 2021). The persistence of this characteristic suggests an intrinsic carbon allocation strategy in the USA genotype, which negatively affects forage quality.

The impact of interannual variation on plant characteristics is a crucial factor for management. The increases in PH, FDM, and LSR in the first year, as indicated in Tables 1 and 3, reflect higher water availability and soil fertility. This interpretation aligns with the findings of Liu et al. (2021), who demonstrated that seasonal precipitation is a major determinant of forage yield variability in perennial grasses.

The more favorable environmental conditions in the first year resulted in greater development and maturation of vegetative structures, evidenced by the higher %STE and %SEN (Table 5). Advancement in shoot development brings about changes in growth patterns, with leaf accumulation predominating in the early stages after defoliation. Achieving the critical LAI marks a significant change in the light environment with high competition that drives plants to increase stem accumulation and, consequently, accumulate senescent leaves (Macedo et al. 2021).

The environmental conditions of the first year, which favored biomass production, also led to higher fiber content, with superior NDF and ADF (Table 8). This is due to the greater accumulation of structural components (%STE and %SEN), which are rich in cellulose and lignin, compared to the second year. Conversely, the second year, with less favorable conditions for vegetative growth, induced the flowering in most genotypes, with %INF (inflorescence percentage) more than doubling compared to the first year (Table 6).

The genotype x year interaction for %INF (Table 6) confirms that reproductive expression in buffelgrass is highly sensitive to both genetic constitution and annual environmental variation. The increase in %INF observed in the second year indicates that buffelgrass responds to low water availability by enhancing inflorescence emission. This species flowers earlier than most tropical plants (Rodríguez-Ortega et al. 2022), and stressful factors such as fire tend to promote its spread (Ryan-Colton et al. 2024). Moreover, this response is associated with a reduced biomass at the end of the dry season and the onset of the rainy period.

Inflorescence was the only variable with a differential response because the physiological mechanisms of floral transition are extremely sensitive to environmental cues such as water stress. This stress acts as a survival trigger that overrides genetic variation in the reproductive phase, altering the ranking of genotypes (Table 6), while most vegetative traits (PH, FDM, LSR) maintained more consistent genetic expression. The stability of Biloela, which maintained consistent %INF values (Table 6), suggests lower phenotypic plasticity in reproductive terms, which can be desirable in forage systems that demand predictability and consistent forage quality (Sánchez-Gutiérrez et al. 2024).

The %INF result is valuable information for the producer and should be used as an indicator of stress and a decline in forage quality. A high %INF in the second year, indicative of water stress, signals the need for quicker management intervention.

The producer should anticipate the grazing or cutting frequency to avoid the drop in forage quality caused by the lignification of inflorescences and the increase in NDF and ADF.

In less favorable years, characterized by lower FDM (Table 4), the stocking rate must be reduced or the grazing period shortened to avoid overgrazing and pasture degradation. The higher LSR and %LEAF in the second year, despite the lower FDM, indicate that the remaining forage had better structural quality but was in smaller volume.

The observation that NDF and ADF were more influenced by the year than by the genotype (Table 8) emphasizes that environmental conditions are the main driver of nutritional quality. The increase in CP in the second year may indicate a higher concentration of nitrogen in the leaf structures due to less nutrient dilution in smaller biomass, highlighting the need to adjust the fertilization plan to the expected precipitation.

5 | Conclusion

The results demonstrate striking differences among the six buffelgrass genotypes evaluated, confirming wide variability in agronomic performance, morphological attributes, and bromatological composition under semi-arid conditions. Biloela showed the greatest biomass accumulation and superior agronomic performance, while Áridus and Buffel 131 stood out for their higher proportion of leaves and better structural quality of the forage. The strong influence of the evaluation year on all variables reinforces that the phenotypic expression of these genotypes is highly sensitive to edaphoclimatic variations, with the percentage of inflorescences being the most responsive trait to environmental stress.

Based on the set of productive and qualitative attributes, the Biloela, Áridus, and Buffel 131 genotypes appear to be the most suitable for forage systems in the semi-arid region of Minas Gerais. Furthermore, the differentiated sensitivity of genotypes to reproductive induction offers strategic information for management and breeding programs, especially in scenarios of increasing climate instability. The identified genetic variability constitutes a strategic resource for selecting more productive, stable, and adapted materials, strengthening the advancement of technologies aimed at improving forage grasses in semi-arid regions.

Author Contributions

In supplementary files to avoid exposing the authors' identities.

Acknowledgments

The authors gratefully acknowledge the financial support provided by Barenbrug do Brasil and FAPEMIG (grant code APQ-02257−21) to this research, as well as CAPES (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior, Finance Code 001) for the scholarship.

The Article Processing Charge for the publication of this research was funded by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) (ROR identifier: 00x0ma614).

Funding

The authors have nothing to report.

Conflicts of Interest

The authors declare no conflicts of interest.

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