Availableonlineathttp://www.journalijdr.com

IJDR

International Journal of Development Research
Vol. 16, Issue, 06, pp.70567-70573, June, 2026
https://doi.org/10.37118/ijdr.30940.06.2026

ISSN: 2230-9926

REVIEW ARTICLE

OPEN ACCESS

EFFECTS OF CUTTING HEIGHT AND AGE AT HARVEST ON CHEMICAL COMPOSITION OF ELEPHANT GRASS *(PENNISETUMPURPUREUM* "SCHUMACH."*)* GROWN IN THE SOUTH-EASTERN NIGERIA

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ARTICLE INFO

Article History:

Received 19th March, 2026
Received in revised form
14th April, 2026
Accepted 20th May, 2026
Published online 30th June, 2026

Key Words:

Elephant Grass, Chemical Composition, Forage Quality, Cutting Height, Harvest age.

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ABSTRACT

The nutritive value of grass for livestock is influenced by the dry matter consumed, its chemical composition, and digestibility. The study, conducted at the Teaching and Research Farm of Michael Okpara University of Agriculture, Umudike, aimed to investigate the effect of cutting height and harvest age on the organic chemical composition of Elephant grass (*Pennisetum purpureum* Schumach). Using a 4 x 3 factorial layout in a Completely Randomized Block Design with three replicates, the study involved treatments of four cutting heights (0, 10, 20, and 30 cm) and three harvest ages (30, 60, and 90 days), totaling twelve treatments. Field underwent a standard preparation, divided into blocks (2.5m x 34.3m) and plots (2.5m x 2m). Basal NPK 15:15:15 applied at 100 – 150 kg/ha by broadcasting. Crown splits were planted at 50 x 40 cm spacing (5 rows/plot, 5 stands/row). Harvested forage was weighed, dried and the ground subsamples sent for chemical composition parameters analyses using a standard scientific method. Data collected were analyzed using Genstat statistical package and mean separation was carried out using Fishers' least significant difference. Results showed that with a 90-day harvest, grass dry matter, carbohydrate, ether extract, and essential minerals contents, significantly increased ($P<0.05$), while phytate, cyanogenic glycoside, and flavonoid contents significantly decreased ($P<0.05$). Additionally, a 30-day harvest yielded higher crude[44] protein and ash contents, with lower crude fiber, alkaloid, and saponin contents compared to 60 or 90 days. Therefore, cutting height and harvest age can significantly enhance the nutritive value of Elephant grass for livestock.

Citation: ***Onya, Godswill Uzoma; Essen, Paulinus Ogbonnaya; Njoku, Godwin Nnamdi; Okoro, Damian Chukwunyerem.*** **et al., 2026.** *"*Effects of Cutting Height and Age at Harvest on Chemical Composition of Elephant Grass *(Pennisetumpurpureum* "Schumach."*)* Grown in the South-Eastern Nigeria.*"* **International Journal of Development Research, 16 (06), 70567-70573.**

INTRODUCTION

Livestock production plays a crucial role in subsistence crop-livestock mixed farming systems. The deterioration of natural pasture lands has resulted in a reduction of available fodder for livestock. As the population grows, the number of livestock also rises, leading to greater food requirements for fodder. This necessitates finding alternative methods to supply feed, particularly during the dry season. Green fodders play a crucial role in sustainable livestock production (Mohammed and Adar, 2021). Livestock cannot do without feed, with green feed providing approximately all the nutrients required by animals. Elephant grass (*Pennisetum purpureum* Schumach) is a fast-growing perennial found in Sub-Saharan Africa and widely cultivated in tropical and subtropical regions (Negawo *et al.*, 2017). It became ready for harvesting within 3-4months after planting and harvesting can continue at an interval of 6-8 weeks for more than five years where there is no moisture stress and fertility problem.

Elephant grass is renowned for its high production potential and nutritional value. This deeply rooted perennial plant can grow up to four meters tall, spreading through underground stems to form a thick ground cover that remains in the land for extended periods. It is highly valued for its abundant herbage yield, palatability, and excellent fodder quality throughout the year. Elephant grass grows rapidly, producing substantial herbage, and has tough stems. With proper agronomic and management practices, Elephant grass can significantly contribute to biomass production (Getiso and Mijena, 2021).
The nutrient value of grasses decreases as they mature. According to Manyawu *et al.* (2003), there is a significant effect of growth stage on yield and quality, with a cutting interval of six to seven weeks being optimal for Napier grass and Hybrid Pennisetums. Ansah *et al.,* (2010) found the highest crude protein concentration but the lowest dry matter yield when harvested at intervals shorter than nine weeks in the local variety of Napier grass. Lounglawan *et al.,* (2014) recommended harvesting Napier grass (Pennisetum purpureum x Pennisetum americanum) at six to eight weeks of growth to optimize dry matter yield and nutritive value. Haryani *et al*., (2021) reported that dry matter yield production increased with longer cutting intervals (6th, 7th and 8th weeks old). However, the crude protein value decreased as the harvesting interval lengthened. Therefore, they recommended to harvest Napier Pakchong at 7 to 8 weeks to achieve optimal dry matter yield and nutritive value. These findings highlight the importance of an optimal cutting interval and its varying effects on yield and quality. When choosing forage species for cultivation, it's essential to consider nutrient composition and yield (Yusuf *et al.,* 2022). The concentration of anti-nutrients in forage species depends on the seasonal climate, environmental conditions, and management practices (Salakinkop *et al.,* 2020). Anti-nutrients, like hydrogen cyanide, glycosides, and tannins, can negatively impact livestock performance by reducing forage intake and digestibility, leading to nutritional imbalances (Diribi and Fromsa, 2024; Dingfu and Tiantian, 2024; Song *et al.,* 2023). Studying the impacts of agricultural practices on Elephant grass fodder is crucial for optimal yield and quality. There is limited information on how cutting height and harvest age affect the dry matter yield and chemical composition of Elephant grass. This research aims to investigate these effects.

MATERIALS AND METHODS

Experimental site: The study was carried out at the center described by Essen *et al.* (2024).

Analytical Procedures and Data Collection

Dry matter of fraction: Two treatments used for the experiment comprised cutting height (0cm, 10cm, 20cm, and 30cm) and age at harvest (30days, 60days and 90days). The harvested herbage was divided into grass and weed fractions and weighed separately. Sub-samples of grass species, each weighing 100g, were placed in paper envelopes and dried in a forced-air oven at 80°C until they reached a constant weight. The dry matter yield and dry matter content of the herbage were then calculated as follows:

Total dry weight of herbage (kg/ha)

$$= \frac{Dry\ weight\ of\ sample\ (Kg)}{Sample\ fresh\ weight\ (Kg)}\ x\ \frac{Total\ fresh\ weight\ of\ herbage}{Sample\ area\ (m^2)}\ x\ \frac{10{,}000m^2}{1}$$

$$\text{Dry matter content (\%)} = \frac{Dry\ weight\ of\ sample\ (g)}{Sample\ fresh\ weigh\ \ (g)}\ x\ \frac{100}{1}$$

Chemical evaluation: The proximate and essential mineral analyses followed the AOAC (2000) recommended method. Parameters determined included Moisture, Ash, Crude fiber (CF), Ether extract (EE), Manganese, Zinc, Iron, Sodium, Magnesium, Phosphorus, Potassium and Calcium contents of the samples, while Carbohydrate content was calculated as the Nitrogen free extractive (NFE) using the formula below:

% CHO (NFE) = 100 % – (Protein + Fat + Fiber + Ash + M.C). The Crude protein (CP) content of the sample was determined using the Macro-Kjeldahl method.

Anti-nutrients analysis parameters, including Tannin, Saponin, and Oxalate contents, as well as Phytate, Alkaloid and Hydrogen cyanide contents, were determined using the methods described by Pearson (1976), Rex *et al.* (1977), Harborne (1973), respectively. Nitrogen (N %) and hydrogen (H) contents were determined using the Micro-Kjeldahl distillation method as described by Pearson (1976) and Harborne (1973), respectively.

Experimental Design and Statistical Analysis: A 4 × 3 factorial arrangement was implemented in a completely randomized block design with three replications. The grasses were analyzed independently from the legumes. All data were statistically analyzed following Steel and Torrie's (1980) procedures for factorial experiments in a completely randomized block design, utilizing the GenStat (2009) statistical package. The Fisher’s least significant difference (F-LSD) method, as described by Obi (1986), was used to determine statistical significance among treatments.

RESULTS

The effects of cutting height and age at harvest on the anti-nutrient contents of Elephant grass are presented in Tables 1 and 2. Cutting height, as well as the interaction between cutting height and age at harvest, showed no significant (*P>0.05*) effect on phytate and alkaloid contents. However, age at harvest had a significant (*P<0.05*) effect on both phytate and alkaloid levels, with phytate decreasing progressively as the age at harvest increased, while alkaloid content increased. The mean alkaloid value was lowest at 30 days of harvest and highest at 90 days, whereas phytate showed the opposite trend.
Similarly, cutting height and the interaction between cutting height and age at harvest did not significantly (*P>0.05*) affect saponin content. Age at harvest, however, had a significant (*P<0.05*) influence, with saponin values increasing steadily from 0.85 mg/100g at 30 days to 0.88 mg/100g at 60 days and 1.79 mg/100g at 90 days. For tannin, oxalate, cyanogenic glycosides (CGL), and flavonoid contents, neither cutting height nor the interaction between cutting height and age at harvest had significant effects (*P>0.05*). Age at harvest, on the other hand, significantly (*P<0.05*) affected CGL and flavonoid levels. Both decreased progressively as the plant matured, with CGL values declining due to metabolic degradation and utilization during maturation, and flavonoid content reducing in association with increased less digestible carbohydrates and decreased crude protein content as the grass aged. The effects of cutting height and age at harvest on the essential mineral contents of Elephant grass are presented in Table 3 and 4. The results revealed that cutting height and cutting height × age at

Table 1. Effects of cutting height and age at harvest on ant-nutrient contents (TAN, PHY, ALK and SAP) of Elephant grass

	Age at harvest (days)				Age at harvest (days)				Age at harvest (days)				Age at harvest (days)			
CH (cm)	30	60	90	Mean	30	60	90	Mean	30	60	90	Mean	30	60	90	Mean
TAN (mg/100g)					PHY (mg/100g)				ALK (mg/100g)				SAP (mg/100g)			
0	0.22	0.21	0.20	0.21	9.93	9.48	8.23	9.21	2.50	2.53	2.90	2.64	0.85	0.89	1.76	1.17
10	0.21	0.21	0.20	0.21	9.49	9.39	8.23	9.04	2.49	2.51	2.90	2.63	0.85	0.88	1.78	1.17
20	0.21	0.21	0.20	0.21	9.30	9.23	8.46	9	2.50	2.51	2.90	2.64	0.86	0.88	1.73	1.16
30	0.21	0.21	0.19	0.20	9.23	9.11	8.51	8.95	2.51	2.54	2.88	2.64	0.85	0.87	1.93	1.22
Mean	0.21	0.21	0.20	0.21	9.49	9.30	8.36	9.05	2.50	2.52	2.90	2.64	0.85	0.88	1.79	1.17
$LSD_{0.05}$				TAN				PHY				ALK				SAP
Cutting height				NS				NS				NS				NS
Age				NS				0.03				0.04				0.01
CH *Age				NS				NS				NS				NS

CH= Cutting height; TAN=Tannin; PHY=Phytate; ALK= Alkaloid; SAP= Saponin.

Table 2. Effects of cutting height and age of harvest on anti-nutrient contents of Elephant grass: OXA, CGL and FLA

	Age at harvest (days)				Age at harvest (days)				Age at harvest (days)			
Cutting height (cm)	30	60	90	Mean	30	60	90	Mean	30	60	90	Mean
OXA (mg/100g)					CGL (mg/100g)				FLA (mg/100g)			
0	4.39	4.39	4.39	4.39	1.80	1.61	1.30	1.57	3.67	2.85	2.02	2.85
10	4.39	4.39	4.39	4.39	1.80	1.61	1.30	1.57	3.65	2.85	2.04	2.85
20	4.39	4.39	4.39	4.39	1.81	1.61	1.30	1.57	3.65	2.85	2.04	2.85
30	4.39	4.39	4.39	4.39	1.80	1.60	1.30	1.57	3.64	2.83	2.04	2.84
Mean	4.39	4.39	4.39	4.39	1.80	1.61	1.30	1.57	3.65	2.85	2.03	2.84
$LSD_{0.05}$				OXA				CGL				FLA
Cutting height				NS				NS				NS
Age				NS				0.02				0.02
Cutting height *Age				NS				NS				NS

OXA= Oxalate, CGL = Cyaegenic glycocides, FLA = Flavonoid

Table 3: Effects of cutting height and age at harvest on mineral contents of Elephant grass: Fe, Mn, Zn, and Na

	Mineral Content Parameters															
	AGE AT HARVEST (DAYS)				AGE AT HARVEST (DAYS)				AGE AT HARVEST (DAYS)				AGE AT HARVEST (DAYS)			
Cutting height (cm)	30	60	90	Mean	30	60	90	Mean	30	60	90	Mean	30	60	90	Mean
Fe (mg/100g)					Mn (mg/100g)				Zn (mg/100g)				Na (mg/100g)			
0	2.96	2.74	3.68	3.13	0.89	0.33	0.93	0.72	0.73	0.91	0.94	0.86	7.68	9.93	9.18	8.93
10	2.96	2.74	3.68	3.13	0.89	0.33	0.94	0.72	0.73	0.91	0.95	0.86	7.68	9.93	9.19	8.93
20	2.96	2.73	3.68	3.12	0.88	0.33	0.94	0.72	0.73	0.91	0.95	0.86	7.68	9.93	9.19	8.93
30	2.96	2.74	3.68	3.13	0.88	0.33	0.94	0.72	0.73	0.91	0.96	0.87	7.68	9.93	9.19	8.93
Mean	2.96	2.74	3.68	3.13	0.89	0.33	0.94	0.72	0.73	0.91	0.95	0.86	7.68	9.93	9.19	8.93
$LSD_{0.05}$				Fe				Mn				Zn				Na
Cutting height				NS				NS				NS				NS
Age				0.03				0.02				0.02				0.02
Cutting height *Age				NS				NS				NS				NS

Fe= Iron, Mn= Manganese, Zn= Zinc, Na= Sodium.

Table 4. Effects of cutting height and age of harvest on mineral contents of Elephant grass: Mg, P, K and Ca

	Mineral Content Parameters															
	AGE AT HARVEST (DAYS)				AGE AT HARVEST (DAYS)				AGE AT HARVEST (DAYS)				AGE AT HARVEST (DAYS)			
Cutting height (cm)	30	60	90	Mean	30	60	90	Mean	30	60	90	Mean	30	60	90	Mean
	Mg (mg/100g)				P (mg/100g)				K (mg/100g)				Ca (mg/100g)			
0	0.19	0.30	0.38	0.29	12.28	15.08	17.91	15.09	4.80	3.16	8.53	5.50	0.52	0.68	0.74	0.65
10	0.19	0.30	0.38	0.29	12.28	15.08	17.91	15.09	4.80	3.16	8.53	5.50	0.52	0.68	0.74	0.65
20	0.19	0.30	0.38	0.29	12.28	15.08	17.91	15.09	4.79	3.16	8.53	5.49	0.52	0.68	0.74	0.65
30	0.19	0.30	0.38	0.29	12.28	15.08	17.91	15.09	4.80	3.16	8.53	5.50	0.52	0.68	0.74	0.65
Mean	0.19	0.30	0.38	0.29	12.28	15.08	17.91	15.09	4.80	3.16	8.53	5.50	0.52	0.68	0.74	0.65
$LSD_{0.05}$				Mg				P				K				Ca
Cutting height				NS				NS				NS				NS
Age				0.01				0.01				0.01				0.01
Cutting height *Age				NS				NS				NS				NS

Mg= Magnesium, P= Phosphorus, K= Potassium, Ca= Calcium

Table 6. Effects of cutting height and age at harvest on nutrient content of Elephant grass: Ash, CHO and DMC

	Age at harvest (days)					Age at harvest (days)					Age at harvest (days)			
Cutting height (cm)	30	60	90	Mean		30	60	90	Mean		30	60	90	Mean
	Ash (%)					CHO (%)					DMC (%)			
0	14.04	12.44	10.39	12.29		2.55	4.56	4.72	3.94		12.42	15.15	18.48	15.35
10	14.03	12.46	10.45	12.31		2.55	4.56	4.71	3.94		12.40	15.12	18.51	15.34
20	14.03	12.40	10.35	12.26		2.55	4.56	4.71	3.94		12.42	15.08	18.47	15.32
30	14.07	12.45	10.36	12.29		2.55	4.56	4.71	3.94		12.44	15.12	18.58	15.38
Mean	14.04	12.44	10.39	12.29		2.55	4.56	4.71	3.94		12.42	15.11	18.51	15.35
$LSD_{0.05}$				Ash					CHO					DMC
Cutting height				NS					NS					NS
Age				0.02					0.01					0.18
Cutting height *Age				NS					NS					NS

CHO= Carbohydrate; DMC= Dry Matter Content harvest interaction had no significant (*P>0.05*) effect on all the essential parameters determined. However, age at harvest had a significant (*P<0.05*) impact on all measured parameters, including iron, manganese, zinc, sodium, magnesium, phosphorus, potassium, and calcium contents.Manganese content was lowest at 60 days and highest at 90 days of harvesting. Zinc content increased progressively with plant age. Sodium content peaked at 60 days and was lowest at 30 days. The magnesium content of grass decreased significantly (*P<0.05*) with increase in age of plant. The phosphorus content increased (*P<0.05*) progressively with increase in age at harvest. The value of potassium recorded at 90 days of harvesting was higher than those at 30 or 60 days. There was a steady and significant (*P<0.05*) increase in the calcium content as the age at harvest increased. Table 5 and 6 presents the effects of cutting height and age at harvest on the proximate analysis of Elephant grass. The table indicates that cutting height and cutting height × age at harvest interaction had no significant (*P>0.05*) effect on the moisture content (MC) and crude protein (CP). However, age at harvest significantly (*P<0.05*)affected both MCand CP content, with values decreasing progressively from 88.78% and 11.26% at 30 days to 83.89% and 6.86% at 90 days, respectively.

The study found that cutting height, age at harvest, and their interaction significantly (*P<0.05*) affected the crude fiber (CF) content. A cutting height of 30 cm notably (*P<0.05*) lowered the CF content compared to other heights. CF content increased significantly (*P<0.05*) with age, reaching its peak at 90 days. The lowest CF content was observed with the combination of 30 days x 0 cm, while the highest was seen with 90 days x 20 cm. The cutting height and cutting height × age at harvest interaction had no significant (*P>0.05*) effect on the ether extract (EE), ash, carbohydrate (CHO), and dry matter (DM)contents. However, age at harvest significantly (*P<0.05*) influenced all the four parameters, with values generally increasing as the plant aged, except for ash content, which decreased progressively with age. The highest carbohydrate and DM contents were observed at 90 days, while the lowest were recorded at 30 days.

DISCUSSION

The findings of this study demonstrate that age at harvest plays a more critical role than cutting height in determining the anti-nutrient composition of Elephant grass. The progressive increase in alkaloid content with age at harvest can be attributed to their active biosynthesis and accumulation in the cells during plant growth (Kong *et al.,* 2017). This effect of age at harvest aligns with the findings of Sreelatha and Padma (2009), who reported an increase in alkaloid content with the aging of *Moringa oleifera* leaves. In contrast, phytate content declined as the grass matured, suggesting that phytates are gradually metabolized or diluted by structural carbohydrates during plant development. The results indicated that neither cutting height nor the interaction between cutting height and age at harvest had a significant effect on saponin content. However, the age at harvest significantly influenced saponin content, which increased progressively from 0.85 mg/100g at 30 days to 0.88 mg/100g at 60 days and 1.79 mg/100g at 90 days. The increase in saponin content in Elephant grass as it ages may be due to the rates of metabolic catabolism and biosynthesis. This process can be influenced by hormonal balance or directly controlled by enzymes and the balance of their substrates (Siqueira *et al.,* 1991). Additionally, factors such as carbohydrate levels, nutrition, and water quality can affect the biosynthesis of saponin. The table showed that cutting height, age at harvesting, and the interaction between cutting height and age at harvest had no significant effect on the tannin, oxalate, Cyanogenic glycosides (CGL), and flavonoid contents of Elephant grass. However, the age at harvest had a significant effect on CGL and flavonoid contents, with their values decreasing progressively as the plant's age at harvest increased. The decrease observed in CGL content with the age at harvest may be due to metabolic degradation and utilization during plant maturation (Green and Fry, 2005). As Elephant grass matures, the flavonoid content decreases significantly. This decrease is closely linked to an increase in less digestible carbohydrates and a reduction in crude protein content as the grass ages (Kaplan *et al.,* 2014).These changes reflect the natural shift in plant composition as grasses mature, with younger plants generally richer in secondary metabolites and protein, while older plants accumulate more fibrous material.

Overall, the results emphasize that while cutting height has little influence on anti-nutrient levels, the age at harvest significantly alters the phytochemical profile of Elephant grass. Younger plants tend to have higher phytate and flavonoid contents, whereas older plants accumulate more alkaloids and saponins. This knowledge is valuable for optimizing harvest strategies to balance nutritional quality and anti-nutrient levels in forage production systems. The increase observed in iron content with the age at harvest is in agreement with the report of Oduntan *et al.* (2011). The tapering off in the contents of iron during the latter ages at harvest may indicate the diversion of these minerals to flower development (Khader and Rama, 1998). Such redistribution of minerals is an example of nutrient conservation, where limiting nutrients may be reclaimed from senescing tissues and translocated to other parts where they are reutilized (Flyman and Afolayan, 2008). The manganese concentration of the grasses in this study as influenced by age at harvest is in agreement with the findings by Cheema *et al.* (2011) The observed increase in the concentration of zinc content of Elephant grass with increase in age at harvest may be attributed to the high mobility of the mineral (Taiz and Zeiger, 2002) The variations in sodium content as affected by age at harvest is similar to the findings of Olanite *et al.* (2006) who submitted that the age of harvest was undoubtedly a critical factor that impacted the grass sodium mineral composition. The observed increase in phosphorus content with age at harvest was similar to the observations of Makobo *et al.* (2010). The phosphorus element is also involved in controlling keys enzyme reactions and in metabolic pathway regulation (Wang *et al.,* 2013). Potassium plays a crucial role in plant growth, metabolism, and stress tolerance. It contributes greatly to plant survivability that is under various biotic and abiotic stresses (White and Broadley, 2003). The results of this study showed that the potassium content decreased as age increased, and this corroborates the findings of Rahman *et al.* (2006). The potassium element is essential for structural development of the cell wall and membrane of the plant (Miller, 1999). Overall, the results highlight that while cutting height has little influence, age at harvest significantly alters the mineral composition of Elephant grass. Younger plants tend to have higher magnesium and sodium levels, whereas older plants accumulate more iron, manganese, zinc, phosphorus, potassium, and calcium. These findings provide practical insights for optimizing harvest timing to balance mineral nutrition in forage production systems. The results obtained in this present study are in agreement with previous findings. Lounglawn *et al.,* (2014) and Essen *et al*., (2025) reported that increasing the cutting interval (i.e. advancing age of maturity) increased dry matter, crude fiber, and nutrient yield significantly but decreases crude protein percentage. Mohammed and Adar (2021) concluded in their work that the cutting periods significantly affectedorganic matter components of Napeir grass forage which supports the result of this present study. Thus, the study confirms that while cutting height plays a minor role in nutrient composition, the age at harvest is a critical determinant of forage quality in Elephant grass. Strategic harvest management is therefore essential to optimize both yield and nutritional value.

CONCLUSION

Grass dry matter content, carbohydrate content, ether extract, and the contents of iron, manganese, zinc, magnesium, phosphorus, potassium, and calcium in the grass species were significantlyincreased at 90 days of harvest compared to other harvest periods. Meanwhile, the contents of phytate, cyanogenic glycoside, and flavonoid were significantly reduced at 90 days of harvest compared to other periods. Harvesting at 30 days after planting resulted in significantly higher crude protein and ash contents, along with lower crude fiber, alkaloid, and saponin contents when compared to those harvested at 60 or 90 days. These findings confirm that harvest timing is the key determinant of forage quality, with younger grass offering higherprotein and lower anti-nutrient levels, while older grass enhances fiber, minerals, and dry matter yield.

RECOMMENDATION

Based on the findings of this study, the following recommendations are made:

- To achieve higher crude protein and ash contents with lower crude fiber, alkaloid, and saponin contents, it is advisable to harvest Napier grass pasture at 30 days after planting.
- Further research is recommended to explore harvesting at intervals younger than 30 days to determine potential improvements in crude protein and ash contents, as well as reductions in crude fiber, saponin, and alkaloid contents.
- Additionally, extending the study beyond the 90-day harvest period may reveal greater benefits in terms of total herbage dry matter yield.

ACKNOWLEDGMENT

We thank the Michael Okpara University of Agriculture Umudike, located in Ikwuano Local Government Area, Abia State, Nigeria, for generously providing the necessary facilities and space that contributed to the success of this research. Their invaluable support played a key role in ensuring the completion of this study.

Author's contributions: We reviewed the results and approved the final version of the manuscript. Contributions to the study were made by the authors as follows: Conceptualization, methodology, data curation, formal analysis, investigation, validation, software, resources, project administration, visualization, writing – original draft, and writing – review and editing: Onya Godswill Uzoma, Essen Paulinus Ogbonnaya, Njoku Godwin Nnamdi, Okoro Damian Chukwunyerem, Essen Joshua Ifeanyi, and Edeh Ernest Chukwuka; Supervision, methodology, and writing – review and editing: OnyeonaguChike Chinonye

Funding: The study has not received any external funding.

Conflict of Interest Declaration: The Authors declare that no conflict of interest exists.

Data and materials availability: All data associated with this study are present in the paper.

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