FUDMA Journal of Agriculture and Agricultural Technology
ISSN: 2504-9496
Vol. 12 No.1, March 2026: Pp.162-170

https://doi.org/10.33003/jaat.2026.1201.19

GROWTH AND FORAGE QUALITY OF NAPIER GRASS AS RUMINANT FEED, INFLUENCED BY POULTRY LITTER APPLICATION RATE AND HARVEST AGE

[1]Onaleye, Kayode Jacob, [1]Yakubu, Aliyu, [2]Patrick, John Adakole John and [1]Adili, Otuto Chikaodili
[1]Department of Animal Science, Federal University Wukari, Taraba State, Nigeria
[2]Department of Agricultural Education, Federal College of Education, Odugbo, Benue State
Corresponding author: Onaleye Kayode Jacob, Email: onaleye@fuwukari.edu.ng ORCID ID 0000-0001-5514-2637

ABSTRACT

This study evaluated the effects of poultry litter application rates (0, 5, 10, and 15 tons/ha) and harvest ages (45, 60, 75, and 90 days after cutback, DAC) on the growth parameters, biomass yield, proximate composition, and cell wall fiber fractions of Napier grass. A 4 × 4 factorial experiment was arranged in a split-plot design with three replications at the Livestock Teaching and Research Farm, Federal University Wukari. Poultry litter application rate significantly ($p < 0.05$) influenced plant height, leaf width, number of tillers, leaf: stem ratio, leaf area index (LAI), and biomass yield, with the highest biomass yield (41.04 tons/ha) recorded at 10 tons/ha. Harvest age significantly affected all measured parameters except leaf: stem ratio and stand circumference. Biomass yield peaked at 75 DAC (38.86 tons/ha), while crude protein (CP) content was highest at 60 DAC (7.85%) and lowest at 75 DAC (4.97%). Fiber fractions increased with maturity. Significant interactions ($p < 0.05$) between poultry litter and harvest age were observed for most growth and quality parameters. The combination of 15 t/ha poultry litter harvested at 45 DAC produced the highest CP (9.65%), while 10 tons/ha harvested at 75 DAC gave the highest biomass (48.76 tons/ha). Crude protein values across all treatments fell below the 8–12% requirement for goat production, indicating the necessity for protein supplementation. For an optimal balance of biomass yield and forage quality in smallholder goat production systems in Taraba State, poultry litter application at 10 t/ha combined with harvest at 60–75 DAC is recommended

Keywords: biomass yield, forage quality, harvest age, Napier grass, poultry litter, Taraba State

INTRODUCTION

Sustainable livestock production in sub-Saharan Africa is fundamentally constrained by chronic feed scarcity, particularly during the dry season when natural pastures deteriorate in quantity and quality. In Taraba State, Nigeria, the situation is especially acute: smallholder farmers and pastoralists depend heavily on diminishing natural grazing lands, while the ongoing escalation of farmer-herder conflicts has further restricted access to traditional pasture areas (Aderinoye-Abdulwahab & Oyewale, 2024). Climate variability and prolonged dry seasons compound this challenge, threatening the food security and livelihoods of millions of rural households whose income depends on ruminant livestock. Against this backdrop, the development of locally appropriate, high-yielding forage production systems has emerged as a priority for agricultural research and development in the region (FAO, 2021).

Napier grass (*Pennisetum purpureum* Schumach.), also commonly referred to as elephant grass, is a perennial C4 grass native to Sub-Saharan Africa that has attracted considerable attention as a climate-smart forage crop. Its attributes include rapid growth rates, high tillering capacity, tolerance to drought and marginal soils, and suitability for cut-and-carry feeding systems widely practiced by smallholder farmers across tropical Africa (Akinfemi & Ogunwole, 2024). When managed intensively under favorable conditions, Napier grass is capable of producing dry matter yields of 20–40 tons/ha/year, thus offering the potential for year-round feed availability for ruminants (Hyelda *et al.*, 2025). Modern improved varieties, commonly designated as Napier grass, have been developed through interspecific hybridization and exhibit even greater productivity, with reportedly higher biomass yields and improved palatability compared to traditional varieties (Onaleye *et al.*, 2026).

The productivity and nutritional value of Napier grass are, however, not static; they are substantially shaped by soil fertility status and harvest management. Soil fertility management represents a key agronomic lever in tropical forage production. Poultry litter, a composite organic material comprising excreta, bedding material, spilled feed, and feathers, has emerged as a valuable and increasingly accessible fertilizer resource for smallholder farmers in Nigeria, owing to the rapid expansion of commercial and backyard poultry enterprises across the country (Ojo *et al.*, 2016). Its fertilizer value derives from its relatively high nitrogen, phosphorus, and potassium content, complemented by a range of secondary nutrients and micronutrients. Unlike synthetic inorganic fertilizers, poultry litter releases nutrients gradually over an extended period, thereby improving soil organic matter, enhancing soil water-holding capacity, and supporting long-term soil health (Dombar *et al.*, 2023; Hyelda *et al.*, 2025).

Harvest timing is the other critical management variable in Napier grass production. As Napier grass matures beyond the optimal harvest window, a characteristic physiological trade-off occurs: biomass yield increases progressively while forage quality declines. Specifically, advancing maturity leads to the accumulation of cell wall structural polysaccharides comprising neutral detergent fiber (NDF), acid detergent fiber (ADF), and acid detergent lignin (ADL), a simultaneous decline in crude protein (CP) content and dry matter digestibility (Onaleye *et al.*, 2026). For ruminant production, which typically demands dietary CP concentrations of 8–12% for maintenance and production (Idris *et al.*, 2025), the optimal harvest age is one that achieves an acceptable balance between biomass yield and nutritional adequacy. Harvesting too early reduces total biomass per harvest cycle and may not be economically efficient, while harvesting too late produces high-fiber, low-protein forage with limited nutritional value for productive animals.

Despite the recognized agronomic and economic potential of Napier grass, site-specific research on optimized organic fertilization strategies and harvest management for Napier grass under the specific pedoclimatic conditions of Taraba State remains insufficient. The majority of existing studies have focused either on inorganic fertilizers (Onaleye *et al.*, 2026) or have been conducted under contrasting agro-ecological conditions in other regions of Nigeria (Akinfemi & Ogunwole, 2024; Girgiri *et al.*, 2024). The FAO has actively promoted Napier grass cultivation in Taraba State as an instrument for peace building between farming and pastoralist communities (FAO, 2021), yet evidence-based agronomic recommendations tailored to smallholder farmers in the region are lacking.

This study was therefore designed to address this knowledge gap by investigating the independent and combined effects of poultry litter application rates (0, 5, 10, and 15 tons/ha) and harvest ages (45, 60, 75, and 90 days after cutback) on the growth parameters and biomass yield, proximate composition that comprised dry matter, crude protein, ether extract, crude fiber, ash, and nitrogen-free extract; and cell wall fiber fractions comprising NDF, ADF, ADL, cellulose, and hemicellulose. The findings are intended to provide practical, evidence-based recommendations for smallholder goat producers in Taraba State and comparable agro-ecological zones across Nigeria.

MATERIALS AND METHODS

Study Location and Agro-ecological Setting

The field experiment was conducted at the Livestock Teaching and Research Farm, Federal University Wukari, Taraba State, Nigeria, during the 2025 rainy season. Wukari is situated in the southern Guinea savanna agro-ecological zone of Nigeria, at approximately 7°52′N latitude and 9°47′E longitude, with an elevation of 190 m above sea level. The area experiences a bimodal tropical climate characterized by a pronounced wet season extending from April to October and a dry season from November to March. Mean annual rainfall ranges from 1,200 to 1,500 mm, while mean annual temperature varies from 25 to 32°C. Soils at the experimental site are sandy-loam, moderately fertile, and representative of the Guinea savanna zone. The study location is within an area identified by the FAO as a hotspot for farmer-herder conflicts where improved forage production can contribute to peacebuilding (FAO, 2021).

Land Preparation and Experimental Layout

The experimental land was thoroughly ploughed and harrowed to achieve a fine tilth suitable for transplanting. Twelve main plots, each measuring 6 m × 5 m (30 m²), were demarcated with 1 m inter-plot spacing to minimize border effects and facilitate passage during management activities. Each main plot was further subdivided into four subplots (3 m × 2.5 m) corresponding to the four harvest age treatments. The final experimental layout comprised 48 experimental units. Each subplot accommodated 20 Napier grass stands planted at a spacing of 80 cm × 40 cm, giving a plant population density of approximately 25,000 stands per hectare, a density consistent with agronomic recommendations for intensive Napier grass production in the Guinea savanna zone (Onaleye *et al.*, 2026).

Experimental Design and Treatments

The experiment was arranged as a 4 × 4 factorial design in a split-plot arrangement with three replications. The main-plot factor was poultry litter application rate at four levels: T_1 = 0 tons/ha (unfertilized control), T_2 = 5 tons/ha, T_3 = 10 tons/ha, and T_4 = 15 tons/ha. The subplot factor was harvest age at four levels: 45, 60, 75, and 90 days after cutback (DAC). Each treatment combination was replicated three times, yielding 48 experimental units in total. The split-plot arrangement was adopted to minimize the physical disturbance associated with differential harvest operations across age treatments within each main plot.

Poultry Litter Collection, Characterization, and Application

Poultry litter was obtained from a commercial layer Farm in Wukari. Prior to application, the litter was air-dried under shade to a constant moisture content and subsequently characterized for nutrient content according to standard procedures (AOAC, 1995). Application rates were computed on a dry weight basis: 0, 0.5, 1.0, and 1.5 kg/m² for T_1, T_2, T_3, and T_4, respectively. The litter was uniformly broadcast over each plot and incorporated into the top 10 cm of soil using a hand hoe. Plots were left fallow for two weeks after incorporation to permit partial decomposition and nutrient stabilization before planting, following the protocol recommended by Dombar *et al.* (2023) and Ojo *et al.* (2016).

Planting and Crop Establishment

Stem cuttings of Napier grass with a minimum of three nodes were procured from the National Animal Production Research Institute (NAPRI), Zaria, Nigeria. Cuttings were planted at an angle of approximately 45°, with two nodes inserted into the soil at a depth of 15 cm. Planting was carried out when rainy season has established (June, 2025) to exploit adequate soil moisture for rapid establishment. Initial establishment growth was allowed for 45 days post-planting, after which a uniform cutback was performed at 10 cm above ground level to synchronize subsequent regrowth across all experimental units.

Harvesting and Sample Collection

Regrowth was subsequently harvested at 45, 60, 75, and 90 DAC. At each harvest, grass was cut at 10 cm above ground level using a clean, sharp knife to ensure uniformity and prevent damage to regrowth meristems. Three randomly selected plants from the middle rows of each subplot were separated into leaf and stem fractions for growth parameter measurement. Fresh samples were immediately placed in labeled airtight zipper-lock bags and transported to the Central Laboratory, Federal University Wukari, for oven-drying, following the protocol described by Meel *et al.* (2025).

Growth Parameters and Biomass Yield

The following growth parameters were measured: (1) plant height (cm), measured from ground level to the tip of the tallest leaf using a calibrated graduated ruler; (2) leaf length and leaf width (cm), measured on the third fully expanded leaf from the apex; (3) stand circumference (cm), measured at the plant base using a flexible measuring tape; (4) number of leaves per plant, counted as the total number of fully expanded leaves; (5) number of tillers per plant, recorded as the number of shoots arising from the base; (6) stem girth (cm), measured at the midpoint of the main stem; (7) leaf area index (LAI), calculated as total leaf area per unit ground area using the method described by Onaleye *et al.* (2026); and (8) leaf: stem ratio, calculated from the ratio of leaf wet weight to stem wet weight. Biomass yield (tons/ha) was estimated by weighing the total fresh biomass from each subplot and extrapolating to a per-hectare basis using the established plant population density.

Proximate Composition and Cell Wall Fiber Analysis

Representative sub-samples from each treatment were oven-dried at 65°C for 48 hours to constant weight for determination of dry matter (DM) content. Dried samples were then ground to pass through a 1 mm sieve using a hammer mill. Proximate composition consisting crude protein (CP), ether extract (EE), crude fiber (CF), total ash, and nitrogen-free extract (NFE) was determined according to the methods of the AOAC (1995). Crude protein was calculated from total nitrogen determined by the Kjeldahl procedure ($N \times 6.25$). Ether extract was determined by Soxhlet extraction using petroleum ether. Total ash was determined by incineration at 550°C for 4 hours in a muffle furnace. NFE was calculated by difference: $100 - (CP + EE + CF + Ash)$. Cell wall fiber fractions (NDF, ADF, and ADL) were determined according to the sequential detergent fiber analysis system of Van Soest (1994). Cellulose was calculated as ADF minus ADL, and hemicellulose was calculated as NDF minus ADF.

Statistical Analysis

All data were subjected to two-way analysis of variance (ANOVA) using JMP Clinical 18 (SAS Institute Inc., Cary, NC, USA). The statistical model used incorporated the fixed effects of poultry litter application rate, harvest age, and their two-way interaction, along with the random effect of replication ($Y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + r_k + \varepsilon_{ijk}$) where Y_{ijk} = response variable, μ = overall mean, α_i = fixed effect of poultry litter application rate, β_j = fixed effect of harvest age, $(\alpha\beta)_{ij}$ = fixed effect of the interaction between litter rate and harvest age, r_k = random effect of replication and ε_{ijk} = residual error. Where the F-test was significant at $P < 0.05$, treatment means were separated using Tukey's Honest Significant Difference (HSD) test at the 5% level of probability. Standard errors of the means (SEM) are presented alongside p-values for all comparisons.

RESULTS AND DISCUSSION

Effect of Poultry Litter Application Rate on Growth Parameters and Yield

Poultry litter application significantly ($P < 0.05$) influenced plant height, leaf length, leaf width, stand circumference, number of tillers, leaf: stem ratio, LAI, and biomass yield, but had no significant effect on number of leaves ($p = 0.9581$) or stem girth ($p = 0.0669$) as shown in Table 1. Plant height increased significantly ($P<0.05$) with increasing poultry litter application, with T_3 (10 tons/ha) and T_4 (15 tons/ha) producing significantly taller plants (237.02 cm and 239.64 cm, respectively) compared to T_1 (201.97 cm) and T_2 (208.80 cm), representing a 17.4% increase at the highest application rate relative to the control. Enhanced plant height under organic fertilization reflects the stimulatory effect of nitrogen on meristematic activity and cell elongation in grasses (Girgiri *et al.*, 2024).

The number of tillers increased significantly ($P<0.05$) with T_4 producing the greatest tiller count (12.78), representing a 27.8% improvement over the control (10.00). This enhanced tillering capacity is agronomically important because tillers are the primary biomass-bearing units in Napier grass. The positive tillering response observed herein is consistent with the findings of Dombar *et al.* (2023), who reported that poultry manure at 10 tons/ha increased tiller numbers by approximately 25% of unfertilized controls. Mechanistically, the nitrogen supplied by poultry litter promotes cytokinin biosynthesis, thereby stimulating axillary bud break and tiller emergence (Girgiri *et al.*, 2024). LAI increased substantially from 6.15 in T_1 to 8.37 in T_4, indicating improved canopy development and light interception efficiency with higher fertilization.

Biomass yield was significantly affected by poultry litter ($P < 0.0001$), with the highest yields recorded at T_3 (41.04 tons/ha) and T4 (39.97 tons/ha), representing a 38.9% increase over T_1 (29.54 tons/ha). Notably, biomass yield did not increase further as the application rate was elevated from 10 to 15 tons/ha, suggesting that 10 tons/ha represents an agronomic optimum under the prevailing soil and climate conditions of the study site. This is consistent with the principle of diminishing returns in crop-fertilizer response relationships (Hyelda *et al.*, 2025) and is slightly higher than the 8 t/ha optimum reported by Girgiri *et al.* (2024) for Maiduguri, a difference attributable to contrasting soil types, rainfall, and Napier varieties. The lack of significant effect of poultry litter on leaf number and stem girth suggests that these parameters are more genetically controlled and less plastic in response to nutrient supply (Onaleye *et al.*, 2026).

Table 1. Effect of poultry litter application rate on growth parameters and yield of Napier grass.

P.L.A Rate	Plant Height (cm)	Leaf Length (cm)	Leaf Width (cm)	Stand Circum-ference (cm)	No. of Leaves	No. of Tillers	Leaf: Stem Ratio	Stem Girth (cm)	LAI	Biomass (t/ha)
T1	201.97^{b}	111.76^{b}	3.41^{c}	49.68^{b}	20.03	10.00^{b}	0.68^{a}	6.20	6.15^{b}	29.54^{b}
T2	208.80^{b}	112.51^{b}	3.50^{bc}	50.52^{a}	19.86	10.08^{b}	0.73^{a}	6.64	6.10^{b}	29.95^{b}
T3	237.02^{a}	114.95^{b}	3.77^{a}	54.78^{a}	19.83	10.92^{ab}	0.65^{b}	6.82	6.96^{b}	41.04^{a}
T4	239.64^{a}	125.47^{a}	3.67^{ab}	54.77^{a}	19.92	12.78^{a}	0.70^{a}	7.09	8.37^{a}	39.97^{a}
SEM	4.65	1.88	0.069	1.84	0.33	0.60	0.030	0.135	0.36	1.92
p-value	<0.0001	0.0110	0.0042	0.0042	0.9581	0.0005	<0.0001	0.0669	<0.0001	<0.0001

Key. Means within the same column with different superscript differ significantly ($p < 0.05$). T1 = 0 tons/ha (control); T2 = 5 tons/ha; T3 = 10 tons/ha; T4 = 15 tons/ha. LAI = leaf area index; SEM = standard error of the means.

Effect of Harvest Age on Growth Parameters and Yield

Harvest age significantly ($P < 0.05$) affected all measured growth parameters with the exception of stand circumference ($p = 0.0913$) and leaf: stem ratio (P= 0.272 in Table 2. Plant height increased continuously with advancing maturity, with the tallest plants (254.08 cm) recorded at 90 DAC, compared to 202.68 cm at 45 DAC, a 25.4% increase that reflects the characteristic indeterminate vegetative growth of C4 perennial grasses (Akinfemi & Ogunwole, 2024). Conversely, leaf dimensions (length and width) declined progressively with age, reflecting the preferential allocation of assimilates to stem elongation and structural development over leaf area expansion as plants mature, a pattern with direct implications for forage digestibility, since leaf tissue is generally more nutritious and palatable than stem tissue (Onaleye *et al.*, 2026).

The number of tillers was highest at 45 DAC (13.14) and declined significantly to approximately 10 tillers per plant at 60–90 DAC. This response indicates that frequent harvesting stimulates tiller regeneration, likely through the removal of apical dominance and increased light availability at the plant base. For farmers aiming to maximize stand persistence and soil cover, a harvest interval of 45–60 days would therefore be preferable, whereas those targeting maximum biomass for silage or hay should extend the interval to 75–90 days (Akinfemi & Ogunwole, 2024).

Biomass yield increased from 30.44 tons/ha at 45 DAC to a peak of 38.86 tons/ha at 75 DAC, a 27.7% gain. Yield at 90 DAC (36.44 tons/ha) did not differ significantly from either the 60 or 75 DAC values, indicating that maximum biomass accumulation is effectively achieved by 75 DAC. A marginal (non-significant) decline in yield at 90 DAC relative to 75 DAC may reflect increased leaf senescence and shedding as plants transition toward reproductive maturity (Bardeson, 2023). This finding suggests that delaying harvest beyond 75 DAC provides no biomass advantage while compromising forage quality through leaf loss and progressive lignification of stem tissues.

Table 2. Effect of harvest age on growth parameters and yield of Napier grass.

Age (DAC)	Plant Height (cm)	Leaf Length (cm)	Leaf Width (cm)	Stand Circum-ference (cm)	No. of Leaves	No. of tillers	Leaf: Stem Ratio	Stem Girth (cm)	LAI	Biomass (t/ha)
45	202.68^{c}	118.38^{a}	3.76^{a}	52.63	17.28^{c}	13.14^{a}	0.879	6.47^{b}	7.59^{a}	30.44^{b}
60	206.17^{c}	119.11^{a}	3.60^{ab}	46.92	17.72^{c}	10.39^{b}	0.746	6.97^{a}	6.30^{b}	34.76^{ab}
75	224.50^{b}	116.19^{ab}	3.57^{ab}	54.31	21.03^{b}	10.08^{b}	0.623	6.64^{ab}	6.48^{b}	38.86^{a}
90	254.08^{a}	111.00^{b}	3.41^{b}	55.89	23.61^{a}	10.17^{b}	0.514	6.67^{ab}	7.20^{ab}	36.44^{ab}
SEM	4.65	1.88	0.069	1.84	0.267	0.60	0.030	0.135	0.192	1.92
p-value	<0.0001	<0.0001	0.0011	0.0913	<0.001	0.0032	0.2727	<0.0001	0.0386	0.0177

Keye. Means within the same column with different superscript differ significantly ($p < 0.05$). DAC = days after cutback; L:S = leaf: stem ratio; SEM = standard error of the means.

Interaction Effects of Poultry Litter Application Rate and Harvest Age on Growth Parameters and Yield

Significant two-way interactions ($p < 0.05$) between poultry litter and harvest age were observed for plant height ($p = 0.0205$), leaf width ($p = 0.0243$), stand circumference ($p = 0.0019$), number of tillers ($p = 0.0001$), leaf: stem ratio ($p = 0.0001$), stem girth ($p < 0.0001$), LAI ($p < 0.0001$), and biomass yield ($p < 0.0001$), as shown in Table 3. The interactions for leaf length ($p = 0.4428$) and number of leaves ($p = 0.0901$) were not significant ($P>0.05$).

Significantly ($P < 0.05$) highest biomass yield (48.76 tons/ha) was produced by the combination of T_3 (10 tons/ha) at 75 DAC, which was significantly superior to most other treatment combinations and represented a 184% improvement over the lowest-yielding combination (T_1 at 45 DAC: 17.15 tons/ha). The T_4 × 60 DAC combination also produced high biomass (48.37 tons/ha), demonstrating that intensive organic fertilization can accelerate biomass accumulation sufficiently to allow an earlier harvest while achieving yields comparable to those of moderately fertilized plots harvested later. This interaction implies that the agronomic benefit of higher poultry litter rates becomes more pronounced as harvest age increases, as the additional available nutrients are progressively captured in biomass over time, which aligns with the finding of Dombar *et al.* (2023).

The highest leaf: stem ratio (1.00) was recorded for T_4 at 45 DAC, while the lowest (0.45) occurred for T_3 at 90 DAC, confirming the expected decline in leafiness with advancing maturity. High leaf: stem ratios are associated with improved palatability, higher protein content, and greater voluntary intake by ruminants. The exceptionally high LAI recorded for T_4 at 45 DAC (10.91) further confirms that intensive fertilization promotes rapid canopy closure, with potential benefits for weed suppression and soil moisture conservation. The LAI values in this study are similar to the 5.7 – 9.49 range previously noted by Soumya (2011) with Napier grass.

Table 3. Effect of the interaction poultry litter application rate and harvest age on growth parameters and yield of Napier grass.

Rate × Age	Plant Height (cm)	Leaf Length (cm)	Leaf Width (cm)	Stand Circ. (cm)	No. Leaf	No. Tillers	Leaf: Stem Ratio	Stem Girth (cm)	LAI	Biomass (t/ha)
T1 × 45	184.78^{f}	116.14	3.56^{abc}	51.96^{abc}	17.89	9.33^{bc}	0.70^{bcdef}	5.93^{bcd}	5.26^{bcd}	17.15^{d}
T1 × 60	188.33^{f}	116.11	3.18^{bc}	39.11^{c}	17.33	9.11^{bc}	0.81^{abcd}	6.33^{bcd}	5.09^{cd}	26.07^{cd}
T1 × 75	184.44^{f}	107.78	3.42^{abc}	53.33^{abc}	20.78	11.22^{bc}	0.72^{abcdef}	5.56^{d}	6.58^{bcd}	33.19^{abcd}
T1 × 90	250.33^{abcd}	107.00	3.49^{abc}	54.33^{abc}	24.11	10.33^{bc}	0.49^{ef}	6.98^{abc}	7.65^{abcd}	41.75^{abc}
T2 × 45	202.42^{ef}	117.13	3.88^{a}	53.62^{abc}	17.56	13.44^{ab}	0.84^{abc}	6.67^{abcd}	7.71^{abcd}	30.43^{abcd}
T2 × 60	190.44^{f}	109.89	3.64^{abc}	42.33^{bc}	17.78	8.67^{bc}	0.75^{abcde}	7.00^{abc}	4.97^{cd}	29.84^{bcd}
T2 × 75	202.44^{ef}	118.00	3.42^{abc}	50.56^{abc}	21.22	7.11^{c}	0.68^{cdef}	7.00^{abc}	4.43^{d}	25.48^{cd}
T2 × 90	239.89^{abcde}	105.00	3.04^{c}	55.56^{abc}	22.89	11.11^{bc}	0.66^{cdef}	5.78^{cd}	7.28^{bcd}	34.04^{abcd}
T3 × 45	209.51^{def}	114.58	3.69^{abc}	46.78^{abc}	16.33	12.44^{abc}	0.98^{ab}	6.24^{bcd}	6.48^{bcd}	37.33^{abc}
T3 × 60	222.00^{bcdef}	121.00	3.90^{a}	47.56^{abc}	17.22	10.33^{bc}	0.61^{cdef}	6.78^{abcd}	6.55^{bcd}	34.77^{abcd}
T3 × 75	248.22^{abcd}	115.22	3.80^{ab}	60.56^{a}	20.78	9.67^{bc}	0.56^{cdef}	7.11^{ab}	6.45^{bcd}	48.76^{a}
T3 × 90	268.33^{a}	109.00	3.69^{abc}	64.22^{a}	25.00	11.22^{bc}	0.45^{f}	7.13^{ab}	8.35^{abc}	43.32^{abc}
T4 × 45	214.00^{cdef}	125.67	3.93^{a}	58.18^{ab}	17.33	17.33^{a}	1.00^{a}	7.02^{abc}	10.91^{a}	36.85^{abc}
T4 × 60	223.89^{abcdef}	129.44	3.69^{abc}	58.67^{ab}	18.56	13.44^{ab}	0.82^{abcd}	7.67^{a}	8.61^{ab}	48.37^{ab}
T4 × 75	262.89^{ab}	123.78	3.64^{abc}	52.78^{abc}	21.33	12.33^{abc}	0.53^{def}	6.89^{abc}	8.47^{abc}	48.00^{ab}
T4 × 90	257.78^{abc}	123.00	3.40^{abc}	49.44^{abc}	22.44	8.00^{bc}	0.46^{ef}	6.78^{abcd}	5.50^{bcd}	26.64^{cd}
SEM	9.30	3.77	0.138	3.69	0.66	1.19	0.060	0.271	0.720	3.85
p-value	0.0205	0.4428	0.0243	0.0019	0.090	0.0001	0.0001	<0.0001	<0.0001	<0.0001

Means within the same column followed by different superscript letters differ significantly ($p < 0.05$). T1 = 0 tons/ha; T2 = 5 tons/ha; T3 = 10 tons/ha; T4 = 15 tons/ha. DAC = days after cutback; SEM = standard error of the means.

Effect of Poultry Litter Application Rate on Proximate Composition and Cell Wall Fiber Fractions

From the results in Table 4, poultry litter application significantly ($P < 0.05$) influenced CP, EE, total ash, cellulose, and hemicellulose, but had no significant effect on DM, CF, NFE, NDF, ADF, or ADL. Contrary to the commonly observed positive effect of nitrogen fertilization on plant protein content, CP declined significantly ($P<0.05$) with increasing application rates, from 7.32% in the control to 5.76% at 15 tons/ha. This paradoxical response is explained by the dilution effect: higher fertilization rates promoted substantially greater vegetative growth (Table 1), leading to the distribution of absorbed nitrogen across a larger biomass, thereby reducing the nitrogen concentration, and hence the CP content, in plant tissues. A comparable dilution effect under high-fertility conditions has been reported for other tropical forages (Onaleye *et al.*, 2026). The practical implication is that farmers maximizing biomass through intensive poultry litter application may simultaneously compromise the protein value of the forage, necessitating dietary supplementation for animals with elevated protein demands, thereby further increasing cost of production.

Ether extract was significantly ($P < 0.05$) highest in T_1 (3.47%) and declined to 3.16% in T_4, possibly reflecting a shift in carbon allocation from lipid synthesis toward structural carbohydrate production under elevated nitrogen availability (Hyelda *et al.*, 2025). Total ash content was slightly but significantly higher in T_1 and T_3 relative to T_2, though the biological magnitude of these differences is modest. The statistically significant effects on cellulose and hemicellulose were also minor in absolute terms (18.03–18.76% and 12.56–13.31%, respectively), indicating that poultry litter application rate has a comparatively limited influence on cell wall composition relative to its pronounced effects on biomass yield and CP.

Table 4. Effect of poultry litter application rate on the proximate composition and cell wall fiber fractions of Napier grass (% DM basis).

Rate	DM (%)	CP (%)	EE (%)	CF (%)	Total Ash (%)	NFE (%)	NDF (%)	ADF (%)	ADL (%)	Cellulose (%)	Hemicel. ulose(%)
T1	92.49	7.32^{a}	3.47^{a}	25.37	13.27^{a}	44.04	45.84	32.53	13.94	18.59^{ab}	13.31^{a}
T2	93.14	7.29^{a}	3.44^{a}	25.13	12.72^{c}	44.50	45.22	32.61	13.85	18.76^{a}	12.62^{b}
T3	92.41	6.37^{b}	3.39^{a}	25.06	13.16^{ab}	45.27	45.17	32.61	14.06	18.55^{ab}	12.56^{b}
T4	92.47	5.76^{c}	3.16^{b}	24.74	12.78^{bc}	44.27	45.41	32.35	14.32	18.03^{b}	13.06^{a}
SEM	0.80	0.060	0.030	0.217	0.112	0.386	0.394	0.282	0.122	0.161	0.116
p-value	0.907	<0.0001	<0.0001	0.253	0.003	0.145	0.619	0.902	0.060	0.019	0.0001

Note: Means within the same column followed by different superscript letters differ significantly (p < 0.05).
T1 = 0 tons/ha; T2 = 5 tons/ha; T3 = 10 tons/ha; T4 = 15 tons/ha. DM = dry matter; CP = crude protein; EE = ether extract; CF = crude fiber; NFE = nitrogen-free extract; NDF = neutral detergent fiber; ADF = acid detergent fiber; ADL = acid detergent lignin; SEM = standard error of the means.

Effect of Harvest Age on Proximate Composition and Cell Wall Fiber Fractions

From the results in Table 5, harvest age significantly (P < 0.05) affected all proximate composition and fiber fractions (Table 5). Crude protein content exhibited a non-linear pattern with advancing harvest age: it increased from 7.40% at 45 DAC to a peak of 7.85% at 60 DAC, then declined sharply to 4.97% at 75 DAC before recovering to 6.52% at 90 DAC. This quadratic pattern is consistent with documented forage quality decline with maturity in tropical grasses (Akinfemi & Ogunwole, 2024) and has profound management implications.

The 36.7% reduction in CP from 60 to 75 DAC is particularly consequential as forage harvested at this stage falls well below the minimum dietary CP requirement (8%) for goat maintenance as specified by Idris *et al.* (2025), rendering supplementation essential. The partial recovery in CP at 90 DAC may reflect nitrogen remobilization to reproductive tissues or the inclusion of younger tillers in the sample. Ether extract attained its significantly (P <0.05) least value at 75 DAC (2.73%) and its peak at 90 DAC (3.81%), a pattern that may coincide with peak stem lignification at 75 DAC followed by reproductive-stage lipid accumulation at 90 DAC. Crude fiber was highest at 60 DAC (26.13%) and lowest at 90 DAC (23.72%), a trend that may reflect dilution of structural carbohydrates by non-structural reserve materials at advanced maturity. NFE increased consistently with age (from 43.88% at 45 DAC to 46.83% at 90 DAC), reflecting the accumulation of non-structural carbohydrates as plants prepare for reproduction, an increase that can improve the energy density of the forage for ruminants (Idris *et al.*, 2025).

NDF peaked at 60 DAC (48.85%) and was lowest at 75 DAC (42.78%), while ADF declined progressively from 34.79% at 45 DAC to 31.18% at 90 DAC, suggesting a net reduction in cellulose and hemicellulose digestibility-limiting fractions with advancing age. ADL declined from 14.83% at 45 DAC to 12.81% at 75 DAC, then rose to 14.76% at 90 DAC, reflecting the expected secondary lignification of stem tissues approaching reproductive maturity (Van Soest, 1994). Cellulose declined progressively with age (from 19.97% at 45 DAC to 16.42% at 90 DAC), while hemicellulose demonstrated an oscillating pattern, low at 45 DAC (8.28%), high at 60 DAC (16.54%), lower at 75 DAC (10.97%), and high again at 90 DAC (15.76%), possibly reflecting the changing contributions of leaf and stem fractions to the bulk sample across harvest ages, given that these tissues differ substantially in their cell wall polysaccharide composition (Van Soest, 1994).

Table 5. Effect of harvest age on the proximate composition and cell wall fiber fractions of Napier grass (% DM basis).

Age (DAC)	DM (%)	CP (%)	EE (%)	CF (%)	Total Ash (%)	NFE (%)	NDF (%)	ADF (%)	ADL (%)	Cellulose (%)	Hemicel. ulose (%)
45	92.09-	7.40^{b}	3.47^{b}	25.04^{b}	12.29^{c}	43.88^{bc}	43.07^{c}	34.79^{a}	14.83^{a}	19.97^{a}	8.28^{d}
60	93.84^{a}	7.85^{a}	3.44^{b}	26.13^{a}	13.77^{a}	42.64^{c}	48.85^{a}	32.31^{b}	13.78^{b}	18.54^{b}	16.54^{a}
75	90.88^{b}	4.97^{d}	2.73^{c}	25.41^{ab}	13.05^{b}	44.72^{b}	42.78^{c}	31.81^{bc}	12.81^{c}	19.00^{b}	10.97^{c}
90	93.69^{a}	6.52^{c}	3.81^{a}	23.72^{c}	12.82^{b}	46.83^{a}	46.93^{b}	31.18^{c}	14.76^{a}	16.42^{c}	15.76^{b}
SEM	0.80	0.060	0.030	0.217	0.112	0.386	0.394	0.282	0.122	0.161	0.116
p-value	0.0414	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

Key: Means within the same column followed by different superscript letters differ significantly ($p < 0.05$). DAC = days after cutback; DM = dry matter; CP = crude protein; EE = ether extract; CF = crude fiber; NFE = nitrogen-free extract; NDF = neutral detergent fiber; ADF = acid detergent fiber; ADL = acid detergent lignin; SEM = standard error of the means.

CONCLUSION

This study examined the independent and combined effects of poultry litter application rates and harvest ages on the growth, biomass yield, proximate composition, and cell wall fiber fractions of Napier grass under the agro-ecological conditions of Wukari, Taraba State, Nigeria. The results demonstrate that poultry litter application at 10 tons/ha optimally enhances plant growth and biomass yield (41.04 tons/ha as a main-plot mean; up to 48.76 tons/ha in combination with 75 DAC harvest), without incurring the additional input cost of higher application rates that do not confer proportional biomass gains. Harvest age significantly modulates both yield and quality, maximum biomass accumulates by 75 DAC, while CP peaks at 60 DAC. The sharp decline in CP between 60 and 75 DAC underscores the sensitivity of forage nutritional value to harvest timing and reinforces the importance of precise harvest management.

Significant interaction of poultry litter application rates and harvest age for key parameters, particularly CP and biomass, indicate that optimal Napier grass management requires the integrated consideration of both factors rather than their independent optimization. The CP levels recorded across all treatment combinations (4.97–7.85%) fall below the minimum nutritional requirement of 8% for goat maintenance, confirming that Napier grass alone cannot fully meet the protein demands of productive ruminants. Also, the combination of 10–15 t/ha poultry litter with harvest at 60–75 DAC optimize biomass productivity and nutritional quality for smallholder goat production. It is recommended therefore to apply 10 t/ha poultry litter and harvest between 60 and 75 DAC, and to supplement Napier grass so produced with protein-rich supplementary feeds, such as legume forages, oilseed cakes, or commercial concentrates particularly for lactating does and growing kids.

Future research is also recommended to explore the integration of Napier grass with leguminous companion species to enhance the overall protein value of the forage system and as well as to evaluate animal performance responses to optimized Napier grass management.

REFERENCES

Aderinoye-Abdulwahab, S. A. and Oyewale, O. F. (2024). Pastoralists' knowledge of Napier cultivation: Implication for social and environmental security in Nigeria. Scientific African, 24, e02185. https://doi.org/10.1016/j.sciaf.2024.e02185

Akinfemi, A. and Ogunwole, O. A. (2024). Forage growth biomass, yield and quality responses of three varieties of Napier grass at cutting intervals in the South West Nigeria. Trends in Agricultural Sciences, 3(4), 245–256.

AOAC (1995). Association of Official Analytical Chemists. Official methods of analysis (16th ed.).

Bardeson, D. (2023, November 20). Elephant grass, also known as Napier grass, is a perennial tropical grass that can grow up to 4 meters tall [LinkedIn post]. LinkedIn. https://www.linkedin.com/posts/desmond-dogara-bardeson_elephant-grass-also-known-as-napier-grass-activity-7132644817263546368-tpsl

Dombar, B. Y., Joseph, S. D. and Ngoran, T. (2023). Effect of poultry manure rates on the growth and yield of Napier grass (Pennisetum purpureum) in the derived savanna zone of Nigeria. Journal of Agricultural Science and Environment, 23(1), 45–58.

FAO (2012). Food and Agriculture Organization.Peace building: Farmers, pastoralists receive inputs, planting materials for pasture development. FAO Nigeria. https://www.fao.org/nigeria/news/detail-events/zh/c/1440375/

Girgiri, A. Y., Chana, Z. M., Kolo, U. M., Babale, A. I., Bislava, M. B. and Jibrin, T. A. (2024). Effects of poultry manure rates on growth components and forage quality of Napier grass (Pennisetum purpureum) in semi-arid region of Maiduguri, Nigeria. Journal of Agriculture and Environment, 21(2), 45–56.

Hyelda, A. J., Gworgwor, Z. A., Yakubu, A. K., Tuwanga, J. V. and Ahmed, A. (2025). Effect of different fertilizers on the chemical and mineral compositions of Napier grass under irrigation system. Nigerian Journal of Animal Production, 52, 1582–1585.

Idris, A., Gumel, I. A. and Santuraki, A. H. (2025). Enhancing sustainable ruminant nutrition through hydroponic maize fodder production. Journal of Animal Production and Environmental Sustainability, 1(4), 43–48.

Meel, B. L., Sharma, S. and Singh, R. (2025). Sampling and analytical techniques for forage quality assessment. Journal of Forage Science, 42(1), 78–92.

Ojo, V. O., Dele, P. A. and Amole, T. A. (2016). Effect of poultry manure application on the growth and nutritive value of Panicum maximum. Nigerian Journal of Animal Production, 43(1), 156–165.

Onaleye, K. J., Amos, N. D. and Yakubu, A. (2026). Effect of inorganic fertilizer application rates and age on morphological characteristics, fresh biomass and chemical composition of Super Napier grass (*Pennisetum purpureum* hybrid) regrowth. Journal of Animal Production and Environmental Sustainability, 2(1), 169–179.

Soumya, P. (2011). Evaluation of Promising hybrid Napier Cultivars under Varying Plant Population. Dissertation, College of Horticulture, Vellanikkara, Kerala Agricultural University, Thrissur, India. 73p.

Van Soest, P. J. (1994). Nutritional ecology of the ruminant (2nd ed.). Cornell University Press.