



Growth Performance and Nutritional Quality of Tiller-Propagated Napier Grass as Influenced by Poultry Litter Application Rates and Harvesting Age

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ABSTRACT

The study evaluated the growth characteristics, herbage yield, and nutritional quality of tiller-propagated Napier grass (*Pennisetum purpureum* Schumach.) under graded poultry litter application rates and varying harvesting ages. A 4 × 4 factorial experiment was conducted using a randomized complete block design (RCBD) with three replications. Four poultry litter rates; T₁ (0 t/ha), T₂ (5 t/ha), T₃ (10 t/ha), and T₄ (15 t/ha), were evaluated with four harvesting ages (45, 60, 75, and 90 days). Using a measuring tape where applicable, agronomic characteristics (plant height, leaf length, leaf width, stand circumference, number of leaves, number of tillers, stem girth, and leaf-to-stem ratio), fresh biomass yield was determined using a weighing scale while proximate composition, and cell-wall fibre fractions were analyzed according to standard procedures. Results showed that increasing poultry litter rates significantly ($P < 0.05$) enhanced fresh biomass yield from 100.04 t/ha (control) to 123.52 t/ha (15 t/ha), while plant height peaked at T₃ (10 t/ha; 348.91 cm). Harvesting age significantly ($P < 0.0001$) influenced all parameters; fresh biomass yields more than doubled from 74.92 t/ha at 45 days to 148.97 t/ha at 90 days. Crude protein was highest at the 60-day harvest (13.91%), whereas neutral detergent fibre (NDF) peaked at 75 days (44.50%). Significant interaction effects were detected for crude protein, ether extract, total ash, acid detergent lignin, cellulose, and hemicellulose. The combination of 10–15 t/ha poultry litter and a 60-day harvesting age optimally balances yield and nutritional quality, while a 90-day harvest with 15 t/ha maximizes biomass output.

Keywords: *Pennisetum purpureum*; Organic manure; Forage yield; Crude protein; Fibre fractions

INTRODUCTION

Napier grass (*Pennisetum purpureum* Schumach.), commonly referred to as elephant grass, is among the most productive and widely cultivated perennial forages in tropical and subtropical regions (Kariuki *et al.*, 2023). Its extraordinary biomass potential, reportedly exceeding 80 t fresh matter ha⁻¹ per cutting cycle under optimal management, combined with its adaptability to a broad range of soil and climatic conditions make it the backbone of cut-and-carry forage systems for ruminant

livestock across sub-Saharan Africa (Olanite *et al.*, 2022; Kariuki *et al.*, 2023). In Nigeria, rapidly expanding cattle, sheep, and goat populations against a backdrop of shrinking arable land and seasonal feed deficits have intensified demand for high-yielding, nutrient-dense forage species (FAO, 2024). Napier grass features prominently in national forage improvement programmes as a strategic crop for bridging dry-season feed gaps.

Conventional establishment of Napier grass relies on stem node cuttings. However, tiller propagation, the deployment of basal shoot clumps detached from the parent crown, offers several agronomic advantages, which include: faster field establishment, a higher multiplication ratio of planting material, and consistent phenotypic uniformity in the resulting stand (Habte *et al.*, 2020; Tadesse *et al.*, 2022). Despite these merits, systematic evaluation of the growth dynamics, biomass accumulation, and herbage quality of tiller-propagated stands under contrasting management inputs remains limited in the West African derived savanna zone.

Soil nitrogen supply is the primary determinant of Napier grass productivity (Adedapo *et al.*, 2023). Although inorganic nitrogenous fertilizers can supply nutrients rapidly, their escalating cost and associated environmental concerns, including nitrate leaching and greenhouse gas emissions, have stimulated interest in organic amendments (Bello and Ibrahim, 2022; Adedapo *et al.*, 2023). Poultry litter, a composite of excreta, spilled feed, feathers, and bedding material, contains approximately 2.5–3.5% total nitrogen alongside appreciable phosphorus, potassium, and micronutrients (Dauda *et al.*, 2021). Its slow-release nitrogen mineralisation kinetics are particularly suited to perennial grass systems, sustaining vegetative growth across successive regrowth cycles without the flush-and-crash response associated with inorganic nitrogen applications (Oso *et al.*, 2022). While Girgiri *et al.* (2024) reported that poultry litter application rates up to 8 t/ha had no significant effect on forage quality but regrowth vigor, Onwubiko and Okwor (2025) reported that 10 – 15 t/ha of poultry litter improved forage quality while 20 t/ha reduced Napier performance, attributable to nutrient toxicity or soil structure issues. Despite several studies on manure application in Napier grass (Egbe and Akwiwu, 2021; Makkar and Beeker, 2023), limited information exists on optimal rates, nutrient-use efficiency and nutritive responses in tiller-propagated Napier under derived savanna conditions of Nigeria and such require site-specific validation.

Harvesting age is a critical management lever that governs the balance between biomass yield and herbage nutritive value. Young herbage is characterised by high crude protein (CP), greater digestibility, and lower fibre fractions, whereas advanced maturity favours biomass accumulation at the expense of nutritional quality through progressive lignification and cell-wall thickening (Aderinola *et al.*, 2020; Onyeonagu and Asiegbu, 2021). Identifying the harvesting interval that optimises both quantity and quality of forage, particularly in relation to organic nitrogen input, is therefore essential for smallholder farmers seeking maximum animal performance per unit area.

Against this background, the present study was designed to: (i) determine the effects of graded poultry litter application rates on agronomic performance and herbage nutritional quality of tiller-propagated Napier grass; (ii) assess the influence of harvesting age on growth characteristics, fresh biomass yield, proximate composition, and cell-wall fibre fractions; and (iii) evaluate the interaction between poultry litter application rates and harvesting age on all measured traits.

MATERIALS AND METHODS

Study Area

The study was conducted at the Pasture Unit of the Livestock Teaching and Research Farm of Federal University Wukari, Taraba State, Nigeria. Wukari is located within Latitude 7°51'N; Longitude 9°46'E; altitude approximately 178 m above sea level. The climate is characterized by two seasons; a rainy season (April–October) and a dry season (November–March), with a mean annual rainfall of approximately 1,200 mm and temperatures ranging from 22°C to 34°C. The soil type is classified as Alfisol, commonly found in the derived savanna zone of West Africa (Gani and Awwal, 2025)

Experimental Design and Treatments

A 4 × 4 factorial experiment was laid out in a Completely Randomized Block Design (CRBD) with three replications, giving 48 experimental units. The two factors were: poultry litter application rate ($T_1 = 0$ t/ha

[control], $T_2 = 5$ t/ha, $T_3 = 10$ t/ha, $T_4 = 15$ t/ha) and harvesting age ($H_1 = 45$, $H_2 = 60$, $H_3 = 75$, and $H_4 = 90$ days after cutback (DAC). Each plot measured $3.5 \text{ m} \times 3 \text{ m}$ (10.5 m^2), with a 1-m inter-plot alley. Already composted poultry litter was sourced from a commercial deep-litter layer unit, air-dried to a stable moisture content, broadcast and incorporated into the top 15 cm of soil on the 45th day after planting when cutback was done, so that mineralized nutrients would be absorbed by well-established roots to reduce nutrient loss through leaching.

Planting and Crop Management

Tiller propagules of Napier grass were harvested from an established Napier pasture, cleaned, and trimmed to a uniform size of approximately 20 cm with at least two visible nodes. Planting was carried out at the onset of the first main rainy season at a spacing of $1 \text{ m} \times 0.5 \text{ m}$ (equivalent to $20,000 \text{ plants ha}^{-1}$). Manual weeding was performed at 2 and 4 weeks after planting (WAP) to minimise weed competition during the early establishment phase. No supplemental irrigation or inorganic fertilizer was applied throughout the trial period which lasted 90 days.

Data Collection

Growth characteristics including plant height (cm), leaf length (cm), leaf width (cm), stand circumference (cm), number of leaves per tiller, number of tillers per stool, and stem girth (cm) were measured at 45, 60, 75, and 90 days after regrowth initiation, on 5 randomly selected stool and then plant at middle rows per plot, using measuring tape and Vernier calipers where appropriate. However, Leaf-to-stem ratio (L: S) and fresh biomass yield were determined at 45 and 90 DAC only as proposed for the study. While all sampling and harvesting at 45 and 90 DAC were entirely destructive, those at 60 and 75 DAC were conservative as only five selected plants per plot, one plant per sampled stool, were destructively sampled as representatives for laboratory analysis.

Harvesting of all treatment combinations at 45 and 90 DAC was done once by cutting all

plants on designated plots at 15cm stubble height and weighing using 50 Kg sensitive handing scale. The weight per plot area was subsequently extrapolated to tons per hectare on a fresh matter basis. Leaf to stem ratio (L: S) was determined by manually detaching all leaves from the stem of a randomly selected plant per stool and separately weighing and dividing the leaf weight by the stem weight.

Laboratory Procedures

At each sampling and or harvesting stage for laboratory analysis, 500g of fresh forage samples were collected from five randomly sampled stools from the four middle rows (across the 50cm plant spacing) of each plot to exclude boarder row stools, and then sub-sampled for laboratory analysis. Samples were oven-dried at 65°C to constant weight and ground to pass a 1-mm screen. Proximate composition including dry matter (DM), crude protein (CP), ether extract (EE), crude fibre (CF), ash, and nitrogen-free extract (NFE) was determined according to the methods of the Association of Official Analytical Chemists (AOAC, 2019). Cell wall fractions, neutral detergent fibre (NDF), acid detergent fibre (ADF), and acid detergent lignin (ADL) were analyzed following the procedures of Van Soest *et al.* (2021) while cellulose, and hemicellulose were calculated from NDF, ADF and ADL.

Statistical Analysis

Data collected were subjected to two-way analysis of variance (ANOVA) using the JMP Clinical 18 of SAS (SAS Institute Inc., Cary, NC, USA) with factorial statistical model, $Y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \epsilon_{ijk}$. Generally, treatment means were separated using Tukey's Honestly Significant Difference (HSD) test at a 5% level of significance. However, for L: S ratio and fresh biomass at the two harvest ages (45 and 90 days), an independent-students' t-test was employed to compare means. Results are expressed as means $\pm$ standard error of the mean (SEM) with their corresponding p - or t-values.

RESULTS AND DISCUSSION

Effect of Poultry Litter Application Rates on Agronomic Characteristics and Fresh Biomass Yield of Tiller-Propagated Napier Grass

The effects of poultry litter application rates on the agronomic traits and fresh biomass yield of tiller-propagated Napier grass are presented in Table 1. Plant height was significantly ($P = 0.042$) influenced by poultry litter application, with T_3 (10 t/ha) recording the tallest plants (348.91 cm), significantly surpassing T_4 (15 t/ha; 339.09 cm), which paradoxically had the shortest stature among fertilised treatments. The initial height increase from T_1 to T_3 likely reflects progressive improvement in nitrogen-mediated meristematic activity and internodal elongation (Adedapo *et al.*, 2023). The slight height depression at the highest rate (T_4) may be probably be attributed to osmotic stress resulting from excess soluble salts at 15 t/ha, or nutrient antagonism arising from imbalanced cation ratios in the soil solution, a phenomenon reported in tropical grasses receiving high organic inputs (Dauda *et al.*, 2021; Oso *et al.*, 2022).

Leaf width, number of leaves, stem girth, and leaf-to-stem ratio were all significantly ($P < 0.0001$) influenced by poultry litter rates. Leaf width declined progressively from 4.96 cm (T_1) to 4.63 cm (T_4), and the number of leaves decreased similarly from 25.13 (T_1) to 21.71 (T_4). The inverse relationship between poultry litter rate and leaf number may perhaps, indicate accelerated leaf senescence under high-nitrogen conditions, as nitrogen-stimulated rapid stem elongation reduces the longevity of lower leaves (Onyeonagu and Asiegbu, 2021). The over 20 tillers recorded in this study is about doubled the 11.6 as the highest reported by Onwubiko and Okwori (2025) who used stem cuttings for elephant

grass, underscoring the effect of planting material and variety. The 22.42 tillers recorded for control this study is 4 time the 5.4 tillers reported by Girgiri *et al.* (2024) in similar study with Napier propagation by tillers at 8 t poultry manure/ha in Maiduguri, Nigeria. The variation may be due to differences in location and may be an indication that Wukari may be more suitable for Napier grass cultivation than Maiduguri. Stem girth was significantly highest in T_2 (7.70 cm), similar to T_1 (7.65 cm), and declining at T_3 and T_4 , which is consistent with findings by Egbe and Akwiwu (2021) who noted stem diameter reductions in Napier grass at poultry litter rates above 10 t/ha. Leaf-to-stem ratio was significantly highest in T_4 (0.75), possibly reflecting proportionally greater leaf biomass relative to heavily diluted stem mass per plant. Leaf length, stand circumference, and number of tillers were not significantly ($P > 0.05$) affected, indicating that tiller proliferation and canopy spread in this cultivar are more strongly governed by genotypic potential and environmental cues than by the organic nitrogen range tested.

Fresh biomass yield was significantly ($P < 0.001$) affected by poultry litter rates, rising from 100.04 t/ha in the control to 123.52 t/ha at T_4 (15 t/ha), giving a 23.5% yield advantage. This response underscores the importance of organic nitrogen supply in driving canopy expansion and photosynthetic productivity in high-biomass C4 grasses (Kariuki *et al.*, 2023). The results align with Makkar and Beeker (2023), who reported a 19–28% fresh yield improvement in Napier grass fertilised with poultry manure at rates of 10–20 t/ha relative to unfertilised controls and attributed the response to improved soil nitrogen mineralisation, enhanced root development, and greater leaf area index.

Table 1: Effect of Poultry Litter Application Rates on Agronomic Characteristics and Fresh Biomass Yield of Tiller-propagated Napier Grass

Parameters	Poultry Litter Application rate				SEM	P/t* - value
	T ₁ (Control)	T ₂ (5 t/ha)	T ₃ (10 t/ha)	T ₄ (15 t/ha)		
Plant height (cm)	340.87 ^{bc}	347.13 ^{ab}	348.91 ^a	339.09 ^c	2.8543	0.0419
Leaf length (cm)	131.82	131.54	133.70	130.73	1.2934	0.4213
Leaf width (cm)	4.96 ^a	4.85 ^{ab}	4.67 ^{bc}	4.63 ^c	0.0513	< 0.0001
Stand circumference (cm)	75.858	74.42	76.78	72.96	1.7304	0.4259
Number of leaves	25.125 ^a	23.74 ^b	22.44 ^c	21.71 ^c	0.2836	< 0.0001
Number of tillers	22.42 ^{ab}	23.57 ^a	20.33 ^b	21.25 ^{ab}	0.2836	0.0506
stem girth (cm)	7.65 ^a	7.70 ^a	7.38 ^b	7.09 ^c	0.0719	< 0.0001
Leaf: Stem ratio	0.61 ^b	0.51 ^b	0.55 ^b	0.75 ^a	0.0326	< 0.0001*
Biomass (t/ha)	100.04 ^c	108.22 ^{bc}	116.00 ^{ab}	123.52 ^a	4.1157	0.0007*

Key: Means within rows bearing different superscripts differ significantly ($P < 0.05$). T₁ = Control (0 t/ha); T₂ = 5 t/ha; T₃ = 10 t/ha; T₄ = 15 t/ha. SEM = standard error of means; * = t - values

Effect of Harvesting Age on Agronomic Characteristics and Fresh Biomass Yield of Tiller-Propagated Napier Grass

Table 2 presents the effects of harvesting age on agronomic characteristics and fresh biomass yield. Harvesting age exerted highly significant ($P < 0.0001$) effects on all measured agronomic traits. Plant height increased progressively from 308.37 cm at 45 DAC to 386.04 cm at 90 DAC, perhaps driven by sustained apical meristem activity and continuous internode elongation under the prevailing humid-sub humid conditions. This consistent height gain is well-documented for Napier grass in West Africa (Onyeonagu and Asiegbu, 2021) and reflects the species' indeterminate vegetative growth habit in the absence of terminal drought or photoperiod-induced flowering. Stand circumference expanded from 59.68 cm at 45 DAC to 91.13 cm at 90 DAC, indicating progressive crown enlargement and spread as the basal clump matured. Number of tillers per plant increased markedly from 16.76 at 45 DAC to 30.00 at 90 DAC, a near doubling that highlights the strong tillering dynamics of this tiller-propagated material with age. The 16.76 tillers observed in this study for control is more than 4 times the 3.6 tillers reported by Onwubiko and Olwori (2025),

both for control at comparative 45 and 42 days' regrowth period respectively. This increased tiller density at later harvest ages is critically important for ratoon productivity, as it translates directly into stand longevity and the potential for sustained high yields across successive cuts (Kariuki *et al.*, 2023). Leaf length declined from 140.48 cm (45 DAC) to a minimum of 119.27 cm at 75 DAC before recovering to 129.85 cm at 90 DAC, possibly reflecting a shift in assimilate partitioning from leaf blade elongation to stem and root storage during mid-growth. Stem girth remained statistically stable between 45 and 75 DAC (7.51–7.61 cm) but declined significantly at 90 DAC (7.12 cm), consistent with reports of relative stem girth reduction at advanced maturity as cell-wall composition shifts toward increased lignification (Aderinola *et al.*, 2020). Fresh biomass yield increased significantly from 74.92 t/ha at 45 DAC to 148.97 t/ha at 90 DAC, approximately a 99% increase, demonstrating the enormous capacity of Napier grass for biomass accumulation with extended growing periods. This yield trajectory underscores the critical role of harvesting interval in determining total fresh matter output and forms the basis of the

yield–quality trade-off central to practical

forage management (Tadesse *et al.*, 2022).

Table 2: Effect of Harvesting Age on Agronomic Characteristics and Yields of Tiller-Propagated Napier grass

Parameters	Harvesting Age (Days after cutback)				SEM	P/t* - value
	45	60	75	90		
Plant height (cm)	308.37 ^d	328.26 ^c	353.33 ^b	386.04 ^a	2.854	< 0.0001
leaf length (cm)	140.48 ^a	138.19 ^a	119.27 ^c	129.85 ^b	1.293	< 0.0001
leaf width (cm)	4.47 ^c	4.544 ^{bc}	5.37 ^a	4.70 ^b	0.051	< 0.0001
stand circumference (cm)	59.68 ^d	66.83 ^c	82.39 ^b	91.13 ^a	1.730	< 0.0001
Number of leaves	17.51 ^d	20.42 ^c	24.83 ^d	30.25 ^a	0.284	< 0.0001
Number of tillers	16.76 ^c	17.14 ^c	23.67 ^b	30.00 ^a	0.867	< 0.0001
stem girth (cm)	7.59 ^a	7.51 ^a	7.61 ^a	7.12 ^b	0.072	< 0.0001
Leaf: Stem ratio	0.67 ^a			0.54 ^b	0.023	< 0.0001*
Biomass (t/ha)	74.92 ^b			148.97 ^a	2.910	< 0.0001*

Key: Means within rows with different superscripts are significantly ($p < 0.05$) different, * t- value, SEM = standard error of means

Interaction Effect of Poultry Litter Rates and Harvesting Age on Agronomic Characteristics and Yield

The interaction effects of poultry litter rates and harvesting age on growth and yield traits are presented in Table 3. The interaction between poultry litter rates and harvesting age was significant for plant height ($P = 0.0001$), leaf length ($P < 0.0001$), stand circumference ($P = 0.042$), number of leaves ($P < 0.0001$), stem girth ($P < 0.0001$), and leaf-to-stem ratio ($P < 0.0001$), but not for leaf width ($P = 0.322$), number of tillers ($P = 0.100$), or fresh biomass yield ($P = 0.402$). The highest individual plant height was recorded in T₁H₄ (398.97 cm), followed by T₂H₄ (385.67 cm) and T₃H₄ (382.17 cm), confirming the dominant positive influence of advanced age on height regardless of fertilizer level. The tallest plants at early harvest (T₂H₁: 316.24 cm and T₃H₁: 321.17 cm) showed a modest early-cycle nitrogen advantage from intermediate poultry litter rates, suggesting that available nitrogen is most effectively converted to height gain during the first six weeks of growth (Bello and Ibrahim, 2022). The highest fresh biomass in the interaction was recorded in T₄H₄ (15 t/ha, 90 DAC: 165.11 t/ha), significantly surpassing T₁H₄ (134.00 t/ha)

and T₂H₁ (75.00 t/ha). Although the overall ANOVA did not detect significant differences among treatments, post-hoc analysis suggested that some pairwise contrasts may exist. This apparent discrepancy arises because the omnibus test evaluates equality across all groups simultaneously, whereas Tukey's HSD examines individual pairwise differences, ($F = 0.9847$, $df = 3$, $p = 0.4020$). Specifically, T₄H₄ (15 t/ha, 90 DAC: 165.11 t/ha) was ranked higher than T₁H₄ (Control, 90 DAC, 134.00 t/ha) which was similar ($P > 0.05$) to T₂H₄ (5 t/ha, 90 DAC: 141.44 t/ha and T₃H₄ (10 t/ha, 90 DAC: 155.33 t/ha) while all fertilizer rates at first harvest (45 DAC) did not differ significantly. Mean values are presented in Table 3, with superscript letters denoting Tukey groupings. The non-significant interaction for fresh biomass ($P = 0.402$) indicates that the effects of poultry litter rate and harvesting age are additive rather than synergistic for yield, simplifying the recommendation framework: each additional unit of poultry litter contributes proportionally to yield across all harvesting ages, and each additional day of growth contributes proportionally to yield across all fertilizer levels (Olanite *et al.*, 2022).

The significant interaction for leaf-to-stem ratio, with T₄H₁ recording the highest value (0.99), indicates that at the earliest harvest age, high poultry litter application

disproportionately promotes leaf relative to stem tissue, a finding with positive implications for herbage digestibility.

Table 3: Interaction Effect of Poultry Litter Application Rates and Harvest Age on Agronomic Characteristics and Yield of Tiller-Propagated Napier grass

P.L.A.*HA	Plant height	Leaf length	leaf width	stand circum-ference	Number of leaves	Number of tillers	stem girth	Leaf: Stem ratio	Fresh Biomass (t/ha)
T ₁ H ₁	288.72 ^g	143.74 ^{ab}	4.60 ^{de}	56.49 ^g	16.72 ^h	18.11 ^{efg}	7.011 ^{efg}	0.61 ^b	66.09 ^c
T ₁ H ₂	314.56 ^{efg}	134.71 ^{abcd}	4.82 ^{cd}	71.78 ^{cdefg}	21.22 ^{ef}	18.22 ^{efg}	8.09 ^{ab}		
T ₁ H ₃	361.23 ^{bc}	114.33 ^g	5.56 ^a	83.67 ^{abcd}	25.56 ^{cd}	23.00 ^{bcde}	7.93 ^{abc}		
T ₁ H ₄	398.97 ^a	134.50 ^{abcd}	4.87 ^{bcd}	91.50 ^{ab}	37.00 ^a	30.33 ^{ab}	7.57 ^{bcdef}	0.61 ^b	134.00 ^b
T ₂ H ₁	316.24 ^{efg}	146.03 ^a	4.63 ^{de}	61.94 ^{fg}	17.78 ^{gh}	21.22 ^{cdefg}	8.39 ^a	0.51 ^b	75.00 ^c
T ₂ H ₂	339.56 ^{cde}	140.56 ^{abc}	4.67 ^{de}	68.41 ^{defg}	20.67 ^f	16.44 ^{efg}	7.62 ^{bcdef}		
T ₂ H ₃	347.07 ^{cd}	117.20 ^{fg}	5.37 ^{ab}	82.67 ^{bcde}	25.00 ^{cd}	26.78 ^{abcd}	7.64 ^{bcde}		
T ₂ H ₄	385.67 ^{ab}	122.38 ^{defg}	4.72 ^{cde}	84.67 ^{abcd}	31.50 ^b	29.83 ^{ab}	7.13 ^{defg}	0.52 ^b	141.44 ^{ab}
T ₃ H ₁	321.17 ^{def}	132.17 ^{bcde}	4.37 ^{de}	62.00 ^{fg}	17.89 ^{gh}	13.33 ^g	7.60 ^{bcdef}	0.58 ^b	76.67 ^c
T ₃ H ₂	333.91 ^{cdef}	144.09 ^{ab}	4.38 ^{de}	66.60 ^{efg}	20.33 ^{fg}	18.33 ^{defg}	7.22 ^{defg}		
T ₃ H ₃	358.38 ^{bc}	124.53 ^{defg}	5.20 ^{abc}	78.33 ^{bcdef}	24.89 ^{cd}	22.00 ^{bcdef}	7.78 ^{abcd}		
T ₃ H ₄	382.17 ^{ab}	134.00 ^{abcd}	4.73 ^{cde}	100.17 ^a	26.67 ^c	27.67 ^{abc}	6.93 ^{fg}	0.51 ^b	155.33 ^{ab}
T ₄ H ₁	307.37 ^{fg}	139.98 ^{abc}	4.28 ^e	58.29 ^g	17.67 ^{gh}	14.39 ^{fg}	7.34 ^{cdefg}	0.99 ^a	81.93 ^c
T ₄ H ₂	325.00 ^{def}	133.42 ^{abcde}	4.31 ^e	60.51 ^g	19.44 ^{fgh}	15.56 ^{efg}	7.09 ^{defg}		
T ₄ H ₃	346.64 ^{cd}	121.02 ^{efg}	5.42 ^a	84.89 ^{abcd}	23.89 ^{de}	22.89 ^{bcde}	7.09 ^{defg}		
T ₄ H ₄	377.37 ^{ab}	128.50 ^{cdef}	4.50 ^{de}	88.17 ^{abc}	25.83 ^{cd}	32.17 ^a	6.83 ^g	0.52 ^b	165.11 ^a
SEM	5.709	2.587	0.103	3.461	0.567	1.735	0.144	0.046	5.821
P/t* – value	0.0001	<0.0001	0.322	0.0423	<0.0001	0.101	<.0001	<.0001*	0.402*

Key: Means in the same columns bearing different superscripts differed significantly ($P < 0.05$), T₁ = Control, T₂ = 5 tons/Ha, T₃ = 10 tons/Ha, T₄ = 15 tons/Ha, H₁ = Harvested at age 45 days, H₂ = Harvested at age 60 days, H₃ = Harvested at 75 days, H₄ = Harvested at 90 days, * t- value, SEM = standard error of means

Effect of Poultry Litter Application Rates on Proximate Composition and Cell-Wall Fibre Fractions

Table 4 shows the effects of poultry litter application rates on proximate composition and cell-wall fibre fractions of tiller-propagated Napier grass. Dry matter content, crude fibre, NDF, ADF, and cellulose were not significantly ($P > 0.05$) affected by poultry litter rates, suggesting that gross structural carbohydrate and cell-wall composition are relatively insensitive to the range of organic nitrogen inputs tested. These findings corroborate Oso *et al.* (2022), who observed that NDF and ADF of Napier grass were unresponsive to organic manure rates between 0 and 20 t/ha, attributing the stability

to the strong genotypic regulation of fibre synthesis pathways in this species.

Crude protein was significantly ($P < 0.0001$) influenced by poultry litter rates. The highest CP was recorded at T₄ (12.38%), and the lowest at T₃ (11.13%), with T₁ (12.13%) and T₂ (11.82%) occupying intermediate positions. The elevated CP at T₄ relative to T₃ likely reflects adequate nitrogen uptake at the highest manure rate, where the accumulation of organic-N mineralised from 15 t/ha poultry litter exceeded the dilution effect of accelerated biomass production (Makkar and Beeker, 2023). The lower CP at T₃ compared to T₁ and T₂ may reflect a growth dilution effect, rapid vegetative growth at 10 t/ha increased total dry matter yield faster than nitrogen could be assimilated into protein.

This phenomenon was earlier reported by Kariuki *et al.* (2023) in Napier grass receiving moderate organic nitrogen.

Total ash increased significantly with poultry litter rate, peaking at T₄ (13.00%), consistent with the higher mineral content supplied by the litter, particularly potassium, calcium, and phosphorus (Dauda *et al.*, 2021). Nitrogen-free extract was highest in T₂ (44.11%) and lowest in T₄ (42.24%), reflecting an inverse relationship between fermentable

carbohydrate storage and total nitrogen assimilation. Acid detergent lignin was highest at T₃ (11.81%), and hemicellulose declined from T₁ (8.57%) to T₃ and T₄ (7.95% and 8.01%, respectively), suggesting that intermediate-to-high nitrogen application may slightly increase cross-linking of cell-wall polysaccharides through enhanced lignin deposition, a mechanism that could marginally reduce hemicellulose solubility and digestibility (Van Soest *et al.*, 1991).

Table 4: Effect of Fertilizer Treatment on Proximate Composition and Cell wall fiber fraction on Napier Grass Propagated by Tillers

Parameters	T ₁	T ₂	T ₃	T ₄	SEM	P – Value
Dry Matter	90.32	91.32	90.71	91.13	0.830	0.8323
Crude Protein	12.13 ^{ab}	11.82 ^b	11.13 ^c	12.38 ^a	0.109	< 0.0001
Ether Extract	1.81 ^b	2.018 ^a	1.87 ^b	1.86 ^b	0.018	< 0.0001
Crude Fibre	21.38	21.18	21.43	21.65	0.196	0.4057
Total Ash	12.33 ^b	12.19 ^b	12.47 ^b	13.00 ^a	0.116	<0.0001
Nitrogen Free Extract	42.67 ^{ab}	44.11 ^a	43.82 ^a	42.24 ^b	0.395	0.0025
Neutral Detergent Fiber	40.29	40.02	39.63	39.81	0.366	0.6115
Acid Detergent Fiber	31.73	31.64	31.68	31.80	0.290	0.9817
Acid Detergent Lignin	11.54 ^{ab}	11.39 ^b	11.81 ^a	11.71 ^{ab}	0.106	0.0362
Cellulose	20.19	20.25	19.87	20.10	0.184	0.4978
Hemicellulose	8.57 ^a	8.38 ^{ab}	7.95 ^b	8.01 ^b	0.076	0.0022

Key: Means within rows with different superscripts differed significantly ($P < 0.05$), T₁ = Control, T₂ = 5 tons/Ha, T₃ = 10 tons/Ha, T₄ = 15 tons/Ha

Effect of Harvesting Age on Proximate Composition and Cell-Wall Fibre Fractions

Table 5 presents the effects of harvesting age on proximate composition and cell-wall fibre fractions. Harvesting age significantly ($P < 0.0001$) influenced all nutritional parameters except dry matter ($P = 0.257$). Crude protein was highest at 60 DAC (13.91%) and significantly lower and statistically comparable at 45, 75, and 90 DAC (11.28%, 11.11%, and 11.17%, respectively). The peak CP at the 60-day harvest rather than the youngest (45-day) harvest is noteworthy. It may reflect the rapid canopy expansion and peak photosynthetic nitrogen assimilation occurring around this stage, following the initial lag phase of establishment during the

first 45 days when roots are still developing and nutrient uptake is below its maximum (Tadesse *et al.*, 2022). The relatively low CP at 45 DAC (11.28%) supports this interpretation. The CP levels at 60 DAC (13.91%) exceed the threshold of 7% commonly cited as minimum for adequate rumen microbial function, and are broadly consistent with values reported for Napier grass harvested at 45–60 DAC in earlier Nigerian studies (Aderinola *et al.*, 2020; Onyeonagu and Asiegbu, 2021).

Neutral detergent fibre increased from 37.51% at 45 DAC to 44.50% at 75 DAC before declining to 37.16% at 90 DAC. A similar curvilinear pattern was observed for ADF (29.39% → 34.59% → 30.91%), ADL (10.75% → 12.71% → 12.06%), and

hemicellulose (8.12% → 9.91% → 6.24%). The decline in NDF and ADF at 90 DAC relative to 75 DAC may appear counterintuitive but has been reported previously in studies of advancing maturity in Napier grass, possibly reflecting selective translocation of soluble carbohydrates to the stem base, a relative decrease in the proportion of high-fibre young leaf tissue, or dilution of structural carbohydrates by rapidly accumulating stem storage

parenchyma (Bello and Ibrahim, 2022). Total ash increased continuously from 9.63% at 45 DAC to 15.81% at 90 DAC, consistent with progressive mineral accumulation and silicification of epidermal tissues in C4 grasses over time. NFE declined progressively from 46.49% at 45 DAC to 41.23% at 90 DAC, indicating a reduction in readily fermentable non-structural carbohydrates as the plant aged.

Table 5: Effect of Harvesting Age on Proximate Composition and Cell-wall Fibre Fractions (% DM basis) of Tiller-Propagated Napier Grass

Parameters	45 days	60 days	75 days	90 days	SEM	P – Value
Dry Matter	89.65	92.03	90.86	90.93	0.830	0.2574
Crude Protein	11.28 ^b	13.91 ^a	11.11 ^b	11.17 ^b	0.109	< 0.0001
Ether Extract	1.183 ^d	2.033 ^b	1.69 ^c	2.65 ^a	0.018	< 0.0001
Crude Fibre	21.06 ^b	21.27 ^b	23.23 ^a	20.07 ^c	0.196	< 0.0001
Total Ash	9.63 ^d	12.03 ^c	12.51 ^b	15.81 ^a	0.116	< 0.0001
Nitrogen Free Extract	46.49 ^a	42.79 ^b	42.33 ^{bc}	41.23 ^c	0.395	< 0.0001
Neutral Detergent Fiber	37.51 ^c	40.58 ^b	44.50 ^a	37.16 ^c	0.366	< 0.0001
Acid Detergent Fiber	29.39 ^c	31.95 ^b	34.59 ^a	30.91 ^b	0.290	< 0.0001
Acid Detergent Lignin	10.75 ^c	10.93 ^c	12.71 ^a	12.06 ^b	0.106	< 0.0001
Cellulose	18.64 ^c	21.03 ^b	21.89 ^a	18.85 ^c	0.184	< 0.0001
Hemicellulose	8.12 ^c	8.63 ^b	9.91 ^a	6.24 ^d	0.076	< 0.0001

Key: Means within rows with different superscripts differed significantly ($P < 0.05$), SEM = standard error of means.

Interaction Effect of Poultry Litter Rates and Harvesting Age on Proximate Composition and Cell-Wall Fibre Fractions

Table 6 presents the interaction effects of poultry litter application rates and harvesting age on herbage nutritional quality.

The interaction between poultry litter rates and harvesting age was significant for crude protein ($P = 0.005$), ether extract ($P < 0.0001$), total ash ($P = 0.011$), acid detergent lignin ($P = 0.033$), cellulose ($P = 0.005$), and hemicellulose ($P = 0.0002$), while dry matter, crude fibre, NFE, NDF, and ADF were non-significant. The most notable interaction was observed for crude protein (see also Fig.1), where T₂H₂ (5 t/ha, 60 DAC) recorded the highest CP (14.67%), followed by T₁H₂ (14.26%) and T₄H₂ (13.88%). The pattern clearly shows that the 60-day harvest

captures the peak CP irrespective of fertilizer treatment, but the magnitude of the CP peak is modified by poultry litter rate. Specifically, moderate nitrogen supply (T₂ = 5 t/ha) gave the highest CP at 60 DAC, suggesting that this combination best aligns nitrogen availability with the period of maximum leaf protein synthesis. The lowest CP was recorded in T₂H₄ (10.05%), indicating that at 90 DAC, even moderate organic nitrogen supply is insufficient to prevent protein dilution by excessive structural and storage carbohydrates.

Ether extract was highest in T₂H₄ (2.88%) and T₄H₄ (2.85%), indicating that extended growing periods combined with poultry litter application favour lipid accumulation in stem tissue, possibly through deposition of cutin, wax, and storage lipids as the plant approaches reproductive maturity (Aderinola

et al., 2020). As evident in Fig. 3 also, total ash showed the greatest value in T₄H₄ (16.70%) and peaks at 90 DAC irrespective of the fertilizer treatment which is consistent with the additive mineralisation of soil minerals from high litter rates and prolonged mineral uptake with advancing age. Acid detergent lignin was highest in T₄H₃ (13.03%), while cellulose peaked in T₃H₃ (22.33%), indicating that the 75-day harvest with 10 t/ha poultry litter maximises cell-wall structural component deposition. Hemicellulose was highest at T₁H₃ (10.79%) and T₂H₃ (10.15%) but declined sharply to below 7% at 90 DAC across all fertilizer

treatments, corroborating the earlier main-effect finding and underscoring the critical loss of potentially fermentable cell-wall polysaccharides at the latest harvest age.

From a practical feeding perspective, these interaction results reinforce the recommendation that producers targeting maximum crude protein density should prioritise the 60-day harvest with 5 t/ha poultry litter (T₂H₂), while those prioritising maximum biomass yield, for silage or biogas, for instance, should use 15 t/ha poultry litter and harvest at 90 DAC (T₄H₄: 165.11 t/ha), accepting a compromise on herbage protein content.

Table 6: Interaction Effect of Interaction of Poultry Litter Application Rates and Harvest Age on Proximate Composition and Cell wall fiber fraction of Napier Grass

P.L.A x HA	DM	CP	EE	CF	ASH	NFE	NDF	ADF	ADL	C	HC
T ₁ H ₁	89.25	11.01 ^{efg}	1.01 ^g	20.87	9.20 ^f	47.16	37.55	28.95	10.33 ^e	18.62 ^{de}	8.60 ^{cde}
T ₁ H ₂	91.57	14.26 ^a	1.89 ^{de}	21.23	12.33 ^{cde}	41.86	41.12	32.44	10.66 ^e	21.78 ^{abc}	8.68 ^{cde}
T ₁ H ₃	90.39	11.41 ^{def}	1.89 ^{de}	23.01	12.40 ^{cde}	41.68	44.98	34.19	12.58 ^{ab}	21.61 ^{abc}	10.79 ^a
T ₁ H ₄	90.05	11.83 ^{cde}	2.45 ^b	20.41	15.40 ^b	39.96	37.51	31.32	12.58 ^{ab}	18.74 ^{de}	6.19 ^g
T ₂ H ₁	89.84	11.13 ^{efg}	1.18 ^{fg}	20.97	9.80 ^f	46.76	37.32	28.87	10.54 ^e	18.33 ^e	8.45 ^{cde}
T ₂ H ₂	93.48	14.67 ^a	2.23 ^c	20.99	11.66 ^{de}	43.93	40.63	32.71	10.82 ^{de}	21.89 ^{ab}	7.92 ^{def}
T ₂ H ₃	91.67	11.44 ^{def}	1.78 ^e	22.83	11.93 ^{cde}	43.69	44.74	34.59	12.46 ^{ab}	22.13 ^{ab}	10.15 ^{ab}
T ₂ H ₄	90.27	10.05 ^g	2.88 ^a	19.93	15.35 ^b	42.06	37.38	30.39	11.75 ^{bcd}	18.64 ^{de}	6.99 ^{fg}
T ₃ H ₁	89.96	11.11 ^{efg}	1.24 ^f	20.88	9.59 ^f	47.14	37.65	29.84	11.33 ^{cde}	18.51 ^e	7.81 ^{ef}
T ₃ H ₂	91.35	12.82 ^{bc}	2.04 ^d	21.46	11.58 ^e	43.45	39.89	31.12	11.13 ^{cde}	19.99 ^{cde}	8.77 ^{cde}
T ₃ H ₃	90.07	10.08 ^g	1.77 ^e	23.47	12.89 ^c	41.86	44.40	35.08	12.75 ^{ab}	22.33 ^a	9.32 ^{bc}
T ₃ H ₄	91.46	10.52 ^{fg}	2.42 ^b	19.89	15.8 ^{ab}	42.83	36.56	30.68	12.02 ^{abc}	18.66 ^{de}	5.88 ^g
T ₄ H ₁	89.55	11.88 ^{cde}	1.30 ^f	21.53	9.94 ^f	44.90	37.52	29.91	10.81 ^{de}	19.10 ^{de}	7.61 ^{ef}
T ₄ H ₂	91.71	13.88 ^{ab}	1.97 ^d	21.41	12.55 ^{cde}	41.90	40.67	31.53	11.09 ^{cde}	20.44 ^{bcd}	9.14 ^{bcd}
T ₄ H ₃	91.32	11.51 ^{def}	1.32 ^f	23.61	12.80 ^{cd}	42.08	43.89	34.51	13.03 ^a	21.48 ^{abc}	9.38 ^{bc}
T ₄ H ₄	91.94	12.26 ^{cd}	2.85 ^a	20.06	16.70 ^a	40.07	37.17	31.26	11.9 ^{bc}	19.36 ^{de}	5.91 ^g
SEM	1.659	0.218	0.036	0.391	0.231	0.790	0.731	0.580	0.213	0.368	0.241
P-value	0.993	0.005	<0.0001	0.929	0.011	0.4045	0.999	0.317	0.033	0.005	0.0002

Key: Means in the same column bearing different superscripts differ significantly ($P < 0.05$). DM = dry matter; CP = crude protein; EE = ether extract; CF = crude fibre; NFE = nitrogen-free extract; NDF = neutral detergent fibre; ADF = acid detergent fibre; ADL = acid detergent lignin; C = cellulose; HC = hemicellulose. T₁ = 0 t/ha; T₂ = 5 t/ha; T₃ = 10 t/ha; T₄ = 15 t/ha. H₁ = 45 DAC; H₂ = 60 DAC; H₃ = 75 DAC; H₄ = 90 DAC. SEM = standard error of means

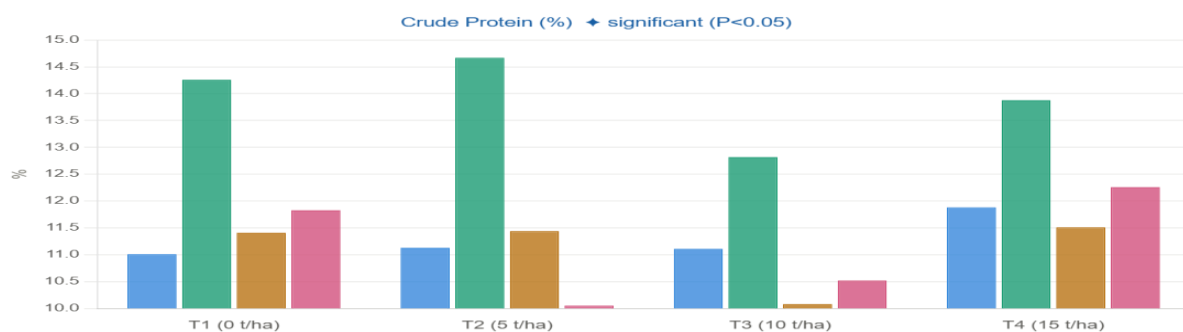


Figure 1: Interaction Effect of Poultry Litter Application Rates and Harvest Age on Crude Protein of Tiller-propagated Napier Grass Blue = 45 Days' Harvest, Green = 60 days' Harvest, Orange = 75 days' Harvest, Pink = 90 days' Harvest

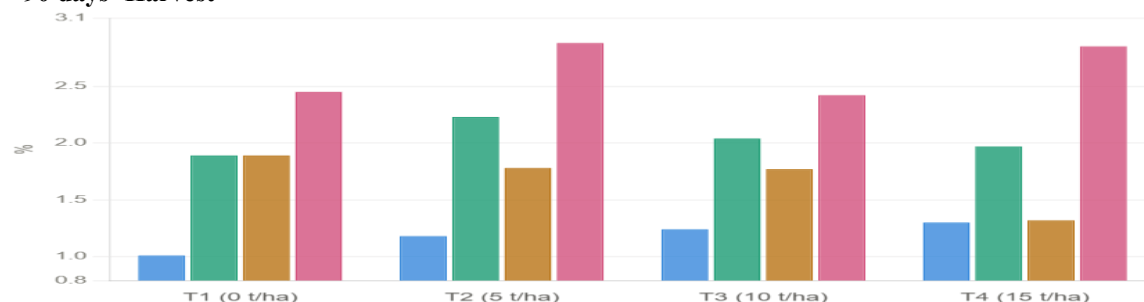


Figure 2: Interaction Effect of Poultry Litter Application Rates and Harvest Age on Ether Extract of Tiller-propagated Napier Grass Blue = 45 days' Harvest, Green = 60 days' Harvest, Orange = 75 Days' Harvest, Pink = 90 Days' Harvest

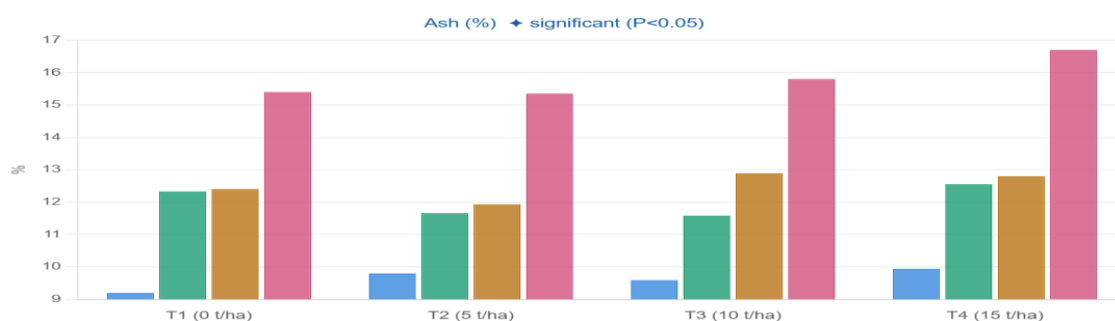


Figure 3: Interaction Effect of Poultry Litter Application Rates and Harvest Age on Ash content of Tiller-propagated Napier Grass Blue = 45 Days' Harvest, Green = 60 Days' Harvest, Orange = 75 Days' Harvest, Pink = 90 Days' Harvest

CONCLUSION

This study provides quantitative evidence that both poultry litter application rate and harvesting age are critical determinants of the agronomic performance and herbage nutritional quality of tiller-propagated Napier grass. Poultry litter application at 10–15 t/ha significantly enhanced fresh biomass yield by up to 23.5% relative to the unfertilized control, with the highest individual plot yield of 165.11 t/ha recorded at the T₄H₄ combination. Harvesting age had the most

profound influence on all parameters, with plant height, tiller number, and fresh biomass increasing consistently up to 90 DAC. Crude protein peaked at 60 DAC (13.91%), while cell-wall fibre fractions and total ash generally increased with advancing maturity. Significant interactions between poultry litter rate and harvesting age were detected for crude protein, ether extract, total ash, acid detergent lignin, cellulose, and hemicellulose, confirming that the nutritional quality responses to organic fertilization are age-dependent.

RECOMMENDATIONS

Based on the findings of this study, the following management guidelines are recommended for tiller-propagated Napier grass in the Nigerian derived savanna and similar agro ecological environments:

Combining 5 t/ha poultry litter and harvest at 60 DAC gives the highest forage quality (CP = 14.67%) with moderate biomass which may be best suited for dairy and other high-performing livestock whose productivity is sensitive to dietary protein concentration. Also, combination of 10-15 t/ha poultry litter application rates with 60-75 days' harvest age balances yield and quality (116-155 t/ha fresh yield with CP of 10.1-13.9%). For maximum biomass suitable for silage making, combination of 15 t/ha poultry litter and harvest at 90 DAC is recommended. Furthermore, tiller propagation provides an efficient and practical alternative to conventional stem-cutting propagation, particularly where planting material is scarce. Extension services should incorporate tiller propagation protocols into forage production training curricula.

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