FORAGE GROWTH BIOMASS, YIELD, AND QUALITY RESPONSES OF THREE VARIETIES NAPIER AT CUTTING INTERVALS IN THE SOUTH WEST NIGERIA

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Forage crops are essential for livestock production, particularly in tropical regions like Southwest Nigeria. Napier grass (*Pennisetum purpureum*), widely known for its high biomass yield and nutritional value, is a popular choice for livestock feed. This study aims to evaluate the growth, biomass yield, and forage quality of three Napier grass varieties (Pakchong-1, CO-3, and Giant Napier) under three different cutting intervals (40 days, 60 days, and 80 days), providing insights for optimizing forage management practices. The experiment involved planting the three Napier grass varieties and evaluating their responses to cutting intervals of 40, 60, and 80 days. Key parameters measured included plant height, tiller number per plant, leaf-to-stem ratio (LSR), fresh and dry biomass yield, and forage quality indicators such as crude protein, neutral detergent fibre (NDF), acid detergent fibre (ADF), calcium, magnesium, and phosphorus content. Data were statistically analysed to determine significant differences among the varieties and cutting intervals.The results revealed significant growth and biomass yield differences among the three varieties. Pakchong-1 exhibited the tallest plants, the highest tiller number, and the greatest biomass yield across all cutting intervals. CO-3 maintained a higher LSR, indicating better leaf retention. Biomass yield increased with longer cutting intervals, with Pakchong-1 yielding the highest fresh and dry biomass at 80 days. However, shorter cutting intervals favoured higher crude protein content, which decreased as intervals lengthened. Fibre content (NDF and ADF) increased with longer intervals, reducing digestibility. Pakchong-1 is ideal for maximizing biomass production, particularly at longer cutting intervals, while CO-3 offers advantages in forage quality at shorter intervals. These findings emphasize the need to select Napier grass varieties and cutting intervals based on specific production goals, providing valuable recommendations for improving livestock productivity and sustainability in tropical regions.

Napier grass varieties, Cutting intervals, Biomass yield, Forage quality, Livestock production, Tropical agriculture

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INTRODUCTION

Forage crops are vital for the sustainability of livestock production, particularly in tropical regions where they provide the primary feed source for ruminants. *Pennisetum purpureum, commonly known as Napier grass,* stands out due to its high biomass yield, nutritional quality, and adaptability to various environmental conditions (Singh et al., 2020). Napier grass, widely known as elephant grass, is mostly cultivated in Africa, Asia, and Latin America to meet the growing feed demands of dairy and beef cattle (Islam et al., 2023).

Napier grass has the ability to produce substantial biomass even under marginal soil conditions and minimal inputs, which makes it a cost-effective forage option for smallholder farmers (Mutimura et al., 2017). Furthermore, its nutritional profile, characterized by relatively high crude protein content and digestible fibre, supports the health and productivity of ruminants (Rengsirikul et al., 2011). These attributes make Napier grass preferred over other forages, such as maize and sorghum. Cutting interval refers to the frequency at which the grass is harvested, and it significantly influences growth dynamics, nutrient composition, and overall productivity (Deng et al., 2024). Thus, exploring cutting intervals of Napier grass is crucial for maximizing the yield and quality. Shorter cutting intervals enhance forage quality by harvesting younger, more nutritious leaves but may reduce overall biomass yield (Singh et al., 2020). In contrast, longer intervals allow for greater biomass accumulation but result in lower nutritional quality as the plant matures and fibre content increases (Singh et al.,2020; Aleme et al 2024).

Different Napier grass varieties exhibit varying responses to cutting intervals due to genetic differences in growth patterns, nutrient uptake, and stress tolerance. Hybrid varieties such as Pakchong-1 and CO-3 are known for their superior yield and nutritional quality compared to traditional varieties like Giant Napier (Hassan et al., 2020). Therefore, comparative studies of different Napier grass varieties under Environmental factors like climate, soil type, slope, and drainage greatly impact the optimal planting spacing for Napier grass. In areas with high rainfall and fertile soils, closer spacing can enhance biomass yield. Conversely, wider spacing reduces competition for water and nutrients in drier or less fertile conditions. On slopes or poorly drained soils, wider spacing helps prevent erosion and waterlogging, ensuring healthier root development and overall plant growth. Tailoring spacing to these conditions optimizes productivity and, under various cutting intervals, is essential to optimize forage management practices (Lardner et al., 2015).

This study aims to evaluate the growth, biomass yield, and quality responses of three varieties of Napier grass (Pakchong-1, CO-3, and Giant Napier) at three different cutting intervals (40 days, 60 days, and 80 days) The 40, 60, and 80-day cutting intervals balance forage quality and biomass yield, reflecting young growth, mid-point balance, and maximum biomass, aiding practical management and research comparability in Southwest Nigeria. By providing empirical data on these parameters, the study seeks to inform best practices for forage management, thereby enhancing livestock productivity and sustainability in the region. Planting spacing in Napier grass typically ranges from 0.5 to 1 meter between rows and plants. Closer spacing increases plant density and biomass yield per area but can heighten resource competition. Wider spacing improves air circulation, reduces disease risk, and facilitates easier cutting and maintenance, depending on management goals (Bureenock et al., 2013).

METHODOLOGY

1 Study Area

The study was conducted at the Teaching and Research Farm of the Federal University Oye-Ekiti, located in Oye-Ekiti, Ekiti State, Nigeria. The farm's geographical coordinates are approximately 7.75°N latitude and 5.33°E longitude. The site is situated at an altitude of 370 meters above sea level, providing a representative environment for studying tropical forage crops. The study was conducted in 2023 and 2024 for a two-year study duration.

1.1 Climate

Oye-Ekiti experiences a tropical climate characterized by distinct wet and dry seasons. The wet season typically spans from April to October, with peak rainfall occurring between July and September. The average annual rainfall is about 1400 mm. The dry season extends from November to March, with lower humidity and minimal rainfall. The average temperature ranges from 22°C to 28°C, with relative humidity between 60% and 80%.

1.2 Soil Characteristics

The soil in the study area is classified as sandy loam, which is well-drained and suitable for the cultivation of Napier grass. Soil samples were collected at a depth of 0–20 cm for initial analysis to determine baseline soil properties. The following key parameters were measured:

- pH: 5.8 (moderately acidic)
- Organic Matter Content: 2.5% (moderate)
- Total Nitrogen (N): 0.12% (low)
- Available Phosphorus (P): 10.5 mg/kg (moderate)
- Exchangeable Potassium (K): 0.34 cmol/kg (moderate)
- Cation Exchange Capacity (CEC): 7.8 cmol/kg (moderate fertility)

2 Experimental Design

A 3 x 3 factorial experiment was designed to evaluate the effects of three cultivars of Napier hybrid grass (*Pennisetum purpureum* x P. glaucum, CO-3, and Giant Napier) and three cutting intervals (40 days, 60 days, and 80 days) on forage growth, dry matter (DM) yield, and crude protein (CP) concentration.

2.1 Treatments

The treatments consisted of:

- Cultivars: Pakchong-1, CO-3, and Giant Napier
- Cutting Intervals: 40 days, 60 days, and 80 days

2.2 Plot Layout

The experimental plots were laid out in a rectangular field. Each plot measured 5 meters by 5 meters, with a 1-meter buffer zone between plots to minimize edge effects and ensure uniformity in growth conditions. The total experimental area covered approximately 0.5 hectares.

2.3 Randomization

The treatments were randomly assigned to the plots within each block to reduce the impact of spatial variability on the results. The randomization process was carried out using a random number generator to assign treatments to plots within each block.

3 Soil Preparation and Planting

3.1 Land Preparation

The study area was cleared of existing vegetation and debris before soil preparation. The following steps were taken to prepare the soil for planting:

● Ploughing: The field was ploughed to a depth of 20 cm to break up the soil and improve aeration.

● Harrowing: The field was harrowed to further break down soil clods and create a fine tilth suitable for planting.

● Ridging: Ridges were created at a spacing of 1 meter apart to facilitate planting and management of the crops.

3.2 Planting Materials

Stem cuttings of the Pakchong-1, CO-3, and Giant Napier hybrids were obtained from a certified nursery. The cuttings were approximately 20-25 cm long and contained 3-4 nodes each to ensure adequate root development and establishment.

3.3 Planting Procedure

The stem cuttings were planted horizontally in the ridges at a spacing of 1 meter by 1 meter. This spacing was chosen to provide adequate space for the growth and development of the plants and to allow for easy management practices such as weeding and irrigation. Each cutting was buried to a depth of 10 cm, leaving a portion of the stem exposed to facilitate sprouting.

4 Irrigation and Weed Control

Initial irrigation was provided to ensure good establishment of the cuttings. Subsequently, the plots were irrigated as needed, particularly during dry spells, to maintain optimal soil moisture levels. Weeds were controlled manually to minimize competition for nutrients and water.

5 Data Collection

5.1 Growth Parameters

Growth data were collected at regular intervals, measuring:

● Plant Height: Measured from the base to the tallest leaf tip every two weeks.

● Number of Tillers: Counted manually per plant at each interval.

● Leaf Area: Measured using a leaf area meter from representative samples.

5.2 Yield Parameters

● Fresh Biomass Yield: Measured immediately after cutting using a digital scale.

● Dry Matter Yield: A subsample was oven-dried at 65°C until a constant weight was recorded.

5.3 Forage Quality Analysis

Nutritional parameters were analyzed using standard procedures:

● Crude Protein Content: Determined via the Kjeldahl method.

● Fibre Content: Neutral detergent fibre (NDF) and acid detergent fibre (ADF) were measured.

● Mineral Content: Calcium (Ca), magnesium (Mg), and phosphorus (P) were analyzed using atomic absorption spectrophotometry.

5.4 Sampling Procedure

Representative samples were collected at each cutting interval. Fresh biomass was weighed in the field, and subsamples were taken to the laboratory for further analysis.

6 Statistical Analysis

6.1 Data Management

Data were recorded in Microsoft Excel, checked for accuracy, and cleaned before analysis.

6.2 Analysis of Variance (ANOVA)

ANOVA was used to evaluate the effects of hybrid variety and cutting interval on growth, yield, and forage quality parameters.

Statistical significance was determined at $P < 0.05$. (A O A C I990)

6.3 Mean Separation

Where significant differences were found, Least Significant Difference (LSD) test was conducted to compare treatment means.

7 Experimental Timeline

The study spanned 12 months to capture the full growth cycle of Napier grass. The timeline included:

1. Preparation Phase: Soil preparation and planting (Month 1).

2. Establishment Phase: Initial growth and establishment (Months 2–3).

3. Growth and Harvest Phase: Data collection and harvesting at cutting intervals (Months 4–12).

4. Analysis Phase: Laboratory forage quality and statistical analysis (Months 6–12).

8 Environmental and Management Practices

8.1 Fertilization

A balanced NPK fertilizer (20:10:10) was applied at planting and after each harvest.

Fertilizer rates were adjusted based on soil test results and plant requirements.

8.2 Pest and Disease Management

Integrated Pest Management (IPM) was used, incorporating biological control agents and eco-friendly pesticides.

Resistant planting materials and proper sanitation were practiced to reduce disease risks.

9 Data Quality Control

To ensure accurate and reliable data:

- **Calibration of Instruments:** Scales, leaf area meters, and spectrophotometers were calibrated regularly.
- **Training of Personnel:** Field and laboratory personnel were trained in standardized data collection methods.
- **Replicate Measurements:** Multiple measurements were taken to account for variability and improve precision.

DISCUSSION

Plant Height

The data on plant height across three cutting intervals (40, 60, and 80 days) in Table 1. for Pakchong-1, CO-3, and Giant Napier reveals significant differences among the varieties. At 40 days, Pakchong-1 recorded the highest plant height at 180.5 cm, followed by Giant Napier at 160.3 cm and CO-3 at 150.4 cm. These trends continue as the cutting intervals increase, with Pakchong-1 reaching 220.6 cm at 80 days, CO-3 at 190.4 cm, and Giant Napier at 200.1 cm. The consistent superiority of Pakchong-1 in plant height may indicate its robustness and suitability for conditions in Southwest Nigeria. The statistical analysis shows significant differences ($p < 0.05$) among the varieties, with Pakchong-1 outperforming the others. The results align with the findings of Rahetla et al., 2014, which showed that Elephant grass (*Pennisetum purpureum*) responded positively to fertilization, resulting in increased plant height and biomass yield.

Tiller Number per Plant

The tiller number per plant in table 1, is crucial for understanding the biomass potential and the overall health of forage crops. At 40 days, CO-3 had the highest tiller number (14.8), followed by Giant Napier (13.2) and Pakchong-1 (12.3). As the cutting interval increased to 80 days, CO-3 maintained its lead with 18.2 tillers per plant, Giant Napier followed with 17.5, and Pakchong-1 with 16.8. The significant differences in tiller numbers among the varieties ($p < 0.05$) suggest that CO-3 might be better suited for higher biomass production in a shorter time frame, which is beneficial for frequent harvesting schedules.

Leaf Ratio (LSR)

The leaf ratio (LSR) is a critical parameter affecting the forage quality, as leaves generally have higher nutritional value compared to stems. At 40 days, CO-3 had the highest LSR (2.2), followed by Giant Napier (2.0) and Pakchong-1 (1.8). This trend persisted through 60 and 80 days, with CO-3 maintaining the highest leaf ratio. The decreasing LSR across all varieties as the cutting interval increased indicates that the proportion of leaves to stems decreases over time, affecting the overall forage quality. This parameter showed significant differences ($p < 0.05$) among the varieties, highlighting the importance of selecting varieties with higher leaf ratios for better nutritional outcomes.

Fresh Biomass Yield

Fresh biomass yield is a direct measure of the productivity of forage crops. Pakchong-1 yielded the highest biomass at all cutting intervals, starting at 5.8 kg/m² at 40 days, 7.4 kg/m² at 60 days, and peaking at 9.4 kg/m² at 80 days. CO-3 and Giant Napier followed a similar trend but with lower yields, indicating that Pakchong-1 has superior biomass production capabilities.

The differences in fresh biomass yield were statistically significant ($p < 0.05$), suggesting that Pakchong-1 could be the most productive variety under the given conditions.

Dry Matter Yield

Dry matter yield is essential for understanding the actual usable biomass after moisture is removed. Pakchong-1 again led in dry matter yield at all intervals, from 2.0 kg/m² at 40 days to 3.5 kg/m² at 80 days. CO-3 and Giant Napier had comparable but lower yields. The significant differences ($p < 0.05$)

Table 1: Forage Growth Biomass, Yield, and Quality Responses of Three Napier Grass Varieties at Different Cutting Intervals

Growth and Nutritional Characteristics at 40 Days Cutting Interval			
Parameter	**Pakchong-1**	**CO-3**	**Giant Napier**
Plant Height (cm)	180.5 ± 7.2^{b}	150.4 ± 6.5^{a}	160.3 ± 6.9^{a}
Tiller Number per Plant	12.3 ± 1.5^{a}	14.8 ± 2.0^{b}	13.2 ± 1.8^{a}
Leaf to Stem Ratio (LSR)	1.8 ± 0.2^{a}	2.2 ± 0.3^{b}	2.0 ± 0.2^{b}
Fresh Biomass Yield (kg/m²)	5.8 ± 0.3^{b}	5.3 ± 0.2^{a}	5.6 ± 0.2^{a}
Dry Matter Yield (kg/m²)	2.0 ± 0.2^{b}	1.8 ± 0.2^{a}	1.9 ± 0.2^{a}
Crude Protein Content (%)	17.0 ± 0.6^{a}	17.5 ± 0.5^{a}	17.2 ± 0.5^{a}
NDF (%)	52.6 ± 1.8^{a}	50.3 ± 1.7^{a}	51.3 ± 1.7^{a}
ADF (%)	34.4 ± 1.2^{a}	33.6 ± 1.3^{a}	34.0 ± 1.3^{a}
Calcium (Ca, %)	0.35 ± 0.02^{a}	0.33 ± 0.02^{a}	0.34 ± 0.02^{a}
Magnesium (Mg, %)	0.18 ± 0.01^{a}	0.17 ± 0.01^{a}	0.17 ± 0.01^{a}
Phosphorus (P, %)	0.15 ± 0.01^{a}	0.14 ± 0.01^{a}	0.14 ± 0.01^{a}
Growth and Nutritional Characteristics at 60 Days Cutting Interval			
Parameter	**Pakchong-1**	**CO-3**	**Giant Napier**
Plant Height (cm)	200.5 ± 8.2^{c}	170.3 ± 7.8^{b}	180.2 ± 7.5^{b}
Tiller Number per Plant	14.2 ± 1.7^{b}	16.5 ± 2.3^{c}	15.4 ± 2.1^{b}
Leaf to Stem Ratio (LSR)	1.6 ± 0.1^{a}	2.0 ± 0.2^{b}	1.9 ± 0.1^{b}
Fresh Biomass Yield (kg/m²)	7.4 ± 0.4^{c}	W6.9 ± 0.3^{b}	7.1 ± 0.3^{b}
Dry Matter Yield (kg/m²)	2.8 ± 0.3^{c}	2.5 ± 0.2^{b}	2.6 ± 0.3^{b}
Crude Protein Content (%)	15.3 ± 0.4^{b}	16.0 ± 0.4^{b}	15.7 ± 0.4^{b}
NDF (%)	54.6 ± 2.0^{b}	52.1 ± 1.9^{b}	53.0 ± 1.9^{b}
ADF (%)	36.7 ± 1.5^{b}	35.8 ± 1.4^{b}	36.2 ± 1.4^{b}
Calcium (Ca, %)	0.32 ± 0.02^{a}	0.31 ± 0.02^{a}	0.31 ± 0.02^{a}
Magnesium (Mg, %)	0.16 ± 0.01^{a}	0.15 ± 0.01^{a}	0.15 ± 0.01^{a}
Phosphorus (P, %)	0.13 ± 0.01^{a}	0.13 ± 0.01^{a}	0.13 ± 0.01^{a}
Growth and Nutritional Characteristics at 80 Days Cutting Interval			
Plant Height (cm)	220.6 ± 9.8^{d}	190.4 ± 8.9^{c}	200.1 ± 8.8^{c}
Tiller Number per Plant	16.8 ± 2.0^{c}	18.2 ± 2.5^{d}	17.5 ± 2.3^{c}
Leaf to Stem Ratio (LSR)	1.4 ± 0.1^{b}	1.8 ± 0.1^{b}	1.7 ± 0.1^{b}
Fresh Biomass Yield (kg/m²)	9.4 ± 0.5^{d}	8.3 ± 0.4^{c}	8.6 ± 0.4^{c}
Dry Matter Yield (kg/m²)	3.5 ± 0.4^{d}	3.1 ± 0.3^{c}	3.3 ± 0.3^{c}
Crude Protein Content (%)	13.8 ± 0.3^{c}	14.5 ± 0.3^{c}	14.2 ± 0.3^{c}
NDF (%)	56.3 ± 2.3^{c}	53.8 ± 2.1^{c}	54.5 ± 2.1^{c}
ADF (%)	38.2 ± 1.8^{c}	37.4 ± 1.6^{c}	37.7 ± 1.6^{c}
Calcium (Ca, %)	0.30 ± 0.02^{a}	0.28 ± 0.02^{a}	0.29 ± 0.02^{a}
Magnesium (Mg, %)	0.14 ± 0.01^{a}	0.13 ± 0.01^{a}	0.14 ± 0.01^{a}
Phosphorus (P, %)	0.12 ± 0.01^{a}	0.11 ± 0.01^{a}	0.12 ± 0.01^{a}

Note: Superscripts (^{a}, ^{b}, ^{c}, ^{d}) indicate statistical differences ($P < 0.05$). Values with different letters are significantly different within a row.

in dry matter yield among the varieties emphasize Pakchong-1's suitability for producing high-quality forage with substantial dry matter content, which is crucial for livestock feeding.

This finding is supported by Lardner et al., (2015), who evaluated different grass species and found significant differences in dry matter yield and nutritive value, with certain varieties outperforming others under similar conditions.

Crude Protein Content

Crude protein content is a vital nutritional parameter for forage quality. In table 1 At 40 days, CO-3 had the highest crude protein content (17.5%), followed by Giant Napier (17.2%) and Pakchong-1 (17.0%). However, as the cutting interval increased, crude protein content decreased across all varieties, with Pakchong-1 showing the least reduction, maintaining 13.8% at 80 days compared to CO-3's 14.5% and Giant Napier's 14.2%. The significant differences ($p < 0.05$) indicate that while CO-3 starts with the highest protein content, Pakchong-1 retains its protein content better over time, making it a more reliable source of protein for extended harvest periods.

These results are consistent with the study by Rahetla et al.,2014 ;Setimela et al.,2014 which found that the level of crude protein in forage crops significantly influences their nutritional value and digestibility in livestock.

Neutral Detergent Fiber (NDF) and Acid Detergent Fiber (ADF)

NDF and ADF are indicators of forage digestibility and quality. Lower values are preferable as they indicate higher digestibility. At 40 days, CO-3 had the lowest NDF (50.3%) and ADF (33.6%), followed by Giant Napier and Pakchong-1 in table 1. These values increased with longer cutting intervals, with Pakchong-1 reaching the highest NDF (56.3%) and ADF (38.2%) at 80 days in table 1. The significant differences ($p < 0.05$) among the varieties suggest that CO-3 may offer more digestible forage, especially at shorter cutting intervals. found that N fertilization impacts the fibre content and digestibility of different forage grasses, supporting the findings on the NDF and ADF values among the varieties.

Mineral Content (Calcium, Magnesium, Phosphorus)

Mineral content is crucial for the nutritional quality of forage. All three varieties had similar calcium, magnesium, and phosphorus content, with no significant differences noted ($p > 0.05$). However, there was a slight decrease in mineral content as the cutting interval increased Ghimire et al., 2020; Chanthakhoun et al.,2012; Khan et al.,2008 suggests that while the choice of variety may not significantly impact mineral content, earlier harvesting could help maintain higher mineral levels Negawo et al., 2020

CONCLUSION

Overall, the analysis reveals that Pakchong-1 is the most productive variety in terms of plant height, fresh biomass yield, and dry matter yield, making it highly suitable for forage production in Southwest Nigeria. CO-3, on the other hand, excels in crude protein content and tiller number per plant, suggesting its potential for high-quality forage with frequent harvesting. Giant Napier presents a balanced performance across parameters but does not lead in any specific category. For optimal forage production, a combination of Pakchong-1 for high biomass and CO-3 for high nutritional quality could be considered, depending on the specific needs and harvesting schedules of the forage system.

AUTHORS CONTRIBUTION

All authors contributed significantly to the research. Joshua Femi Oluwadele designed the study, conducted the experiments, and wrote the manuscript. Anthony Henry Ekeocha assisted in data collection and statistical analysis, while Adeolu Ademiju Aganga contributed to the review and finalization of the manuscript.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this research.

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