Effects of Harvest Age and Nitrogen Fertilization Levels on Nutrient Composition and Yield of Red Elephant Grass (*Pennisetum purpureum* cv. Red)

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Abstract. This study evaluated the effect of harvest age and fertilisation rate on nutrient production of Red Napier Grass (*Pennisetum purpureum* cv. Red) (RNG) in the fifth harvest period. The design used was a factorial completely randomised design (CRD), with two factors, namely harvest age (50, 60, 70, and 80 days) and fertilization level (P0: 0 kg N/ha/year, P1: 150 kg N/ha/year, and P2: 300 kg N/ha/year). Each treatment combination was repeated three times, resulting in 12 treatments. Parameters observed included nutrient content i.e. Dry Matter (DM), Organic Matter (OM), Crude Protein (CP), Crude Fiber (CF), Crude Fat and nutrient production of DM, OM and CP. The results showed that harvesting age and fertilization rate had a significant effect on nutrient content. The interaction between harvest age and fertilizer level also had a very significant effect on nutrient content. The results also showed that harvest age and fertilizer level had a significant effect ($P<0.05$) on DM production and a very significant effect ($P<0.01$) on OM and CP production. The interaction between harvest age and fertilizer level did not have a significant effect nutrient production ($P>0.05$). The highest DM and OM production was found in the P2 treatment at the age of 80 days, while CP production reached its peak at the age of 60 days with the same fertilizer level. It is recommended to harvest Red Napier Grass at the age of 80 days with fertilizer treatment P2 (300 kg N/ha/year) to get optimal yields. In addition, the CP content that decreases at older harvest ages can be added with concentrate feed in animal.

Keywords: Biomass Production, Fertilization, Harvest Age, Nutrient Content, Red Napier Grass.

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1 Introduction

Forage is a crucial nutritional component for ruminant livestock, supporting maintenance, productivity, and reproductive performance. Forages provide essential nutrients such as protein, carbohydrates, vitamins, and water required by ruminants[1]. Ruminant animals, including cattle and goats, rely heavily on forages due to their ability to digest fibrous materials through microbial fermentation in the rumen. The forage requirement for large ruminants accounts for approximately 40–80% of total dietary dry matter or about 1.5–3% of body weight. Therefore, a continuous and sustainable supply of forage throughout the year is essential [2]

The Indonesian cattle sector is largely dominated by smallholder farmers, who typically manage a small number of animals under intensive management systems relying on locally available feed resources[3]. One of the most widely cultivated forage species under this system is elephant grass (*Pennisetum purpureum*). Elephant grass (*Pennisetum purpureum*), native to tropical Africa, is widely cultivated across tropical and subtropical regions for forage due to its remarkable biomass yield, high adaptability, and resilience to environmental stresses [4] and subtropical regions worldwide due to its high productivity, palatability, and favorable nutritional value[5]. Since its introduction to Southeast Asia in the early twentieth century, various cultivars of elephant grass have been developed and used extensively for ruminant feeding.

Elephant grass cultivars are generally classified based on plant height. Tall-type cultivars (>130 cm) include common elephant grass, red elephant grass, Taiwan elephant grass, Indian elephant grass, Uganda elephant grass, and King grass, whereas short-type cultivars (<90 cm) include dwarf elephant grass, Mott elephant grass, and Australian dwarf elephant grass. Among these, RNG *(Pennisetum purpureum cv. Red*) has gained increasing attention due to its distinctive reddish-purple coloration. This cultivar originated from Africa and has been introduced to Southeast Asia, including Indonesia, where planting materials have become increasingly available through commercial markets and online platforms.

RNG is characterized by rapid growth and high annual biomass production; however, its performance is strongly influenced by climatic conditions, water availability, and fertilization management. Previous studies have reported that red elephant grass can produce high dry matter yields with moderate crude protein content [6]. Nevertheless, forage yield and nutritional quality are strongly affected by harvest age and soil fertility

Harvest age plays a critical role in determining forage yield and nutritive value. Increasing harvest age generally leads to higher dry matter accumulation due to prolonged photosynthetic activity, but it is also associated with increased fiber and lignin contents and a reduction in crude protein concentration. In addition to harvest age, soil fertility—particularly nitrogen availability—is a key factor influencing vegetative growth and chlorophyll formation. Nitrogen fertilization, commonly applied in the form of urea, is widely used to enhance forage productivity and nutritional quality.

The characteristics of RNG also vary across harvest cycles. During early harvests, plants are still undergoing adaptation and root system establishment, resulting in suboptimal biomass production and nutritional quality. In contrast, by the fifth harvest cycle, plants tend to be more physiologically stable, enabling higher biomass production and more consistent nutrient composition. Despite its considerable potential as a forage resource, scientific information regarding the nutrient composition and nutrient yield of red elephant grass, particularly during the fifth harvest cycle, remains limited. Therefore, this study aims to evaluate the effects of harvest age and nitrogen fertilization levels on the nutrient composition and nutrient production of RNG during the fifth harvest cycle.

2 Materials and methods

2.1 Location

The experiment was conducted at the Sumbersekar Field Station, Faculty of Animal Science, Universitas Brawijaya, Malang Regency, Indonesia. The site is located in a tropical humid zone at 112°34’35’’ E and 7°55’07’’ S. Nutrient of the forages was analyzed at the Animal Nutrition Laboratory, Faculty of Animal Science, Universitas Brawijaya.

2.2 Research Variables

The parameters evaluated in this study included the nutrient composition of red elephant grass, namely dry matter (DM), organic matter (OM), crude protein (CP), crude fiber (CF), and ether extract (EE), nitrogen free extract (NFE) as well as the nutrient yields of DM, OM, and CP.

2.3 Research Procedure

This study used RNG that had been planted since March 5, 2023 and had undergone four previous harvests. The fourth harvest was conducted between December 19, 2023 and April 30, 2024, and this research focused on the fifth harvest cycle. The experiment was arranged in a factorial Completely Randomized Design (CRD) with two treatment factors: harvest age and nitrogen fertilization level. Harvest age consisted of four levels (50, 60, 70, and 80 days), while nitrogen fertilization level consisted of three levels, namely P0 (no fertilizer), P1 (150 kg N ha^{-1} $year^{-1}$), and P2 (300 kg N ha^{-1} $year^{-1}$). Each treatment combination was replicated three times using plots measuring 3 m × 4 m.

Harvesting was conducted during the fifth harvest cycle according to the assigned harvest ages by cutting the plants at approximately 5 cm above ground level. Fresh biomass from each plot was weighed using a hanging scale to determine fresh yield, and ten plants were randomly selected from each plot as samples.

The collected samples were separated into stems, leaf sheaths, and leaves to determine the proportion of aerial plant components. The samples were chopped, oven-dried at 60°C for 2–3 days to determine air-dry matter content, and then ground into fine powder. Ground samples were composited across replicates (10 g per plant component) prior to analysis. Composited samples were analyzed for nutrient composition using proximate analysis according to AOAC (2005) methods

2.4 Research Variables

The data were analyzed using Analysis of Variance (ANOVA). When significant differences were detected among treatments, the means were further compared using Duncan’s Multiple Range Test (DMRT). The ANOVA was performed based on the following statistical model:

$$Yijk=\mu+\alpha i+\beta j+(\alpha\beta)ij+\varepsilon ijk$$

Where :
Yijk = observed value for factor A at level i, factor B at level j and replication k
μ = overall mean;
αi = effect of factor A at level i;

βj = effect of factor B at level jjj
(αβ)ij= interaction effect between factor A at level i and factor B at level j
εijk = experimental error associated with factor A at level iii, factor B at level jjj and replication kkk [7]

3 Results and discussion

3.1 Nutrient composition

The analysis of variance showed that harvest age, fertilization level, and the interaction between these factors had highly significant effects (P < 0.01) on DM, OM, CP, CF, EE and NFE)contents. The nutrient composition of Red Napier under the different treatments is presented in Table 1.

Table 1. Nutrient composition of RNG as affected by harvest age and fertilization level

Treatments		DM	Nutrient Composition (%)				
			OM	CP	CF	EE	NFE
Harvest age	50	17.16^{a}±0.50	85.54^{a}±1.19	7.58^{c}±1.05	33.90^{d}±0.62	1.84^{a}±0.31	42.22^{a}±2.47
	60	18.39^{b}±1.17	88.13^{d}±0.25	5.87^{b}±0.82	31.35^{a}±1.00	1.91^{b}±0.35	49.00^{d}±0.41
	70	19.19^{c}±0.93	87.41^{c}±0.73	5.19^{a}±0.73	33.51^{c}±0.24	1.85^{a}±0.25	46.86^{b}±1.10
	80	20.23^{d}±1.33	87.01^{b}±1.46	5.24^{a}±0.64	32.31^{b}±1.23	2.08^{c}±0.50	47.38^{c}±2.29
	P-value	P<0.01	P<0.01	P<0.01	P<0.01	P<0.01	P<0.01
Fertilizer level	P0	19.08^{b}±0.85	86.23^{a}±1.84	7.00^{c}±0.79	32.18^{a}±1.49	2.14^{c}±0.14	44.92^{a}±3.69
	P1	19.03^{b}±1.87	87.27^{b}±0.99	5.31^{a}±0.79	32.78^{b}±0.76	1.53^{a}±0.08	47.65^{c}±2.22
	P2	18.11^{a}±0.85	87.58^{b}±0.70	5.61^{b}±1.22	33.34^{c}±1.39	2.09^{b}±0.38	46.54^{b}±2.70
	P-value	P<0.01	P<0.01	P<0.01	P<0.01	P<0.01	P<0.01
Harvest age × Fertilizer level	P0 50	16.65^{a}±0.31	83.98^{a}±0.06	8.93^{g}±0.07	33.83^{g}±0.04	1.99^{f}±0.04	39.22^{a}±0.13
	P0 60	19.81^{c}±0.34	88.36^{e}±0.17	6.87^{e}±0.18	30.23^{a}±0.02	2.33^{i}±0.03	48.85^{ef}±0.40
	P0 70	20.11^{c}±0.31	87.43^{d}±0.17	6.12^{d}±0.12	33.27^{e}±0.15	2.17^{h}±0.02	45.87^{d}±0.15
	P0 80	19.74^{c}±0.80	85.16^{b}±0.51	6.06^{cd}±0.25	31.30^{b}±0.07	2.06^{fg}±0.04	45.74^{d}±0.84
	P1 50	17.69^{ab}±0.20	86.14^{c}±0.03	6.59^{e}±0.01	33.22^{e}±0.06	1.43^{a}±0.01	44.89^{c}±0.07
	P1 60	17.41^{ab}±0.09	88.04^{de}±0.06	5.01^{b}±0.03	32.61^{d}±0.05	1.54^{b}±0.00	48.89^{ef}±0.03
	P1 70	19.24^{bc}±0.75	86.58^{c}±0.31	4.90^{ab}±0.23	33.58^{f}±0.27	1.64^{c}±0.04	46.45^{d}±0.31
	P1 80	21.79^{d}±0.76	88.31^{e}±0.31	4.73^{ab}±0.15	31.70^{c}±0.15	1.52^{b}±0.01	50.37^{g}±0.32
	P2 50	17.13^{ab}±0.18	86.52^{c}±0.14	7.22^{f}±0.08	34.64^{h}±0.03	2.09^{g}±0.11	42.56^{b}±5.49
	P2 60	17.93^{ab}±0.79	87.98^{de}±0.28	5.73^{c}±0.20	31.12^{b}±0.06	1.86^{e}±0.06	49.27^{f}±0.59
	P2 70	18.22^{b}±0.28	88.22^{e}±0.14	4.53^{a}±0.09	33.68^{fg}±0.04	1.73^{d}±0.02	48.27^{e}±0.20
	P2 80	19.14^{bc}±0.33	87.58^{d}±0.14	4.94^{b}±0.08	33.92^{g}±0.03	2.67^{j}±0.05	46.04^{d}±0.24
	P-value	P<0.01	P<0.01	P<0.01	P<0.01	P<0.01	P<0.01

Different superscripts within the same column indicate highly significant differences (P < 0.01). P0 = control (no fertilization); P1 = urea fertilizer at 150 kg N ha^{-1} $year^{-1}$; P2 = urea fertilizer at 300 kg N ha^{-1} $year^{-1}$.Dry matter (DM), organic matter (OM), crude protein (CP), crude fiber (CF), and ether extract (EE), nitrogen free extract (NFE).

The results of this study demonstrated that harvest age and nitrogen fertilization level significantly affected the nutrient composition of RNG both as main factors and through their interaction during the fifth harvest cycle. DM content increased with advancing harvest age, reaching the highest value at 80 days. This increase is associated with reduced moisture content and enhanced lignification of plant tissues as the grass matures. In contrast, increasing nitrogen fertilization levels tended to reduce DM content, likely due to excessive nitrogen promoting succulent growth and higher water accumulation in plant tissues. This finding supports previous reports indicating that high nitrogen availability can lower DM concentration by increasing tissue hydration.

OM content was highest at intermediate harvest age (60 days) and tended to decline at later stages of maturity. The reduction in OM at older harvest ages may be related to increased ash content and structural carbohydrate accumulation. Conversely, higher nitrogen fertilization levels increased OM content, reflecting the role of nitrogen in supporting organic biomass formation and enhancing soil–plant nutrient dynamics. CP content was highest at younger harvest ages and declined as plants matured. This decline is commonly attributed to a dilution effect caused by increased structural biomass and reduced metabolic activity in older tissues [8]. Unexpectedly, higher nitrogen fertilization did not consistently increase CP content, which may be explained by changes in plant morphological composition, particularly the increased proportion of stems that contain lower protein levels than leaves [5]. CF content exhibited variable responses to harvest age and fertilization level. Although fiber accumulation is generally expected to increase with plant maturity, the observed fluctuations suggest that environmental and agroclimatic factors played a significant role in influencing cell wall development [9]. The interaction between harvest age and fertilization further highlights the complexity of structural carbohydrate responses to management practices [10].

EE content remained relatively low across treatments but showed a slight increase at older harvest ages. The response of EE to nitrogen fertilization was inconsistent [11] indicating that lipid accumulation in forage is influenced more by plant physiological adaptation and repeated harvesting than by nitrogen input alone. NFE content was significantly affected by harvest age, fertilization level, and their interaction. Higher NFE values were generally observed at intermediate to late harvest ages combined with moderate nitrogen fertilization. Changes in nitrogen-free extract (NFE) or non-fiber carbohydrate fractions are generally coupled with shifts in structural carbohydrate components (e.g., crude fiber), reflecting the inverse balance between readily fermentable non-structural carbohydrates and more resistant structural carbohydrates in forage feeds[12].

Overall, the findings indicate that harvesting red elephant grass at intermediate to late maturity with appropriate nitrogen fertilization during the fifth harvest cycle can optimize the balance between forage yield and nutritional quality. However, nutrient concentrations during the fifth harvest were generally lower than those reported for earlier harvest cycles, likely due to plant adaptation processes and differences in agroclimatic conditions across harvest periods.

3.2 Production of DM, OM, CP in Red Napier

The analysis of variance indicated that harvest age and fertilization level individually had significant effects ($P < 0.05$) on dry matter (DM) yield and highly significant effects ($P < 0.01$) on organic matter (OM) and crude protein (CP) yields. In contrast, the interaction between harvest age and fertilization level had no significant effect ($P > 0.05$) on DM, OM, and CP yields. The nutrient yields of RNG under the different treatments are presented in Table 2.

Table 2. Nutrient Production of DM, OM, CP in Red Napier Grass

Treatments		Nutrient yield (kg per 12 m² per harvest)		
		DM	OM	CP
	50	6.24^{a}±2.27	5.35^{a}±2.00	0.46^{ab}±0.23
Harvest age	60	9.92^{a}±3.63	8.74^{ab}±3.69	0.58^{b}±0.23
	70	8.72^{ab}±5.21	6.14^{b}±6.48	0.31^{a}±0.15
	80	11.28^{b}±4.12	9.82^{b}±3.62	0.57^{b}±0.20
	P-value	P<0.05	P<0.01	P<0.01
Fertilizer level	P0	8.08^{a}±4.69	5.87^{a}±3.02	0.43^{ab}±0.11
	P1	7.39^{a}±4.87	6.47^{ab}±2.35	0.38^{a}±0.24
	P2	11.64^{b}±6.58	10.20^{b}±3.94	0.62^{b}±0.24
	P-value	P<0.05	P<0.01	P<0.01
Harvest age × Fertilizer level	P0 50	4.47±0.88	3.75±0.74	0.40±0.08
	P0 60	8.86 ±3.13	7.83±2.77	0.61±0.22
	P0 70	8.79 ±3.39	3.19±1.38	0.11±0.05
	P0 80	10.22±2.49	8.71±2.16	0.62±0.13
	P1 50	5.41±0.44	4.66±0.38	0.36±0.03
	P1 60	8.15±4.19	7.18±3.69	0.41±0.21
	P1 70	6.17±0.18	5.34±0.14	0.30±0.02
	P1 80	9.85±1.40	8.70±1.27	0.46±0.05
	P2 50	8.84±1.98	7.65±1.70	0.64±0.14
	P2 60	12.73±4.13	11.21±3.66	0.72±0.21
	P2 70	11.20±4.73	9.88±4.18	0.51±0.21
	P2 80	13.77±6.77	12.05±5.91	0.68±0.34
	P-value	P>0.05	P>0.05	P>0.05

Different superscripts within the same column indicate significant ($P < 0.05$) and highly significant ($P < 0.01$) differences. P0 = control (no fertilization); P1 = urea fertilizer at 150 kg N ha^{-1} $year^{-1}$; P2 = urea fertilizer at 300 kg N ha^{-1} $year^{-1}$

The results presented in Table 2 indicate that harvest age and fertilization level significantly affected the production of dry matter (DM), organic matter (OM), and crude protein (CP) of RNG. DM and OM production increased with increasing harvest age, with the highest values recorded at 80 days of harvest [10], [13]. This increase was associated with greater biomass accumulation at more advanced plant maturity[14]. In contrast, the highest CP production was observed at a harvest age of 60 days, indicating that the active vegetative growth phase is more favorable for protein synthesis than later growth stages. Fertilization level also had a significant effect on nutrient production. High urea application (P2: 300 kg N ha^{-1} $year^{-1}$) resulted in the highest DM, OM, and CP production compared to other treatments. This finding suggests that increased nitrogen availability enhances vegetative growth, photosynthetic activity, and nutrient accumulation in the plant. No interaction effect between harvest age and fertilization level was observed on DM, OM, and CP production during the fifth harvest period. Nevertheless, the nutrient yields obtained in this study were higher than those reported in several previous studies, indicating that the combination of optimal harvest age and higher nitrogen fertilization has strong potential to significantly improve the productivity of red elephant grass[15].

4 Conclusion

This study demonstrates that harvest age and nitrogen fertilization level significantly affect the nutritional composition of Red Napier grass (*Pennisetum purpureum cv. Red*) during the fifth harvesting period. Both factors, as well as their interaction, markedly influenced dry matter, organic matter, crude protein, crude fiber, and ether extract contents, indicating that plant maturity and nitrogen availability play critical roles in determining forage quality. Furthermore, harvest age and fertilization level independently affected dry matter, organic matter, and crude protein yields, whereas no significant interaction between the two factors was observed for nutrient production. The highest dry matter and organic matter yields were obtained at 80 days of harvest under the highest nitrogen application rate (300 kg N ha^{-1} $year^{-1}$), reflecting increased biomass accumulation at later growth stages. In contrast, crude protein yield peaked at 60 days of harvest under the same fertilization level, suggesting that the vegetative growth phase is more favorable for protein synthesis than advanced maturity stages. These findings indicate that optimizing harvest timing in combination with adequate nitrogen fertilization is essential to maximize both forage yield and nutritional quality of Red Napier grass.

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