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# Effect of Different Nitrogen Fertilizer Rates on the Forage Yield of Mombasa Guinea Grass (*Panicum maximum* cv. Mombasa) in the Benadir Region

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## Abstract

Forage production is crucial for livestock development, especially in regions where feed availability is limited. Among tropical forage grasses, *Panicum maximum* (Mombasa Guinea Grass) is highly valued for its adaptability, high biomass production, and nutritional quality. Effective fertilizer management, particularly nitrogen application, is vital to maximize yield while maintaining economic viability. A field experiment was carried out at Somali National University's Gaheyr Campus in Mogadishu from September 2022 to March 2023 to assess how different rates of nitrogen fertilizer affect the growth and yield of *Panicum maximum*. The study used a randomized complete block design (RCBD) with three replications over a total area of 264 m$^2$, consisting of 21 plots of 9 m$^2$ each. Seven nitrogen levels were tested: 0, 25, 50, 75, 100, 125, and 150 kg·N/ha. Data were analyzed using Statistix 8.0, and the results showed that nitrogen application had a highly significant impact ($P < 0.01$) on all growth and yield measurements. Fresh yield increased from 20,333 kg/ha at 0 N to 60,417 kg/ha at 150 kg·N/ha, while dry yield grew from 5,917 kg/ha to 28,167 kg/ha across the treatments. The findings indicate that 100 kg·N/ha is the optimal application rate, providing the highest statistically significant yield while remaining economically feasible for farmers. This highlights the potential of improved nitrogen management to boost forage supply and support livestock productivity in Somalia. The study suggests further research on forage nutrient quality and long-term soil fertility effects to promote sustainable pasture management.

**Keywords**

*Panicum maximum*, Nitrogen Fertilizer, Forage Yield, Mombasa Grass, Somalia, RCBD

## 1. Introduction

Globally, Mombasa Guinea Grass (*Panicum maximum*) is widely used in tropical and subtropical pastures to feed livestock, given its high yield and quality. This perennial crop grows well on well-drained, fertile soils but also tolerates drought [1]. In sub-tropical and tropical environments, this grass can produce an annual dry matter yield of up to 33 t/ha with nitrogen fertilizer management [2]. Mombasa Guinea Grass is characterized by its persistence under intensive management conditions and high productivity, which are results of its photosynthetic and water efficiency and high phenotypic plasticity. In Africa, Mombasa Guinea Grass (*Panicum maximum*) is native to 13 tropical and subtropical countries, including Angola, Benin, Botswana, Cameroon, Côte d'Ivoire, Democratic Republic of Congo, Eritrea, Ethiopia, Ghana, Kenya, Lesotho, Liberia, and Malawi. Furthermore, this grass has been introduced to almost all tropical countries as a source of animal forage. For example, in Kenya, *Panicum maximum* is found growing naturally in the delta wetland region of Tana River County. The pastoralist communities in Tana Delta, who keep cattle, sheep, goats, camels, and donkeys as their main livelihood, heavily depend on *Panicum maximum* as their primary pasture source [3].

Mombasa Guinea Grass (*Panicum maximum* Jacq.) is a forage grass found in tropical and subtropical regions. It is an apomictic, tetraploid species originating from Africa [4]. Mombasa Guinea Grass was previously known as *Panicum maximum* Jacq. In 2003, the subgeneric name *Megathyrsus* was added, and it was renamed *Megathyrsus* maximus (Jacq.). The Poaceae family is ecologically dominant and by far the most economically important plant family in the world. Mombasa Guinea Grass, a perennial forage species in this family, forms an agamic complex with *Panicum infestum* and *Panicum trichocladum* (tribe of Paniceae), belonging to the subfamily Panicoideae. It is native to Africa (tropical origin). Still, due to its good forage quality, particularly as beef feed, it has been distributed to nearly all tropical countries as a source of animal forage. Thanks to its high forage production, nutritional value, and adaptability to various ecological regions, Mombasa Guinea Grass has been widely introduced and exploited in most tropical and subtropical zones, including Brazil, Japan, the USA, and Australia. After being introduced to the subtropical rainfall zones (900 mm) in the last decade, it has been cultivated in many arid and semi-arid regions of North Africa and the Middle East [5].

Mombasa Guinea Grass (*Panicum maximum*) is a clump-forming perennial that grows best in warm, frost-free areas. Mombasa Guinea Grass can withstand continuous heavy grazing, with stocking rates of 2.5 cattle/ha for extended periods under heavy annual rainfall, and it performs better under rotational grazing. For optimal nutritional value, it is best cut when it reaches 60 - 90 cm in height; however, for higher yields, it can be cut when up to 1.5 m tall [6]. In the Somali Region of Ethiopia, [7] studied the effect of nitrogen fertilizer application on the nutritive value of *Cenchrus ciliaris and Panicum maximum* grown under irrigation at Gode. The researchers concluded that both grasses are locally adaptable with high yield and nutritional value. In Somalia, *Panicum maximum* is a native range grass commonly known by Somalis as "Baldhoole" [8].

Somalia possesses one of the largest livestock populations in the region, comprising an estimated 7.1 million camels, 5.3 million cattle, 30.9 million goats, and 13.6 million sheep. The livestock sector forms the backbone of the Somali economy, contributing about 80% of agricultural GDP and nearly 45% of the national GDP [9]. Pastoralism and livestock trade provide the principal source of livelihood for the majority of Somalis and account for approximately 80% of the country's annual export earnings. Overall, the sector supports more than 65% of the population, making livestock the single largest contributor to Somalia's economy and livelihoods [10].

Despite this importance, livestock in Somalia primarily depend on rangeland resources under a free grazing system. However, like many pastoral regions, these rangelands are increasingly vulnerable to environmental changes and degradation. Contributing factors include rising population pressure, overstocking, absence of grazing management strategies, deforestation for fuelwood, and lack of clear ownership or regulation of rangeland resources [11]. Such pressures have led to severe drought-induced livestock losses, with up to 60% of herds perishing in some areas, devastating pastoralists' livelihoods. According to FAO, these losses pose a serious threat to food security, particularly in the central and northern pastoral zones where conditions remain critical [12]. Given the heavy reliance on natural pastures and the increasing forage scarcity, there is a critical need to explore improved forage production systems. Therefore, the introduction of locally adaptable forage species with high yield and nutritional value is an essential step in addressing the fodder gap, improving livestock nutrition, and consequently enhancing productivity [13].

*Panicum maximum* (Guinea grass) has high potential as a sustainable and high-yielding forage crop. However, limited information exists on the optimal nitrogen fertilization rates needed to maximize its growth and forage yield under Somali conditions. Considering all the above-mentioned, it is important to determine the effect of nitrogen fertilizers on Mombasa Guinea Grass production, as well as the critical dose of nitrogen fertilizers above which Mombasa Guinea Grass fodder does not respond to increased rates of fertilizers in the Benadir region. This study aims to evaluate the impact of different nitrogen fertilizer rates on the productivity of *Panicum maximum* in the Benadir region of Somalia. Specifically, it seeks to:

1) Assess yield responses to varying nitrogen application rates;
2) Identify the critical nitrogen dose beyond which additional fertilizer no

longer improves forage yield;

3) Provide data-based recommendations for sustainable and profitable Mombasa Guinea Grass production in Somalia.

The information provided by this study on the appropriate nitrogen fertilizer dosage for achieving the highest possible yield of *Panicum maximum* grass, as well as the critical nitrogen levels beyond which plant responses diminish, is valuable for local fodder-producing farmers assessing the effects of nitrogen fertilization on *Panicum maximum* yield. This research serves as an important reference for future studies, providing both a foundation for literature reviews and a practical guide for conducting similar experiments. Moreover, the study's findings and recommendations assist national and local governments in formulating policies that promote *Panicum maximum* production as a sustainable fodder source for livestock maintenance in Somalia. Lastly, the results of this study serve as a key reference material for researchers, policymakers, and agricultural practitioners interested in improving forage productivity through efficient fertilizer management.

## 2. Materials and Methods

### 2.1. Study Area

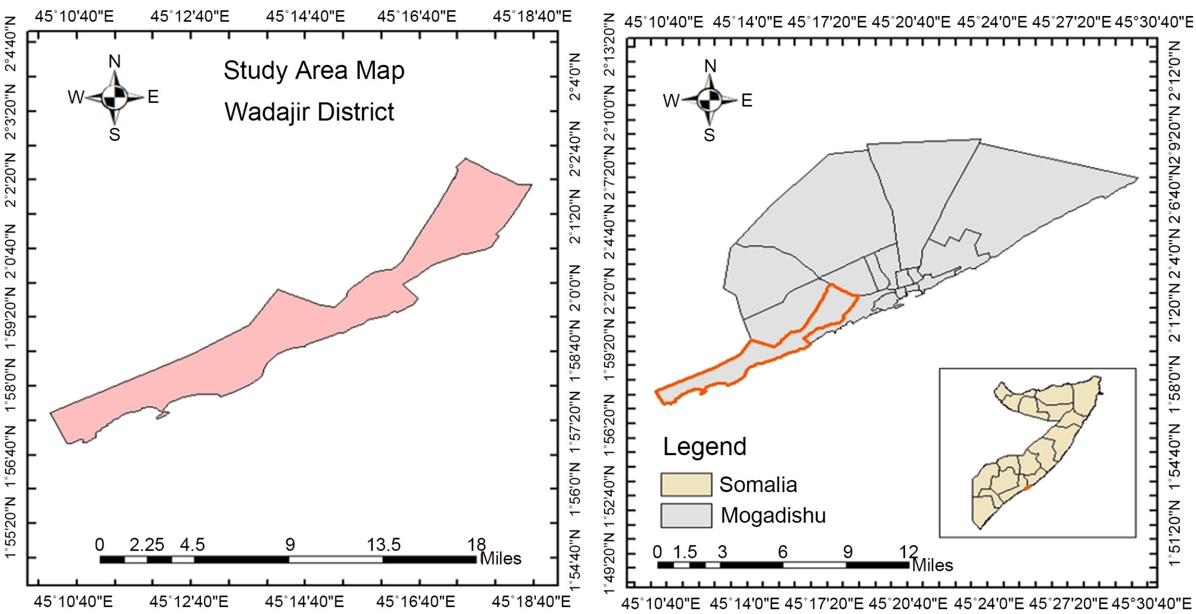


**Figure 1.** Study area map (Primary data).

The experiment was carried out at Somali National University's experimental farm, Gaheyr Campus, Wadajir district, Mogadishu (See **Figure 1**). The study area has a semi-arid to arid climate, marked by very low, highly variable, and often unpredictable rainfall. The Benadir region, like much of southeastern Somalia, experiences a hot, semi-arid climate (Köppen classification, BSh—mid-latitude steppe and desert) [14]. In Mogadishu, the average annual rainfall is about 474 mm, falling mainly during two rainy seasons. The first, called "Gu," runs from April to

June and accounts for roughly 52% of the annual total, while the second, "Deyr," occurs from October to November and accounts for about 28% of the year's rainfall. The region is generally dry, with potential evapotranspiration reaching around 1,782 mm per year. The initial dry season 20% of the year's rainfall, known as "Xagaa" (July-September), is relatively mild with occasional showers along the coast. The second dry season, "Jilaal" (January-March), is hot and very dry, with almost no rainfall. Wind speeds in Mogadishu tend to be low, ranging from 3 to 5 m/s throughout the year, usually lowest in April and November, coinciding with the peaks of the rainy seasons [14] (see **Figure 2**).

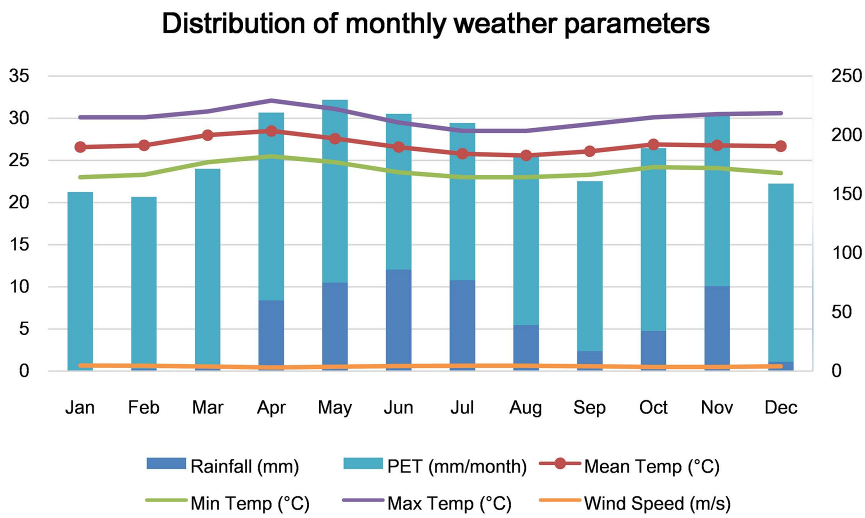


**Figure 2.** Distribution of monthly weather parameters (Benadir regional administration, 2022).

## 2.2. Experimental Design

The study examined the effect of different nitrogen fertilizer rates on the growth and yield of *Panicum maximum* (Mombasa Guinea Grass). The experiment was conducted on a 264 m$^2$ field (24 m × 11 m) using a Randomized Complete Block Design (RCBD) with three replications. Seven nitrogen fertilizer rates were tested (0 as control, 25, 50, 75, 100, 125, 150 kg·N/ha). The experimental area consisted of 21 plots (3 m × 3 m each), separated by 0.5 m between plots and 1 m between replications. Land preparation involved hoeing and hand leveling to create a uniform seedbed. Seeds of *Panicum maximum* were sown on October 30, 2022, at a spacing of 50 cm × 50 cm.

Nitrogen fertilizer treatments were randomly assigned to plots according to the RCBD. Randomization was done manually using a lottery method, where each nitrogen rate was written on a separate piece of paper, folded, and randomly placed on the plots. The papers were then opened to reveal the nitrogen level assigned to each plot. This method ensured unbiased allocation of treatments within each replication. To address phosphorus deficiency, 108.7 kg/ha of DAP (46% $P_2O_5$) was applied during land preparation. Nitrogen was supplied as urea (46% N) and used in three equal splits at 20, 35, and 50 days after germination to coincide with critical growth phases. Organic compost was incorporated uniformly across all experimental plots at a rate of 27.8 t·ha$^{-1}$, equivalent to 25 kg per 9 m$^2$ plot, to improve and standardize soil fertility before fertilizer treatments. The total treated area (189 m$^2$) included only the cultivated plots, excluding paths and borders. The compost rate was calculated as:

$$\begin{aligned}\text{Rate }\left(\text{t}\cdot\text{ha}^{-1}\right) &= \frac{\text{Total compost applied }(\text{kg})}{\text{Treated area }\left(\text{m}^2\right)}\times 10,000\\ &= \frac{525}{189}\times 10,000\\ &= 27,778\text{ kg}\cdot\text{ha}^{-1}\\ &\approx 27.8\text{ t}\cdot\text{ha}^{-1}\end{aligned}$$

## 2.3. Soil Fertility and Irrigation Management

The experiment was conducted on loamy sand soils typical of the coastal lowlands of the Benadir region in southern Somalia, which are characterised by low fertility. The laboratory results confirmed extremely low OM (0.009%) and N (0.0015%), very low available phosphorus ($P_2O_5$—4 ppm; $NaHCO_3$ extract), low exchangeable potassium ($K_2O$—0.25 meq/100 g), and a measured pH of 7.6, indicating a slightly alkaline soil environment.

The net water requirement (NWR) for the Mombasa Guinea Grass was estimated using the monthly PET and rainfall data over the experimental period. The general formula applied was $\text{NWR}(\text{mm}) = \text{PET} - \text{Effective Rainfall}(\text{Pe})$, where PET = potential evapotranspiration (mm/month), and Pe = effective rainfall (mm/month). For sandy loam soils, effective rainfall was assumed to be 100% of the monthly rainfall, given high infiltration and moderate runoff. Total NWR = 75 + 141 + 151.9 = 367.9 mm

**Table 1.** Water requirement for the growing period.

| Month | PET (mm) | Rainfall (mm) | Net (mm) |
|---|---|---|---|
| Nov | 147.0 | 72.0 | 75.0 |
| Dec | 149.0 | 8.0 | 141.0 |
| Jan | 151.9 | 0.0 | 151.9 |

We calculated total water requirement for the growing period, using the monthly values for November to January (See Table 1)

$$\text{Water Volume }(\text{L}) = \text{NWR }(\text{mm})\times\text{Plot Area }\left(\text{m}^2\right)$$

$$\text{V} = 367.9\text{ mm}\times 9\text{ m}^2 = 3,311\text{ L}\approx 3.31\text{ m}^3$$

1 mm of water over 1 m$^2$ corresponds to 1 L of water. The daily water requirement was calculated by dividing the total water requirement by the number of days in the growing period (2022 November-2023 January, 92 days):

$$\text{Daily NWR }(\text{L/day}) = \frac{\text{Total Volume }(\text{L})}{\text{Number of days}}$$

$$\text{Daily NWR} = \frac{3,311}{92} \approx 36\ \text{L/day}$$

The irrigation duration for each 3 × 3 m plot was determined based on the computed daily water requirement using the following formula:

$$t = \frac{\text{Water required (L)}}{\text{Flow rate (L/min)}} = \frac{36}{12} = 3\ \text{minutes}$$

Accordingly, each plot was irrigated for 3 minutes per day in a single session using a 5/8-inch garden hose delivering water at 12 L/min. This schedule ensured that the Mombasa Guinea Grass received sufficient moisture to meet its physiological needs while compensating for the high evaporation characteristic of the hot Benadir climate.

## 2.4. Data Collection, Edibility, and Economic Analysis

Data on growth parameters (plant height, tillers per plant, leaves per plant, and leaf area estimated using Sticker's formula: LA = Length × Width × 0.75) [15]. were collected from 10 randomly selected plants per plot within a 4 $m^2$ sample area. Yield components included fresh and dry biomass yield. Using Statistix 8.0, data were subjected to analysis of variance (ANOVA) to ascertain how nitrogen fertilizer rates affected *Panicum maximum* growth and yield metrics. Plant height, the number of tillers per plant, the number of leaves per plant, and the area of the leaves were among the growth factors that were examined; fresh weight and dry weight were among the yield characteristics. The Least Significant Difference (LSD) test was used to differentiate treatment means at a 5% probability level ($\alpha = 0.05$). The appropriateness of the model and the assumption of additivity were also evaluated using Tukey's one degree of freedom test for no additivity.

A palatability/edibility test was conducted using four livestock species (Camel, Cattle, Sheep, and Goats) to evaluate the acceptability of both fresh and dry *Panicum maximum* forage. A total of 28 animals were used, comprising seven animals from each species. Each animal was offered 1 kg of either fresh or sun-dried grass, and the amount consumed was recorded after feeding. The animals used in the test were locally kept livestock whose owners regularly provided them with feed. To ensure uniformity and eliminate the effect of prior feeding, all animals were offered the test forage early in the morning before receiving any other feed. The edibility percentage was calculated using the formula. Edibility percentage was calculated as:

$$\text{Edibility (\%)} = \frac{\text{Amount offered} - \text{Amount unconsumed}}{\text{Amount offered}} \times 100$$

The economic analysis was conducted to evaluate the profitability of nitrogen application using the following formulas. The fixed cost (FC) was calculated as the sum of seed and DAP input costs: FC = (Seed quantity (kg/ha) × Seed price per kg) + (DAP quantity (kg/ha) × DAP price per kg). Substituting the actual values gives FC = (4 × 40) + (108.7 × 2) = 160 + 217 = 377 $/ha. The urea input per treatment, considered as the variable input, was determined using the formula Urea input (kg/ha) = (N rate/0.46) × 1.5, where 0.46 represents the nitrogen content in urea. The variable cost (VC) was then computed as VC = Urea input (kg/ha) × Urea price per kg. The total cost (TC) was obtained by adding fixed and variable costs, TC = FC + VC. The revenue (R) was calculated based on the dry yield multiplied by the market price per kilogram of dry matter: R = Dry yield (kg/ha) × 0.50 (Price per kg of dry yield). Finally, profit ($\pi$) was estimated as the difference between revenue and total cost: $\pi = R - TC$.

## 3. Results and Discussions

### 3.1. Growth Performance

According to **Table 2**, plant height increased significantly (P < 0.01) with increasing nitrogen rates compared to the control, but declined slightly beyond 125 kg·N/ha. The lowest plant height (116.87 cm) was observed at 0 kg·N/ha, while the highest (179.7 cm) was recorded with 125 kg·N/ha. This increase can be attributed to nitrogen's role in promoting vegetative growth and internodal elongation. Similar findings were reported by [16], who observed a maximum plant height of 101 cm at 60 kg·N/ha compared to 47 cm at 0 kg·N/ha. The number of tillers per plant also increased significantly (P < 0.01) with nitrogen application. The maximum mean (30.9) was achieved at 150 kg·N/ha, while the minimum (12.9) occurred under zero treatment. The increase is linked to nitrogen stimulating shoot development and tiller initiation. Comparable results were obtained by [17], where tiller numbers of *Panicum maximum* increased progressively up to 250 kg·N/ha, with values ranging from 181 to 424 tillers/m$^2$. Leaf production responded strongly to nitrogen, with significant differences (P < 0.01) among treatments.

**Table 2.** Effect of different rates of nitrogen fertilizer on vegetative growth parameters.

| N (Kg/ha) | Mean plant height (cm) | Mean No. of tillers/plant | Mean No. of leaves/plant | Mean leaves/tiller | Mean leaf area (cm$^2$) |
|---|---|---|---|---|---|
| 0 | 116.87 e | 12.9 g | 67.2 e | 4.4 d | 173.04 e |
| 25 | 137.81 d | 17.6 f | 88.0 d | 4.67 cd | 242.49 d |
| 50 | 146.06 cd | 21.3 e | 116.0 c | 4.87 bc | 274.29 c |
| 75 | 157.50 bc | 23.8 d | 124.0 bc | 4.93 bc | 289.64 c |
| 100 | 163.62 b | 26.1 c | 136.0 b | 5.1 b | 299.08 bc |
| 125 | 179.70 a | 28.1 b | 162.0 a | 5.53 a | 317.25 ab |
| 150 | 176.42 a | 30.9 a | 169.0 a | 5.73 a | 330.99 a |

P = 0.0000; CV = 2.65 - 7.24; SEM = 0.11 - 8.72.

The highest number of leaves per plant (169) was recorded at 150 kg·N/ha, compared to 67.2 leaves at 0 kg·N/ha. Nitrogen is essential for node formation, which directly contributes to increased leaf numbers. Leaf area also expanded markedly, rising from 173.04 cm$^2$ at 0 kg·N/ha to 331 cm$^2$ at 150 kg·N/ha. This result is consistent with [18], who showed that nitrate-ammonium mixtures at 70:30 and 55:45 ratios ( $NO_3^-$ : $NH_4^+$ ) enhanced leaf area and shoot growth by up to 30%. Similarly, the number of leaves per tiller increased significantly (P < 0.01) under nitrogen application, peaking at 5.73 leaves/tiller with 125 - 150 kg·N/ha compared to 4.4 at 0 kg·N/ha. According to [19], they also reported a steady rise in leaves per tiller with higher nitrogen rates, from 3 at 0 mg/dm$^3$ to 6 at 200 mg/dm$^3$. Overall, nitrogen application consistently improved growth parameters of Mombasa Guinea Grass, with 125 - 150 kg·N/ha emerging as the most effective range for promoting height, tillering, leaf number, and leaf area.

## 3.2. Yield Performance (kg/ha)

As shown in **Table 3**, Nitrogen application had a marked influence on the fresh yield of *Panicum maximum*. The differences were highly significant (P < 0.01) across treatments compared to the control. Fresh yield increased progressively with nitrogen application from 0 up to 100 kg·N/ha, after which the response became less pronounced. The maximum fresh yield (60,417 kg/ha) was obtained at 150 kg·N/ha, while the lowest yield (20,333 kg/ha) occurred in the untreated plots. The yield improvement is closely associated with enhanced leaf and stem growth, reflecting the positive effect of nitrogen on photosynthetic activity and vegetative development. Similar results were reported by [19] [20], who found that nitrogen sources significantly influenced fresh matter yields of tropical pastures, with urea treatments consistently outperforming control plots by 13% - 17%.

**Table 3.** Effect of different rates of nitrogen fertilizer on yield parameters.

| N (Kg/ha) | Mean fresh yield (kg/ha) | Mean dry yield (kg/ha) |
|---|---|---|
| 0 | 20,333 d | 5,917 e |
| 25 | 34,917 c | 11,083 d |
| 50 | 42,417 bc | 15,250 c |
| 75 | 49,500 ab | 21,083 b |
| 100 | 59,000 a | 27,167 a |
| 125 | 60,250 a | 27,750 a |
| 150 | 60,417 a | 28,167 a |

P = 0.0000 - 0.0001; CV = 9.57 - 15.66; SEM = 1076.5 - 4.22.

The effect of nitrogen on dry yield followed a similar trend, with highly significant (P < 0.01) differences observed among treatments compared to the control. Dry matter yield increased steadily up to 100 kg·N/ha, beyond which the response plateaued. Although the highest dry yield (28,167 kg/ha) was achieved at 150 kg·N/ha, the increase was statistically insignificant compared to 125 kg·N/ha. In contrast, the lowest dry matter yield (5,917 kg/ha) was recorded under the zero treatment. This suggests that while nitrogen strongly promotes biomass accumulation, there may be diminishing returns beyond moderate application levels.

These findings are in line with [21], who examined different nitrogen rates (0 - 300 kg·N/ha) in *Panicum maximum* and observed a progressive rise in stem, leaf, and total dry matter production with increasing fertilizer. In their study, the highest dry yield (9,734 kg/ha) was obtained at 300 kg·N/ha, while the lowest (3,636 kg/ha) occurred in unfertilized plots. Together, these results confirm that nitrogen fertilization enhances both fresh and dry matter production, though the economic efficiency of very high rates may not justify their application.

Overall, the results of this study highlight that nitrogen fertilizer significantly improves forage yield in Mombasa Guinea Grass. Moderate rates between 100 and 150 kg·N/ha appear most effective in balancing productivity gains with input efficiency, ensuring both higher forage biomass and sustainable management for farmers.

### 3.3. Palatability/Edibility Test

A palatability/edibility test was conducted on the fresh and dry yield of *Panicum maximum* by selecting four different farm animals: camels, cattle, sheep, and goats. In terms of fresh yield, camels scored the greatest palatability rate, followed by cattle, sheep, and goats, with the latter having the lowest palatability rate. The grass's palatability was high in fresh yield compared to dry yield because it was soft, had higher moisture content in the stem, and had more leaves, which enabled the animals to consume almost all parts of the grass, including both stem and leaves.

Fresh palatability tests of *Panicum maximum* (see **Table 4**) have shown that the grass is highly preferred by ruminants when offered at young regrowth stages. The forage is characterized by high succulence and digestibility, which enhances voluntary intake across cattle, sheep, and goats [22]. Studies further demonstrate that both yield and palatability are influenced by management factors such as variety, soil type, and fertilizer application. For instance, [23] reported significant variation in fresh biomass production and voluntary intake of different *Panicum maximum* varieties fed to sheep. Similarly, [24] observed that palatability decreases with advancing maturity, with younger stands producing higher fresh yield quality and better animal preference compared to older, stemmy growth. Overall, *Panicum maximum* is recognized as one of the most palatable tropical grasses for livestock feeding under fresh forage systems.

**Table 4.** Fresh palatability/edibility test.

| Animal type | Amount offered | Amount consumed | Amount left | Edibility % |
|---|---|---|---|---|
| Camel | 1,000 gr | 1,000 gr | 0 gr | 100% |
| Cattle | 1,000 gr | 934 gr | 66 gr | 93% |
| Sheep | 1,000 gr | 777 gr | 223 gr | 78% |
| Goat | 1,000 gr | 744 gr | 256 gr | 74% |

In terms of dry yield (see **Table 5**), camels scored the highest palatability rate, followed by cattle, then sheep, and lastly goats, which had the lowest palatability rate. When the grass was dried by using the sun drying method, it became less palatable due to the reduced moisture levels and increased toughness, resulting in animals consuming less of it, around 3/4 compared to fresh grass. Consequently, animals are divided into two groups. Large ruminants (camel, cattle), which can consume large amounts of dried grass, and small ruminants (Goat and Sheep), which consume less due to the change in the grass's characteristics resulting in greater toughness, low water content, and reduced palatability.

Dry *Panicum maximum* (Guinea grass) is widely used as hay and remains moderately palatable to ruminants, although its nutritive value and intake decline with maturity. When cut at early flowering and properly cured, the hay retains acceptable levels of crude protein and digestibility for cattle, sheep, and goats [25]. Again [23], reported that voluntary intake of *Panicum maximum* decreases significantly when the forage is fed in dried form compared to fresh, reflecting the reduction in moisture content and increased fiber concentration. Also, [24] found that hay prepared from younger stands was more palatable and supported higher intake in small ruminants than hay from older, stemmy plants. Despite this reduction, *Panicum maximum* hay remains an important feed resource in the dry season, providing bulk forage when fresh grasses are scarce and supporting maintenance or moderate production in ruminants.

**Table 5.** Dry palatability/edibility test.

| Animal type | Amount offered | Amount consumed | Amount left | Edibility % |
|---|---|---|---|---|
| Camel | 1,000 gr | 950.43 gr | 49.21 gr | 95% |
| Cattle | 1,000 gr | 823.43 gr | 176.57 gr | 83% |
| Sheep | 1,000 gr | 766.43 gr | 233.57 gr | 66% |
| Goat | 1,000 gr | 604.29 gr | 395.71 gr | 60% |

### 3.4. Economic Analysis

According to the economic analysis data presented in **Table 6**, the profit increases with higher rates of fertilizer application. The profit can potentially increase up to input level 5 (100 Kg·N/ha), where it reaches $12,881/ha. Although applying 100 kg·N·ha$^{-1}$ required an additional $81 ha$^{-1}$ compared to the 75 kg·N·ha$^{-1}$ rate, it yielded an extra profit of $2,961 ha$^{-1}$. Increasing the fertilizer application beyond 100 Kg·N/ha leads to a decrease in profit due to the rise in input cost and decline in output. It is important to note that the rate of 100 Kg·N/ha, which is economically optimal for this study, also results in the highest statistically significant yield increase compared to the control treatment (27,167 Kg/ha).

**Table 6.** Economic analysis.

| In put level | Input Kg·N/ha | Input urea Kg/ha | Output dry yield Kg/ha | Fixed cost $/ha | Variable cost $/ha | Total cost $/ha | Total revenue $/ha | Profit $/ha | **Incremental profit $** |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 5,917 | 377 | 0 | 377 | $2,959 | $2,582 | ___ |
| 2 | 25 | 54 | 11,083 | 377 | 81 | 458 | $5,542 | $5,084 | $2,502 |
| 3 | 50 | 109 | 15,250 | 377 | 164 | 541 | $7,625 | $7,084 | $2,001 |

Continued

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 4 | 75 | 163 | 21.083 | 377 | 245 | 622 | $10,542 | $9,920 | $2,836 |
| 5 | 100 | 217 | 27,167 | 377 | 326 | 703 | $13,584 | $12,881 | $2,961 |
| 6 | 125 | 272 | 27,750 | 377 | 408 | 785 | $13,875 | $13,090 | $210 |
| 7 | 150 | 326 | 28,167 | 377 | 489 | 866 | $14,084 | $13,218 | $128 |

## 4. Conclusion and Recommendation

This pioneering experiment in the Benadir region confirmed that nitrogen fertilizer significantly improves the growth and yield of *Panicum maximum*. Increasing nitrogen rates enhanced plant height, tiller number, leaf number, leaf area, and overall fresh and dry biomass. However, while yields continued to rise with higher nitrogen levels, the response plateaued beyond 100 Kg·N/ha, making this the critical and most profitable dose for small-scale farmers on sandy soils. In order to optimize nitrogen uptake and reduce losses, we advise farmers in the Benadir region to apply 100 kg·N/ha, divided into three treatments at 20-, 35-, and 50-day intervals following germination. The suggested split application schedule supports early vegetative establishment and root development (20 days after germination), the active tillering and leaf expansion phase (35 days), and the rapid stem elongation and biomass accumulation period (50 days). These three applications correspond to the critical growth stages of *Panicum maximum*. Nitrogen application during these critical phases increases the efficiency of fertilizer usage, reduces leaching and volatilization losses, and fosters long-term forage development and productivity. Farmers should also provide special care during the first month of growth when the grass is most vulnerable to pests and integrate cultural practices, including intercropping, to reduce pest pressure. Given its high palatability for camels and cattle, *Panicum maximum* is highly suitable for farmers rearing large ruminants, especially in fertile riverine areas with sufficient water and pesticide access.

Profit increased with nitrogen fertilizer rate up to 100 kg·N·ha$^{-1}$, where the maximum profit of $12,881 ha$^{-1}$ was obtained. Although applying 100 kg·N·ha$^{-1}$ required an additional $81 ha$^{-1}$ compared to the 75 kg·N·ha$^{-1}$ rate, it yielded an extra profit of $2,961 ha$^{-1}$. Beyond this level, further increases in nitrogen application led to negligible profit gains due to rising costs and diminishing yield response. Therefore, 100 kg·N·ha$^{-1}$ was identified as the economically optimal rate.

However, further research is needed to evaluate its performance under different soils, climates, nutritional quality (protein, fiber, and ash and lignin contents), and its response to nitrogen in subsequent harvests. Additional studies should also explore palatability and digestibility for goats and sheep, where initial results were less favorable. In summary, *Panicum maximum* is an early maturing, high-yielding forage that, when managed with the recommended nitrogen practices, can sustainably improve livestock feed availability and profitability for small-scale farmers in the region.

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## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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