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Response of napier grass (*Pennisetum purpureum* Schum.) to different levels of nitrogen fertilizer in the Philippines

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ABSTRACT

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Napier grass is a high yielding and easy to propagate forage crop with broad ecological adaptation making it highly popular for smallholder farmers. Sustained production of forage is necessary for the nutrition of ruminant animals, which can be attained if the right amount of nitrogen fertilizer is applied. This study was conducted to: 1) evaluate the response of napier grass to different levels of nitrogen fertilization; 2) determine the appropriate nitrogen level for optimum napier grass production; and 3) assess the economic benefit of napier grass production under different levels of nitrogen fertilizer application. The study was laid out in a Randomized Complete Block Design (RCBD) with three replications and five treatments (T_0–Unfertilized, T_1–30kg N ha^{-1}, T_2–60kg N ha^{-1}, T_3–120kg N ha^{-1}, T_4–240kg N ha^{-1}).

Plant height, fresh herbage and dry matter yields were significantly affected by the different rates of nitrogen fertilizer. Plants applied with 240kg N ha^{-1} were the tallest and had the heaviest fresh herbage and dry matter yields, but comparable to those plants applied with 120kg N ha^{-1}. Increasing the levels of nitrogen fertilization correspondingly improved the overall forage performance with optimum level at 120kg N ha^{-1}.

Cost and return analysis showed that plants applied with 240kg N ha^{-1} resulted in the highest net income of PHP55,690 ha^{-1} while the least net income of PHP17,213 ha^{-1} was obtained with unfertilized plants.

Keywords: forage crop, application rate, optimum level, herbage yield, dry matter

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INTRODUCTION

Napier grass or elephant grass (*Pennisetum purpureum* Schum.) is a very large, robust, tufted, perennial member of the Poaceae family, subfamily Panicoideae, tribe Paniceae native to the African grasslands but is now grown in many tropical countries. It is a heterozygous plant, but seeds are rarely fully formed. More often it reproduces vegetatively through stolons which are horizontal shoots above the soil that extend from the parent plant to offspring (Aminah et al 1997, FAO 2015).

Napier grass is a high yielding and easy to propagate forage crop with broad ecological adaptation making it highly popular for smallholder farmers. According to Lekasi (2000), farmers in the highlands of Kenya allocate 21-28% of their land to production of said grass. It is palatable and can be grazed directly in the field, or cut and fed either fresh or as silage (Woodard and Prine 1991, Woodard et al 1991). It is considered to be high in structural cell wall carbohydrates that increase rapidly with advance in maturity. It has crude protein content ranging from 7 to 15% (Collins 2010) and 9.52 to 12.62% (Tshering and Penjor 2016). However, its crude protein (CP) and digestibility decrease with maturity (Bayble 2007, Wangchuk et al 2015, Haryani et al 2018), which implies the need for production strategies that can help improve its CP concentration and digestibility.

Napier grass, according to Relwani et al (1982), could outyield many other grasses such as Guinea grass (*Panicum maximum* Jacq.) and Rhodes grass (*Chloris gayana* Kunth). It has the advantage of withstanding repeated cuttings from four to six cuts in a year which can produce 50-150t ha^{-1} fresh herbage (Purseglove 1972). Kariuki et al (2016) reported that it has the advantage of withstanding eight repeated cuttings producing forage dry matter that ranged from 18.1-51.2t ha^{-1} and cuttings can be made at 45-90 day intervals, depending on the location (FAO 2015). ICRAF (1997) reported it as the main feed for dairy cows supplemented with crop residues such as maize stover, bean haulms, banana leaves and pseudo-stems, and fodder trees during the dry season. In spite of the potential for high yields, on-farm yields of napier grass are much lower and variable depending on management factors such as application of manure or fertilizer, cutting frequency and weed control.

In improving the production of napier grass, an important consideration is to apply fertilizer (Rosacia et al 2007). Fertilizer application is necessary to replenish the essential elements taken up by the crop for vigorous growth and development. Fertilizer can improve soil fertility, enhance vegetative growth and increase productivity. Applying fertilizer to plants involves consideration of the kind of fertilizer or nutrient requirements of the crop as well as the proper rate and timing of its application. It is an economic investment and therefore, should be done wisely to insure profitable monetary return.

Studies have shown that nitrogen application increased the yield of napier grass. Its dry matter herbage yield significantly increased with the application of 100kg N ha^{-1} (Gelayenew et al 2019) and the highest yield was obtained by harvesting at 60 day intervals with the application of 80 or 120kg N ha^{-1} (Arshadullah et al 2010). Moreover, Norsuwan et al (2014) reported that the application of 240kg N ha^{-1} was sufficient to obtain the highest total dry matter yield 7,911kg ha^{-1}.

Limited studies have been conducted in the Philippines on the response of napier grass to different levels of nitrogen fertilization. This study was conducted to evaluate the response of napier grass to different levels of nitrogen fertilization, determine the appropriate level of nitrogen for optimum napier grass production and assess the economic benefit of napier grass production under different levels of nitrogen fertilizer application.

MATERIALS AND METHODS

Location of the Study

This study was conducted at the experimental area of the Department of Agronomy, Visayas State University, Baybay City, Leyte, Philippines with a moist tropical climate during the wet season.

Soil Sampling and Analysis

Before planting in the experimental area, ten soil samples were collected, composited, air dried, pulverized, and sieved using 2mm wire screen. A kilogram was brought to the Central Analytical Services Laboratory (CASL) of the PhilRootCrops, Visayas State University (VSU), Visca, Baybay City, Leyte, Philippines for analysis of the soil pH (potentiometer method at 1:2.5 soil-water ratio, Kalra 1995), % organic matter (modified Walkley and Black method, Walkley and Black 1934), available P (modified Olsen's, Bray and Kurtz 1945), total N (modified Kjeldhal method, Jackson 1958) and extractable K (NH_4OAc pH7.0 method, Jones 2001).

Final soil sampling was done immediately after the final harvest by collecting five samples from each treatment plot. The samples were composited per treatment plot, mixed thoroughly, processed, and then a kilogram was sent to the aforementioned laboratory and analyzed for the same soil parameters mentioned above.

Experimental Design and Field Layout

The experimental area was laid out in a Randomized Complete Block Design (RCBD) with five treatments replicated three times. Each replication was divided into five plots, each measuring 3mx3m with six rows per plot. Alleyways of 1.0m between replication and treatment plots were provided to facilitate farm operations and management as well as data gathering. The different treatments were: T_0-Unfertilized, T_1-30kg N ha^{-1}, T_2-60kg N ha^{-1}, T_3-120kg N ha^{-1}, and T_4-240kg N ha^{-1}.

Fertilizer Application

The actual amount of nitrogen applied per plot was based on the rates specified for each treatment. All the treatments were applied uniformly with 30kg ha^{-1} P_2O_5 and 30 kg ha^{-1} K_2O, except for T_0. Half of the amounts of N, P_2O_5 and K_2O per hectare were applied basally at planting. The remaining amounts of N, P_2O_5 and K_2O were applied right after the first harvest (60 days from planting). Urea (46%), solophos (20% P_2O_5) and muriate of potash (60% K_2O) were the fertilizer materials used to satisfy the nutrient requirements in each treatment plot.

Preparation of Cuttings and Planting

Cuttings with 3 nodes from the middle portion of 3 months old stems were prepared. These were placed in a cool shady place a day prior to planting to maintain their freshness and avoid loss of water. These cuttings were planted at a spacing of 50cmx50cm in a slanting position on ridges with two nodes buried in the soil. Each plot was planted with 36 cuttings equivalent to a population of 40,000 plants ha^{-1}. The soil around the stem was pressed lightly for better root establishment and growth.

Harvesting

Harvesting was done at 60 and 105 days after planting by cutting the tillers using a sharp sickle about 10cm from the ground, excluding the two outer rows and two end hills in each row of each treatment plot.

Data Gathered

The plant height and number of tillers per hill were gathered from 10 sample plants in each treatment plot while the basal stem diameter was taken from 3 sample hills prior to harvesting at 60 and 105 days after planting. The fresh herbage yield was obtained by weighing the harvested herbage within the harvestable area in each treatment plot at 60 and 105 days and converted to tons per hectare. The dry matter yield was determined by oven drying for 72h at 70^0C the herbage of three sample hills taken from each treatment plot at 60 and 105 days. After which, the samples were weighed and the values obtained were converted to tons per hectare.

Cost and return analysis was determined by computing all expenses incurred throughout the conduct of the study from land preparation up to harvesting. These included chemicals, materials and labor used in the field. The gross return was computed by multiplying the fresh herbage yield by the current price of napier grass per kilogram. The net return was computed by deducting from the gross return the total production cost.

Data on total weekly rainfall (mm) and minimum and maximum temperatures (^{0}C) throughout the conduct of the study were taken from the records of the Philippine Atmospheric, Geophysical, and Astronomical Services Administration (PAGASA) Station, VSU, Visca, Baybay City, Leyte, Philippines.

The data obtained were analyzed using Statistical Analysis System (SAS version 9.1.3). Mean comparison was done using Tukey's Honestly Significant Difference (HSD) test.

RESULTS AND DISCUSSION

General Observation

The total weekly rainfall (mm), maximum and minimum temperatures (^{0}C) throughout the conduct of the study are presented in Figure 1. The total weekly rainfall ranged from 1.4 to 156.1mm. The minimum and maximum temperatures ranged from 23.3 to 24.7^{0}C and 30.35 to 32.35^{0}C, respectively. The total rainfall for the entire duration of the study reached 981.6mm. According to Russell and Webb

(1976), napier grass grows best in high rainfall areas in excess of 1500mm per year. Data showed that during the conduct of the experiment, rainfall was within the rainfall requirement for normal growth and development.

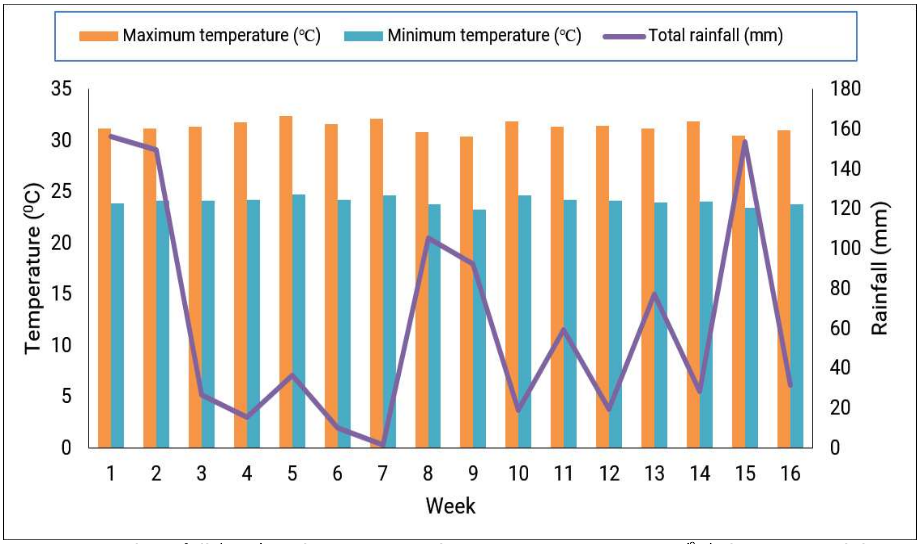

Figure 1. Total rainfall (mm) and minimum and maximum temperatures (°C) that occurred during the conduct of the study

Weeds associated in the area were particularly dominated by itch grass or "aguingay" (*Rottboellia cochinchinensis* Lour.). Two weeks after the first harvest, fungal disease (*Helminthosporium sacchari* Butler) was observed infecting the leaves of the plants in all treatments. Hand weeding seemed to minimize the infection.

Generally, differences on the morphological appearance of napier grass among treatments were observed. The unfertilized plants were the shortest while the tallest were those that received the highest amount of N fertilizer at 240kg N ha^{-1}. After the first harvest, regrowth in all treatments were shorter but with numerous and thinner tillers.

Soil Analysis

Soil test results are presented in Table 1. Initial soil analysis showed that the experimental area had a pH of 5.98, 0.897% organic matter, 0.1007% total nitrogen, 20.724mg kg^{-1} available P and 0.397me $100g^{-1}$ extractable K. These results imply that the soil was moderately acidic, with very low organic matter and low total nitrogen but with a high amount of phosphorus and a medium amount of potassium (Landon 1991).

Results of the final analysis showed an increase in soil pH, total nitrogen and available phosphorus. However, a slight decrease in organic matter content and extractable potassium was noted relative to the initial analysis. The increase of total N with application of N peaked at 60kg N ha^{-1} and decreased as the amount of N application was further doubled. This could be attributed to greater N demand for vegetative growth as exhibited by significantly heavier herbage yield of napier applied with higher rates of N.

Table 1. Soil chemical properties before planting and after harvest of napier grass at different levels of nitrogen fertilizer

	Soil pH (1:2.5)	OM (%)	Total N (%)	Available P (mg kg^{-1})	Extractable K (me 100 g^{-1})
Initial Analysis	5.980	0.897	0.101	20.724	0.397
Final Analysis					
T_0–control	6.300	0.780	0.091	23.860	0.360
T_1–30kg N ha^{-1}	6.310	0.663	0.122	23.529	0.394
T_2–60kg N ha^{-1}	6.280	0.819	0.133	24.449	0.179
T_3–120kg N ha^{-1}	6.330	0.780	0.125	24.569	0.178
T_4–240kg N ha^{-1}	6.290	0.819	0.116	25.025	0.099
Mean	6.302	0.772	0.117	24.286	0.242

Agronomic Characteristics of Napier Grass

Plants applied with 240kg N ha^{-1} grew vigorously and the tallest at 255.83cm and 220.47cm during the first and second harvests, respectively, although comparable with those plants applied with 120kg N ha^{-1} (Figure 2). The unfertilized plants and those applied with 30kg N ha^{-1} were the shortest. Application of different rates of nitrogen fertilizer improved the overall growth performance of the plant. This conformed to the findings of Zahid et al (2002) who reported a linear increase in stem length from base to the top leaf collar as N rates were increased from 0 to 120kg ha^{-1}.

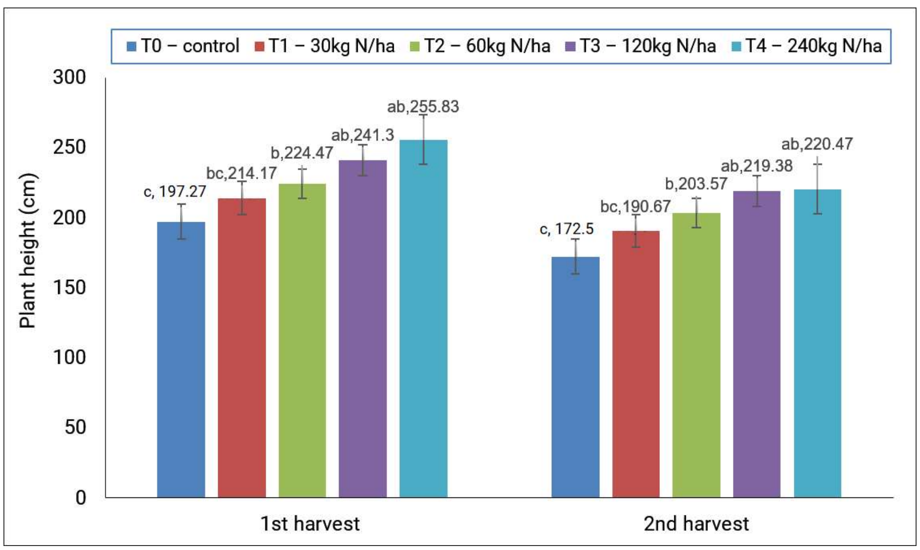

Figure 2. Plant height (cm) of napier grass as affected by levels of nitrogen fertilizer

The number of tillers and basal stem diameter of the plants at first and second harvests were not significantly increased with the application of nitrogen fertilizer (Table 2). This contradicts the findings obtained by Woodard and Prine (1990) that an increase in number of tillers was due to the increase in N fertilization. In contrast, Novo et al (2016) reported a high number of tillers, height and stem diameter of three napier genotypes at the lowest N and K doses.

Table 2. Number of tillers hill^{-1} and basal stem diameter (cm) of napier grass as affected by different levels of nitrogen fertilizer (1st harvest and 2nd harvest)

Treatment	No. of tillers hill^{-1}		Basal stem diameter (cm)	
	1st	2nd	1st	2nd
T_0–control	6.00	11.97	1.44	0.98
T_1–30kg N ha^{-1}	6.17	11.87	1.41	0.86
T_2–60kg N ha^{-1}	6.30	11.83	1.48	0.95
T_3–120kg N ha^{-1}	7.10	11.47	1.40	0.91
T_4–240kg N ha^{-1}	6.97	12.33	1.47	0.91
Mean	6.45	11.89	1.44	0.92
CV (%)	10.36	9.04	12.14	9.86

Treatment means within a column without letter are not significantly different at 5% level of significance based on Tukey's test.

Fresh Herbage Yield and Dry Matter Yield

The fresh herbage yield of plants applied with 240kg N ha^{-1} at first and second harvest and their total were heavier than the other treatments except those plants applied with 120kg N ha^{-1} (Figure 3). The lightest fresh herbage yields were produced from plants without fertilizer and those applied with 30kg N ha^{-1}. These corroborated with the findings of Bilal et al (2001) that application of N increased the green fodder yield with maximum yield obtained at 300kg N ha^{-1}.

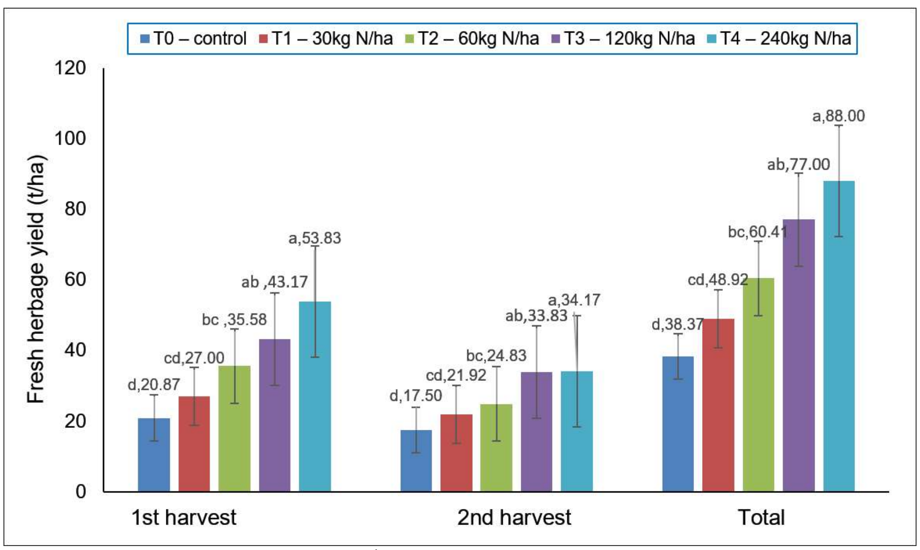

Figure 3. Fresh herbage yield (t ha^{-1}) of napier as affected by different levels of nitrogen

In terms of dry matter yield, significant differences among treatments were noted only on the first harvest and total yield (Figure 4). At first harvest, plants applied with 240kg N ha^{-1} had the heaviest dry matter yield but comparable with 120kg N ha^{-1} and 60kg N ha^{-1}. The lightest dry matter yields were obtained from unfertilized plants and those applied with 30kg N ha^{-1}. The results confirmed the findings of Rahman et al (2010) that application of higher N at 300kg ha^{-1} produced higher dry matter yield than at 150kg ha^{-1}.

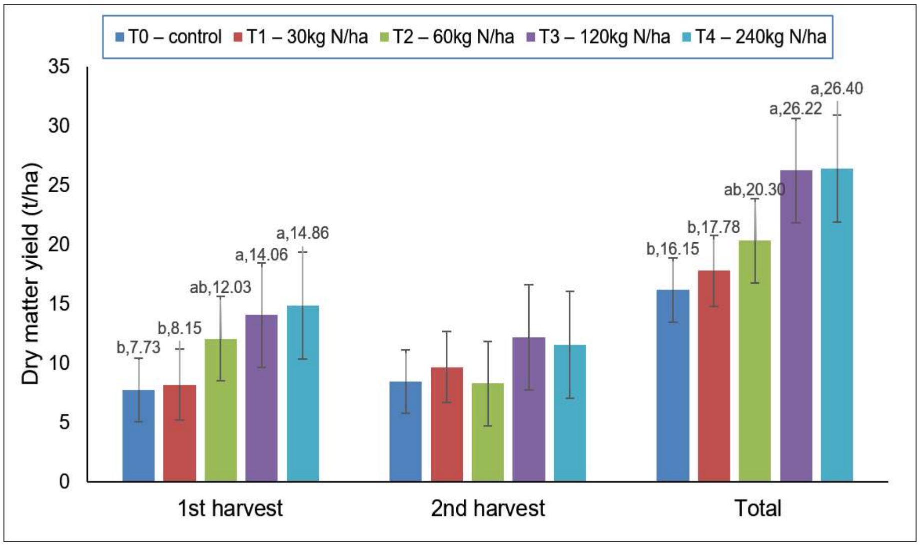

Figure 4. Dry matter yield (t/ha) of napier grass as affected by different levels of nitrogen fertilizer

A similar trend was also observed on total dry matter yield. Plants applied with 60-240kg N ha^{-1} produced higher yields (20.3-26.4t ha^{-1}) than the control and those plants applied with 30kg N ha^{-1}. The results coincided with that of Norsuwan et al (2014) that application of 240kg N ha^{-1} resulted in an increase in total dry matter yield from 2,340 to 7,911kg ha^{-1}, however, the interaction of 1.0x ET_0 (reference evapotranspiration) and the application of 300kg N ha^{-1} could potentially reach an above ground dry matter yield of up to 12,000kg DM ha^{-1}.

The foregoing results imply that application of nitrogen to napier grass is necessary to produce higher fresh and dry matter yields so as to sustain the feed requirements of ruminants. According to Leghari et al (2016), nitrogen significantly increases and enhances the yield and its quality by playing a vital role in the biochemical and physiological functions of the plant.

Cost and Return Analysis

The economics of producing napier grass applied with different levels of nitrogen fertilizer is presented in Table 3. Combining the two harvests, a total fresh herbage yield of 88t ha^{-1} was attained by the application of 240kg N ha^{-1} which was significantly greater than plants applied with 30 and 60kg N ha^{-1} and the untreated control. However, those plants applied with 120kg N ha^{-1} had comparable yield to those applied with 240kg N ha^{-1}. Highest gross income was achieved on plants applied with 240kg N ha^{-1} (PHP110,000 ha^{-1}) followed by those applied with 120kg N ha^{-1} (PHP96,250 ha^{-1}). The lowest gross income was attained from unfertilized plants (PHP47,963 ha^{-1}).

Table 3. Cost and return analysis of napier grass as affected by different levels of nitrogen fertilizer

Treatments	Total Fresh Herbage Yield (t ha^{-1})	Gross Income[a] (PHP ha^{-1})	Production Cost (PHP ha^{-1})	Net Income (PHP ha^{-1})
T_0–control	38.37	47,963	30,750	17,213
T_1–30kg N ha^{-1}	48.92	61,150	38,834	22,316
T_2–60kg N ha^{-1}	60.42	75,525	42,051	33,474
T_3–120kg N ha^{-1}	77.00	96,250	46,724	49,526
T_4–240kg N ha^{-1}	88.00	110,000	54,310	55,690

[a]Calculated by multiplying the fresh herbage yield with the pick up price of PHP1.25 kg^{-1} set by Philippine Carabao Center (PCC), VSU, Visca, Baybay City, Leyte, Philippines

Application of 240kg N ha^{-1} also resulted in the highest net income of PHP55,690.40 ha^{-1} followed by those applied with 120kg N ha^{-1} (PHP49,526) and 60kg N ha^{-1} (PHP33,474). On the other hand, the least net income of PHP17,213 ha^{-1} was obtained from unfertilized plants. This finding indicates that raising napier grass is promising since an income can still be obtained even if plants were not fertilized. Application of higher amounts of fertilizer at the rate of 200-70-60kg NPK ha^{-1} were found by Velayudham et al (2011) to be profitable for hybrid napier grass under irrigated conditions.

CONCLUSIONS AND RECOMMENDATIONS

The application of nitrogen fertilizer at the rate of 120-240kg N ha^{-1} significantly increased the plant height, fresh herbage yield and dry matter yield of napier grass. However, the optimum rate of production of napier grass was attained by the application of 120kg N ha^{-1} under VSU conditions. This application rate is recommended for optimum napier grass production under similar soil and climatic conditions as this experiment. It is further recommended to verify the response of napier grass to N fertilization in places with different agro-climatic conditions.

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