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Effect of different nitrogen levels on growth and forage productivity of *elephant grass* in southern Ethiopia

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Abstract

An experiment was conducted at Agricultural Research Station, Bule Hora University Ethiopia to assess the growth and forage productivity of elephant grass through different nitrogen levels in 2021-2022. The experiment was conducted with six treatments in a randomized block design (RBD) with 3 replications. Treatments were six different levels of nitrogen fertilizer *i.e.*, T₀ (0.0 kg N/ha), T₁ (25 kg N/ha), T₂ (50 kg N/ha), T₃ (75 kg N/ha), T₄ (100 kg N/ha) and T₅ (125 kg N/ha). The data was collected from experiment plots such as; morphometric characteristics of grass and yield attributes of grass analysed. The results of experiment revealed that plant height (cm), number of leaves per plant, number of leaves per tiller, leaves length per plant (cm), leaves blade width (cm), stem production/tiller (kg), leaf production/tiller (kg), fresh fodder production/tiller (kg), green fodder/plot (kg/6 m²), green fodder yield (t/ha), and dry fodder yield (t/ha) significantly ($p < 0.05$) greater recorded in T₅ (125 kg N/ha) as 166.78 cm, 14.11, 86.56, 85.11 cm, 4.15 cm, 2.16 kg, 1.86 kg, 4.02 kg, 19.56 Kg/6 m², 32.59 t/ha, and 6.85 t/ha, respectively however number of plants per tiller (14.67) in T₄ and basal circumference of stem (2.67 cm) in T₀. Looking for partial budget analysis of elephant grass maximum net returns recorded in 9393.75, 8626.89, 6481.60, 6766.47, 4235.63, and 1873.28 ETB ha⁻¹. Hence 125 kg N ha⁻¹ was economically feasible. This study suggests that the rate of 125 kg N ha⁻¹ dose is more optimum for improve the forage crop productivity with high dry matter yield at reduced nitrogen fertilizer cost.

Keywords: Forage dry matter, plant height, stem diameter, net returns

Introduction

Ethiopia is endowed with huge potential livestock resources and holds the largest livestock population in Africa, estimated at about 60 million cattle, 60 million sheep and goats, 52 million chickens, 4.5 million camels, 10 million bee colonies and 7.2 million equines (CSA, 2018) [14]. In rural Ethiopia, livestock is a valuable asset that serves a variety of economic, social, and risk management activities. Livestock production currently contributes 12 to 16 percent of Ethiopia's GDP and 16 percent of its foreign revenues. Livestock farming is a major source of revenue and a means of life for Ethiopian farmers (Bewket *et al*, 2015) [7], accounting for more than 85 percent of agricultural cash income (Yeshitila *et al*, 2008) [54]. However, despite the large livestock resource base and the importance of livestock to the livelihoods of millions of people, the productivity and economic contribution of the livestock sector are below potential due to technical and nontechnical constraints (Tolera, 2012) [50]. One of the major technical constraints limiting the productivity of livestock is the shortage and poor quality of feeds. According to a study conducted by the FAO in 2018, Ethiopia has a deficit of 27 million MT of feed each year and needs to fill this gap in order to ensure feed security (FAO, 2018) [18]. Inadequate supply of feed for the existing livestock population and poor quality of the available feed resources are the two main factors that contribute to the low production and productivity of livestock in Ethiopia (Asresie *et al*, 2015) [5]. Ethiopia has a net annual fodder biomass production of 144.5 million tons, with ME and CP values of 890 x 109 MJ and 7.49 million tons, respectively (Aranguiz and Creemers, 2019) [4]. Except in the Harari region, where improved forages account for 1.68 percent of the diet, hay and crop residues together with natural grass account for more than 90 percent of all

animal diets (Aranguiz and Creemers, 2019) ^[4]. Even though the feed is available to a certain extent, in the majority of cases, it is not in a position to satisfy the quality for higher productivity of our livestock sector in Ethiopia. Available concentrate feeds and agro-industrial by-products are still at a very low level of supply to feed the present livestock population. One of the recommended profitable options to address this challenge of feed shortage is improved forage production using strategies suitable for a given farming system (Adugna, 2012) ^[2]. The utilization of locally accessible forage plants as feed resources is highly suggested to address existing livestock nutritional limits because they are familiar to smallholder farmers, grow with minimal input and adapt to local environments (Bimrew *et al*, 2017) ^[8].

In Ethiopia, certain information on Elephant Grass (*Pennisetum purpureum*) grass is generated in the form of publications and working papers (Ebrahim *et al*, 2020^a; Gelayenew *et al*, 2020 and Gadisa *et al*, 2021) ^[16, 17, 21, 22]. Elephant grass (*Pennisetum purpureum*) is a fast-growing perennial grass native to Sub-Saharan Africa that is widely grown across the tropical and subtropical regions of the world (Negawo *et al*, 2017) ^[38]. It is a multipurpose forage crop, primarily used to feed cattle in cut and carry feeding systems (Negawo *et al*, 2017) ^[38]. Elephant grass is a source of feed for most ruminants and is found to be one of the most preferred types of grass favoured by livestock. However, its production varies in the rainy season and dry season. Elephant Grass, also known as Napier grass or Uganda grass, is one of the most important tropical forage crops. It is widely used in cut and carry systems and is of growing importance in other agricultural systems.

For most forage, fertilizer levels, harvesting times, and intervals can have a significant effect on both yield and nutritional qualities (Okwori and Magani, 2010) ^[39]. However, farmers do not have sufficient information on optimal management practices for elephant grass (Mutegi *et al*, 2008) ^[36]. Nitrogen (N) fertilizer is frequently deficient in soils (Havlin *et al*, 1999) and plants grown on nitrogen-deficient soils show stunted growth, yellowish colour and reduced yield (Pandey and Sinha, 2006). Nitrogen fertilizer

develops stronger cells for photosynthesis (Bob, 2011) and increasing of forage grass's dry matter yield and quality in terms of crude protein content, voluntary feed intake and digestibility (Aderinola, 2007) ^[1]. These qualities of forage are a function of many factors including the species, height of harvest, plant parts, agroecology, agronomy and postharvest processing practices (Ball *et al*, 2001) ^[6]. Keeping in view the importance of nitrogen, different experiments have been conducted to boost the elephant grass in countries, but less attention has been paid to the rainfed condition of Ethiopia. The present research was designed, to assess the effects of different doses of nitrogen on growth, yield and other yield components of elephant grass to standardize balanced nutrition at Bule Hora University, Ethiopia.

Materials and Methods

Descriptions of the experimental site

The experiment was conducted at an Agricultural Research Station, Bule Hora University Ethiopia. The experimental field was located at 5°62'N latitude and 38°21'E longitude and an altitude of 1716 meters above sea level. The site was selected based on the suitability of soil for growing elephant fodder under rainfed conditions. The topography of the experimental plot was sloppy. The area has a bimodal rainfall pattern with a long rainy season (June to September) and a short rainy season (February to May). The average maximum and minimum temperatures of the area are 23.6 °C and 6.3 °C, respectively. The average monthly maximum and minimum air temperature, relative humidity and annual rainfall distribution of the experimental periods more or less showed similar trends with the long-term average at both experimental sites. Before planting, representative soil samples were taken from the experimental fields using a soil sampling augur at a depth of 0 to 22.5 cm layer. The composite samples were analysed for their physio-chemical analysis and presented in Table 1. The soil analysis (Table 1) indicated that the experimental plot was clay in texture, available nitrogen (0.614%) and phosphorus (1.98 ppm), very high in organic carbon (6.55%) and slightly acidic in reaction (pH 5.30).

Table 1: Mechanical, physical and chemical composition of the soil of the experimental plot (0-22.5 cm)

S. N.	Soil component analysed	values	Methods used and references
A. Mechanical analysis			
	Sand (%)	21.48	Bouyoucos Hydrometer Method (Bouyoucos, 1962)
	Silt (%)	52.24	
	Clay (%)	26.28	
	Textural class	Clay	Triangular diagram of Preswift, Taylor and Marshall (Piper, 1966)
B. Physical properties			
	Bulk Density (g cc ⁻¹)	1.28	Clod coating method (Black, 1965)
	Particle Density (g cc ⁻¹)	2.65	Pycnometer method (Black, 1965)
	Porosity (%)	51.69	Calculation by formula TP (%) = [1-(Bd/Pd)] ×100
C. Chemical composition			
	Total nitrogen (%)	0.614	Alkaline permanganate method (Subbaiah and Asija, 1956)
	Available phosphorus (ppm)	1.98	Bray's Methods No. 1 (Bray and Kurtz, 1945)
	Organic carbon (%)	6.55	Walkely and Black Titration method (Black, 1965)
	pH	5.30	Beckman pH meter (Jackson, 1973)

Field preparation and management

After the selection of the experimental site, the experimental land was cleaned manually with the help of labour. Consequently, the experimental field was ploughed and harrowed using a tractor-mounted moldboard plough and

disc harrow. The elephant grass root splits obtained from a local farmer were planted at the beginning of the main rainy season on a plot size of 5 m x 3 m (15 m²) with a spacing of 1 and 0.5 m between rows and plants, respectively. Diammonium phosphate (DAP) fertilizer at the rate of 50

kg/ha (18 kg N and 46 kg P₂O₅) was uniformly applied for all treatments at the planting of elephant grass for better root development and in addition, nitrogen was applied in the form of urea. Hand weeding was done during establishment and after every harvest of elephant grass to facilitate regrowth.

Experimental design and treatments

The experiment was conducted with six treatments in a randomized block design (RBD) with 3 replications. Treatments were six different levels of nitrogen fertilizer namely, T₀ (0.0 kg N/ha), T₁ (25 kg N/ha), T₂ (50 kg N/ha), T₃ (75 kg N/ha), T₄ (100 kg N/ha) and T₅ (125 kg N/ha).

Data collection

Morphometric characteristics of grass

The sample of five tillers of plants were randomly selected and tagged from the inner rows of each plot and used for the evaluation of 13 growth parameters (Halim *et al*, 2013) [27]. Plant height was determined by measuring beginning from its base to the longest leaf with a steel tape (Marafon, 2012) [35]. Leaf number was determined by counting the number of leaves on each stand from the oldest to the one just emerging from the five stands of elephant grass (Desalegn, 2017) [15]. Leaf length was measured from the tip to the ligules of elephant grass which was conducted by using a meter rule on five stands that were previously selected (Desalegn, 2017) [15]. Leave width have been conducted by measuring the length of the leaf half way and at that point measure its width on five stands (Marafon, 2012) [35]. Tiller number was determined by direct counting of the tillers from five plants that were randomly selected (Desalegn, 2017) [15]. The stem diameter, measured in five plants per plot with a digital caliper (Marafon, 2012) [35].

Yield and fodder productivity

The forages were harvested about 5 to 10 cm from the ground using sickles. The fresh weight of the harvested fodder in each plot was measured using spring balance. The biomass yields were calculated by using formula stated by Mutegi *et al*, (2008) [36]. Fresh subsamples of 500 g were taken from each experimental plot. Fodder samples were chopped and shredded to facilitate drying. Drying was done using a forced air draft oven at 65 °C for 72 hours. Dry matter percentage was estimated by dividing the dried forage sample by the fresh sample and multiply it by hundred. The dry biomass yield (DM, t/ha) was calculated using the following formula as

$$\text{DM yield (t/ha)} = \text{TFW} \times (\text{DWss} / \text{HA} \times \text{FWss}) \times 10$$

Where; TFW = total fresh weight kg/plot, DWss = dry weight of subsample in grams, FWss = fresh weight of subsample in grams, HA = Harvest plot area in square meters and 10 is a constant for conversion of yields in kg/m² to t/ha.

Partial budget analysis

Partial budget analysis for this experiment was performed according to Upton (1979) [52] to evaluate the profitability of the treatments. It was assessed by the variable costs of fertilizer and labor. The sale price of elephant grass was estimated using local market observations. The difference in the sale and purchase of all inputs in each treatment was

considered as a total return (TR). The net return (NR) was calculated by subtracting the total variable cost (TVC) from the total return (TR):

$$\text{NR} = \text{TR} - \text{TVC}$$

The change in net return (ΔNR) was calculated as the difference between the change in total return (ΔTR) and the change in total variable cost (ΔTVC) as:

$$\Delta\text{NR} = \Delta\text{TR} - \Delta\text{TVC}$$

The marginal rate of return (MRR) measures the increase in NR and is associated with each additional unit of expenditure (ΔTVC), which was the difference among the three rates of nitrogen fertilizer excluding positive control and normally expressed as a percentage.

$$\text{MRR} = \Delta\text{NR} / \Delta\text{TVC} \times 100$$

Data analysis

The collected field performance data (plant height, number of tillers, number of leaf and biomass yield) were analysed using analysis of variance (ANOVA) procedures of SPSS. Critical differences (CD) at 5% significance level were used for comparison of means. The following general model was used for data analysis:

$$Y_{ij} = \mu + B_i + T_j + E_{ij}$$

Where, Y_{ij} = Response of parameters, μ = Overall mean, B_i = i th block effect, T_j = j th treatment effect, E_{ij} = Random error.

Results and discussion

Morphological observation of elephant grass plant height (cm)

Plant height of a crop at harvest is a function of the well-coordinated interplay of the inherent and the environmental factors. The data of plant height (cm) are presented in Table 2. In present experiment plant height increase with increasing of nitrogen dose. Application of N increased plant height significantly over T₀ (89.44 cm) as well as 25 kg N ha⁻¹ (111.33 cm) and 50 kg N ha⁻¹ (132.67 cm) in entire experimental period. On an average, crop fertilized @ 125 kg N ha⁻¹ produced the tallest plants (166.78 cm) but that did not differ significantly from the crop fertilized @ 100 kg N ha⁻¹ (164.22 cm) and 75 kg N ha⁻¹ (150.11 cm). In otherwise lowest plant height was recorded in control treatment (89.44 cm). However, T₅, T₄ and T₃ treatments are at par with each other. The findings of present experiment are supported by the Ebrahim *et al*, (2020^b) [16, 17] who recorded the plant height as 80, 130, 190, and 210 cm fertilized 0, 69, 115, 161 kg N/h⁻¹, respectively. Wang *et al*, (2002) [53] also recorded the similar results ranging from 43 to 111 cm. In the contrary, Francisco *et al*, (2018) [55] recorded the smaller plant heights than current findings. However, Plant height of elephant grass ranging from 186 to 275 cm was reported when fertilized with 50 kg N ha⁻¹ (Mamaru, 2018) [34], which was higher than observed value in the current study.

Number of plants per tiller

Number of plants/tillers increased progressively up to harvest with the application of fertilizers. The number of

plants/tillers significantly ($p < 0.05$) maximum recorded in T_4 (14.67) as compared to T_0 (8.78), T_1 (10.33), T_2 (11.44) and T_3 (12.33). However, T_4 and T_5 treatments are at par with each other's. The lowest number of plants per tiller was recorded in T_0 (8.78). The result studied was agree with findings reported by Hendarto *et al.*, (2021) [30], who recorded that the number of plants/tillers as 13.00, 15.33 and 19.33 stem/clump application of nitrogen at 100, 200 and 300 kg N/h⁻¹, respectively. The variation tiller number due to different genetic variation, soil fertility, soil moisture and environmental factors. This idea is agreed with the variation of elephant grass tillers per plant reported under central Kenya by Mwendia *et al.*, (2008) [37]. Furthermore, Mamaru (2018) [34] which ranged from 9- 12 plant per tiller from Ethiopia. Apart from, Tessema (2008) [49] recorded higher number of plant/tillers ranging 18.80 to 25.53 with average mean 21.75 compared to present experiment.

Number of leaves/plants

The data pertaining to number of plants/clumps under different treatments are given in Table 2. The analysis of the result indicated that there was significantly ($p < 0.05$) higher number of leaves/plants in T_5 (14.11) as compared to control group (9.00), T_1 (10.89), T_2 (12.22), and T_3 (12.56). Even so, T_5 and T_4 was at par with each other. The findings of experiment are supported by Teshale *et al.*, (2022) [48] who recorded number of leaves per plants as 15, 14, 17.67, 14.6, 16.3, and 13.3 from ILRI-16840, ILRI-16791, ILRI- 16819, ILRI-16800, ILRI-16798 and ILRI-15743, respectively. However, Gadisa *et al.*, (2021) [21] recorded higher number of leaves/plants than present experiment findings in different varieties of elephant fodder namely; ILRI-1684, ILRI-1679, ILRI-16801, Local, ILRI-16787 and ILRI- 16800 as 27.8, 26.2, 32.47, 22.27, 37.4, 26.6, respectively. The variation in number of leaves per plant might be due to verity, soil, climate, management, nutrient application etc (Teshale *et al.*, 2022) [48].

Leaves length per plant (cm)

The mean of leaves length per plant (cm) of the experiment are shown in Table 2. The maximum average leaf length per plant was recorded in T_5 followed T_4 , T_3 , T_2 , T_1 and T_0 as 85.11, 84.00, 83.78, 72.00, 67.78 and 63.22 cm, respectively. The lowest average leaf length per plant was recorded from T_0 (63.22 cm). This result of experiment was numerically different. The result studied was agree with result reported by values by Teshale *et al.*, (2022) [48] which ranged from 62.6 to 82 leaf length per plant from Ethiopia. Similar, results also recorded by Fauzi *et al.*, (2020) [19]. They had recorded as 73.2, 82.8 and 81.9 cm leaf length fertilized by 0 kg N/ha/year, 500 kg N/ha/year, and 1000 kg N/ha/year, respectively. Rahetlah *et al.*, (2014) [44] also perceive leaf length from 66 to 84.7 cm with average 76.5 cm. The variation length of leaves due to different genetic variation, soil fertility, soil moisture, environmental factors and harvesting times.

Leaf blade width (cm)

The maximum average leaf blade width (cm) per plant was recorded in T_5 followed T_4 , T_3 , T_2 , T_1 and T_0 as 4.15, 4.04, 3.51, 3.47, 2.98 and 2.41 cm, respectively. This result of experiment was numerically different. The result studied was supported by Favare *et al.*, (2019) [20]. Who observed that leaf blade width as 1.23 to 5.37 cm in dry season and

3.06 to 5.09 cm in rainy season. Although, Fauzi *et al.*, (2020) [19] recorded lower leaf blade width as 1.8, 2.3 and 2.2 cm fertilized by 0.0, 500 and 1000 kg N/ha/year, respectively. In the contrary, Almeida *et al.*, (2016) [3] observed maximum width of leaf blade as 6.60, 6.00 and 6.03 cm in Cubano Pinda genotype of elephant grass fertilized through 400, 1000 and 1600 kg N ha⁻¹.

Basal circumference of stem (cm)

As per the Table 2, the results regarding the stem diameters (cm) significantly ($p < 0.005$) higher noted in T_0 (2.67 cm) group followed by T_2 , T_3 , T_4 , and T_5 as 2.22, 2.34, 2.31, and 2.02 cm, respectively. However, T_0 (2.67 cm) and T_1 (2.56 cm) treatments are at par with each other's. The results of current experiment is in line with the findings by Bueno *et al.*, (2020) [13] 2.10±0.05, 2.07±0.06, 2.07±0.06, 2.14±0.04, 2.21± 0.03 cm stem diameters of elephant fodder application of N @ 0.0, 50, 100, 150 and 200 kg N ha⁻¹. The findings of present experiment are also comparable with Maleko *et al.*, (2019) [33]. They observed that basal circumferences of stem as 2.19, 1.81, 1.18, 1.73 cm from Bana, KK₂, Ouma and LN varieties of elephant fodder.

Productivity of elephant grass

Stem production/tiller and leaves production per tiller (kg)

The average stem production/tiller (kg) is presented in Table 3. The significantly ($p < 0.05$) higher production of stem production/tiller found in T_5 (2.16 kg) as compared to over the T_4 (1.86 kg), T_3 (1.76 kg), T_2 (1.55 kg), T_1 (1.23 kg) and T_0 (0.99 kg). However, T_3 and T_2 and as well as T_1 and T_0 treatments had numerically difference or at par with each other's. The findings of present experiment are agreed with Osak *et al.*, (2018) [41] who recorded 2.72±0.19 kg stem production per tiller at harvested 45 days of sowing.

In term of leaves production per tiller, the maximum leaf production per tiller recorded in T_5 followed by T_4 , T_3 , T_2 , T_1 and T_0 as 1.86, 1.68, 1.45, 1.29, 1.10 and 0.86 kg, respectively. The higher dose of nitrogen increases the leaf production per tiller (kg) as compared to control group. Osak *et al.*, (2018) [41] findings were supported to present experiment results. They were recorded 2.26±0.11 kg leaf production per tiller at harvested 45 days of sowing.

Fresh biomass yield/tiller (kg)

The data of fresh fodder production per tiller (Kg) is shown in Table 3. Application of nitrogen increase the fresh fodder production/tiller significantly ($p < 0.005$) over the control group in entire experimental period. On other hand, fodder fertilized @ 125 kg N ha⁻¹ yielded the maximum fresh fodder production/tiller (4.02 kg) that significantly differ from rest of treatment groups. The findings of present experimental trial were supported by Osak *et al.*, (2018) [41]. They had recorded 4.98±0.27 kg fresh fodder production per tiller under Coconut-Beef Cattle Integrated Farming System in South Minahasa, Indonesia.

Fresh biomass yield (t/ha)

The data regarding the fresh biomass yield ha⁻¹ is presented in Table 3. The fresh biomass yield is important parameters, which allow farmers and pastoralists for cut and carry system for using the herbage yield of forage (Getnet, 2003; Getiso and Mijena, 2021) [23, 24]. The average fresh biomass production of elephant grass is 25.27 kilograms per plot (6

m²). This production is much higher than the research of Hendarto *et al.*, (2020) [29] which was recorded only about 2 kg per square meter, due to differences in the conditions of the research location. However, production is still lower than the production potential of elephant grass. The average fresh forage production of elephant grass application of N increased green fodder yield significantly ($p < 0.005$) over control treatment. On an average, fodder fertilized @ 125 kg N ha⁻¹ produced significantly maximum yield (32.59 t ha⁻¹) as compared to T₄ (26.95 t ha⁻¹), T₃ (24.97 t ha⁻¹), T₂ (22.59 t ha⁻¹), T₁ (18.62 t ha⁻¹) and T₀ (14.12 t ha⁻¹). However, T₄ and T₃ and T₃ and T₂ and T₂ and T₁ treatments are the at par with each other's. The results of current experiment are supported by Hendarto *et al.*, (2021) [30], who stated that the green fodder yield as 36.59, 37.24 and 39.95 t/ha⁻¹ fertilized 100, 200 and 300 kg/ha/urea, respectively. The current results for fresh biomass yield were lower than the results (22.2 to 57.3 t/ha) for fresh biomass yield reported by Habtie *et al.*, (2020) [26]. In addition, Hidosa *et al.*, (2022) [31] also observed similar findings as 38.16, 29.15, 29.57 and 18.60 ton/ha fresh biomass yield for ILRI-16840, Werer-1333, Areka-local and Werer-local, respectively in South Omo, South-Western Ethiopia. Although, Getiso and Mijena (2021) [23] stated higher fresh biomass yield as 64.14, 44.82, 51.66, 54.16, 68.42 and 44.80 t/ha for different Napier grass accessions (14983, 14984, 16808, 16788, 15743, 16819) at Sidama Regional state, Wondo Genet woreda, Ethiopia.

Dry fodder yield (t/ha)

The effects of nitrogen levels on dry biomass yields of elephant grass are presented in Table 3. Dry matter yield is the basic component related to the forage production. The dry matter yield of elephant grass increased as well as the nitrogen level increased (Table 3). The result revealed that the T₅ (6.85 t/ha) yielded higher ($p < 0.05$) dry biomass yields than T₃ (5.00 t/ha), T₂ (4.34 t/ha), T₁ (3.24 t/ha) and T₀ (1.96 t/ha) treatments, but dry biomass yields in T₅ and T₄, and T₄ and T₃ as well as T₃ and T₂ treatments are at par with each other's. Nitrogen element is basically related with the growth of crop or grass. This showed that nitrogen level significantly affected the dry matter yield. The results of present experiment are agreed with Ullah *et al.*, (2010) [51], who stated that different levels of nitrogen application in elephant grass significantly affected dry matter yield. They

recorded as 1.2, 1.7, 2.0 and 2.0 t ha⁻¹ dry matter yield of elephant grass after applied nitrogen @ 0, 40, 80 and 120 kg N ha⁻¹, respectively. Furthermore, the dry biomass yield from this experiment is also similar reported by Gezahagn *et al.*, (2017) [25] as 6.84 ton/ha for six elephant grass cultivars and Tesfaye (2018) [47] as 4.2 ton/ha for nine Elephant grass cultivars, but it was lower than reported value ranged from 7.22 to ton/ha by Getiso and Mijena (2021) [23] in Wondo Genet, Ethiopia and 8.70 to 18.27 ton/ha by Hidosa *et al.*, (2022) [31] under rainfed condition in South Omo, Southwestern Ethiopia.

Partial budget analysis of elephant grass

The rate of N fertilizer application determines the cost and biomass production of elephant grass (Sant'Ana *et al.*, 2018) [45] so that Partial budget analysis is very vital to evaluate its' economic feasibility (Oliveira *et al.*, 2015) [40]. In the present experiment, the partial budget analysis was done to evaluate the elephant grass grower farmers' profitability by producing elephant grass fertilized with different rates of N (Table 4). The result of the partial budget analysis revealed that fertilizing elephant grass with N resulted in a relatively higher net return such as T₅ (9393.75 ETB/ha or 60.71 USD/ha), followed by T₄ (8626.89 ETB/ha or 55.75 USD/ha), T₂ (6766.47 ETB/ha or 43.73 USD/ha), T₃ (6481.60 ETB/ha or 41.89 USD), T₁ (4235.63 ETB/ha or 27.37 USD/ha) and the control group (1873.28 ETB/ha or 12.11 USD/ha). Although the change in net return was positive across all the rates of N fertilizer, it was higher for elephant grass fertilized with 110 kg N ha⁻¹ (3492.76 ETB/22.57 USD) compared to the other rate of N fertilizer. The result of this experiment showed that per unit of expenditure could result in a return of 22.31/0.14, 26.38/0.17, 12.15, 15.03/0.079 and 12.01/0.078 ETB/USD per unit of investment for 25, 50, 75, 100 and 125 kg N ha⁻¹, respectively. Therefore, fertilizing the elephant grass at 50 kg N ha⁻¹ was economically feasible because it resulted in a high net return than the other rate of N fertilizer and hence it could be recommended for smallholder elephant grass producers as a fodder crop. The results of current experiment are supported by Ebrahim *et al.*, (2020^b) [16, 17] who recorded net returns as 2491.5, 6700.9, 9992.9 and 9509.1 ETB/ha applied nitrogen 0.0, 69, 115 and 161 kg N ha⁻¹, respectively.

Table 2: Effect of different nitrogen levels of growth performance of Elephant fodder

Parameters	Treatments						SEM	C.D. ($P < 0.05$)	P
	T ₀	T ₁	T ₂	T ₃	T ₄	T ₅			
Plant height (cm)	89.44 ^e	111.33 ^{de}	132.67 ^{cd}	150.11 ^{abc}	164.22 ^{ab}	166.78 ^a	7.58	22.75	0.0002
Number of plants per tiller	8.78 ^e	10.33 ^d	11.44 ^{cd}	12.33 ^c	14.67 ^a	14.33 ^{ab}	0.52	1.58	<0.0001
Number of leaves per plant	9.00 ^e	10.89 ^d	12.22 ^{cd}	12.56 ^{bc}	13.67 ^{ab}	14.11 ^a	0.47	1.40	0.0013
Number of leaves per tiller	57.56 ^d	68.00 ^{cd}	71.89 ^{cd}	73.44 ^{bc}	79.44 ^{ab}	86.56 ^a	2.46	7.41	0.0020
Leaves length per plant (cm)	63.22 ^e	67.78 ^{de}	72.00 ^d	83.78 ^{abc}	84.00 ^{ab}	85.11 ^a	2.19	6.57	<0.0001
Leaves blade width (cm)	2.41 ^f	2.98 ^e	3.47 ^{cd}	3.51 ^c	4.04 ^{ab}	4.15 ^a	0.14	0.44	<0.0001
Basal circumference of stem (cm)	2.67 ^a	2.56 ^{ab}	2.22 ^{cde}	2.34 ^c	2.31 ^{cd}	2.02 ^f	0.05	0.16	<0.0001

a,b,c,d,e means within a row with different superscripts are significantly different ($p < 0.05$), T₀ = Control group (0.0 kg N ha⁻¹), T₁ = 25 kg N ha⁻¹, T₂ = 50 kg N ha⁻¹, T₃ = 75 kg N ha⁻¹, T₄ = 100 kg N ha⁻¹ and T₅ = 125 kg N ha⁻¹, m= meter, cm = centimetre, SEM =Standard Error of Mean, C.D. = Critical differences, P = Probability values

Table 3: Effect of different nitrogen levels of fodder productivity and yield of Elephant fodder

Parameters	Treatments						SEM	C.D. ($P < 0.05$)	P
	T ₀	T ₁	T ₂	T ₃	T ₄	T ₅			
Stem production/tiller (kg)	0.99 ^e	1.23 ^e	1.55 ^{cd}	1.76 ^{bc}	1.86 ^b	2.16 ^a	0.09	0.28	<0.0001
Leaf production/tiller (kg)	0.86 ^e	1.10 ^{de}	1.29 ^{cd}	1.45 ^{bc}	1.68 ^{ab}	1.86 ^a	0.08	0.25	<0.0001

Fresh fodder production /tiller (kg)	1.85 ^e	2.33 ^{de}	2.84 ^{cd}	3.21 ^{bc}	3.54 ^{ab}	4.02 ^a	0.18	0.54	<0.0001
Green fodder/plot (Kg/6 m ²)	8.47 ^f	11.17 ^e	13.55 ^{cd}	14.98 ^{bc}	16.17 ^b	19.56 ^a	0.87	2.61	<0.0001
Green fodder yield (t/ha)	14.12 ^f	18.62 ^{de}	22.59 ^{cd}	24.97 ^{bc}	26.95 ^b	32.59 ^a	1.45	4.34	<0.0001
Dry fodder yield (t/ha)	1.96 ^e	3.24 ^{de}	4.34 ^{cd}	5.00 ^{bc}	6.03 ^{ab}	6.85 ^a	0.53	1.59	<0.0001

^{a,b,c,d,e} means within a row with different superscripts are significantly different ($p < 0.05$), T₀ = Control group (0.0 kg N ha⁻¹), T₁ = 25 kg N ha⁻¹, T₂ = 50 kg N ha⁻¹, T₃ = 75 kg N ha⁻¹, T₄ = 100 kg N ha⁻¹ and T₅ = 125 kg N ha⁻¹, Kg = kilogram, m² = square meter, t/ha = ton per hectare, SEM = Standard Error of Mean, C.D. = Critical differences, P = Probability values

Table 4: Partial budget analysis of Elephant grass fertilized with different nitrogen rates

S.N.	Descriptions	Treatments					
		T ₀	T ₁	T ₂	T ₃	T ₄	T ₅
1.	Dry matter yield in ton DM ha ⁻¹	1.96	3.84	4.34	5.00	6.03	6.85
2.	Selling price per ha ⁻¹ (@ETB 6568 ton/DMY) *	12873.28	25221.12	28505.12	32840.0	39605.04	44990.80
3.	Nitrogen quantity (kg) required for ha ⁻¹	0.0	54.34	108.69	163.04	217.39	271.73
4.	Price of urea fertilizer @ 100 birr/kg for ha ⁻¹	0.0	5435.0	10869.0	16304.0	21739.0	27173.0
5.	Cost of ploughing, labour for land and pit preparation in ETB ha ⁻¹	4000.0	4000.0	4000.0	4000.0	4000.0	4000.0
6.	Cost of labour for planting and harvest in ETB ha ⁻¹	4000.0	4000.0	4000.0	4000.0	4000.0	4000.0
7.	Cost of labour for fertilizer application in ETB ha ⁻¹	0.0	1500.0	1500.0	1500.0	1500.0	1500.0
8.	Cost of labour for weed management in ETB ha ⁻¹	3000.0	3000.0	3000.0	3000.0	3000.0	3000.0
9.	TVC (4+7)	0.00	6118.90	10738.65	15358.40	19978.15	24597.05
10.	TR [(2)-5+6+8]	1873.28	10354.53	17505.12	21840.00	28605.04	33990.80
11.	NR (10-9)	1873.28	4235.63	6766.47	6481.60	8626.89	9393.75
12.	ΔTVC	0.00	6934.00	12369.00	17804.00	23239.00	28673.00
13.	ΔTR	0.00	8481.25	15631.84	19966.72	26731.76	32117.52
14.	ΔNR	0.00	1547.25	3262.84	2162.72	3492.76	3444.52
15.	MRR	0.00	22.31	26.38	12.15	15.03	12.01

Note: TVC = Total Variable Cost (ETB ha⁻¹); TR = Total Return (ETB ha⁻¹); NR = Net Return (ETB ha⁻¹); ΔTVC = Change in Total Variable Cost (ETB ha⁻¹); ΔTR = Change in Total Return (ETB ha⁻¹); ΔNR = Change in Net Return (ETB ha⁻¹); MRR = Marginal Rate of Return (%) and ETB = Ethiopian Birr

Conclusion and recommendations

From the results of present experiment, it can be concluded that nitrogen fertilizer rate had a significant effect on the growth characteristics and on forage yield of elephant grass. Forage yield and morphological characteristics increased in response to increasing the rate of nitrogen fertilizers. The treatment T₅ group (125 kg N/ha) yielded maximum dry matter (6.85 t/ha) over the control treatment group (1.96 t/ha). Looking on the basis of net returns, T₅ group provided maximum return (9393.75 ETB/ha) then other experimental treatment groups. However, marginal rate of return (%) higher found in T₂ as compared to control as well as other experimental treatment groups. Therefore, it was observed that as an economically feasible N fertilizer rate, suggesting 125 kg N ha⁻¹ to be recommended for farmers to grow as it may lead to economical forage production.

Conflict of interest

Authors declare no conflict of interest associated with present publication

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