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Effect of Levels of N-fertilizer and Cutting Height on Nutrient Content and Nitrogen Recovery Rate of Elephant Grass (*Pennisetum purpureum* L.) in Mersa, Ethiopia

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ABSTRACT

This study was carried out to evaluate the effects of nitrogen fertilizer rates (NFR) and cutting height (CH) on the nutrient contents and nitrogen recovery of elephant grass when grown in Eastern Amara Region of Ethiopia. The experiment consisted of two factors: Factor A: Nitrogen (4 levels) and Factor B: Cutting height (3 levels). Experiments were laid out in randomized complete block design (RCBD) with 3 replications. The results indicated that nitrogen and plant height significantly affected dry matter yield (DMY) of *Pennisetum purpureum* L. in which N application of 161 kg ha^{-1} and cutting height of 15 cm showed the highest leaf while leaf to stem ratio did not affected due to these two factors. Similarly, application of N and cutting height significantly influenced on nutrient contents in which N application at the rate of 69 kg ha^{-1} and cutting at the height of 15 cm brought the highest crude protein content whereas NDF and ADF contents were higher at cutting height of 22.5 cm with the lowest application of N (69 kg ha^{-1}). Nitrogen recovery rate did not positively correlated with increased levels of N fertilizer applications as the maximum value (473.79 %) was recorded for those treated at the rate of 69 kg ha^{-1}. Therefore**,** from this study it can be conclude that N application at the rate of 69 kg ha^{-1} and harvesting at a cutting height of 15 cm might be optimum for better nutrients content, greater DM yield and efficient N recovery rate of *Pennisetum purpureum* L.

HIGHLIGHTS

- The fiber contents of the grass appeared to increase as the level of N fertilization decreased and cutting height used in the current study increased.
- The organic matter content increased as the cutting height decreased and the reverse order is for the ash content.

Keywords: Nutrient content, Elephant grass, Nitrogen, cutting height

Livestock production in Ethiopia has considerable economic and social importance at household and national levels and provides significant export earnings (CSA, 2018). About 80–85% of the people are employed in agriculture, especially farming (Negash *et al.,* 2017). However, livestock productivity is very low attributable to different factors of which poor nutrition is the major one. A large proportion of livestock feed resources in Ethiopia are natural pastures, crop residues and aftermath grazing (Negash *et al*., 2017 and CSA, 2018). These feed resources cannot support higher animal productivity due to their low productivity, low nutritive content and poor digestibility. Therefore, so as to improve the productivity of livestock, alternative strategies of improving both the quality and quantity of feed resources should be implemented. And one of the alternatives might be the cultivation of improved forages by using species which could be integrated into the existing farming system (Dahipahle *et al*., 2017). Of the

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forage species, Elephant grass (*Pennisetum purpureum*) can be easily cultivated, develops rapidly, and yields high amounts of dry matter and green forage of higher quality when managed properly. Yields of elephant grass is ranging from 2 to 85 tons DM/ha depending on soil and environmental conditions (Joy 2018), while concentration of nutrients, specially the crude protein content, could be varied depending on the soil nitrogen levels (Kabirizi *et al*., 2015) and cutting height above the soil surface (Tessema *et al*., 2010; Lounglawan *et al*., 2014). But, in this area there is no concrete information whether application of nitrogen fertilizer and cutting height affect the biomass and nutrient content of this grass species. Therefore, this study was carried out to evaluate the impacts of nitrogen fertilizer application and cutting height on yield and nutritive value of elephant grass.

MATERIALS AND METHODS

Description of the experimental area

The experiment field was established during July 2018-January 2019 at Mersa College of Agriculture Campus (11°40′N-11°66.7′ N, 39°39.5′E-39°65′ E; elevation 1,600 masl), Amhara National Regional State, Ethiopia. The pattern of rainfall is bimodal (summer and autumn) and ranges between 650 and 700 mm with an average annual temperature of 21 ºC.

Soil characteristics of the experimental area

Nine soil samples of 300 kg were collected from the field on a diagonal transect to a depth of 30 cm before the establishment of elephant grass and were mixed to form a composite sample for each treatment. The composite soil sample was dried and analyzed at the soil laboratory of Sirinka Agricultural Research Center to reveal the following details: the soil was a clay loam (60% clay, 25% silt and 15% sand) with pH - 6.7, total N - 0.02%, organic matter - 0.95%, organic carbon - 0.55%, electrical conductivity - 0.054 ds/m and available P - 22.6 ppm.

Source of planting material, experimental design and treatments

Stems of the local parent plant of ILRI 14984 were obtained from Mersa College of Agriculture Campus. The experiment was a 4 × 3 factorial arrangement of treatments in a randomized complete block design (RCBD) with 3 replications. Treatments were combinations of 4 levels of nitrogen fertilizer (0, 69, 115 and 161 kg N/ha) and 3 cutting heights (7.5, 15 and 22.5 cm above ground-level). Plot size was 5 × 3 m (15 m^2) and there were 36 plots. The spacing between plots and blocks were 0.5 and 1 m, respectively. Row spacing was 1 m and intra-row spacing was 0.5 m, allowing 30 plants per plot. The total area of the experiment was 19.4 × 43.9 m (851.7 m^2).

Land preparation, planting and management practices

The required land was plowed with a tractor once and twice with bullocks and smoothed to present a good tilth. Then, 1,080 pits (20 cm deep) were prepared by using a hand tool of backhoe and pickaxe. Stem cuttings with 3 nodes were prepared and planted in the pits at an angle of about 30-45^o with 2 nodes beneath the soil surface. Appropriate plots were fertilized with the nitrogen, i.e. 0, 69, 115 and 161 kg N/ha in the form of urea 7 and 35 days after the first harvest of 90 days. The other half of the fertilizer was applied after the first harvest. The area was kept weed-free by hand-hoeing during land preparation, and then manually at 30 and 60 days after planting, plus 5 and 35 days after the first harvest. All plots were harvested at cutting heights of 7.5, 15 and 22.5 cm 60 days after the first harvest, and irrigation was applied once. No P fertilizer was applied based on the soil test results.

Data collection

Five representative plants were clipped, weighed and subsampled (about 400 g for stems and leaves and 400 g for nutritional content). The subsamples were oven-dried at 65 °C for 72 hours and leaf and stem DM percentages were determined. Stem and leaf DM yields for each plot were used to calculate leaf:stem ratio (LSR). The samples prepared for nutritional value analysis were ground to pass through a 1 mm sieve and analyzed for ash contents following the procedure of AOAC (1990). Nitrogen concentration was determined following the micro-Kjeldahl procedure (AOAC, 1995). Neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) concentrations were determined as described by Van Soest *et al*. (1991). From the TDMY and its CP content, the N recovery rate was calculated according to the following equation:

$$NR = 100\ (TN - TNW)/NR$$

Where,

NR is *N* recovery (%); *TN* is the total amount of *N* absorbed, with *N* application (kg/ha); *TNW* is the total amount of *N* absorbed, without *N* application (kg/ha); *NR* is *N* rate applied (kg/ha).

Data analysis

Data were analyzed using analysis of variance (ANOVA) of the General Linear Model (GLM) procedure of the statistical analysis system (SAS 2004). Treatment means were separated using Tukey HSD (honestly significant difference) test at P<0.05. The ANOVA model for data analysis consisted of the effects of block, N fertilizer rate, cutting height, interaction of fertilizer rate and cutting height and error term.

RESULTS AND DISCUSSION

Both cutting height and rate of N fertilizer had significant (P<0.05) effects on leaf and stem DM yield with significant interactions between the two factors (Table 1). DMY of both leaf and stem rose as cutting height increased and with increased N fertilizer application but differences were not always significant (P>0.05) between levels. Leaf:stem ratio (LSR) was significantly (P<0.05) affected by N fertilizer application rate and cutting height, but interactions were not significant (P>0.05; Table 2). Effects of cutting height were in the order 15 > 7.5 > 22.5 and those of N fertilizer rate in the order 69 > 115, Control > 161 kg N/ha.

There was a tendency for CP concentration to increase with cutting height in the absence of N fertilizer but the effect diminished as N application rate increased with a negative effect of cutting height at the highest N level (P<0.05; Table 2). Treatment had no consistent effect on OM, NDF, ADF and ADL concentrations (Table 2; P>0.05).

There was a significant effect of both cutting height and the rates of N fertilizer application on N recovery rate with significant difference between the two factors. (P<0.05; Table 1).

The current study has shown that application of N fertilizer with different cutting heights had an influence on nutritional

Table 1: Effect of cutting height, nitrogen fertilizer application and their interactions on total dry matter yield and N recovery rate

Parameter	Cutting height	Nitrogen fertilizer rate (kg N/ha)				Cutting height (cm)			P-value
		0	69	115	161	7.5	15	22.5	CH × N
LDMY	7.5	1.23e	1.57de	2.20cd	2.10cd	1.78q	2.63p	2.21p	<.0001
(t/ha)	15	1.53de	3.10ab	2.57bc	3.30a				
	22.5	1.37e	2.17cd	3.00ab	2.30c				
	Mean	1.38z	2.28y	2.59x	2.57xy				
SDMY	7.5	1.23e	1.37e	2.17cd	2.23c	1.75r	2.23q	2.47p	<.0001
(t/ha)	15	1.27e	2.40bc	2.10cd	3.17a				
	22.5	1.57de	2.17cd	3.20a	2.93ab				
	Mean	1.36z	1.98y	2.49x	2.78w				
LSR	7.5	0.97	1.1	1	0.9	0.99q	1.2p	0.9r	0.3153
	15	1.2	1.3	1.23	1.07				
	22.5	0.9	1	0.9	0.8				
	Mean	1.02y	1.13x	1.04y	0.92z				
N Recovery (%)	7.5	—	95.4c	307.2bc	209.2c	203.9c	518.6a	353.3b	<.0001
	15	—	988.3a	219.5c	347.8bc				
	22.5	—	337.6bc	537.1b	185.3c				
	Mean	—	473.8a	354.6b	247.4b				

TDMY = Total dry matter yield; LDMY = Leaf dry matter yield; SDMY = Stem dry matter yield; LSR = Leaf stem ratio; Means within parameters followed by different letters are significantly differ at P<0.05.

Table 2: Effects of cutting height, nitrogen fertilizer application and their interactions on nutrient contents of elephant grass

Parameter	Cutting height	Nitrogen fertilizer rate (kg N/ha)				Cutting height (cm)			P-value
		0	69	115	161	7.5	15	22.5	C × N
CP	7.5	12.3de	12.3de	15.0b	14.7b	13.6b	14.0a	13.3c	<0.0001
	15	12.9cd	17.9a	11.9ef	13.4c				
	22.5	14.7b	12.2def	14.7b	11.5f				
	Mean	13.3b	14.1a	13.9a	13.2b				
OM	7.5	87.1bc	86.2cd	86.0de	86.6bcd	86.5a	86.9a	83.7b	<0.0001
	15	86.2cd	88.2a	87.2ab	86.2cd				
	22.5	87.2ab	75.5f	85.1e	87.1bc				
	Mean	86.8a	83.3c	86.1b	86.6a				
Ash	7.5	12.9de	13.8cd	14.0bc	13.4cde	13.5b	13.1c	16.3a	<0.0001
	15	13.8cd	11.8f	12.8ef	13.8cd				
	22.5	12.8ef	24.5a	14.9b	12.9de				
	Mean	13.2c	16.7a	13.9b	13.4c				
NDF	7.5	60.6bc	58.1cd	57.5cde	44.0f	55.0c	57.4b	59.3a	<0.0001
	15	53.8e	55.4de	57.4cde	62.9b				
	22.5	56.0de	68.8a	56.0de	56.5cde				
	Mean	56.8b	60.7a	57.0b	54.5c				
ADF	7.5	48.2ab	45.7abc	43.5bc	31.2d	42.2b	44.2ab	46.2a	<0.0001
	15	41.4c	42.9bc	44.7abc	47.9ab				
	22.5	45.8abc	50.9a	44.7abc	43.6bc				
	Mean	45.1a	46.5a	44.3a	40.9b				
ADL	7.5	12.2a	10.5ab	10.6ab	8.6c	10.5	10.7	10.7	<0.0001
	15	10.0bc	10.1bc	11.1ab	11.6ab				
	22.5	10.0bc	12.1a	10.5ab	10.1bc				
	Mean	10.7ab	10.9a	10.7ab	10.1b				

Means within parameters followed by different letters differ at P<0.05. CP = Crude protein; OM = Organic matter; NDF = Neutral detergent fiber; ADF = Acid detergent fiber; ADL = Acid detergent lignin.

value and N recovery rate of elephant grass. The current study highlights the benefit of considering N fertilizer and cutting height as agronomic practices for elephant grass production. The LDMY and SDMY obtained from the grass under the combined effect of 15 cm*161 kg N/ha and 22.5 cm*115 kg N/ha were 2.7 and 2.6 times higher than the control group when harvested at a cutting height of 7.5 cm, respectively. Treatments fertilized with 69 kg N/ha gave the highest LSR (1.13; Table 1), which might be due to the fact that the plants were stemy as the N fertilizer rate increased. This was in agreement with Figueira *et al*. (2016), who noted the statistical effect of cutting heights (30-60 cm) on the LSR with a mean value ranging from 1.07 to 1.36 for elephant grass cultivated in Brazil. Similarly, Jørgensen *et al*. (2010) observed a statistical difference among cutting heights (0-30 cm) on the leaf to stem ratio. Contrary to the present study, Oliveira *et al*. (2015) reported no statistical difference in stem content of the same grass due to the application of N fertilizer. Elephant grass growing under the application of 69 kg N/ha gave the highest CP (17.9%) when harvested at a cutting height of 15 cm, which could be attributed partly to good soil nitrogen (Kabirizi *et al*., 2015) and the higher leaf in a 15 cm × 69 kg N/ha.. Figueira *et al*. (2016) reported increased CP content from 12.5 to 15.04% with increased cutting heights from 30 to 60 cm whereas the highest protein content was obtained at a cutting height of 20 cm (Wijitphan *et al*., 2009; Geren *et al*., 2016) and 10 cm (Rahman *et al*., 2016). Reports also indicated that the content of CP was statistically different among cutting heights (Tessema *et al*., 2010; Lounglawan *et al*., 2014). Contrary to the results in the present study, Rahman *et al*. (2016), Rahetlah *et al*. (2014), and Sant'Ana *et al*. (2018) noted no statistical variation in CP content of Napier grass as affected by N fertilizer rates.

The present study showed that the ash content was statistically highest (24.5%) for treatment at a cutting height of 22.5 cm and a N fertilizer of 69 kg N/ha, possibly due to the adequate quantity of mineral concentration of the soil and higher proportion of leaf. The ash contents in The grass due to the effect of 7.5 cm × 161 kg N/ha produced the lowest content of ADF (31.23%) while the highest was 50.87% for 22.5 cm × 69 kg N/ha, which could be attributed to thicker tillers for 22.5 cm × 69 kg N/ha. Figueira *et al*. (2016), working with elephant grass, reported a statistical difference in the contents of ADF as the result of residual heights as the same as the results of the present study. However, the statistical similarity of ADF contents for Napier grass was noted as influenced by cutting height (Tessema *et al*., 2010; Lounglawan *et al*., 2014) and N fertilizer treatments (Rahetlah *et al*., 2014; the present study was higher than Rengsirikul *et al*. (2013) who noted 7.7 to 16.1% for Napier grass when fertilized with 375 kg N $ha^{-1}year^{-1}$ and harvested at a stuble height of 15 cm. The report on the effect of cutting height on ash content was not consistent while Tessema *et al*. (2010) reported statistical effect at a cutting height of 5 and 25 cm, Lounglawan *et al*. (2014) and Figueira *et al*. (2016) observed no statistical effects. Similarly, insignificant influences of the rates of N fertilizer on the content of ash were reported by Ojo *et al*. (2015), Oliveira *et al.* (2015), Rahman *et al*. (2016) and Rambau *et al.* (2016). There was the highest NDF (68.8%) for a treatment contained 22.5 cm*69 kg N/ha and it was increased at lenient cutting height and lower N fertilizer, which could be caused by the early maturity of the grass (Kabirizi *et al*., 2015). Opposed to the results of the current research, the content of NDF did not show statistical differences due to cutting heights ranging from 30 to 60 cm (Figueira *et al*., 2016) and 5 to 30 cm (Tessema *et al*., 2010), and across N fertilizer treatments (Rahetlah *et al*., 2014; Sant'Ana *et al*., 2018).

The contents of ADF differed between 7.5 and 22.5 cutting heights only; and rates of N fertilizer of 0, 69, and 115 kg N/ha were statistically similar and were higher than the value for 161 kg N/ha. Sant'Ana *et al*., 2018), which was contrary to the results of the current study. The content of ADL was affected (P<0.05) by N fertilizer rates and its interaction with three cutting heights but the effect of cutting height was not statistically different (Table 2). The interaction effect of 22.5 cm and 69 kg N/ha consisted of the highest content of ADL of 12.14% followed by 7.5 cm x 0 kg N/ha (12.17%) whereas the lowest was 8.64% for 7.5 cm x 161 kg N/ha with no apparent difference for other treatments (Table 2). A wide range of lignin content (4.4 to 12.3%) was reported for Napier grass (Rengsirikul *et al*., 2013; Sant'Ana *et al*., 2018). The similar (*P>0.05*) effect of cutting height on the contents of ADL in the present study was in agreement with those of Ferreira *et al*. (2015) and Lounglawan *et al*. (2014) who reported for Napier grass. Contrary to the results of the present study, Namihira *et al*. (2011) reported that the DM content of ADL increased from 32.2 to 39% as the N fertilizer increased and Ojo *et al*. (2015), Rahetlah *et al*. (2014), and Sant'Ana *et al*. (2018) noted the non-statistical influence of the application of N fertilizer. Treatments fertilized with 69 kg N/ha showed the highest N recovery rate (Table 1), indicating that the plant has a limited capacity of N use during the study period. In the treatment with 69 kg/ha N, N recovery rate was 473.79 % that may be due to the positive effect of N on organic matter mineralization or by the N present on the soil. This study supports Sartor *et al*. (2011) who repored a N recovery rate of Alexandergrass pasture of 110.04 and 40.81% to rates of 200 and 400 kg/ha N, respectivery.

CONCLUSION

The study was conducted to evaluate the effect of nitrogen fertilizer rates and cutting height on nutritive values of elephant grass and it underlined that both cutting height and N fertilizer rates have a significant impact. The fiber contents of the grass appeared to increase as the level of N fertilization decreased and cutting height used in the current study increased. However, the crude protein content between 69 and 115, and 0 and 161 kg N/ha fertilizer rates were statistically similar. The organic matter content was in the order of 69<115<161=0 kg N/ha and increased as the cutting height decreased and the reverse order is for the ash content. Looking at the combination of the two factors 15 cm × 69 kg N/ha treatment resulted in higher contents of crude protein and organic matter, suggesting it to be recommended as it may have better nutritive values.

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