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Effect of Harvesting Height and Nitrogen Fertilization on Herbage Yield and Nutritional Qualities of Elephant Grass in the Central Highlands of Ethiopia

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Abstract: The study was conducted at Holetta and Debre Zeit research centers of the Ethiopian Institute of Agricultural Research (EIAR), during main cropping seasons of 2016 and 2017 to identify effects of different harvesting height (HH) and nitrogen (N) fertilizer treatments on top performance of elephant grass dry matter yield (DMY), crude protein yield (CPY) and quality attributes. Three HH (HH1=50 cm, HH2=100 cm and HH3= 150 cm) and four N fertilizer treatments (N1= 0 kg N ha^{-1}, N2= 50 kg N ha^{-1}, N3= 100 kg N ha^{-1} and N4= 150 kg N ha^{-1}) were evaluated in a randomized complete block design with three replications. The DMY and CPY values were significantly ($P<0.05$) affected by HH and N fertilizers. Higher DMY values were recorded at HH2 (6.24 t ha^{-1}; 12.25 t ha^{-1}) and HH3 (6.00 t ha^{-1}; 14.75 t ha^{-1}) at Holetta and Debre Zeit, respectively. The crude protein (CP) content ranged from HH3 (8.87%; 8.27%) to HH1 (9.72%; 8.58%) with overall mean of 9.25%; 8.47% at Holetta and Debre Zeit, respectively. The overall mean neutral detergent fiber (64.69%; 63.39%), acid detergent fiber (40.58%; 41.14%) and acid detergent lignin (5.55%; 5.53%) values were recorded at Holetta and Debre Zeit, respectively. The *in vitro* dry matter digestibility (IVDMD) ranged from HH3 (67.48%; 65.91%) to HH1 (70.41%; 66.95 %) at Holetta and Debre Zeit, respectively. Similarly, significantly the highest DMY values were recorded in treatment N3 (6.12 t ha^{-1}; 13.47 t ha^{-1}) at Holetta and Debre Zeit, respectively. The crude protein (CP) content ranged from N1 (8.78%; 8.06%) to N3 (9.53%; 8.62%) at Holetta and Debre Zeit, respectively. The *in vitro* dry matter digestibility (IVDMD) ranged from N1 (68.47 %; 66.00 %) to N3 (69.38%; 66.83 %) at Holetta and Debre Zeit, respectively. From this study it can be concluded that HH2 (100 cm) with N3 (100 kg N ha^{-1}) fertilizer treatments in elephant grass has resulted in higher annual herbage and crude protein yields and nutritional qualities and hence these are advisable to be adopted by farmers who grow elephant grass as livestock feed in the study areas.

Key words: Elephant Grass · Harvesting Height · Nitrogen Fertilizer · Dry Matter Yield · Crude Protein Yield · Chemical Composition · Digestibility

INTRODUCTION

Livestock plays a crucial role in the Ethiopian agriculture, currently, productivity per animal is very low and the contribution of the livestock sector to the overall economy is much lower than expected. Despite many factors are constraining the development of this sector, among which feed scarcity in terms of both quantity and quality has remained to be the main limiting factor hampering productivity of livestock sector [1-6]. The production of adequate quantities of good quality forages to supplement crop residues and pasture roughages is the only way to economically overcome the feed shortage [7]. Amongst the promising forage species promoted in Ethiopia, elephant grass could play an important role in providing a significant amount of high-quality forage for both smallholder farmer and intensive livestock production systems with appropriate management practices [8, 9, 10].

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For most forage, harvesting treatments and interval can have a significant effect on both yield and nutritional qualities [11]. However, farmers do not have sufficient information on optimal management practices for elephant grass [12]. Nitrogen (N) fertilizer is frequently deficient in soils [13] and plants grown on nitrogen deficient soils show stunted growth, yellowish color and reduced yield [14]. Nitrogen fertilizer develops stronger cells for photosynthesis [15] and increasing of forage grasses dry matter yield and quality in terms of crude protein content, voluntary feed intake and digestibility [16]. These qualities of forage is a function of many factors including the species, height of harvest, plant parts, agro ecology, agronomy and postharvest processing practices [17]. The main limiting factor of grasses is low in protein supply and commonly fertilized with N fertilizer in the form urea because of their ability to increase the herbage yield and to produce forage with more balanced nutrition for livestock feeding [18]. Therefore, the objective of this study was to evaluate the effects of different harvesting height and nitrogen fertilizer levels on herbage yield and nutritional qualities of elephant grass in the central highlands of Ethiopia where information is lacking.

MATERIALS AND METHODS

Descriptions of the Study Locations: The field experiments were conducted at Holetta and Debre Zeit Research Centers of the Ethiopian Institute of Agricultural Research (EIAR) from May 2016 (year 1) to December 2017 (year 2). Holetta Research Center is situated at an altitude of 2400 meter above sea level (masl) between 9° 00`N latitude and 38° 30`E longitude. The area has a bimodal rainfall pattern with a long rainy season (June to September) and a short rainy season (February to May). Average maximum and minimum temperature of the area is 23.6°C and 6.3°C, respectively. The minimum temperature sometimes drops below zero when frost occurs from November to January [19]. Debre Zeit Research Centre is located at an altitude of 1850 masl between 9° N latitude and 39°E longitude. It also experiences a bimodal rainfall pattern with a long rainy season (June to October) and a short rainy season (March to May). Average maximum and minimum temperature of the area is 26.8°C and 11.6°C, respectively. Long term (1971-2017) and the experimental period weather parameters of the experimental sites are shown in Figures 1 and 2. The average monthly maximum and minimum air temperature, relative humidity and annual rainfall distribution of the experimental periods were more or less showed similar trends with the long term average at both experimental sites. Prior to planting, representative soil samples were taken from the experimental fields at Holetta and Debre Zeit using soil sampling augur at a depth of 0 to 30 cm layer. The composite samples were analyzed for its physio- chemical analysis and presented in Table 1.

Table 1: Physio-chemical properties of the soil from experimental sites (depth 0-30 cm) at Holetta and Debre Zeit

	Location	
Parameter	Holetta	Debre Zeit
pH	5.19	6.24
Available phosphorous (ppm)	6.45	25.45
Texture		
Clay (%)	66.66	61.67
Sand (%)	19.16	22.50
Silt (%)	14.26	15.83
Textural class	Clay	Clay
Nutrient		
Total Nitrogen (%)	0.19	0.14
Organic Carbon (%)	1.57	1.17
Organic Matter (%)	2.70	2.01
CEC (meq/100 g soil)	23.33	42.42
Soil type	Nitosol	Vertisol

CEC = cation exchange capacity, ppm = parts per million, meq = milli equivalent, g=gram

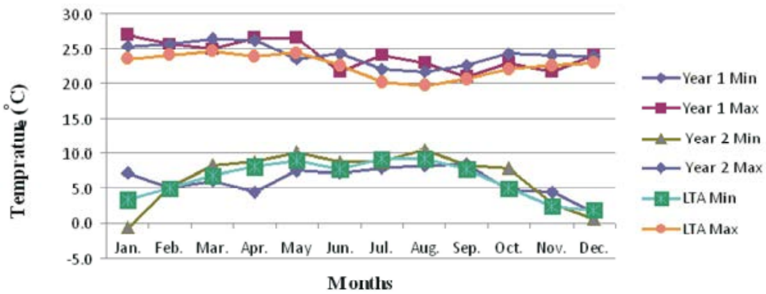
Experimental Design, Treatments and Locations: The experiment was laid out in a factorial arrangement of 3 harvesting height treatments, 4 nitrogen fertilizer treatments and 2 locations in a Randomized Complete Block Design (RCBD) with three replications in the following arrangement.

Table 2: Elephant grass harvesting height treatments at Holetta and Debre Zeit

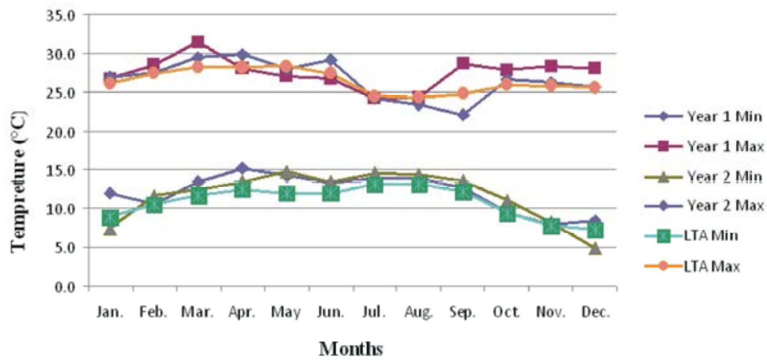
Elephant grass harvesting height treatments	Height of harvesting stage (cm)
Harvesting Height 1 (HH1)	50
Harvesting Height 2 (HH2)	100
Harvesting Height 3 (HH3)	150

Table 3: Nitrogen fertilizer treatments at Holetta and Debre Zeit

Nitrogen fertilizer treatments	Nitrogen fertilizer (kg ha^{-1} yr^{-1})
Nitrogen Fertilizer 1 (N1)	0
Nitrogen Fertilizer 2 (N2)	50
Nitrogen Fertilizer 3 (N3)	100
Nitrogen Fertilizer 4 (N4)	150

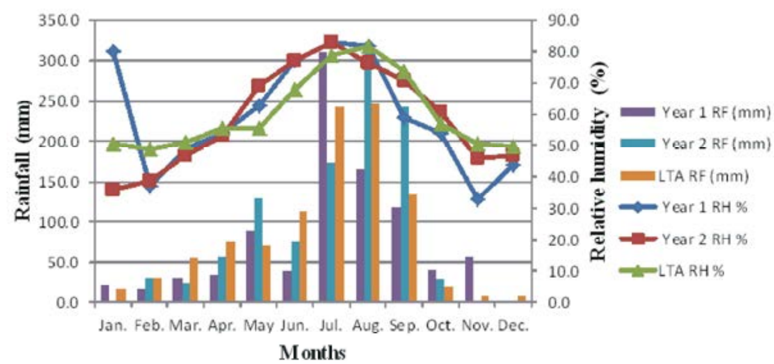


(a) Holetta

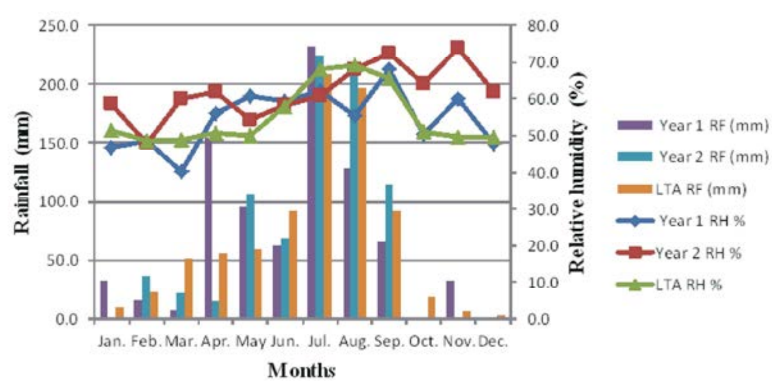


(b) Debre Zeit

Fig. 1: Long-term average/LTA/ (1971-2017 years) and experimental period maximum and minimum air temperature (°C) of the experimental sites at 1a (Holetta) and 1b (Debre Zeit) of year 1 (2016) and year 2 (2017)



(a) Holetta



(b) Debre Zeit

Fig. 2: Long-term average /LTA/ (1971-2017 years) and experimental period total annual rainfall and mean relative humidity of the experimental sites at 2a (Holetta) and 2b (Debre Zeit) of year 1 (2016) and year 2 (2017)

Field Preparation and Management: The land was plowed and harrowed using a tractor mounted moldboard plow and disc harrow. The elephant grass root splits obtained from Holetta research center were planted at the beginning of the main rainy season on a plot size of 2.25 m x 6 m (13.5 m^2) with spacing of 1 and 0.5 m between rows and plants, respectively. Diammonium phosphate (DAP) fertilizer at the rate of 100 kg/ha (18 kg N and 46 kg P_2O_5) was uniformly applied for all treatments at both locations at planting of elephant grass for better root development and in addition nitrogen fertilizers (50, 100 and 150 kg N ha^{-1} yr^{-1}) was annually applied in two splits. Hand weeding and hoeing were done as required.

Data Collection and Forage Sampling: Harvesting of elephant grass was made when the predetermined harvesting height attained: HH1= 50 cm, HH2= 100 cm, HH3= 150 cm. Fresh weight of the harvested herbage in each plot/treatment was measured using spring balance. Fresh subsamples of 900 g were taken from each plot. Forage samples were chopped and shredded to facilitate drying. Drying was done using a forced air draft oven at 65°C for 72 hours (constant weight). Dry matter percentage was estimated by dividing the dried forage sample by the fresh sample and multiply it by hundred. The dry matter yield (DM, t/ha) was calculated using the following formula as:

DM (t/ha) = TFW x (DWss /HA x FWss) x 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/m^2 to t/ha. The crude protein (CP) yield in t/ha was calculated by multiplying CP content with total dry matter yield and then divided by 100.

Chemical Composition and *In-vitro* Digestibility: The laboratory analysis was done at Holetta Agricultural Research Center, Holetta, Ethiopia. Forage samples of year 2 (regrowths in the second year of establishment) were oven dried (65°C, 72h) and ground to pass through 1 mm sieve size screen for chemical and *in vitro* dry matter digestibility (IVDMD) analysis. Analysis was made for the different nutritional parameters (DM, Ash, CP, NDF, ADF, Lignin and IVDMD). The DM and ash contents were determined by oven drying at 105°C overnight and by igniting in a muffle furnace at 500°C for 6 hours [20], respectively. Nitrogen (N) content was determined by Kjeldahl method and CP was calculated as N x 6.25 [21]. The neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) fractions were analyzed according to Van Soest and Robertson [22]. The modified Tilley and Terry *in vitro* method [22] was also used to determine the IVDMD.

Statistical Analysis: Data were organized and analyzed for effects of harvesting height, nitrogen fertilizer and location on forage yield and quality attributes using the general linear model of SAS and mean comparisons were made using least significant difference [23]. Differences were considered significant when P<0.05. The following statistical model was used for data analysis:

$$Y_{ijkl} = \mu + B_i + HH_j + N_k + L_l + (HH*N)_{jk} + (HH*L)_{jl} + (N*L)kl + (HH*N*L)_{jkl} + e_{ijkl}.$$

where; Y_{ijkl} = the response variable, ì = the overall mean; B_i = effect of i^{th} block; HHj= effect of j^{th} harvesting height (j= HH1 (50 cm), HH2 (100 cm), HH3 (150 cm); N_k= effect of k^{th} nitrogen fertilizer (k = N1 (0 kg N/ha), N2 (50 kg N/ha), N3 (100 kg N/ha), N4 (150 kg N/ha) ; L_l = effect of l^{th} location (l= Holetta, Debre Zeit); $(HH*N)_{jk}$= the interaction effects of harvesting height and nitrogen fertilizer ; $(HH*L)_{jl}$ = the interaction effects of harvesting height and location; (N*L)kl = the interaction effects of nitrogen fertilizer and location; $(HH*N*L)_{jkl=}$ the interaction effects of harvesting height, nitrogen fertilizer and location; and e_{ijkl} = the random error.

RESULTS

Herbage Dry Matter (DM) and Crude Protein (CP) Yields: Herbage yield traits are presented in Table 4. The DMY and CPY values were significantly (P < 0.05) affected by different Harvesting Height (HH) and N fertilizer treatments. The effect of interaction between HH and N fertilizer was non-significant (P< 0.05) for DMY and CPY. Significantly (P < 0.05) higher herbage DMY values (6.24 t ha^{-1} and 6.05 t ha^{-1}) were recorded at HH2 and HH3, respectively and significantly (P < 0.05) higher CPY values (0.57 t ha^{-1} and 0.54 t ha^{-1}) were also obtained at HH2 and HH3, respectively compared to HH1 (3.93 t ha^{-1}DMY and 0.39 t ha^{-1} CPY) at Holetta. Similarly, at Debre Zeit significantly (P<0.05) higher herbage DMY values (12.25 t ha^{-1} and 14.75 t ha^{-1}) were obtained at HH2 and HH3, respectively and higher CPY values (1.05 t ha^{-1} and 1.23 t ha^{-1}) were also recorded at HH2 and HH3, respectively compared to HH1 (8.60 t ha^{-1} DMY and 0.73 t ha^{-1} CPY). Herbage DMY was significantly (P < 0.05) lower in treatment N1 (4.48 t ha^{-1}).

Table 4: Herbage DM and CP yields (t ha^{-1}) of elephant grass as influenced by harvesting height and nitrogen fertilizer at Holetta and Debre Zeit

	Dry mater herbage yield (DMY)			Crude protein yield (CPY)		
Treatment	Holetta	Debre Zeit	Mean	Holetta	Debre Zeit	Mean
Harvesting height (cm)						
50	3.93^{b}	8.60^{c}	6.26^{c}	0.39^{b}	0.73^{c}	0.56^{b}
100	6.24^{a}	12.25^{b}	9.24^{b}	0.57^{a}	1.05^{b}	0.81^{a}
150	6.05^{a}	14.75^{a}	10.40^{a}	0.54^{a}	1.23^{a}	0.88^{a}
P-value	0.0001	0.0001	0.0001	0.0002	0.0001	0.0001
Nitrogen fertilizer (kg ha^{-1})						
0	4.48^{b}	9.00^{b}	6.74^{c}	0.39^{c}	0.73^{b}	0.56^{c}
50	5.13^{ab}	11.64^{a}	8.38^{b}	0.47^{bc}	0.99^{a}	0.73^{b}
100	6.12^{a}	13.47^{a}	9.74^{a}	0.57^{a}	1.15^{a}	0.86^{a}
150	6.00^{a}	13.35^{a}	9.68^{a}	0.56^{b}	1.13^{a}	0.84^{a}
Mean	5.41	11.87	8.64	0.50	1.00	0.75
SEM	0.16	0.25	0.16	0.05	0.07	0.05
CV (%)	17.33	19.32	20.20	18.85	19.11	20.01
P-value	0.0050	0.0013	0.0001	0.0016	0.0003	0.0001

Means followed by different superscript letters within a column are significantly different each other at P<0.05, SEM = Standard error of mean, CV = Coefficient of variation

Table 5: Chemical composition of elephant grass as affected by harvesting height and nitrogen fertilizer at Holetta and Debre Zeit during year 2 (regrowths in the second year of establishment)

	DM (% DM basis)			Ash (% DM basis)		
Treatment	Holetta	Debre Zeit	Mean	Holetta	Debre Zeit	Mean
Harvesting height (cm)						
50	91.70^{b}	92.71^{b}	92.20^{c}	18.30^{a}	17.21	17.76
100	92.05^{ab}	92.92^{ab}	92.49^{b}	18.14^{a}	17.39	17.77
150	92.36^{a}	93.20^{a}	92.78^{a}	17.75^{b}	17.46	17.60
P-value	0.0163	0.0320	0.0006	0.0054	0.0953	0.1564
Nitrogen fertilizer (kg/ha^{-1})						
0	91.90	92.88	92.39	18.23	17.33	17.78
50	92.09	92.93	92.51	18.18	17.31	17.74
100	92.07	93.00	92.54	17.94	17.51	17.73
150	92.08	92.96	92.52	17.91	17.24	17.58
Mean	92.04	92.94	92.49	18.07	17.35	17.71
SEM	0.12	0.11	0.08	0.10	0.09	0.07
CV (%)	0.56	0.46	0.51	2.09	1.51	1.86
P-value	0.8474	0.9440	0.8005	0.2067	0.1914	0.2847

Means followed by different superscript letters within a column are significantly different each other at P<0.05, SEM= Standard error of mean, CV = Coefficient of variation

On the contrary, significantly (P <0.05) higher herbage DMY values were attained for the remaining three nitrogen fertilizer treatments *N2* (5.13 t ha $^{-1}$), *N3* (6.12 t ha $^{-1}$) and *N4* (6.00 t ha^{-1}) at Holetta. Comparable and significantly (P <0.05) higher herbage DMY values were recorded in nitrogen fertilizer treatments N2 (11.64 t ha $^{-1}$), N3 (13.47 t ha $^{-1}$) and N4 (13.35 t ha $^{-1}$) than N1 (9.00 t ha $^{-1}$) at Debre Zeit. Significantly (p<0.05) the lowest and highest CP yields were recorded in treatments N1 (0.39 t ha^{-1}) and N3 (0.57 t ha^{-1}), respectively at Holetta. Comparable and significantly (p<0.05) higher CPY values were attained in treatments N3 (1.15 t ha^{-1}), N4 (1.13 t ha^{-1}) and N2 (0.99 t ha^{-1}) than N1 (0.73 t ha^{-1}) at Debre Zeit. The overall mean DMY (11.87 t ha $^{-1}$, 5.41 t ha $^{-1}$) values were at Debre Zeit and Holetta, respectively; the CPY (1.00 t ha $^{-1}$, 0.5 t ha $^{-1}$) values were also at Debre Zeit and Holetta, respectively.

Chemical Composition and *In vitro* Dry Matter Digestibility: Based on DM basis of elephant grass at three harvesting heights (HH) (HH1= 50 cm, HH2= 100 cm and HH3= 150 cm) with four levels of nitrogen fertilizer (N) (N1= 0 kg/ha, N2 = 50 kg/ha, N3= 100 kg/ha and N4= 150 kg/ha) at Holetta and Debre Zeit during year 2 (regrowths in the second year of establishment) are presented in Table 5, 6 and 7.

Table 6: Chemical composition of elephant grass as affected by harvesting height and nitrogen fertilization at Holetta and Debre Zeit during year 2 (regrowths in the second year of establishment)

	CP (% DM basis)			NDF (% DM basis)		
Treatment	Holetta	Debre Zeit	Mean	Holetta	Debre Zeit	Mean
Harvesting height (cm)						
50	9.72[a]	8.58[a]	9.15[a]	64.24[b]	62.79[b]	63.52[b]
100	9.16[b]	8.57[a]	8.86[b]	64.81[a]	63.64[a]	64.22[a]
150	8.87[b]	8.27[b]	8.57[c]	65.02[a]	63.74[a]	64.38[a]
P-value	0.0076	0.0129	0.0003	0.0137	0.0050	0.0001
Nitrogen fertilizer (kg/ha^{-1})						
0	8.78	8.06[b]	8.42[b]	65.24[a]	63.63	64.43[a]
50	9.22	8.61[a]	8.92[a]	64.64[b]	63.80	64.22[a]
100	9.53	8.62[a]	9.08[a]	64.50[b]	63.01	63.76[b]
150	9.45	8.60[a]	9.03[a]	64.39[b]	63.12	63.75[b]
Mean	9.25	8.47	8.86	64.69	63.39	64.04
SEM	0.13	0.09	0.08	0.13	0.14	0.09
CV (%)	6.53	3.11	5.19	0.94	1.09	1.01
P-value	0.0614	0.0003	0.0003	0.0339	0.0654	0.0044

Means followed by different superscript letters within a column are significantly different each other at P<0.05, SEM= Standard error of mean, CV = Coefficient of variation

Table 7: Chemical composition and *in vitro* dry matter digestibility of elephant grass as affected by harvesting height and nitrogen fertilization at Holetta and Debre Zeit during year 2 (regrowths in the second year of establishment)

	ADF (% DM basis)			ADL (% DM basis)			IVDMD (% DM basis)		
Treatment	Holetta	D/Zeit	Mean	Holetta	D/Zeit	Mean	Holetta	D/Zeit	Mean
HH (cm)									
50	40.25[b]	40.85[b]	40.55[b]	5.51	5.52[b]	5.52[b]	70.41[a]	66.95[a]	68.68[a]
100	41.01[a]	41.14[ab]	41.07[a]	5.51	5.56[a]	5.53[a]	69.31[b]	66.58[a]	67.94[b]
150	40.46[ab]	41.43[a]	40.95[a]	5.52	5.56[a]	5.54[a]	67.48[c]	65.91[b]	66.69[c]
P-value	0.0032	0.0229	0.0015	0.1714	0.0135	0.0074	0.0001	0.0014	0.0001
N (kg/ha)									
0	40.96[a]	41.42[a]	41.19[a]	5.51	5.54	5.52	68.47	66.00[b]	67.23[b]
50	40.65[a]	41.29[a]	40.79[ab]	5.51	5.55	5.53	69.12	66.26[ab]	67.69[ab]
100	40.54[ab]	40.69[b]	40.62[c]	5.51	5.55	5.53	69.38	66.83[a]	68.11[a]
150	40.16[b]	41.15[ab]	40.65[bc]	5.51	5.55	5.53	69.29	66.81[a]	68.05[a]
Mean	40.58	41.14	40.86	5.51	5.55	5.53	69.06	66.48	67.77
SEM	0.12	0.12	0.08	0.02	0.03	0.02	0.15	0.13	0.10
CV (%)	1.21	1.16	1.20	0.19	0.60	0.44	1.24	0.92	1.10
P-value	0.0189	0.0223	0.0023	0.4231	0.7448	0.4902	0.1333	0.0183	0.0032

Means followed by different superscript letters within a column are significantly different each other at P<0.05, SEM= Standard error of mean, CV = Coefficient of variation, HH= Harvesting height, N= Nitrogen fertilizer, D/Zeit= Debre Zeit

The effect of the interaction between harvesting height and nitrogen fertilizer levels was non-significant (P<0.05) for DM, Ash, CP, NDF, ADL and IVDMD, except for ADF. The DM content was significantly (P<0.05) highest at HH3 followed by HH2 and the lowest was observed at HH1 at Holetta and Debre Zeit and over locations. The different HH evaluated did not significantly (P>0.05) affect the ash content at Debre Zeit and over locations, whereas, comparable and significantly (P<0.05) higher at HH1 and HH2 than HH3 at Holetta. Significantly (P<0.05) the highest CP content was attained at HH1 followed by HH2 and the lowest was obtained at HH3 at Holetta, while at Debre Zeit comparable and significantly (P<0.05) higher CP content was achieved at HH1 and HH2 than HH3. In the combined analysis, significantly (P<0.05) the highest CP content was recorded at HH1 followed by HH2 and the lowest was obtained at HH3.

The NDF content was comparable and significantly (P<0.05) higher at HH2 and HH3 than HH1 at both locations. The ADF and ADL concentrations were lower at HH1 (P<0.05), with the other harvesting heights (HH2 and HH3) exhibiting comparable and higher values for both fractions at Debre Zeit and over locations. However, the ADL content was non-significant (P<0.05) at Holetta. The IVDMD value was significantly (P<0.05) highest at HH1 followed by HH2 and the lowest was recorded at HH3 at Holetta and over locations, while at Debre Zeit comparable and significantly ($P<0.05$) higher IVDMD was obtained at HH1 and HH2 than HH3. Nitrogen (N) fertilizer levels evaluated did not significantly ($P>0.05$) affect in their DM, Ash and ADL contents. The CP content was comparable and significantly ($P<0.05$) higher in treatment N2, N3 and N4 than N1 (control) at Debre Zeit and over locations. Similarly, the NDF content was comparable and significantly ($P<0.05$) lower values in treatment N2, N3 and N4 than N1 at Holetta. In the combined analysis, the NDF content was comparable and significantly ($P<0.05$) higher in treatment N1 and N2 than N3 and N4, while at Debre Zeit the NDF contents did not significantly (($P>0.05$) differ. The ADF content was comparable and significantly ($P<0.05$) highest in treatment N1 and N2 followed by N4 and the lowest was recorded in treatment N3 at Debre Zeit. In the combined analysis the ADF content was significantly ($P<0.05$) highest in treatment N1 followed by N2, N4 and the lowest was obtained in treatment N3. The IVDMD was comparable and significantly ($P<0.05$) highest in treatment N3 and N4 and the lowest was recorded in treatment N1, with N2 the intermediate value at Debre Zeit and in the combined analysis, while at Holetta did not significantly (($P>0.05$) vary.

DISCUSSION

Herbage DM and CP Yields: The significant difference in herbage DMY among the three harvesting height treatments could mainly be linked to the variations in stand age. In an experiment conducted on the effect of Harvesting Height (HH) and nitrogen (N) fertilizer treatments on elephant grass DMY ranged from 3.93 to 6.24 t ha^{-1}at harvesting heights and 4.48 to 6.12 t ha^{-1} in N fertilizer treatments with a mean of 5.41 t ha^{-1}at Holetta. At Debre Zeit DMY ranged from 8.60 to 14.75 t ha^{-1}at HH and 9.00 to 13.47 t ha^{-1} in N fertilizer with a mean of 11.87 t ha^{-1}; these significant DMY differences were observed within treatments. The present study concurs with other findings [24, 25]. It might be due to the proportional increment of DMY with advance in the age of harvesting [26]; these could be also due to the differences of soil fertility, moisture conditions, light intensity and temperature [27]. Similarly, the DMY of elephant grass increased as the levels of N fertilizer treatment increased. The present result was consistent with the findings of Hazary *et al.* [28] and Galindo *et al.* [29]. The CP yield of elephant grass also varies among HH and N fertilizer treatments, which generally related to the biomass yield (Table 4). The present study showed that the CPY ranged from 0.39 to 0.57 t/ha at HH and 0.39 to 0.57 t/ha in N fertilizer treatments with a mean of 0.50 t/ha at Holetta. Similarly, at Debre Zeit the CPY ranged from 0.73 to 1.23 t/ha at HH and 0.73 to 1.15 t/ha in N fertilizer treatments with a mean of 1.00 t/ha. In assessing forage crops, CP content should not be used as the only parameter to be considered. It is the CP yield, which delineates the overall and actual productivity of forage quality.

Crude Protein, Ash, Fiber, Lignin and *In vitro* Dry Matter Digestibility: The crude protein (CP) content is one of the major nutrients in forage for determination of nutritional quality, since DM intake and rumen microbial growth increase with increasing levels of CP in a feed [30]. In the present study, increased in elephant grass HH resulted in a reduction of CP content and IVDMD. These results were consistent with the finding of Tessema *et al.* [31] in north-western Ethiopia. The CP content of the present study was significantly highest in the early harvesting height (HH1) compared with the intermediate (HH2) and late heights of harvesting (HH3). This could be attributed mainly to dilution of the CP contents of the forage crops by the rapid accumulation of cell wall carbohydrates at the later heights of growth [32]. In other studies also documented that the CP content of elephant grass decreased with maturity [24, 33- 36]. The mean CP (8.9%) content of the present study was higher than the figure (5.4%) reported by Deribe *et al.* [37] at 100 cm HH in different accessions of elephant grasses. In the present study, the final concentration of the CP contents exceeded the minimum CP level (7.5%) required for optimal rumen function at different harvesting heights. This result was in agreement with the findings of Vansoest [38], Adugna and Said [39] and Jusoh *et al.* [35]. The CP content was also statistically significant among the N fertilizer treatments at Debre Zeit and over locations (except at Holetta); in addition the CP content was above the threshold level at each and over locations. This result was consistent with the report of Arshad *et al.* [40].

Ash (mineral) content of forage varies due to plant developmental height, morphological fractions, climatic conditions, soil characteristics and fertilization regime [41, 42]. The ash content of elephant grass was significantly varied indifferent HH at Holetta. This result was in agreement with the finding of Adane and Berhan [43]. The declined in the ash content with increased

HH of forage was probably caused by partly the dilution effect of higher yields in the presence of a constant amount of available minerals in the soil. This result was in agreement with the other observations [44, 45]. Bayble *et al.* [26] also reported similar results, suggesting that the ash contents of herbaceous forages declines as the height of maturity advances. On the other hand, the ash content of elephant grass was decreased numerically due to increased levels of N fertilizer at each and over locations. These results were in line with the finding of Khan *et al.* [46], who reported that application of N fertilizer decreased the ash content of oat fodder.

Digestibility of livestock feed is dependent on the crude fiber. Neutral detergent fiber (NDF) content of elephant grass at different HH showed significant difference at each and over locations. The NDF content increased from HH1 to HH3. The NDF content increased consistently as forage maturity increased reported by Moreira *et al*. [47], Bovolenta *et al*. [48], Ansah *et al.* [24] and Salamone *et al.* [49] which concurred with the present study. Moreover, the mean NDF content of the present study at different HH and N fertilizer applications were reported within the recommended medium quality roughage feeds 45-65% [50], however the NDF contents at each of the treatments lies slightly above aforementioned range. On the other hand, the NDF content of elephant grass was statistically non-significant with the increasing levels of N fertilizer treatment at Debre Zeit. This result was disagreed with the finding of Khaleduzzaman *et al.* [51], while at Holetta and over locations the reported figures were in consistent with the report of Khaleduzzaman *et al.* [51]. The ADF contents increased from early harvesting height (HH1) to intermediate (HH2) and then decreased at the late height of harvesting (HH3) at Holetta and over locations. However, the present study at Debre Zeit agreed with the increasing NDF and ADF contents with advanced in HH was reported by Adane and Berhan [43] and Tessema *et al.* [9]. As with NDF, higher ADF results in reduced digestibility of forage dry matter as a consequence of increased lignification of cellulose in the plants [52]. The ADF contents of elephant grass was in decreasing order at increasing nitrogen fertilizer (N1 < N2 < N3 < N4) treatments. These results were in keeping with the findings of Lee and Lee [53] and Hazary *et al.* [29] who found that ADF content decreased with the increasing rate of N fertilizer treatments.

The ADL contents of the present study were comparable and significantly higher at HH2 and HH3 than at HH1 at Debre Zeit and over locations. These results were consistent with the reports of Moreira *et al*. [47], Bayble *et al.* [26] and Bovolenta *et al*. [48] who observed that increased ADL content with advanced heights of maturity. The late height of harvesting had the highest lignin content, implying that the lignin would bind the cellulose and hemicellulose and prevent them from being digested and utilized efficiently by the rumen microbes [24, 47, 48]. Van Soest [38] was also reported that the ADL content affect digestibility of forage more than any other chemical component. Harvesting height was reported to have a significant effect on IVDMD contents. As height of HH increased from HH1 (50 cm) to HH3 (150 cm), there had been a declined in IVDMD content from 68.68- 66.69%. This result was within the range values (72-61%) reported by Tessema *et al.* [9]. Similarly, according to Taliafero *et al.* [54] harvesting of grasses at a relatively advanced height of development had depressed IVDMD. The effect of N fertilizer treatments on IVDMD of elephant grass was significantly different and increased with increasing levels of N fertilizer at Debre Zeit and over locations, except at Holetta. This result was in agreement with findings of Tegegn [55] and Naroon *et al.* [56] who reported that the application of different levels of N fertilizer had significant effects on IVDMD of *Panicum coloratum* at all heights of harvest and across four grass species, respectively. The critical threshold level (50%) of IVDMD for feeds considered as having acceptable digestibility [57]. Similarly, Mugerwa *et al.* [58] indicated that digestibility higher than 65% indicates good nutritive value and values below this level limit intake. The IVDMD of elephant grass attained in the present study was higher than (65%) and it was within acceptable ranges reported by Owen and Jayasuriya [57] and Mugerwa *et al.* [58]. The IVDMD of any forage crop varies with harvesting height [59]; fiber and cell wall constituents [32]; proportions of morphological fractions [60]; soil, plant species and climate [61].

CONCLUSIONS

This study concluded that application of 100 kg N fertilizer per hectar annually in split applications and harvesting elephant grass at the height of 100 cm resulted in higher annual herbage and crude protein productivity under Holetta and Debre Zeit conditions.

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