Effect of Fertilizer Level and Harvesting Date on Yield and Nutritive Value of Desho Grass (*Pennisetum pedicellatum)* in Hula and Bule districts of the Southern Region of Ethiopia

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ABSTRACT

A study was conducted to investigate the effect of fertilizer level and harvesting date on agronomic traits, biomass yield and chemical composition of Desho grass (Pennisetum pedicellatum) at Hula and Bule districts of Sidama and Gedeo zones, respectively, Southern Nations, Nationalities and Peoples` Region of Ethiopia. A factorial arrangement was employed using a randomized complete block design with 3 level of nitrogen fertilizer (0, 41 and 73 kg N/ha) and 3 harvesting dates (112, 133 and 154 days). Plant height, number of tillers per plant, leaf length and leaf to stem ratio were determined. The ash, crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL) contents were analyzed. In vitro organic matter digestibility (IVOMD), dry matter yield (DMY) and CP yield were also quantified. Data were analyzed using the general linear model procedures of the Statistical Analysis System. Plant height was greater ($P<0.05$) at 154 days of harvesting than at the other two harvesting dates and when 73 kg N/ha was applied compared to application of 41 kg N/ha or no fertilizer. The tiller number was lower ($P<0.05$) when harvested at 112 days after planting compared to those harvested at 133 and 154 days with no significant differences between the latter two harvesting dates. Tiller number was higher ($P<0.05$) at the application of 73 kg N/ha than no fertilization application (0 kg N/ha). The leaf length was greater ($P<0.05$) when 73 kg N/ha was applied compared to the other two N fertilization levels. The leaf: stem ratio decreased ($P<0.05$) with increasing harvesting date. The CP content was higher ($P<0.05$) when 41 and 73 kg N/ha was applied compared to the unfertilized treatment (0 kg N/ha). Ash and CP contents were higher ($P<0.05$) at 154 days than at 112 days of harvesting. The NDF, ADF and ADL contents increased ($P<0.05$) with increasing harvesting date but showed a decreasing trend with increasing N fertilization level. The IVOMD was higher ($P<0.05$) at early (112 days) harvesting date than at the intermediate (133 days) and late (154 days) harvesting date. The DMY and CP yield increased ($P<0.05$) with increasing harvesting date and N fertilizer level. In conclusion, higher yield could be obtained at later harvesting date (154 days) with application of 73 kg N/ha, without affecting quality attributes. However, further study is needed to verify the cost benefit and environmental impact of increased fertilizer level.

Keywords: *Desho grass, fertilizer level, harvesting date, biomass yield, nutritional value*

INTRODUCTION

Livestock keeping is an integral part of the farming system in Ethiopia. However, the productivity of the Ethiopian livestock is low. The major setback is shortage in terms of both quantity and quality of feed resource (Shapiro *et al.*, 2015; Bimrew *et al*., 2017). Provision of adequate feed supply is essential to ensure economically viable and environmentally friendly livestock production. This requires supplementing the traditionally available feed resource with improved and suitable forage species.

Desho grass *(Pennisetum pedicellatum)* is a grass indigenous to Ethiopia, which is highly popular and widely cultivated in southern Ethiopia as source of livestock feed. The grass is also widely used in soil and water conservation activities to combat land degradation and to improve productivity of land. Farmers in many parts of Ethiopian highlands showed spontaneous adoption of Desho grass production because of its merits as animal feed and in soil and water conservation and management (Getahun *et al.*, 2015; Tekalegn *et al*., 2017). It has the potential to meet the challenges of feed scarcity as it gives high biomass yield per unit area and ensures year round forage supply due to its rapid growth and drought tolerance (Abebe *et al.*, 2011). So far, there is little information on Desho grass production and agronomic managements. Fertilization determines soil and plant nutrient contents, which influence yield and chemical composition of grass pasture. Fertilization is also a major factor that increases pasture yield and nutritive value, including the crude protein content and digestibility, leading to improvement in livestock production (Peyraud and Astigarraga, 1998).

The correct use of relatively inexpensive and simple management practices such as appropriate harvesting date and fertilizer level can help increase the level of fodder production (Yasin *et al.*, 2003). Effect of altitude and harvesting dates, and effect of harvesting dates and spacing on morphological characteristics, yield and nutritive value of Desho grass have been investigated in Ethiopia in earlier studies (Bimrew *et al*., 2017). However, the optimum nitrogen fertilizer level and harvesting date are not well known for Desho grass. Thus, the present study was designed to determine the effect of nitrogen fertilizer level and harvesting date on agronomic traits, biomass yield and nutritive value of Desho grass under highland rain fed conditions of southern Ethiopia.

MATERIALS AND METHODS

Description of the study area

The experiment was conducted for two years from May 2016 to December 2017 at Hula and Bule districts of Sidama and Gedeo zones, respectively, Southern Nations, Nationalities and Peoples` Region of Ethiopia. Hula and Bule districts lie in the highland agro-ecology, where mixed crop livestock production is the predominant farming system. Rainfall pattern is characterized by two rainy seasons (main and short rainy seasons). The main rainy season extends from June to October and the short rainy season is from March to April. During the experimental period, the mean annual rainfall was about 1187mm and 1149 mm for Hula and Bule districts, respectively. The maximum annual temperatures were reported to be 20.5C^0 and 19.4C^0 at Hula and Bule, respectively, with minimum annual temperatures of 4.3C^0 and 9.9C^0 at Hula and Bule, respectively. Map of the study areas is given in Figure1.

Hula district is located between 6o 29`Nourth latitude and 38o 31`East longitude with an elevation of 2759 meters above sea level; Bule is located between 6^o18`Nourth latitude and $38^o$ 24` East longitude and an elevation of 2793 meters above sea level. The soils of Hula site are characterized by sandy loam, low in soil p^H (4.25), total organic matter (2.02%), total available nitrogen (0.21%) and medium available phosphorus (16.3%). The soil type of Bule is loam, low in soil p^H (4.74), total organic matter (3.53%), total available nitrogen (0.17%) and medium available phosphorus (22.6%).

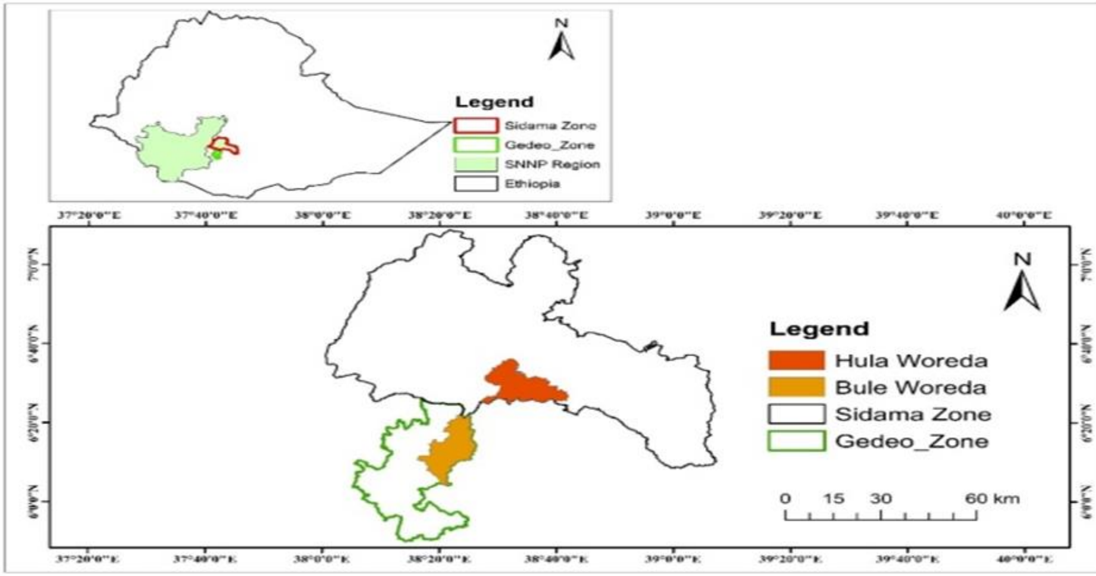

Figure 1: Map of the study districts (woredas) in Sidama and Gedeo Zones, Ethiopia

Treatments and experimental design

A factorial arrangement of treatments was employed using a randomized complete block design with 2 factors (fertilizer level and harvesting stage); 3 nitrogen fertilizer levels (0, 41 and 73 kg N/ha) and 3 harvesting stages (112,133 and 154 days after planting) with 3 replications, which makes nine treatments combinations. The land was ploughed by a tractor and leveled at the start of the main rainy season. The experimental field was divided into three blocks, each containing 9 plots resulting in a total of 27 plots, with each plot measuring 2x5 meter (10m^2). The net harvestable plot size was 1×5 meter (5m^2). The total number of rows per plot was 4. Samples were taken from the two middle rows. Distance between plots and blocks were 1 and 1.5 meter, respectively. Plots in each block were randomly assigned to one of the 9 treatments. The cuttings were planted into a well-prepared seedbed with one root split per hill.

Data collection

The plant height, tillers per plant, leaf length, leaf to stem ratio and forage dry matter yield data were recorded. The number of tillers was counted from the five culms after harvesting. Plant height was based on five culms taken randomly in each plot, measured using a steel tape from the ground level to the highest leaf. Leaf length per plant was taken from five randomly selected plants per plot. Leaves were separated from stems and the leaf to stem ratio was estimated based on the dry weight of each component. The total herbage on each plot at the fixed dates was harvested leaving out border rows. From each plot, an area of 5m2 was used to calculate dry matter yield (DMY). Harvesting was done by hand using a sickle, leaving a stubble height of 5 cm, and the harvested herbage was weighed fresh in the field using a field balance. Samples of 500g of fresh forage were taken from each plot and oven-dried at 60 °C for 72 hours to determine DM content, which was used in the calculation of DMY.

Chemical Analysis

The pre-dried grass samples were ground to pass through a 1 mm sieve (Wiley mill) and stored in airtight plastic bags until required for chemical analysis. Total ash content was determined by combusting the samples in a muffle furnace at 550^oC for 6 hours. Nitrogen content was determined by the Kjeldahl method (AOAC, 1995) and crude protein (CP) content was calculated as N% × 6.25. Standard procedures were used to determine the neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL) contents (Van Soest and Robertson, 1985) and *in vitro* organic matter digestibility (IVOMD) determination (Tilley and Terry, 1963).

Data analysis

Analysis of variance (ANOVA) was employed and differences among treatments were tested using the general linear model (GLM) procedure of the Statistical Analysis System (SAS, 2002). Least significance difference (LSD) at 5% significance level was used for comparison of means. The data were analyzed using the following model: $Y_{ijk} = \mu + A_i + B_k + N_j + A_i * N_j + e_{ijk}$. Where: Y_{ijk} = individual observation, μ = overall mean, A_i = effect of fertilizer, B_k = k^{th} block effect, N_j = effect of harvesting stage, $A_i * N_j$ = interaction effect of fertilizer and cutting and eijk = the random error.

RESULTS

Agronomic traits of Desho grass as affected by fertilizer level and harvesting date

The effects of fertilizer level, harvesting date and interaction between fertilizer level and harvesting date on agronomic traits of Desho grass are shown in Table 1. Plant height was higher (P<0.05) at 154 days of harvesting than at the other two harvesting dates and it was higher (P<0.05) when 73 kg N/ha was applied compared to application of 41 kg N/ha or no fertilizer. The tiller number was lower (P<0.05) when harvested at 112 days after planting compared to those harvested at 133 and 154 days after planting with no significant differences (P>0.05) between the latter two harvesting dates. Fertilizer level also had significant (P<0.05) effects on tiller number.

The tiller number increased with increasing levels of fertilizer application, the number being higher (P<0.05) at the application of 73 kg N/ha than without fertilizer application (0 kg N/ha). The leaf length showed a significant increase (P<0.05) with increasing level of N fertilizer application and it was higher (P<0.05) when 73 kg N/ha was applied compared to application of 41 kg N/ha or no fertilizer. However, the harvesting stage did not have a significant effect (P>0.05) on leaf length. There was interaction (P < 0.05) between harvesting stage and level of fertilizer application on leaf length. The leaf: stem ratio was not affected by the level of fertilizer application (P>0.05) but it showed a significant decrease (P<0.05) with increasing stage of harvesting.

Table 1 Agronomic traits of Desho grass as affected by fertilizer level and harvesting dates

Variable	Harvesting date(HD)	nitrogen fertilizer Level (FL) (kg N/ha)			Mean	SEM	Significance level		
		0	41	73			HD	FL	HD x FL
Plant height(cm)	112	21.25	22.08	23.92	22.42^{B}	0.79	*	***	NS
	133	20.75	24.08	27.08	23.97^{B}	1.83			
	154	27.25	28.08	29.33	28.22^{A}	0.60			
	Mean	23.08^{B}	24.75^{B}	26.78^{A}					
	SEM	2.09	1.76	1.57					
Tiller number	112	43.03	44.33	48	45.12^{B}	1.49	***	*	NS
	133	48.58	55.67	55.92	53.39^{A}	2.41			
	154	50.42	52.75	63.25	55.47^{A}	3.95			
	Mean	47.34^{B}	50.92^{AB}	55.72^{A}					
	SEM	2.22	3.40	4.40					
Leaf length(cm)	112	14.83	17.33	17.67	16.61	0.90	NS	***	*
	133	13.33	16.33	19.50	16.39	1.78			
	154	16.00	16.33	18.33	16.89	0.73			
	Mean	14.72^{C}	16.66^{B}	18.50^{A}					
		0.77	0.33	0.54					
Leaf: Stem	112	0.93	0.8	0.85	0.86^{A}	0.04	***	NS	NS
	133	0.78	0.72	0.72	0.74^{B}	0.02			
	154	0.38	0.43	0.37	0.39^{C}	0.02			
	Mean	0.70	0.65	0.65					
	SEM	0.16	0.11	0.14					

HD x FL=interaction between fertilizer level and harvesting dates; SEM = Standard error of means, Not significant (NS) = P>0.05, significant (*) = P<0.05, *(*P<0.05*); ** (*P<0.01*); *** (*P<0.001*), A, B, C mean values with different superscripts differ significantly for harvesting date within a column and fertilizer level, within a row

Chemical composition of Desho grass as affected by fertilizer level and harvesting dates

The chemical composition of Desho grass as affected by nitrogen fertilizer level and harvesting date is shown in Table2. Ash content was lower (P<0.05) at the intermediate (41 kg N/ha) fertilizer level than at low (0 kg N/ha) and high (73 kg N/ha) fertilizer level. However, the CP content was higher (P<0.05) when 41 and 73 kg N/ha was applied compared to the unfertilized treatment (0 kg N/ha).The DM, ash and CP contents increased with increasing harvesting date, the differences being higher (P<0.05) at 154 days than at 112 days of harvesting after planting.

The fiber (NDF, ADF and ADL) contents showed a significant increase (P<0.05) with increasing harvesting date but showed a decreasing trend with increasing N fertilizer level. The NDF content was lower (P<0.05) when 73 kg N/ha was applied whereas the ADF content was lower (P<0.05) in both fertilized treatments (i.e. 41 and 73 kg N/ha) than in the unfertilized one. The ADL content was not affected (P>0.05) by N fertilization. The IVOMD was higher (P<0.05) at early (112 days) of harvesting date than at the intermediate (133 days) and late (154 days) harvesting date. The application of N fertilizer did not show a clear pattern on IVOMD.

Table 2 Chemical composition and *In vitro* organic matter digestibility of Desho grass as affected by level of fertilizer and harvesting stages

Composition (% DM)	Harvesting date (HD)	nitrogen fertilizer level (FL) (kg N/ha)			Mean	SEM	Significance level		
		0	41	73			HD	FL	HD*FL
Ash	112	15.58	16.32	15.99	15.96^{B}	0.21	*	**	***
	133	18.05	14.01	16.65	16.24^{AB}	1.18			
	154	16.41	16.66	16.68	16.58^{A}	0.09			
	Mean	16.68^{A}	15.66^{B}	16.44^{A}					
	SEM	0.73	0.83	0.23					
CP	112	11.44	11.99	10.65	11.36^{B}	0.39	*	***	***
	133	9.97	12.67	12.26	11.63^{AB}	0.84			
	154	10.18	12.27	13.68	12.04^{A}	1.02			
	Mean	10.53^{B}	12.31^{A}	12.20^{A}					
	SEM	0.46	0.20	0.88					
NDF	112	62.84	61.65	62.12	62.20^{C}	0.35	***	**	***
	133	62.22	63.50	63.34	63.02^{B}	0.40			
	154	67.61	67.46	65.16	66.74^{A}	0.79			
	Mean	64.22^{A}	64.20^{A}	63.54^{B}					
	SEM	1.70	1.71	0.88					
ADF	112	31.74	31.2	30.84	31.26^{C}	0.26	***	**	***
	133	36.12	33.11	36.24	35.16^{B}	1.02			
	154	39.99	40.56	37.68	39.41^{A}	0.88			
	Mean	35.95^{A}	34.96^{B}	34.92^{B}	35.28				
	SEM	2.38	2.86	2.08					
ADL	112	2.19	2.28	1.90	2.12^{C}	0.11	***	NS	***
	133	3.38	2.75	3.26	3.13^{B}	0.19			
	154	3.46	3.94	3.58	3.66^{A}	0.14			
	Mean	3.01	2.99	2.91					
	SEM	0.41	0.49	0.52					
IVOMD (%)	112	68.25	67.13	65.09	66.82^{A}	0.93	***	**	***
	133	57.86	65.02	60.68	61.19^{B}	2.08			
	154	57.41	60.19	61.37	59.66^{B}	1.17			
	Mean	61.17^{B}	64.11^{A}	62.38^{B}					
	SEM	3.54	2.05	1.37					

CP=Crude Protein; NDF=Neutral Detergent Fiber; ADF=Acid Detergent Fiber; ADL= Acid Detergent Lignin; IVOMD= In-vitro Organic Matter Digestibility; FL x HD=interaction between fertilizer level and harvesting date; SEM = Standard error of means; NS=Not significant (P>0.05), significant (*) = P<0.05, *(*P<0.05*); ** (*P<0.01*); *** (*P<0.001*); A, B, C mean values with different superscripts differ significantly for harvesting date within a column and fertilizer level, within a row

Dry matter yield and crude protein yield of Desho grass as affected by fertilizer level and harvesting dates

The effects of fertilizer level and harvesting date on dry matter yield (DMY) and crude protein yield **(**CPY) of Desho grass are shown in Table 3. The DMY showed a significant increase (P<0.05) with increasing harvesting date and it was higher (P<0.05) at the highest level (73 kg N/ha) of fertilizer application than at 41 and 0 kg N/ha with no significant differences between the latter two levels. The CPY was lower (P<0.05) in the unfertilized treatments (0 kg N/ha) than in the fertilized ones (41 and 73 kg N/ha). On the other hand, the CPY was higher (P<0.05) when the grass was harvested at 154 days after planting than at the other two harvesting stages.

Table 3 Dry matter and crude protein yield of Desho grass as affected by fertilizer level and harvesting dates

Yield (t/ha)	Harvesting date (HD)	nitrogen fertilizer level (FL) (kg N/ha)			Mean	SEM	Significance level		
		0	41	73			HD	FL	HD x FL
Dry matter yield	112	0.86	1.04	1.12	1.01^C	0.08	***	*	*
	133	1.03	1.19	1.38	1.20^B	0.10			
	154	1.69	1.71	2.08	1.83^A	0.13			
	Mean	1.19	1.31	1.53					
	SEM	0.25	0.20	0.29					
Crude protein yield	112	0.10	0.12	0.12	0.11^B	0.01	***	**	**
	133	0.10	0.15	0.17	0.14^B	0.02			
	154	0.17	0.21	0.29	0.22^A	0.03			
	Mean	0.12^B	0.16^A	0.19^A					
	SEM	0.02	0.03	0.05					

HD x FL=interaction between fertilizer level and harvesting dates; +SE = Standard error of means, Not significant (NS) = P>0.05, significant (*) = P<0.05, *(*P<0.05*); ** (*P<0.01*); *** (*P<0.001*), A, B, C mean values with different superscripts differ significantly for harvesting date within a column and fertilizer level, within a row.

DISCUSSION

Agronomic traits as affected by fertilizer level and harvesting dates

The increase in plant height at higher fertilizer level is consistent with the findings of previous studies of (Chaparro *et al.,* 1996; Yasin *et al.,* 2003), who reported similar result for Napier grass. The findings also indicated that the changes in plant heights with the changes in the harvesting date are indicative of increased fodder production with application of appropriate management practices for Napier grass. The increased plant height found in this study with increasing harvested date is contrary to previous report of Worku *et al.* (2017), who reported that the plant height of similar grass is not increased significantly as fertilizer level increased. Similarly, this is in agreement with previous study of Abdi Hassan (2014), who reported that no difference were observed at harvesting height among the different nitrogen fertilizer rates for *Cenchrus ciliaris* and *Panicum maximum.*

The number of tillers per plant increased with increasing fertilizer level, which is consistent with findings of Tessema *et al.* (2003) who reported similar results for Napier grass. The increase in number of tillers per plant with increasing harvesting date is also in line with the findings of Tessema and Alemayehu (2010) for Napier grass who reported that Napier grass produced many tillers and dense vegetative growth as the pasture consolidates due to perennial nature of the grass. High tiller productions do not only indicate stable productivity (Mukhtar, 2006) but also is linked to better persistence after periods of unfavorable environmental conditions (Assuero and Tognetti, 2010). Moreover, the increase in tiller number with increasing fertilizer level in the current study agrees with findings of Worku *et al.* (2017). This is in agreement with the finding by Kizima *et al*. (2014) who reported that application of optimal nitrogen fertilization level significantly affects the appearance of new tillers and increases the dynamics of tiller population of *Cenchrus ciliaris*. Generally, tiller production is a key factor in the resistance of grasslands to deterioration by ageing.

The increase in leaf length at later harvesting date is consistent with the findings of Molla *et al.* (2018) who reported that the difference in leaf length between early and late harvesting might be due to the differences between physiological changes of plants observed during the growing periods. The present results are also supported by the findings Asmare *et al.* (2017) who noted increased leaf length in C*hloris gayana* as N fertilizer levels and harvesting stages increased. The decrease in leaf: stem ratio as harvesting date increased agrees with the findings of Yasin *et al.* (2003) that showed reduction in leaf proportion and an increase in the stem fraction of the grass at the advanced harvesting date. Similar observations were reported for tropical forage grasses (Seyoum *et al.*, 1997).

Chemical composition of Desho grass as affected by fertilizer level and harvesting dates

The increased ash content found in this study with increasing harvesting date is contrary to previous report (Kitabe and Tamir, 2005), who found that the ash concentration of grasses declined significantly as cutting interval increased for Napier grass. In a similar manner, previous studies in Kenya (Kariuki *et al.*, 1999; Mukhtar, 2006) showed a decline in macro-mineral content of Napier grass with advancing date of growth. The divergence of the results in this study may be due to the fact that grasses vary in their genetic capacity to take up minerals from the soil and in their mineral requirements for growth. Similarly, Asmare *et al.* (2019) reported that the uptake of soil nutrients is determined by soil characteristics and climatic condition.

In the current study, application of N fertilizer improved CP content of Desho grass as compared to unfertilized plots. The result is in agreement with the previous finding (Ram and Trivedi, 2014) for Guinea grass. Nitrogen fertilization may have resulted in increased leaf N, tissue protein, and digestible carbohydrates as reported earlier for Bermuda grass (Kering *et al.,* 2011).

The fiber (NDF, ADF and ADL) contents increased with increasing harvest date, which is consistent with the previous findings of Bimrew *et al.* (2017) for the same grass species. The NDF of grass was lower than the value (62.20 to 66.74%) that obtained before by Bimrew *et al*., 2017), where NDF content ranged from 73.58 to 76.03%. Similarly, the ADF content was lower than the value (31.26 to 35.95%) reported by the same authors where ADF concentration increased from 41.28% at 90 days to 43.69% at 150 days of age. And also ADL content was lower than the value (5.24 to 5.48%) reported by Bimrew *et al*. (2017). On the other hand, as the level of fertilizer increases there is a reduction in fiber components in conformity with a previous report by Taye *et al.* (2004) for Napier grass, which showed a decreasing trend with increasing N fertilizer level. Moreover, the decrease in the fiber content with increasing fertilizer level agrees with other study (Ram and Trivedi, 2014) for Guinea grass. The difference in fiber contents among the study might be due to difference in variety or species, soil and climate and treatment factors combination (i.e. fertilizer date and harvesting date).

The lower IVOMD observed at higher harvesting date could be due to increased fiber content with increasing harvesting date. This is consistent with the findings of Nelson (1995), who reported highest IVOMD at early harvesting date for Bermuda, Bahia and star grasses. However, the application of N fertilizer did not show a clear pattern on IVOMD in the current study as the IVOMD value was higher when 41 kg N/ha was applied as compared to the non-fertilized treatment and higher rate of fertilization (73 kg N/ha). Thus, under the conditions of the current study, 41 kg N/ha appears to be an optimal level of fertilizer application although there is no clear explanation for it.

Dry matter yield and crude protein yield of Desho grass as affected by fertilizer level and harvesting dates

The increased DMY with increasing harvesting date might be due to additional tillers development with the increase in leaf formation and leaf elongation and development. This is consistent with other findings (Mukhtar, 2006; Leta *et al.*2013) who reported increased herbage yield with increased stage of maturity for elephant grass. Similarly, significant increases in DMY with advancing age of plants were reported by Ramamurthy and Shankar (1998), Choubey *et al.* (1999) and Ram and Trivedi (2014) for *Pennisetum transpacific* hybrid, *Brachiaria mutica* and Guinea grass, respectively. Amongst the major agronomic practices required, harvesting of grass at appropriate harvesting date and fertilizer level are very important to improve DM yield of Desho grass. The highest CPY observed in the late harvest date was due to higher DMY. The higher CPY in the fertilized Desho grass could be attributed to the fact that nitrogen is the main constituent of protein and is involved in the synthesis of amino acids and accumulation of protein in plants.

CONCLUSION

Fertilizer level and harvesting date have the combined effect on dry matter yield and quality of Desho grass. Higher dry matter yield could be harvested at later harvesting date (154 days) with application of 73 kg N/ha, without affecting quality attributes. However; further study is needed to verify the cost benefit and environmental impact of increased N fertilizer level.

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