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Effect of harvesting stage on yield and nutritive value of antelope grass (*Echinochloa pyramidalis*) hay under natural pasture in Nuer Zone of Gambella, Ethiopia

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The study was conducted to evaluate and identify the appropriate harvesting stage of growth and quality of antelopegrass (*Echinochloa pyramidalis*) hay under natural pasture. DM%, fresh biomass yield (FBY), dry matter yield (DMY) and gross energy (GE) were determined. The main analysis such as ash, crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL), ether extract (EE) and nitrogen (N) contents were analyzed. The result showed that FBY, DMY and total nitrogen were affected significantly (p<0.05) by maturity stage of the grass. In contrast, GE of antelope grass hay was not significantly (>0.05) affected by maturity stage of pasture. FBY and total N were decreased with increased maturity stage, while DMY was increased with pasture age. The highest CP% was obtained at booting stage, while the lowest CP was obtained from the dough stage of growth which is significantly (p<0.05) decreased as forage mature. The means for DMY of antelope grass hay under natural pasture was 21.12 t DM/ha. The average crude protein content of antelope grass for this study was 12.56%. Generally, harvesting stages were significantly affected dry matter and CP content.

Key words: *Echinochloa pyramidalis*, hay, pasture, yield, nutritive value, antelope grass, harvesting stage, Nuer Zone.

INTRODUCTION

Natural pasture, crop residue, improved pasture and forage, agro industrial by products and other by-products like food and vegetable refusal are major livestock feed resources of which the first two contribute the largest feed type (Agza et al., 2013). Nowadays, the most important livestock feed resources in Ethiopia are natural pasture, crop residues and grass hay. Ethiopian grasslands account for over 30% of the land cover and constitute to 66% of feed resources for livestock (CSA, 2011).

Natural pasture hay and crop residues which provide the bulk livestock feed in Ethiopia are seasonally produced during particular periods of the year (October-January) following the main rainy season. Excess forage

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production is experienced during the rainy season, but more often, acute shortages occur in the dry season (Wassie et al., 2018). Though it is over matured soon, Antelope grass is the most excessively available grass in Gambella region in the rainy season.

One of the most viable and simple management interventions to avert the severe feed shortage is to improve the quality and quantity of the natural pasture through employing improved management and conservation practices (Ashagre, 2008). The management systems, particularly utilizing the pasture at early stages of growth with proper growing management might improve the productivity of pastures both quantitatively and qualitatively (Ashagre, 2008).

Feed value is the potential of the feed to supply the nutrients required by an animal both quantitatively and qualitatively in order to support a desired type of production (Mlay et al., 2006). As quality and quantity of hay is highly dependent on growth stage of the grass, considerable attention should be given to harvesting time. Though at early stage of growth plants put most of their energy into vegetative growth and contain high concentrations of starches, proteins and minerals, the biomass yield is lower. On the other hand, as plants mature, their fiber component increases and traps the nutrients within indigestible cell walls. Thus, compromising biomass yield and nutritive value is an important issue when we decide the appropriate harvesting age of the grass for quality hay (Isaias et al., 2015).

The high temperature in the tropical countries changes the nutritive values of the grass component rapidly during the late growth stages of the grassland harvesting management is predominantly responsible for these changes (Čop et al., 2009). Time and frequency of harvesting, botanical composition, fertility of the soil and climatic conditions are the major factors that determine biomass yield and nutritive value of pastures (Adane and Berhan, 2005; Tessema et al., 2010; Isaias et al., 2015).

Echinochloa pyramidalis commonly called antelope grass is an erect grass species that grows to about 3 m (rarely 4 to 5 m) in height with laterally creeping rhizomes. The plant grows best in humid environments, mainly swampy areas and along rivers. It is a perennial herb generally soil-attached, but also found floating or submerged. The plant is widely distributed in tropical regions of Africa, America, Asia, and Australia (Pare et al., 2011a).

E. pyramidalis has a variable composition that depends on the season and age of regrowth. *E. pyramidalis* is a good fodder used for hay and silage, and is excellent for dry-season grazing after burning of waste biomass. *E. pyramidalis* is highly palatable, especially at the early growth stage, and was among the most palatable of 15 species evaluated for their feeding potential in Venezuela (Heuzế et al., 2016).

This species and others are known as the key forage species by the Nuer Agro pastoralists in the Gambella rangelands of southwestern Ethiopia and is the dominant grass species of grassland savanna of Itang (Ketema, 2015). Generally, there are some works done on variations in botanical composition, nutritive values of forage species and soil nutrient status across season of locally available feed resources in Gambella. But there is a need to identify the appropriate harvesting stage of growth for most dominant and key species of local forages under natural pasture for optimum yield and quality of hay that would contribute to decision making regarding optimal utilization of the range resources.

Therefore, the objective of the present study was to evaluate and identify the appropriate harvesting stage of growth of Antelope Grass (*E. pyramidalis*) hay under natural pasture in Gambella Region.

MATERIALS AND METHODS

Description of the experiment site

The study was conducted in Nuer zone of the Gambella National Regional State, South West Ethiopia. About 80% of the area is characterized by having sub-humid and humid tropical climate. The topography of the zone presents undulating hills slightly sloping down to low land Plateaus having varying altitudes from 600 to 2800 m.a.s.l. This zone is bordered by South Sudan on the south, west and north and by Anuak Zone on the east; the Pibor defines the border on the south and west, while the Baro defines it for the northern border. Towns in this zone include Tirgol, Matar, Nyinenyang, Kuachthiang and Kuergeng. Nuer Zone consists of five woredas: Akobo, Jikawo, Lare, Makuey (Woreda) and Wentawo (Matar) and is flat at an elevation between 400 and 430 m above sea level.

Meteorological data of the study site indicate that the zone receives an annual rainfall ranging from 900 to 1450 mm with annual minimum and maximum temperature of 20 and 35°C, respectively the zone consists of grasslands, marshes and swamps with some forests. The economy is predominantly based on livestock. The dominant and common grass species in the study area include: *Aristidamicans, Brachiaria xantholeuca, Cenchrus mitis, Chloris gayana, Digitaria adscendens, Echinochloa colunum, Eriochloa procera, Echinochloa pyramidelis, Hyparrhania filipendula, Hyparrhenia hirta, Hyparrhenia rufa, Pennisetum adoensis, Pennisetum clandestinum, Pennisetum glabrum* and *Setaria verticullata* (Ketema et al., 2017).

Treatments and experimental design

The trail was conducted using a randomized complete block design with three replications. The treatments for the study were three different harvesting stages (boot, Anthesis and dough stages), and a pure and dense stand of antelope grass in natural pasture were enclosed, divided into 3 blocks and furtherly divided into 4 plots resulting in a total of 12 plots. The size of each plot comprised an area of 3-m length × 4-m width (12 m^2) and the block was with an area of 209 m^2 (19 m × 11 m); spacing between plots and blocks was 1 and 2 m, respectively, to avoid border effects between each plot and blocks.

Sampling procedure and data collection

One district (Lare) was selected and an area of 209 m^2 natural pasture was enclosed in the district from June to October. Each enclosure was divided into 3 blocks which were fatherly divided into 12 plots giving a total of 36 plots. The size of each plot was 3 × 4 m. Harvesting of three plots per treatment in each stage of growth (boot, Anthesis and dough) was made using a quadrant with 0.5 × 0.5 (0.25 m^2) and data on biomass yield were taken.

Harvesting was done manually by cutting the plants at about 5 cm above the ground using sickle. The fresh weight of the harvested biomass was recorded just after mowing using digital field balance. Then, the harvested biomass was manually chopped into small pieces and a subsample of 500 g was taken to the food science and nutrition laboratory of the Ethiopian Institute of Agricultural Research, for analysis.

The DM yield of each plot was determined by drying a representative sample in an oven at 65°C for 72 h (ILCA, 1990) and the final DM yield was calculated in tons per hectare.

Chemical composition analyses

The chemical analyses for determination of nutritional composition were carried out using proximate analyses method. Crude fiber content, ash, moisture and crude fat (EE) content of feed samples were determined based on AOAC protocols and methods (AOAC, 2005).

Total starch content from feed sample was determined using spectrophotometric and a modified Megazyme method (McCleary et al., 1997). Nitrogen content was determined by taking sub-samples from an oven-dried forage samples employing the Kjeldhal method (AOAC, 1990). The protein content was calculated by multiplying the nitrogen content by 6.25. The VanSoest method of forage analysis was applied to determine Neutral Detergent Fiber (NDF), Acid Detergent Fiber (ADF) and acid detergent lignin (ADL). The amount of hemi-cellulose was determined as the difference between NDF and ADF, whereas cellulose content was determined by subtracting ADL and ADF ash from ADF. The equations developed for estimating the Gross Energy (GE) concentration (kcal/kg on a DM basis) in the feed ingredients was estimated using the equation developed by Son and Kim (2018) as:

$$GE = 4{,}299 + 7 \times CP + 53 \times EE.$$

The forage samples were dried to a constant dry weight in an oven at 100 ± 5°C for 24 h to determine percent dry weight before any analytical procedure. All the chemical analysis of the samples was performed in duplicate. Finally, all results were calculated on a dry matter basis.

Statistical analysis

Data was subjected to analysis of variance (ANOVA) using the GLM procedure of SAS computer software version 9.0 (2002) with harvesting stage/treatment as an independent variable in the model. Treatment differences were declared significant at (5%) Tukey and Least significance difference (LSD) were taken to account to separate the means. Finally, the effect of stage of harvesting periods on yield and chemical composition was determined using mixed model (Miroslav and William, 2004).

$$Yijkp = \mu + Hi + Bj + Tk + + Rp + Eijkp$$

where Yijkp= Yield parameters to be measured, μ = Overall mean, Hi = effect of i^{th}harvesting stage, bj= effect of the j^{th} block, Tk=effect of k^{th} treatment, Rp= effect of p^{th} replication, and Eijkp= Random error (residuals)

RESULTS AND DISCUSSION

Effect of harvesting stage on yield, total nitrogen and gross energy of antelope grass hay

Table 1 shows the effect of harvesting stage on yield, total nitrogen and gross energy of antelope grass hay. The result showed that fresh biomass yield, dry matter yield and total nitrogen were affected significantly (p<0.05) by maturity stage of the grass. In contrast, gross energy of antelope grass hay was not significantly (>0.05) affected by maturity stage of pasture (Table 1). Fresh biomass yield and total nitrogen were decreased with increased maturity stage and range from 20.50 to 32.20 t/ha and 1.57 to 2.56%, respectively, while dry matter yield was increased with pasture age ranging from 15.30 to 27.25 t/ha. For this study, there were no significant different (p>0.5) for gross energy among each maturity stage. The *E. pyramidalis* has the highest gross energy at boot stage and lowest at dough stage of growth. In general, fresh biomass yield was highest at boot stage and DMY was highest at dough stage of growth as expected.

Fresh biomass yield and total nitrogen decreased with increased maturity stage, while dry matter yield was increased with pasture age. The present study was in line with the finding of Zinash et al. (1995), Pare et al. (2011a), Feyissa et al. (2013), Agza et al. (2013) and Wassie et al. (2018) who reported the significant effect of harvesting stage or cutting dates on the yield of natural pasture. For this study, there were no significant difference (p>0.5) for gross energy among each maturity stage. This finding is not in line with the report of Adebowale (1988), for gross energy of antelope grass who stated that, Acid detergent fiber and gross energy values increased, while crude protein and digestible energy values decreased with forage age. In this study, the DMY increase with the advance in maturity stage. This finding is in agreement with the finding of Agza et al. (2013), Wassie et al. (2018), Ghiwot (2019), and Wubetie et al. (2019). The increasing trend in DMY with advance in stage of maturity was due to increase in the structural carbohydrate and reducing the moisture content of the grass (Wassie et al., 2018; Smith et al., 1991; Pare et al., 2011).

Effect of harvesting stage on chemical composition of antelope grass (*E. pyramidalis*) hay

The results of the effect of harvesting stages on chemical composition of antelope grass hay are presented in Table 2. The result showed that there were significant difference (p<0.05) on CF%, Ash%, total CHO, available CHO, NDF%, ADF% and starch with maturity stage of antelope grass hay. In contrast, there were no significant different (p>0.05) on DM (%), EE (%), moisture and ADL with

Table 1. Effect of harvesting stage on yield, total nitrogen and gross energy of antelope grass (*E. pyramidalis*) hay.

Stage of harvesting	Parameters			
	FBY (t/ha)	DMY (t/ha)	TN (%)	GE (MJ/Kg DM)
Boot	32.20^a	15.30^a	2.56^a	19.06^a
Anthesis	22.95^b	20.18^b	1.78^b	18.96^a
Dough	20.50^b	27.25^c	1.57^b	18.97^a
P-Value	0.042	0.005	0.018	0.836
LSD (0.05)	6.64	3.40	0.48	0.35
Sig	*	**	*	NS

Treatment means with different letters in a column are significantly different (P < 0.05) for harvesting stages. NS for non-significant, *for P < 0.05 (5%), **for P < 0.01 (1%). LSD= Least significant difference, sig=significance, FBY= fresh biomass yield, DMY= dry matter yield, TN= total nitrogen, GE= gross energy.
Source: Author

Table 2. Effect of harvesting stage on chemical composition of antelope grass (*E. pyramidalis*) hay.

Stage of harvesting	Parameters (DM %)											
	DM (%)	Ash (%)	CF (%)	EE (%)	M (%)	CP (%)	TCHO (%)	ACHO (%)	ST (%)	NDF (%)	ADF (%)	ADL (%)
Boot	90.56^a	18.21^a	38.74^a	2.67^a	13.16^a	15.10^a	64.55^a	22.15^a	24.12^a	65.41^a	41.30^a	16.95^{ab}
Anthesis	$92.13a^a$	15.72^b	41.74^b	2.71^a	12.93^a	12.14^b	64.38^a	24.87^b	29.92^b	71.02^b	46.78^b	16.49^a
Dough	90.84^a	14.37^c	42.05^b	3.07^a	11.96^a	9.82^b	67.91^s	26.72^c	26.95^{ab}	74.19^b	51.95^c	17.33^b
P-value	0.461	0.008	0.049	0.737	0.470	0.038	0.013	0.002	0.026	0.023	0.027	0.181
LSD(0.05)	6.96	1.29	2.06	1.16	3.05	3.36	1.55	1.08	2.90	3.93	4.98	0.74
Sig	NS	**	*	NS	NS	*	*	**	*	*	*	NS

Treatments means with different letters in a column are significantly different (P < 0.05) for harvesting stages. NS for non-significant, *for P < 0.05, **for P <0.01. LSD=Least significant difference, sig= significant, DM= dry matter, CF= crude fibre, EE=ether extract, M= moisture, CP=crude protein, TCHO= total carbohydrate, ACHO=available carbohydrate, ST=starch, NDF=neutral detergent, ADF=acid detergent fibre, ADL=acid detergent lignin.
Source: Author

maturity stage (booting, Anthesis and dough). The crude protein (CP) contents of the current study range from 9.82 to 15.10%.

The highest CP% was obtained at booting stage of maturity, while the lowest CP was obtained from the dough stage of growth which is significantly (p<0.05) decreased as forage mature. The finding is in line with the results obtained by Pare et al. (2012) in Cameroon with similar grass species, and the reason for the decline in CP content with advancing maturity is usually due to an increase in structural carbohydrate content and lignin content of forage materials and reducing leaf to stem ratio. The CP concentrations of *E. pyramidalis* for two different growing period (45 and 100 days) in leaves and stems ranged from 15.6 to 18.4% DM and 7.5 to 11.9% DM, respectively under free drainage and flooding conditions (Pare et al., 2011b), which is higher than our finding for leave and lower for stem. This difference might be due to difference in experimental location (natural pasture for current work and research station for previous result) and we believe that our finding could be higher than this result if cultivated at the research station.

For fiber contents (NDF, ADF and ADL), the concentrations increased at advanced stage of growth, except for of ADL (*P*>0.05), and the highest contents are observed in dough stage of growth. These increase fiber contents with advanced age may be attributed to their increasing age and their nature as tropical forage. In addition, the tropical forages generally showed an increase in cell wall components such as NDF, ADF and ADL with increasing maturity (Pare et al., 2011; Pare et al., 2012; Feyissa et al., 2014). Ash content was declined with advancing stage of maturity. The result was in agreement with the one reported by Agza et al. (2013) and Ghiwot (2019). The decrease in ash content of the antelope grass under natural pasture in late maturity might be related to dilution and translocation of minerals from vegetative portion of the plant to roots at late stage of maturity according to the report by Agza et al. (2013) and Mobashar et al. (2018). The crude fat or ether extract content shows similar pattern even though there were slight increase with maturity stage.

Table 3. Mean chemical composition and yield of *E. pyramidalis* hay.

Stage of harvesting	Parameter															
	DM (%)	Ash (%)	CF (%)	EE (%)	M (%)	CP (%)	TCHO (%)	ACHO (%)	ST (%)	NDF (%)	ADF (%)	ADL (%)	TN (%)	FBY (t/ha)	DMY (t/ha)	GE (MJ/kg DM)
Boot	90.56^{a}	18.21^{a}	38.74^{b}	2.67^{a}	13.16^{a}	15.10^{a}	64.55^{b}	22.15^{c}	24.12^{b}	65.41^{b}	41.30^{c}	16.95^{ab}	2.56^{a}	32.20^{a}	15.30^{c}	19.06^{a}
Anthesis	92.13a^{a}	15.72^{b}	41.74^{a}	2.71^{a}	12.93^{a}	12.14^{b}	64.38^{b}	24.87^{b}	29.92^{a}	71.02^{a}	46.78^{b}	16.49^{b}	1.78^{b}	22.95^{b}	20.18^{b}	18.96^{a}
Dough	90.84^{a}	14.37^{c}	42.05^{a}	3.07^{a}	11.96^{a}	9.82^{b}	67.91^{a}	26.72^{a}	26.95^{ab}	74.19^{a}	51.95^{a}	17.33^{a}	1.57^{b}	20.50^{b}	27.25^{a}	18.97^{a}
mean	91.18	16.10	40.84	2.82	12.68	12.65	65.62	24.58	26.10	70.21	46.68	16.92	1.97	25.22	21.12	18.10
SE	3.07	0.57	0.91	0.51	1.34	1.49	0.69	0.48	1.28	1.73	2.20	0.33	0.21	2.93	1.50	0.16
CV (%)	3.37	3.52	2.73	18.22	10.60	11.74	1.05	1.94	4.73	2.47	4.71	1.93	10.64	11.62	7.10	0.82
Sig	NS	***	*	NS	NS	*	*	***	**	*	***	NS	*	*	***	NS

Treatment means with different letters in a column are significantly different ($P < 0.05$) for harvesting stages. NS for non-significant, *for $P < 0.05$, **for $P < 0.01$. *SE:* Standard error, CV= coefficient of variation, sig= significant, DM=dry matter, CF=crude fibre, EE=ether extract, M= moisture, CP=crude fibre, TCHO= total carbohydrate, ACHO= available carbohydrate, ST= starch, NDF= neutral detergent fibre, ADF= acid detergent fibre, ADL= acid detergent lignin, TN= total nitrogen, FBY= fresh biomass yield, DMY= dry matter yield, GE= gross energy.
Source: Author

Mean chemical composition and yield of antelope grass

Table 3 contains the details on the mean chemical composition and yield of antelope grass hay at three different harvesting stages (booting, Anthesis and dough). It is reported that *E. pyramidalis* has a variable composition that depends on the season and age of regrowth (Heuzế et al., 2016). In this study, the average DM content of *E. pyramidalis* at three maturity stages was 91.18±3.07%. Similar findings in different countries with the same species show that the mean DM content varied from 82.5 to 94.9% (Skerman and Riveros, 1990; Pare et al., 2012; Heuzế et al., 2016). For this study, the overall means for DMY of antelope grass hay under natural pasture was 21.12 t DM/ha. This result is higher than the study of Heuzế et al. (2016) which reported that *E. pyramidalis* can achieve DM yields of 15.3 t DM/ha/year in 12 harvestings when grown in permanently flooded mangrove areas. In Guyana, DM production increased from 21.3 to 27.6 t/DM ha when harvested after 21 or 35 days (Smith et al., 1991), which is nearly similar to the current result. Comparative studies under the same climatic conditions carried out with manure application exhibited high productivity of *E. pyramidalis* (27 DM/ha/year) compared to 5.4 t DM/ha/year in natural environments.

The average crude protein content of antelope grass for this study was 12.56%. Lower average crude protein content of 21 samples was 6.5% DM (± 3.9) was reported, but much higher values have been reported, such as 15% (Heuzế et al., 2016).

The average DM% contents of main analysis of antelope grass hay recorded in this study are 40.84, 70.21, 46.68, 16.92, 2.82, 16.20, and 18.1 MJ/Kg and 1.97% for CF, NDF, ADL, EE, ash, GE and total nitrogen, respectively as shown in Table 3. This result except for gross energy is higher than the previous studies conducted on similar species reported by (Skerman and Riveros, 1990; Smith et al., 1991; Heuzế et al., 2016) as 33.5, 68.8, 39.2, 5.2, 2.4, 10.2, 18.4 and 1.1%) for CF, NDF, ADL, EE, Ash, GE and total N, respectively. The difference in average of chemical composition and biomass yield in relation to the data obtained in this work with previous work may be related to the factors like degree of maturity stage at cutting, environmental condition and conservation capacity. In general, the mean chemical composition of analysed parameters and yield are lower or higher to the standard average of *E. pyramidalis* documented in Feedipedia.

CONCLUSION AND RECOMMENDATIONS

Based on the current findings, it can be concluded that harvesting stage can significantly affect dry matter and CP content. Results from this study showed that the fresh biomass yield of antelope grass was decreased with increasing maturity; however, the DM yield was increased with advanced stage of growth. The CP contents of *E. pyramidalis*, which is the crucial nutritive value for prediction of forage quality comparable to that of most tropical forage declined as stage of growth increased however. Therefore, based on this conclusion, antelope grass hay could be utilized in the early stage of maturity (booting and Anthesis) as animal feeds. Further work on hay production and conservation scheme is needed in order to build agro-pastoralists, development agents and other stakeholder knowledge and skills, and enhance dairy or meat cattle productivity in the area and further investigations are necessary to evaluate forage intake, digestibility and animal response for milk or meat production on research station.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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