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# A study of forage yield and nutritive value of natural pastures at varying levels of maturity in North West Lowlands of Ethiopia

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A study was conducted to describe forage yield and nutritive value of natural pasture at varying harvesting time from Metekel area. An area of 2,414 m<sup>2</sup> natural pasture was enclosed in three districts at the beginning of the main rainy season in two consecutive years and harvesting was made at 10 days interval starting from late July to November. The average yield of the natural pasture in the study area was 5.40 ton DM/ha. The dry matter yield was significantly ( $P<0.05$ ) increased in advancing flowering while crude protein and in vitro organic matter digestibility was decreased, as expected. Unlike acid detergent fiber which increased significantly ( $p<0.05$ ) with maturity, the neutral detergent fiber and hemicellulose level of the pasture was not significantly different ( $p>0.05$ ) between harvestings. Despite poor balance of grass and legume combinations which contributed for lower protein content and digestibility, the natural pasture of Metekel zone has a high productivity in relation to total DM yield. It could be concluded that appropriate harvesting time for quality hay making is at 40 to 80% of flowering and after  $17\pm 2$  weeks of precipitation.

**Key words:** Metekel lowlands, ruminant, grazing land, biomass yield, chemical composition, Benishangul-gumuz.

## INTRODUCTION

Ethiopian grasslands account for over 30% of the land cover and constitute to 66 percent of feed resources for livestock (CSA, 2011). 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 (Alemayehu, 2003). As in many parts of the country, livestock farmers in Metekel, North West Ethiopia, are highly dependent on grazing lands and crop residues. Native feed resources contribute over 75% of the total feed supplies in this area

(BoARD, 2006) while the contribution of natural pastures to livestock feeding as conserved hay is limited to 2.8% (CSA, 2011). Alemayehu (2002) indicated that hay produced from natural grasses, improved forage legumes and browse legumes is the most appropriate conserved forage for small-scale fattening or dairy production in Ethiopia.

Seasonality in quality and quantity of forage supplied is one of the prior problems of livestock owners in Metekel zone that has a typical tropical lowland climate. 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

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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 cutting age of the grass for quality hay.

The high temperature in tropical countries changes the nutritive values of the grass component rapidly during the late growth stages of the grassland (McDonald et al., 2002) and 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; Yihalem et al., 2005; Tessema et al., 2010). Due to poor agricultural extension service delivery in Metekel zone forage conservation is not practiced and it is a tradition for the native Gumuz people to burn the natural pasture in dry season as means of re-growth stimulation and reducing bush encroachment for ease of hunting (Fitsum et al., 2009).

Though various species of grasses, legumes and other browse plants are available in the area, there is a considerable loss of livestock productivity in the dry season as the animals are restricted only on crop residues and the inadequate dry swards of grasses. If grasses are cut at the right growth stage and dried for later use, the existing feed problem can significantly be reduced. A detailed knowledge of seasonal growth and nutritive value of the grass-lands is also necessary to utilize the available pasture efficiently. Therefore, the objective of this study was to identify the appropriate harvesting time of the natural pasture for optimum quality and yield of hay.

## MATERIALS AND METHODS

### Description of study area

The study was conducted in Metekel zone located in the Benishangul-gumuz National Regional State, North West Ethiopia, covering an area of 3,387,817 hectares. 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. Meteorological data of Pawe Agricultural Research Center 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 dominant vegetation cover of the study area is characterized by different types of woodland which include broad-leaved deciduous woodland, Acacia woodland, riparian woodland along the major rivers, *Boswellia* woodland and bamboo thicket (UNDP/ECA,

1998). According to MoA cited in Engda (2000) the surrounding of Metekel Zone has a wide climatic range within hot to warm moist lowlands (M<sub>1</sub>) and hot to warm sub humid lowlands (SH<sub>1</sub>) agro-ecological zones.

### Sampling procedures and data collection

Three districts (Pawe, Dangur and Dibate) were selected and an area of 2,414 m<sup>2</sup> natural pasture was enclosed in each district from June to November. Each enclosure was divided into 3 blocks that are further divided into 12 plots giving a total of 108 plots. The size of each plot was 5 × 10 m. Harvesting of three plots per treatment was made starting from late July with 10 days interval and in each harvesting day data on biomass yield, leaf to stem ratio, flowering percentage and samples were taken for further feed 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 yield was calculated in tons per hectare.

### Chemical analyses and in vitro dry matter digestibility

The dried samples were ground to pass through a one mm sieve size for quality evaluation. To determine ash the samples were ignited in a muffle furnace at 550°C (AOAC, 1990) and Crude Protein (CP) was determined using Kjeldahl method (AOAC, 1980). Goering and Van Soest (1970) procedure was used to determine Neutral Detergent Fibre (NDF) and Acid Detergent Fibre (ADF). Hemicellulose (HC) was calculated as NDF less ADF. The in vitro Dry Organic Matter Digestibility (DOMD) was determined according to the two stages method outlined by Tilley and Terry (1963). All chemical composition and in vitro DOMD analyses were carried out at Holeta Agricultural Research Center, Nutrition laboratory.

### Statistical analysis

The trial was laid out in randomized complete block design with three replications. General Linear Model was used to compare effects of location, season and harvesting time on quality and yield of hay. Tukey and LSD mean comparisons were deployed. This analysis was conducted using SAS software (SAS Institute, 1990).

## RESULTS AND DISCUSSIONS

### Forage yield at different harvesting times

The early flowering stage of pasture appears to be the most appropriate harvesting time for making hay

**Table 1.** The average flowering, leafiness and dry matter content of natural pasture at advancing stages of maturity in three districts of Metekel, Ethiopia.

No	Harvesting dates	Weeks of precipitation	Flowering (%)	Leaf to stem ratio	Partial dry matter (g/kg)
1	Late July	7.3	0.0	1.6 <sup>b</sup>	172 <sup>f</sup>
2	Early August	8.7	0.0	1.8 <sup>ab</sup>	257 <sup>e</sup>
3	Mid-August	10.2	2.7	2.3 <sup>a</sup>	263 <sup>de</sup>
4	Late August	11.6	3.0	1.6 <sup>d</sup>	278 <sup>de</sup>
5	Early September	13.0	6.3	1.6 <sup>d</sup>	285 <sup>de</sup>
6	Mid-September	14.4	18.6	1.2 <sup>dc</sup>	285 <sup>de</sup>
7	Late September	15.9	21.3	1.2 <sup>dc</sup>	304 <sup>dc</sup>
8	Early October	17.3	42.4	1.1 <sup>bc</sup>	336 <sup>bc</sup>
9	Mid-October	18.7	58.5	1.3 <sup>bc</sup>	379 <sup>ab</sup>
10	Late October	20.2	78.5	1.1 <sup>bc</sup>	380 <sup>ab</sup>
11	Early November	21.6	79.3	1.3 <sup>bc</sup>	381 <sup>ab</sup>
12	Mid-November	23.0	100	0.9 <sup>c</sup>	3895 <sup>a</sup>
13	Late November	24.5	100	0.6 <sup>c</sup>	397 <sup>a</sup>
	C.V.%			51.6	14.7

Means with the same letter in a column are not significantly different ( $p>0.05$ ).

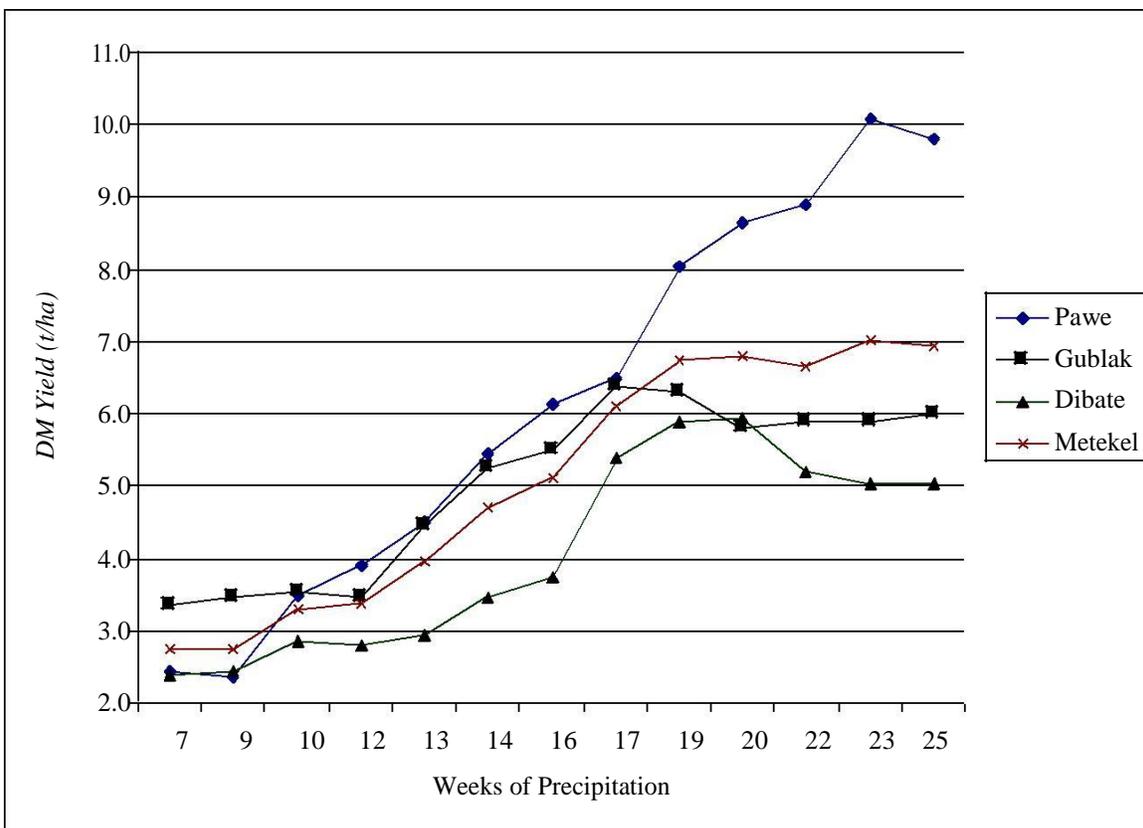
(Crowder and Chheda, 1982). Natural pasture in the study area started flowering after 10 weeks of precipitation and became fully flowered in 24 weeks, and on average the pastures achieved 50% maturity in  $17\pm 2$  weeks after the onset of rain (Table 1). Pastures in Pawe and Gublak areas reach 50% flowering stage about 3 weeks earlier than the one at Dibate location. The average value of leaf to stem ratio (LSR) of the enclosed pasture was 1.4. The plants were leafier in the early harvesting time, at the beginning of flowering, and there was no significant difference ( $P>0.05$ ) observed between 13 and 22 weeks of precipitation, and less proportion of leaf was recorded beyond 22 weeks. The inverse relationship between LSR and DM was manifested in the current study as partial DM content showed increasing trend (from 172 to 397 g/kg) through harvesting time. This indicates that the moisture content of plants in the pasture decreases as the LSR decrease in advancing growth.

Previous reports from different parts of Ethiopia have asserted the significant effect of harvesting stage on the productivity of natural pasture (Kidane, 1993; Zinash et al., 1995; Yihalem, 2004; Adane and Berhan, 2005; Tessema, 2005; Yihalem et al., 2005). Similarly, forage yield significantly varied between harvesting times in the current study (Figure 1). The highest total DM yield of the natural pasture was obtained at the late stages of harvesting towards the end of the rainy season (late October and November) when flowering percentage is more than 75. There are limited studies previously reported on the DM yield of natural pastures in similar agro-ecologies. Reports from central highlands of Ethiopia estimated the annual DM yield of natural pasture

to be 4.5 t/ha on seasonally waterlogged bottomlands (Alemayehu, 1987), 3 t/ha for protected grasslands (Jutzi et al., 1987) and 6 t/ha for well managed natural pasture (Yihalem, 2004). The average yield of natural pasture in the present work was 5.4 t/ha per one growing season which was more than the one reported for protected grasslands and comparable to well managed pasture in the highlands of the country. The highest dry matter was recorded in Pawe (6.2 t/ha) followed by Gublack (5.1 t/ha) and the smallest dry matter yield in Dibate (4.1 t/ha). This variation may be due to the species of grass growing in the area and the nature of the soil. It could also be due to the variations in rainfall amount and pattern between these districts. There was no significant difference of dry matter yield between the two years.

### Chemical composition and in vitro dry matter digestibility

The two years combined analysis of chemical composition and in vitro dry matter digestibility of the pasture is presented on Table 2. In contrast to DM yield, crude protein (CP) content of the pasture was decreased significantly ( $p<0.05$ ) as period of harvesting is advanced (Figure 2). The result was in agreement with many other studies (Hassan et al., 1990; Gebremeskel, 1993; Zinash et al., 1995; Deneke, 2004) who reported a decline in CP content of pasture along with increasing stage of harvesting which may be due to the decrease in leaf to stem ratio and the dilution of the CP content by the increased structural carbohydrates. Ruminants need a minimum of 150 g CP per kg of DM for lactation and growth



**Figure 1.** Forage dry matter yield at various stages of maturity of natural pasture in three districts of Metekel zone, Ethiopia.

**Table 2.** Chemical composition of the natural pasture at different levels of maturity in Metekel zone, Ethiopia.

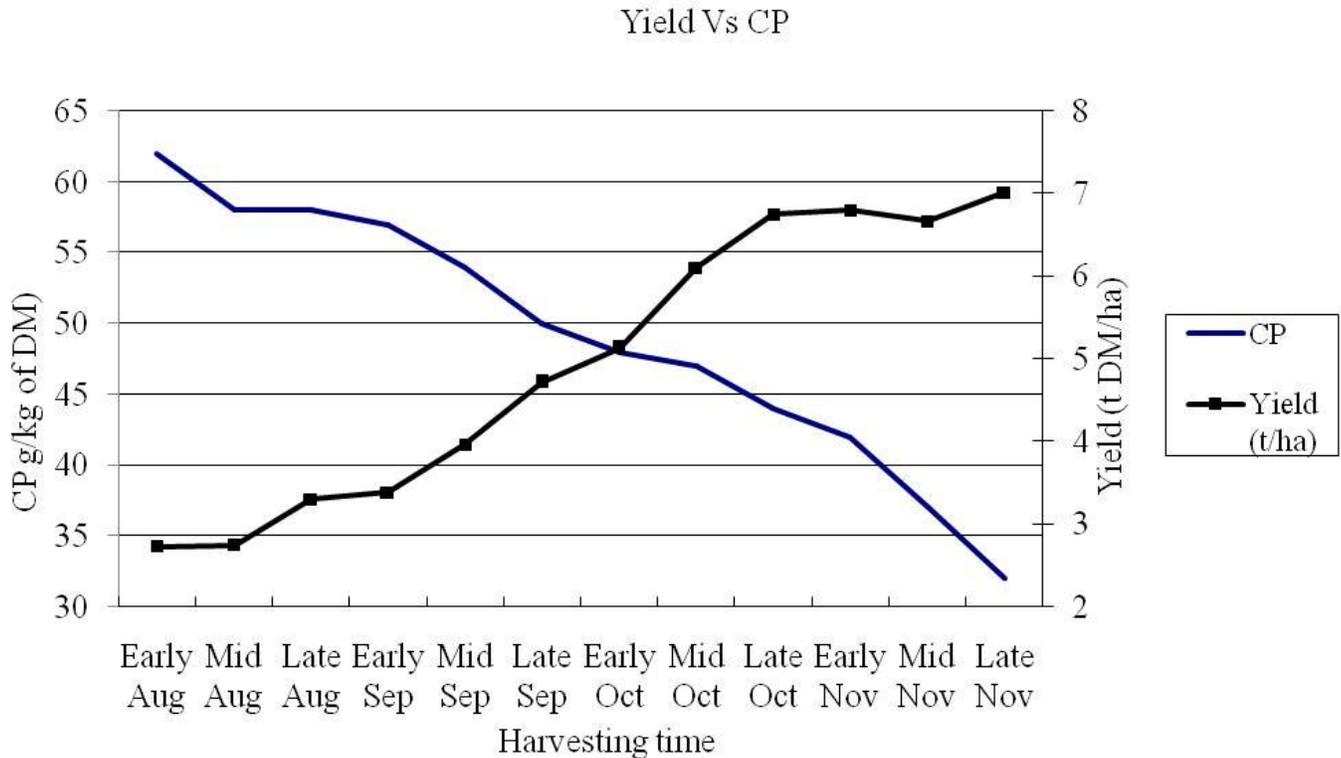
Harvesting time	Ash (g/kg)	CP (g/kg)	NDF (g/kg)	ADF (g/kg)	HC (g/kg)	DOMD (g/kg)
Late July	115 <sup>a</sup>	62 <sup>a</sup>	774 <sup>a</sup>	501 <sup>b</sup>	273 <sup>a</sup>	626 <sup>a</sup>
Early August	100 <sup>b</sup>	58 <sup>ab</sup>	797 <sup>a</sup>	509 <sup>b</sup>	288 <sup>a</sup>	487 <sup>ab</sup>
Mid-August	97 <sup>bc</sup>	58 <sup>ab</sup>	793 <sup>a</sup>	502 <sup>b</sup>	261 <sup>a</sup>	481 <sup>ab</sup>
Late August	93 <sup>bc</sup>	57 <sup>ab</sup>	797 <sup>a</sup>	517 <sup>b</sup>	280 <sup>a</sup>	473 <sup>b</sup>
Early September	86 <sup>cd</sup>	54 <sup>abc</sup>	768 <sup>a</sup>	547 <sup>ab</sup>	220 <sup>a</sup>	460 <sup>b</sup>
Mid-September	87 <sup>cd</sup>	50 <sup>abcd</sup>	800 <sup>a</sup>	552 <sup>ab</sup>	248 <sup>a</sup>	475 <sup>b</sup>
Late September	83 <sup>cd</sup>	48 <sup>abcd</sup>	792 <sup>a</sup>	544 <sup>ab</sup>	248 <sup>a</sup>	451 <sup>b</sup>
Early October	73 <sup>cd</sup>	47 <sup>abcd</sup>	811 <sup>a</sup>	551 <sup>ab</sup>	260 <sup>a</sup>	395 <sup>b</sup>
Mid-October	88 <sup>cd</sup>	44 <sup>abcd</sup>	809 <sup>a</sup>	557 <sup>ab</sup>	272 <sup>a</sup>	392 <sup>b</sup>
Late October	78 <sup>de</sup>	42 <sup>bcd</sup>	811 <sup>a</sup>	552 <sup>ab</sup>	279 <sup>a</sup>	362 <sup>b</sup>
Early November	72 <sup>e</sup>	37 <sup>cd</sup>	815 <sup>a</sup>	572 <sup>a</sup>	244 <sup>a</sup>	305 <sup>b</sup>
Mid-November	59 <sup>f</sup>	32 <sup>d</sup>	825 <sup>a</sup>	573 <sup>a</sup>	252 <sup>a</sup>	306 <sup>b</sup>
C.V.%	8.3	22.4	5.7	5.9	16.3	34.4

Means with the same letter in a column are not significantly different ( $p > 0.05$ ).

(Norton, 1982), and 75 g CP per kg of DM for rumen function (Van Soest, 1994). CP level recorded in this study was insufficient to satisfy the rumen microbial function and delay in harvesting of the pasture beyond

20 weeks aggravates the protein deficiency problem.

The Neutral Detergent Fiber (NDF) and Acid Detergent Fiber (ADF) content was increased with advance in



**Figure 2.** Trends in CP and biomass yield of the natural pasture at varying levels of maturity in Metekel.

harvesting period from July to November. Unlike ADF, the NDF content of the pasture at different cutting dates was not significantly different ( $p>0.05$ ) even if the value was increasing with maturity. The increasing NDF and ADF content with advance in harvesting was also reported by Kitaba and Tamir (2007) and Tessema et al. (2010). This might be associated with an increase in cell wall lignifications as forages get matured. The average value of NDF for tropical grass is 662 g/kg (Van Soest, 1994 and McDonald et al., 2002). Feeds with more than 650 g NDF per kg of DM were classified as low quality roughages (Singh and Oosting, 1992), and the natural pasture in the study area falls in this category (between 770 and 830 g/kg). This could affect the intake of the pasture and would limit production and productivity of livestock. In contrast to many other studies including Kidund et al. (1990), Tessema et al. (2003), Kitaba and Tamir (2007) and Tessema et al. (2010) who reported the hemicellulose content increase with advancing stage of growth, in the current study there was no significant ( $p>0.05$ ) difference among all the cuttings.

*In vitro* dry organic matter digestibility (DOMD) showed a declining trend in advancing maturity (Figure 3). However, a significant difference ( $p>0.05$ ) was not observed in the cutting made beyond August. The reduction of digestibility against maturity is in agreement with the finding of Zinash et al. (1995), Kitaba and Tamir (2007) and Tessema et al. (2010) who reported a decrease

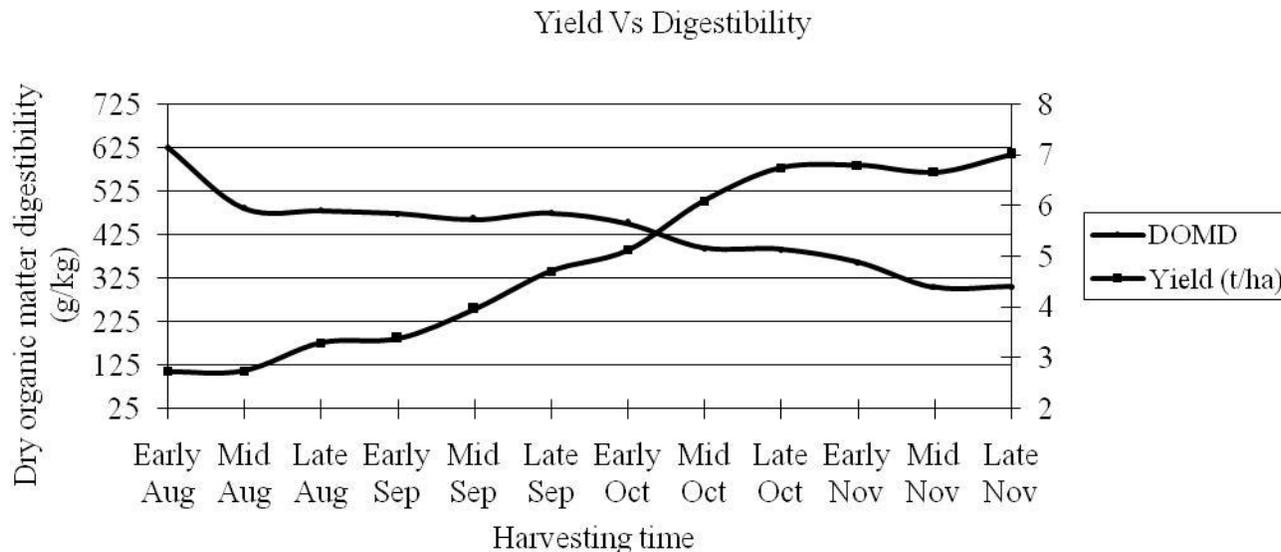
in DOMD when the grass species is harvested at relatively advanced stages of growth. This might be due to deposition of lignin in the cell wall with increasing maturity and the increasing proportion of stem which becomes less digestible when compared with the leaf portion at advanced maturity (McDonald et al., 1995). A significant difference was not observed across years and locations.

The ash content observed in this study varies both in location and years. The average content of ash was declined with advancing stage of cutting. The result was in agreement with the one reported by Solomon et al (2008). The author indicated that there is a decrease in total ash content of the natural pasture in late maturity. This might be related to dilution and translocation of minerals from vegetative portion of the plant to roots at late stage of maturity (Maynard et al., 1981).

## CONCLUSION AND RECOMMENDATION

Feed conservation mechanisms like hay making can improve feed availability in dry season and reduce wild fire after rainy season and enable to utilize the pasture efficiently.

Despite poor balance of grass and legume combinations which attributed for lower protein content and digestibility, the natural pasture of Metekel zone has



**Figure 3.** Trends in digestibility and biomass yield of the natural pasture at varying levels of plant maturity in Metekel.

a huge total DM yield and harvesting the pasture at an appropriate stage of growth is one of the best options to improve the outcome of grazing lands. However, it seems that adjusting harvesting time is not as good as managing good legume mixtures in the pasture to improve the CP content of harvested biomass. In order to optimize quality and quantity of hay producers in Metekel zone can practice cuttings between 15 and 19 weeks of precipitation when the percentage of flowering is 40 to 80. Harvests past this time need treatments like urea and molasses to improve quality of hay for ruminants' consumption.

## REFERENCES

- Adane K, Berhan T (2005). Effects of harvesting frequency and nutrient levels on natural pasture in the central highlands of Ethiopia. *Trop. Sci.* 45, 77–82.
- Alemayehu M (1987). Feed Resources in Ethiopia. In: J.A. Kategile, A.N. Said, and B.H. Dzewela (Eds.). *Animal Feed Resources for Small-scale Livestock Producers*. Proceedings of the 2nd PANESA Workshop Held in Nairobi, Kenya, 11-15 November 1985. pp 143-162.
- Alemayehu M (2002). Forage production in Ethiopia a case study with implications for livestock production. *Ethiopian Society of Animal Production (ESAP)*. Addis Ababa, Ethiopia.
- Alemayehu M (2003). Country Pasture /Forage Resource Profile, Ethiopia. Retrieved February, 2007, from <http://www.fao.org/ag/AGP/AGPC/doc/counprof/Ethiopia/Ethiopia.Htm>
- AOAC (1980). Official method of analysis 12<sup>th</sup> ed. Association of Official Analytical Chemists, Arlington, VA, USA.
- AOAC (1990). Official method of analysis, 5<sup>th</sup> edn. Association of Official Analytical Chemists, Arlington, VA, USA.
- BoARD (2006). Rural Household socioeconomic Baseline Survey. Bureau of Agricultural development, Benishangul-Gumuz Region, Assosa, Ethiopia.
- Čop J, Vidrih M, Hacin J (2009). Influence of cutting regime and fertiliser application on the botanical composition, yield and nutritive value of herbage of wet grasslands in central Europe. *Grass Forage Sci.* 64: 454–465.
- Crowder LV, Chheda HR (1982). *Tropical grassland husbandry*. Harlow: Longman.
- CSA (2011). Central Statistics Authority of Ethiopia. Agricultural Sample Survey. Volume II- Report on Livestock and Livestock Characteristics of Peasant Holdings. Statistical Bulletin 505. pp 109. Addis Ababa, Ethiopia.
- Denekew Y (2004). Assessment of botanical composition and stage of harvesting of selected natural pasture for optimum utilization as hay at Andassa Livestock Research Centre, Northwestern Ethiopia. MSc Thesis. Alemaya University, Alemaya, Ethiopia.
- Engda M (2000). Agroclimatic classification of Ethiopia. Ethiopian Society of Soil science. *Ethiop. J. Nat. Resour.* 2(2), 115-135.
- Fitsum S, Solomon Z, Mikias D, Yigremachew S, Demeke M, Gizachew W (2009). Gender-based participatory Rural Appraisal of Farming System in Wombera, Bullen and Guba Weredas. *Gender Differentials for Planning Agricultural Research*. Proceeding of the Workshop on Gender Analysis in Agricultural Research held 27-29 November 2006 Addis Ababa, Ethiopia. PP 161-187.

- Gebremeskel K (1993). Effect of cutting date on botanical composition and nutritive value of native pasture in the Central Ethiopian Highlands. MSc Thesis. Alemaya University of Agriculture, Alemaya, Ethiopia.
- Goering HK, Van Soest PJ (1970). *Forage fiber analyses (apparatus, reagents and some applications)*. USDA Agricultural Handbook No. 379. Washington, DC: Agricultural Research Service, US Department of Agriculture.
- Hassan WE, Phipps RH, Owen E (1990). Dry matter yield and nutritive value of improved pasture in Malaysia. *Trop. Agric.* 67 (4): 303-308.
- ILCA (International Livestock Center for Africa). 1990. *Livestock research manual*. Addis Ababa: ILCA.
- Jutzi S, Haque I, Abate T (1987). The Production of Animal Feed in the Ethiopian Highlands: Potentials and Limitations: *In: Proceedings of the 1st National Livestock Improvement Conference*, Addis Ababa, Ethiopia. pp. 141-142.
- Kidane G (1993). Effect of stage of harvesting on botanical composition and feeding value of native pasture in the central highlands. MSc thesis, Alemaya University of Agriculture, Dire Dawa, Ethiopia.
- Kidunda RS, Lowga AB, Mtengeti EJ (1990). Utilization of research results on forage and agricultural by products as animal feed resources in Africa. PANESA/ARNAB (Pasture Network for Eastern and Southern Africa/African Research Network for Agriculture By-products), pp. 36 - 56. Proceedings of the first joint workshop held in Lilongwe, Malawi, 5-9 December, 1988, PANESA/ARNAB, Addis Ababa, Ethiopia.
- Kitaba A, Tamir B (2007). Effect of harvesting stage and nutrient levels on nutritive values of natural pasture in central highlands of Ethiopia. *Agricultur tropica et subtropica*. vol. 40 (1).
- Maynard AL, Loosli KJ, Hintz FH (1981). *Animal Nutrition*, 7th edition. Tata McGraw-Hill Publishing Company Limited. New Delhi, India.
- McDonald P, Edwards RA, Greenhalgh JFD, Morgan CA (2002). *Animal nutrition*, 6<sup>th</sup> edn. Harlow: Prentice Hall.
- McDonald PR, Edwards A, Greenhalgh JF, Morgan CA (1995). *Animal Nutrition*, 5<sup>th</sup> edition, Longman, United Kingdom. Minitab Inc. Minitab Statistical Software for Windows Release 12, 1998, Minitab Inc. State College, PA., USA.
- Norton BW (1982). Differences between species in forage quality. In: Hacker JB (eds), *Nutritional limits to animal production from pastures*. Farnham Royal: Commonwealth Agricultural Bureaux. pp 89-110.
- SAS Institute (1990). *SAS Procedures Guide for Personal Computers*, version 8th ed. SAS Institute, Inc., Cary, NC.
- Singh GP, Oosting SJ (1992). A model for describing the energy value of straws. *Indian dairy man XLIV*: pp. 322 - 327.
- Solomon B, Solomon M, Alemu Y (2008). Influence of rainfall pattern on grass/legume composition and nutritive value of natural pasture in Bale Highlands of Ethiopia. Sinana, Ethiopia.
- Tessema Z (2005). Identification of indigenous pasture and the effect of time of harvesting and nitrogen fertilizer in the north western Ethiopian highlands. *Trop. Sci.* 45, 73-77.
- Tessema Z, Ashagre A, Solomon M (2010). Botanical composition, yield and nutritional quality of grassland in relation to stages of harvesting and fertiliser application in the highlands of Ethiopia. *Afr. J. Range Forage Sci.* 27(3), 117-124.
- Tessema Z, Baars RMT, Alemu Y (2003). Effect of plant height at cutting and fertiliser on growth of Napier grass (*Pennisetum purpureum* Schumacher.). *Trop. Sci.* 43, 57-61.
- Tilley JMA, Terry RA (1963). A two-stage technique for in vitro digestion of forage crops. *J. Br. Grassl. Soc.* 18: 104-106.
- UNDP/ ECA (1998). Forestry Program Proposal: Benshangul Gumuz Regional State/ Federal Democratic Republic of Ethiopia. Sustainable Agricultural and environmental rehabilitation program (SARAEP) the Districts Agriculture and rural development integrated Services (WADIS) UNECA. Volume 6. pp. 129
- Yihalem D (2004). Assessment of Botanical Composition and Harvesting Stage of Selected Natural Pasture for Optimum Utilization as Hay at Andassa Livestock Research Center, North-Western Ethiopia. M. Sc. Thesis. Alemaya University of Agriculture, Alemaya, Ethiopia.
- Yihalem D, Berhan T, Solomon M (2005). Effect of harvesting date on composition and yield of natural pasture in northwestern Ethiopia. *Trop. Sci.* 45, 19-22.
- Zinash S, Seyoum B, Lulseged G, Tadesse T (1995). Effect of harvesting stage on yield and quality of natural pasture in the central highlands of Ethiopia. In: Proceedings of third National Conference of the Ethiopian Society of Animal Production (ESAP), pp. 316 - 322. April 27 - 29, 1995, Addis Ababa, Ethiopia.