EFFECT OF HARVESTING STAGE AND NUTRIENT LEVELS ON NUTRITIVE VALUES OF NATURAL PASTURE IN CENTRAL HIGHLANDS OF ETHIOPIA

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Abstract

The effect of harvesting stage and nutrient levels on nutritive values of natural pasture was studied in the central highlands of Ethiopia. The treatments consisted of four harvesting stages with six N + P nutrient levels. Advancing harvesting stage significantly ($p \leq 0.05$) decreased the mean crude protein and in vitro dry matter digestibility (IVDMD), while the mean values of cellulose and Neutral and Acid detergent fibers (NDF and ADF) were significantly ($p \leq 0.05$) increased with advancing harvesting stage. The mean values of hemicellulose and total ash showed an increasing trend with advancing the harvesting stage. Nutrient levels significantly ($p \leq 0.05$) improved the mean crude protein and total ash contents and IVDMD. Nutrient application at 22.5 kg N + 25.9 kg P/ha improved the mean crude protein, total ash and IVDMD from 6.8 to 11.8 %, from 12.3 to 22.5 % and from 67.8 to 79.7 % at 30 days of harvesting stage, respectively. Nutrient levels did not affect the contents of hemicellulose, cellulose, NDF and ADF. In vitro dry matter digestibility, crude protein and total ash contents were significantly ($p \leq 0.05$) negatively correlated to stage of harvesting with correlation coefficients (r = -0.87, -0.81 and -0.16), respectively, but were significantly ($p \leq 0.05$) positively related to nutrient levels with correlation coefficients (r = 0.42, 0.51 and 0.12), respectively. While harvesting stage was significantly ($p \leq 0.05$) positively related to NDF, ADF, cellulose and hemicellulose with correlation coefficients (r = 0.98, 0.95, 0.92 and 0.37), respectively, nutrient application did not relate significantly ($p \geq 0.05$).

Key words: fertility levels, harvesting stage, natural pasture, nutritive values

Abbreviations: ADF = Acid Detergent Fiber; CEL = Cellulose; CP = Crude protein; HCE = Hemicellulose; IVDMD = In vitro dry matter digestibility; N + P = Nitrogen + Phosphorus; NDF = Neutral Detergent Fiber; TASH = Total ash.

INTRODUCTION

Livestock production plays an important role in Ethiopian farming systems providing milk, meat, draught power, manure, hides and skins. The contribution of livestock to the national economy is estimated to be 30 per cent of the agricultural GDP and 19 per cent of the export earnings (Azage and Alemu, 1998). In spite of the immense contribution of the livestock sector to the national economy, animal productivity is extremely low mainly due to poor standard of feeding both in terms of quantity and quality. Livestock derive most of their feed from natural pasture and crop residues. Natural pastures constitute the major feed source providing more than 90 per cent of the livestock feed either in the form of grazing or forages conserved in the form of hay for dry season use (Lulseged, 1985). However, besides the limited acreage, herbage yield and nutritional quality of natural pasture is generally low. The herbage makes rapid growth of fair quality early in the rainy seasons and matures very rapidly, and during the dry season large quantities of over matured herbage are available which are generally poor in quality, and thus animals may loose weight or even die. Similarly, cereal crop residues that are used to augment the year round ruminant feed budget are of low nutritive value and cannot meet the nutrient requirement of livestock even at maintenance level.

The Ethiopian highlands are characterized by high livestock and human population density, which makes up 80 per cent and 88 per cent of the livestock and of human population, respectively (Daniel, 1996). Consequently, the available natural grazing lands are being either encroached by arable farming or are seriously overloaded with livestock beyond their optimum carrying capacity causing overgrazing, soil erosion and overall land degradation leading to low agricultural productivity. The sustainability of livestock production systems in the highlands of Ethiopia could only be ensured through adequate and quality feed supply which may be derived from properly managed natural pasturelands. Harvesting of forage species at early stage of growth with proper grazing management (Zinash *et al*., 1995) and application of inorganic nutrients to natural pasturelands (Teshome, 1987) are among the strategies towards improving the nutritive values of natural pasturelands.

Thus, the present study was designed to assess nutritional quality of the natural pasture at different harvesting stages and levels of inorganic nutrients application.

MATERIALS AND METHODS

The study was conducted during the main rainy season from July to November 2001 on natural pastureland of smallholder farmers in Yayagullele-Debre Libanos District of the Central Highlands of Ethiopia. The study area lies between 38° 30’ E and 38° 39’ E longitude and between 9° 30' N and 9° 50' N latitude. The altitude ranges between 2200 to 2700 m.a.s.l. (meters above see level), which is characterized by bi-modal rainfall pattern ranging from 800 mm to 1200 mm, and temperature varies from 15 to 23°C. The dominant soil type of the area is chromic vertisol with a pH of 5.60 and 4.15% soil organic matter. Livestock production is characterized by group grazing, where cattle, sheep and goats are reared on private grazing lands with a high stocking rate.

The treatments consisted of four stages of harvest (30, 60, 90 and 120 days) in main plots and six N + P levels (0 + 0, 4.5 + 5.1, 9.0 + 10.2, 13.5 + 15.3, 18.0 + 20.4 and 22.5 + 25.9 kg/ha) in sub plots. Thus, altogether 24 treatment combinations were put to split-plot design and replicated thrice. The net plot size for one main and one sub plot treatment consisted of an area of 24 x 2m and 2 x 4 m, respectively. The N + P nutrients were applied in the form of Diammonium Phosphate, DAP (18:46:0).

The forage samples were dried at 60 °C to a constant weight in a forced draft oven to determine nutrient contents and overnight at 100 ± 5 °C to determine per cent dry matter. Crude protein (CP) and total ash (TASH) were determined according to AOAC (1990). Nitrogen (N) was determined by Kjeldhal method, which was then multiplied by 6.25 to estimate the CP content. Total ash was determined by igniting the forage samples in a muffle furnace at 550 ± 50 °C for 5 hrs. Neutral detergent fiber (NDF) and Acid detergent fiber (ADF) were determined according to Goering and van Soest (1970). Hemicellulose was determined as the difference between NDF and ADF, where as the cellulose content was determined by subtracting ADL and ADF-ash from ADF. The modified Tilley and Terry method was used for determination of *in vitro* dry matter digestibility (IVDMD) (van Soest and Robertson, 1985). Data were subjected to statistical and correlation analyses using Minitab (1998).

RESULTS AND DISCUSION

Hemicelluloses and cellulose contents increased significantly ($p \leq 0.05$) with advancing harvesting stage. Hemicellulose and cellulose increased in the control from 24.5 to 26.3 % and 15.5 to 27.0 % at 30 to 120 days of harvesting, respectively (Table 1). However, nutrient levels did not affect the hemicellulose and cellulose contents. Similar results were also obtained by Kidunda *et al*. (1990).The correlation between cellulose and stage of harvesting was significantly ($p \leq 0.05$) positive (r = 0.92). The results of the present study were in line with those reported by Moore and Hatfield (1994).

Harvesting stage significantly ($p \leq 0.05$) increased NDF and ADF contents. The NDF and ADF contents in the control increased from 47.5 to 66.9 % and from 22.4 % to 42.9 % at 30 and 120 days of harvesting, respectively (Table 2). Both the NDF and ADF contents were not significantly ($p \geq 0.05$) affected by nutrient levels. The results of p the present study were in line with the reports of Zinash *et al*., (1995) which described nutrient levels at the same harvesting stage did not affect NDF and ADF contents. The increased NDF and ADF contents with advancing harvesting stage might be associated with an increase in cell wall lignifications as forages get matured.

Advancing the harvesting stage significantly ($p \leq 0.05$) decreased the CP content of the forages from the natural pasture (Table 3). The mean CP in control ranged from 6.8 % at 30 days to 4.8 % at 120 days of harvesting. Nutrient levels significantly ($p \leq 0.05$) improved the CP content. Application of nutrients at 22.5 kg N + 25.9 kg P/ha resulted in the highest CP content of 11.8 % at 30 days of harvesting as compared to the CP content in the control (6.8 %). The results revealed that the reduction in CP content with advancing harvesting stage was not avoided using higher nutrient levels. The results obtained in this study were in agreement with those reported by Zinash *et al*. (1995) who reported the decline in CP content of the pasture along with increasing stage of harvesting, which might be due to the dilution of the CP content by increasing structural carbohydrates of forages harvested at late maturity (Hassan *et al*., 1990). While the relationship between nutrient levels and CP content was significantly ($P<0.05$) positive with correlation coefficient (r = 0.51), the relationship between stage harvesting and the CP content was significantly ($p \leq 0.05$) negative with correlation coefficient (r = −0.81).

Nutrient levels significantly ($p \leq 0.05$) improved total ash (TASH) content from 12.3% in control to 22.4% at 22.5 kg N + 25.9 kg P/ha nutrient levels at 30 days of harvesting (Table 3). But the total ash content of the natural pasture declined with advancing stage of harvesting. These results were in line with those reported by Zinash *et al*. (1995). The authors indicated the decline in total ash content of forages from fertilized natural pastures as cutting interval increased. This might be related to rapid growth of the fertilized pasture which brings about earlier dilution and translocation of minerals from vegetative portion of the plant to roots at late stage of maturity Maynard *et al*., (1981). The interaction between harvesting stage and nutrient levels was also significant ($p \leq 0.05$) for total ash content.

Advancing harvesting stage significantly ($p \leq 0.05$) decreased *in vitro* dry matter digestibility (IVDMD) and increasing nutrient levels significantly ($p \leq 0.05$) increased IVDMD (Table 3). Harvesting at 30 days of growth stage and nutrient application improved the IVDMD from 67.8 % in control to 79.7 % in 22.5 kg N + 25.9 kg P/ha nutrient levels, respectively. The IVDMD declined markedly with increased days of harvesting at the same or different levels of nutrients. Although, nutrient levels did not change the effect of stage of harvesting on the IVDMD, nutrient application in the pasture improved IVDMD at early stages of growth than in control. This was in agreement with reports of Zinash *et al*. (1995) who reported the depressed

IVDMD of the grass species harvested at relatively advanced stages of harvesting. 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). The interaction between harvesting stage and nutrient levels was also significant ($p \leq 0.05$) for IVDMD.

The results of this study revealed that early harvesting and nutrient application resulted in higher nutrient concentration of forages in the pasture. Harvesting at 30 days of growth stage with nutrient levels above 22.5 kg N + 25.9 kg P/ha increased the nutritive values of forages.

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Tab. 1.: Hemicellulose (HCE) and cellulose (CEL) at different harvesting stages and nutrient levels in per cent

Harvesting stages (day)		Nutrients, N + P (kg/ha)						Mean ± SE
		0 + 0	4.5 + 5.1	9 + 10.2	13.5 + 15.3	18 + 20.4	22.5 + 25.9	
30	HCE	24.5^{a}	25.2^{a}	23.5^{a}	24.6^{a}	24.3^{a}	24.4^{a}	$24.53^{a} \pm 0.26$
	CEL	15.5^{a}	14.6^{a}	15.3^{a}	16.3^{a}	16.9^{a}	17.1^{a}	$15.96^{a} \pm 0.39$
60	HCE	27.2^{b}	23.5^{c}	25.3^{b}	19.8^{d}	26.0^{b}	24.7^{bc}	$24.68^{a} \pm 1.10$
	CEL	16.4^{a}	19.7^{b}	19.5^{b}	23.2^{d}	19.5^{b}	17.0^{ab}	$19.21^{b} \pm 0.98$
90	HCE	23.4^{a}	26.1^{a}	28.9^{c}	27.2^{c}	26.1^{bc}	25.6^{bc}	$26.22^{b} \pm 0.74$
	CEL	27.4^{b}	25.0^{c}	22.7^{a}	22.6^{a}	25.0^{dg}	23.9^{e}	$24.42^{c} \pm 0.73$
120	HCE	26.3^{b}	26.5^{ab}	26.9^{a}	26.7^{ab}	27.2^{b}	26.7^{b}	$26.33^{b} \pm 0.48$
	CEL	27.0^{b}	25.2^{c}	25.4^{c}	28.1^{cd}	26.8^{bc}	27.7^{bc}	$26.70^{d} \pm 0.48$
Mean ± SE	HCE	24.95 ± 0.84	25.33 ± 0.67	26.15 ± 1.15	24.58 ± 1.69	25.90 ± 0.60	25.75 ± 0.50	
	CEL	21.56 ± 3.26	21.13 ± 2.51	20.74 ± 2.17	22.51 ± 2.41	22.05 ± 2.31	21.44 ± 2.65	

Means and overall means of similar parameters within rows and columns with different superscripts are significantly different at ($p \leq 0.05$).

Tab. 2.: Neutral detergent fiber (NDF) and Acid detergent fiber (ADF) at different harvesting stages and nutrient levels

Harvesting stages (day)		Nutrients, N + P (kg/ha)						Mean ± SE
		0 + 0	4.5 + 5.1	9 + 10.2	13.5 + 15.3	18 + 20.4	22.5 + 25.9	
30	NDF	47.5^{ab}	46.5^{a}	45.7^{a}	48.1^{b}	48.6^{b}	48.9^{b}	$47.55^{a} \pm 0.51$
	ADF	22.4^{a}	21.4^{a}	22.2^{ac}	23.3^{abc}	24.3^{bc}	24.5^{b}	$23.02^{a} \pm 0.50$
60	NDF	52.2^{c}	52.6^{c}	54.0^{cd}	52.8^{c}	54.7^{d}	51.3^{c}	$52.93^{b} \pm 0.50$
	ADF	25.0^{ad}	29.1^{b}	28.7^{bc}	33.1^{df}	28.7^{bc}	25.1^{ac}	$28.28^{b} \pm 1.23$
90	NDF	64.1^{df}	63.7^{f}	63.6^{f}	61.7^{gh}	63.3^{fg}	61.6^{h}	$63.00^{c} \pm 0.44$
	ADF	40.7^{e}	37.7^{de}	34.7^{ef}	34.5^{f}	37.2^{e}	36.0^{e}	$36.80^{c} \pm 0.94$
120	NDF	66.9^{g}	67.1^{g}	67.5^{g}	70.6^{j}	69.5^{j}	70.0^{j}	$68.60^{d} \pm 0.66$
	ADF	42.9^{fg}	40.6^{fg}	40.6^{g}	43.9^{g}	42.3^{g}	43.4^{g}	$42.28^{d} \pm 0.57$
Mean ± SE	NDF	57.68 ± 4.65	57.48 ± 4.79	57.70 ± 4.90	58.30 ± 4.98	59.03 ± 4.61	57.95 ± 4.87	
	ADF	32.75 ± 5.27	32.20 ± 4.35	31.55 ± 3.95	33.70 ± 4.22	33.13 ± 4.06	32.25 ± 4.56	

Means and overall means of similar parameters within rows and columns with different superscripts are significantly different at ($p \leq 0.05$).

Tab. 3.: Crude protein (CP), Total ash (TASH) and *In vitro* dry matter digestibility (IVDMD) at different harvesting stages and nutrient levels

Harvesting stages (day)		Nutrients, N + P (kg/ha)						
		0 + 0	4.5 + 5.1	9 + 10.2	13.5 + 15.3	18 + 20.4	22.5 + 25.9	Mean ± SE
30	CP	6.8^{c}	7.9^{b}	8.8^{c}	9.3^{d}	10.1^{e}	11.8^{f}	$9.10^{a} \pm 0.71$
	TASH	12.3^{ac}	13.1^{ac}	13.8^{ac}	14.1^{a}	11.0^{bc}	22.4^{de}	$14.45^{ac} \pm 1.65$
	IVDMD	67.8^{a}	70.0^{b}	71.9^{c}	75.2^{d}	78.0^{e}	79.7^{f}	$73.77^{a} \pm 1.90$
60	CP	6.1^{b}	6.9^{c}	8.0^{de}	8.3^{e}	9.2^{f}	10.0^{g}	$8.10^{b} \pm 0.59$
	TASH	16.5^{b}	18.5^{be}	18.6^{be}	11.0^{ac}	15.3^{d}	20.7^{e}	$16.77^{b} \pm 1.38$
	IVDMD	65.6^{be}	66.2^{ae}	68.3^{dj}	68.9^{gj}	74.3^{f}	72.8^{g}	$69.35^{b} \pm 1.43$
90	CP	5.3^{c}	6.0^{df}	6.3^{f}	6.8^{f}	7.6^{gh}	8.0^{h}	$6.67^{c} \pm 0.41$
	TASH	18.2^{d}	24.8^{f}	13.7^{gi}	6.7^{h}	16.4^{di}	14.8^{i}	$15.8^{ab} \pm 2.42$
	IVDMD	51.2^{c}	58.1^{d}	62.5^{e}	65.4^{fk}	66.8^{gk}	68.8^{h}	$62.13^{c} \pm 2.66$
120	CP	4.2^{d}	4.7^{e}	4.9^{f}	4.7^{g}	4.8^{i}	5.4^{k}	$4.78^{d} \pm 0.16$
	TASH	10.0^{ef}	13.9^{d}	8.3^{fg}	6.6^{g}	19.7^{h}	16.3^{i}	$12.50^{cd} \pm 2.06$
	IVDMD	41.1^{d}	43.3^{e}	47.3^{f}	51.0^{g}	53.0^{h}	54.8^{i}	$48.42^{d} \pm 2.23$
Mean ± SE	CP	$5.60^{a} \pm 0.56$	$6.38^{b} \pm 0.68$	$7.00^{c} \pm 0.87$	$7.28^{c} \pm 1.00$	$7.90^{d} \pm 1.15$	$8.80^{e} \pm 1.37$	
	TASH	$14.25^{a} \pm 1.88$	$17.58^{b} \pm 2.69$	$13.60^{a} \pm 2.10$	$9.60^{c} \pm 1.82$	$15.60^{ab} \pm 1.80$	$18.55^{bd} \pm 1.79$	
	IVDMD	$56.43^{a} \pm 6.30$	$59.40^{b} \pm 5.91$	$62.50^{c} \pm 5.42$	$65.13^{d} \pm 5.13$	$68.03^{e} \pm 5.52$	$69.03^{e} \pm 5.25$	

Means and overall means of similar parameters within rows and columns with different superscripts are significantly different at ($p \leq 0.05$).

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