Effect of Altitudes and Harvesting Stages on Agronomic Responses and Chemical Composition of *Brachiaria* grass Cultivars in Northwestern Ethiopia

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Abstract
The effects of altitude and harvesting stages on the performance of *Brachiaria brizantha* (Marandu, and La Libertad) and *B.* hybrid cv. Mulato II grass were evaluated in Ethiopia. The data collected consisted of plant height (PH), tiller density, number and length of leaves, and dry matter yield. Chemical analysis of forage samples was done for dry matter, ash, crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL). Results indicated that the highest PH was recorded at all sites by La Libertad which was followed by Mulato II and the highest DM yield by Mulato II followed by La Libertad. There was significant difference ($P<0.05$) in DM yield with increasing harvesting stages in cultivars. Except, ADF and ADL in Mulato II, NDF, ADF and ADL concentrations significantly ($P<0.05$) increased as harvesting time was delayed. CP content declined with increased harvesting stages. However, highest DMY and CP and lowest NDF and ADF concentrations were recorded by Mulato II. Overall results indicated that *Brachiaria* cultivars were affected by both harvesting stages and altitudes. In Ethiopia, exceptionally all cultivars had high nutritive value and DM yield by many folds in the highlands than of other countries reported and therefore, could be a potential livestock feed in the country.

Keywords: dry matter yield, height, La libertad, Marandu, MulatoII, tiller number

1. Introduction

In Ethiopia, the livestock sector has considerable economic and social importance at regional and national levels [1]. The country has the largest livestock population among African countries [2] and has high potential in livestock genetic resources [3]. However, the productivity of livestock is below the African average due to inadequate supply of feed and poor feeding practice [1]. According to CSA report [2], the major feed resources in the country are green fodder (54.59%), crop residue (31.6%), hay (6.81%) and agricultural byproducts (1.53%). However, such feed sources are inadequate in nutrient content especially during the dry season [4] and crop residues are of low nutritive quality. One of the means of climate smart agriculture which can help to reduce greenhouse gas emissions and increase livestock productivity of the country is through improved livestock feed and feeding practices [5]. Of the adaptable forage grasses is Napier grass (*Pennisetum purpureum*) which is abundant in tropical countries including Ethiopia. However, Napier grass, one of the most widely cultivated forage in Africa is susceptible to smut and stunt diseases causing a decreasing forage production [6]; which has also limited its expansion to drier areas. According to Ghimire et al. [7] *Brachiaria* cultivars are the most promising option for farmers in east-Africa in improving both feed availability during dry season and

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nutritive quality leading to increase animal performance. Grasses have demonstrated to be highly productive, nutritive and socially acceptable in Asia, Africa and in Florida, USA for different livestock production systems [8].

Brachiaria grasses are native to east Africa, are extensively grown as livestock forage in south America [9] and East Asia [10], and are believed to occupy over 99 million hectares in Brazil alone [11]. Morphologically they closer to the genus *pennisetum pedicellatum* (also called Desho grass in Ethiopian) in which it shares the acidic wetter areas of southern Ethiopia [12]. Moreover, the *Brachiaria* grasses have high forage yield [13]; reduced greenhouse gas emission [14]; contribution to carbon sequestration [15] and produce abundant roots which contribute to the collection of water, soil aggregation and aeration [16]. Ghimire et al. [7] reported *Brachiaria* genus increased 15 to 40% milk production in Kenya and is palatable grass to animals [17].

Though the genus *Brachiaria* grasses in improving both feed availability during dry season and nutritive quality have the most promising option to a significant enhancement in livestock productivity, there is little or no research on the agronomic performance and chemical composition under Ethiopian context. Hence, the grass's performance needs to be understood because of different climate extremes (mainly drought), the prevalence of low fertility soils, and the anticipated high incidence of tropical pests and diseases. Therefore, the present study was conducted to evaluate agronomic responses and chemical composition of selected *Brachiaria* grass in different harvesting frequencies at different altitudes.

2. Materials and methods

Description of experimental areas

The study was conducted in three agro-ecologies under rainfed management. The low altitude area was Futan (11^0 22'' N, 28^0 19'' E) at Tach Gayint district located at an altitude of 1230 masl. According to Tessera [18], annual temperature of the district ranges from 13ºC to 27ºC and precipitation from 900 to 1000 mm per annum. The mid altitude location was represented by a place called Woreta at Fogera district which is situated at 11º58N and 37º41E at an altitude ranges 1774 masl and is predominantly classified as mid altitude agro-ecology. The mean annual rainfall is 1216.3 mm and ranges from 1103 to 1336 mm. According to the district Office of Agriculture, the dominant soil type is black clay soil (ferric vertisols). The highland area was represented by a place named as "Melo", is located near Debre Tabor Town, South Gondar Administrative Zone, Amhara Regional State. The area is located at an altitude of 2650 masl. Farta district lies between 11°32′ and 12°03′N latitude and 37°31′ and 38°43′E longitude. The soils of Melo site are characterized by clay and sand mixture with chemical composition of 2.26% organic matter, 0.11% total nitrogen and pH of 5.47 [19]. The mean annual rainfall is about 1570 mm and the mean maximum and minimum annual temperatures were reported to be 21.5 C and 9.6 C respectively [20].

Land preparation, planting and experimental design

The experiment was laid-out in a factorial arrangement of three altitudes (low, mid and high) and three harvesting stages (60-, 90- and 120-d) in a randomized complete block design with three replications. A total area of 341 m^2 was selected from each of the three locations. The experimental land was ploughed in May and harrowed in June 2017. The land was divided into three blocks each of which comprised three plots (3*3 m each). Planting materials of root splits (*Brachiaria brizantha* cultivars (cv Marandu 16550, cv La Libertad 16551), were collect from International Livestock Research Institute (ILRI) Forage Gene Bank Addis Ababa and *Brachiaria* hybrid cv. Mulato II obtained from ICIPE). The cultivars were planted in rows using root splits on a well-prepared soil. The spacing between rows and plants was 50 cm and 30 cm, respectively. Land preparation, planting, weeding and harvesting were undertaken according to the recommendations of. Chemical fertilizers, di-ammonium phosphate and urea, were applied at rate of 100 kg ha^{-1} and urea at 25 kg ha^{-1}, respectively, during planting and after establishment based on the recommendations for the grass. After planting, weed control and related management practices were applied according to standard practice for the grass.

Data collection
Plant height and leaf length were measured from 10 plants that were randomly selected from middle rows of each plot at 60-, 90- and 120-d after planting at three locations. The tiller density and leaves were determined as mean counts taken from 10 plants that were randomly selected from middle rows of each plot at 60 d, 90 d and 120 d after planting at all locations. To determine biomass yield the forage harvesting was done by hand using a sickle leaving a stubble height of 8 cm according to recommended practice. A fresh herbage yield of *B. brizantha* cultivars and *B.* hybrid cv. Mulato II grasses were measured immediately after each harvest using a portable balance with a sensitivity of 0.01 g. Representative samples were taken from each plot at each site and were dried in a draft oven at 65^{o}C for 72 h before being sent to the laboratory for chemical analysis.

Chemical composition
The chemical composition of all samples was conducted at Debre Berhan Agricultural Research Center Animal Nutrition Laboratory. Samples were dried at 65^{o}C for 72 hours and ground to pass through a 1mm sieve. Ash/Organic matter (OM), Dry mater (DM), Crude protein and total ash were determined according to AOAC [21]. The neutral detergent fibers (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL) were determined according to Van Soest and Robertson [22]. The CP was calculated as percentage of nitrogen in the sample multiplied by a factor of 6.25.

Data Analysis Data on agronomic parameters and nutritive value of samples were subjected to ANOVA based on the model below. The data analyses were conducted using general linear model of SAS version 9.0 [23]. When necessary, Tukey's test was performed for separation of treatment means using $P<0.05$ as significance level. The statistical model for data analysis was:

$$Yijk=\mu+Ai+Hj+Ck+Ai*Hj+A*H+A*C+H*C+A*C*H+\varepsilon ijk$$

where:
Yijk is the response (plant morphological parameters, chemical composition, and yield of *B. brizanthagrass*) at each altitude and harvesting days;
μ=overall mean;
Ai=altitude (i=low, mid and high);
Hj=effect of harvesting days (j=60, 90, and 120 days);
Ck=cultivars (Marandu, La libertad and Mulato II*)*
Ai*Hj=the interaction of i^{th} altitude and j^{th}harvesting day;
A*H=interaction of altitude cutting age;
A*C=interaction of altitude and cultivars;
H*C=interaction of cutting age and cultivars;
A*H*C=interaction of altitude, harvesting stages and cultivars;
εijk=the residual error.

3. Results and discussion

Effect of harvesting Stages and altitudes on agronomic responses of Brachiria cultivars

The results of the effect of harvesting stages and altitudes and their interactions on agronomic responses of Mulato II, Marandu and La Libertad are presented in Table 1.
The results obtained in the three agro-ecologies indicated that with the exception of leaf length (LLPP) in Mulato II and Marandu, all morphological characteristics were scored highest performance at low altitude. All morphological characteristics of the cultivars were significantly affected ($P<0.05$) by harvesting stage and altitudes. La Libertad scored highest in plant height (PH) and NLPP followed by Mulato II and Marandu respectively; whereas number of tillers per plant (NTPP) and Leave length per plant (LLPP) scored highest by Mulato II followded by La Libertad in the former. There was no significant ($P<0.05$) difference between in LLPP between La Libertad and Marandu

Table 1. Effects of altitude, harvesting stages and their interactions on plant morphological characteristics of Mulato II, Marandu and La Libertad grasses

Factors		Cultivars		
		Mulato II	Marandu	La Libertad
Parameters	Altitudes			
	low	71.52[a]	65.39[a]	82.70[a]
	Mid	57.26[ab]	58.72[b]	71.62[b]
	High	49.03[b]	42.82[c]	65.96[b]
PH	Days to harvest			
	60	40.67[c]	34.59[c]	57.53[c]
	90	58.78[b]	55.64[b]	76.56[b]
	120	78.37[a]	76.70[a]	86.19[a]
	SE	3.62	3.94	3.00
	Cul	59.27[b]	55.64[c]	73.43[a]
	Cul* al		<0001	
	Cul* hd		<0001	
	Al*hd		<0001	
	cul*al*hd		<0001	
	low	75.39[a]	54.37[a]	55.12[a]
	Mid	64.82[ab]	45.14[b]	55.92[a]
	High	53.69[b]	26.58 [c]	41.27[b]
NTPP	Days to harvest			
	60	46.46[c]	22.98c	37.62[c]
	90	64.37[b]	41.94b	49.77[b]
	120	83.08[a]	61.17a	64.92[a]
	SE	3.48	3.86	2.57
	Cul	64.63[a]	42.03[c]	50.77[b]
	Cul*al		<0001	
	Cul*hd		<0001	
	Al*hd		<0001	
	cul*al*hd		<0001	
	low	8.32[a]	9.42[a]	18.67[a]
	Mid	7.78[a]	8.26[a]	17.82[a]
	High	5.69[b]	6.23[b]	5.20[b]
NLPP	Days to harvest			
	60	6.11[b]	5.93[c]	12.01[c]
	90	7.82[a]	7.64[b]	14.27[b]
	120	7.86[a]	10.34[a]	15.41[a]
	SE	0.29	0.50	1.25
	cul	7.26[c]	7.97[b]	13.90[a]
	cul*al		<0001	
	Cul*hd		<0001	
	Al*hd		0.0212	
	cul*al*hd		0.0004	
	low	24.29[ab]	21.10[a]	22.07[a]
	Mid	28.63[a]	21.38[a]	20.38[b]
	High	17.07[b]	14.60[b]	13.03[c]
LLPP	Days to harvest			
	60	19.76[c]	12.80[c]	16.12[c]
	90	23.69[b]	18.79[b]	18.86[b]
	120	26.54[a]	25.49[a]	20.50[a]
	SE	1.16	1.22	0.88
	cul	23.33[a]	19.03[b]	18.49[b]
	cul* al		<0001	
	Cul* hd		<0001	
	Al*hd		<0001	
	cul*al*hd		<0001	

Treatments means with different letters in a column and rows are significantly different (P<0.05) for altitudes and harvesting stages. ns for non-significant; SE=Standard error; cul=cultivar; al=altitude; PH=plant height; NTPP=number of tillers per plant; NLPP=number of leaf per plant. LLPP=leaf length per plant.

Effect of harvesting stages and altitudes on chemical composition and forage mass of Brachiaria grass

The effect of harvesting stage, altitudes and their interaction on chemical composition, dry matter yield (DMY) and crude protein (CPY) of Mulato II, Marandu and La Libertad grasses are shown in Table 2.

Table 2. Effect of altitude, harvesting stage and their interactionon chemical composition and yield of Mulato II, Marandu and La Libertad grasses

Factors		Cultivars		
		Mulato II	Marandu	La Libertad
Parameters	Altitudes			
	low	37.83[a]	36.47[a]	37.72[a]
	Mid	36.93[b]	35.38[a]	36.94[a]
	High	35.78[c]	31.02[b]	33.48[b]
DM(%)		Days to harvest		
	60	35.50[b]	32.74[b]	34.17[c]
	90	36.51[b]	34.19[ab]	35.83[b]
	120	38.54[a]	35.94[a]	38.13[a]
	SE	0.54	0.97	0.88
	Cul	36.85[a]	34.40[b]	36.05[a]
	Cul* al		0.0175	
	Cul* hd		ns	
	Al*hd		ns	
	cul*al*hd		ns	
	low	11.71[a]	10.00[a]	10.39[a]
	Mid	10.38[b]	8.61[b]	8.75[b]
	High	7.42[c]	4.19[c]	6.20[c]
DMY(t/ha)	Days to harvest			
	60	8.20[c]	5.92[c]	6.28[c]
	90	9.71[b]	8.12[b]	8.29[b]
	120	11.60[a]	9.29[a]	10.24[a]
	SE	0.81	1.05	0.80
	Cul	9.84[a]	8.27[b]	7.78[b]
	Cul* al		<.0001	
	Cul* hd		ns	
	Al*hd		ns	
	Cul*al*hd		ns	
	low	13.19	12.66	11.20
	Mid	12.88	12.81	10.85
	High	10.98	12.46	10.38
Ash(%)	Days to harvest			
	60	13.62a	14.13a	11.60[a]
	90	10.99b	12.21b	10.27[b]
	120	12.44ab	11.58b	9.09[b]
	SE	0.62	0.51	0.64
	Cul	12.35[a]	12.64[a]	10.81[b]
	Cul* al		0.0059	
	Cul* hd		<0001	
	Al*hd		0.0024	
	cul*al*hd		<0001	

Table 2. Effect of altitude, harvesting stage and their interaction on chemical composition and yield Marandu and La Libertad grasses (continued)

Factors		Cultivars		
		Mulato II	Marandu	La Libertad
Parameters	Altitudes			
	low	14.03	13.24[a]	12.13[b]
	Mid	13.00	11.51[a]	13.50[a]
	High	11.75	8.99[b]	11.15[b]
CP(%)	Days to harvest			
	60	16.81[a]	16.70[a]	17.88[a]
	90	12.61[b]	10.51[b]	11.77[b]
	120	9.36[c]	6.53[c]	7.03[c]
	SE	1.26	1.66	1.61
	cul	12.93[a]	11.24[c]	12.23[b]
	cul* al		<0001	
	Cul* hd		<0001	
	Al*hd		<0001	
	cul*al*hd		<0001	
	low	1.36[a]	1.17[a]	1.34[a]
	Mid	1.32[a]	0.96[a]	1.04[b]
	High	0.78[b]	0.32[b]	0.71[c]
CPY(t/ha)	Days to harvest			
	60	1.47[a]	1.03a	1.09
	90	1.16[b]	0.77b	1.05
	120	0.82[c]	0.64b	0.95
	SE	0.14	0.15	0.10
	Cul	1.15[a]	0.82[c]	1.03[b]
	Cul* al		0.0042	
	Cul* hd		0.0001	
	Al*hd		<0001	
	Cul*al*hd		ns	
	low	59.9	63.68[ab]	65.63[ab]
	Mid	61.98	67.78[a]	67.74[a]
	High	60.93	62.71[b]	62.25[b]
NDF(%)	Days to harvest			
	60	55.64[c]	54.51[c]	55.11[b]
	90	62.03[b]	64.80[b]	68.73[a]
	120	65.22[a]	74.87[a]	71.78[a]
	SE	1.49	3.28	2.95
	Cul	60.96[b]	64.72[a]	65.21[a]
	Cul* al		<0001	
	Cul* hd		<0001	
	Al*hd		<0001	
	Cul*al*hd		<0001	

The results obtained indicate that with the exception of ash in all altitudes of the cultivars, CP, NDF, ADF and ADL of Mulato II and ADL and CPY of La Libertad by altitude and harvesting stage respectively, all chemical composition, dry matter yield (DMY) and crude protein yield (CPY) of Mulato II, Marandu and La Libertad grasses significantly affected (P<0.05) by altitude and harvesting stages. The dry matter yield (DMY) of Marandu significantly (P<0.05) lower than both Mulato II and La Libertad. Although there was no significant (P<0.05) differencce between Mulato II and La Libertad in DMY, numerically Mulato II greater in yield than La Libertad. Mulato II was highest both in CP and CPY value, whereas Marandu was the lowest. In crude fiber (NDF, ADF and ADL) Mulato II was significantly (P<0.05) lower than both Marandu and La Libertad. Significant (P<0.05) differeence was not observe between Marandu and La Libertad in crude fiber (NDF, ADF and ADL).

Almost all the nutrient values and yields of all cultivars were show at low altitude.

Table 2. Effect of altitude, harvesting stage and their interaction on chemical composition and yield of Mulato II, Marandu and La Libertad grasses (continued)

Parameters		Cultivars		
		Mulato II	Marandu	La Libertad
Factors	Altitudes			
	low	39.79	39.03^{b}	44.00^{a}
	Mid	38.31	42.88^{ab}	44.70^{a}
	High	38.17	46.45^{a}	41.48^{b}
ADF(%)	Days to harvest			
	60	34.23^{b}	31.03^{c}	36.06^{c}
	90	37.13^{b}	46.39^{b}	44.46^{b}
	120	44.91^{a}	50.94^{a}	49.65^{a}
	SE	1.93	3.35	2.10
	Cul	38.76^{b}	42.90^{a}	43.39^{a}
	Cul* al		<0001	
	Cul* hd		<0001	
	Al*hd		<0001	
	cul*al*hd		<0001	
	low	9.77	10.26^{b}	12.57
	Mid	10.44	12.45^{b}	12.57
	High	10.58	15.03^{a}	12.44
ADL(%)	Days to harvest			
	60	7.68^{b}	6.90^{c}	9.90^{c}
	90	9.81^{b}	13.38^{b}	12.50^{b}
	120	13.30^{a}	17.45^{a}	15.18^{a}
	SE	0.99	1.75	0.82
	Cul	10.27^{b}	12.58^{a}	12.53^{a}
	Cul* al		<0001	
	Cul* hd		<0001	
	Al*hd		<0001	
	cul*al*hd		<0001	

DM=dry matter, DMY=dry matter yield, CP=crude protein, CPY=crude protein yield, NDF=neutral detergent fiber, ADF=acid detergent fiber, ADL=acid detergent lignin. SE=Standard error; Mean values followed by a different lowercase superscript letter in the same column are statistically signi*fi*cant at p <0.05; ns for non-significant.

The findings of this research showed that both harvesting stages and altitudes have effects on plant characteristics and composition on studied *Brachiaria* grass cultivars. The overall results of the grasses in all altitude show that greatest PH, NTPP, NLPP and leaf lengths were recorded for later harvesting (120 d) than for the shorter harvesting periods (60 d and 90 d). The highest significant (P<0.05) difference of PH at low altitude of all cultivars, NTPP at low altitude by both Mulato II and Marandu cvs and both low and mid by La Libertad, number of leaves by all cultivars both at low and mid altitude and also length of leaves recorded at mid altitude by Mulato II and at low by both Marandu and La Libertad may be due to environmental conditions more suitable for the cultivars at low and mid altitude compared to high altitude. Leaf length in grasses plays an essential role in shaping the physical structure of the canopy and consequently on competition for light within the sward. One of the major adaptive responses to light competition in plants is an increase of plant height, i.e., leaf length during the vegetative period in grasses [24]. This increase in plant height is affected by phenotypic plasticity. The leaf length result is contrary to reports for other species of grasses in which the leaf length was reported to decrease as the result of stem development at a later stage of harvesting [25, 26] for grasses. Increments in plant height at later harvest stages could be due to massive root development and efficient nutrient uptake, allowing the plant to continue to increase in height as mentioned by Melkie [27]; the high DM yields of the cultivars can be attributed among other factors, to well-established root

system that enabled the grass to extract growth resources from the soil [28]. Moreover, this might have been due to the differences between the physiological changes of plants observed during the growing periods [29].

At the end of 120 days, Mulato II recorded highest tiller numbers (83.08 tillers/plant) than Marandu (61.17 tillers/plant) and La libertad (64.92 tillers/plant) that might be Mulato II had better DMY than the two cultivars as Nelson and Zarrough [30] report that tiller numbers are an indicator of resource use efficiency by different grass species and that the weight of a plant's tillers will determine its productivity. However, all cultivars had shown higher tiller recruitment than reported by Nguku [31] reported that Mulato II (23.8 tillers/plant) and Marandu (16.8tillers/plant). Tillers increase the chance of survival and the available forage resource of grasses [32]. Therefore, all studied cultivars had high chance of survival ability and be good source of forage in all areas. Mulato II had higher tillering and dry matter production ability than the rest of the cultivars. The distinct variation in tiller densities of the cultivars implies that these cultivars would recover faster after defoliation. Mulato II presents more tolerance to drought, fast recovery after grazing, high plant vigor and very good forage quality [33].

DM intake and contents of nutrients in feeds are major factors determining feed quality and animal productivity [34]. All studied cultivars of DMY, CP although was no significant ($P<0.05$) difference in Mulato II, CPY had highest significant ($P<0.05$) difference at low altitude than both mid and high indicate that the studied grasses perform best at low altitude. In addition to these though no significant ($P<0.05$) difference, Mulato II had lowest crude fiber (NDF, ADF and ADL) and highest dry matter yield (Table 2) at low attitude and had highest (9.84, 8.27 and 7.78 t/ha Mulato II, Marandu and La Libertad respectively) DMY in general in than other studied cultivars make outstanding cultivar especially at low altitude. Variations in DM production across the cultivars might be attributed to differences in growth rate and growth habit, which are mediated through the genotypic and phenotypic differences. This is a common phenomenon in grasses [35]. In this study, the high primary DM yield by Mulato II might be largely attributed to its large size leaves (24.29, 28.63 and 17.07 cm long at low, mid and high altitude respectively) and tiller number (75.39, 64.82 and 53.69 at low, mid and high altitude respectively) than the other two cultivars (Table 1). However, the leafy nature might be a disadvantage in dry areas where water supply is limited, as it facilitates rapid water loss through transpiration [36]. Grasses which yield the highest DM should be the most sought since they can supply the highest amount of forage to livestock. DMY of all cultivars were significantly ($P<0.05$) affected by harvesting stages with highest value at last stage (120 d) of harvesting. The higher total DM yield observed in all cultivars at the last harvest stage (120 d) were in agreement with [19, 29, 37-40] for cultivated grasses and Feyissa et al. [41] for natural pasture, in Ethiopia. Yield increment might have been due to additional tillers developed which increased leaf formation, leaf elongation and stem development [42, 27]. All these characteristics would contribute to increased photosynthetic activity and hence higher DM production. Generally, all the tested grasses Mulato II, Marandu and La Libertad showed outstanding potential as a forage plant at low followed by mid altitudes might be due to variations in altitude, temperature and soil characteristics of the three locations.

Crude protein is one of the major criteria for determining the nutritional quality of a feed [43]. This is because as level of CP increases, the DM intake by livestock and rumen microbial growth would also increase [44]. Mulato II had significantly ($P<0.05$) highest CP than other both studied cultivars. However; according to Abebe [45] productivity and nutritive value of feed resources (Natural pasture, Rhodes grass, Tef straw, Maize stover and Finger millet straw) found in the region had very low CP value 5.5, 7.1, 4.2, 2.84 and 4.12 respectively compared to all the studied grasses cvs ((La Libertad ((12.13, 13.50 and 11.15) and Marandu (13.24, 11.51 and 8.99) *and* hybrid cv. Mulato II (14.03, 13.00 and 11.75) in low, mid and high altitude respectively). Crude protein content from all the plant materials analyzed met the minimum requirements for ruminants (>7%), i.e., 6.9% for maintenance, 10.0% for beef production and 11.9% for milk production (Humphreys, 1978). All the studied *Brachiaria* cultivars had a CP content which was almost double the minimum requirement except in the high altitude of Marandu cv. The overall mean values obtained in all tested *Brachiaria* grass

observed high performance in low land (Table 1). The high temperatures at low altitude could have contributed to plants having higher CP than expected as temperatures have been reported to have effect of quality of grasses [46] although La Libertad in mid altitude (13.50%) had better CP content.

The highest CP concentration was obtained at the earliest stage of harvesting; with values declining as harvesting was delayed. This result agrees with the findings of Njarui et al. [4] and Mupenzi [47] in *Brachiaria* grasses, [17, 38] for Desho grass, and Bayble et al. [48] and Ansah et al. [42] reported for Napier grass a decreasing trend of CP with increase in harvesting age (60>90>120 days).This phenomenon is referred to as a growth dilution effect with increase in structural carbohydrate content of forage materials harvested at late maturity reducing the percentage of protein in the forage. At 60 DAP cv. Mulato II, cv. Marandú and cv. La Libertad had highest values of CP (16.81, 16.70 and 17.88%) respectively. This could satisfy the daily CP requirement of a lactating cow producing 20 to 30 L of milk per day [49]. The CP content was generally high in all the tested *Brachiaria* grasses (11.24-12.93%) compared with mean of (5.3-7.7%) in coastal lowlands of Kenya and (7-10%) in the semi-arid region of eastern Kenya as reported by Ondiko et al. [50] and Nguku et al. [31] respectively.

As would be expected, neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) concentrations all increased significantly ($P<0.05$) as harvesting time was delayed. The increasing trend of NDF concentration with increase in harvesting age agrees with Mupenzi [47] in *Brachiaria* and Asmare et al. [19] in Desho grass, where NDF concentration increased from 72.8% at 90 days to 77.7% at 150 days of age. Bayble et al. [48] recorded a similar trend when Napier grass was harvested at 60, 90 and 120 days. The ADF contents of Marandu and La libertad cultivars were higher were less digestible than Mulato II (significantly ($P<0.05$) lower NDF, ADF and ADL) indicating that Mulato II *Brachiaria* grass is superior to Marandu and La libertad cultivars. Acid detergent Lignin (ADL) content for cultivars increased with age and their mean values showed significant ($p<0.05$) differences in all cultivars during the harvest intervals as shown in Table 2. This result agrees with the findings of Nguku [31]. NDF is relevant to improvement of forage nutritional value and can be an important parameter in defining forage quality. More fibrous (NDF, ADF and ADL) pasture is associated to longer ruminal retention and limits the intake rate. For all grasses used in the study, the value of NDF was low during in all stages of harvesting except Marandu at the third harvest (74.87%). A high NDF that is above 72% will cause low intake of forage [51] and as NDF percentages increase, dry-matter intake generally will decrease [52].

The quantity of ash in any feed is a positive indicator of the inorganic (minerals) content. Generally, most forage has ash content ranging from 3% to 12% [53]. La Libertad (10.81%) which was in the range while Mulato II and Marandu cultivars investigated in this study had more than 12% ash content. Mulato II and Marandu had 12.35% and 12.64% ash content respectively, which was much higher than those reported by Kungwan et al. [54], of 6%. Overall, all the studied cultivars had a higher biomass yield and better chemical composition than natural pasture at all altitudes of Ethiopia. However, they perform best at low altitude and *Brachiaria* hybrid cv. Mulato II is a superior in both forage quantity and quality than Marandu and La Libertad.

4. Conclusions

It can be concluded that all cultivars have potential as an alternative ruminant feed in all altitude areas of Ethiopia with best at low altitude. To fully utilize the potential of these cultivars, further studies on agronomic and nutritional evaluation involving live-animal experiments are recommended.

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