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EFFECT OF HARVESTING STAGE AND ALTITUDE ON AGRONOMIC AND QUALITIES OF SIX *Brachiaria* GRASS IN NORTHWESTERN ETHIOPIA

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Abstract

Inadequate quantity and quality of feeds is the major constraints to livestock production in majority of smallholder farms in Ethiopia. A study was conducted to evaluate the effect of altitude and harvesting stages on productivity and quality of 6 (six) Brachiaria grasses (1 hybrid, 2 cultivars and 3 ecotypes) in northwestern Ethiopia. A factorial arrangement of treatments was employed with a combination of three altitudes and three harvesting stages. The data collected consisted of plant height (PH), number of tillers, number and length of leaves and fresh yield. Moreover, the forage was analyzed for dry matter content and yield, ash, crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin. All data were subjected to analysis of variance procedures, with significance test at P<0.05. Results indicated that the highest plant height (PH) was recorded in all sites (low, mid- and high altitudes) by La Libertad cultivar (cv.) followed by Mulato II (low and high altitudes) and Eth. 13726 ecotype (mid altitude). The highest number of tiller per plant (NTPP) was recorded in all sites by Mulato II followed by La Libertad. The highest DM yield was recorded by Mulato II at all altitudes, which was followed by Marandu at low and mid altitudes and in high altitude by La Libertad. There was significant difference (P>0.05) in dry matter yield (DMY) with increasing harvesting dates for all six grasses except La Libertad at high altitude. CP content declined with increased harvesting date in all studied Brachiaria grasses in all study sites. Although all six grasses had potential as an alternative ruminant feed in all altitude areas in Ethiopia, highest DMY and CP and lowest NDF and ADF concentrations were recorded by Mulato II. Thus, among the tested Brachiaria grasses Mulato II showed outstanding potential as a forage plant especially at low altitude area of northwestern Ethiopia which could be used as potential feed for ruminant livestock. However, further study on feed value of Mulato II using suitable experimental animals is recommended.

Key words: *cultivar, ecotype, hybrid, Mulato II.*

INTRODUCTION

Ethiopia owns the largest livestock population among African countries (CSA, 2017) and has high potential in livestock genetic resources (Teweldemedhn, 2018). Livestock production is an important component of the farming systems in all parts of Ethiopia and plays a vital role in the livelihood of many people (Tekliye et al., 2018*)*. However, the productivity of livestock is below the African average due to inadequate supply of feed and poor feeding practice (Shapiro et al., 2015; Gelayenew et al., 2016). The major feed resources in the country are green fodder (54.59%), crop residue (31.6%), hay (6.81%) and agricultural by products (1.53%) (CSA, 2017); such feed resources are inadequate in nutrient content especially during the dry seasons (Njarui et al., 2016) and crop residues are of low nutritive quality. To combat the livestock feed shortage, the use of improved forage plants as a feed source is recommended (Shapiro et al., 2015, FAO, 2016). One of the candidate forages that can help to alleviate ruminant feed shortage and thereby enable the country to exploit livestock resource potential is *Brachiaria* grass. *Brachiaria* grass is the most extensively grown tropical forage in Latin America (Cezário et al., 2015) and East Asia (FAO, 2015), South

Pacific, and Australia with an estimated acreage of 99 million hectares in Brazil alone (Jank et al., 2014). Recently, there has been considerable interest in *Brachiaria* grass in Africa and tropical regions of the world and several initiatives are ongoing to promote *Brachiaria* to support the emerging livestock industry in the region, especially in the dry season (Maass et al., 2015). This is due to the fact that the grass has a number of desirable traits over other species of grasses. Among the characteristics known are: adaptation to drought and low fertility soils, ability to sequester carbon; increase nitrogen use efficiency through biological nitrification inhibition (BNI) and reduce greenhouse gas emissions (Njarui et al., 2016). Recently, *Brachiaria* hybrid cv. Mulato II (MII) grass is being used in dual purpose both 'push-pull' technology (Khan et al., 2014) and its potential as livestock feed in Ethiopia reported by Adnew et al. (2018). The geographical distribution of *B. brizantha* is high in Africa encompasses Ethiopia (CIAT, 1992) and needs more research to generate valuable information that in turn help exploit maximum potential of the grass in the region where large number of livestock reside. Recent experiments elucidate that adoption of *B. brizantha* cultivars has the potential to increase milk yield from 3 to 5 liter per cow per day at farmers' condition in Kenya by 15-40% (Schiek, 2018). Similar result was obtained from a research in Rwanda that showed an increment of milk yield and meat output by 30% and 20%, respectively (CSB, 2016). Though there are diverse species of *Brachiaria* grass in Eastern and Central Africa, relatively little information is available on their agro-morphological characteristics, yield and chemical composition. The performance and yield of the different grass species could be markedly different and is also influenced by area of origin, including temperature, light intensity, total rainfall, soil type, fertilization level, and stage of maturity at harvest (Huhtanen et al., 2006; Jančík et al., 2009). In East Africa, a research report by Bogdan (1955) indicated that *B. brizantha* is very variable and several varieties show striking differences in habit, morphology and seed setting potential. It is presumed that different varieties would perform distinctly in different ecological zones, but information of this kind is not abundant in Ethiopia. The *B. brizantha* grass available in Ethiopia is the wild one and ecologically different (an ecotype) from that in other countries, which is not developed/ enriched like that of other countries such as Brazil. Therefore, the study was aimed to evaluate the performance of *B. brizantha* cultivars (Marandu, La Libertad), hybrid (Mulato II) and ecotypes /wild (Eth. 13726, Eth. 13809 and Eth. 13777) in three distinct agro-ecologies of northwestern Ethiopia to select the best herbage yielding and quality so as to exploit properly the better performing grasses for wider distribution among subsistence and commercial livestock producers in the country.

MATERIALS AND METHODS

Description of the study areas

The study was conducted in south Gondar, (Amhara Regional State, Ethiopia) at three agro-ecologies (i.e. low, mid and high altitudes) using a rain fed system. The low altitude area was represented by a location called Futan at Tach Gayint district located at 11°22′N and 28°19′E at an altitude of 1230 m above sea level. Mean minimum and maximum annual temperature of the district ranges from 13 to 27°C and the mean minimum and maximum annual rainfall ranges 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 11°58′N and 37°41′E at an altitude range of 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 (ferric vertisols) (personal communication). The highland area was represented by Farta district, Tsegure Eyesus Kebele at a site called Melo located near Debre Tabor Town, at 11°11′N and 38°E and at an altitude of 2650 m above sea level. 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. 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.

Land preparation, planting and experimental design

A total land area of 682 m^2 was prepared from each location. The experimental land was properly plowed 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 *Brachiaria brizantha* cultivars (Marandu, La Libertad), hybrid (Mulato II) and ecotypes/wild (Eth. 13726, Eth. 13809 and Eth. 13777) were collect from International Livestock Research Institute (ILRI), Forage Gene Bank Addis Ababa, Ethiopia. The grasses were planted using vegetative root splits in rows.

The experiment was laid out in a factorial arrangement of three altitudes (low, mid and high) and three harvesting stages (60 days, 90 days and 120 days) in a randomized complete block design with three replications. The spacing between rows and plants was 50 cm and 30 cm, respectively. Land preparation, planting, weeding, harvesting and related management practices were applied according to standard practice for the grass (Nguku et al., 2016).

Artificial fertilizers (di-ammonium phosphate and urea) were applied at rate of 100 kg/ha and urea at 25 kg/ha during planting and after establishment based on the recommendations for the grass. Weed management and observation of plant growth characteristics were done from the inception of experiment up to data collection time.

Data collection

Morphological parameters such as plant height and leaf length were measured from 10 plants that were randomly selected from middle rows of each plot at 60 days, 90 days and 120 days after planting. Plant height was measured on the primary shoot from the soil surface to the base of the top-most leaf using a meter rule as described by (Rayburn and Lozier, 2007).

The number of tillers and leaves was computed as mean counts of ten plants from each row in each replication.

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. The fresh herbage yield was 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°C for 72 h before chemical analysis. The dried sample was kept in cool dry place until it was analyzed for chemical constituents.

Chemical analyses

The grass samples were dried at 65°C for 72 h and ground to pass through a 1 mm sieve. Ash/organic matter (OM), dry mater (DM), crude protein and total ash were determined according to AOAC (1990). The neutral detergent fibers (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL) were determined according to Van Soest and Robertson (1985). The CP was calculated as percentage of nitrogen in the sample multiplied by a factor of 6.25.

Data analysis

The collected data were analyzed using general linear model of statistical analysis system (SAS) procedures of 2002 version 9.0. Tukey honest significant test was employed for variables whose *F* values declared a significant difference ($P<0.05$).

The statistical model for data analysis was:

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

Where: Yijk is the response (plant morphological parameters, chemical composition, and yield of *B. brizantha* cv and hybrid and ecotypes grass) 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 = *Brachiaria brizantha* ecotypes (Marandu, La libertad, Mulato II, Eth. 13726, Eth. 13809 and Eth. 1377);

Ai*Hj = the interaction of i^{th} altitude and j^{th} harvesting date;

A*C = interaction of altitude and cultivars;

H*C = interaction of harvesting date and cultivars;

εijk = the residual error.

RESULTS AND DISCUSSIONS

Effects of harvesting stages on morphological characteristics (PH, NTPP, NLPP and LLPP) of six *Brachiaria* grasses in three altitudes

Results of the effect of harvesting stages on plant morphological characteristics (PH, NTPP, NLPP and LLPP) of six *Brachiaria* grasses in three altitudes are presented in Table 1. The finding indicated that with the exception of number of leaf per plant (NLPP) of Eth. 13726 and Eth.13809 at low, Mulato II and Eth. 13777 at mid and leaf length per plant (LLPP) of La Libertad in all the three altitudes, the morphological characteristics (PH, NTPP, NLPP and LLPP) of all the studied six *Brachiaria* grasses were significantly affected (P<0.05) by harvesting stages in all altitudes.

The overall results of the grass in all altitude show that greatest PH, NTPP, NLPP and leaf lengths were recorded for later harvesting stages (120 d) than for the shorter harvesting periods (60 d and 90 d). Leaf length in grasses plays an essential role in shaping the physical structure of the grass canopy and consequently on competition for light within the sward. Mean plant heights for the grasses generally increased and were significantly different (P<0.05) throughout the growth period. The increment in PH at latter stage with advancement in harvesting dates in all altitudes might be due to full development of stem and leaf. This result is in agreement with Asmare et al. (2017) and Taye et al. (2007) who reported the same characteristics for Desho and Napier grass, respectively.

Although height may not be an important estimate on the expected biomass yield, as it has been clearly demonstrated that the shorter Mulato II than La Libertad had the best primary DM yield, all six *Brachiaria* grasses had higher PH than *Brachiaria* grass cultivars (Llanero, MG4, Marandu, Piata, Mulato II, Basilisk and Xaraes) in Kenya dry lands as reported by Nguku et al. (2016).

The number of tillers per plant in studied grasses were significantly (P<0.05) increased in all altitude in relation to the advance in harvesting date of plants as the result of the development of new shoots bearing on each plant result in greater number of tillers as the plant matures.

Effect of harvesting dates on chemical composition and yield of *Brachiaria* (hybrid, cultivars and ecotypes) grass

The results of the effect of harvesting stages on chemical composition and forage biomass yield of *Brachiaria* hybrid (cv Mulato), cultivars (Marandu and La Libertad) and ecotypes (Eth 13726, Eth.13809 and Eth.13777) grasses in three altitudes are presented in Table 2. According to the current study, except dry matter (DM) content of Mulato II grass at low altitude, there were significance difference (P<0.05) in the studied *Brachiaria* grasses by harvesting stages in all altitudes. Similarly, with the exception of dry matter yield (DMY) of La Libertad at high altitude, there were significance difference (P<0.05) in the studied *Brachiaria* grasses by harvesting stages at all altitudes of DM yield. All studied grasses of CPY and Ash in all altitudes were significantly affected (P<0.05) by harvesting stages, except CPY and ash of Marandu and La Libertad in all and high altitudes respectively and also at mid of ecotype Eth. 13777 of CPY and ecotype (Eth. 13726 and Eth.13809) at low and all altitudes, respectively.

Moreover; with the exception of acid detergent fiber (ADF) at mid for Mulato II, NDF at low altitude of Eth.13809, acid detergent lignin (ADL) in the mid altitude of La Libertad and at high altitude of Eth. 13777 other chemical compositions (NDF, ADF and ADL) of all studied grass at all altitudes were significantly affected (P<0.05) by harvesting stages. However, CP of all studied grasses were significantly affected (P<0.05) by harvesting stages at all altitudes.

The highest total DM yield observed at the last harvest stage (120 d) was in agreement with Asmare et al. (2017) in desho grass and Feyissa et al. (2014) for natural pasture, in Ethiopia. This high DM yield might be due to high number of tillers and leaf formation (Nguku et al., 2016), leaf elongation and stem development (Asmare et al., 2017); due to the rapid increase in the tissues of the plant (Minson, 1990). The declined trend of CP might be due to maturity of the grasses as stated by Vega et al. (2006).

Table 1. Effects of harvesting dates and altitudes on plant morphological characteristics (PH, NTPP, NLPP and LLPP) of six *Brachiaria* grasses

Parameters	Attitudes	HD	Mulato II	Marandu	La Libertad	Eth. 13726	Eth.13809	Eth.13777
		60	51.90^{c}	49.90^{c}	71.47^{b}	32.30^{c}	36.57^{c}	55.74^{c}
	Low	90	72.93^{b}	65.87^{b}	87.70^{a}	66.17^{b}	52.97^{b}	66.52^{b}
		120	89.73^{a}	80.40^{a}	88.93^{a}	79.70^{a}	79.67^{a}	74.90^{a}
		SE	5.47	4.43	3.09	0.50	6.30	2.78
		60	32.73^{c}	30.77^{c}	46.43^{c}	29.00^{c}	33.83^{c}	50.41^{c}
	Mid	90	57.57^{b}	59.47^{b}	72.07^{b}	64.73^{b}	59.80^{b}	60.04^{b}
PH		120	81.47^{a}	85.93^{a}	96.37^{a}	77.17^{a}	65.33^{a}	78.30^{a}
		SE	7.04	7.97	7.24	7.24	4.86	4.12
		60	37.37^{c}	23.10^{c}	54.70^{b}	18.77^{c}	29.03^{c}	37.52^{c}
	High	90	45.83^{b}	41.60^{b}	69.90^{a}	39.60^{b}	46.27^{b}	49.71^{b}
		120	63.90^{a}	63.77^{a}	73.27^{a}	52.20^{a}	59.80^{a}	55.48^{a}
		SE	3.94	5.92	2.92	4.9	4.49	2.65
		60	63.17^{c}	32.73^{c}	42.53^{c}	18.33^{c}	27.60^{b}	16.33^{c}
	Low	90	73.70^{b}	54.90^{b}	54.00^{b}	24.73^{b}	30.07^{b}	21.74^{b}
		120	89.30^{a}	75.47^{a}	68.83^{a}	31.07^{a}	49.63^{a}	37.19^{a}
		SE	3.84	6.18	3.86	1.00	3.40	3.16
		60	41.83^{c}	25.50^{c}	42.53^{c}	22.70^{c}	26.30^{c}	20.19^{c}
	Mid	90	65.77^{b}	49.43^{b}	55.20^{b}	29.77^{b}	32.07^{b}	28.22^{b}
NTPP		120	86.87^{a}	60.50^{a}	70.03^{a}	48.53^{a}	46.83^{a}	48.00^{a}
		SE	6.51	5.17	4.04	3.86	3.08	4.16
		60	34.37^{c}	10.70^{c}	27.80^{c}	12.63^{c}	21.50^{c}	19.11^{c}
	High	90	53.63^{b}	21.50^{b}	40.10^{b}	20.70^{b}	27.43^{b}	29.11^{b}
		120	73.07^{a}	47.53^{a}	55.90^{a}	28.67^{a}	40.23^{a}	44.56^{a}
		SE	5.60	5.47	4.07	2.32	2.79	3.72
		60	7.43b	7.63^{b}	16.13^{b}	4.03	4.30	3.45^{c}
	Low	90	8.83a	9.50^{ab}	19.31^{ab}	4.33	4.70	5.37^{b}
		120	8.70ab	11.13^{a}	20.57^{a}	5.57	5.30	7.63^{a}
		SE	0.45	0.57	0.76	0.79	0.24	0.64
		60	6.77	5.03^{b}	15.77^{b}	4.47^{b}	3.63^{b}	4.33
	Mid	90	8.23	7.37^{b}	18.53^{a}	5.33^{ab}	4.47^{ab}	5.00
NLPP		120	8.33	12.37^{a}	19.17^{a}	6.73^{a}	5.47^{a}	5.89
		SE	0.33	1.12	0.57	0.37	0.32	0.31
		60	4.13^{b}	5.10^{b}	4.13^{b}	3.40^{b}	2.93^{b}	3.63^{b}
	High	90	6.50^{a}	6.07^{ab}	4.97^{ab}	4.07^{ab}	3.70^{ab}	4.15^{ab}
		120	6.43^{a}	7.53^{a}	6.50^{a}	4.77^{a}	4.70^{a}	5.66^{a}
		SE	0.42	0.43	0.42	0.22	0.29	0.36
		60	23.03^{b}	14.17^{c}	20.07	16.63^{c}	17.02^{c}	15.09^{b}
	Low	90	24.03^{b}	19.97^{b}	20.77	18.43^{b}	19.61^{b}	18.56^{a}
		120	25.80^{a}	29.17^{a}	24.37	20.77^{a}	23.89^{a}	20.37^{a}
		SE	0.44	2.21	0.84	0.46	1.03	0.85
		60	21.60^{b}	13.93^{c}	16.60	15.70^{b}	21.13	13.63^{b}
	Mid	90	30.00^{a}	21.80^{b}	21.80	20.93^{a}	24.91	18.41^{a}
LLPP		120	34.30^{a}	28.40^{a}	22.73	21.50^{a}	25.65	20.13^{a}
		SE	1.93	2.11	1.21	1.01	1.00	1.04
		60	14.63^{c}	10.30^{c}	11.70	10.53^{b}	14.41^{b}	10.20^{b}
	High	90	17.03^{b}	14.60^{b}	13.00	12.33^{b}	15.02^{b}	13.19^{ab}
		120	19.53^{a}	18.90^{a}	14.40	18.80^{a}	19.37^{a}	16.37^{a}
		SE	0.75	1.26	0.56	1.32	0.83	0.98

*Treatments means with different letters in a rows are significantly different (***P<0.00); **P<0.01, *P<0.05) for harvesting dates. SE=Standard error; HD= harvesting dates; PH=plant height; NTPP= number of tillers per plant; NLPP= number leafs per plant; LLPP=leaf length per plant.*

Table 2. Effect of harvesting dates and altitudes on chemical composition and yield of *Brachiaria (hybrid,* cultivars and ecotypes) grass

Cultivar	altitudes	Harvesting Dates	DM (%)	DMY (t/ha)	Ash (%)	CP (%)	CPY (t/ha)	NDF (%)	ADF (%)	ADL (%)
		60	36.47^{b}	10.09^{c}	14.43^{a}	18.76^{a}	1.80^{a}	55.67^{b}	37.11^{b}	8.25^{b}
		90	37.24^{b}	11.69^{b}	10.87^{b}	14.14^{b}	1.42^{b}	61.22^{a}	38.78^{a}	10.20^{a}
	Low	120	39.77^{a}	13.36^{a}	14.29^{a}	9.20^{c}	0.85^{c}	63.04^{a}	43.48^{a}	10.87^{a}
		SE	0.53	0.47	0.58	1.38	0.14	1.13	0.98	0.45
		60	35.63	8.43^{b}	13.68^{a}	18.93^{a}	1.60^{a}	54.74^{b}	33.68	8.42^{b}
		90	36.77	10.37^{ab}	13.40^{a}	11.15^{b}	1.37^{a}	63.16^{a}	40.00	10.53^{a}
	Mid	120	38.40	12.34^{a}	11.58^{b}	8.91^{c}	0.99^{b}	68.04^{a}	41.24	12.37^{a}
Mulato II		SE	0.58	0.62	0.38	1.54	0.09	2.06	1.46	0.61
		60	34.39	6.08^{b}	12.77^{a}	12.74^{a}	1.02^{a}	56.52^{b}	31.91^{b}	6.38^{b}
	High	90	35.52	7.08^{ab}	8.70^{b}	12.54^{ab}	0.70^{b}	61.70^{a}	32.61^{b}	8.70^{b}
		120	37.44	9.11^{a}	11.46^{a}	9.98^{b}	0.61^{b}	64.58^{a}	50.00^{a}	16.67^{a}
		SE	0.61	0.54	0.68	0.54	0.07	1.32	2.98	1.58
		60	34.13	8.51^{b}	15.31^{a}	19.70^{a}	1.68^{a}	51.02^{c}	30.61^{c}	6.12^{c}
		90	36.67	10.78^{a}	12.24^{b}	13.37^{b}	1.04^{b}	60.42^{b}	37.50^{b}	8.33^{b}
	Low	120	38.61	11.87^{a}	10.42^{b}	6.65^{c}	0.79^{b}	79.59^{a}	48.98^{a}	16.33^{a}
		SE	0.94	0.52	0.75	1.91	0.14	4.24	2.58	1.57
		60	34.46	6.67^{b}	14.58^{a}	15.56^{a}	1.04	56.25^{c}	31.25^{b}	6.25^{b}
	Mid	90	35.21	9.37^{a}	11.34^{b}	10.11^{a}	0.94	68.75^{b}	47.92^{a}	14.43^{a}
Marandu		120	36.46	10.21^{a}	12.50^{ab}	8.85^{b}	0.90	78.35^{a}	49.48^{a}	16.67^{a}
		SE	0.55	0.59	0.53	1.04	0.04	3.23	2.95	1.64
	High	60	29.62	2.58^{b}	12.50	14.84^{a}	0.38	56.25^{b}	31.25^{b}	8.33^{b}
		90	30.69	4.21^{ab}	13.04	8.04^{b}	0.34	65.22^{a}	53.76^{a}	17.39^{a}
		120	32.74	5.78^{a}	11.83	4.08^{c}	0.24	66.67^{a}	54.35^{a}	19.35^{a}
		SE	0.73	0.51	0.44	1.59	0.03	1.69	3.89	1.76
		60	35.24	7.94^{b}	13.83^{a}	17.92^{a}	1.49	53.19^{c}	38.30^{b}	10.64^{b}
		90	37.83	10.10^{ab}	10.31^{b}	12.15^{b}	1.43	69.47^{b}	44.21^{ab}	12.63^{ab}
	Low	120	40.08	11.97^{a}	9.47^{b}	6.33^{c}	1.10	74.23^{a}	49.48^{a}	14.43^{b}
		SE	0.88	0.69	0.74	1.75	0.13	3.21	1.76	0.66
		60	35.53	6.28^{c}	13.83^{a}	18.93^{a}	1.19	53.19^{b}	38.30^{b}	10.64
		90	36.58	8.63^{b}	10.31^{ab}	13.25^{ab}	0.96	74.23^{a}	46.32^{a}	12.63
La Libertad	Mid	120	38.70	10.92^{a}	8.42^{b}	8.01^{b}	0.97	75.79^{a}	49.48^{a}	14.43
		SE	1.53	0.06	0.58	1.15	0.06	0.58	0.58	1.15
		60	31.74	4.61	11.58	16.79^{a}	0.59	58.95^{b}	31.58^{c}	8.42^{b}
		90	33.09	6.15	10.20	9.92^{b}	0.77	62.50^{ab}	42.86^{b}	12.24^{ab}
	High	120	35.62	7.84	9.37	6.74^{b}	0.78	65.31^{a}	50.00^{a}	16.67^{a}
		SE	2.89	1.15	0.40	0.58	0.12	1.15	1.15	0.35
		60	36.08	2.38^{b}	10.42	17.14^{a}	0.41^{a}	64.58^{b}	39.58^{b}	8.33^{b}
		90	37.73	2.29^{b}	8.25	7.81^{b}	0.23^{b}	70.10^{b}	55.67^{a}	16.49^{a}
	Low	120	38.99	8.06^{a}	8.25	4.47^{c}	0.36^{ab}	80.41^{a}	57.73^{a}	18.56^{a}
		SE	0.63	0.97	0.48	1.91	0.03	2.44	2.90	1.62
		60	34.78	1.61^{c}	11.46^{a}	18.28^{a}	0.30^{b}	62.50^{b}	41.67^{c}	14.29^{b}
		90	36.48	5.12^{b}	8.16^{b}	11.38^{b}	0.58^{a}	69.39^{a}	53.06^{b}	14.58^{b}
Eth. 13726	Mid	120	38.40	7.16^{a}	9.37^{b}	7.42^{c}	0.53^{a}	70.83^{a}	58.33^{a}	20.83^{a}
		SE	0.81	0.82	0.51	1.59	0.05	1.35	2.48	1.11
		60	34.22	1.08^{c}	16.13^{a}	13.58^{a}	0.15^{b}	64.52^{b}	45.16^{b}	12.90^{b}
		90	35.72	3.48^{b}	16.13^{a}	12.70^{a}	0.44^{a}	66.67^{b}	49.46^{ab}	15.05^{ab}
	High	120	38.02	5.27^{a}	9.68^{b}	8.26^{b}	0.43^{a}	77.08^{a}	56.25^{a}	16.67^{a}
		SE	0.75	0.62	1.13	0.87	0.05	2.18	1.80	0.65
		60	37.54	3.90^{c}	14.13	17.50^{a}	0.68^{b}	64.52	38.71^{b}	8.60^{b}
		90	38.80	8.05^{b}	15.93	13.70^{b}	1.10^{ab}	64.58	41.67^{ab}	10.42^{a}
	Low	120	39.96	9.83^{a}	16.13	13.58^{b}	1.33^{a}	66.67	45.16^{a}	12.90^{a}
		SE	0.57	0.90	0.43	0.67	0.11	1.01	1.14	0.67
		60	37.06^{b}	2.78^{c}	9.37	13.77^{a}	0.38^{b}	63.04^{b}	41.67^{b}	10.42^{b}
		90	37.83^{ab}	6.49^{b}	8.70	9.92^{b}	0.64^{a}	64.58^{b}	43.21^{b}	12.50^{ab}
	Mid	120	39.49^{a}	8.68^{a}	9.37	7.94^{b}	0.69^{a}	72.92^{a}	50.00^{a}	13.04^{a}
Eth.13809		SE	0.43	0.88	0.26	0.91	0.05	1.62	1.39	0.49
		60	35.15	2.17^{b}	13.54	10.34^{a}	0.22^{b}	52.17^{c}	36.96^{b}	8.33^{b}
		90	36.48	4.98^{ab}	10.87	8.17^{ab}	0.41^{ab}	62.50^{b}	41.67^{b}	8.70^{b}
	High	120	37.43	6.34^{a}	13.04	7.19^{b}	0.46^{a}	78.26^{a}	52.17^{a}	15.22^{a}
		SE	0.70	0.70	0.51	0.55	0.04	3.84	2.45	1.19
		60	36.20	3.61^{b}	12.63^{b}	18.08^{a}	0.65^{b}	58.95^{c}	40.00^{c}	8.42^{b}
		90	36.86	7.27^{a}	9.68^{c}	12.77^{b}	0.93^{a}	66.67^{b}	49.46^{b}	15.05^{a}
	Low	120	37.81	7.97^{a}	14.58^{a}	8.26^{c}	0.66^{b}	77.08^{a}	56.25^{a}	16.67^{a}
		SE	0.44	0.72	0.72	1.44	0.05	2.74	2.39	1.32
		60	34.41	2.29^{b}	11.58^{b}	15.36^{a}	0.35	63.04	37.89^{b}	10.53^{b}
		90	34.96	5.34^{a}	8.70^{c}	9.50^{b}	0.51	63.16	43.48^{a}	13.04^{b}
Eth.13777	Mid	120	36.06	6.40^{a}	14.13^{a}	8.65^{b}	0.55	65.22	47.83^{a}	15.22^{a}
		SE	0.58	0.66	0.81	1.12	0.04	1.03	1.56	0.73
		60	33.95	2.04^{c}	10.53^{a}	10.95^{a}	0.22^{b}	61.05^{b}	44.21^{b}	10.87
		90	34.88	4.56^{b}	10.87^{a}	8.17^{b}	0.37^{ab}	76.09^{a}	50.00^{ab}	14.74
	High	120	36.28	6.29^{a}	8.70^{b}	6.68^{b}	0.42^{a}	78.26^{a}	52.17^{a}	15.22
		SE	1.00	0.64	0.39	0.65	0.04	2.79	1.44	0.99

*Treatments means with different letters in a column are significantly different (***P<0.001; **P<0.01, *P<0.05) for harvesting dates; ns=non significant; HDs=harvesting dates; 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.*

At all altitudes the levels of CP in the harvested forage exceeded the minimum of 7.5% suggested as necessary for optimum rumen function by Van Soest (1994) during all harvesting stages of Mulato II and day 60 and 90 harvesting stages of all other studied grasses. In addition, at the third harvest some grasses achieved lower CP content than optimum rumen function (at low and high altitudes of Marandu and La Libertad, high altitude of Eth. 13809 and Eth. 13777 and low altitude of Eth. 13726).

Fiber fractions are important as they describe those forage components that have low solubility in a specific solvent system and are relatively less digestible than starch (Tavirimirwa et al., 2012). With the except of Marandu and La Libertad (high), Eth.13809 (low), Eth.13777 (mid) and in all altitudes of Mulato II at all harvesting stages, the studied grasses had low dry matter intake at late (third) stage of harvesting as NDF percentages increase, dry-matter intake generally decreased (Schroeder, 2012) and a high NDF above 72% will cause low intake of forage (Lima et al., 2002). For all grasses used in the study, the value of NDF was high during the third cut and varied between 63.04-80.41%. Except that of Mulato II at mid altitude, the trend of ADF content in all studied areas, the studied grasses significantly increased ($P<0.05$) with advance in maturity confirming the results of similar studies by Tilahun et al. (2017). ADF is the value that refers to the cell wall portions of the forage that are made up of cellulose and lignin. These values are important because they relate to the ability of an animal to digest the forage. The digestibility of foods is related to the fiber because the indigestible portion has a proportion of ADF, and the higher the value of ADF the lower the food digestibility (Costa et al., 2005; Albayrak et al., 2011). The studied grasses attain more than 40% ADF after first harvest. The ecotypes at most location maintained higher values for ADF during all the harvest intervals, which will have low intake and digestibility as reported by Nussio et al. (1998) that forage with ADF content around 40%, or more, shows low intake and digestibility. Acid detergent Lignin (ADL) content for cultivars increased with age and their mean values showed significant ($P<0.05$) differences by harvesting stages except La Libertad at mid and high altitude of Eth. 13777.

Effects of altitude, harvesting stages and their interactions on morphological characteristics of six *Brachiaria* grasses in three altitudes

The results of the effect of altitude, harvesting days and their interactions on plant morphological characteristics of six tested *Brachiaria* grasses in three altitudes are presented in Table 3. The results obtained indicate that with the exception of LLPP at low and PH at mid altitude, other morphological characteristics of the six *Brachiaria* grasses studied were significantly ($P<0.05$) different in all altitude.

La Libertad recorded the highest average mean plant heights (82.70, 71.62 and 65.96 cm at low, mid and high altitude, respectively) followed by Mulato II at low (71.52 cm) and high altitude (49.03 cm) and Eth. 13777 at mid altitude (62.91). Mean plant height of all studied grasses were significantly ($P<0.05$) different at low and high altitude. The numerical result indicated that the highest mean plant height at grasses harvesting was recorded at low followed by mid altitude. Mean tiller number increased progressively for all studied six grasses and there were significant differences between harvesting in each grass ($P<0.05$) as shown in Table 1.

The large numbers of tillers produced by some grass species allows them to attain maximum growth at an earlier age and recover faster after defoliation (Laidlaw, 2005). Tillers density is an important attribute of grasses as it increases the chances of survival and amount of available forage (Laidlaw, 2005; Skerman and Riveros, 1990). Moreover, it is an indicator of resource use efficiency by the different grass species. The large numbers of tillers produced by some grass species allows them to attain maximum growth at an earlier age and recover faster after defoliation (Laidlaw, 2005). Mean tiller number increased progressively for all studied grass, and there were significant ($P<0.05$) differences among the six *Brachiaria* grass in all altitude which is Mulato II recorded the highest. Thus, highest DM yield of Mulato II might be due to high number of tillers (Table 4). The results in this study are similar to the findings by Mganga (Mutimura et al., 2017) and Machogu (Machogu, 2013), where the tiller density differed among the local range grasses in Kenya.

Table 3. Mean value (%) of plant morphological characteristics (PH, NTPP, NLPP AND LLPP) values of six *Brachiaria* grasses

	Altitude											
Variety	Low				Mid				High			
	PH	NTPP	NLPP	LLPP	PH	NTPP	NLPP	LLPP	PH	NTPP	NLPP	LLPP
Mulato II	71.52^{ab}	75.39^{a}	8.32^{b}	24.29	57.26	64.82^{a}	7.78^{bc}	28.63^{a}	49.03^{b}	53.69^{a}	5.69^{a}	17.07^{a}
Marandu	65.39^{ab}	54.37^{b}	9.42^{b}	21.10	58.72	45.14^{bc}	8.26^{b}	21.38^{bc}	42.82^{b}	26.58^{c}	6.23^{a}	14.60^{ab}
La Libertad	82.70^{a}	55.12^{b}	18.67^{a}	21.73	71.62	55.92^{ab}	17.82^{a}	20.38^{bc}	65.96^{a}	41.27^{ab}	5.20^{ab}	13.03^{b}
Eth. 13726	59.39^{b}	24.71^{c}	4.64^{c}	18.61	57.00	33.67^{c}	5.51^{bc}	19.38^{bc}	36.86^{b}	20.67^{c}	4.08^{bc}	13.89^{ab}
Eth.13809	56.40^{b}	35.77^{c}	4.77^{c}	20.17	52.99	35.07^{c}	4.52^{c}	23.89^{ab}	45.03^{b}	29.72^{bc}	3.78^{c}	16.27^{ab}
Eth.13777	65.72^{ab}	25.09^{c}	5.48^{c}	18.01	62.91	32.14^{c}	5.07^{bc}	17.39^{c}	47.57^{b}	30.93^{bc}	4.48^{bc}	13.25^{b}

		PH	NTPP	NLPP	LLPP
P-value	Al	***	***	***	***
	Hd	***	***	***	***
	cul*al	ns	***	***	*
	cul*hd	*	**	*	*
	al*hd	*	Ns	Ns	Ns
	cul*al *ha	***	***	***	***

*Treatments means with different letters in a column are significantly different (***P < 0.001; **P < 0.01, *P < 0.05) for altitudes. SE=Standard error; PH=plant height; NTPP= number of tillers per plant; NLPP= number leafs per plant; LLPP=leaf length per plan*

Effects of altitude, harvesting stages and their interactions on chemical compositions and yields six *Brachiaria* grasses in three altitudes

The results obtained indicate that DM, DMY and CPY were show significant (P<0.05) difference in the six *Brachiaria* grasses. In addition, ash at low and ADF both at low and mid altitudes showed significant difference (P<0.05) in the six *Brachiaria* grasses.

On the basis of DMY production, the most promising from the studied six *Brachiaria* grasses were hybrid Mulato II and cultivars (Marandu and La Libertad) compared to the three ecotypes (Eth. 13726, Eth. 13809 and Eth. 13777). Among studied grasses the highest DMY were recorded by Mulato II in all of the three altitudes and it was in agreement with the results of studies in Thailand by Hare et al. (2009) and in Rwanda by Mutimura and Everson, (2012) showed that *Brachiaria* cultivars, Mulato and Mulato II attained the highest primary forage productions.

The DM yields of cv. Mulato II obtained at low (11.71 t/ha) and mid (10.38 t/ha) altitudes higher than reported by Mutimura and Everson (2012) 8.3 t/ha in Rwanda.

This superior dry matter production confirms why *Brachiaria* grass is now the most commonly (extensively) grown as livestock forage in south America (Cezário et al., 2015) and East Asia (FAO, 2015), and are believed to occupy over 99 million hectares in Brazil alone (Jank et al., 2014) and supporting a highly vibrant beef industry.

Variations in DM production across the grasses can 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 (Mganga, 2009). Generally, the larger number of tillers and leaves recorded at low altitude and that enable them to attain highest DM yield for all the studied *Brachiaria* grasses at low altitude and the lowest at high altitude, may be due to the better environmental conditions for the *Brachiaria* grasses at low and mid altitude than at high altitude. However, the current study revealed that *Brachiaria* grasses performed well at high altitudes in Ethiopia than other studied countries elsewhere and the natural pasture in Ethiopia. Forage in nutrients and yields vary according to many factors such as forage species and climate (Baron and Belanger, 2007).

The CP content was generally higher in all the *Brachiaria* grasses of three altitudes (8.57-14.93%) compared with mean of 7-10% reported by Nguku et al. (2015) in the semi-arid region of eastern Kenya and Ondiko et al. (2016) (5.3-7.7%) in coastal lowlands of Kenya but lower than reported by Kifuko-Koech et al. (2016) (12.9-16.2%) at western Kenya.

Table 4. Mean value (%) of chemical composition and yield (DM, DMY, ASH, CP, CPY, NDF, ADF and ADL) values of six *Brachiaria* grasses

Altitude	Parameters	Mulato II	Marandu	La Libertad	Eth. 13726	Eth.13809	Eth.13777
Low	DM (%)	37.83^{ab}	36.47^{b}	37.72^{ab}	37.60^{ab}	38.77^{a}	36.96^{ab}
	DMY (t/ha)	11.71^{a}	10.39^{a}	10.00^{ab}	4.24^{c}	7.26^{bc}	6.28^{c}
	ASH (%)	13.20^{ab}	12.65^{ab}	11.20^{ab}	8.97^{b}	15.40^{a}	12.30^{ab}
	CP (%)	14.03	13.24	12.13	9.81	14.93	13.04
	CPY (t/ha)	1.36^{a}	1.17^{ab}	1.34^{a}	0.33^{b}	1.04^{ab}	0.75^{ab}
	NDF (%)	59.98	63.68	65.63	71.70	65.26	67.57
	ADF (%)	39.79^{b}	39.03^{b}	44.00^{ab}	50.99^{a}	41.85^{ab}	48.57^{ab}
	ADL (%)	9.77	10.26	12.57	14.46	10.64	13.38
Mid	DM (%)	36.93^{b}	35.38^{c}	36.94^{b}	36.55^{b}	38.13^{a}	35.14^{c}
	DMY (t/ha)	10.38^{a}	8.75^{b}	8.61^{b}	4.63^{c}	5.98^{c}	4.68^{c}
	ASH (%)	12.89	12.81	10.85	9.66	9.15	11.47
	CP (%)	13.00	11.51	13.40	12.36	10.54	11.17
	CPY (t/ha)	1.32^{a}	0.96^{abc}	1.04^{ab}	0.47^{c}	0.57^{bc}	0.47^{c}
	NDF (%)	61.98	67.78	67.74	67.57	66.85	63.81
	ADF (%)	38.31^{b}	42.88^{ab}	44.70^{ab}	51.02^{a}	44.96^{ab}	43.07^{ab}
	ADL	10.44^{b}	12.45^{ab}	12.57^{ab}	16.57^{a}	11.99^{ab}	12.93^{ab}
High	DM (%)	35.78^{ab}	31.02^{d}	33.48^{c}	35.99^{ab}	36.35^{a}	35.04^{b}
	DMY (t/ha)	7.42^{a}	4.19^{cd}	6.20^{b}	3.28^{d}	4.50^{c}	4.30^{cd}
	ASH (%)	10.98	12.46	10.38	13.98	12.48	10.03
	CP (%)	11.75	8.99	11.15	11.51	8.57	8.60
	CPY (t/ha)	0.78^{a}	0.32^{b}	0.71^{ab}	0.34^{b}	0.36^{ab}	0.34^{b}
	NDF (%)	60.93	62.71	62.25	69.42	64.31	71.80
	ADF (%)	38.17	46.45	41.48	50.29	43.60	48.79
	ADL (%)	10.58	15.02	12.44	14.87	10.75	13.61

P-value		DM	DMY	ASH	CP	CPY	NDF	ADF	ADL
	al	***	***	ns	***	***	ns	ns	ns
	hd	***	***	*	***	Ns	***	***	***
	cul*al	***	***	*	**	**	ns	ns	ns
	cul*hd	*	*	ns	Ns	**	ns	ns	ns
	al*hd	ns	ns	ns	*	Ns	ns	ns	ns
	cul*al *ha	***	***	*	***	***	**	***	**

*Treatments means with different letters in a rows are significantly different (***P < 0.001; **P < 0.01, *P < 0.05) for altitudes; ns=non significant; HDs=harvesting dates; 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.*

From the studied grasses the highest DMY and CP and lowest NDF and ADF concentrations were recorded by Mulato II. Similarly, the highest CP and lowest NDF concentrations were recorded in Mulato II at western Kenya by Kifuko-Koech et al. (2016). From all studied grasses Mulato II had low proportion and best digestibility as the chemical characteristics of forage with high concentrations of lignin in the cell wall impair the digestibility of dry mass and thus limit consumption by ruminants (Clipes et al., 2010). Although there were no significant (P<0.05) difference in ADL by altitude, numerically indicate that most of the studied grasses had poorer digestibility in mid and high than low altitude because of greater proportion of lignified tissues (Wijiphans et al., 2009). Nsinamwa et al. (2005) agree on the fact that the fiber content in forage increases with age and that the higher the fiber fractions, the lower the digestibility. In the present study, the observed differences in terms of the quality and yields of grass hybrid, cultivars and ecotypes across sites could be both the effects of climatic and physical factors that are responsible for the variation in the quality of forage species across altitudes (Moore and Jung, 2001; Mutanga et al., 2004).

The mean ash contain obtained from which was much higher than those reported by Kungwan et al. (2010), of 6%. Majority of the studied grasses in different location had high mineral at early harvesting. Similar study reported by Tergas and Blue (1971) that the reduction in the proportion of stem with the increase of age, influences the decrease in mineral content.

CONCLUSIONS

The results of this study indicated that *Brachiaria* grasses have potential of increasing quality feeds for livestock production in the northwestern Ethiopia. Based on the results, the harvesting stage can affect the forage DM yield and nutritive values of *Brachiaria* grasses. Harvesting at day 60 could be the optimal level for harvesting all the studied *Brachiaria* grasses since the quality forage is high and yield are not compromised. Although all six studied *Brachiaria* grasses had potential as an alternative ruminant feed in all altitude areas in Ethiopia, highest DMY and CP and lowest NDF and ADF concentrations were recorded by Mulato II. Its capability to grow at low rainfall maintaining high yields is an additional advantage over the others. Thus, among the tested *Brachiaria* grasses Mulato II showed outstanding potential as a forage plant especially at low altitude area of northwestern Ethiopia. This indicates that *Bracharia* forages production in the lowlands of the country would benefit from the cultivar Mulato II for sustainable ruminant livestock production in the future. To fully utilize the potential of Mulato II grass, further studies on agronomic and nutritional evaluation involving live-animal experiments are recommended.

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