Hindawi
Advances in Agriculture
Volume 2022, Article ID 7373145, 11 pages
https://doi.org/10.1155/2022/7373145

Research Article

Morphoagronomical and Nutritive Performance of *Brachiaria* Grasses Affected by Soil Type and Fertilizer Application Grown under Rainfed Condition in Ethiopia

Beyadglign Hunegnaw,[1] **Yeshambel Mekuriaw**,[2] **Bimrew Asmare**,[2] **and Shigdaf Mekuriaw**[1]

[1]*Andassa Livestock Research Center, Amhara Regional Agricultural Research Institute (ARARI), P. O. Box 527, Bahir Dar, Ethiopia*
[2]*Department of Animal Sciences, Bahir Dar University, P. O. Box 5501, Bahir Dar, Ethiopia*

Correspondence should be addressed to Yeshambel Mekuriaw; yeshambel166@gmail.com

Received 1 March 2022; Revised 26 September 2022; Accepted 12 November 2022; Published 1 December 2022

Academic Editor: Euripedes Garcia Silveira Junior

The objective of the field experiment was to evaluate the agronomic performance and nutritive values of brachiaria grass in response to cultivars, soil type, and fertilizer application. A randomized complete block design containing three replications with three factors (fertilizer, cultivars, and soil types) was used. The cultivars were *Brachiaria mutica*, *Brachiaria* hybrid Mulato-II, *Brachiaria* hybrid Mulato-I, *Brachiaria birzantha* Marandu, and *Brachiaria birzantha* La liberated. The root splits were means of propagation for all cultivars. The spacing between blocks and plots was 1 meter while between plants and rows was 0.5 meter. Agronomic performance such as plant height (PH), number of tillers (NT), number and length of leaves, forage dry matter (DM) yield, and nutritive values of the cultivars were measured and analyzed. Forage samples were taken at 90 days harvesting age. A general linear model of statistical analysis system (SAS) version 9.0 is used as a statistical method. The results revealed that all three factors interaction was highly significant ($p < 0.001$) on all agronomic and nutritive values of *Brachiaria* grass cultivars. The agronomic performance and most of its nutritive values of *brachiaria* cultivars were higher ($p < 0.05$) at black soil than in red soil; except for crude protein. The *Brachiria mutica* cultivar had a higher agronomic performance at both soil types than hybrid Mulato-II and hybrid Mulato-I. Based on the response recorded, it can be concluded that hybrid Mulato-II, *B. mutica,* and hybrid Mulato-I cultivars were performing better in the study areas. As a recommendation, farmers should consider cultivar, soil type, and presence of fertilizer in establishing *brachiaria* grass in the production system.

1. Introduction

Livestock population in Ethiopia is the largest as compared from African countries, but lower in terms of its production and productivity [1]. The lion share for the lower livestock productivity is the shortage of quantity and quality feed. The annual dry matter deficit in Ethiopia is ranging from 27–40% [2]. This deficit could be more in terms of critical nutrients such as protein and energy. In addition, the largest cost of livestock production is feed cost. This is really affecting the per capita livestock product consumption in Ethiopia and it becomes lower than the African average [3]. Contrary, the human population is increasing and this could be also considered as an opportunity for the livestock producers for marketing the livestock products. The major feed resources in Ethiopia are natural pasture and crop residues; however both of them are nutritionally poor and could not satisfy the animal requirement which in turn the animals lost their body weight fed sole of these feedstuff [1, 4]. Understanding the feed challenge in the country, the government has allocated unreserved efforts to improve forage cultivation though its national livestock feed contribution is still negligible [1]. Hence, looking for other productive, adaptable, and scalable improved forage plants in the production system are critically important. In Ethiopia, the natural pastures area coverage was almost half of the country, but they are on shrinking in size, becoming less botanical composition, low in biomass production, and poor in quality especially from the protein and mineral point of view [5]. The possible reasons for this are continuous grazing and missing of grazing land management principles. As a subsequent effect, most of the natural pastures in Ethiopia are characterized as degraded land; soils have been degraded similar to the cultivated land [5]. If there are more productive and adaptable improved forages on the menu for the choice for the livestock producers in the production systems, they can change the status of natural pasture from unproductive, degraded, and to be productive status using these alternatives improved forages [6]. Among the introduced improved grasses such as Napier (*Pennisetum purpureum*) and Rhodes grasses (*Chloris gayana*), *Brachiaria* grasses are also promising grass to change the forage production status of Ethiopia since it could adapt to the environment easily since it was originally from Africa before improved in Brazil [7].

Previous studies acknowledged that improved forages could make natural pasture productive, improve soil fertility through atmospheric nitrogen fixation, through soil and soil microbes stabilizing, carbon sequestration to mitigate climate change, and enhance natural assets and system reliance and biological inhibition of nitrification especially by *brachiaria* grasses [8–12]. Therefore, the promising candidate for improved grass that could be suitable for the existing production system on the tropical ecology and adaptable for climate change are *Brachiaria* grass species. It is also acknowledged that the climate smart grass and it is high productive and quality which can grow on low rainfall and acidic soil; wider adaptable grass. This productive trait makes *brachiraia* a more promising improved forage grass in filling the forage deficit in Ethiopia either in standing hay; hay, or silage forms.

Forage production and quality could be affected by agronomic practices such as fertilizer application, soil type where forage plants growing, and the type of cultivar [12, 13]. In general previous studies reported that soil type, fertilizer application, and forage cultivar differences were observed in terms of forage plants' morphoagronomical and nutritive values [13–15]. Specifically, [13] reported that there was a difference among *brachiaria* ecotypes in Ethiopia in terms of their forage dry matter yield. Since *brachiaria* cultivars in Ethiopia have been introduced in recent times so there is limited knowledge on *B. cultivars* morphoagronomical and nutritive performance. Knowing the contribution of these factors in forage production could be used as a source of knowledge for scaling the technology through an extension system. This study was therefore designed to learning the effects of fertilizer, type of cultivars, and soil type on agronomic performance and nutritive value of *Brachiaria* grass cultivars grown under rain fed condition in northwestern Ethiopia.

2. Materials and Methods

2.1. Study Areas. The field experiment was conducted at site of black soil (Andassa livestock research center; ALRC) and site of red soil (Ambo Mesk; Mecha district) Amhara Region, Ethiopia. The ALRC is located 21 Km far from the capital city of Amhara region Bahir Dar. The center is located 11°29°N latitude and 37°29°E longitude and 1730 meters above sea level. Annual rain fall, maximum and minimum annual temperature were 1330.4 mm, 27.9°C, and 13°C, respectively. While Mecha district is 34 km far from Bahir Dar city. The district is located 9°23′ to 9°26′N latitude and 41°59′ to 42°02′E and 1807–2300 m above sea level. Annual rain fall, maximum and minimum annual temperature were 3043.9 mm, 28.01°C, and 10.57°C, respectively [16]. Both districts are characterized by monomodal rain fall pattern. Figure 1 depicts the experimental districts monthly rainfall and maximum and minimum temperature.

2.2. Experimental Cultivars Description. In terms of its origin, cv. Mulato II is the hybrid result of three cycles and screen carried out by the International Center for Tropical Agriculture (CIAT) Tropical Forages Project. The cultivar originated from crosses performed in 1988/9 at CIAT between *Brachiaria ruziziensis R. Germ* and Evrard clone 44–6 (sexual tetraploid) X B. decumbens (apomictic tetraploid) [17]. Cultivar Mulato-II (*Brachiaria* hybrid CIAT 36087) a high quality forage grass, resistant to spittlebugs and adapted to well-drained acid tropical soils. It is the second commercial hybrid released by CIAT Tropical Forages Project and other collaborating research institutes. Mulato I, is a hybrid of *Brachiaria ruziziensis* with *B. brizantha* by Grupo Papalotla in 2004 [18] with less seed yield. *Brachiaria mutica*/Urochloa mutica is a species Common names: buffalo grass/para grass. *Brachiaria brizantha*/Urochloa brizantha c.v marandu developed in Brazil. According to [19], *B. bizantha* is widely distributed in Africa including Ethiopia. All experimental cultivars were brought from International Livestock Research Institute (ILRI) gene bank, Addis Ababa, Ethiopia which are initially adopted and screen at ILRI forage experimental site.

2.3. Soil Sample Collection and Analysis. Soil samples were collected in May 2018 before planting of experimental *Brachiaria* grass cultivars at the depth of 30 cm using an auger for analysis. Plant materials on the soil surface were removed before collecting the samples to minimize its effect on the soil properties. Diagonal (X) method of soil sampling and composite sample of soils were made and put into a sterile plastic bag and then thoroughly mixed; duplicate samples were delivered to the Andassa Livestock Research Center. After air dried, it was crushed with a mortar and pestle with 1 mm in size. Six soil samples, totaling two soil samples per block, were delivered to Adet Agricultural Research Center for chemical analysis and pH following standard methods as described by [20].

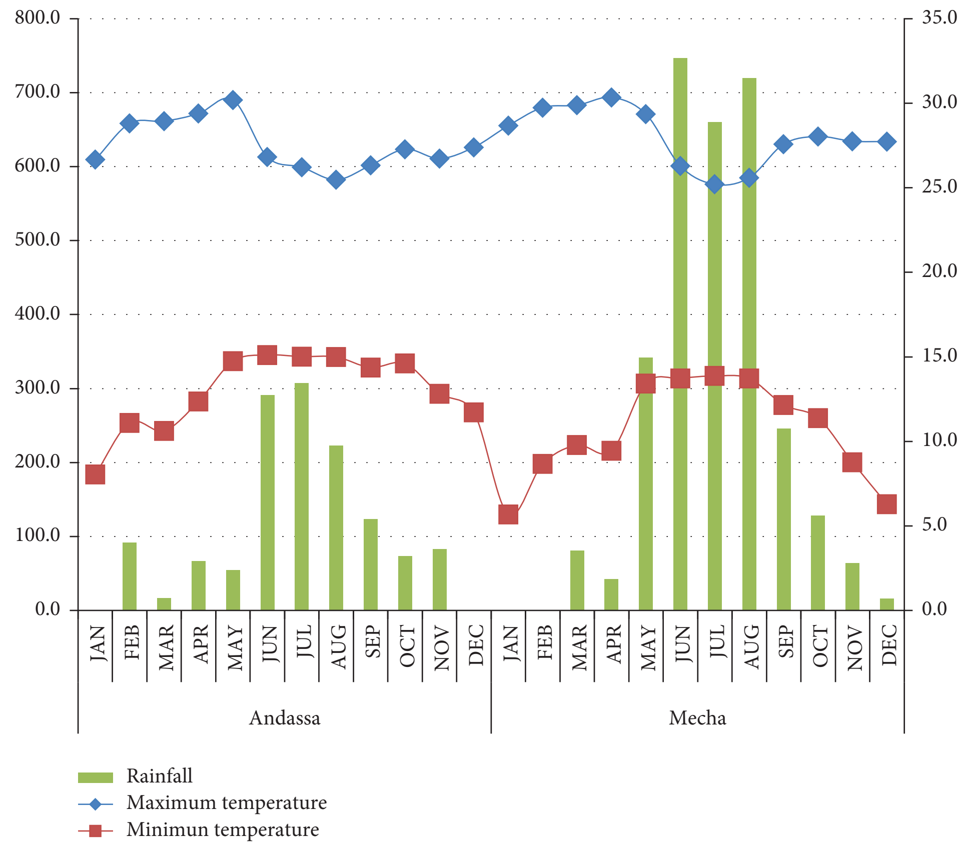

Figure 1: Monthly rainfall (mm) and maximum and minimum temperature (°C) of experimental districts.

2.4. Treatments, Experimental Design, Land Preparation, and Management. The study was conducted at red and black soil type simultaneously, of which all experimental materials, design, and treatments were the same. A factorial arrangement of treatments in a randomized complete block design consisting of three factors (fertilizer, soil type, and cultivars) with three replications was used in the study. The field experiment consisted of five *Brachiaria* grass cultivars namely *Brachiaria mutica*, *Brachiaria* hybrid cv. Mulato-I, *Brachiaria* hybrid cv. Mulato-II, *Brachiaria brizantha* marandu and *Brachiaria brizantha* la liberated. The experiment had a total of 20 treatments with a $(2 * 2 * 5)$ factorial combination of two fertilizers application (with and without), two soil types (Red and Black), and five *Brachiaria* grass cultivars. The inter-row and intra-row spacing were 0.5 m, the same for all treatments while the spacing between block and plots were 1 m. The plot size of each treatment was $9\,m^2$ $(3\,m \times 3\,m)$ and net harvestable plot area was $6\,m^2$ $(3\,m * 2\,m)$ excluding outer rows. Each plot consisted of six rows with 5 plants per row with a total of 30 plants per plot for all treatments. After proper land preparation, the cultivars were planted at two locations in June 2018 by root split propagation mechanism in the main rain season. The NPS fertilizer application was applied at the time of planting, with a rate of NPS 100 kg/ha and urea with a rate of 50 kg/ha was applied after 30 days of planting grass [21]. Two-thirds of the *Brachiaria* grasses root splits were buried at the depth of 10–15 cm on the experimental plot, and the apical third was left on the ground according to the recommendation made by [22]. Weeding was done by hand to avoid nutrients competition.

2.5. Data Collection. The morphoagronomical data and nutritive value were collected and analyzed at 90 days. The number of tiller per plant (NTPP), total number of leaves per plant (TLPP), leaf length per plant (LLPP), length and number of root per plant, and leaf: stem ratio (LSR) were recorded from ten plants of each experimental plot harvested by hand using a sickle according to [23, 24].

2.5.1. Morphoagronomical Data Collection Procedures. The plant height (PH), leaf length (LL), and root length (RL) were measured with using a measuring tape and number of tillers, number of leaves, and number of roots per plant were calculated as mean of counts. The PH was measured on the primary shoot from the soil surface to the tip of the longest leaf using measuring tape [25]. The numbers of roots per plant were counted and mean was calculated. The length of the root was measured from the crown part to the tip of the root using measuring tape. The LSR was determined following the method used by [26]. A fresh herbage yield of *Brachiaria* grass cultivars was measured immediately after harvesting and weighed on the field using a sensitive spring balance. The crude protein yield (CPY, t/ha) was determined by multiplying of DMY by crude protein content (CP).

Finally, adequate quantities of subsamples were air dried and stored in airtight bags. The dried samples were ground to pass a 1-mm Wiley mill screen and were stored in airtight bags pending for nutritive value analysis.

2.5.2. Forage Nutritive Values. The CP of the forage sample was analyzed using Kjeldhal standard procedure [27], while acid detergent fiber (ADF), neutral detergent fiber (NDF), and acid detergent lignin (ADL) were determined following the standard procedure used by [28]. Ash was determined by igniting at 550°C overnight, total DM by drying at 105°C by the procedure [27], and in vitro organic matter digestibility (IVOMD) following the standard methods as described by [29]. The forage sample nutritional analyses were carried out at Holetta Agricultural Research Center, Animal Nutrition Laboratory. The metabolizable energy (ME) was estimated from digestible energy (DE) and IVOMD, based on the formula used by [30].

2.6. Data Analysis. All morphoagronomical performance and nutritive values were statistically analyzed using the procedure outlined by [31] for a factorial experiment using the General Linear Model (GLM) procedure of the SAS statistical computer package version 9.0 [32]. Significant treatment means were compared by the Duncan's Multiple Range Test ($p < 0.05$) while, the *T*-test was employed for the soil chemical composition analysis. Differences were considered statistically significant at 0.05%. The statistical model was

$$Y_{ijk} = \mu + F_i + C_j + S_k + \left(F_i * C_j * S_k\right) + E_{ijk}, \quad (1)$$

where Y_{ijk} = all dependent variables (morphoagronomical and nutritive value), μ = Overall mean, F_i = the effect of fertilizer (with and without fertilizer), C_j = effect of cultivars (five cultivars), S_k = effect soil type (black and red), $F_i * C_i$ = interaction effect of fertilizer and cultivars, $C_i * S_k$ = interaction effect of cultivars and soil type, $F_i * C_i * S_k$ = interaction effect (fertilizer, cultivars, and soil type), E_{ijk} = residual error.

The statistical model for the analysis of soil chemical composition data was

$$Y_{ijk} = \mu + s_i + B_j + E_{ijk}, \quad (2)$$

Y_{ijk} = all dependent variables (soil chemical composition parameters), μ = Overall mean, S_i = effect soil type (black and red), B_j = effect of block, E_{ijk} = residual error.

3. Results and Discussion

3.1. Soil Chemical Characteristics of Experimental Site. The soil chemical compositions of experimental sites before the experiment are presented in Table 1. The pH, organic matter, and available phosphorus were significant ($P < 0.05$) in soil type of this study. Relatively the higher pH content (6.94) was recorded at black soil than in red soil (5.45). The higher organic matter (2.86) was recorded at red soil than in black soil (2.42). Similarly, the highest available phosphorus content (7.49) was observed at red soil than in black soil (4.57). The organic carbon and total nitrogen contents were not significantly different ($P < 0.05$) between two soil types.

The current study overall mean of soil sample chemical analysis showed both experimental sites (red and black soils) had medium total nitrogen content (0.225%) as compared to the values of soil classification based on total nitrogen reported by [33]. The pH of red soil is an acidic condition than black soil in this study, but this was not reflected in terms of organic carbon and available phosphorus. The longtime inorganic fertilizer application in Ethiopia could be a possible reason for acidic soil [34] and organic fertilizer is recommended as mitigations of acidic soil in a sustainable manner. Supporting this, a report earlier made by [35] showed that *Brachiaria* grass species could give better production between in pH ranging from 4.2 to 8. Though the difference between soil types recorded in this study for available phosphorus, the amount of available soil P level was classified as low which could be a limiting factor for forage production and quality [36, 37]. Similarly, the current result of soil organic carbon contents at both soil types were medium level as compared to the classification made by [38] and the possible driving factor for the low level is the land use practices mostly arable lands have a lower value than protected land uses [39].

3.2. Fertilizer, Cultivars, and Soil Type on Brachiaria Grasses Morphoagronomical Performance. Significant interaction ($P < 0.001$) effects of fertilizer application, cultivars, and soil type on all morphological characteristics and forage yield of *Brachiaria* grasses are presented in Table 2.

3.2.1. Plant Height. The longest plant height (PH: 1.55 and 1.45 m) was recorded from mutica grass cultivar at black and red soil with fertilizers, respectively. While the shortest PH was recorded from *Brachiaria* grass c.v Marandu (0.32 m) and c.v La liberated (0.3 m) without fertilizer application at both soil types. This indicates that PH can be differing among *B. cultivars* with the same management system, due to the genetic potential of species/cultivars. As expected fertilizer application favored PH significantly ($P < 0.001$) as compared to control at both soil types and in all experimental *Brachiaria* grass cultivars; associated with massive root development and efficient nutrient uptake, allowing the forage grass to continue to increase in height [40, 41]. In addition, the implication that both soil types in the study area is demanding fertilizer application for the better forage production. This present study was in agreement with the findings of [42] who noted that as the level of NKP fertilizer increase (0 to 150 to 300 kg/ha) the mean PH of *Brachiaria* brizantha c.v Marandu was increased from 6.74 to 7.86 to 10.13 cm, respectively at 60 days of harvesting age. But, the current study values of all experimental *Brachiaria* grass cultivars are higher than these values (74 to 7.86 to 10.13 cm) reported by [42]. This difference might be attributed by the genetic variation of grasses, soil type an fertility, rain fall condition, harvesting age, and methods of establishment. Similarly, the overall mean of *Brachiaria* grass cultivars PH

Table 1: Soil sample chemical composition of experiment sites before planting.

Soil type	N (N = 12)	Soil chemical composition parameters				
		PH	Organic carbon (%)	Organic matter (%)	Total nitrogen (%)	Available phosphorus (ppm)
Black	6	6.94^{a}	1.41	2.42^{b}	0.22	4.57^{b}
Red	6	5.45^{b}	1.64	2.86^{a}	0.23	7.49^{a}
Mean		6.194	1.52	2.64	0.225	6.03
SEM		0.22	0.06	0.11	0.01	0.43
Sig		***	Ns	**	Ns	**
CV		0.908	12.876	12.188	17.117	10.4

Ppm = part per million, SEM = standard error of the mean, CV = coefficient of variation, Ns = not significant, Sig = significance level.

Table 2: Effect of fertilizer, cultivars type and soil type on morphological characteristics and forage yield of *Brachiaria* grasses.

Variables			Parameters							
Soil type	FER	Cultivars	PLH (m)	NTPP (count)	NLPP (count)	LL (cm)	NRPP (count)	RL (cm)	LSR	DMY (ha)
Black	With	Mutica	1.55^{a}	40^{bc}	333.3^{b}	22^{a}	133.67^{ef}	13.6^{bc}	1.04^{hi}	20.37^{a}
		Mulato-II	0.82^{d}	46^{a}	380.93^{a}	20.2^{b}	154.3^{bc}	15.6^{a}	2.17^{ab}	18.61^{b}
		Mulato-I	0.52^{fg}	36.3^{efg}	233.7^{de}	17.9^{cd}	154.7^{bc}	11.9^{de}	1.96^{abc}	11.07^{e}
		Marandu	0.51^{fg}	29.8^{j}	185.03^{fg}	15.9^{e}	148.7^{cd}	13.8^{bc}	1.84^{bcd}	7.13^{g}
		La liberated	0.49^{fg}	26.2^{k}	153.49^{ghij}	13.6^{hi}	138.3^{e}	14.07^{b}	1.76^{bcde}	5.7^{jkl}
	Without	Mutica	1.12^{c}	32.2^{hi}	173.03^{gh}	18^{c}	113^{h}	10.13^{fg}	1.14^{ghi}	6.95^{gh}
		Mulato-II	0.55^{f}	36.3^{efg}	185.2^{fg}	17.5^{cd}	125.3^{g}	11.13^{ef}	1.52^{defg}	6.5^{hi}
		Mulato-I	0.37^{ij}	31.03^{ij}	157.27^{ghi}	15.2^{ef}	138^{e}	8.53^{hi}	1.47^{efgh}	5.33^{kl}
		Marandu	0.32^{jk}	26.67^{k}	143.15^{hij}	14.9^{fg}	137.3^{e}	7.8^{i}	1.78^{bcde}	3.85^{n}
		La liberated	0.35^{jk}	24.9^{k}	124.07^{j}	11.17^{k}	132.67^{ef}	7.6^{i}	1.3^{fghi}	2.75^{o}
Red	With	Mutica	1.45^{b}	41.67^{b}	264.0^{c}	17.03^{d}	134.53^{ef}	11.8^{de}	1.09^{i}	17.19^{c}
		Mulato-II	0.62^{e}	45.27^{a}	366.68^{a}	13.07^{ij}	163.33^{a}	14^{b}	1.98^{abc}	13.29^{d}
		Mulato-I	0.52^{fg}	39c^{d}	244.23^{cd}	12.57^{j}	147.3^{d}	9.8^{fgh}	1.82^{bcd}	11.55^{e}
		Marandu	0.5^{fg}	37.67^{de}	217.8^{de}	20.27^{b}	159.33^{ab}	11.9^{de}	2.27^{a}	6.02^{ij}
		La liberated	0.46^{gh}	36.03^{efg}	154.49^{ghij}	20.58^{b}	149.5^{cd}	12.6^{cd}	1.77^{bcde}	5.87^{jk}
	Without	Mutica	0.85^{d}	20.33^{l}	135.67^{ij}	14.7^{fg}	105.5^{i}	5.87^{j}	1.02^{i}	5.27^{l}
		Mulato-II	0.42^{hi}	34.8^{fg}	163.52^{ghi}	10.74^{k}	138^{e}	9.7^{gh}	1.7^{cdef}	8.2^{f}
		Mulato-I	0.36^{ij}	31.17^{ij}	208.97^{ef}	13.03^{ij}	133.3^{ef}	8.5^{hi}	1.68^{cdef}	5.65^{jkl}
		Marunda	0.38^{ij}	37.0^{def}	222.07^{de}	17.13^{cd}	134^{ef}	7.8^{i}	1.769^{bcde}	4.44^{m}
		La liberated	0.3^{k}	34.0^{gh}	208.5^{ef}	14.13^{gh}	129.67^{fg}	7.6^{i}	1.39^{efghi}	3.47^{n}
		Overall mean	0.62	34.32	212.76	15.98	138.53	10.69	1.63	8.46
		SEM	0.04	0.86	9.19	0.41	3.42	0.34	0.05	0.63
		CV	5.6	3.74	8.19	3.17	2.79	7.15	13.23	3.78
		R^2	0.993	0.974	0.963	0.983	0.952	0.948	0.805	0.997
		Sig	***	***	***	***	***	***	***	***

ST = soil type, FER = fertilizer, R^2 = coefficient of determination, CV = coefficient of variation, SEM; standard error mean; Sig = significance level.

recorded in the present study was higher than reported by [13] which reaffirms that *brachiaria* grasses could grow well on drained acidic soil as reported by [43, 44].

3.2.2. Number of Tillers per Plant. Similar to the PH; fertilizer application also favored the number of tillers per plant (NTPP). The maximum NTPP ($p < 0.001$) were obtained from hybrid Mulato-II (46 and 45.25) with fertilizer application at black and red soils, respectively. The lowest NTPP was obtained from *Brachiaria mutica* (20.3) without fertilizer at red soil followed by c.v La liberated and c.v Marandu (24.9 and 26.6) without fertilizer at black soil. This finding is in line with [44] who indicated that the NTPP were advantaged by the fertilizer application for *brachiaria* grass. The NTPP is an important parameter to determine forage productivity and it has to be considered in the forage evaluation program. The NTPP is an important attribute trait of grasses; it increases the chances of survival and the amount of available forage production.

3.2.3. Number of Leaves per Plant. The *brachiaria* cultivars differences were reflected in all morphological parameters and this was also reported by [13] for three *Brachiaria brizantha* grass ecotypes in Ethiopia. This difference might be attributed from the genetics and agronomic practices of the different studies. The maximum number of leaves per plant (NLPP) was recorded from hybrid Mulato-II (380.93 and 366.68) with fertilizer at black and red soil, respectively. The lowest NLPP was obtained from *Brachiaria* c.v La liberated (124.07) without fertilizer at black soil ($p < 0.001$). Like the other parameters, fertilizer application favored the NLLP of brachiaria species in the current study and supported with findings reported by [40]; as NKP fertilizer increases from 0 to 150 to 300 kg/ha, the number of leaves per plant of *Brachiaria* c.v Marandu were increased. Nitrogen increased plant growth and plant height which resulted in more nodes, internodes, and consequently more leaves per plant as reported by [23, 45]. The parameter NLPP is an important parameter determining both the quantity and quality of the forage; both are equally important for Ethiopia livestock feed situation. The increased number of leaves could facilitate more photosynthetic activities. The NLPP was affected by type cultivars in the current study are in line with the report of the three *Brachiaria brizantha* grass ecotypes in Ethiopia as indicated by [13].

3.2.4. Leaf Length per Plant. The longest leaf length per plant (LLPP) was recorded from *B. mutica* (22 cm) with fertilizer at black soil. The shortest overall mean LLPP was obtained from hybrid Mulato-II (10.74 cm) and *Brachiaria* c.v La liberated (11.17 cm) without fertilizer at red and black soil, respectively. So, for the *brachiaria* grasses to be well grown in the study area of the present study, fertilizer application is commendable since a significant difference was observed between fertilized and unfertilized ones. Moreover, the observed significant variations among the studied *brachiaria* cultivars in the current study could give for the livestock producers an ample choice to select the high performing *brachiaria* cultivars. The LLPP is an important parameter to influence both forage productivity and quality and is supported with the idea [45]. The advantage of fertilizer application noticed in this study also reflected from the previous study by [41, 46] who reported that as the level of NKP fertilizer increases from (0 to 150 to 300 kg/ha), the mean leaf length of *Brachiaria* Marandu was progressively increased. The mean leaf length of our current result from all experimental *B. cultivars* (15.98 cm) was longer than *Brachiaria* c.v Marandu as reported by [41]; might be attributed by agronomic, edaphoclimate, and forage plants genetic variation. Overall, the forage producers in the study area should simultaneously consider all three factors (soil type; *B. cultivars,* and fertilizer application) for quality and quantity forage production since their interaction effect was significant for all aerial morphology of the studied grasses.

3.2.5. Number of Roots and Root Length per Plant. The below ground forage parameters like root parameters are becoming increasingly important equally like the above biomass since it affects its quality, quantity, and for sustainability of the established forage in the production area. The maximum number of roots per plant (NRPP) was obtained from hybrid Mulato-II (163.33) at red soil with fertilizer while the minimum number of roots was observed from *B. mutica* (111) without fertilizer at black soil. Similarly, the finding of the fertilizer application improved the root length for Mulato-II grass grown in low land of Ethiopia [46]. Forage plants with better roots also keep the soil in place, improve soil fertility, reduce water leaching and soil erosion and are keys for soil phytoremediation [47, 48]. The root parameters also serve for the better soil nutrient absorption and critically determine the overall grass performance by increasing the grass tillering [49].

The longest root length per plant (RLPP) was recorded from hybrid Mulato-II (15.6 cm) at black soil, while the shortest was obtained from mutica (5.87 cm) at red soil without fertilizer. Similarly, fertilizer application favored the RLPP in the current study is in agreement with [46] who reported a similar finding for Mulato-II grass grown in the lowland area of Ethiopia. As the root length increases, water and mineral absorption increased significantly which could improve the establishment and sustainability of the *brachiaria* grasses in the production area because as the greater the root length, the shorter the distance the nutrient has to travel to the root. So forage producers should consider at the same time the soil type, fertilizer application, and the type of *brachiaria* grass cultivars during the forage establishment.

3.2.6. Leaf to Stem Ratio. The highest leaf to stem ratio (LSR) was recorded from c.v Marandu (2.27) at red soil with fertilizer application, while the lowest was observed at *B. mutica* (1.04 to 1.13) with and without fertilizer at both soil types, respectively. Similarly, [50] reported the differences among *brachiaria* cultivars in terms of LSR by which the highest was recorded for Marandu cultivar. This difference might be attributed to the genetic potential of cultivars ability to respond with similar agronomic practices (fertilizer) at different edaphoclimatic conditions and the production of more number of leafs per plant. Moreover, fertilizer application improved the LSR of Mulato-II grass which was grown in the lowland part of Ethiopia [46]. The LSR is an important trait for forage grass evaluation, especially in the tropics where most of the forage plants do not satisfy the protein requirement of ruminant animals. As consequence, grasses with higher LSR are favored in animal nutrition since it is an important factor affecting diet selection, quality, and intake of forage [51].

3.2.7. Dry Matter Yield. The highest forage dry matter yield (DMY) was recorded from mutica (20.37 t/ha) at black soil with fertilizer, followed by hybrid Mulato-II (18.62 t/ha) while the lowest was recorded from c.v La liberated (2.75 t/ha) without fertilizer at black soil. In line with this study the difference among *brachiaria* grass cultivar were reported for forage dry matter yield by [52]. Contrarily; however a previous study by [53] claimed that non-significant difference of forage yield among *Brachiaria* grass cultivars grown in Kenya. *Brachiaria* grass cultivars of the current study responded more forage yield to the fertilizer application at both soil types could be attributed to the formation of additional tillers developed which conveyed an increase in leaf formation, leaf elongation, stem and root development [54]. Similarly to the current findings, [46, 50] reported that fertilizer application enhanced the forage production of different *brachiaria cultivars.* The overall mean and results from all current experimental cultivars except *Brachiaria*

Table 3: Effect of fertilizer, soil type and cultivars on chemical composition of *Brachiaria cultivars*.

Variables			Parameters (dry matter basis)					
ST	FER	Cultivars	DM (%)	ASH (%)	OM (%)	NDF (%)	ADF (%)	ADL (%)
Black	WF	Mutica	93.89^{ab}	10.13^{f}	89.872^{b}	73.93^{c}	56.35^{c}	10.78^{b}
		Mulato-II	93.37^{fgh}	12.71^{cd}	87.29^{ed}	65.75^{i}	48.58^{g}	9.64^{de}
		Mulato-I	93.61^{cdef}	11.52^{e}	88.48^{c}	67.28^{fghi}	49.13^{fg}	10.67^{bc}
		Marandu	93.29^{ghi}	12.76^{cd}	87.24^{ed}	71.3^{d}	53.53^{d}	10.23c
		La liberated	93.4^{fgh}	12.98^{c}	87.024^{e}	66.51^{ghi}	52.46^{de}	9.48^{de}
	WO	Mutica	93.78^{bcd}	8.56^{g}	91.44^{a}	78.97^{a}	63.66^{a}	12.09^{a}
		Mulato-II	92.97^{j}	9.8^{f}	90.2^{b}	68.98^{def}	55.68^{c}	10.43^{bc}
		Mulato-I	93.9^{ab}	11.35^{e}	88.65^{c}	65.07^{i}	49.21^{fg}	9.14^{ef}
		Marandu	93.41^{fgh}	12.3^{d}	87.7^{d}	70.89^{d}	53.69^{d}	10.31^{bc}
		La liberated	93.53^{efg}	12.92^{c}	87.08^{e}	76.22^{b}	50.28^{fg}	8.94^{f}
Red	WF	Mutica	93.78^{bcd}	8.56^{g}	91.44^{a}	78.97^{a}	63.66^{a}	12.09^{a}
		Mulato-II	93.28^{hi}	11.391^{e}	88.61^{c}	68.46^{efg}	49.78^{fg}	9.78^{d}
		Mulato-I	93.55^{def}	11.18^{e}	88.82^{c}	66.09^{hi}	49.39^{fg}	10.77^{b}
		Marandu	93.07^{ij}	12.73^{cd}	87.27^{ed}	68.08^{efgh}	49.19^{fg}	9.43^{def}
		La liberated	93.4^{fgh}	13.58^{b}	86.42^{f}	69.05^{def}	50.9^{ef}	9.34^{def}
	WO	Mutica	93.82^{abc}	8.56^{g}	90.41b	77.91^{ab}	58.51^{b}	10.24^{c}
		Mulato-II	94.04^{a}	10.92^{e}	89.079c	69.74^{de}	49.84^{fg}	9.53^{de}
		Mulato-1	93.9^{ab}	11.35^{e}	88.65c	65.07^{i}	49.21^{fg}	9.14^{ef}
		Marandu	93.75^{bcde}	14.37^{a}	85.63^{g}	65.36^{i}	45.59^{1h}	9.35^{def}
		La liberated	93.39^{fgh}	13.58^{b}	86.42^{f}	69.05^{def}	50.9^{ef}	9.34^{def}
		Overall mean	93.56	11.6	88.39	70.13	52.48	10.04
		SEM	0.05	0.26	0.26	0.74	0.77	0.14
		CV	0.11	2.31	0.3	1.4	1.5	2.1
		R^2	0.937	0.986	0.986	0.976	0.986	0.972
		Sig	***	***	***	***	***	***

ST = soil type, FER = fertilizer, R^2 = coefficient of determination, CV = coefficient of variation, SEM = standard error mean; Sig = significance level, WF = with fertilization, WO = without fertilizer.

La liberated without fertilizer was higher than *Brachiaria brizantha* ecotypes harvested at 90 days [13]. This difference could be attributed from the environmental condition and genetic/accession variation.

3.3. *Effects of Fertilizer, Cultivars and Soil Type on Brachiaria Grasses*

3.3.1. Dry Matter Content. The three factors interaction significantly ($P < 0.001$) affected the nutritive values of *brachiaria cultivars* (Tables 3 and 4). The current study was a significant effect on the DM content difference among cultivars in this study is in line with [13] who reported that DM content was significantly affected by *Brachiaria brizantha* ecotypes. The overall mean of DM content in the current study was (93.55%) was lower than *Brachiaria mutica* grass as reported by [55]. The overall mean of DM content in the current study was (93.55%) was higher than *brachiiaria mutica* harvested at 90 days [55]. This difference might be attributed from soil condition, genetics, fertilizer, and drying methods of samples.

3.3.2. Ash and Organic Matter. The highest organic matter (OM) content was at the lowest ash content and the lowest organic matter content was at the highest ash content. The high ash content in the some *Brachiaria* grass cultivars (Marandu and La liberated) in the current study could be a mineral source. This mineral concentration varies among cultivars could be attributed from morphological fractions, climatic conditions, soil characteristics, and fertilizer application. Contrary to this study, increased fertilizer application did not bring the OM difference between *B. decumbens* v. Basilisk and *B. ruziziensis* cv. Kennedy where conducted in Indonesia [56]. The concentrations of mineral nutrients in a forage plant could be influenced either by environment or agronomic practice management.

3.3.3. Fiber Contents. The neutral detergent fiber (NDF), acid detergent fiber (ADF), and acid detergent lignin (ADL) are the major fiber constituent of the tropical forage grasses influencing the nutritional value of the forage in the livestock performance. The highest NDF, ADF, and ADL were obtained from mutica (78.97, 63.66, and 12.09), respectively, without fertilizer at black soil. Even the lowest recorded fibers from hybrid Mulato-II (65.75) and Mulato-I (65.007) are beyond the maximum fiber recommendation in ruminant nutrition [30]. The effect of fertilizer application could not bring satisfactory fiber levels for the ruminant animals although lower fibers as compared to the nonfertilized one reported in the current study. In general, there is a positive trend that fertilizer application could reduce the forage fibers and in turn improve forage quality [56, 57]. The positive influence of fertilizer could be explained in terms of faster plant growth, raise new leaves, tillers, and shoots and indeed reduces the fiber content.

Table 4: Effect of fertilizer, soil type, and cultivars on nutritive values of *Brachiaria* grasses.

Variables			Parameters (dry matter basis)				
ST	FER	Cultivars	CP (%)	CPY (t/ha)	IVDMD (%)	IVOMD (%)	ME (MJ/kg)
Black	With	Mutica	10.78^{f}	2.2^{b}	55.25^{g}	48.32^{ghi}	7.27^{ef}
		Mulato-II	13.04^{bc}	2.43^{a}	65.82^{abc}	57.24^{ab}	8.21^{bc}
		Mulato-I	12.7^{cd}	1.41^{d}	68.77^{a}	60.5^{a}	8.78^{a}
		Marandu	13.78^{a}	0.98^{e}	57.1f^{g}	49.35^{fgh}	7.17^{ef}
		La liberated	11.6^{e}	0.66^{h}	60.42^{def}	52.2^{def}	7.52^{de}
	Without	Mutica	7.2^{k}	0.5^{i}	52.24^{h}	46.15^{hi}	7.12^{ef}
		Mulato-II	8.65^{j}	0.96^{e}	52.36^{h}	45.5^{i}	6.92^{f}
		Mulato-I	9.2^{h}	0.49^{i}	67.72^{ab}	58.78^{ab}	8.56^{ab}
		Marandu	9.97^{g}	0.38^{k}	57.57^{efg}	49.99^{efg}	7.3^{def}
		La liberated	8.03^{j}	0.22^{m}	60.85^{de}	52.54^{cdef}	7.57^{de}
Red	With	Mutica	10.3^{g}	1.77^{c}	52.24^{h}	46.15^{hi}	7.12^{ef}
		Mulato-II	13.21^{bc}	1.75^{c}	64.35^{bc}	55.91^{bc}	8.17^{bc}
		Mulato-I	12.6^{d}	1.46^{d}	68.45^{a}	60.56^{a}	8.82^{a}
		Marandu	14.02^{a}	0.67^{h}	66.98^{ab}	58.34^{ab}	8.36^{ab}
		La liberated	11.31^{e}	0.66^{h}	62.6^{cd}	53.37^{cde}	7.62^{de}
	Without	Mutica	7.1^{k}	0.43^{jk}	47.27^{i}	40.7^{j}	6.28^{g}
		Mulato-II	9.02^{hi}	0.74^{g}	58.89^{ef}	51.37^{efg}	7.61^{de}
		Mulato-I	8.8^{i}	0.5^{i}	67.72^{ab}	58.78^{ab}	8.56^{ab}
		Marunda	10.7^{f}	0.84^{k}	64.41^{bc}	55.36^{bcd}	7.79^{cd}
		La liberated	8.19^{j}	0.28^{l}	62.59^{cd}	53.36^{cde}	7.62^{de}
		Overall mean	10.55	0.96	60.68	52.72	7.72
		SEM	0.34	0.1	1.01	0.89	0.11
		CV	1.62	2.58	2.55	3.00	2.72
		R^2	0.997	0.999	0.979	0.959	0.952
		Sig	***	***	***	***	***

ST = soil type, FER = fertilization, CP = crude protein, CPY = crude protein yield, IVDMD = in vitro dry matter digestibility, IVOMD = in vitro organic matter digestibility, ME = metabolizable energy, coefficient of determination, CV = coefficient of variation, SEM = standard error of mean, Sig = significance level.

3.3.4. Crude Protein. The crude protein (CP) content of the forage is the critical parameter for the forage evaluation indicator since it is an essential nutrient required by the ruminant animals. The highest CP content was recorded from c.v Marandu (14.02) with fertilizer at red soil, while the lowest was recorded from *B. mutica* (7.25 and 7.2) without fertilizer at red and black soil, respectively. But, the highest CP was recorded by Mulato II than c.v Marandu in the previous study [28, 57]. The difference explained here among *brachiaria cultivars* in the current study also supported by [58] who reported the CP content difference in *brachiaria* species cultivars. The CP content is one of the most important criteria to determine the nutritional quality of livestock feeds; this due to a level of CP increases, the DM intake by livestock and rumen microbial growth would also increase; as explained by [59]. The difference in CP content of *Brachiaria* grass cultivars in the current study can be explained by the inherent characteristics of each *Brachiaria* species associated with the ability to extract and accumulate nutrients from the soil and fix nitrogen from the atmosphere.

3.3.5. Crude Protein Yield. The highest crude protein (CPY) was recorded from hybrid Mulato-II (2.43) at black soil with fertilizer while the lowest CPY was recorded from La liberated (0.22) without fertilizer at black soil. Fertilizer had a significant effect on *Brachiaria* grass cultivars CPY at both soil types in the current study. Variations in CPY of cultivars in the current is in line with [13] reported that the highest CPY of *Brachiaria brizantha* grass was recorded from Eth. 13809 (0.66 t/ha) followed by Eth. 1377 (0.52 t/ha) and Eth. 13726 (0.38 t/ha). Overall the current result was significantly higher CPY than the *Brachiaria* brizantha [13] at both soil types except *Brachiaria* La liberated cultivars without fertilizer. This difference might be attributed from genetics, environmental conditions, and agronomic practices.

3.3.6. In Vitro dry Matter and Organic Matter Digestibility. The highest IVDMD was recorded from hybrid Mulato-I (68%) with fertilizer in both soil types and the lowest IVDMD was recorded from mutica (47.275) at red soil without fertilizer. In line with the current study [56] reported that IVDMD differences are affected by *brachiaria* grass cultivars. In general, the mean IVDMD value (60.68) of the current study explaining that these grass cultivars are promising feed resources to be a better feed stuff as compared to the major feed resources (crop residues and hay) in Ethiopia. The highest IVOMD (%) was recorded from hybrid Mulato-I (60) in both soil types with fertilizer. The lowest IVOMD was recorded from mutica (40.66) without fertilizer at red soil. In line with the current study [60] reported that IVOMD differences were noted by *brachiaria* species cultivars. The highest IVOMD was obtained from hybrid Mulato-II (50.9), hybrid Mulato (49.4), and marandu (43.7) at 90 days of harvesting age. The current result is higher than that of the same *Brachiaria* species reported by [57] harvested at 90 days. The environmental conditions, soil type, and fertility, agronomic practices could be a responsible factor for the discrepancy.

3.3.7. Metaboliazble Energy. The highest ME was recorded from hybrid Mulato-I (8.78 and 8.82 MJ/kg) with fertilizer at black and red soil, respectively. The lowest ME was recorded from mutica (6.28 MJ/kg) at red soil without fertilizer. These grass cultivars could be potential energy feed stuff in the ruminant nutrition though not reaching to the required level, i.e. 12 MJ/kg [60]. Hereafter, according to this classification, all *Brachiaria cultivars* grown in both soil types and fertilizer application in the current study was classified as low energy feed content that are below the minimum maintenance energy requirement of livestock production [60] of course it explains the feature of tropical forage plants.

4. Conclusion

Agronomic performance and nutritive values of the forage harvested at 90 days were significantly affected by the three factors interactions. *Brachiaria mutica* cultivar had better forage at both soil types followed by hybrid Mulato-II and hybrid Mulato-I with fertilizer application. Hybrid Mulato-I, hybrid Mulato-II and c.v Marandu were better in nutritional value at both soil types with fertilizer as compared to without fertilizer. Based on evaluated parameters, *Brachiaria* hybrid Mulato-II, *Brachiaria mutica,* and *Brachiaria* hybrid Mulato-I were selected better to fulfill the forage quantity and quality shortage and to enhance the livestock production and productivity in Ethiopia. Hence, soil type, fertilizer application, and *brachiaria* species cultivar could be simultaneously considered by the farmers while they are going to establish the permanent pasture. As a limitation of the study, the current study sites were in different edaphoclimatic condition and might have an effect on the research findings, hence we recommend its consideration for future similar research.

Data Availability

The [DATA TYPE] data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest regarding the publication of this paper.

Acknowledgments

The first author would like to thank Amhara Agricultural Research Institute (Andassa livestock Research Center) for facilitating the research process through graduate tuition fee payment and research funding.

References

[1] CSA (Central Statistics Agency), *Agricultural Sample Survey 2020/2021: Report on Livestock and Livestock Characteristics*, CSA, Addis Ababa, Ethiopia, 2021.

[2] G. A. W. G. Assefa Woldemariam, "Efforts, successes and challenges of green feed production in Ethiopia," *Online Journal of Animal and Feed Research*, vol. 11, no. 1, pp. 13–17, 2021.

[3] A. Asresie, L. Zemedu, and E. Adigrat, "The contribution of livestock sector in Ethiopian economy," *A Review Advances in Life Science And Technology*, vol. 29, 2015.

[4] Y. Mekuriaw, M. Urge, and G. Animut, "Intake, digestibility, live weight changes and rumen parameters of Washera sheep fed mixtures of lowland bamboo (Oxytenanthera abyssinica) leaves and Natural Pasture Grass Hay at different ratios," *Pakistan Journal of Nutrition*, vol. 11, no. 4, pp. 322–331, 2012.

[5] R. Tschopp, A. Aseffa, E. Schelling, and J. Zinsstag, "Farmers' perceptions of livestock, agriculture, and natural resources in the rural Ethiopian highlands," *Mountain Research and Development*, vol. 30, no. 4, pp. 381–390, 2010.

[6] S. Damene, A. Bahir, and G. B. Villamor, "The role of Chomo grass (Brachiaria humidicola) and exclosures in restoring soil organic matter, total nitrogen, and associated functions in degraded lands in Ethiopia," *Regional Environmental Change*, vol. 20, no. 3, pp. 92–13, 2020.

[7] S. R. Ghimire, D. M. Njarui, M. Mutimura et al., *Climate-smart Brachiaria for Improving Livestock Production in East Africa: Emerging Opportunities*, 2019.

[8] J. Li, G. S. Okin, L. Alvarez, and H. Epstein, "Quantitative effects of vegetation cover on wind erosion and soil nutrient loss in a desert grassland of southern New Mexico, USA," *Biogeochemistry*, vol. 85, no. 3, pp. 317–332, 2007.

[9] J. K. Mutegi, D. N. Mugendi, L. V. Verchot, and J. B. Kung'u, "Combining napier grass with leguminous shrubs in contour hedgerows controls soil erosion without competing with crops," *Agroforestry Systems*, vol. 74, no. 1, pp. 37–49, 2008.

[10] R. C. Byrnes, J. Nùñez, L. Arenas et al., "Biological nitrification inhibition by Brachiaria grasses mitigates soil nitrous oxide emissions from bovine urine patches," *Soil Biology and Biochemistry*, vol. 107, pp. 156–163, 2017.

[11] A. C. R. Marques, L. B. D Oliveira, F. T. Nicoloso, R. J. S. Jacques, S. J. Giacomini, and F. L. F. D Quadros, "Biological nitrogen fixation in C4 grasses of different growth strategies of South America natural grasslands," *Applied Soil Ecology*, vol. 113, pp. 54–62, 2017.

[12] L. Momesso, C. A. Crusciol, M. F. Leite, J. W. Bossolani, and E. E. Kuramae, "Forage grasses steer soil nitrogen processes, microbial populations, and microbiome composition in a long-term tropical agriculture system," *Agriculture, Ecosystems & Environment*, vol. 323, Article ID 107688, 2022.

[13] W. A. Wassie, B. A. Tsegay, A. T. Wolde, and B. A. Limeneh, "Evaluation of morphological characteristics, yield and nutritive value of Brachiaria grass ecotypes in northwestern Ethiopia," *Agriculture & Food Security*, vol. 7, no. 1, pp. 89–10, 2018.

[14] M. Getnet, H. Arega, E. Shitaneh, and B. Worku, "Determination of appropriate cutting date of perennial elite lowland adaptive forage grass species: chifir bequa (pennisetum polystachion)," *International Journal of Scientific Engineering and Science ISSN (Online)*, vol. 2456, no. 7361, pp. 1–3, 2020.

[15] M. Mutimura and T. Everson, "On-farm evaluation of improved Brachiaria grasses in low rainfall and aluminium toxicity prone areas of Rwanda," *International Journal of Biodiversity and Conservation*, vol. 4, no. 3, pp. 137–154, 2012.

[16] Alrc (Andassa Agricultural Research center), *Participatory evaluation of productive Napier accessions in north western Amhara Region Ethiopia. Presentend at Annual Completed Review Forum*, Amhara Agreicultural Research Institute, Ethiopia, Bahir Dar, 2018.

[17] J. A. Pedro, J. W. Miles, D. J. Guiot, H. Cuadrado, and C. E. Lascano, *Cultivar Mulato II (Brachiaria hybrid CIAT 36087): a high-quality forage grass, resistant to spittlebugs and adapted to well-drained, acid tropical soils, CIAT, Cali, Colombia*, 2007.

[18] J. W. Miles, V. C. B. do, I. M. Rao, and V. P. B. Euclides, "Brachiaria grasses," in *Warm-season (C4) Grasses*, L. E. Moser, L. E. Burson, and L. E. Sollenberger, Eds., pp. 745–783, ASA, CSSA, SSSA, Madison, WI, USA, 2004.

[19] S. L. Lapointe, M. S. Serrano, G. L. Arango, G. Sotelo, and F. Cordoba, "Antibiosis to spittlebugs (Homoptera: cercopidae) in accessions of Brachiaria spp," *Journal of Economic Entomology*, vol. 85, no. 4, pp. 1485–1490, 1992.

[20] J. R. Okalebo, K. W. Gathua, and P. L. Woomer, *Laboratory Methods of Soil and PlantAnalysis: A Working Manual*, p. 128, TSBF-KARI, SSEA, SACRED Africa, Nairobi, Kenya, 2002.

[21] A. H. Tessema Zewdu, T. Zewdu, M. Urge, and F. Sisal, "Effect of nitrogen fertilizer application on nutritive value of cenchrus ciliaris and Panicum maximum grown under irrigation at gode, Somali region," *Journal of Nutrition & Food Sciences*, vol. S11, p. 005, 2015.

[22] A. G. Cameron and B. Lemcke, *Para Grass: A Pasture Grass for Wet and Flooded Soils*, p. E30, 2008.

[23] T. Zewdu, R. M. T. Baars, and A. Yami, "Effect of plant height at cutting and fertilizer on growth of Napier grass (Pennisetum purpureum)," *Tropical Science*, vol. 43, no. 1, pp. 57–61, 2003.

[24] S. Tudsri, S. T. Jorgensen, P. Riddach, and A. Pookpakdi, "Effect of cutting height and dry season closing date on yield and quality of five Napier grass cultivars in Thailand," *Tropical Grasslands*, vol. 36, pp. 248–252, 2002.

[25] E. B. Rayburn, J. D. Lozier, M. A. Sanderson et al., *Estimating pasture forage mass from pasture height*, pp. 1-2, Extension service west Virginia University, Morgantown, West Virginia, 2007.

[26] H. Arzani, M. Zohdi, E. Fish, G. Z. Amiri, A. Nikkhah, and D. Wester, "Phenological effects on forage quality of five grass species," *Journal of Range Management*, vol. 57, no. 6, pp. 624–629, 2004.

[27] Aoac (Association of Official Analytical Chemists), *Official Methods of Analysis*, Association of Official Analytical Chemists, Washington, DC, USA, 2004.

[28] P. J. Van soest, J. Robertson, and B. A. Lewis, "Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition," *Journal of Dairy Science*, vol. 74, no. 10, pp. 3583–3597, 1991.

[29] J. M. A. Tilley and R. A. Terry, "A two-stage technique for the in vitro drymatter digestibility of forage crops," *Grass and Forage Science*, vol. 18, no. 2, pp. 104–111, 1963.

[30] Nrc (National Research Council), *Nutrient Requirement of Domestic Animals, No.4: Nutrient Requirement of Dairy Cattle*, National Academy Press, Washington, DC, USA, 2001.

[31] R. D. G. Steel and J. H. Torrie, *Principles and Procedures of Statistics. A Biometrical Approach*, McGraw-Hill International Book Company, New York, NY, USA, 1986.

[32] Sas (Statistical analysis Software), *SAS User's Guide: Statistics*, SAS inst. Inc, Cary, NC, USA, 2002.

[33] J. R. Landon, *Booker Tropical Soil Manual*, p. 474, Longman scientific and technical essex, Essex, UK, 1991.

[34] A. Tesfaye, M. Githiri, J. Derera, and T. Debele, "Subsistence farmers' experience and perception about the soil, and fertilizer use in Western Ethiopia," *Ethiopian Journal of Applied Science and Technology*, vol. 2, no. 2, pp. 59–70, 2011.

[35] A. M. Larry, L. Mark, and M. C. Farland, "Soil pH and Forage Production," 2013, http://soilcrop.tamu.edu.SCS-2013-11.

[36] Y. Abera and S. Kassa, "Status of soil micronutrients in Ethiopian soils: a review," *Journal of Environment and Earth Science*, vol. 7, no. 4, pp. 85–90, 2017.

[37] T. Chippano, I. García, N. Cofré, and R. Mendoza, "Forage biomass yield and arbuscular mycorrhizal symbiosis in a legume and C3 and C4 grasses under increasing soil phosphorus availability," *Crop & Pasture Science*, vol. 71, no. 10, pp. 907–915, 2020.

[38] W. Amanuel, F. Yimer, and E. Karltun, "Soil organic carbon variation in relation to land use changes: the case of Birr watershed, upper Blue Nile River Basin, Ethiopia," *Journal of Ecology and Environment*, vol. 42, no. 1, pp. 16–11, 2018.

[39] Y. Abera and T. Belachew, "Land use effects on soil organic carbon and nitrogen in some soils of bale, southeastern Ethiopia," *Tropical and subtropical agroecosystems*, vol. 14, no. 1, pp. 229–235, 2010.

[40] U. Nafatul, P. D. Meita, S. Bambang et al., "Growth and Productivity of Brachiaria brizantha cv MG 5 under the effect of different dose of NPK fertilization," in *Proceedings of the 6th International Seminar on Tropical Animal Production Integrated Approach in Developing Sustainable Tropical Animal Production*, pp. 20–22, Yogyakarta, Indonesia, October 2015.

[41] I. M. Rao, P. C. Kerridge, and M. C. M. Macedo, "Nutritional requirements of Brachiaria and adaptation to acid soils," *Brachiaria: Biology, Agronomy, and Improvement*, vol. 53, no. 259, 1996.

[42] R. Heinrichs, F. G. Grano, L. G. D. F. Bueno et al., "Brachiaria sp yield and nutrient contents after nitrogen and sulphur fertilization," *Revista Brasileira de Ciência do Solo*, vol. 37, no. 4, pp. 997–1003, 2013.

[43] R. J. Van Saun, "Determining forage quality: understanding feed analysis," *Lamalink.com*, vol. 3, no. 8, pp. 18-19, 2006.

[44] M. Argel, J. Pedro, J. W. Miles, J. D. Guiot García, H. Cuadrado Capella, and C. E. Lascano, *Cultivar Mulato II (Brachiaria Hybrid CIAT 36087): A High-Quality Forage Grass, Resistant to Spittlebugs and Adapted to Well-Drained, Acid Tropical Soils*, CIAT, Colombia, CA, USA, 2007.

[45] R. E. Rodriguez, J. M. Debernardi, and J. F. Palatnik, "Morphogenesis of simple leaves: regulation of leaf size and shape," *Wiley Interdisciplinary Reviews: Developmental Biology*, vol. 3, no. 1, pp. 41–57, 2014.

[46] N. Yiberkew, Y. Mekuriaw, and B. Asmare, "Effects of fertilizer types and plant spacings on plant morphology, biomass yield and chemical composition of brachiaria hybrid mulato II grass grown in lowlands of Northwest Ethiopia," *Scientific Papers: Animal Science and Biotechnologies*, vol. 53, no. 1, 2020.

[47] J. Dessureault-Rompre, "Restoring soil functions and agroecosystem services through phytotechnologies," *Front. Soil Sci*, vol. 2, Article ID 927148, 2022.

[48] X. Zhu, W. Liu, J. Chen et al., "Reductions in water, soil and nutrient losses and pesticide pollution in agroforestry practices: a review of evidence and processes," *Plant and Soil*, vol. 453, no. 1-2, pp. 45–86, 2020.

[49] E. L. L. Véras, G. S. Difante, A. L. C. Gurgel et al., "Tillering capacity of Brachiaria cultivars in the Brazilian Semi-Arid Region during the dry season," *Tropical Animal Science Journal*, vol. 43, no. 2, pp. 133–140, 2020.

[50] A. J. Smart, W. H. Schacht, L. E. Moser, and J. D. Volesky, *Prediction of leaf/stem ratio using near-infrared reflectance*

*spectroscopy (NIRS): A Technical Note*Agronomy & Horticulture Faculty Publications, Lincoln, Nebraska, 2004.
[51] J. R. Garay, S. Joaquin Cancino, P. Zarate Fortuna et al., "Dry matter accumulation and crude protein concentration in Brachiaria spp. cultivars in the humid tropics of Ecuador," *Tropical Grasslands-Forrajes Tropicales*, vol. 5, no. 2, pp. 66–76, 2017.
[52] L. V. Crowder and M. R. Chheda, *Tropical Grassland Husbandry*, p. 562, Longman, London, UK, 1982.
[53] N. Umami, B. Suhartanto, M. P. Dewi et al., "Productivity of two varieties Brachiaria sp. on different level of fertilizer in Yogyakarta Indonesia," in *Proceedings of the 17th Asian-Australasian Association of Animal Production Societies Animal Science Congress*, Hotel Nikko Fukuoka, August 2016.
[54] C. R. Johnson, B. A. Reiling, P. Mislevy, and M. B. Hall, "Effects of nitrogen fertilization and harvest date on yield, digestibility, fiber, and protein fractions of tropical grasses," *Journal of Animal Science*, vol. 79, no. 9, pp. 2439–2448, 2001.
[55] M. Zemene, Y. Mekuriaw, and B. Asmare, "Effect of plant spacing and harvesting age on plant characteristics, yield and chemical composition of para grass (Brachiaria mutica) at Bahir Dar, Ethiopia," *Scientific Papers: Animal Science and Biotechologoes*, vol. 53, no. 2, pp. 137–145, 2020.
[56] M. Mupenzi, E. Cyprian, M. R. Idupulapati, and V. N. Ignatius, "Effect of cutting time on agronomic and nutritional characteristics of nine commercial cultivars of Brachiaria grass compared with Napier grass during establishment under semi-arid conditions in Rwanda," *African Journal of Agricultural Research*, vol. 12, no. 35, pp. 2692–2703, 2017.
[57] V. Chanthakhoun, M. Wanapat, and J. Berg, "Level of crude protein in concentrate supplements influenced rumen characteristics, microbial protein synthesis and digestibility in swamp buffaloes (Bubalus bubalis)," *Livestock Science*, vol. 144, no. 3, pp. 197–204, 2012.
[58] A. Mustaring, I. Subagyo, A. Soebarinoto, and A. Marsetyo, "Growth, yield and nutritive value of new introduced brachiaria species and legume herbs as ruminant feed in central sulawesi, Indonesia," *Pakistan Journal of Agricultural Research*, vol. 27, no. 2, pp. 89–98, 2014.
[59] P. McDonald, R. A. Edwards, J. F. D. Greenhalgh, C. A. Morgan, L. A. Sinclair, and R. G. Wilkinson, *Animal Nutrition*, Longman Group UK Ltd, England, UK, 6th edition, 2010.
[60] F. Erdem, N. Cetinkaya, C. Nisbet, and E. Altin, "Estimation of organic matter digestibility, metabolizable energy, phenolic compounds and antioxidant activity of stems and seeds of the *Juncus acutus* plant in ruminant nutrition," *South African Journal of Animal Science*, vol. 45, no. 5, p. 502, 2016.