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Morphometric Characteristics and Herbage Accumulation of Guinea (Panicum Maximum) Grass Influenced by Cultivar and Harvesting Age in West Gojjam Zone, Ethiopia

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ABSTRACT

Guinea (Panicum maximum) grass has shown promising results for livestock producers to cope with feed shortages in tropical areas. The objective of this study was to evaluate the morphometric characteristics and herbage accumulation of Guinea grass cultivars across different harvest ages. The experiment was set up with a 3×3 factorial arrangement using a randomized complete block design. The Guinea grass cultivars were Mombasa, Tanzania, and Degun gizia, and harvesting ages were at 60, 81, and 102 days after planting. The parameters measured were morphometric characteristics (plant height, tiller number, number of leaves per plant, length of leaf, number and length of root, leaf-to-stem ratio) and herbage accumulation. Data were analyzed using GLM procedure of SAS (9.0), and mean separation was done using Duncan Multiple Range Test, and significance was declared at P<0.05. All examined morphometric characteristics of guinea grass, except for leaf-to-stem ratio and herbage accumulation values, showed no interaction (P > 0.05) effect with the harvesting age and cultivars. The result indicated that morphometric characteristics and herbage accumulation were affected (P < 0.05) by harvesting age and cultivars. At Yigoma Huletu location, Mombasa had scored better values on herbage accumulation (11.94 t/ha DMY) at late harvesting age. Mombasa and Tanzania had better values on most morphometric characteristics except LSR, which had the highest values (1.77) by Degun gizia. At Kudmi location, Mombasa scored better values on plant height (109.1cm) and DMY (6.16 t/ha). Degun gizia scored the highest values on LSR and DMY (6 t/ha). Early harvest age (60 days) resulted in the highest leaf-stem ratio, while at late harvesting age (102 days) high morphometric characteristics and herbage accumulation. In order to increase ruminant productivity, these grass varieties are potential forages as an alternative fodder feed.

1. INTRODUCTION

Despite having one of Africa's largest livestock populations, Ethiopia's livestock output is still low (Bachewe, 2018). This is due to the major challenges that limit livestock production and productivity, such as feed shortages both in quality and quantity, disease, marketing problems, inefficient management, and poor breed performance (Demeke et al., 2017; Mengistu et al., 2021). Among these, lack of availability and access to quality feed continues to be a major technical constraint limiting animal productivity, especially in the dry season in the country as well as in the study areas (Balehegn et al., 2020; Demeke et al., 2017). According to an initial evaluation of Ethiopia's feed supply and demand, the feed deficiency was 10% when represented as DM but 42% and 45% when expressed as crude protein (CP) and metabolizable energy (ME), respectively (FAO, 2018).

Natural pasture grazing and crop residues cover a major proportion of the annual feed supply in the country (Begna & Masho, 2024). The excessive conversion of grazing fields into cultivated land and settlement areas is causing a decline in the amount of livestock feed derived from natural pastures. Most of the grazing /browsing lands have been overgrazed and degraded, therefore, providing only limited feed of inferior quality (Amsalu & Addisu, 2014). To assist animal producers and experts, introduce and screen to choose productive alternative perennial forage types with an emphasis on high yield, superior nutritional quality, improved disease resistance, decreased greenhouse gas emissions, and stress tolerance in the face of climate change (Tulu et al., 2023). The introduction and use of alternative forage that can integrate with current land usage and farming systems are essential to address issues concerning the amount and quality of forage produced (Mijena, 2022).

Small-scale traditional irrigation has been practiced for decades throughout the region. Farmers having good access to irrigation can practice improved forage growth three times a year in the North Mecha district (Shiferaw et al., 2018). Thus, potential candidates and better types of grass like guinea grass cultivars might be appropriate for the current farming methods in the tropical environment.

The introduction of guinea grass in the farming system would contribute to the feed domain of tropical countries. The grass is a C4 grass that is widely used in the tropics to feed ruminants due to its high yield and quality (Carvalho et al., 2020). Its deep, dense, and fibrous root system allows it to withstand drought while also being well-suited to well-drained, fertile soils (Bilgin, 2021). Because of their C4 photosynthetic pathway, tropical forage grasses exhibit high growth rates and biomass yields. In connection with this pathway, the morphology, anatomy, and chemical makeup of the leaf blades may affect the grass's overall forage quality, digestibility, and consumption (Batistoti et al., 2012). In primarily irrigation areas, guinea grass is grouped with tolerant plants that can be utilized in saline soils for proper management (Kusmiyati, 2018). Potential yield and quality of the forages vary greatly with harvesting age and cultivars. Despite guinea grass has a high level of diversity (Jank et al., 1997), few cultivars are used in Africa and abroad. Mombasa and Tanzania guinea grass cultivars currently show excellent qualities for cattle feeding, highlighting their good adaptability to various conditions of the tropics, and they can achieve high production of dry matter in Mombasa (53 t/yr) and Tanzania (19 to 20 t/yr) (Obando et al, 2024). On the other hand, Guinea grass 'Degun Gizia' variety, native to Ethiopia, is well-adapted and is productive with a dry matter yield of 9–14 t/ha and can grow up to 2,000 meters above sea level. However, many factors including harvesting age, soil types, water availability, temperature, forage genotype, season, and management influence the morphometric traits and herbage yield of forage (Moore et al., 2020). Understanding the effect of cultivar and harvesting age on morphological characteristics and herbage yield of forage species is extremely important to select suitable cultivars and appropriate harvesting age to maximize yield and quality. In this paper, we present the effect of cultivars and harvesting age on morphological characteristics and yield of guinea grass grown under irrigation conditions in West Gojjam Zone, Ethiopia

2. MATERIALS AND METHODS

2.1. Description of the Study Areas

The study was conducted in the year 2022 under irrigation conditions at two selected districts in the West Gojjam zone, Ethiopia. The specific site of the experiments for Bahir Dar Zuria district is called Yigoma Huletu Kebele, and Kudmi Kebele is for the North Mecha district. Soil samples were taken using a diagonal soil sampling technique at a depth of 30cm using an auger (Mutuku et al., 2020). Description of the experimental locations (geographical position, soil analysis result, rainfall, and temperature) during the experimental period is presented in Table 1.

Table 1. Description of experimental locations

SN	Parameter	Yigoma Huletu	Kudmi	Analysis method
1	Latitude	11° 29' N	11° 23' N	
2	Longitude	37° 29' E	37° 06'E	
3	Altitude (m.a.s.l)	1730	11966	
4	Distance from Addis Ababa (km)	587	524	
5	Monthly rainfall (mm)	1.27	0.83	
6	Monthly minimum temperature (^{0}C)	11.5	9.5	
7	Monthly maximum temperature (^{0}C)	29.44	29.2	
8	Soil type	Vertisols	Nitosols	
9	pH (1:2.5 H_2O)	7.03	4.98	(McLean, 1982)
10	Total nitrogen (%)	0.16	0.15	(Bremner & Mulvaney, 1982)
11	Total organic matter (%)	2.83	2.69	(Nelson & Sommers, 1982)
12	Available phosphorus (ppm)	4.46	4.72	(Olsen, 1954)

2.2. Experimental Design, Treatments, and Land Preparation

The experiment was laid out in a randomized complete block design with a 3 × 3 factorial arrangement with three replications. Plot size was 3 x 3 m (9 m^2) and spacing between plots and blocks were 1m and 1.5m, respectively. The land was cleared of weeds and unwanted debris, then ploughed four times and harrowed to a fine tilth before plots were outlaid, blocked and planted. Treatments were consisted of the 3 Guinea grass cultivars (Mombasa, Tanzania, and *Degun gizia*) with 3 harvesting ages (60, 81, and 102 days after planting).

2.3. Planting Materials, Planting, and Management

Mombasa and Tanzania cultivars were obtained from the International Livestock Research Institute (ILRI) forage gene bank while *Degun gizia* variety was obtained from Pawi Agricultural Research Center. Root splits were used for propagation and planted based on the spacing of 50 by 50 cm between rows and plants (Wouw et al., 2008). Furrow irrigation method were used to irrigate the grass at weekly intervals (Wouw et al., 2008). At the planting, 100 kg/ha NPS fertilizer was applied, and 100 kg /ha of urea fertilizer was top-dressed close to the root slips after establishment (Galindo et al., 2017).

2.4. Data Collection

2.4.1. Morphometric parameters

Plant morphometric characteristics mainly consisting of plant height (PH), number of tillers per plant (NTPP), number of leaves per plant (NLPP), leaf length (LL), number of roots per plant (NRPP), number of root (NR) root length (RL) and leaf to stem ratio (LSR) were measured. Ten plants were randomly selected from the middle 4 rows, avoiding the two border rows for every harvesting age and location and average value was calculated for each plot.

Plant height measurement was done immediately before forage harvesting and measured from the ground to the tip of the longest leaf (Rayburn et al., 2003) by using a steel tape meter. The numbers of tillers per plant were recorded by counting from all shoots raised from ten main randomly selected plants. The number of leaves per plant was counted for expanding and expanded leaves of each plant. The length of fully expanded leaves was measured from the tip of the leaf to its ligule or collar region by a graduated ruler as described by Souza (2013). The number and length of roots were recorded after harvesting the middle four rows of ten sets of randomly selected plant samples, digging out from the soil surface properly. The roots were gently washed with tap water and cleaned up from any residual soil the average value was taken. The length of the root was measured from the crown part to the tip of the root. Leaf to stem ratio (LSR) was determined by cutting randomly five plants from four middle rows, and fresh biomass yield was measured separately for leaves and stems, and samples were taken for dry matter determination. The leaf-to-stem ratio was calculated using the dried weight of leaves and stems.

2.4.2. Herbage accumulation (DMY t/ha)

Guinea grass was harvested from the middle 4 rows at 60, 81, and 102 days after planting using sickle, and cutting was done, leaving a stubble height of 5cm above the ground (Arega et al., 2020). The fresh biomass yield was immediately weighed in the field, and a 500g representative fresh sample was taken by using a paper bag, then dried in a well-ventilated shed up to reach a constant weight was reached for dry matter determination.

2.5. Statistical Analysis

The General Linear Model (GLM) procedure of SAS (Statistical Analysis System, 2002 version 9.0) was used to perform an analysis of variance (ANOVA). The Duncan Multiple Range Test (Duncan, 1995) was used for mean separation, and significance was declared at $P<0.05$. Pearson's correlation coefficients were determined among all the studied parameters using SAS software.

The data were analyzed using the following model:

$Y_{ijk} = \mu + C_i + H_j + C_i * H_j + E_{ijk}$ Where;

Y_{ijk} = all dependent variables (morphological data and forage biomass yield)

μ = Overall mean

C_i=effect of cultivars (i =Mombasa, Tanzania and *Degun gizia*)

H_j = the effect of harvesting age (j=60, 81 and 102 days)

C_i*H_j = interaction of cultivar by harvesting age

E_{ijk} = residual error

3. RESULTS AND DISCUSSION

3.1. Effect of Cultivars and Harvesting Ages on Plant Morphometric Characteristics

The effect of harvesting ages and cultivars on morphometric characteristics is presented in Table 2-8. Except leaf to stem ratio at Yigoma Huletu site, there was no interaction ($P > 0.05$) between cultivar and harvesting age for all the studied morphometric parameters,

3.1.1. Plant height

Plant height of the Guinea grass was highly affected ($P < 0.0001$) by cultivars (Table 2). The tallest plant height was recorded for Mombasa (114.54cm), while the shortest plant height was for *Degun gizia* (86.72cm) at Yigoma Huletu. Similarly, the tallest plant height was recorded for Mombasa (109.1cm) while the shortest Tanzania (81.7cm) at Kudmi. This variation might be due to variability in the genetic makeup of cultivars and its physiological interaction with a given environmental condition. The current result was similar to Hare et al., (2014) who reported that Mombasa is taller than Tanzania in Thailand.

The plant height of Guinea grass was significantly affected by harvesting age ($P < 0.0001$). The tallest plant height was obtained at late harvesting age at 102 days, while the shortest (69.31cm) at the early harvesting age at 60 days at both sites. The increment of plant height in later harvesting ages might be due to increments of leaf number and size that captured the greater amount of solar radiation for the photosynthesis process, as well as root development that allows nutrient uptake for the plant to continue growth (Zemene et al., 2020).

The current result agrees with the finding of (Jibril, 2018) who reported the greatest plant height was reported at late harvesting age and lowest at early age for Mombasa grass in Nigeria.

Table 2. Plant height (cm) as influenced by cultivar and harvesting age

	Yigoma Huletu				Kudmi			
Cultivar	Harvesting Age				Harvesting Age			
(C)	HA1	HA2	HA3	LSMEAN	HA1	HA2	HA3	LSMEAN
Mom	77.53	108.73	157.36	114.54^{a}	80.97	103.43	143	109.1^{a}
Tan	69.17	94.6	141.2	101.65^{b}	56.47	80.37	108.27	81.7^{c}
Deg	61.23	85.73	113.2	86.72^{c}	71.06	91.7	131.83	98.2^{b}
LSMEAN	69.31^{c}	96.36^{b}	137.26^{a}	100.97	69.5^{c}	91.8^{b}	127.7^{a}	96.34
SEM	3.3				2.5			
P-value								
C	<0.0001				<0.0001			
HA	<0.0001				<0.0001			
C*HA	0.175				0.59			

Note: ^{abc} *Main factors means with similar superscripts in row and column are not significantly different at (P>0.05); Mom = Mombasa, Tan = Tanzania, Deg = Degun gizia, HA1= Harvesting age of 60 days, HA2= Harvesting age of 81 days, HA3 = Harvesting age of 102 days, SEM= standard error of mean, C*HA=interaction effect*

3.1.2. Number of tillers per plant (NTPP)

The number of tillers per plant was varied (*P = 0.0002*) among the cultivars at Yigoma Huletu, while non-significant at Kudmi (Table 3). The higher number of tillers was shown for Tanzania *and* Mombasa than *Degun gizia* at Yigoma Huletu. The variation in the number of tillers among cultivars could be attributed to genetic variations among the cultivars and their interactions with environmental components such as temperature and soil types. The current result at Yigoma Huletu was in agreement with (Méndez-Martínez et al., 2018) who reported that the highest (112) number of tillers was recorded by Tanzania, while the lowest (29) count was by the common cultivar. And also, Luna *et al*. (2016) reported *Panicum maximum* cv. Massai has scored the highest tiller number per plant (107) than the Mombasa cultivar (56) at the same harvesting age in Brazil. The tillering performance of Tanzania and Mombasa in the present study was lower than that of (Méndez-Martínez et al., 2018) and (Fortes et al., 2016). The difference might arise due to variation in management, irrigation, type of soil, duration of the experimental period, harvesting stage, rainfall, and temperature during the period of the experiment. The population of tillers is dynamic because their life span is a balance between appearance and death, and is extremely dependent on the cutting regime used (Luna et al., 2016).

The number of tillers per plant of cultivars was significantly affected by harvesting age (*P < 0.0001*). The maximum tiller number (31.53 count) was obtained at late harvesting age (102 days), followed by an intermediate (81 days) 24.92, while the minimum (22.47 count) was recorded for early harvesting age (60 days). Similarly, as harvesting ages increase from 60 to 102 days, tiller number linearly increases from 15.6 to 23.3 counts at Kudmi. The current result indicates that tiller number increased with harvesting age and extended to the mature stage. The increment of tiller number in later harvesting ages might be due to enormous root formation that is responsible for tillering and axillary buds, allowing the plant to continue to increase tiller number.

In contrast to current result Umar Saleh (2018) reported on Mombasa grass, a lower count (5) at early age of 6 weeks and then the highest tiller number (23) was observed at 8 weeks, it then decreased to 18 and 14 tillers at 10 and 12 weeks (late stage) after planting, respectively. This difference might be due to altitude, soil moisture content, solar radiation, and environmental factors that affect the dynamic nature of tillering of grasses. Water, light, and different combinations of intensity and cutting frequency all have an impact on the population of tillers (Luna et al., 2016).

Table 3. Number of tillers per plant (count) as influenced by cultivar and harvesting age

Cultivar (C)	Yigoma Huletu				Kudmi			
	Harvesting Age				Harvesting Age			
	HA1	HA2	HA3	LSMEAN	HA1	HA2	HA3	LSMEAN
Mom	23.07	26.2	32.7	27.32[a]	16.13	18.8	21.53	18.8
Tan	24.93	26.7	33.5	28.38[a]	15.17	20.23	23.43	19.6
Deg	19.4	21.87	28.4	23.22[b]	15.47	20.63	25.07	20.4
LSMEAN	22.47[c]	24.92[b]	31.53[a]	26.3	15.6[c]	19.9[b]	23.3[a]	19.6
SEM	0.72				0.64			
P-value								
C	<0.0002				0.257			
HA	<0.0001				<0.0001			
C*HA	0.986				0.444			

Note: [abc] *Main factors with similar superscripts in row and column are not significantly different at (P>0.05); Mom = Mombasa, Tan = Tanzania, Deg = Degun gizia, HA1= Harvesting age of 60 days, HA2= Harvesting age of 81 days, HA3 = Harvesting age of 102 days, SEM= standard error of mean, C*HA=interaction effect*

3.1.3. Number of leaves per plant

The number of leaves per plant was highly affected (P<0.0001) by cultivar at Yigoma Huletu, while the number of leaves was similar (*P > 0.05*) among cultivars at Kudmi (Table 3). The greatest (145.07 and 140.63) number of leaves per plant was obtained for Mombasa and Tanzania, respectively, while the lowest (116.31) was for *Degun gizia* at Yigoma Huletu. The difference in the number of leaves produced per plant among evaluated grass cultivars could be attributed to genetic variations among the cultivars and their adaptation performance to the given environmental condition. The number of leaves determines the photosynthetic capacity of the plants, which affects plant productivity and quality (Pessarakli, 2024). The variation in the number of leaves by cultivars at Yigoma Huletu in the current result agrees with the report of Méndez-Martínez et al., (2018) who conducted a research study on guinea grass cultivars.

Harvesting age highly affected (*P* < 0.0001) the number of leaves per plant of guinea grass at both locations, and the number of leaves linearly increased with harvesting age at both locations. Increased number of leaves with harvesting age might be related to additional development of tillers and shoots with new leaves, similar to report of (Asmare et al., 2017) on desho grass.

Table 4. Number of leaves per plant of Guinea grass as influenced by cultivar and harvesting age

Cultivar (C)	Yigoma Huletu				Kudmi			
	Harvesting Age				Harvesting Age			
	HA1	HA2	HA3	LSMEAN	HA1	HA2	HA3	LSMEAN
Mom	133.73	144.27	157.2	145.07[a]	74.9	93.07	109.23	92.4
Tan	115.9	143.5	162.5	140.63[a]	56.53	75.6	117.63	83.3
Deg	90.63	118.4	139.9	116.31[b]	67.17	84.3	120.87	90.7
LSMEAN	113.42[c]	135.59[b]	153.2[a]	134	66.2[c]	84.3[b]	115.9[a]	88.81
SEM	3.07				2.96			
P-value								
C	<0.0001				0.093			
HA	<0.0001				<0.0001			
C*HA	0.158				0.089			

Note: [abc] *Main factors means with similar superscripts in row and column are not significantly different at (P>0.05); Mom = Mombasa, Tan = Tanzania, Deg = Degun gizia, HA1= Harvesting age of 60 days, HA2= Harvesting age of 81 days, HA3 = Harvesting age of 102 days, SEM= standard error of mean, C*HA=interaction effect*

3.1.4. Leaf length

Leaf length was affected ($P < 0.01$) by cultivars (Table 4). The greatest leaf length (59.29cm) was obtained for Mombasa than Tanzania, and *Degun gizia* at Yigoma Huletu. Whereas, greater leaf lengths (53.17 and 55.16cm) were obtained for Mombasa and *Degun gizia*, respectively, than in Tanzania at Kudmi. This indicates that the Mombasa cultivar performs better at both locations. The longer leaf length facilitates the uptake of light energy and its conversion into chemical energy and favors biomass production (Taiz & Zeiger, 2010). In agreement with the present study, Mombasa resulted in longer leaves than Tanzania in Thailand (Hare et al., 2014). The leaf length for Mombasa and Tanzania cultivars in the current study was greater than the value reported by Fortes et al. (2016) in Cuba, while lower than the value reported by Oliveira et al. (2019) in Brazil. The discrepancy is attributed to variability in harvesting age, soil type, irrigation method (sprinkler irrigation), temperature, and light intensity during the cultivation of grasses.

At both locations, greater ($P < 0.01$) leaf length was found at late harvesting ages of 102 days and 81 days and no difference was observed between the harvesting ages of 102 and 81 days. This indicates optimum leaf length can be found at the harvesting age of 81 days. The result found in the present study is in line with the findings of Oliveira et al.(2019), who stated that an increase in leaf length occurred as the cut interval day increased for guinea grass cultivars. Increase in leaf length at late harvesting was due to increased cell number, area, and volume (Jibril, 2018). Leaf size has a significant effect on the photosynthetic rate, transpiration, and carbon fixation, which all contribute to increased biomass yield (Xu et al., 2018). Therefore, harvesting at a later stage is advisable. However, because there is no advantage in leaf length after 81 days, harvesting at 81 days is recommended.

Table 5. Leaf length (cm) as influenced by cultivar and harvesting age

	Yigoma Huletu				Kudmi			
Cultivar	Harvesting Age				Harvesting Age			
(C)	HA1	HA2	HA3	LSMEAN	HA1	HA2	HA3	LSMEAN
Mom	52.3	62.2	63.37	59.29^{a}	52.23	53.53	53.77	53.17^{a}
Tan	44.47	54	54.67	51.04^{b}	44.43	48.53	48.87	47.27^{b}
Deg	40.8	54.73	58.3	51.28^{b}	48.67	53.4	63.43	55.16^{a}
LSMEAN	45.86^{b}	56.98^{a}	58.78^{a}	53.87	48.4^{b}	51.8^{ab}	55.3^{a}	51.87
SEM	1				1.36			
P-value								
C	<0.0001				0.0019			
HA	<0.0001				0.0078			
C*HA	0.291				0.079			

Note: ^{abc} *Main factors with similar superscripts in rows and columns are not significantly different at (P>0.05); Mom = Mombasa, Tan = Tanzania, Deg = Degun gizia, HA1= Harvesting age of 60 days, HA2= Harvesting age of 81 days, HA3 = Harvesting age of 102 days, SEM= standard error of mean, C*HA=interaction effect*

3.1.5. Number of roots per plant

The number of roots per plant were affected ($P < 0.0001$) by harvesting ages, whereas root number is similar ($P > 0.05$) among cultivars at both sites (Table 6). The number of roots increased as harvesting age progressed at both sites. This indicates that as the plant matures, there is cell division and elongation that initiates the root tip to produce a new lateral root. The maximum root number (187.38) count was recorded at Yigoma Huletu, while the lower count was shown at Kudmi (138.7) site for the same late harvesting ages. This could be due to differences in soil acidity, type, nutrients, and temperature. Plant growth and most soil processes, including nutrient availability and microbial activity, are favored by a soil pH range of 5.5 – 8. Lower root number for Kudmi than Yigoma Huletu location due to acid soil in the subsurface restricts root access to water and nutrients, then reduces root mass, length, and volume (Baligar et al., 1998).

Table 6. Number of roots per plant (count) of Guinea grass as influenced by cultivar and harvesting age

	Yigoma Huletu				Kudmi			
Cultivar	Harvesting Age				Harvesting Age			
(C)	HA1	HA2	HA3	LSMEAN	HA1	HA2	HA3	LSMEAN
Mom	120.93	144.27	168.2	144.47	64.6	126.6	139.4	110.2
Tan	126	152.57	206.6	161.72	67.13	124.4	130.7	107.4
Deg	109.06	150.93	187.33	149.11	83.47	139.67	146	123
LSMEAN	118.67^{c}	149.26^{b}	187.38^{a}	151.76	71.7^{b}	130.2^{ab}	138.7^{a}	113.53
SEM	5.9				5.43			
P-value								
C	0.138				0.123			
HA	<0.0001				<0.0001			
C*HA	0.414				0.969			

Note: ^{abc} *Main factors with similar superscripts in rows are not significantly different at (P>0.05); Mom = Mombasa, Tan = Tanzania, Deg = Degun gizia, HA1= Harvesting age of 60 days, HA2= Harvesting age of 81 days, HA3 = Harvesting age of 102 days, SEM= standard error of mean, C*HA=interaction effect*

3.1.6. Root length

The root length was affected ($P < 0.001$) by cultivars at Yigoma Huletu, while similar at Kudmi (Table 6). Mombasa cultivar scored the longest root length (41.98cm) than Tanzania and *Degun gizia,* no difference in root length was observed between Tanzania and *Degun gizia*. This indicates that the Mombasa cultivar was more adaptable, and roots were penetrating the soil surface to absorb nutrients and moisture. Root length was affected by harvesting age, and greater root length was observed for later harvesting ages (Table 7). The present study revealed that as the plant matured, the development of roots also increased. The current result agreed with the report of Zemene et al. (2020) who indicated that the harvesting age of Brachiaria mutica DZF-483 grass increases from 60 to 120 days of harvesting age, root length t increased from 12.2cm to 16.4cm.

Table 7. Root length (cm) as influenced by cultivar and harvesting age

	Yigoma Huletu				Kudmi			
Cultivar	Harvesting Age				Harvesting Age			
(C)	HA1	HA2	HA3	LSMEAN	HA1	HA2	HA3	LSMEAN
Mom	40.13	42.6	43.2	41.98^{a}	21.4	23.33	26.93	23.9
Tan	29.1	35.06	37.27	33.81^{b}	18.63	23.67	27.53	23.3
Deg	33.73	34.87	36.47	35.02^{b}	21.93	22.8	28.27	24.3
LSMEAN	34.32^{b}	37.51^{ab}	38.98^{a}	36.93	20.6^{c}	23.3^{b}	27.6^{a}	23.83
SEM	1.19				0.86			
P-value								
C	0.0003				0.694			
HA	0.037				<0.0001			
C*HA	0.649				0.635			

Note: ^{abc} *Main factors with similar superscripts in rows and columns are not significantly different at (P>0.05); Mom = Mombasa, Tan = Tanzania, Deg = Degun gizia, HA1= Harvesting age of 60 days, HA2= Harvesting age of 81 days, HA3 = Harvesting age of 102 days, SEM= standard error of mean, C*HA=interaction effect*

3.1.7. Leaf-to-stem ratio

Leaf to stem ratio of guinea grass was highly affected ($P < 0.0001$) by cultivar and harvesting age at all locations, and there is an interaction ($P = 0.0011$) between cultivar and harvesting age only at Yigoma Huletu (Table 8). A greater leaf-to-stem ratio was observed for Degun gizia cultivar than the rest of the cultivars across two locations. Leaf-to-stem ratio declines as the harvesting stage progresses across all locations. At Yigoma Huletu, a greater leaf-to-stem ratio was observed for Degun giza at early harvesting age. The present study indicated that *Degun gizia* is leafier than Mombasa and Tanzania cultivars. Leafiness is a quality feature in forages (Moore et al., 2020). Therefore, *Degun giza* is preferred as far as quality is concerned, and all cultivars should be harvested earlier to achieve good quality guinea grass. The current result was comparable to the result reported by Jibril, (2018), who reported that the highest leaf-to-stem ratio was recorded at early harvesting age. Generally, LSR is an important quality trait, and higher LSR shows good quality, affecting diet selection, quality, and intake of forage (Garay et al., 2017).

Table 8. Leaf to stem ratio as influenced by cultivar and harvesting age

	Yigoma Huletu				Kudmi			
Cultivar	Harvesting Age				Harvesting Age			
(C)	HA1	HA2	HA3	LSMEAN	HA1	HA2	HA3	LSMEAN
Mom	1.7b^{c}	1.59^{cd}	0.95^{e}	1.42^{b}	1.62	1.27	0.77	1.22^{b}
Tan	1.79^{b}	1.62^{c}	0.99^{e}	1.46^{b}	1.7	1.33	0.88	1.3^{b}
Deg	2.07^{a}	1.77^{b}	1.48^{d}	1.77^{a}	1.92	1.68	1.08	1.56^{a}
LSMEAN	1.86^{a}	1.66^{b}	1.14^{c}	1.55	1.75^{a}	1.43^{b}	0.91^{c}	1.36
SEM	0.03				0.03			
P-value								
C	<0.0001				<0.0001			
HA	<0.0001				<0.0001			
C*HA	0.0011				0.557			

Note: ^{abcde} *Main factors with similar superscripts in rows and columns are not significantly different at (P>0.05); Mom = Mombasa, Tan = Tanzania, Deg = Degun gizia, HA1= Harvesting age of 60 days, HA2= Harvesting age of 81 days, HA3 = Harvesting age of 102 days, SEM= standard error of mean, C*HA=interaction effect*

3.2. Effect of Cultivars and Harvesting Ages on Herbage Accumulation (DMY t/ha)

Dry matter yield of guinea grass was affected (*P* < 0.0001) by cultivar and harvesting age across locations, and there is an interaction (*P* < 0.0001) between cultivar and harvesting age on dry matter yield (Table 9). The greatest biomass yield was observed for Mombasa and the least for *Degun gizan* at Yigoma Huletu, whereas Mombasa and *Degu gizan* had higher, but similar biomass yields to Tanzania at Kudmi. Dry matter yield was increased as harvesting age progressed, and the greatest dry matter yield was found for 102 days of harvesting across two locations. The greater dry matter yield (11.94 t/ha) was recorded from Mombasa at late harvesting age (102 days) at Yigoma Huletu, whereas Mombasa and Degu gizan had similar but greater biomass yield than Tanzania at Kudmi. At late harvesting, DMY increased due to the cumulative effect of plant growth and environmental factors that influence the energy distribution and soil nutrients mobilizing, to sustain above-ground growth through photosynthesis (Capstaff & Miller., 2018). The DMY of Mombasa cultivar at late stage 11.94 at Yigoma Huletu and 9.28t/ha at Kudmi was higher than the value reported by Costa et al. (2022) with a value of 4.82 t/ha, whereas lower than the value reported by Hare et al. (2013) for the same cultivar (12.4 t/ha). This difference might be due to differences in the stage of harvest, type of soil, and weather conditions of the study area. *Panicum maximum* cv. Riversdale grown on acid soils (pH 4.5) has decreased morphology, forage production, and seed production than non-acid soils (pH 7.1) (Fanindi et al., 2021).

Table 9. Dry matter yield (t/ha) of Guinea grass as influenced by cultivar and harvesting age

	Yigoma Huletu				Kudmi			
Cultivar	Harvesting Age				Harvesting Age			
(C)	HA1	HA2	HA3	LSMEAN	HA1	HA2	HA3	LSMEAN
Mom	4.4^{e}	8.5^{c}	11.94^{a}	8.28^{a}	3.32^{f}	5.89^{c}	9.28^{a}	6.16^{a}
Tan	3.86^{ef}	6.86^{d}	10.39^{b}	7.04^{b}	2.61^{f}	4.18^{e}	7.14^{b}	4.64^{b}
Deg	3.01^{f}	5.07^{e}	6.95^{d}	5.01^{c}	3.19^{f}	4.97^{d}	9.84^{a}	6^{a}
LSMEAN	3.75^{c}	6.81^{b}	9.76^{a}	6.67	3.04^{c}	5.01^{b}	8.75^{a}	5.6
SEM	0.34				0.24			
P-value								
C	<0.0001				<0.0001			
HA	<0.0001				<0.0001			
C*HA	0.001				0.0015			

Note: *abcdef factors with similar superscripts in rows and columns are not significantly different at (P>0.05); Mom = Mombasa, Tan = Tanzania, Deg = Degun gizia, HA1= Harvesting age of 60 days, HA2= Harvesting age of 81 days, HA3 = Harvesting age of 102 days, SEM= standard error of mean, C*HA=interaction effect*

3.3. Correlation Among Parameters

The simple linear correlation analysis among morphometric parameters and DMY is shown in (Table 10). All morphometric parameters (except LSR) were highly and positively correlated ($P < 0.0001$) with each other, and DMY was similar to the result reported by Asmare et al., (2017) for desho grass. This is due to when the grass increases height, leaf, roots, and tillers accelerate the efficiency of photosynthesis, nutrients, and moisture absorption, resulting then forage yield linearly increased. On the other hand, the increased forage yield decreases forage LSR as a quality indicator.

Table 10. Correlation among morphometric parameters and DMY of Guinea grass cultivars

	PH	TN	NLPP	LL	NR	LSR	DMY
PH	1	0.67***	0.63***	0.7***	0.66***	-0.82***	0.94***
TN		1	0.88***	0.53***	0.81***	-0.45**	0.76***
NLPP			1	0.54***	0.76***	-0.39**	0.74***
LL				1	0.52***	-0.43**	0.7***
NR					1	-0.46**	0.7***
LSR						1	-0.77***
DMY							1

Note: Level of significance: * = P<0.05, ** = P<0.01, *** = P<0.001, PH = plant height, TN = number of tillers per plant, NLPP=number of leaves per plant, LL = leaf length, NR= number of root; LSR = Leaf to Stem Ratio, DMY = dry matter yield,

4. CONCLUSION

The results of this experiment indicated that harvesting ages and cultivars greatly affected forage morphometric characteristics and herbage accumulation of guinea grass. At Yigoma Huletu, Mombasa had scored better values on dry matter yield at late harvesting age. Mombasa and Tanzania had better values on most morphometric characteristics measured, except LSR, which had the highest values by *Degun gizia*. *At* Kudmi, Mombasa scored better values on plant height and DMY. *Degun gizia* scored the highest values on leaf length, LSR, and DMY. All morphometric characteristics and DMY revealed an increasing trend as harvesting ages prolonged, while at the early age of harvest (60 days), there was a better its nutritional quality with a high leaf-stem ratio. Therefore, these grass cultivars can be used as an alternative forage feed for ruminants to maximize their production.

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REFERENCES

Amsalu, T., & Addisu, S. (2014). Assessment of Grazing Land and Livestock Feed Balance in Gummara-Rib Watershed, Ethiopia. *Current Agriculture Research Journal, 2*(2), 114--122. doi:http://dx.doi.org/10.12944/CARJ.2.2.08

Arega, H., Getnet, M., Shitaneh, E., & Worku, B. (2020). Determination of Appropriate Cutting Time of Perennial Elite Lowland Adaptive Forage Grass Species of Degun Gizia/Panicum Maximum/For Optimum Yield and Quality of Hay in Metekel Zone of Benishangul Gumuz. *International Journal of Scientific Engineering and Science, 4*(4), 7-11.

Asmare, B., Demeke, S., Tolemariam, T., Tegegne, F., Haile, A., & Wamatu, J. (2017). Effects of altitude and harvesting dates on morphological characteristics, yield and nutritive value of desho grass (Pennisetum pedicellatum Trin.) in Ethiopia. *Agriculture and Natural Resources,, 51(3),* 148-153. https://doi.org/10.1016/j.anres.2016.11.001

Bachewe, F. M. B., Tadesse F and Taffesse A. (2018). *The evolving livestock sector in Ethiopia: Growth by heads, not by productivity* (Vol. 122): Intl Food Policy Res Inst.

Balehegn, M., Duncan, A., Tolera, A., Ayantunde, A. A., Issa, S., Karimou, M., Varijakshapanicker, P. (2020). Improving adoption of technologies and interventions for increasing supply of quality livestock feed in low-and middle-income countries. *Global food security, 26*, 100372. https://doi.org/10.1016/j.gfs.2020.100372

Baligar, V., Fageria, N., & Elrashidi, M. (1998). Toxicity and nutrient constraints on root growth. *HortScince, 33*(6), 960-965.

Batistoti, C., Lempp, B., Jank, L., Morais, M. d. G., Cubas, A., Gomes, R., & Ferreira, M. (2012). Correlations among anatomical, morphological, chemical and agronomic characteristics of leaf blades in Panicum maximum genotypes. *Animal Feed Science and Technology, 171*(2-4), 173-180. https://doi.org/10.1016/j.anifeedsci.2011.11.008

Begna, R., & Masho, a. W. (2024). Valuation of livestock population and national feed security to enhance livestock productivity in Ethiopia. *Veterinary Medicine and Science, 10*(3), e1415. https://doi.org/10.1002/vms3.1415

Bilgin, F. D. (2021). Guinea Grass (Panicum maximum) Forage: A Review. *MAS Journal of Applied Sciences, 6*(1), 77-82. https://doi.org/10.52520/masjaps.25

Bremner, J. M., & Mulvaney, C. (1982). Nitrogen—total. *Methods of soil analysis: part 2 chemical and microbiological properties, 9*, 595-624. https://doi.org/10.2134/agronmonogr9.2.2ed.c3 1

Capstaff, N., & Miller., A. (2018). Improving the yield and nutritional quality of forage crops. *Frontiers in plant science, 9,* (535). https://doi.org/10.3389/fpls.2018.00535

Carvalho, J. M., Barreto, R. F., Prado, R. d. M., Habermann, E., Branco, R. B. F., & Martinez, C. A. (2020). Elevated CO2 and warming change the nutrient status and use efficiency of Panicum maximum Jacq. *PLoS One, 15*(3), e0223937.

Costa, N., Jank, L., Magalhães, J. A., Bendahan, A. B., Rodrigues, B. H. N., & Santos, F. J. (2022). Agronomic performance and chemical composition of genotypes and cultivars of Megathyrsus maximus in Roraima's savannas. *Research, Society and Development, 11*(9), 1-8. https://doi.org/10.33448/rsd-v11i9.32285

Demeke, S., Yeshambe, M., & Bimrew, A. (2017). Assessment of livestock production system and feed balance in watersheds of North Achefer District, Ethiopia. *Journal of Agriculture and Environment for International Development, 111*(1), 175-190. http://dx.doi.org/10.12895/jaeid.2017111.574

Fanindi, A., Sutedi, E., & Herdiawan, I. (2021). *Productivity and morphology of Benggala grass Riversdale cultivar (Panicum maximum cv Riversdale) on acid soils.* Paper presented at the IOP Conference Series: Earth and Environmental Science.

FAO. (2018). Report on feed inventory and feed balance. *FAO: Rome, Italy*, 160. https://reliefweb.int/report/ethiopia/ethiopia-report-feed-inventory-and-feed-balance

Fortes, D., Valenciaga, D., García, C., García, M., Cruz, A. M., & Romero, A. (2016). Evaluation of three varieties of Megathyrsus maximus in the dry period *Cuban Journal of Agricultural Science, 50*(1), 131-137.

Galindo, F. S., Buzetti, S., Filho, M. C. M. T., Dupas, E., & Ludkiewicz, M. G. Z. (2017). Application of different nitrogen doses to increase nitrogen efficiency in Mombasa guinegrass (Panicum maximum cv. mombasa) at dry and rainy seasons. *Australian Journal of Crop Science, 11*, 1657-1664. https://doi.org/10.21475/ajcs.17.11.12.pne907

Garay, J. R., Cancino, S. J., Zarate Fortuna, P., Ibarra Hinojosa, M. A., Martinez Gonzalez, J. C., Gonzalez Davila, R. P., & Cienfuegos Rivas, E. G. (2017). Dry matter accumulation and crude protein concentration in Brachiaria spp. cultivars in the humid tropics of Ecuador. *Tropical Grasslands, 5*(2), 66-76. https://doi.org/10.17138/tgft(5)66-76

Hare, M. D., Phengphet, S., Songsiri, T., & Sutin, N. (2014). Botanical and agronomic growth of two Panicum maximum cultivars, Mombasa and Tanzania, at varying sowing rates. *Tropical Grasslands-Forrajes Tropicales, 2*(3), 246-253.:https://doi.org/10.17138/tgft(2)246-253

Hare, M. D., Phengphet, S., Songsiri, T., Sutin, N., & Stern, E. (2013). Effect of cutting interval on yield and quality of two Panicum maximum cultivars in Thailand. *Tropical Grasslands-Forrajes Tropicales, 1*(1), 87-89. https://doi.org/10.17138/tgft(1)87-89

Jank, L., Calixto, S., Costa, J., Savidan, Y., & Curvo, J. (1997). Catalogue of the characterization and evaluation of Panicum maximum germplasm: morphological description and agronomic performance. *Campo Grande Embrapa Gado de beef,, 68:*, 53.

Jibril, U. S. (2018). Effects of Fertilizer Levels and Harvest Time on Yield of Panicum Maximum Cv. Mombasa and Its Nutrient Digestibility by Red Sokoto Bucks. 95.

Kusmiyati, F. (2018). Turnitin-Nfluence of Rice Straw Mulch on Saline Soil: Forage Production, Feed Quality and Feed Intake by Sheep. *International Society for Southeast Asian Agricultural Sciences, 22*(1), 42-51.

Luna, A. A., Difante, G. d. S., Montagner, D. B., Emerenciano Neto, J. V., Araujo, I. M. M. d., & Fernandes, L. S. (2016). Tillering dynamic and structural characteristics of tropical grasses under cutting management. *Bioscience Journal, 32*(4), 1008-1017. doi:biblio-965635

McLean, E. (1982). Soil pH and lime requirement. *Methods of soil analysis, In part, 2*. https://doi.org/10.2134/agronmonogr9.2.2ed.c12

Méndez-Martínez, Y., Verdecia, D., Reyes-Pérez, J., Luna-Murillo, R., Rivero-Herrada, M., Montenegro-Vivas, L., & Herrera, R. (2018). Quality of three Megathyrsus maximus cultivars in the Empalme area, Ecuador. *Cuban Journal of Agricultural Science, 52*(4), 423-434.

Mengistu, S., Nurfeta, A., Tolera, A., Bezabih, M., Adie, A., Wolde-Meskel, E., & Zenebe, M. (2021). Livestock production challenges and improved forage production efforts in the Damot Gale District of Wolaita Zone, Ethiopia. *Advances in Agriculture, 2021*(1), 5553659. https://doi.org/10.1155/2021/5553659

Mijena, D. (2022). Improved forage production in Ethiopia: efforts done, success achieved, challenges, and future opportunities. *International Journal of Food Science and Agriculture, 6*(3), 260_266. doi:DOI: 10.26855/ijfsa.2022.09.004

Moore, K. J., Lenssen, A. W., & Fales, S. L. (2020). Factors affecting forage quality. *Forages: The science of grassland agriculture, 2*, 701-717. https://doi.org/10.1002/9781119436669.ch39

Mutuku, E. A., Roobroeck, D., Vanlauwe, B., Boeckx, P., & Cornelis, W. M. (2020). Maize production under combined Conservation Agriculture and Integrated Soil Fertility Management in the sub-humid and semi-arid regions of Kenya. *Field Crops Research, 254*, 107833.https://doi.org/10.1016/j.fcr.2020.107833

Nelson, D. W., & Sommers, L. E. (1982). Total carbon, organic carbon, and organic matter. *Methods of soil analysis: Part 2 chemical and microbiological properties, 9*, 539-579. https://doi.org/10.2134/agronmonogr9.2.2ed.c29

Obando, W. A. I., López, L. J. M., Boada, Á. F. C., Cedeño, V. A. C., & Rivas, C. D. M. (2024). Nutritional evaluation of guenea grass (Panicum máximum) varieties, mombasa, tanzania and zuri, 35 days after harvest. *Centrosur Agrarian, 1*(22), 15-29.

Oliveira, J. d. S., Emerenciano Neto, J. V., Difante, G. d. S., Lista, F. N., Santos, R. d. S., Bezerra, J. D. d. V., Ribeiro, J. S. M. (2019). Structural and productive features of Panicum cultivars submitted to different rest periods in the irrigated semiarid region of Brazil. *Bioscince journal(Online), 35*(3), 682-690. doi:id:biblio-1048623

Olsen, S. (1954). Estimation of Available Phosphorus in Soils by Extraction with Sodium Bicarbonate. *US Department of Agriculture*.

Pessarakli, M. E. (2024). Handbook of photosynthesis. CRC press.

Rayburn, E., Lozier, J., & Sanderson, M. (2003). Estimating pasture forage mass from pasture height. *Fact Sheet. October*, 2.

Shiferaw, M., Asmare, B., Tegegne, F., & Ketema, D. M. (2018). Farmers perception and utilization status of improved forages grown in the natural resource areas of north western Ethiopia. *Biodiversitas Journal of Biological Diversity, 19*(4), 1568_1578. https://doi.org/10.13057/biodiv/d190450

Souza., M. W. M. (2013). Cutting interval in cultivars of panicum maximum jacq. Dissertation Viçosa University Minas Gerais, Brazil. . 72.

Taiz, L., & Zeiger, E. (2010). Plant Physiology. 5th ed., ,. *Sunderland, MA: Sinauer Associates, Inc*, 782

Tulu, D., Gadissa, S., Hundessa, F., & Kebede, E. (2023). Contribution of Climate-Smart Forage and Fodder Production for Sustainable Livestock Production and Environment: Lessons and Challenges from Ethiopia. *Advances in Agriculture, 2023*(1), 8067776. https://doi.org/10.1155/2023/8067776

Wouw, M. v. d., Jorge, M., Bierwirth, J., & Hanson, J. (2008). Characterisation of a collection of perennial Panicum species. *Tropical Grasslands, 42*(1), 40-53. https://hdl.handle.net/10568/1273

Xu, P., Ali, A., Han, B., & Wu, X. (2018). Current advances in molecular basis and mechanisms regulating leaf morphology in rice. *Frontiers in plant science, 9*, 1528. https://doi.org/10.3389/fpls.2018.01528

Zemene, M., Mekuriaw, Y., & Asmare, B. (2020). 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 Biotechnologies, 53*(2), 137-137.