NUTRITIVE VALUE OF GUATEMALA GRASS (*Tripsacum andersonii)* HARVESTED AT THREE STAGES OF MATURITY IN GEDEO AGROFORESTRY SYSTEMS, SOUTHERN ETHIOPIA †

[VALOR NUTRITIVO DEL HIERBA DE GUATEMALA (*Tripsacum andersonii)* COSECHADA EN TRES ETAPAS DE MADUREZ EN LOS SISTEMAS AGROFORESTALES DE GEDEO, SUR DE ETIOPÍA]

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SUMMARY

Background: Gedeo agroforestry is characterized as the integration of trees, crops and livestock on the same unit of land. Land scarcity is a common characteristic in the Gedeo agroforestry system. Hence integrating forage crops with the agroforestry system is one of the options to alleviate feed scarcity in the area. **Objectives:** To evaluate the biomass yield and nutritional value of Guatemala grass harvested at three stages of maturity: Early (120days), Mid (150days) and Late (180 days) cultivated at three different altitudes (high, medium and low). **Methodology:** A randomized complete block design with three replications was employed. Morphological parameters and chemical composition were measured at each stage of maturity and altitude. **Result:** The results showed that the number of leaves per plant (NL), plant height (PH), leaf length (LL) and dry matter yield (DMY) exhibited ($p<0.05$) an increasing trend as harvesting days were delayed. Contrarily the number of tillers (NT) showed ($p<0.05$) decreasing trend as harvesting dates advanced. The highest ($p<0.05$) CP (12.6±0.25%DM) was recorded at 120 days. The highest ($p<0.05$) NDF (61.27±0.07%DM) and ADF (42.3±0.91%DM) were recorded at 180 days of harvesting. The highest ($p<0.05$) IVDMD (56.7±1.97%) was recorded at 120 days of harvesting, whereas the least ($p<0.05$) (48.0±2.06) was at 180 days of harvesting. Generally, as the harvesting date advanced, CP and IVDMD showed a decreasing trend, whereas the fiber content (ADF, NDF and ADL) showed an increasing trend. **Implication:** Based on the morphological characteristics and dry matter yield, the best harvesting stage of Guatemala grass was at the late (180days) stage of maturity. On the other hand, considering the chemical composition and IVDMD, the best harvest stage was at the early (120days) stage of maturity. **Conclusion:** Cutting Guatemala grass at the proper growth stage is crucial for forage management. However, to fully utilize the potential of Guatemala grass, further studies on live animal experiments should be carried out.
Key words: Altitudes; Chemical composition; Days of harvesting; Morphological characteristics.

RESUMEN

Antecedentes: La agrosilvicultura de Gedeo se caracteriza por la integración de árboles, cultivos y ganado en una misma unidad de terreno. La escasez de tierras es una característica común en el sistema agroforestal de Gedeo, en el sur de Etiopía. La integración de cultivos forrajeros con el sistema agroforestal es una de las opciones para aliviar la escasez de alimentos en la zona. **Objetivos:** Evaluar el rendimiento de biomasa y el valor nutricional del pasto guatemalteco cosechado en tres etapas de madurez: temprana (120 días), media (150 días) y tardía (180 días) cultivadas en tres altitudes diferentes (alta, media y baja). **Metodología:** Se empleó un diseño de bloques completos al azar con tres repeticiones. Se determinaron parámetros morfológicos y composición química en cada etapa de madurez. **Resultados:** El número de hojas por planta (NL), la altura de la planta (PH), la longitud de la hoja (LL) y el rendimiento de materia seca (DMY) se incrementaron con el retraso en los días de cosecha ($p<0.05$). Por el contrario, el número de macollos (NT) disminuyeron con los días de cosecha ($p<0.05$). La PC más alta ($p<0.05$) (12.6±0.25% MS) se registró a los 120 días. Las mayores ($p<0.05$) FDN (61.27±0,07%MS) y FDA (42.3±0.91%MS) se registraron a los 180 días de cosecha. La mayor ($p<0.05$) DMSIV (56,7±1,97%) se registró a los 120 días de cosecha, mientras que la menor ($p<0.05$) (48.0±2,06) fue a los 180 días de cosecha. En general, con el avanzo de la fecha de cosecha, la

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PC y la DMSIV disminuyeron, mientras que el contenido de fibra (FDA, FDN y LDA) incrementó. **Implicación:** En base a las características morfológicas y el rendimiento de materia seca, la mejor fecha de cosecha del pasto guatemalteco fue la tardía (180 días de madurez). Por otro lado, considerando la composición química y DMSIV, la mejor fecha de cosecha fue la temprana (120 días de madurez). **Conclusión:** Cortar el pasto guatemalteco en la etapa más adecuada de crecimiento es crucial para el manejo del forraje. Sin embargo, para aprovechar al máximo el potencial del pasto guatemalteco, aún se deben realizar experimentos con animales vivos.
Palabras clave: Altitudes; Composición química; Días de cosecha; Características morfológicas.

INTRODUCTION

Scarcity of land is a common characteristic in the Gedeo agroforestry system southern Ethiopia. Gedeo agroforestry is characterized as the integration of trees, crops, and livestock on the same unit of land (Degefa, 2016). Hence integrating forage crops with the agroforestry system is one of the options to alleviate feed scarcity in the area. A potential forage grass to be integrated is Guatemala grass (*Tripsacum andersonii J.R. Gary*). Guatemala grass is a vigorous leafy perennial grass characterized by strongly rhizomatous, tufted, and that can produce many bunches. It is a warm climate grass that can be cultivated from sea level to an altitude of 2000m and is one of the high productive grasses (Cook *et al.*, 2005). The grass is cultivated primarily for fodder in a cut-and-carry system. Moreover, it can be used for making good silage. Guatemala grass also provides several environmental benefits, particularly preventing soil erosion (Nivyobizi *et al.*, 2010).

In southern Ethiopia, Guatemala grass is one of the early introduced high yielding forage species to the agroforestry systems. However, little is known on its adaptability related to growth features, forage productivity and forage quality. Therefore, knowing information on morphological parameters such as plant height, number of leaves, leaf length, number of tillers, days to maturity, growth habit, and production potential of the grass are important to integrate with food crops in the existing farming systems. Accordingly, the current study aimed to evaluate morphological traits, the biomass yield, chemical composition as well as *in vitro* dry matter digestibility of the grass related to harvesting days.

MATERIALS AND METHODS

Description of the test environment

This study was conducted at Dilla University main campus and two Agricultural Research and Technology Transfer villages of the University in Southern Ethiopia. A full description of the study sites is presented in (Table 1).

The research sites were: Dilla University main campus, Tumata Chirecha, and Domorso Agricultural Research and Technology Transfer villages (Figure 1). Based on the altitude difference, the study sites were stratified as high, medium, and low altitudes.

Land preparation, planting, and experimental design

The experimental fields were hand-dug at three different times, and whole plots for each site were prepared. Rhizomes, made from root cuttings, were collected from the forage nursery site. Planting was carried in November 2018 and was established in a sunken bed system in which experimental plots in a plot size of 1.5m x 1.5m. The beds were prepared and arranged in a randomized complete block design with three replications against the slope gradient of the land. Rhizomes of approximately 10 cm in length were planted on established plots inclined about 45^0. Replicates are arranged in three blocks and each block contains three plots in a row. A total of 25 cutting rhizomes were planted per plot with a row spacing of 0.3m each. There was an alley of 1m width between blocks and 1m width between plots.

Sampling techniques

Morphological parameters were measured from six randomly selected plants in a plot at early (120 days), mid (150 days), and late (180 days) stages of maturity.

Table. 1 Description of Study sites.

District	Research Site	Location	Altitude	Rainfall (mm)	Temperature
Yirga Chefe	Dumerso	38° 22’E and 6° 21’N	1849 m (High)	1100 to1380	11 °C to 25 °C
Wonago	Tumata Chirecha	38° 19’ E and 6° 20’N	1599m (Mid)	870 to 1449	11 °C to 29 °C
Dilla	Dilla University	38° 30’E and 6°27’N	1450m (Low)	1200 to 1800	13 °C to 27 °C

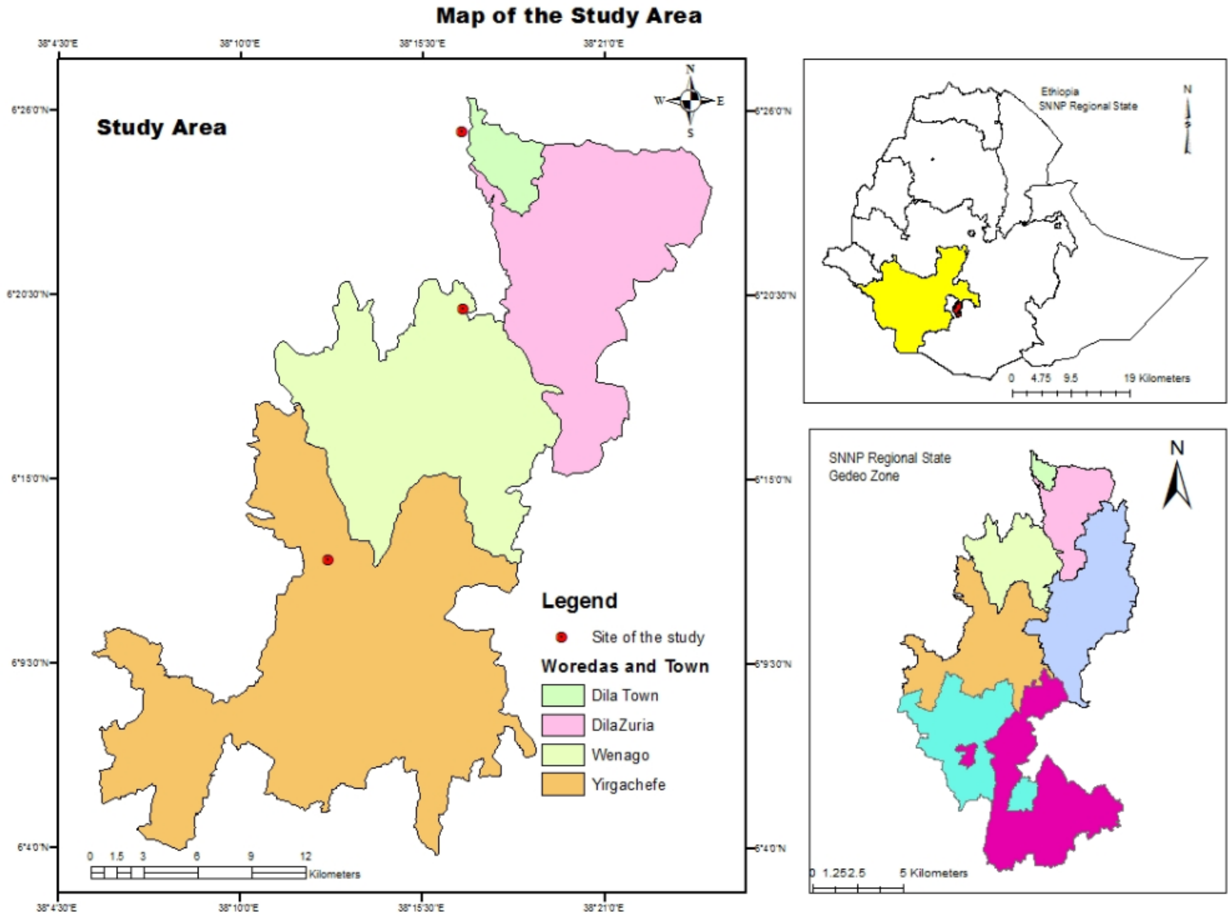

Figure 1. Map of the study sites.

Plant height was measured on the primary shoot from the soil surface to the base of the top-most leaf using a meter rule as described by (Rayburn *et al.*, 2007). The number of tillers, the number of leaves per plant, and plant density per square meter were determined based on the procedure set by Tarawali *et al.* (1995). Harvesting was carried out using a hand sickle, leaving a stubble height of 10 cm. The total number of seedlings in a row was calculated to determine plant density per square meter (Tarawali *et al.*, 1995). The dry matter yield (DMY) was estimated as described by Mutegi *et al.* (2008).

Chemical analyses

Grass samples for chemical analysis were harvested at early (120 days), mid (150 days), and late (180days) maturity. Samples were dried at 65 ^oC for 72h and ground to pass through a 1mm sieve and were analyzed on a % dry matter (DM) basis. Total ash was determined by igniting the samples in a muffle furnace at 550 ^oC for 6h (AOAC, 1990). Organic matter (OM) was determined by subtracting the ash component from the initial weight of the sample weighed before ashing. Nitrogen (N) was determined following the Kjeldahl procedures AOAC (1995), and the crude protein (CP) content was estimated by multiplying the N content by 6.25. Crude fat was determined as described by AOAC (1995). The fiber contents, including neutral detergent fiber (NDF), acid detergent fiber (ADF), and acid detergent lignin (ADL) were determined according to Van Soest *et al.* (1991). The *in vitro* dry matter digestibility (IVDMD) was determined according to Tilley and Terry (1963). Hemicellulose and cellulose contents were estimated by subtracting acid detergent fiber (ADF) from neutral detergent fiber (NDF) and acid detergent lignin (ADL) from acid detergent fiber (ADF), respectively, as described by Hindrichsen *et al.* (2006).

Data Analyses

Data were analyzed with the General Linear Model (GLM) procedure of SAS version 9.1 (2008) for analysis of variance. Mean comparisons were done using Duncan's Multiple Range Test (DMRT). The

ANOVA test was applied to compare the mean of nutritional value for the three stages of maturity and altitudes as well as the interaction effect of altitude and stages of maturity. Pearson's correlation coefficient was used to measure the relationship between nutrient contents. Differences between means were declared significant at $P<0.05$. The following statistical model was used:

$$Y_{ijk} = \mu + A_i + B_j + A^* B_{(ij)} + e_{(ijk)} ,$$

Where:
Y = parameter studied (DM yield, morphological characteristics, chemical composition and IVOMD)
μ = Overall mean
A_i =The effect *of* location (i= 1, 2, 3)
B_j = The effect of stage of maturity (j=1, 2, 3)
$A^*B_{(ij)}$ = The interaction effect of location and stages of maturity and
$e_{(ijk)}$ = The error term

RESULTS AND DISCUSSION

Morphological characteristics

The effect of altitudes and harvesting days on morphological characteristics is shown in Table 2. The leaf length was increased (p<0.05) with delayed harvesting days. The difference in leaf length between early, mid and late harvesting might be due to the differences in physiological growth conditions of the plant (Terefe, 2017). The highest mean leaf length per plant was observed at high altitude than low and medium altitudes. This could be related to different environmental factors such as temperature, soil fertility, and rainfall. The highest leaf length recorded at late maturity had a positive relationship with the increment of biomass yield (Gzehagn *et al*., 2016).

The highest (p<0.05) mean leaf number per plant was counted from the medium altitude at late harvesting. The higher number of leaves in the later harvesting time might be due to the increment of plant height, tillers number, and many nodes that produce comparable numbers of leaves. An increase in the number of nodes is followed by the production of an equal number of leaves in grass cut at matured one compared to the harvesting of younger plants and a high number of leaves per plant at later harvesting stages (Asmare, 2016; Terefe, 2017).

Plant height recorded at three different harvesting days was significantly different (p<0.05) in all altitudes (Table 2). The highest plant height was recorded at high altitude (184 cm) followed by low altitude (171 cm) whereas the least was from medium altitude (147 cm). Plant height recorded at high altitude was higher compared to plant height recorded at medium and low altitude. On the other hand, the least plant height was recorded at mid-altitude compared to plant height recorded at high and low altitudes. Harvesting stages had shown an important effect on plant height (p<0.05). The highest mean plant height was recorded at late harvesting (214cm) followed by mid-harvesting (158cm) whereas the least was from early harvesting (130 cm).

Mean plant height was low at the early stage of growth, but enhanced growth was observed after 150 days of harvesting. The plant height difference between altitudes could be due to the differences in moisture content and soil fertility of the testing environments. Plant height increased as plant age at harvest advanced (Asmare, 2016). Increments in plant height at later harvest stages could be due to massive root development and efficient nutrient uptake, allowing the plant to continue to increase in height

Table 2. Effect of altitude and harvesting stage on morphological characteristics and dry matter yield.

	Parameters				
	LL (cm)	**NL**	**PH(cm)**	**NT**	**DMY(t ha^{-1})**
ALT					
High	112[a]	9.97[a]	184[a]	14.5[a]	24.3[a]
Medium	89.7[c]	10.4[a]	147[b]	5.61[c]	7.80[c]
Low	98.2[b]	10.4[a]	171[c]	10.4[b]	15.8[b]
p-value	<0.0001	0.094	<0.0001	<0.0001	<0.0001
HD					
120 days	78.6[c]	8.5[c]	130[c]	8.79[a]	6.84[c]
150 days	99.5[b]	10.4[b]	158[b]	9.77[ab]	14.9[b]
180 days	122[a]	11.9[a]	214[a]	11.9[b]	26.2[a]
p-value	<0.0001	<0.0001	<0.0001	0.0152	<0.0001
Interaction (ALT x HD)	***	***	***	NS	***

*Means in each column with different superscripts are significantly different at p<0.05. NS=None Significant, LL=Leaf Length, NL=Number of Leaf, PH=Plant Height, NT=Number of Tiller, DMY=dry matter yield cm=Centimeter, ALT= Altitude, HD= Harvesting Date, *** =significantly different.*

(Demlew *et al.,* 2019). The current finding is supported by the findings of Terefe, (2017) for Rhodes grass and Demlew *et al.* (2019) for Buffelgrass, who stated that plant height was increasing with the advanced stage of harvesting.

Harvesting days had shown a significant effect on the number of tillers (p<0.05) (Table 2). The number of tillers per plant increased with the advance in harvesting date of plants as the result of the development of new shoots bearing on each plant resulting in a more significant number of tillers as the plant matures (Demlew *et al.,* 2019). The tillering capacity of Guatemala grass observed between the three altitudes was quite different. At medium and low altitudes, the advanced increment was seen after 150 days of harvesting. While in high altitudes, tillering continued even after 120 days of harvesting. The mean number of tillers at high altitudes looks approximately equal in the three harvesting stages. This could be related to the favourable environmental conditions (rainfall, temperature, humidity, and soil fertility) in high altitudes than the rest two altitudes. The increase in the tiller number might be due to longer days of maturity and the associated continuous increment in the photosynthetic rate of the grass (Demlew *et al.,* 2019). Tillers density is an important attribute of grasses as it increases the chances of survival and the amount of available forage (Laidlaw, 2005). Moreover, it is an indicator of resource use efficiency by the different grass species. The large numbers of tillers produced by some grass species allow them to attain maximum growth at an earlier age and recover faster after defoliation (Laidlaw, 2005). Tillering is also important in forage plants because it influences leaf-area production and dry matter yield (Berhanu *et al.,* 2007; Terefe, 2017; Demlew *et al.,* 2019).

Biomass Yield (BMY)

The biomass yield of Guatemala grass recorded at three stages of maturities had shown a significant difference (p<0.05) in all altitudes (Table 2). The highest BMY was recorded at the late stage of harvesting (26.2 t ha^{-1}) followed by the mid-stage of harvesting (14.8 t ha^{-1}) whereas the least was from the late stage of harvesting (6.84 t ha^{-1}). The increasing trend of biomass yield in Guatemala grass could be due to the development of additional tiller in the grass, leaf formation, leaf elongation, stem development, and vegetative growth of the plant. At late harvesting, BMY increased due to the cumulative effect of plant growth and environmental factors. This condition influences the energy distribution and soil nutrients mobilizing, to sustain aboveground regrowth through photosynthesis (Capstaff and Miller, 2018). The highest biomass yield recorded at high altitude at the third stage of harvesting (180 days) was due to the longest height and highest number of tillers the grass had in this stage (Nivyobizi *et al.,* 2010). The DM yield showed an increasing trend with delayed harvesting because of decreased moisture content in leaves as the plants aged and became lignified (Amare, 2016).

Effects of Altitudes and Harvesting Days on Chemical Compositions and *in vitro* Dry Matter Digestibility

Non-Fiber contents

Chemical Compositions and *in vitro* Dry Matter Digestibility of Guatemala grass harvested at three stages of maturity is presented in Table 3. Ash content of Guatemala grass showed a significant difference (P<0.05) at different harvesting stages as well as among altitudes. The highest ash content was recorded at high altitude (14.9 % DM) followed by low altitude (13.4 % DM) whereas the least was from medium altitude (11.8 % DM). The decreasing trend of total ash as harvesting time increases might be due to a decline in the total ash content of forages which brings about earlier dilution and translocation of different minerals associated with the vegetative portion of the leaf at later maturity (Minson,1990). The current result in line with (Berhanu *et al.,* 2007); Terefe (2017), and Demlew *et al.,* 2019) reported a decreased trend of total ash content as the age of the plant advanced. Most grass forages had ash content ranging from 2 to 22% (Lee, 2018). The ash content investigated in this study was within this range at all altitudes.

Both altitudes and harvesting days had shown a significant (P<0.05) effect on CP. The highest CP content was recorded from high altitude (10.6 % DM) followed by low altitude (9.80 % DM) whereas the least was from medium altitude (8.69 % DM). Harvesting days had shown a significant effect on the CP content of Guatemala grass (p<0.05). Harvesting at 120 days of harvesting had the highest crude protein content compared to 150 and 180 days of harvesting. The CP content of Guatemala grass was decreasing with increasing days of harvesting at all altitudes. The increase in age in grasses is usually negatively associated with CP content. It is explained that protein in mature leaves is hydrolyzed, and its breakdown products are translocated to other parts of the plant (Ammar *et al.*, 2004).

Fiber content

Altitude and harvesting days showed a significant effect on the fiber content of Guatemala grass (P<0.05). The highest NDF content of Guatemala

Table 3. Effect of altitude and harvesting stage on chemical compositions and IVDMD.

	Parameters (%DM basis)							
	DM(%)	**Ash**	**CP**	**EE**	**NDF**	**ADF**	**ADL**	**IVDMD(%)**
ALT								
High	19.6^{c}	14.9^{a}	10.6^{a}	8.10^{a}	55.9^{c}	38.9^{b}	6.66^{b}	54.5^{a}
Medium	23.6^{a}	11.8^{c}	8.69^{c}	6.98^{a}	60.9^{a}	40.6^{a}	7.00^{a}	51.2^{b}
Low	20.6^{b}	13.4^{b}	9.80^{b}	7.58^{a}	58.5^{b}	39.7^{ab}	6.81^{ab}	52.5^{b}
p-value	<0.0001	<0.0001	<0.0001	0.1155	<0.0001	0.0023	0.0109	0.0002
HD								
120days	20.8^{b}	14.9^{a}	11.4^{a}	8.72^{a}	54.8^{c}	37.5^{c}	6.50^{b}	56.7^{a}
150days	20.9^{b}	13.5^{b}	9.45^{b}	7.53^{ab}	58.6^{b}	39.5^{b}	6.77^{b}	53.5^{b}
180days	22.2^{a}	11.7^{c}	8.25^{c}	6.40^{b}	61.3^{a}	42.3^{a}	7.23^{a}	48.0^{c}
Sig	<0.0001	<0.0001	<0.0001	0.0010	<0.0001	<0.0001	<0.0001	<0.0001
Interaction (ALT x HD)	***	NS	***	NS	NS	NS	NS	NS

*Means in each column with different significantly different at p<0.05, NS=None significant, DM= Dry Matter, CP= Crude Protein, NDF=Neutral Detergent Fiber, ADF=Acid Detergent Fiber, ADL= Acid Detergent Fiber, IVDMD=Invitro Dry Matter Digestibility, ALT= Altitude, HD=harvesting days, ***=significantly different*

grass was recorded from medium altitude (60.9 % DM) followed by low altitude (58.6 % DM) whereas the least was from high altitude (55.9 % DM). The highest mean value of NDF was recorded at 180 days of harvesting (61.2 % DM) followed by 150 days of harvesting (58.5 % DM), whereas the least was from 120 days of harvesting (54.8 % DM). In the current study, as harvesting was prolonged, the NDF content also increased. This could be demonstrated by the reduction in crude protein content and a substantial increment in cell wall content. This might be related to such factors as temperature and moisture stress of the cultivation environment which affects the nature of cell content and leading to less carbohydrate content (McDonald *et al.,* 2010)

The acid detergent fiber (ADF) content increased as harvesting was delayed. This could be due to the decreased leaf-to-stem ratio and more stem content increased lignification with delayed days of harvesting (Berhanu *et al.,* 2007; Taye *et al.,* 2007; Terefe, 2017). The recommended minimum ADF content in the feed is 170 to 210 g kg^{-1} DM feed, but it depends on various factors such as particle size, feeding methods, supplements, rate and extent of fermentation of fiber source (NRC, 2001). Forage with higher ADF has lower cellulose digestibility in the rumen, thereby reducing the energy available to the lactating cow for milk production. The overall investigation of the ADF content of Guatemala grass in this study had shown above the minimum required level. However, the result indicated that increasing ADF content with stages of maturity showed a negative impact on digestibility and strongly correlated negatively with IVDMD (r=-0.92) (Table 6).

The highest ADL content was recorded at the late stage of harvesting (7.23 % DM) followed by the mid-stage of harvesting (6.77 % DM), whereas the least was from the early stages of harvesting (6.50 % DM). Lignin is a component that attributes selectivity, strength, and resistance to plant tissue thereby limiting the ability of rumen microorganisms to digest the cell wall polysaccharides, cellulose, and hemicellulose contents. Ammar *et al.(* 2004) reported an increased in fiber content affected the digestibility of forage negatively. The mean ADL content of Guatemala grass recorded between altitudes and days of maturities had shown more than 60 g kg^{-1} which indicated a negative impact on IVDMD of the grass. This is due to the fact that cell wall content (NDF, ADF, and ADL) is augmented with maturity in the process of cell wall lignification (Chebli *et al.*, 2021). As plants mature, photosynthetic products are more rapidly converted to structural components. Thus, it decreases protein and soluble carbohydrates but increases the structural cell wall components (Ammar *et al.,* 2004).

In vitro Dry Matter Digestibility

Altitude and harvesting stages had shown a significant effect on the IVDMD of Guatemala grass (p<0.05). The highest IVDMD was recorded from high altitude (54.5 % DM) followed by low altitude (52.5 % DM) and whereas the least was from medium altitude (51.2 % DM). The highest IVDMD was recorded from the early stages of harvesting (56.6 % DM) followed by the mid-stage of harvesting (53.5 % DM) whereas the least was from the late harvesting stage. The IVDMD

Table 4. Effect of altitude and harvesting stage on Organic matter, Cellulose, and Hemicellulose.

	Parameters (DM basis, %)		
	OM	**Cellulose**	**HC**
ALT			
High	85 ± 2[c]	32.2 ± 2.2[b]	32.1[a]
Medium	88 ± 1[a]	33.6 ± 1.8[a]	32.2[a]
Low	86 ± 1.7[b]	32.9 ± 2.1[ab]	32.3[a]
p-value	<0.0001	0.0028	0.7927
HD			
120days	85.1[a]	30.9[a]	32.3[a]
150days	86.5[b]	32.7[b]	32.6[a]
180days	88.3[c]	34.1[c]	31.6[a]
p-value	<0.0001	<0.0001	0.0795
Interaction (ALT x HD)	NS	NS	NS

Means in each column with different letters have a significant difference at (p <0.05). NS= None Significant, HC= Hemicellulose, OM=Organic Matter, ALT= Altitude, HD= Harvesting Days

of Guatemala grass was better at the early days of maturity related to both mid and late harvesting stages. The fall in digestibility with the increasing harvesting stage is related to the drops in CP content and an increased in fibers portion (Fekede, 2004).

Organic Matter and Structural carbohydrates content

Altitudes showed a significant (p<0.05) effect on OM content (Table 4). The highest OM content was recorded from medium altitude (88.1 % DM) followed by low altitude (86.5 % DM) whereas the least was from high altitude (85.1 % DM). Organic matter obtained from medium altitude was higher than OM recorded at high and low altitudes. Harvesting days had shown a significant effect on organic matter (p<0.05). The highest OM content was recorded at 180 days of harvesting (88.2 % DM) followed by 150 days of harvesting (86.4 % DM) whereas the least was from 120 days of harvesting (85.4 % DM). The OM recorded in this study had shown an increasing trend with the advanced stage of maturity at all altitudes.

The primary reason influencing forage digestibility is the structure and content of cell walls. Cell walls are predominately composed of cellulose, hemicellulose, and lignin. The cellulose content of Guatemala grass showed a significant difference (p<0.05) at different altitudes and stages of maturity (Table 4). The cellulose content recorded was ranging from 30.9 to 35.4 % DM. According to Fekede (2004), the harvesting stage and morphological fractions affected the content of cellulose. The digestibility of the intact cell wall is limited by the occurrence of cellulose. Although cellulose is composed of simple linear chains of glucose, the individual chains are very tightly packed into large fiber bundles which results in slower cellulose digestion by rumen microbes than digestion rates observed for hemicellulose (Harper and McNeill 2015).

Table 5. Pearson's Correlation Coefficients between Morphological Parameters.

Para-meters	LL	NL	PH	NT	DMY
LL	1	O.32***	0.56***	0.3	0.62
NL		1	0.56***	0.14	-0.35
PH			1	0.33***	0.55
NT				1	0.41
DMY					1

****= significantly different at p<0.05 LL=Leaf Length, NL=Number of Leaf, PH=Plant height, NT=Number of Tiller, DMY=Dry Matter Yield, DMY=Dry Matter Yield,*

The hemicellulose content of Guatemala grass did show a significant difference (P<0.05), at all altitudes and stages of maturity (Table 4). The hemicellulose content in this study showed increasing150 days of harvesting between altitudes; while decreasing with increasing days of maturity at 180 days of harvesting. Intake and digestibility of forage are usually limited by the extent of hemicellulose (Harper and McNeill 2015).

Correlation between Morphological Parameters

The linear correlation coefficient among morphological parameters and DMY is shown in Table 5. The leaf length (LL) significantly correlated positively with the number of leaves (NL) (r= 0.32)

Table 6. Pearson's Correlation Coefficients between Nutritional Qualities of Guatemala Grass.

Parameter	DM	ASH	CP	CF	NDF	ADF	ADL	IVDMD	Cellulose	HC	OM
DM	1	-0.22	-0.23	0.06	-0.07	0.04	0.09	0.02	-0.07	-0.06	0.22
ASH		1	0.91*	0.77*	-0.09*	0.83*	-0.79*	0.85*	-0.82*	0.18	-1.00*
CP			1	0.75*	-0.94*	0.91*	-0.84*	0.89*	-0.92*	0.22	-0.91
FAT				1	-0.75*	0.73*	-0.68*	0.75*	-0.73*	0.17	-0.77*
NDF					1	0.93*	0.84*	-0.92*	0.94*	-0.13	0.86*
ADF						1	0.94	-0.93*	0.1	-0.48*	0.83*
ADL							1	-0.87*	0.91*	-0.54*	0.79
IVDMD								1	-0.93*	0.33	-0.85*
Cellulose									1	-0.46*	0.82
HC										1	-0.18
OM											1

**=p<0.05, DM=Dry Matter, CP=Crude Protein, CF=Crude Fat, NDF=Neutral Detergent Fiber, ADF=Acid Detergent Fiber, ADL=Acid Detergent Lignin, IVDMD=Invitro Dry Matter Digestibility, CEL=Cellulose, HC=Hemicellulose, OM=Organic Matter*

and plant height (PH) (r=0.56), but it was not significantly correlated positive with NT (r=0.30) and DMY(r=0.62). The number of leaves (NL) was significantly correlated positively with plant height (PH) (r=0.56), but it was none significantly even though it is a positive association with NT (r=0.14) and negatively associated with DMY (r=-0.35). This result shows that as plant height increased with the advanced stage of maturity and there was a new development of internodes and an increase in the number of leaves (Asmare, 2016; Asmare et al., 2017). Plant height was a significantly positive correlation with NT (r=0.33) and no significant positive correlations with DMY (r=0.41). The number of tillers (NT) was correlated positively with Dry matter yield (DMY) (r=0.41). Correlation between Morphological parameters (PH, NL, LL, and NT) and DMY had shown correlated positively except NL. This result indicated, increasing DMY with advanced days of maturity could be due to increasing PH, LL, and NT with increasing stage of harvesting; however, NL did not influence DMY (Asmare et al., 2017).

Correlations between Nutritional Traits

The linear correlation coefficients among nutritional parameters are shown in Table 6.The DM content correlated positive with ADF (r= 0.04), ADL (r=0.09), IVDMD (r=0.02) and OM (r=0.22) But, it was negatively associated with CP (r= -0.22), cellulose content (r=-0.07) and hemicelluloses (r=-0.06). The Crude protein content was correlated positive with IVDMD (r=0.89), but it was correlated negative with NDF (-0.94), ADL (r=-0.84), cellulose (r=-0.92) and OM (r=-0.91). Therefore higher CP could supply an adequate protein base for microbial growth and improves digestibility. This concurs with other findings of Solomon and Teferi (2010) Tessema *et al.*, (2002). This result shows that decreasing the IVDMD content of Guatemala grass was due to decreasing CP content with an advanced stage of maturity. The NDF content was positively correlated with ADF (r=0.93), ADL (r=0.84), Cellulose (r=0.94) and OM (r=0.86), but it was negatively correlated negatively with IVDMD (r=-0.92) and HC (r=-0.13). The result indicated that the negative impact of NDF on IVDMD is related to increasing ADL content with an advanced stage of maturity and increasing NDF content by itself. According to Gezahagn *et al.*, (2016) the NDF content showed a not significantly correlated negative with ADF content (r= -0.45), ADL content (r= -0.25), IVOMD (r= -0.15), cellulose content (r= -0.37) and hemicellulose content (r = -0.06) in Napier grass. The ADL content had been shown to correlate positively with cellulose (r=0.91) and OM (r=0.79), but it was negatively correlated with IVDMD (r=-0.87) and hemicellulose (r=-0.54). According to Gezahagn *et al.*, (2016) the ADL content had a not significant correlated negative with IVOMD (r= -0.40), cellulose content (r= -0.11), CP yield (r= -0.05) and digestible yield (r= -0.51).The IVDMD had been shown to correlate positively with hemicelluloses (r=0.33), but it was negatively correlated with cellulose (r=-0.93) and OM (r=-0.85). The cellulose content had been shown to correlate positively with OM (r=0.82), but it was correlated negatively with hemicelluloses (r=-0.46). The hemicellulose content had shown correlated negatively with OM (r=-0.18):

CONCLUSION

The results of the current study indicated that harvesting stages highly determined the forage morphological characteristics, DM yield, and nutritive values of Guatemala grass. All morphological characteristics except the number of tillers (NT) revealed increasing trends as harvesting days prolonged. Early harvested forage has nutritional traits that create a favorable environment for IVDMD. In conclusion, based on the morphological characteristics and dry matter yield, the best harvesting stage of Guatemala grass was at the late (180days) stage of maturity. On the other hand, considering chemical composition and IVDMD the best harvest stage was at the early (120days) stage of maturity.

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Author contribution statement (CRediT). D. Andualem: Conceptualization, Data curation, Formal analysis, Software, Writing – review & editing **M. Hundessa:** Investigation, Writing – original draft

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