AGRONOMIC CHARACTERISTICS, FORAGE YIELD AND CHEMICAL COMPOSITION OF *Urochloa* GRASS CULTIVARS UNDER MIDLAND CLIMATIC CONDITIONS OF SOUTHERN ETHIOPIA †

[CARACTERÍSTICAS AGRONÓMICAS, RENDIMIENTO FORRAJERO Y COMPOSICIÓN QUÍMICA DE CULTIVARES DEL PASTO Urochloa EN CONDICIONES CLIMÁTICAS DE TIERRAS MEDIAS DEL SUR DE ETIOPIA]

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SUMMARY

Background. Different forage innovations have been used to alleviate livestock feed shortage in Ethiopia. Napier, Rhodes, and Desho grasses are the most widely cultivated forage grasses in the backyard system. **Objective.** To evaluate the effect of harvesting age of *Urochloa* grass cultivar/ accessions on morphology, forage yield, chemical composition at Wolaita Sodo State dairy farm, Ethiopia. **Methodology.** The experiment involved a 5 × 3 factorial arrangement in a Randomized Complete Block Design with three replications, three harvesting ages (60, 90, and 120 days of age), and five *Urochloa* grass cultivars/ accessions (*Urochloa* hybrid 'Mulato II', *Urochloa mutica* (Forssk.) T.Q. Nguyen, *Urochloa brizantha* (Hochst. ex A. Rich.) R.D. Webster 'acce. no. DZF13151', *Urochloa brizantha* (Hochst. ex A. Rich.) R.D. Webster 'Piata' and *Urochloa brizantha* (Hochst. ex A. Rich.) R.D. Webster 'acce no. DZF16550') during 2020-2021. **Results.** Plant height and number of leaves were greater (P<0.05) for *U. mutica* than for the remaining cultivars across the three harvesting ages. The tillers number was greater (P<0.05) for *U. brizantha* acce. no. 16550 at120 days of harvesting than the remaining cultivars and harvesting ages over the two years. The greatest leaf length was for Piata at 120 days of harvesting compared to the other cultivars and harvesting ages. The leaf: stem ratio was also the highest (P<0.05) for Piata at early age of harvesting. The dry matter, crude protein and digestible organic matter yields varied significantly among cultivars with the highest (P<0.05) values obtained for *U. mutica* across the three harvesting ages. The highest (P<0.05) crude protein (CP), *in vitro* organic matter digestibility (IVOMD) and metabolizable energy concentrations were observed for Mulato II and the lowest (P<0.05) value was recorded in *U. brizantha* acce. no. 13151 across the three harvesting ages. Most morphological characteristics and yield parameters increased (P<0.05) with increasing harvesting age. However, the CP, IVOMD, and leaf: stem decreased with increasing harvesting ages. **Implications.** The higher DM yield and forage quality of *U. mutica* and Mulato II may be an indicator of adaptation to midland climatic condition. **Conclusion.** Growing the outperforming cultivars, Mulato II and *U. mutica*, and harvesting at 90 days of age is considered as a suitable practice to improve fodder production and availability in the midland agroecology of Ethiopia.
Key words: Harvesting age; dry matter yield; correlation; crude protein; chemical composition.

RESUMEN

Antecedentes. Se han utilizado diferentes innovaciones en forrajes para aliviar la escasez de alimento para el ganado en Etiopía. Los pastos Napier, Rhodes y Desho son los pastos forrajeros más cultivados en el sistema de traspatio. **Objetivo.** Evaluar el efecto de la edad de cosecha del cultivar/accesiones de pasto Urochloa sobre la morfología, el rendimiento de forraje y la composición química en la granja lechera estatal de Wolaita Sodo, Etiopía. **Metodología.** El experimento involucró un diseño con arreglo factorial 5 × 3 en bloques completos aleatorizados con tres repeticiones, tres edades de cosecha (60, 90 y 120 días de edad) y cinco cultivares/accesiones de pasto Urochloa (híbrido Urochloa 'Mulato II', *Urochloa mutica* (Forssk.) T.Q. Nguyen, *U. brizantha* (Hochst. ex A. Rich.) R.D. Webster 'n.º de acceso DZF13151', *U. brizantha* (Hochst. ex A. Rich.) R.D. Webster 'Piata' y *U. brizantha* (Hochst . ex A. Rich.) R.D. Webster 'n.º de acceso DZF16550') durante 2020-2021. **Resultados.** La altura de la planta y el

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número de hojas fueron mayores (P<0.05) para *U. mutica* que para los cultivares restantes en las tres edades de cosecha. El número de macollos fue mayor (P<0.05) para *U. brizantha* acce. No. 16550 a los 120 días de cosecha que los cultivares restantes y edades de cosecha durante los dos años. La mayor longitud de hoja fue para Piata a los 120 días de cosecha en comparación con los otros cultivares y edades de cosecha. La relación hoja:tallo también fue la más alta (P<0.05) para Piata en la edad temprana de cosecha. Los rendimientos de materia seca, proteína cruda y materia orgánica digestible variaron significativamente entre los cultivares con los valores más altos (P<0.05) obtenidos para *U. mutica* en las tres edades de cosecha. Las concentraciones más altas (P<0.05) de proteína cruda (PB), digestibilidad de materia orgánica in vitro (IVOMD) y energía metabolizable se observaron para Mulato II y el valor más bajo (P<0.05) se registró en *U. brizantha* acce. No. 13151 en las tres edades de recolección. La mayoría de las características morfológicas y parámetros de rendimiento aumentaron (P<0.05) al aumentar la edad de cosecha. Sin embargo, la PB, la IVOMD y la hoja:tallo disminuyeron al aumentar las edades de cosecha. **Implicaciones**. El mayor rendimiento de MS y calidad del forraje de *U. mutica* y Mulato II puede ser un indicador de adaptación a las condiciones climáticas de la zona media. **Conclusión.** El cultivo de los cultivares de mejor rendimiento, Mulato II y *U. mutica*, y la cosecha a los 90 días de edad se considera una práctica adecuada para mejorar la producción y disponibilidad de forraje en la agroecología de la zona central de Etiopía.

Palabras clave: Edad de cosecha; rendimiento de materia seca; correlación; proteína cruda; composición química.

INTRODUCTION

Livestock contributes as a major source of animal protein, a source of power for crop cultivation, means of transportation, export commodities, source of manure for farm land household energy, means of wealth accumulation, and is the basis of livelihood of over 27 to 35% of rural households in Ethiopia (Shapiro *et al.*, 2017). In most of sub-Saharan African countries including Ethiopia, intensification of ruminant livestock production is increasing due to growing population pressure and declining grazing areas (Thornton, 2010). According to CSA (2021), in Ethiopia, 54.54 and 31.13 % of the total livestock feed supply is derived from grazing/ green fodder and crop residues, respectively. However, the contribution of the natural pasture is decreasing due to poor management and continued expansion of crop farming (Solomon *et al*., 2003), indicating that livestock feed shortage in the country is further aggravated by the continuous conversion of grazing land to cropland.

Various forage innovations have been used to alleviate livestock feed shortage in Ethiopia. Napier, Rhodes, and Desho grasses are the most widely cultivated forage grasses in the backyard system by smallholder farmers in the country (Tulu *et al.,* 2021; Tilahun *et al.,* 2017). However, still there is a need to introduce a wide range of climate-smart forage technologies for sustainable improvement of livestock production and productivity in Ethiopia. One of the best options to increase availability of high-quality forage and improve livestock productivity is cultivation of *Urochloa* grass (Njarui *et al.,* 2021; Ngila *et al.,* 2016). *Urochloa* grass is one of the best tropical forage grasses for improving forage production, year-round forage availability, and livestock productivity in addition to addressing the issues of climate variability across the tropical and sub-tropical regions of the World (Keller-Grein *et al.*, 1996; Cezário *et al*., 2015; Ghimire *et al.*, 2015). The demand for seeds of *Urochloa* grass is increasing due to benefits gained in terms of highly nutritious features and increased milk production from livestock fed on the grass (Mutimura *et al.,* 2018; Njarui *et al.*, 2021a). *Urochloa* grass produces a high yield of forage biomass, fixes atmospheric carbon into soils, and improves soil fertility while reducing pests and diseases on crops (Ghimire *et al.,* 2015; Mutimura and Ghimire, 2021).

Urochloa grass cultivars identified in evaluations conducted by the Ethiopian Institute of Agricultural Research on the adaptation of the cultivars to the midland climatic conditions released by the national agricultural system could bridge the gap in livestock feed scarcity. The forage biomass yield of *Urochloa* grass could vary depending on agro-ecology, cultivars, moisture and fertility of soil, pest, and disease, and management practices. There's limited information available on the productivity of *Urochloa* cultivars in the midland agroecological zones of Ethiopia. The effect of agroecology and harvesting ages on the morphological characteristics and nutritional quality of *Urochloa* grasses have been reported in Ethiopia (Adnew *et al.,* 2019). However, the best-performing cultivar and the optimum harvesting age are not well-known for different *Urochloa* cultivars/ accessions. The objective of this study was to evaluate the effect of harvesting ages on morphological fractions, yield, and chemical composition of selected *Urochloa* grass cultivars/ accessions grown in the midland climatic condition of southern Ethiopia.

MATERIALS AND METHOD

Description of the study area

The field experiment was conducted in 2019/ 2020 (year I) and 2020/ 2021 (year II) at the Wolaita Sodo state dairy farm, in southern Ethiopia. The area lies between 06°49' 42.20 N latitude and 037°44' 48.58 E longitude with an altitude of 1875 m.a.s.l. The agroecology is classified as midland according to the traditional classification of agroecological zones (IFPRI, 2006). The field trial was established on a silt clay loam, moderately drained and slightly acidic soil. The soil chemical analysis result indicated that the soil type at Wolaita Sodo state farm is classified as a silt clay loam with 3.47 % organic carbon, 36.98 ppm available phosphorous, 0.30 % total N and pH of 6.4 in the year I and, with 3.33 % organic carbon, 38.03 ppm available phosphorous, 0.0.39 % total N and pH 6.6 in year II (Table 1).

Mean monthly total rainfall and minimum and maximum temperatures of the study area shown in Figure 1. The rainfall during the cropping period varied from 10.6 to 309.4 mm with major precipitation from May through August in 2019/ 2020 while the major rainfall was from April to July with the range of 0 to 255.1 mm in 2020/ 2021 cropping season. Land is used intensively with a cropping system, commonly intercropping adopted to maximize yield. Major food crops include, in order of importance, maize, sweet potato, enset (*Ensete ventricosum*), teff (*Eragrostis tef*), haricot bean, and taro (Aynalem, 2021).

Experimental design and treatments

The field trial was conducted in Wolaita Sodo State Dairy Farm from 2020 to 2021. It involved a 3 × 5 factorial experiment with three harvesting ages (60 days, 90 days and 120 days) and five *Urochloa* grass cultivars/ accessions [*Urochloa brizantha* (Hochst. ex A. Rich.) R.D. Webster 'accession no. DZF 13151', *Urochloa brizantha* (Hochst. ex A. Rich.) R.D. Webster. 'accession no. DZF 16550', *Urochloa mutica* (Forssk.) T.Q. Nguyen, *Urochloa brizantha* (Hochst. ex A. Rich.) R.D. Webster 'Piata' and *Urochloa* hybrid 'Mulato II'] in a Randomized Complete Block Design with three replications each. The five *Urochloa* cultivars/ accessions tested were selected based on previous varietal evaluations conducted at Ethiopian Institute of Agricultural Research on the adaptation of the cultivars to the midland climatic condition and released by national agricultural system.

Table 1. Pre-plant soil physico-chemical property (0-30 cm) at the experimental site.

Year	pH	OC (%)	TN (%)	OM (%)	AP (PPM)	Soil texture (%)			Texture class	Rate
						Sand	Clay	Silt		
2020	6.4	3.47	0.30	5.99	36.98	12	40	48	Silt clay loam	Slightly acidic
2021	6.6	3.33	0.39	5.74	38.03	15.5	33	51.5		

OC: organic carbon; TN: total nitrogen; OM: organic matter; AP: Available Phosphorous; PPM: parts per million.

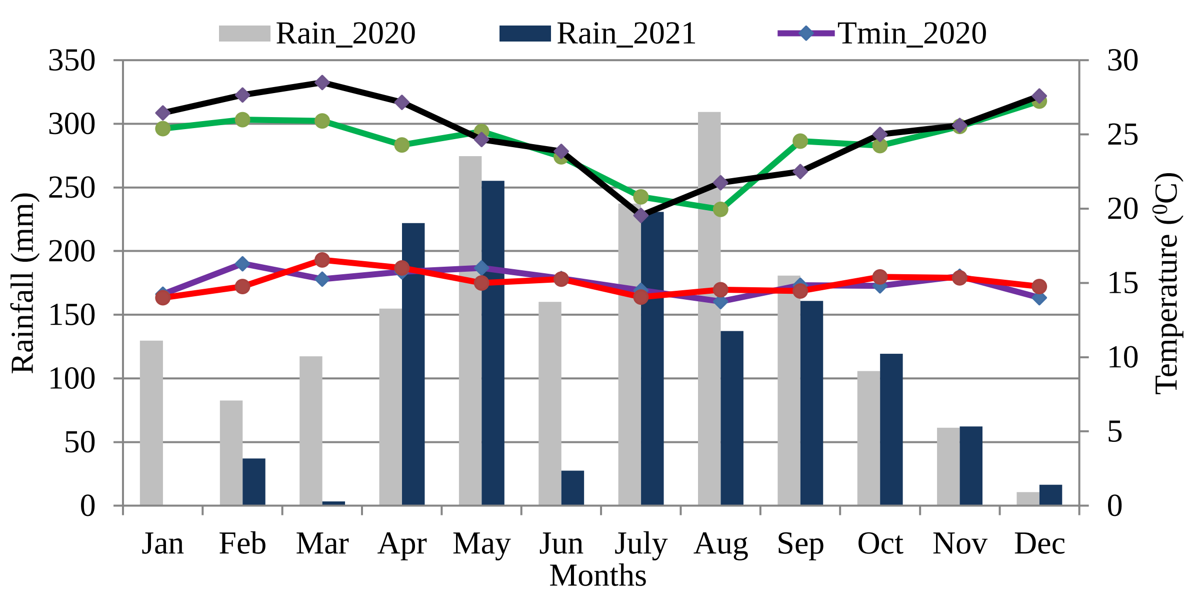

Figure 1. Mean total rainfall, minimum and maximum temperatures of the study area. Source: Ethiopian Meteorology Agency, 2020 and 2021.

The land was ploughed by a tractor, and then by oxen four times in order to provide a good seedbed, and divided into plots. Forty-five 12 m^2 plots (3 × 4 m) were established and the seeds (vegetative root splits) of *Urochloa* grasses, obtained from the Ethiopian Institute of Agricultural Research (EIAR), Wondo Genet Center, were planted by hand on 19 September 2020 (year I) and 22 September 2021 (year II) into a well-prepared seedbed with a row spacing of 50 cm and 0.3 cm between plant spacing (Ben *et al.*, 2018; Njarui *et al.*, 2021b). Compound fertilizer (NPS) containing N: P: S at the rate of 200 kg/ ha was incorporated into the soil at planting (Rao and Ghimire, 2016), and was dressed with 50 kg urea/ ha at knee-height (40 days after planting). The plots were supplemented with irrigation depending on the soil moisture and rainfall status during the dry months (particularly, from mid October to the end of December) using manual water cans. The experimental plots were irrigated in the evening every day with 40 L of water per plot until the end of harvest age. Weeds were hand-removed from the plots twice a week to avoid soil nutrient competition.

Data collection and sampling

The grasses were closely examined beginning from the early vegetative growth and data were collected at the end of each harvesting age (60, 90 and 120 days of age). The plant height and leaf length were measured with measuring tape. The number of tillers and leaves was computed as a mean of counts taken from ten plants that were randomly selected from the middle rows (ILRI, 2013) of each plot across the treatments. Ten plants from randomly selected two consecutive rows from each plot were fractionated into leaf and stem and oven-dried to constant weight at 60 °C for 48 hours to determine leaf: stem ratio on a dry matter basis (Arzani *et al.*, 2004). For herbage yield measurements, 1 m^2 area of all plots was harvested manually using a sickle leaving a stubble height of 5 cm above the ground (Ben *et al*., 2018) at the end of each harvesting age. Fresh herbage yield was weighed immediately after each harvest and sub-samples were air-dried and taken for further analysis. The dry fodder yield was calculated after drying the sample in an oven at 60 ºC for 48 hours. Crude protein yield (CPY) was determined by multiplying DMY by CP, and that of digestible organic matter yields (DOMY) was determined by multiplying *in vitro* organic matter digestibility (IVOMD) contents (Schroeder, 2013).

Chemical analysis

For chemical analysis, a total of 90 samples (45 in each year) were collected and analyzed at the animal nutrition laboratory of the International Livestock Research Institute (ILRI) in Addis Ababa, Ethiopia. The samples were dried in an oven at 60 ºC for 48 hours and ground to pass through a 1-mm sieve (Willey mill). Dry matter (DM) and ash were determined according to AOAC (1990). Crude protein (CP), neutral detergent fibers (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL) *in vitro* organic matter digestibility (IVOMD) and metabolizable energy (ME) were estimated using near-infrared reflectance spectrophotometry (NIRS) using predictive equations developed for *Urochloa* grasses from conventional analysis of proximate chemical fractions conducted previously on more than 500 samples (AOAC, 1990; Van Soest et al., 1991). The NIRS instrument used was Foss 5000 forage analyzer with software package Win ISI-II at ILRI. This was also confirmed with wet chemistry.

Statistical analysis

Data were analyzed using the General Linear Model procedure of the Statistical Analysis System (SAS, 2002; version 9.0). Differences in the proportion of morphological fractions, yields, *in vitro* digestibility, and chemical composition among *Urochloa* cultivars and harvesting ages were examined using the following model:

$$Y_{ijkl} = \mu + D_h + A_i + B_j + C_k + AB_{ij} + AC_{ik} + BC_{jk} + ABC_{ijk} + e_{ijkhl}$$

Where, Y_{ijkl}: response variable; μ: overall mean; D_h: block effect; A_i: Effect of *Urochloa* cultivars; B_j: Effect of harvesting age; C_k: Year effect; A_iB_j: Interaction effect of cultivar and harvesting age, A_iC_k: Interaction effect of cultivar and year; B_jC_k: Interaction effect of harvesting age and year, $A_iB_jC_k$: Interaction effect of cultivar, harvesting age and year, e_{ijk}: the error term associated with each Y_{ijkl}. Tukey's Student Range Test was employed to separate means at α = 0.05. Pearson correlation analysis was used to determine the relations among morphological characteristics, yield parameters, nutritional composition, and *in-vitro* organic matter digestibility.

RESULTS

Morphological characteristics

The LSR (leaf: stem ratio) was lower at day 90 to 120 days of harvesting compared with 60 days. On the other hand, Piata harvested at early age had the highest (P< 0.01) LSR compared to the remaining cultivars/ accessions and harvesting age across the two years. The LSR was higher at day 60 of harvesting while PH (plant height), NTPP (number of tillers per plant), NLPP (number of leaves per plant) and LLPP (leaves length per plant) were greater (P<

0.05) at 120 days for all *Urochloa* grass cultivars/ accessions. The highest (P< 0.01) values of PH and NLPP were for *U. mutica* at each harvesting age, but more (P< 0.01) NTPP was recorded for *U. brizantha* acce. no.16550 at the harvesting age of 120 days than the remaining cultivars/ accessions and harvesting ages across the two years. Moreover, the longest (P<0.01) LLPP was observed for Piata harvested at 120 days. *U. brizantha* acce. no. 13151 (23.3 cm) and *U. mutica* harvested at days 60 of age had lower (P<0.01) LLPP compared to the remaining cultivars/ accessions and harvesting ages

Forage dry matter, crude protein, and digestible organic matter yields

Dry matter, digestible organic matter, and crude protein yields of *Urochloa* grass cultivars/ accessions are presented in Figure 2. In general, the DM yields of *Urochloa* grasses increased (P < 0.05) as harvesting age increased from day 60 to 120 days. The highest (P <0.01) DM yield was recorded for *U. mutica* at 120 days of harvesting while the lowest value was for ***U.** brizantha* acce. no. 13151 harvested at the age of 60 days. There was an interaction (P < 0.05) between harvesting age and *Urochloa* cultivar on DOMY. The DOMY showed a progressive increment with an increase in the age of harvest for all *Urochloa* grass cultivars. Significant differences (P< 0.01) were observed in CP yields among *Urochloa* cultivars, harvesting ages, and their interaction. The CPY was higher (P<0.01) when the grasses were harvested at 90 days of harvesting than those harvested at 60 and 120 days of age (Figure 2). Higher (P<0.01) CPY was observed for *U. mutica* compared with other cultivars/ accessions across the three harvesting ages.

Table 2. Means for plant height, number of tillers per plant, number of leaves per plant, leaf length per plant, and leaf: stem of *Urochloa* grass cultivars/ accessions harvested at different ages over two years.

Urochloa cultivar/ accession	PH (cm)	NTPP (n)	NLPP (n)	LLPP (cm)	LSR
60 days of harvesting					
Mulato II	58.4^{h}	34.5^{g}	4.90^{j}	28.3^{efg}	3.08^{bc}
U. mutica	149.8^{cd}	34.1^{g}	10.30^{c}	25.4fg	0.65^{f}
U. brizantha acce. no. 13151	79.9^{gh}	49.8^{ef}	5.70^{hij}	23.3^{g}	1.92^{de}
Piata	76.2^{gh}	36.7^{fg}	5.33^{ij}	47.9^{c}	4.21^{a}
U. brizantha acce. no. 16550	98.8^{fg}	52.0^{e}	6.00^{hij}	34.6^{de}	1.83^{de}
90 days of harvesting					
Mulato II	78.5^{gh}	54.6^{e}	6.43^{ghi}	37.4^{d}	3.30^{ab}
U. mutica	194.0^{b}	52.7^{e}	16.37^{b}	28.9^{efg}	0.53^{f}
U. brizantha acce. no. 13151	100.7^{fg}	71.1^{cd}	7.73^{efg}	26.4^{fg}	1.70^{de}
Piata	114.8^{ef}	51.9^{e}	6.90^{fgh}	57.8^{b}	2.54^{bcd}
U. brizantha acce. no. 16550	132.7^{de}	81.8^{c}	7.67^{efg}	45.4^{c}	1.19^{ef}
120 days of harvesting					
Mulato II	102.9^{fg}	98.6^{b}	8.20^{def}	47.3^{c}	2.20^{cd}
U. mutica	274.7^{a}	58.9^{de}	20.27^{a}	31.6^{def}	0.38^{f}
U. brizantha acce. no. 13151	130.5^{de}	103.9^{b}	8.00^{def}	28.2^{efg}	0.73^{f}
Piata	160.3^{c}	96.9^{b}	9.17^{cde}	69.8^{a}	1.88^{de}
U. brizantha acce. no. 16550	169.3^{bc}	151.7^{a}	9.47^{cd}	52.1^{bc}	1.18^{ef}
SEM	5.30	2.78	0.30	1.50	0.19
Significance (***P-value***)					
Year (Y)	<.0001	0.0176	<.0001	<.0001	0.0161
Harvesting age (H)	<.0001	<.0001	<.0001	<.0001	<.0001
Cultivar/ accession ©	<.0001	<.0001	<.0001	<.0001	<.0001
H*©	<.0001	<.0001	<.0001	<.0001	<.0001
Y*H	<.0001	0.0138	<.0001	0.0266	0.1733
Y*©	0.0003	0.1557	0.0276	<.0001	0.2862
Y*H*©	0.4724	0.5019	0.0108	0.4473	0.0069

SEM: standard error of means; H*©: interaction between harvesting age and cultivar/ accession; Y*H: interaction between year and harvesting age; Y*©: interaction between year and cultivar/ accession; Y*H*©: interaction of year, harvesting age and cultivar/ accession; LSR: leaf: stem; NTPP: number of tillers per plant; NLPP: number of leaves per plant; LL: leaf length and PH: plant height; cm: centimeter; n: number. Means labeled by different superscript letters in the columns are significantly different according to Tukey's Student Range Test (*p<0.05*).

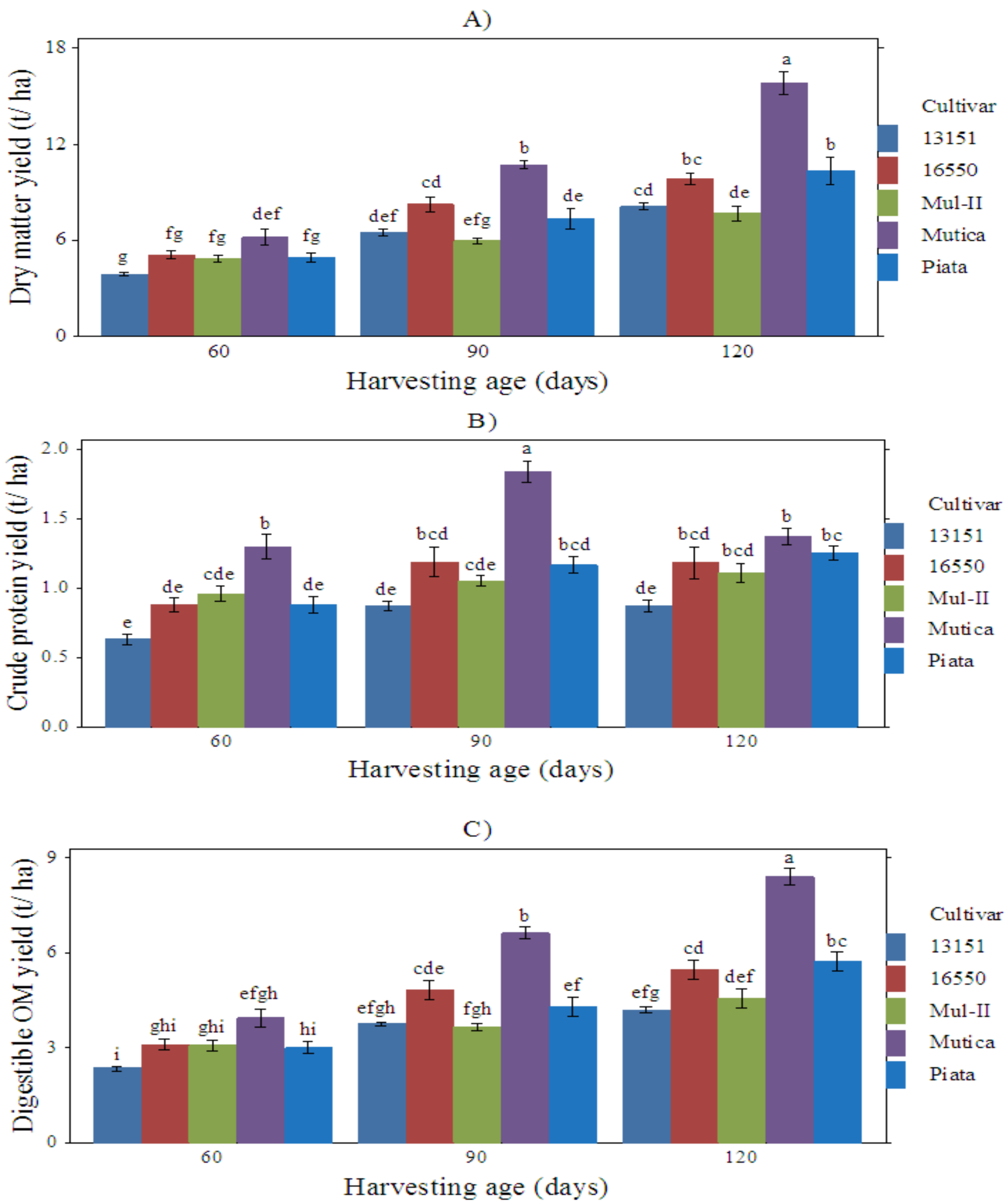

Figure 2. Dry matter (A), crude protein (B), and digestible organic matter (OM) yields (C) as affected by *Urochloa* grass cultivars/ accessions and harvesting ages over the two years (2020- 2022). The error bars represent the standard error of the mean; means labeled by different superscript letters are significantly different (Tukey's Student Range Test, $p < 0.05$).

Chemical composition and *in vitro* organic matter digestibility

The chemical composition, *in-vitro* organic matter digestibility, and metabolizable energy of *Urochloa* grass cultivars/ accessions are shown in Table 3. The highest CP (crude protein) concentrations were observed in Mulato II across the three harvesting ages while the lowest values were recorded in *U. brizantha* acce. no. 13151. The CP values in *U. mutica* were comparable with Mulato II at 60 and 90 days of harvesting. Similarly, Mulato II had the highest IVOMD (*in vitro* organic matter digestibility) and ME (metabolizable energy) contents while *U. mutica* showed intermediate values with respect to IVOMD and ME across the three harvesting ages. As the harvesting age was delayed from day 60 to 120 days, the CP, IVOMD and ME values were reduced ($P < 0.05$) for all cultivars. Mulato II and *U. mutica* harvested at 60 days had better IVOMD, whereas that of *U. mutica* and *U. brizantha* acce. no. 13151 at the age of 120 days had lower IVOMD than the remaining cultivars/ accessions and harvesting ages.

The NDF (neutral detergent fiber), ADF (acid detergent fiber), and ADL (acid detergent lignin) concentrations of the *Urochloa* cultivars ranged from 46.9 to 69.6 %, 26.6 to 34.3 %, and 5.1 to 6.8 %, respectively. The three fiber concentrations observed in Mulato II was lower (P<0.01) and that of *U. mutica* was higher (P<0.01) than the remaining cultivars. In general, the fiber fractions (NDF, ADF and ADL) increased with increasing harvesting age.

Correlation analysis

The relationships among morphological characteristics, chemical compositions, and yields of *Urochloa* grass cultivars/ accessions are presented in Table 4. The result revealed that there was a positive and highly significant correlation (p<0.01) between plant height and number of leaves per plant (r = 0.837), dry matter yield (r = 0.820), crude protein yield (r = 0.590) and neutral detergent fiber (r = 0.649). The plant height was negatively correlated with leaf: stem ratio (r= -0.615), crude protein (r = -0.551) and *in-vitro* organic matter digestibility (r= -0.602), with the highest correlation coefficient value for number of leaves per plant. On the other hand, leaf: stem and *in-vitro* OM digestibility values showed positive correlation while crude protein yield, neutral detergent fiber, and most morphological parameter showed negative relation with crude protein content. Dry matter yield was negatively (P<0.01) correlated with the quality parameters such as leaf: stem (r=-0.537) and crude protein content (r= -0.666). Moreover, *in-vitro* OM digestibility was negatively correlated with all morphological parameters, neutral detergent fiber and yield parameters, and positively correlated with crude protein (r=0. 867) and leaf: stem ratio (r = 0.386).

Table 3. The chemical composition (%), *in-vitro* organic matter digestibility (%), and metabolizable energy (Mcal/ kg DM) of *Urochloa* grass cultivars/ accessions harvested at different ages over the two years.

Urochloa cultivar/ accession	Ash	CP	NDF	ADF	ADL	IVOMD	ME
60 days of harvesting							
Mulato II	16.4^{a}	19.9^{a}	49.6^{f}	27.9^{g}	5.4^{ef}	65.5^{a}	2.08^{a}
Mutica	15.3^{bc}	19.7^{a}	56.0^{e}	32.1^{ef}	5.80^{bcde}	63.91^{a}	2.03^{a}
U. brizantha acce. no. 13151	14.7^{cde}	15.1^{de}	57.6^{de}	32.5^{def}	5.44^{def}	60.7^{bcde}	1.95^{abc}
Piata	14.8^{bcd}	17.6^{b}	58.3^{cde}	33.2^{cde}	5.76^{cde}	61.3^{bcd}	1.95^{abc}
U. brizantha acce. no. 16550	15.0^{bcd}	17.2^{bc}	57.4^{de}	33.0^{cde}	5.14^{f}	60.4^{bcd}	1.97^{abc}
90 days of harvesting							
Mulato II	15.4^{bc}	17.7^{b}	52^{f}	30.3^{fg}	5.83^{bcde}	63.2^{abc}	1.98^{abc}
Mutica	14.9^{bcd}	17.1^{bc}	59.4^{cd}	34.5^{cde}	5.96^{bcde}	63.6^{abc}	2.01^{ab}
U. brizantha acce. no. 13151	15.0^{bcd}	13.5^{ef}	59.2^{cd}	34.4^{cde}	5.90^{bcde}	58.4^{def}	1.87^{cde}
Piata	14.8^{bcd}	15.7^{cd}	58.9^{cd}	34.9^{cd}	6.17^{abc}	61.2^{bcd}	1.89^{bcd}
U. brizantha acce. no. 16550	14.9^{bcd}	14.5^{de}	59.9^{cd}	35.1^{c}	6.02^{bcd}	60.3^{cde}	1.88^{bcde}
120 days of harvesting							
Mulato II	15.7^{ab}	14.4^{de}	60.5^{c}	32.4^{ef}	6.0^{bcd}	61.2^{bcd}	2.0^{ab}
Mutica	13.7^{ef}	8.8^{g}	69.9^{a}	40.3^{a}	6.76^{a}	55.9^{f}	1.69^{fg}
U. brizantha acce. no. 13151	13.0^{f}	10.3^{g}	69.1^{ab}	38.8^{ab}	6.23^{abc}	51.6^{g}	1.67^{g}
Piata	14.0^{de}	12.4^{f}	67.7^{ab}	38.7^{ab}	6.39^{ab}	56.9^{f}	1.81^{def}
U. brizantha acce. no. 16550	14.7^{cde}	10.3^{g}	66.4^{b}	37.8^{b}	6.26^{abc}	57.4^{ef}	1.77^{efg}
SEM	0.24	0.46	0.72	0.74	0.17	0.99	0.04
Significance (*P-value*)							
Year (Y)	<.0001	0.0190	0.1126	0.0398	0.0015	0.0011	<.0001
Harvesting age (H)	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
Cultivar ©	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
H*©	0.0054	<.0001	0.0010	0.8032	<.0001	0.0004	0.0003
Y*H	0.7836	0.6393	0.4671	0.3196	0.2644	0.1189	0.0023
Y*©	0.1579	0.0400	0.8434	0.8684	0.8733	0.4555	0.0003
Y*H*©	0.9111	0.7231	0.4621	0.9666	0.3305	0.5378	0.1032

SEM: standard error of means; H*©: interaction between harvesting age and cultivar/ accession; Y*H: interaction between year and harvesting age; Y*©: interaction between year and cultivar/ accession; Y*H*©: interaction of year, harvesting age and cultivar/ accession; DM: dry matter; CP: crude protein; NDF: neutral detergent fiber; ADF: acid detergent fiber; ADL: acid detergent lignin; IVOMD: *in vitro* organic matter digestibility and ME: metabolizable energy. Means labeled by different superscript letters in the columns are significantly different according to Tukey's Student Range Test (*p<0.05*).

Table 4. Correlation coefficients among morphological characteristics, chemical composition, *in vitro* organic matter digestibility, and yields of *Urochloa* grass cultivars/ accessions across the two years.

Variables	PH	NTPP	NLPP	LL	LSR	DMY	CP	CPY	NDF	IVOMD
PH	1									
NTPP	0.239*	1								
NLPP	0.837**	0.080	1							
LL	0.215*	0.405**	-0.070	1						
LSR	-0.615**	-0.300**	-0.612**	0.210*	1					
DMY	0.820**	0.355**	0.815**	0.239*	-0.537**	1				
CP	-0.551**	-0.639**	-0.400**	-0.282**	0.406**	-0.666**	1			
CPY	0.590**	-0.003	0.652**	0.205	-0.382**	0.744**	-0.116	1		
NDF	0.649**	0.617**	0.486**	0.338**	-0.518**	0.692**	-0.844**	0.249*	1	
IVOMD	-0.602**	-0.564**	-0.302**	-0.355**	0.386**	-0.565**	0.867**	-0.089	-0.823**	1

* and **: significant at P<0.05 and P<0.01, respectively. DMY: dry matter yield; CP: crude protein; CPY: crude protein yield; IVOMD: *in vitro* organic matter digestibility; NDF: neutral detergent fiber; LSR: leaf: stem; NTPP: number of tillers per plant; NLPP: number of leaves per plant; LL: leaf length and PH: plant height.

DISCUSSION

Morphological characteristics

The increment in plant height at late harvest (day 120) is consistent with the findings of previous studies (Wassie *et al.*, 2018, Zemene *et al*., 2020; Worku *et al.*, 2022) which reported similar results for different *Urochloa* grasses. This finding shows that variation in plant heights with changes in the harvesting age is indicative of increased fodder production. *U. mutica,* Piata and ***U.*** *brizantha* acce. no. 16550 were taller than the other cultivars/ accessions and also produced high dry matter yields at 120 days of harvest. The plant height for *U. mutica* harvested at later age in the current study is higher than the findings of Zemene *et al.* (2020) and Mustaring *et al*. (2014) for the same cultivar in the late harvest. Moles *et al.* (2009) and Ogilo (2010) stated that grass species which grow fast and tall are more efficient in the use of resources and therefore, are more competitive than species of smaller height. The higher tillering ability in ***U.*** *brizantha* acce. no. 16550 and ***U.*** *brizantha* acce. no. 13151 accessions is an indication of the ability of the accessions to produce more biomass yield and recover faster after defoliation according to Mganga *et al.* (2016). *U. mutica* in our study was not able to maintain a high tillering which could be due to the allelopathic effect exhibited by the cultivar as suggested by Cook *et al.* (2005). Halim *et al.* (2013) reported that taller varieties of Napier grass had fewer numbers of tillers but produce higher DM yields compared with those of smaller height which has higher tillers number. The higher leaf number across all harvest ages in *U. mutica* compared to other *Urochloa* cultivars/ accessions in this study may suggest better quality forage grass that can be used for veld restoration of degraded grassland. Mnene (2006) indicated that grasses having more leaves and superior pigmentation are used possibly to achieve a bigger photosynthetic capability which will enable the grasses to grow rapidly. Grass leaves determine the forage quality for livestock with green leaves contributing to the increase in crude protein (Arzani *et al.*, 2004). The increase in the length of the leaf at a later harvesting age is consistent with the findings of Zemene *et al*. (2020) and Wassie *et al.* (2018) for various *Urochloa* ecotypes. This change in leaf growth rate could be due to an increase in cell division (Philippe *et al.*, 2015) because leaf length in grasses is greatly influenced by the developmental stage of the plant. The higher leaf: stem ratio observed for Mulato II and Piata than the remaining cultivars/ accessions might be due to the higher proportion of leaves observed for both cultivars. The decrease in leaf: stem ratio as harvesting age increased agrees with the findings of Wassie *et al.* (2018), Adnew *et al.* (2019), and Zemene *et al.* (2020) that indicated a reduction in leaf proportion and an increase in the stem fraction of *U. mutica* grass at the advanced harvesting age. Relatively lower leaf: stem ratio was recorded at the latter age of harvest due to the accumulation of more cell wall components in plant tissues as a result of stem development with advancing maturity rather than leaves. Zailan *et al.* (2016) stated that the proportion of leaves in forage decreases when the plant matures.

Forage dry matter, crude protein, and digestible organic matter yields

The greater DM yield of *Urochloa* grass cultivars/ accessions in year II could be due to differences in climate (Figure 1) and soil condition (Table 1). Environmental stress can be caused by several factors, including high temperatures, water deficit, and lack of nutrients which are usually observed during the 2020 cropping season. There were greater concentrations of total nitrogen (N) and available phosphorus (P) in the soil which may have resulted in increased biological nitrogen fixation and consequently greater N uptake (Campillo *et al.*, 2005), thereby affecting forage yield. Variations in DM yield across the cultivars/ accessions can be attributed to differences in growth rate and growth habit, which could be related to the genotypic and phenotypic differences. The highest dry matter yield of *U. mutica* at 120 days of harvest could be due to the outperforming property of the cultivar which may have been influenced by the creeping nature of this cultivar and it also spreads rapidly from stolon, had more leaves and the tallest compared to other *Urochloa* cultivars/ accessions. In agreement with this, Hunegnaw *et al.* (2022) observed that *U. mutica* height has contributed to high biomass yield than the species with a lower height. The increased DM yields with increasing harvesting age are consistent with other studies (Hare *et al.*, 2013; Wassie *et al.*, 2018; Gadisa *et al.*, 2020; Zemene *et al.*, 2020) that showed increased herbage yield with increased stage of harvest for various *Urochloa* grass cultivars. The increase in DM yields with increasing age at harvest might be due to additional tillers' development with the increase in plant height, leaf formation, and leaf elongation and development (Johnson *et al.*, 2001). In terms of digestible OM yield, *U. mutica* out-yielded the other cultivars/ accessions across the three harvesting age due to its high dry matter yield. This variation among *Urochloa* cultivars/ accessions with the same management system could be due to the genetic variation of cultivars/ accessions. The crude protein yield of the grass cultivars/ accessions increased considerably with their age in the current study. Similar findings have been reported by Zemene *et al.* (2020) and Wassie *et al.* (2018) for *Urochloa* ecotypes, Bantihun *et al.* (2022) for selected grass species, and Asmara *et al.* (2017) for Desho grass species.

Chemical composition and *in-vitro* organic matter digestibility

All the *Urochloa* cultivars/ accessions had higher ash content than the values reported by Njarui *et al.* (2021) and Njarui *et al.* (2016) for the *Urochloa* cultivars. The decrease in ash concentration as harvesting age advanced from day 60 to day 120 in the current study is in agreement with other reports (Tudsri *et al.*, 2002; Zemene *et al.*, 2020). This could be due to the fact that the mineral content declines as grasses mature (Minson, 1990). The CP content in Mulato II in the current study is higher compared to the values reported for the same cultivar by Mutimura and Everson (2012). Similarly, Njarui *et al.* (2021) reported a lower CP value for Piata compared with the current finding. On the contrary, Worku *et al.* (2022) reported slightly higher CP content in Mulato II than the current study for the same cultivar. Generally, all *Urochloa* cultivars/ accessions across the three harvesting ages contained higher CP than the mean values of 8.57 – 14.93 % (Adnew *et al.*, 2019) and 7-10% (Nguku *et al.*, 2015) for *Urochloa* grass species. The variation in CP concentration among the cultivars/ accessions could be due to their leaf: stem ratio, genetic differences, their respective advancing age, and accumulation of more proportion of fiber corresponding to plant growth (Minson, 1990; Van Soest, 1994; Salamone, 2012). It was reported that there is an accumulation of structural carbohydrate (fiber) content as the plant matures and a decrease in leaf: stem ratio with delayed forage harvest (Minson, 1990). In line with the current result, Njarui *et al*. (2016), Mutimura *et al*. (2017), Wassie *et al.* (2018) and Zemene *et al*. (2020) reported a declining trend in CP content with an increase in harvesting age for *Urochloa* grasses. The CP content of all *Urochloa* grass cultivars/ accessions across the three harvesting age in this study is above the critical threshold level for ruminant maintenance (8.5%) (Van Soest, 1994; NRC, 2000) and milk production (12%) (McDonald *et al.*, 2011), except for *U. mutica* at latter harvest, which had CP value below the threshold level for milk production. This clearly indicates the need for an appropriate choice of *Urochloa* cultivar/ accession for optimum utilization. The lowest NDF content observed for Mulato II (harvested at 60 days) in the current study is higher than the value reported by Mutimura and Ghimire (2021) but lower than the value reported by Wubetie *et al.* (2019) for the same cultivar at 60 days of harvesting in the mid-altitude of northwestern Ethiopia. The low NDF concentration of Mulato II at a young age in the current study may be due to its high proportion of leaves and higher number of leaves (Coêlho *et al.*, 2018). Similarly, the NDF content in *Urochloa* cultivars/ accessions across the three harvesting ages in the current study is lower than the value reported by Wassie *et al.* (2018) for *Urochloa* cultivars. The lower concentration of NDF for Mulato II across the three harvesting ages shows the superiority of this cultivar over the remaining ones. For all cultivars/ accessions across the three harvesting ages, the NDF content is lower than 72%, above which forage intake is reduced (Lima *et al.*, 2002). The ADF concentration exceeding 40% in forages resulted in reduced intake and digestibility (Nussio *et al.*, 1998). For all cultivars/ accessions, the ADF content in the current study is less than 40%, indicating that harvesting forages before maturity age is a good option for providing quality feed for livestock; hence there is recovery of emergence of new tillers, providing yield and forage with good digestibility (Nussio *et al.*, 1998; Costa *et al.*, 2005; Albayrak *et al.*, 2011). Forage digestibility is crucial for ruminant production because it affects how much protein and energy animals can extract from the forage and how much feed they consume. The *in-vitro* OM digestibility values of all cultivars/ accessions in the current study fall within the range (50–60%) reported by Owen and Jayasuriya (1989) for tropical grasses. The major difference among *Urochloa* cultivars/ accessions in *in-vitro* OM digestibility could be associated with the chemical composition of the plant material. Similarly, Minson (1990) pointed out that OM digestibility is related to chemical constituents (CP, NDF, ADF, and ADL) of forage. Moreover, Kozloski *et al.* (2005) suggested that variations in chemical composition and digestibility are expected with increasing harvesting age. Previous studies (Chen *et al.*, 2006; Mustering *et al.*, 2014) suggested that the higher CP content and the lower contents of fiber fractions (NDF and ADF contents) resulted in higher *in-vitro* OM digestibility. Besides, the higher *in-vitro* OM digestibility of Mulato II and Piata harvested at 60 and 90 days of age was also associated with the proportion of leaf and stem of the plant material. Similarly, Poppi *et al.* (1980) and Minson (1990) indicated that the leaf is more digestible than the stem component of the plant.

Correlation analysis

The observed strong positive correlation between plant height with yield parameters and the number of leaves per plant in our finding is comparable to the results reported by Tiruneh *et al.* (2022) for various *Urochloa* cultivars. This is due, mainly, to the fact that growth parameters are critical in increasing forage biomass yield (Imran *et al.*, 2007). The negative correlation of dry matter yield with forage quality parameters such as leaf: stem ratio and CP content in the current study agreed with the finding of Endalkachew (2021) for Mulato II. On the other hand, the negative correlations of leaf: stem ratio, CP, and *in-vitro* OM digestibility with NDF are expected, because as indicated by Wilson (1994), fiber fractions are cell types with thickened secondary walls, and are highly lignified, contributing to poor quality of forage. Moreover, the higher negative correlation trend between *in-vitro* OM digestibility and NDF in the present study is similar to the results of Enoh *et al.* (2005) in *Urochloa* cultivars. The strong positive relation between CP and *in-vitro* OM digestibility values in our findings is consistent with the result of Pereira *et al.* (2021) who observed a positive correlation between CP and in-vitro OM digestibility values of *Megathyrsus maximus* genotypes.

CONCLUSION

In this study, harvesting age and cultivar have an interacting effect on DM yield and quality of *Urochloa* grass cultivars/ accessions. The study highlighted that the yields of *Urochloa* cultivars/ accessions increased with an increase in harvesting age and showed a decline in quality, in terms of reduced crude protein (CP) as well as leaf: stem ratio and increasing trend in fiber fractions (NDF, ADF, and ADL) when maturity advances. *U. mutica* consistently produced the highest DM yield across the three harvesting ages and thus could be considered a suitable forage grass in the midland agroecological zones of Ethiopia. On the other hand, Mulato II had the highest CP content (across all harvesting ages) which suggests growing these top performing cultivars, Mulato II and *U. mutica* could be the best practice to retain high yield and quality. The harvesting age affected forage DM yield, CP, and *in-vitro* OM digestibility of *Urochloa* grasses. Harvesting at 60 days resulted in the highest quality (better CP and leaf: stem ratio) but the lowest forage DM yield. On the contrary, the yield was highest at day 120 but the quality was poor. Therefore, harvesting at day 90 could be the best option to get a high yield without compromising the quality traits. However, there is a need to evaluate animal performance by feeding the best-performing *Urochloa* cultivars for cultivars/ accessions cultivated under the current experimental conditions.

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Author contribution statement (CRedit).
Tamene Tadesse- Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Writing original draft; Writing-review & editing; **Ajebu Nurfeta-** Data curation; Methodology; Validation; Project administration; Supervision; Writing-review & editing; **Adugna Tolera-** Conceptualization; Data curation; Methodology; Project administration; Supervision; Writing-review & editing.

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