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Research Paper

Evaluation of ten perennial forage grasses for biomass and nutritional quality

Evaluación de biomasa y calidad nutricional en diez gramíneas forrajeras perennes

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Abstract

A study was carried out to evaluate 10 perennial forage grass accessions from 4 species for herbage dry matter yield and nutritional quality at Holetta Agricultural Research Center. The evaluated grass species and varieties were one Desho grass (*Pennisetum*) variety Kulumsa, four *Urochloa decumbens* (ILRI-14721, ILRI-14720, ILRI-13205 and ILRI-10871), three *Urochloa ruziziensis* (ILRI-14813, ILRI-14774 and ILRI-13332) and two *Setaria sphacelata* (ILRI-143 and ILRI-6543) accessions. Plant height and forage dry matter yield were significantly affected by accession over years, during the establishment and production phases. Combined analysis indicated that the tested accessions varied significantly for plant height with the *Setaria* accessions taller than the other tested species. Combined data analysis revealed that forage dry matter yield significantly varied according to species and Desho grass (variety Kulumsa) was higher in dry matter yield than the other grasses tested. Fiber contents (NDF, ADF and ADL) were significantly influenced by accession. Crude protein yield differed among the accessions and Desho grass had higher crude protein, followed by *U. decumbens* 13205, *U. decumbens* 14721 and *S. sphacelata* 6543. Based on dry matter yield and crude protein *U. decumbens* 13205, *U. ruziziensis* 13332, *S. sphacelata* 6543 and Desho grass (var. Kulumsa) are recommended as alternative forage grasses for the study area and similar agro-ecologies.

Keywords: Desho grass, forage yield, *Urochloa*, *Setaria*, crude protein.

Resumen

Se llevó a cabo un estudio para evaluar 10 accesiones de gramíneas forrajeras perennes de 4 especies para determinar el rendimiento de materia seca y la calidad nutricional del forraje en el Centro de Investigación Agrícola de Holetta. Las especies y variedades de gramíneas evaluadas fueron una pasto Desho (*Pennisetum*) variedad Kulumsa, cuatro accesiones de *Urochloa decumbens* (ILRI-14721, ILRI-14720, ILRI-13205 e ILRI-10871), tres de *Urochloa ruziziensis* (ILRI-14813, ILRI-14774 e ILRI -13332) y dos de *Setaria sphacelata* (ILRI-143 e ILRI-6543). La altura de la planta y el rendimiento de materia seca del forraje se vieron afectados significativamente por la accesión a lo largo de los años, durante las fases de establecimiento y producción. El análisis combinado indicó que las accesiones probadas variaron significativamente la altura de la planta en las accesiones de *Setaria*, siendo más altas que las otras especies probadas. El análisis de datos combinados reveló que el rendimiento de materia seca del forraje varió significativamente según la especie y el pasto Desho (variedad Kulumsa) fue mayor en rendimiento de materia seca que los otros pastos evaluados. El contenido de fibra (NDF, ADF y ADL) se vio significativamente influenciado en cada accesión. En cuanto a rendimiento de proteína cruda el pasto Desho fue el mayor, seguido por *U. decumbens* 13205, *U. decumbens* 14721 y *S. sphacelata* 6543. Basado en el rendimiento de materia seca y proteína cruda *U. decumbens* 13205, *U. ruziziensis*

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13332, *S. sphacelata* 6543) y pasto Desho (var. Kulumsa) se recomiendan como pastos forrajeros alternativos para el área de estudio y condiciones agroecológicas similares.

Palabras clave: proteína cruda, *Pennisetum,* rendimiento forrajero, *Setaria*, *Urochloa*.

Introduction

The central highland of Ethiopia is characterized by a crop-livestock mixed farming system. Livestock is an integral component of most of the agricultural activities in the country. The share of the livestock subsector in the national economy is estimated to be 12–16% of the total Gross Domestic Product (GDP), 30–35% of the agricultural GDP (LMA 1999), 19% of the export earnings (FAO 2004) and 31% of the total employment (Feleke 2003). Although Ethiopia has a large livestock population (CSA 2016), the productivity of livestock is low with the major hindrances being shortage of feed resources in terms of quantity and quality (Demeke et al. 2017). To combat these nutritional constraints, the use of locally available and introduced forage species adapted to the local agro-ecological conditions is recommended. The cultivation of high quality forages with high herbage yield and adaptability to biotic and abiotic environmental stresses is one of the options to increase livestock production under smallholder farmer conditions (Tessema 2005). The introduction of promising improved forage crops like *Urochloa, Setaria* and Desho grass is an advocated strategy to alleviate the prevailing feed crisis in the country.

Most of the *Urochloa* (previously named as *Brachiaria*) species and varieties that have been developed are resistant to Napier grass stunt and smut disease affecting Napier grass varieties in Eastern Africa (Ghimire et al. 2015; Maass et al.2015). *Urochloa* is well adapted to low-fertility soils and diseases. It withstands heavy grazing and sequesters carbon through its large root system with enhanced nitrogen use efficiency and minimized greenhouse gas emissions (Arango et al. 2014; Moreta et al. 2014). *Urochloa decumbens* (Stapf) R. D. Webster (previously named as *Brachiaria decumbens* Stapf) is reported to be drought resistant and resilient when grown on infertile soils, producing high herbage yields with relatively low levels of fertilizer inputs. *U. ruziziensis* (R. Germ. & C. M. Evrard) Crins [previously named as *Brachiaria ruziziensis* (R. Germ. & C. M. Evrard)] plays an important role in soil erosion control and ecological restoration. The grass has high dry matter yield potential (Rodrigues et al. 2014). *U. ruziziensis* also produces abundant roots which contribute to the collection of water, soil aggregation and aeration (Kluthcouski et al. 2004). Recent studies indicate that adoption of *U. brizantha* (Hochst. ex A. Rich.) R. D. Webster [previously named as *Brachiaria brizantha* (Hochst. ex A. Rich.)] cultivars as cut-and-carry fodder for dairy cattle have increased milk production on participating farms in Kenya by 15–40% (Schiek et al. 2018). Similarly, use of the *Urochloa* hybrid Mulato II fodder in dairy and beef enterprises in Rwanda enabled a 30% increase in milk production and a 20% increase in meat production (CSB 2016).

Setaria sphacelata (Schumach.) Stapf & C. E. Hubb. is a perennial C_4 grass, which can produce more than 20 t DM/ha annually (Taylor et al. 1976; Sithamparanathan 1979). It has been recommended for use in tropical and subtropical countries with a minimum yearly rainfall of 750 mm or 580 mm on very fertile soils (Botha 1948). However, it grows better in wetter areas with no prolonged dry season (Rattray 1960). *S. sphacelata* has the desirable forage attributes of high yield (Singh et al. 1995), high crude protein concentration (de Almeida and Flaresso 1991) and good animal performance (Jones and Evans 1989).

Desho [*Cenchrus glaucifolius* (Hochst. ex A. Rich.) Rudov & Akhani] formally known as *Pennisteum glaucifolium* Hochst. ex A. Rich. is a perennial grass and is palatable to cattle, sheep and other herbivores (FAO 2010). Desho grass serves as a business opportunity for farmers in Ethiopia (Shiferaw et al. 2011; Tilahun et al. 2017). According to Lukuyu et al. (2011), it is very important to have chemical composition and utilization information of locally available feeds for their inclusion into livestock feeding programs. Despite their significant potential for forage production, there is little research on the comparative advantage of producing Desho, *Urochloa* and Setaria species in the central highlands of Ethiopia. The present study aimed to evaluate the performance of *Urochloa, Setaria* and Desho grass species and varieties and recommend the best ones with combined attributes of high herbage yield and quality for wider distribution among livestock producer communities in the Ethiopian highlands.

Materials and Methods

Description of the study area

The experiment was conducted at the Holetta Agricultural Research Center (HARC), Ethiopia, during the main cropping seasons of 2014 to 2019 under rain-fed conditions. HARC is located at 9°00'N latitude and 38°30'E longitude at an altitude of 2,400 m.a.s.l. It is characterized by a long term (30 years) average annual rainfall of 1,055 mm, average relative humidity of 60.6%, and average maximum and minimum air temperature of 22.2°C and 6.1°C, respectively. Rainfall is bimodal and about 70% of the precipitation falls in the period from June to September while the remaining thirty percent falls in the period from March to May (EIAR 2005). The soil type of the area (Table 1) is predominantly red Nitosol (Keneni 2007).

Experimental treatments and design

The study involved ten perennial forage grass species and varieties (Table 2). Seeds of the *Urochloa* and *Setaria* species were obtained from the International Livestock Research Institute (ILRI), while Desho grass was obtained from the Debre Zeit Research Center (DZARC). The experiment was conducted as a Randomized Complete Block Design (RCBD) with three replications. The experimental fields were ploughed and harrowed to a fine seedbed. The seeds were grown in a nursery and vegetative parts in the form of root splits from mature plants were used for planting which was accomplished at the beginning of the main rainy season (in mid-June). Plot size was 7.2 m^2 (3x 2.4m). The root splits were planted with the intra and inter row spacing of 0.25 m and 0.5 m respectively. The spacing between plots and blocks was 1.5 m. Phosphorus fertilizer was uniformly applied to all plots at planting in the form of diammonium phosphate (DAP, 18% N, 20% P, 1.5% S) at the rate of 100 kg/ha. After every harvest, the plots were top dressed with 100 kg urea (46% N)/ha of which one-third was applied at the first shower of rain (in May) and the remaining two-thirds applied during the active growth stage of the plant, during the mid-growing season (July–August).

Table 1. Properties of soils in the study area

Parameter	Values	Method of Analysis
pH (1:2.5 H_2O)	4.94	Potentiometric method
Organic carbon (%)	1.79	Dichromate oxidation method (Walkley and Black 1934)
Total nitrogen (%)	0.20	Kjeldhal method (Jackson 1958)
Available P (ppm)	5.60	Olsen method (Olsen et al. 1954)
CEC (meq/100 g)	18.24	NH_4OAc method (pH=7)
Na^+ (meq/100 g)	0.16	NH_4OAc method (Okalebo et al. 1993)
K^+ (meq/100 g)	5.03	NH_4OAc method (Okalebo et al. 1993)
$Ca2^+$ (meq/100 g)	29.50	NH_4OAc method (Okalebo et al. 1993)
$Mg2^+$ (meq/100 g)	13.75	NH_4OAc method (Okalebo et al. 1993)
P(mg kg^{-1})	5.6	NH_4OAc method (Okalebo et al. 1993)
Texture		
Sand (%)	18	Bouyoucos hydrometric method
Silt (%)	15	Bouyoucos hydrometric method
Clay (%)	67	Bouyoucos hydrometric method

Source: Holetta Agricultural Research Center meteorological data report

Table 2. Evaluated grass species

Species	Common name	Accession	Country of origin
Cenchrus glaucifolius (Hochst. ex A. Rich.) Rudov & Akhani)	Desho grass	Kulumsa	Ethiopia
Setaria sphacelata (Schumach.) Stapf & C. E. Hubb.	common setaria	ILRI-143= cv. Kazungula	Zambia
Setaria sphacelata (Schumach.) Stapf & C. E. Hubb.	common setaria	ILRI-6543= cv. Narok	Kenya
Urochloa decumbens (Stapf) R. D. Webster	signal grass	ILRI-10871 = cv. Basilisk	Uganda
Urochloa decumbens (Stapf) R. D. Webster	signal grass	ILRI-13205	Kenya
Urochloa decumbens (Stapf) R. D. Webster	signal grass	ILRI-14720	Rwanda
Urochloa decumbens (Stapf) R. D. Webster	signal grass	ILRI-14721	Rwanda
Urochloa ruziziensis (R. Germ. & C. M. Evrard) Crins	ruzi grass	ILRI-13332	unknown
Urochloa ruziziensis (R. Germ. & C. M. Evrard) Crins	ruzi grass	ILRI-14774	Burundi
Urochloa ruziziensis (R. Germ. & C. M. Evrard) Crins	ruzi grass	ILRI-14813	Burundi

Data collection

This experiment involved two phases, namely establishment (in mid June 2014) and productive phases (2015–2019). Data were collected on vigor, plant height at harvesting and forage dry matter yield. Plant vigor was recorded during the establishment phase (mid June 2014–June 2015) on a scale from 1–5 and converted to a percentage. Plant height was measured from the ground to the highest leaf at the time of forage harvesting stage. Plant height and number of tillers per plant were recorded from 6 randomly selected plants from the whole plot. For the determination of biomass yield, Setaria accessions were harvested at 10% flowering stage using a quadrat measuring 3 * 2.4 m^2 (7.2 m^2) areas. Desho and *Urochloa* were harvested at >40cm before flowering, the height of cutting determined by previous studies. The plot was cut twice per year in May–June and October–November. Weight of the total fresh biomass yield was recorded from each plot in the field and a 500 g sub-sample was taken from each plot to the laboratory to determine dry matter yield. Sub-samples were oven dried at 65°C for 72 hours. The oven dried samples were ground to pass through a 1 mm sieve for laboratory analysis. Before scanning, the samples were dried at 60 °C overnight in an oven to standardize the moisture and then 3 g of each sample was scanned by Near Infra-Red Spectroscopy (NIRS). Percentage dry matter (DM), ash, crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL) and *in-vitro* dry matter digestibility (IVDMD) were predicted using a calibrated NIRS (Foss 5000 apparatus and WinISI II software).

Statistical analysis

The analysis of variance (ANOVA) procedure of the SAS general linear model (GLM) (ersion 9.4 was used to analyse the quantitative data (SAS 2002). The LSD test at 5% significance was used for comparison of means.

Results

Plant vigor and height

The result of the analysis indicated that vigor was significantly (P<0.001) affected by species (Table 3) with a rating of more than 50% plant vigor except for *U. decumbens* 14720. The plant vigor percentage performance of the species was positively associated with the forage dry matter yield during the establishment year showing plant vigor can be a good indicator of the forage dry matter yield potential.

The result of a combined analysis during the production phase (2015–2019) showed that plant height at harvesting was significantly (P<0.001) influenced by accession (Table 3). *S. sphacelata* accessions were significantly (P<0.001) taller than the other evaluated perennial forage grass species in 2014, 2015, 2018 and 2019 experimental years but in 2018 the plant height recorded for *S. sphacelata* accessions was non-significant (P>0.05) with Desho grass (variety Kulumsa).

Dry matter yield

Forage dry matter yield was significantly (P<0.001) different for accessions over the production years (Table 4). Desho grass had significantly (P<0.001) higher forage dry matter yield than other evaluated grasses in 2014, 2015, 2016 and 2017, excluding *U. decumbens* 13205 that was not significantly (P>0.05) different from Desho grass in the 2016 production phase. In 2018 *U. decumbens* 10871, *U. decumbens* 13205 and *U. decumbens* 14721 had higher (P<0.001) forage dry matter yield than the other grasses.

The forage dry matter yield increased with production years for the first three consecutive years (2014–2016) for each evaluated grass species, exclusive of *S. sphacelata* 143 which showed a slight decrease from the first (2015) year of production to fourth year (2018) of production. However, in the third and fourth years of production all accessions showed a decrease in forage dry matter yield except *U. ruziziensis* 13332 and *U. decumbens* 10871. During the fifth (2018) year of production to the end of this experiment, all evaluated grasses showed biomass yield increase. Desho grass had higher forage dry matter yield during the establishment phase (2014) than the other grasses.

Forage chemical composition

Nutritional qualities of the perennial forage grass species evaluated at Holetta are presented in Table 5. NDF and ADF content were significantly (P<0.001) different among the accessions and *U. ruziziensis* had lower ADF and NDF content than the other grasses.

ADL was significantly (P<0.05) different among the accessions. IVDMD and crude protein percentage were not significantly (P>0.05) influenced either by species or accession.

Crude protein yield (CPY) was significantly (P<0.001) different among the accessions. Despite having the lowest CP percentage, Desho grass had higher (P<0.001) CPY than *U. ruziziensis*, *S. sphacelata* and *U. decumbens* accessions, except *U. decumbens* 14721 and *S. sphacelata* 6543.

Table 3. Vigor and plant height (cm) of perennial forage grass species at harvest.

S. No	Species	Plant height (cm) in year						Productive phase	Combined analysis	Vigor (%)
		2014	2015	2016	2017	2018	2019			
1	*U. ruziziensis* ILRI-14813	44.13^{cde}	42.23^{d}	76.20^{d}	38.87^{e}	54.19^{bc}	39.20^{d}	50.14^{d}	49.14^{e}	60.00^{cde}
2	*U. ruziziensis* ILRI-14774	34.67^{de}	49.45^{cd}	50.87^{e}	50.00^{e}	45.00^{c}	37.80^{d}	46.62^{d}	44.63^{e}	56.20^{def}
3	*U. ruziziensis* ILRI-13332	52.20^{c}	61.67^{c}	81.40^{d}	42.77^{e}	65.00^{bc}	39.73^{d}	58.11^{d}	57.13^{de}	70.00^{bc}
4	*U. decumbens* ILRI-14721	40.67^{cde}	59.93^{cd}	103.03^{bc}	112.77^{abc}	67.88^{b}	56.13^{bc}	79.95^{bc}	73.40^{c}	53.40^{def}
5	*U. decumbens* ILRI-10871	45.23^{cd}	66.67^{c}	92.37^{cd}	102.77^{abc}	68.09^{b}	60.30^{bc}	78.04^{c}	72.57^{c}	80.00^{ab}
6	*U. decumbens* ILRI-14720	29.23^{e}	54.72^{cd}	94.80^{cd}	101.13^{bcd}	59.58^{bc}	61.97^{bc}	74.44^{c}	66.90^{cd}	46.60^{f}
7	*U. decumbens* ILRI-13205	41.33^{cde}	60.55^{c}	91.77^{cd}	92.77^{d}	64.55^{bc}	54.73^{c}	72.87^{c}	67.62^{cd}	63.40^{cd}
8	*S. sphacelata* ILRI-143	119.47^{a}	130.83^{a}	119.37^{ab}	114.47^{ab}	113.22^{a}	82.53^{a}	112.08^{a}	113.31^{a}	76.60^{b}
9	*S. sphacelata* ILRI-6543	121.67^{a}	130.00^{a}	127.00^{a}	117.74^{a}	116.22^{a}	85.00^{a}	115.19^{a}	116.27^{a}	50.00^{ef}
10	Desho grass (var. Kulumsa)	89.43^{b}	91.67^{b}	105.30^{bc}	100.00^{cd}	95.47^{a}	65.57^{b}	91.60^{b}	91.24^{b}	90.00^{a}
	Mean	61.80	74.77	94.21	88.33	74.93	58.30	77.91	75.22	64.62
	CV	15.18	14.13	12.54	8.97	16.99	10.87	23.20	25.48	9.27
	Significance level	***	***	***	***	***	***	***	***	***

***=P<0.001; Means with the same letter are not significantly different.

Table 4. Dry matter yield (t/ha) per year of perennial forage grass species tested per year at Holetta from 2014 to 2019.

S. No	Species	Dry matter yield (t/ha) in each year						Productive phase	Combined analysis
		2014	2015	2016	2017	2018	2019		
1	*U. ruziziensis* ILRI-14813	2.43^{cd}	13.04^{bc}	19.11^{cde}	8.37^{d}	7.64^{de}	9.75^{cde}	11.58^{e}f	10.06^{de}
2	*U. ruziziensis* ILRI-14774	1.30^{de}	5.07^{e}	12.23^{e}	8.16^{d}	4.33f	8.08^{de}	7.56f	6.52^{e}
3	*U. ruziziensis* ILRI-13332	3.45^{c}	17.37^{bc}	24.12^{bcd}	8.70^{d}	7.62^{de}	11.53^{cde}	13.87^{de}	12.13^{cd}
4	*U. decumbens* ILRI-14721	0.96^{e}	10.92^{cde}	30.07^{ab}	23.24^{b}	17.04^{a}	19.78^{ab}	20.21^{bc}	17.00^{bc}
5	*U. decumbens* ILRI-10871	0.76^{e}	7.39^{de}	25.03^{bc}	14.93^{cd}	18.62^{a}	20.92^{a}	17.38^{bcd}	14.61^{bcd}
6	*U. decumbens* ILRI-14720	0.64^{e}	10.03^{de}	23.32^{bcd}	16.70^{bc}	12.40^{bc}	13.57^{bcd}	15.20^{cde}	12.78^{cd}
7	*U. decumbens* ILRI-13205	1.19^{de}	14.23^{bcd}	36.53^{a}	22.77^{b}	18.36^{a}	18.30^{ab}	22.04^{ab}	18.56^{b}
8	*S. sphacelata* ILRI-143	5.27^{b}	18.62^{b}	23.26^{bcd}	14.70^{cd}	9.86^{cd}	8.41^{de}	14.97^{de}	13.35^{bcd}
9	*S. sphacelata* ILRI-6543	5.74^{b}	18.41^{b}	17.19^{de}	12.20^{cd}	5.88^{e}f	7.22^{e}	12.18^{e}f	11.11^{de}
10	Desho grass (var. Kulumsa)	13.14^{a}	33.41^{a}	36.55^{a}	34.48^{a}	13.54^{b}	15.69^{abc}	26.75^{a}	24.27^{a}
	Mean	3.49	14.84	24.74	16.43	11.53	13.33	44.15	14.06
	CV	24.39	27.75	18.45	27.41	16.54	27.72	16.17	59.18
	Significance level	***	***	***	***	***	***	***	***

***=P < 0.001; Means with the same letter are not significantly different.

Table 5. Nutrient content of perennial forage grasses

S. No	Species	DM%	Ash%	NDF%	ADF%	ADL%	CP%	CPY (t/ha)	IVDMD%
1	*U. ruziziensis* ILRI-14813	91.35^{de}	17.72^{a}	61.95^{b}	29.92^{b}	4.44^{bc}	6.33	0.64^{cd}	59.81
2	*U. ruziziensis* ILRI-14774	91.37^{de}	16.72^{abc}	63.55^{b}	31.27 ^{b}	4.74^{abc}	6.72	0.44^{d}	59.56
3	*U. ruziziensis* ILRI-13332	91.16^{e}	17.14^{ab}	62.68^{b}	30.68 ^{b}	4.27^{c}	6.22	0.75^{bcd}	60.92
4	*U. decumbens* ILRI-14721	91.60^{bcd}	16.52^{abcd}	67.14^{a}	34.72 ^{a}	4.86^{ab}	5.57	0.95^{abc}	55.35
5	*U. decumbens* ILRI-10871	91.83^{bc}	15.25^{cd}	69.48^{a}	37.50 ^{a}	5.25^{a}	5.58	0.81^{bc}	55.68
6	*U. decumbens* ILRI-14720	91.47^{cde}	15.56^{bcd}	67.55^{a}	35.32 ^{a}	5.19 ^{a}	6.87	0.88^{bc}	57.16
7	*U. decumbens* ILRI-13205	91.72^{bcd}	16.26^{abcd}	68.03^{a}	35.34 ^{a}	4.84^{ab}	5.57	1.04^{ab}	56.26
8	*S. sphacelata* ILRI-6543	91.70^{bcd}	14.94^{d}	67.55^{a}	35.74 ^{a}	4.80^{abc}	6.98	0.92^{abc}	54.14
9	*S. sphacelata* ILRI-143	92.26^{a}	15.69^{bcd}	66.99^{a}	36.32 ^{a}	4.59^{bc}	6.96	0.77^{bc}	54.51
10	Desho grass (variety Kulumsa)	91.92^{ab}	12.92^{e}	69.29^{a}	37.64 ^{a}	4.48^{bc}	5.04	1.23^{a}	56.44
	Mean	91.64	15.87	66.42	34.45	4.75	6.18	0.84	56.98
	CV	0.27	5.83	2.27	4.97	7.06	13.22	59.77	4.37
	Significance level	**	***	***	***	*	ns	***	ns

DM% = Dry matter percentage; Ash% = Ash percentage; NDF% = Neutral detergent fiber percentage; ADF% = Acid detergent fiber percentage; ADL% = Acid detergent lignin percentage; CP% = Crude protein percentage; CPY = Crude protein yield; IVDMD = In-vitro dry matter digestibility; ** = P<0.01; * = P<0.05; *** = P<0.001; ns = non-significant; Means with the same letter are not significantly different.

Discussion

Desho and *Setaria* showed better vigor than *Urochloa*, suggesting that Desho and *Setaria* were faster to establish and had superior competition against the weeds than *Urochloa* species especially in the establishment phase. This can be an important characteristic to establish these forages on soil bunds for soil conservation in the livestock-crop mixed area. Soil bunds are available for free grazing during the non-cropping season and these grasses can tolerate the grazing due to their fast establishment characteristics. *S. sphacelata* accessions and Desho grass were taller during the establishment year, possibly due to the morphological vertical growth characteristics of the species and plant vigor. Plant height differences can be attributed to the morphological and physiological differences among the cultivars (Nguku 2015), Setaria having different morphology to the *Urochloa* accessions.

U. ruziziensis accessions provided the highest forage dry matter yield in the establishment phase, suggesting that this species is fast growing and more easily established than *U. decumbens* accessions. During the production phase, Desho grass produced significantly more forage dry matter yield than other evaluated grass species. This implies Desho grass is more adaptable to Nitosol and cold air conditions than *U. ruziziensis*, *U. decumbens* and *S. sphacelata* grasses. The *Urochloa* accessions are true tropical plants and their growth almost stops when temperatures drop below about 20 °C. *Setaria* is more subtropical and will continue to grow at much lower temperatures than the *Urochloa* accessions. Forage dry matter yield increased with production years for the first three consecutive years due to climatic variation (rainfall pattern, temperature, frost). Desho grass had the highest forage dry matter yield and more vigorous growth that resulted in the well-established root system that enabled the grass to extract better growth resources from the soil.

Although differences were seen in nutrient content, all grasses studied were low quality. This may be the result of harvesting when over mature with only two harvests per year. Farmer practices of harvesting were followed in the experiment to reflect the local feeding situation. Grasses are usually harvested after 6 to 8 weeks of growth to obtain better quality feed. In this study, forage materials from all the grass species had greater than 60% NDF which may result in low intake and digestibility in livestock. McDonald et al. (2002) reported that the primary chemical composition of feeds that determines the rate of digestion is NDF, which is itself a measure of cell-wall content; thus there is a negative relationship between the NDF content of feeds and the rate at which they are digested. Schroeder et al. (2012) also reported that as NDF percentages increase, dry-matter intake generally will decrease. *U. ruziziensis* accessions had ADF above the minimum recommended value (17–21 percent) for NRC (2001). This result suggests that *U. ruziziensis* species will have moderate digestibility compared to the other grasses evaluated in this experiment. Nussio et al. (1998) reported that forage with ADF content around 40% or more, shows low intake and digestibility. In this study forage materials from all the grass species had low CP below the 7% CP required for microbial protein synthesis in the rumen that can support at least the maintenance requirement of ruminants (Van Soest, 1994). IVDMD levels were low and Mugeriwa et al. (1973) reported that the IVDMD values greater than 65% indicate good feeding value and values below this threshold level result in reduced intake due to lowered digestibility.

Conclusions

Based on dry matter yield and crude protein yield data, *U. decumbens* 13205, *U. ruziziensis* 13332, *S. sphacelata* 6543 and Desho grass (variety Kulumsa) are recommended for the study area and similar agro-ecologies as alternative forage grasses.

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