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Research Article

Dry matter accumulation dynamics, morphological characteristics and nutritive value of desho (*Pennisetum glaucifolium*) grass varieties in the central Highlands of Ethiopia

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Abstract: *Desho (Pennisetum glaucifolium) grass is one of the indigenous cultivated multipurpose perennial forage crops grown for animal feed and soil conservation practices in Ethiopia. This study was conducted to evaluate desho grass varieties for their morphological characteristics, dry matter yield performance, and nutritive value in the central highlands of Ethiopia. The study was conducted at Holetta Agricultural Research Center during the main cropping seasons of 2013 - 2017 under rain fed conditions. Four varieties of desho grass, viz. Areka (DZF # 590), Kulumsa (DZF # 592), Kindu Kosha-1 (DZF # 591), and Kindu Kosha-2 (DZF # 589) were planted in a randomized complete block design with three replications. Though the plant height of desho grass varieties was not significant (P>0.05) at each production year and combined over years, it significantly differed among the production years. The number of nodes per plant and leaf to stem ratio varied significantly while the internode length was not significant among desho grass varieties. The combined over years analysis indicated that the leaf and stem dry matter yields varied significantly (P<0.05) for desho grass varieties. Furthermore, the leaf and stem dry matter yields differed significantly among the production years. The total dry matter yield accumulated by desho grass varieties varied significantly and Areka (DZF # 590) variety accumulated the highest dry matter yield (23.8 t/ha) followed by Kulumsa (DZF # 592) variety (23.1 t/ha), while Kindu Kosha-1 (DZF # 591) accumulated the least (18.8 t/ha) dry matter yield. The first year of production produced the lowest dry matter yield while the accumulation of dry matter yield increased for consecutive production years but the yield declined in the last production year. The highest dry matter yield was accumulated in the 2016 production year and it had 19.8 and 4.3% advantages over the 2014 and 2015 production years, respectively. The crude protein yield and nutritive value among desho grass varieties was not significant. The result indicated that the crude protein yield of desho grass varieties ranged from 2.8 to 4.0 t/ha with a mean of 3.4 t/ha. Similarly, the crude protein content ranged from 10.7 to 12.5% with a mean of 11.7%. Generally, the varieties have comparable performances for measured traits in the study area. However, further study should be conducted over locations and years to select and recommend the best variety for the study area and to other similar agro-ecologies.*

Keywords: Crude protein yield, Desho grass, Feed, Forage yield, Nutritive value

1. Introduction

Livestock is an integral component of most of the agricultural activities in Ethiopia. It provides draught power and manure for crop production and is the source of food and industrial raw material (Getahun, 2019). The livestock population of the country is estimated to be 70.3 million cattle, 42.9 million sheep, 52.5 million goats, 2.1 million horses, 0.4 million mules, 10.8 million donkeys, 8.1 million camels, and 57.0 million poultry (CSA, 2021). The share of the livestock sub-sector in the national economy is estimated to be 12-16% to the total Gross Domestic Product (GDP), which is 30- 35% to the agricultural GDP (Ayele *et al*., 2002); 19% to the export earnings (FAO, 2003); and 31% of the total employment (Getachew, 2003).

Despite the enormous contribution of livestock to the livelihood of farmers, the availability of poor quality feed resources remains to be the major bottleneck to livestock production in Ethiopia (Seyoum and Zinash, 1995; Zinash *et al*., 1995; Alemayehu, 2005). The feed resources potential in Ethiopia is variable over seasons (Adugna, 2007; Firew and Getnet, 2010; Yayneshet, 2010) and natural pasture grazing accounts for the major share of feed supply (54.5%) followed by crop residues (31.1%) and hay which contribute 7.4% of the total feed (CSA, 2021). Agro-industrial by-products, improved forage crops, and non-conventional feed resources like animal by-products, vegetable and fruit wastes contribute the remaining 2.0, 0.6, and 4.4% of the total feed, respectively (CSA, 2021).

Traditional livestock production system mainly depends upon poor pasturelands and crop residues which are usually inadequate to support reasonable livestock production (Tsige, 2000; Assefa, 2005). These feed resources are high in fiber, with low to moderate digestibility and low levels of nitrogen (Preston, 1995; Tsige, 2000). Such low-quality feeds are associated with a low voluntary intake, thus resulting in insufficient nutrient supply, low productivity, and even weight loss (Hindrichsen *et al*., 2004; Adugna, 2008; Shapiro *et al*., 2017). However, Berhanu *et al*. (2003) reported that improved nutrition through the adoption of sown forage could substantially increase livestock productivity.

Among the different improved forage crops recommended for various agro-ecological zones of Ethiopia, desho (*Pennisetum glaucifolium*) grass is one of the useful perennial forage crops abundantly grown for soil conservation practices and animal feed in the highlands of Ethiopia (Welle *et al*., 2006; Leta *et al*., 2013; Yakob *et al*., 2015). Desho grass is native to tropical countries including Ethiopia (Ecocrop, 2010; Leta *et al*., 2013; EPPO, 2014) and it is suitable for intensive management and performs well at an altitude ranging from 1500 to 2800 meter above sea level (Leta *et al*., 2013) but performs best at an altitude greater than 1700 2800 meter above sea level (Welle *et al*., 2006). The grass is collected from the Chencha district in Southern Ethiopia (Welle *et al*., 2006). It is a highly popular, drought-tolerant species, and is used as one of the major feeds for ruminants (FAO, 2010; Bimrew, 2016). The grass provides more quantities of good quality forage per unit area and ensures regular forage supply due to its multi-cut nature and it is very palatable for ruminants (Ecocrop, 2010). For sustainable production, the grass is used through cut-and-carry feeding systems (Danano, 2007) and is also useful for hay and silage preparation (Ecocrop, 2010). Moreover, the grass serves as a business opportunity for farmers in Ethiopia (Shiferaw *et al*., 2011; Leta *et al*., 2013). The use of indigenous cultivated multipurpose forage crops as livestock feed is very important to mitigate the feed shortage problem (Abebe *et al*., 2008; Anele *et al*., 2009). According to Anele *et al*. (2009), indigenous forages are familiar with the smallholder farmers, grow with low inputs, and are adaptable to different agro-ecological conditions. However, the yield and nutritional qualities of forage are influenced by seasonal variations, stage of maturity, ecological conditions, and management practices. Since desho grass is a perennial grass, collection of data for many years can provide the performance of the grass across years. Therefore, this study was conducted to evaluate desho grass varieties for their morphological characteristics, productivity, and chemical composition at Holetta, in the central highland of Ethiopia.

2. Materials and Methods

2.1. Description of the study area

The experiment was conducted at Holetta Agricultural Research Center (HARC) during the main cropping seasons of 2013 - 2017 under rain fed conditions. The center is located at 9°00'N latitude, 38°30'E longitude at an altitude of 2400 m above sea level. It is 34 km west of Addis Ababa on the road to Ambo and is characterized by the long-term (30 years) average annual rainfall of 1055.0 mm, average relative humidity of 60.6%, and average maximum and minimum air temperature of 22.2°C and 6.1°C, respectively. The soil type of the area is predominantly red nitosol, which is characterized by an average organic matter content of 1.8%, total nitrogen 0.17%, pH 5.24, and available phosphorus 4.55ppm (Gemechu, 2007). The monthly total precipitation and mean maximum and minimum air temperatures during the experimental periods of the study site are indicated in Table 1.

Table 1: Weather of the study site during the experimental periods (2013-2017)

	Monthly total precipitation (mm)												
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2013	0.0	0.0	23.0	133.2	43.8	120.7	81.8	201.9	110.1	19.1	0.0	0.0	733.6
2014	20.7	21.0	31.1	36.1	94.3	68.4	137.3	222.4	70.3	9.8	2.6	2.6	716.6
2015	0.0	25.3	1.0	31.3	86.6	87.6	287.2	157.8	195.7	53.6	64.4	3.5	994.0
2016	0.0	14.0	73.6	36.4	73.5	253.3	159.3	249.5	88.5	18.8	0.0	0.0	966.9
2017	17.5	11.3	48.1	84.2	13.6	117.1	194.0	237.2	107.4	10.0	0.0	8.4	848.8
30-yr	17.0	35.1	53.7	73.2	63.9	116.0	242.3	246.4	132.1	18.9	7.6	5.5	1011.9
Year	Monthly mean maximum air temperature (^{0}C)												Mean
2013	27.1	28.4	28.8	26.4	25.9	25.7	19.8	22.9	21.6	25.2	23.9	19.3	24.6
2014	19.6	19.3	21.2	24.4	25.3	24.9	21.4	20.9	21.4	19.9	18.9	23.1	21.7
2015	21.0	22.4	25.0	25.0	25.0	25.0	24.0	24.3	20.1	24.3	23.6	22.8	23.5
2016	22.4	25.6	23.9	24.3	23.9	21.6	21.6	20.9	21.6	23.4	25.6	25.9	23.4
2017	23.5	23.5	24.0	23.0	24.0	21.2	19.0	19.1	19.6	23.4	23.2	23.5	22.2
30-yr	23.5	24.2	24.7	23.6	24.6	22.5	20.3	19.7	20.6	22.1	22.7	23.3	22.6
Year	Monthly mean minimum air temperature (^{0}C)												Mean
2013	-0.6	1.9	2.4	5.7	8.9	10.7	10.5	9.8	8.5	6.8	6.4	4.1	6.3
2014	5.1	8.7	6.7	6.3	7.0	7.2	9.0	8.4	10.3	6.5	4.3	2.8	6.8
2015	0.9	0.6	3.8	8.3	8.9	8.5	9.4	8.8	7.0	1.0	3.1	0.3	5.1
2016	5.3	8.8	8.9	10.5	10.8	9.8	10.5	10.3	8.0	3.6	2.3	0.4	7.4
2017	7.8	5.0	7.6	10.1	10.0	8.7	9.6	10.2	9.0	8.3	3.1	0.9	7.5
30-yr	3.6	5.2	6.9	8.5	9.6	7.9	9.2	9.0	7.5	4.6	2.3	2.1	6.4

30-yr = a 3o years average that was calculated from 1983 to 2012

2.2. Experimental treatments and study design

Four varieties of desho grass, viz. Areka (DZF # 590), Kulumsa (DZF # 592), Kindu Kosha-1 (DZF # 591), and Kindu Kosha-2 (DZF # 589) were used as a treatment. The varieties were initially collected from altitudes of high, medium, and low areas of Ethiopia. Accordingly, the variety Kulumsa (DZF # 592) was collected from a higher elevation of Kulumsa site (8°01'007"N; 03°09'350"E; 2200 meter above sea level); Areka variety (DZF # 590) from a medium elevation of Areka site (07°06'426"N; 037°41'703"E; and 1717 meter above sea level); Kindu Kosha-1 variety (DZF # 591) from lower elevation of Kindu Kosha site one (06°54'260"N; 037°35'557"E ; and 1631 meter above sea level); and Kindu Kosha-2 variety (DZF # 589) also from lower elevation of Kindu Kosha site two (06°54'418"N; 037°35'054"E; 1524 meter above sea level) as reported by Solomon *et al.* (2019). The experiment was aimed at comparing the performance of desho grass varieties over years. This experiment was conducted during the main cropping seasons of 2013 - 2017 under rain fed conditions. It was conducted in randomized complete block design with three replications. The plot size was 3 by 2 m, and the spacing between rows and plants was 30 and 20 cm, respectively. A spacing of 1.5 m and 1.0 m was also used between blocks and plots, respectively.

2.3. Management of experimental plots

The land was plowed in April and harrowed in early June for the experiment. The prepared experimental land was divided into three blocks and desho grass was planted vegetatively using root splits on a well-prepared seedbed. The recommended fertilizer rate of 18 kg N ha^{-1} + 20 kg P ha^{-1} in the form of diammonium phosphate (DAP) was uniformly applied at the sowing. Plots were hand-weeded twice per year to reduce the effect of weeds on crop performance. Moreover, appropriate agronomic management was uniformly applied for all varieties to improve the yield per unit area. Accordingly, one-third of 50 kg N ha^{-1} in the form of urea was applied during the short rainy season and the remaining two-thirds were applied at the active vegetative growth stage every year. The first-hand weeding was done 30 days after full crop emergence and the second-hand weeding was performed 30 days after the first weeding. Single harvest was made for the first year of production while double cuts were made for subsequent production years. The first cut was made in early August while the second cut was done in early November prior to the onset of frost in the study area.

2.4. Data collection and measurements

Sampling for the determination of morphological characteristics and yields were made from the interior rows. Plant height was measured using steel tape from the ground level to the tip of a plant at the forage harvesting stage. Five randomly selected plants were used to determine the plant height of each treatment. The plants were clipped 5 cm above the ground at the forage harvesting stage to determine the yield and nutritional quality of desho grass varieties. The weight of the total fresh biomass yield was recorded from each plot in the field and the estimated 500 g sample was taken from each plot to the laboratory. The sample taken from each plot was weighed to know the total sample fresh weight using sensitive table balance and oven-dried for 24 hours at a temperature of 105^{o}C for herbage dry matter yield determination. The second estimated 500 g sample taken from each plot was weighed to know the total sample fresh weight using sensitive table balance and manually fractionated into leaf and stem. The morphological parts were separately weighed to know their sample fresh weight, and then oven-dried for 24 hours at a temperature of 105^{o}C and separately weighed to estimate the dry proportions of these morphological parts. The proportion of each morphological part in percent was then computed as the ratio of each dry biomass proportion to total dry biomass multiplied by 100. The dried leaf and stem proportion were also used to estimate the leaf to stem ratio. The leaf and stem dry matter yields were estimated by multiplying the dried proportion of the respective morphological part by the total dry matter yield and then dividing by 100. Moreover, the crude protein yield was determined by multiplying the total dry matter yield with the crude protein and then divided by 100. Five plants were randomly taken at the forage harvesting stage to determine the number of nodes and internode length per plant.

2.5. Chemical analysis

The harvested forage samples were oven-dried at a temperature of 65^{o}C for 72 hours to determine the chemical composition and *in-vitro* dry matter digestibility. The dried samples were then ground to pass a 1 mm sieve for laboratory analysis. The total ash content was determined by oven drying the samples at 105^{0}C overnight and by combusting the samples in a muffle furnace at 550^{o}C for 6 hours (AOAC, 1990). The nitrogen (N) content was determined following the micro-Kjeldahl digestion, distillation, and titration procedures (AOAC, 1995), and the crude protein (CP) content was estimated by multiplying the N content by 6.25. The NDF, ADF, and ADL contents were determined according to Van Soest and Robertson's procedure (1985). The two-stage *in-vitro* fermentation technique of Tilley and Terry as modified by Van Soest and Robertson procedure (1985) was used to determine *in-vitro* dry matter digestibility (IVDMD).

2.6. Statistical analysis

The collected data were subjected to the analysis of variance procedures of the SAS general linear model statistical software package (SAS, 2002). Only traits that show a significant difference in analysis of variance (ANOVA) were promoted to mean comparisons using the least significance difference (LSD) at a 5% probability level.

The data were analyzed using the following model:

$$Yijk = \mu + Vi + Yj + (VY)ij + (B)k + eijk \quad [1]$$

Where,

- Y_{ijk} is the dependent variable
- µ is overall mean
- V_i is the effect of variety i
- Y_j is the effect of year j
- $(VY)_{ij}$ is the interaction effect of variety i and year j
- B_k is the effect of the block k
- e_{ijk} is a random error

3. Results and Discussion

3.1. Plant height and morphological characteristics of desho grass

The plant height of desho grass varieties at forage harvesting did not vary significantly (P>0.05) at each production year and combined over years (Table 2). However, the plant height of desho grass varieties was significantly (P<0.05) affected by the production years. Accordingly, the highest plant height was recorded in 2014 followed by 2017 and 2015 while the lowest was obtained in the 2013 production year. The shortest plant height for perennial forage crops like desho grass in the first production year is expected in the cooler tropical highlands. Because the first year is the establishment year for perennial forage crops in the cooler highland areas and they express their genetic potential afterward.

The variation in plant height among the production years might be due to differences in precipitation, minimum and maximum temperatures, and the differential response of the varieties for the variable weather conditions that existed during experimental periods. The variation in plant height of desho grass varieties reported by different studies is also non-significant (Tekalegn *et al*., 2017; Denbela and Demerew, 2021). However, significant variation in plant height of desho grass varieties was also reported (Birmaduma *et al*., 2019; Solomon *et al*., 2019; Denbela *et al*., 2020). The mean plant height recorded in the current study was comparable with the mean value reported in the highland but relatively lower than the mean value reported in midland areas of the Guji zone, southern Oromia, Ethiopia (Teshale *et al*., 2021). The plant height values reported recently (Mulisa *et al*., 2021; Mulisa *et al*., 2022) from the same site were slightly lower than the value reported in the current study might be due to variation in varieties and weather conditions of experimental periods.

The number of nodes per plant, internode length, and leaf to stem ratio of desho grass varieties at forage harvesting are indicated in Table 3. The results indicated that the number of nodes per plant and leaf to stem ratio varied significantly (P<0.05) among desho grass varieties while non-significant (P>0.05) variation was observed for internode length. The highest number of nodes per plant was recorded for Kindu Kosha-2 (DZF # 589) followed by Kindu Kosha-1 (DZF # 591) while Kulumsa (DZF # 592) variety produced the lowest. However, Kulumsa (DZF # 592) variety produced the highest leaf to stem ratio followed by Areka (DZF # 590) and Kindu Kosha-1 (DZF # 591) while the lowest was recorded from Kindu Kosha-2 (DZF # 589).

The mean leaf to stem ratio of desho grass varieties in the present study was higher than the values reported by other scholars for the same varieties (Tekalegn *et al*., 2017; Birmaduma *et al*., 2019; Denbela *et al*., 2020; Teshale *et al*., 2021) this could be due to variation in soil, weather and management conditions. The leaf to stem ratio is one of the indicators of nutritional quality and it is highly affected by the stage of harvesting. It is positively correlated with the nutritive value and a higher value has better nutritive value and vice versa. The leaf to stem ratio in tropical forage grasses plays a significant role in ruminant diet selection, forage value determination, and intake by ruminants. The proportion of stem in grass plants increases as they mature or progress from the vegetative to the reproductive stage (Mitchell *et al*., 1997). Relative proportions of the different morphological components (leaves and stems) have an essential role in controlling the chemical composition of tropical forage grasses.

Table 2: Average plant height (cm) of desho grass varieties grown at Holetta over years

Variety	2013	2014	2015	2016	2017	Mean
Areka (DZF # 590)	34.5	139.9	110.0	93.3	125.0	100.5
Kulumsa (DZF # 592)	36.1	140.6	98.9	90.0	119.7	97.1
Kindu Kosha-1 (DZF # 591)	37.8	127.3	98.9	95.0	113.1	94.4
Kindu Kosha-2 (DZF # 589)	44.5	126.1	119.5	97.8	122.8	102.1
Mean	38.2[e]	133.5[a]	106.8[c]	94.0[d]	120.1[b]	98.5
LSD (0.05)	12.767	16.702	36.813	13.059	21.056	7.7307
P-value	0.3273	0.1433	0.5059	0.5628	0.5739	0.1943

Means with different superscript letter/s for varieties within column and for experimental years within row varied significantly at p<0.05

Table 3: Average growth parameters and leaf to stem ratio of desho grass varieties grown at Holetta in 2016

Variety	Number of nodes per plant (cm)	Internode length per plant (cm)	Leaf to stem ratio (%)
Areka (DZF # 590)	4.8[b]	6.5	1.7[a]
Kulumsa (DZF # 592)	4.6[b]	5.5	1.9[a]
Kindu Kosha-1 (DZF # 591)	5.1[b]	6.1	1.5[ab]
Kindu Kosha-2 (DZF # 589)	7.9[a]	5.8	1.2[b]
Mean	5.6	6.0	1.6
LSD (0.05)	2.202	1.8626	0.4984
P-value	0.0296	0.6163	0.0500

Means with different superscript letter/s for varieties within the column varied significantly at p<0.05

3.2. Yields of botanical fractions

The leaf dry matter yield of desho grass varieties grown at Holetta over years is indicated in Table 4. The results showed that the leaf dry matter yield of desho grass varieties varied significantly (P<0.05) in the 2014 production year and in the combined over years analysis. In the combined analysis, the highest mean leaf dry matter yield was recorded from Kulumsa (DZF # 592) variety followed by Areka (DZF # 590) while Kindu Kosha-1 (DZF # 591) produced the lowest leaf dry matter yield.

The leaf dry matter yield of desho grass varieties was significantly (P<0.05) affected by the production years. The results showed that the establishment year produced the lowest leaf dry matter yield while the yield increased at a decreasing rate until 2016 and the yield decreased in the 2017 cropping season. The maximum leaf dry matter yield was obtained in the 2016 cropping season. The leaf dry matter yield obtained in the 2016 cropping season had 16.3 and 2.4% advantages over the 2014 and 2015 production years, respectively. Similarly, the leaf dry matter yield in the 2015 and 2017 production years had 13.6 and 7.5% advantages over the 2014 production year, respectively. The results confirm that biomass allocation to different morphological components of plants is not fixed and may vary among forage species (Müller *et al*., 2000; Poorter *et al*., 2012). Higher mean voluntary intake of leaf than of stem biomass has been demonstrated in tropical forage grass due to its shorter retention time of dry matter in the rumen (Mero and Udén, 1998). Tropical grass forage species with high leafy biomass are more nutritious and will be consumed and digested more readily than those with a higher stem biomass proportion.

The stem dry matter yield of desho grass varieties did not vary significantly (P>0.05) at each production year but the variation was significant (P<0.05) for the combined over years analysis (Table 5). The results revealed that Kindu Kosha-2 (DZF # 589) variety produced the highest stem dry matter yield over years followed by Areka (DZF # 590) while Kulumsa (DZF # 592) and Kindu Kosha-1 (DZF # 591) gave the same lowest stem dry matter yield. Moreover, the stem dry matter yield of desho grass varieties was significantly (P<0.05) affected by the production years.

The results showed that the establishment year produced the lowest stem dry matter yield while the yield increased at a decreasing rate until 2016 and the yield decreased in the 2017 cropping season. The maximum stem dry matter yield was obtained in the 2016 cropping season and the stem dry matter yield obtained in the 2016 cropping season had 23.7 and 6.2% advantages over the 2014 and 2015 production years, respectively. Similarly, the stem dry matter yield in the 2015 and 2017 production years had 16.5 and 9.3% advantages over the 2014 production year, respectively. The leaf dry matter yield of 44.4, 51.5, 47.8, 42.5, and 49.1% advantages were recorded over stem dry matter yield from the establishment year to outwards, respectively. The leaf dry matter yield in the combined analysis also had a 47.7% advantage over stem dry matter yield. Generally, desho grass varieties had a higher leaf dry matter yield than stem dry matter yield. According to Beaty and Engel (1980), cultivars high in leaf content were much higher in quality than cultivars that produced more stems. As reported for most grasses, both tropical and temperate, leaves contain noticeably higher concentrations of crude protein than stems (Tadesse *et al*., 2004). Leafy biomass is usually retained in the rumen for a shorter period than stems because of faster rates of NDF digestion and higher rates of passage (Delagarde *et al*., 2000).

Table 4: Average leaf dry matter yield (t ha^{-1}) of desho grass varieties grown at Holetta over years

Variety	2013	2014	2015	2016	2017	Mean
Areka (DZF # 590)	2.0	17.9^{a}	18.0	19.3	17.1	14.9^{a}
Kulumsa (DZF # 592)	1.5	17.8^{a}	19.8	18.0	18.2	15.1^{a}
Kindu Kosha-1 (DZF # 591)	0.7	11.5^{b}	14.4	12.9	14.4	10.8^{b}
Kindu Kosha-2 (DZF # 589)	1.1	11.4^{b}	14.6	18.2	13.5	11.7^{b}
Mean	1.3^{c}	14.7^{b}	16.7^{ab}	17.1^{a}	15.8^{ab}	13.1
LSD (0.05)	1.1725	3.7039	6.2918	10.211	4.5614	2.1512
P-value	0.1252	0.0062	0.1960	0.4826	0.1280	0.0001

Means with different superscript letter/s for varieties within column and for experimental years within row varied significantly at p<0.05

Table 5: Average stem dry matter yield (t ha-1) of desho grass varieties grown at Holetta over years

Variety	2013	2014	2015	2016	2017	Mean
Areka (DZF # 590)	1.2	10.7	108	12.0	10.2	9.0^{ab}
Kulumsa (DZF # 592)	0.8	9.5	10.4	9.6	9.7	8.0^{b}
Kindu Kosha-1 (DZF # 591)	0.5	8.3	10.7	10.1	10.3	8.0^{b}
Kindu Kosha-2 (DZF # 589)	0.9	10.2	13.1	16.3	12.1	10.5^{a}
Mean	0.9^{c}	9.7^{b}	11.3^{ab}	12.0^{a}	10.6^{ab}	8.9
LSD (0.05)	0.5224	2.3657	5.9681	10.383	4.2462	1.89
P-value	0.0860	0.1883	0.6969	0.4498	0.5756	0.0335

Means with different superscript letter/s for varieties within column and for experimental years within row varied significantly at p<0.05

3.3. Total dry matter and crude protein yields

The total dry matter yield accumulation of desho grass varieties was not found significant (P>0.05) except in the 2014 cropping season and in the combined over years analysis. In the second year of production and combined over years analysis, Areka (DZF # 590) variety accumulated the highest dry matter yield followed by Kulumsa (DZF # 592) and Kindu Kosha-2 (DZF # 589) while Kindu Kosha-1 (DZF # 591) accumulated the least dry matter yield.

The variation of dry matter yield was significant (P<0.05) for production years. The first year produced the lowest dry matter yield while the accumulation of dry matter yield increased with increasing production years but the yield declined in the last production year. The recent studies also indicated that the dry matter yield of desho grass increased with increasing production years but the yield declined after the third year of production (Mulisa *et al*., 2021; Mulisa *et al*., 2022). The dry matter yield accumulated in the 2016 cropping season had 19.8 and 4.3% advantages over the 2014 and 2015 production years, respectively. Similarly, the dry matter yield accumulated in the 2015 and 2017 production years had 14.8 and 8.6% advantages over the 2014 production year, respectively.

The mean dry matter yield accumulated in desho grass varieties in this study was lower (Tekalegn *et al*., 2017; Birmaduma *et al*., 2019; Teshale *et al*., 2021) and higher (Worku *et al*., 2017; Solomon *et al*., 2019; Denbela *et al*., 2020; Mulisa *et al*., 2022) than the values reported by different scholars. The variation could be due to differences in soil fertility, weather condition, and management conditions. The comparable dry matter yield accumulated at each production year could be attributed to the existence of comparable agro-morphological characteristics among desho grass varieties in terms of plant height, tillering performance, and morphological components. However, the variations in dry matter yield accumulation during the production years might be due to variation in amount and distribution of precipitation, temperature, and the inherent genetic characteristics of perennial forage crops to express their maximum genetic potential either in the third, fourth, or fifth year of production depending on the species and varieties. Moreover, varieties of desho grass might be exploited the growth resources more efficiently from the soil in the later production years due to the established root systems and better utilization efficiency of photosynthetic active radiation due to its better canopy cover with advancing production years. The photosynthetic active radiation intercepted by a crop canopy is one of the main factors determining biomass production, being the source of energy for the process of photosynthesis (Monteith, 1969).

Table 6: Average dry matter yield (t/ha) of desho grass varieties grown at Holetta over years

Variety	2013	2014	2015	2016	2017	Mean
Areka (DZF # 590)	3.2	28.6^{a}	28.8	31.3	27.3	23.8^{a}
Kulumsa (DZF # 592)	2.3	27.3^{a}	30.2	27.6	27.9	23.1^{a}
Kindu Kosha-1 (DZF # 591)	2.0	19.9^{b}	25.1	23.1	24.7	18.8^{b}
Kindu Kosha-2 (DZF # 589)	1.2	21.6^{b}	27.6	34.4	25.6	22.2^{ab}
Mean	2.2^{c}	24.3^{b}	27.9^{ab}	29.1^{a}	26.4^{ab}	22.0
LSD	1.6695	4.0093	11.055	20.368	7.1204	3.762
P-value	0.1182	0.0044	0.7201	0.5888	0.6898	0.0483

Means with different superscript letter/s for varieties within column and for experimental years within row varied significantly at p<0.05

The dry matter yield and crude protein yield accumulated among desho grass varieties in the fourth year of production are indicated in Figure 1. The result showed that the variation for crude protein yield was non-significant (P>0.05) among desho grass varieties. The crude protein yield generally depends on the dry matter accumulation and crude protein concentration performances of the crop. Accordingly, Areka (DZF # 590) variety which accumulated better dry matter yield and crude protein concentration produced better crude protein yield while Kindu Kosha-1 (DZF # 591) which accumulated the lowest dry matter yield produced the least crude protein yield. The crude protein yield of desho grass varieties ranged from 2.8 to 4.0 t/ha with a mean of 3.4 t/ha. The mean crude protein yield of desho grass varieties reported in the current study is higher than the values reported recently from the same site (Mulisa *et al*., 2021; Mulisa *et al*., 2022) might be due to differences in varieties, soil fertility, weather condition, and management conditions.

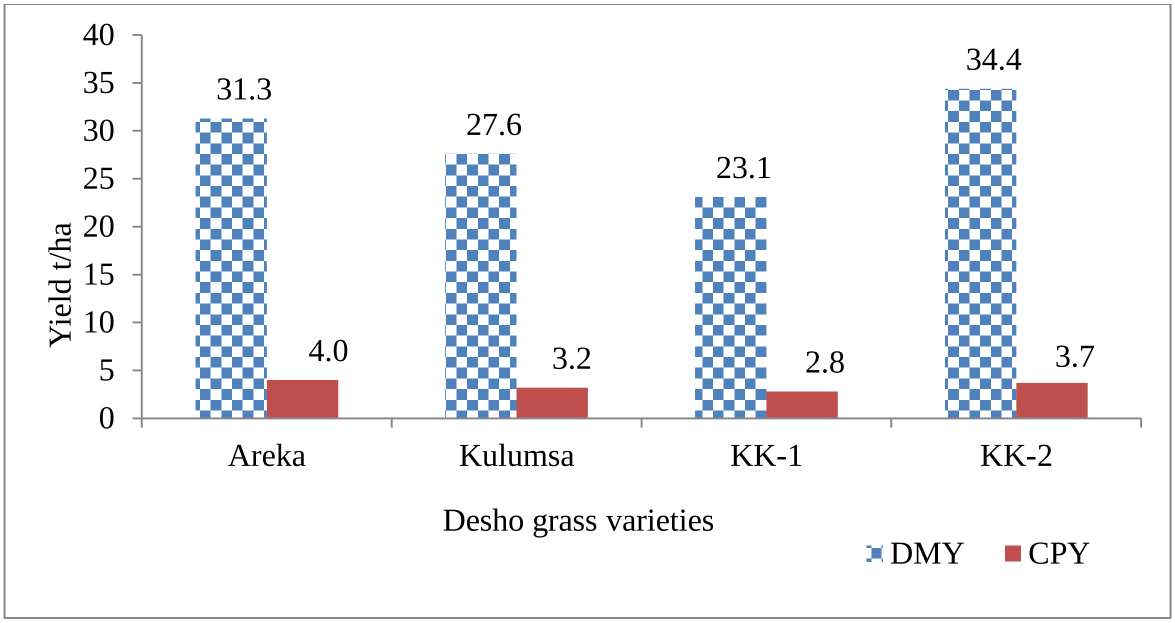

Figure 1: Effect of desho grass variety on dry matter and crude protein yields during the fourth year (2016) of production
DMY = dry matter yield; CPY = crude protein yield

3.4. Nutritive value of desho grass

The nutritive value of desho grass varieties was not significantly (P>0.05) different in the 2016 production year (Table 7). The result showed that the ash content of the varieties ranged from 14.9 to 16.4 with a mean of 15.7% at the forage harvesting stage. Ash is the total mineral (non-organic) content of the forage. The study also indicated that the ash content of desho grass varieties was non-significant (P>0.05) and the reported mean value was slightly higher at midland and lower at the highland of areas of Guji Zone, Ethiopia (Teshale *et al.*, 2021) than the value reported in this study indicating altitudinal variation had a significant effect on ash content of the forage. The total ash content in harvested forages can have a significant role in animal performance. Much of the ash content of forage is made up of minerals, such as phosphorus, potassium, calcium, magnesium, and others and these minerals are essential for both plants and livestock.

The total ash content of forage can be affected by varieties, soil conditions, weather conditions, and management practices. Moreover, the genetic capacity of the plant to uptake minerals from the soil and the mineral requirement of the plant for growth significantly affect the total concentration of ash in forage. The forage harvested at the early growth stage has a better ash concentration compared to the late-harvested forage. The mineral concentration of desho grass varied with location and harvesting stage (Bimrew *et al.*, 2018a). The ash concentration of different grasses declined significantly with advancing age (Zinash *et al.*, 1995; Adane and Berhan, 2005; Taye *et al.*, 2007) and varies with morphological components (Fekede *et al.*, 2007). Hence, producers should pay attention to ash because it lowers forage intake, reduces digestibility, negatively affects fermentation, and dilutes forage nutritive value. Poor-quality forage will simply take up space in a cow's stomach, not delivering nutritional value and declining milk production. Generally, a mineral concentration decreases as plants mature and is greater in forages grown in soils that contain high concentrations of available minerals.

The crude protein (CP) content of desho grass varieties was found non-significant (P>0.05) in the 2016 production year as shown in Table 7. The CP content of desho grass varieties ranged from 10.7 to 12.5 with the man of 11.7% at forage harvest. The CP content of forage crops is significantly affected by varieties, species, forage type, the proportion of morphological parts, stage of harvest, soil factors, weather conditions, management conditions, and their interaction effect. As forages mature, their crude protein is diluted with increasing fiber content. The varieties had better CP content than most tropical forage grasses; this might be due to a higher proportion of leaf than stem at forage harvest.

Leafiness is a good indicator to determine the quality of feed. Leafy forage crops have better nutritional quality than high stem-producing forage crops. Leaves are more digestible, richer in crude protein, and poorer in cell-wall constituents than stems; thus an increasing or decreasing forage value depends on the proportion of these plant parts (Delagarde *et al*., 2000). The CP content in the current study is higher (Genet *et al*., 2017; Bimrew *et al*., 2018b; Solomon *et al*., 2019; Denbela and Demerew, 2021; Mulisa *et al*., 2022) and lower (Denbela *et al*., 2020; Teshale *et al*., 2021) than the values reported indicating the CP content influenced by variation in altitude, soil conditions, weather conditions, and management conditions. Plants grown at high temperatures generally produce lower quality forage than plants grown under cooler temperatures. Hence, forage of any species tends to be lower in quality if produced in a warm region rather than a cool region. According to Teshale *et al*. (2021), desho grass varieties produced better CP at highland areas than midland areas.

The fibers (NDF, ADF, and ADL) and *in-vitro* dry matter digestibility (IVDMD) contents of desho grass varieties were not found significant (P>0.05) at forage harvest (Table 7). The mean neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL), and IVDMD contents of desho grass varieties were 69.4, 37.6, 4.4, and 60.7% at forage harvest, respectively. The quality of feed mainly depends on NDF, ADF, and ADL concentration, and feeds with a lower concentration of these fibers are more nutritious than feeds with high fiber concentration. The values recorded from this study for NDF were laid in the previously reported values which ranged from 65.8 to 72.6% at Guji highland area (Teshale *et al*., 2021) and from 60.9 to 69.2% (Denbela and Demerew, 2021) but it was lower than the values reported (Bimrew *et al*., 2017; Genet *et al*., 2017) and slightly higher than the values reported by other scholars (Solomon *et al*., 2019; Denbela *et al*., 2020).

The NDF content of feed has a detrimental effect on forage intake while the digestibility of the feed is affected by the ADF content of forage crops (Van Soest, 1994). The ADF and ADL contents of desho grass varieties in the current study were slightly lower than the values reported previously (Bimrew *et al*., 2017; Bimrew *et al*., 2018b; Mulisa *et al*., 2022). As the ADL content in a feed increases, the digestibility of its cellulose decreases, thereby lowering the amount of energy potentially available to the animal. Therefore, ADL causes the forage to be much less digestible and less capable of providing the energy needs of the animal.

The IVDMD values reported previously were lower than the value reported in this study (Bimrew *et al*., 2017; Solomon *et al*., 2019; Mulisa *et al*., 2021; Mulisa *et al*., 2022). Young and leafy forage has a higher level of digestible nutrients and protein, which declines as the plants' progress toward maturity. Matured forage has fewer leaves, and more stems resulting in higher NDF content. Delaying a harvest beyond the recommended maturity stage will result in forage that is less digestible and much less capable of being consumed at a high rate of intake.

Table 7: Effect of variety on the nutritive value of desho grass grown at Holetta in 2016 production year

Variety	Ash	CP	NDF	ADF	ADL	IVDMD
Areka (DZF # 590)	16.0	12.5	69.7	38.4	4.5	58.0
Kulumsa (DZF # 592)	16.4	11.6	68.8	37.0	4.3	61.5
Kindu Kosha-1 (DZF # 591)	15.6	12.2	69.5	37.1	4.3	62.4
Kindu Kosha-2 (DZF # 589)	14.9	10.7	69.4	38.0	4.5	60.9
Mean	15.7	11.7	69.4	37.6	4.4	60.7
LSD	1.2555	1.8965	2.4219	2.6187	0.3837	6.2077
P-value	0.1128	0.2021	0.8247	0.5349	0.2742	0.4093

CP = crude protein; NDF = neutral detergent fiber; ADF = acid detergent fiber; ADL = acid detergent lignin; IVDMD = *in-vitro* dry matter digestibility

4. Conclusion and Recommendation

The performance of desho grass varieties at each production year was comparable for most traits in the study area. However, the performance varied remarkably among the production years; this might be due to the increasing trend of perennial forage crops to accumulate more yields for three to five consecutive years. The varieties produced the lowest dry matter yield during the first year of production but the accumulation of dry matter yield increased for three subsequent years but declined afterward. The varieties accumulated maximum dry matter yield in the fourth year of production in the study area. The varieties have higher leaf than stem proportion which resulted in better contents of ash, crude protein, and digestibility and lower fiber contents of the crop. Therefore, the cultivation and proper utilization of the four desho grass varieties in the study area is vital to reduce the feed shortage problem in the crop-livestock mixed production system. However, further study should be conducted over locations and years to select and recommend the best variety for the study area and similar agro-ecologies.

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Declaration of interest's statement

The authors declare no competing interests.

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