Heliyon 10 (2024) e28757

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Forage yield and nutritive value of Desho grass (*Pennisetum glaucifolium* Trin.) as affected by cutting heights in the central highlands of Ethiopia

Gezahegn Mengistu [a,*], Mulisa Faji [a], Kedir Mohammed [a], Mezgeb Workiye [b], Gezahagn Kebede [a], Gebremariyam Terefe [a], Mesfin Dejene [a], Fekede Feyissa [c]

[a] *Holetta Agricultural Research Center, P.O. Box31, Holetta, Ethiopia*
[b] *Kulumsa Agricultural Research Center, P.O. Box 489, Kulumsa, Ethiopia*
[c] *Ethiopian Institute of Agricultural Research Institute, P.O. Box 2003, Addis Abeba, Ethiopia*

A R T I C L E I N F O

Keywords:
Chemical composition
Desho grass
Dry matter yield
Locations
Year

A B S T R A C T

Desho grass (Pennisetum glaucifolium Trin) an important fodder grass. However, information on its production is lacking. This study was carried out to evaluate the forage dry matter yield and nutritive value of Desho grass harvested at different cutting heights (CH), under rain-fed conditions in two different sites in central highlands of Ethiopia for two years. The treatments (T1-T8) were: 50, 60, 70, 80, 90, 100, 110, and 120 cm cutting heights, distributed in a randomized complete block design with three replications. The root splits of the grass were planted in a 3 m × 4 m (12 m^2) plot size with 0.5 m × 0.25 m inter and intra-row spacing. In the two locations, over the years, significant differences were observed among cutting heights. The interaction of cutting heights by locations, and location by years were also significant. The interaction among cutting height, location, and year was insignificant. The highest (number of leaves per plant) NLPP was attained as the plant height advance, while the number of tillers per plant (NTPP) showed non-significant differene in different treatments. The dry matter yield (DMY) increased linearly with an increase in CH (ranging from 12.2 to 20.1 t ha^{-1} at Holetta, and 4.2 to 11.4 t ha^{-1}at Kulumsa). The grass's ash and crude protein (CP) contents decreased as the cutting height increased. An increase in CH increased the fiber content Neutral detergent fiber (NDF), acid detergent fiber (ADF), and Acid detergent lignin (ADL), resulting decrease in in-vitro dry matter digestibility (IVDMD). We recommend that desho grass be managed at 80–90 cm height resulting in optimum dry matter yield and nutritive value for use in smallholder farmers and market-oriented livestock producers of the central highlands of Ethiopia and major growing areas.

1. Introduction

Livestock production is one of the most prominent agricultural systems in the world [1]. However, the livestock sector in Sub-Saharan Africa (SSA) in a large context, and Ethiopia in particular has been challenged by various constraints. The limited feed supply both in amount and quality is the most challenging constraint [2–4]. (;.In the livestock industry, feed is the major input cost,

* Corresponding author.
E-mail address: gezemen19@gmail.com (G. Mengistu).

https://doi.org/10.1016/j.heliyon.2024.e28757
Received 31 July 2023; Received in revised form 11 March 2024; Accepted 24 March 2024
Available online 28 March 2024

accounting for 65–75% of the total cost of livestock operation [5,6]. The feed constraints are aggravated by multiple causes such as; recurrent drought and long dry season, the decline of pasture land due to inappropriate grazing management, conversion to crop production, soil degradation, feeding practices mainly relying on crop residues, and lack of improved forage seeds [4,6,7]. (. Consequently, the animal depends on poor-quality feed resulting in low voluntary intake, low productivity, and loss of body weight [8].

Livestock productivity in the country increased through improved livestock feed and feeding practices. Moreover, utilizing a locally available forage crops, adaptable to the existing agro-environmental conditions, (biotic and abiotic environmental stresses), and familiar to livestock producers is very important to cope with the feed challenge, and to sustain livestock production in the country [1, 9]. Indeed, Desho (*Pennisetum glaucifolium* Trin.) is the most productive perennial grass found in tropical countries and belongs to the *Panicae* tribe [9]). In Ethiopia, the grass is highly cultivated and well known for animal feed and soil water conservation practices particularly the in central and southern highlands part of the country [9–11]. The grass performs well at an altitude between 1500 and 2800 m above sea level and it is grown in woodland plains and in the humid tropical highland [12]. Desho grass is established in vegetative form with root splits and/or cuttings has good survival rates [9]. It has a massive root system that anchors to the soil and gives a large biomass yield. The grass has best-bet characteristics of; wider environmental adaptability, ease of establishment, high biomass production potential, tolerant to abiotic factors (tend to be drought tolerant, frost, and seasonal water logging), and able to grow fast and regrowth after cutting, and provides multi-cut harvesting in diversified climates and soil types of Ethiopia [13,14] Desho grass can be cut and fed to the animals in several approaches; chopped fresh, or without chopping, made into silage, and dried and baled into hay [9,15].

The productivity and quality of both annual and perennial grass species could be influenced by different factors. For instance; area of origin, climatic conditions (temperature, light intensity, total rainfall), and, soil type, fertilizer level, and stage of maturity [14,16]. The effect of agronomic, and management practices, such as plant spacing, type and level of fertilizer also can improve the productivity and nutritive value of Desho grass [15]. Different studies indicated that stage of harvesting influenced the yield and nutritional value of grass [17–19]. Cutting height at harvest will obviously affect both the quantity and quality of the stover removed from the field for livestock [19]. Although the grass has multi-advantages, there is, however, limited research study has been done on cutting height and its effect on herbage yield and nutritive value of desho grass, and, information in this regards is lacking for a diverse set of agro-ecological conditions in Ethiopia. Therefore, this study was planned to evaluate forage yield, and nutritive value of Desho grass with different harvesting heights, and to recommend the appropriate stage of harvesting that ensures the optimum dry matter yield and quality for livestock producers.

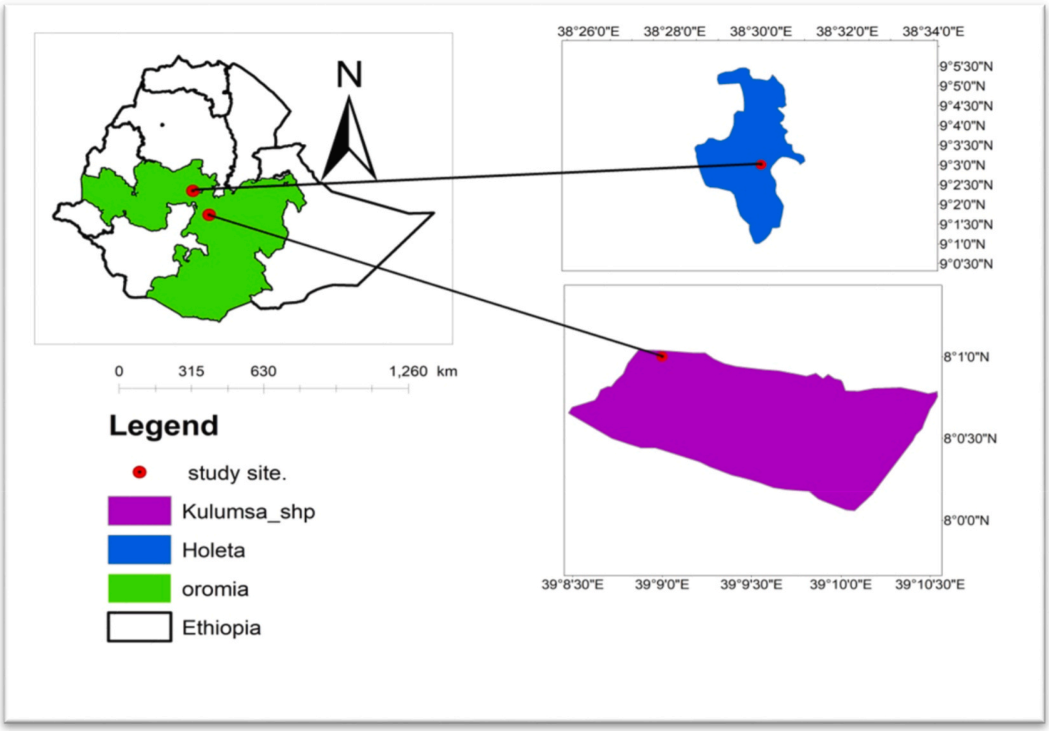

Fig. 1. Map of experimental areas.

2. Materials and methods

2.1. Experimental site, soils profile, and climate

The study was conducted at Holetta and Kulumsa Agricultural Research Centers (Fig. 1) in the central highlands of Ethiopia, for two years under rain-fed conditions. Holetta is located at 9° 3′ N latitude and 38° 30′ E longitude at an altitude of 2400 m. a.s.l. Kulumsa is located at 8° 01′ N latitude and 39° 09′ E longitude with an elevation of 2200 m. a.s.l. The farming system of the study areas is characterized by a mixed crop-livestock production system.

The physical and chemical properties of Holettas' soil are characterized predominately by red nitisol soil type and texturally clay dominated over sand and silt with a moderately acidic pH of 4.9. Soil analysis performed in 0.20 cm revealed low organic carbon content (1.8%), total nitrogen (0.18%), and available phosphorus 5.6 ppm, 5.03 mg kg^{-1} potassium, 29.5 mg kg^{-1} calcium, 13.7 mg kg^{-1} magnesium and 0.16 mg kg^{-1} Sodium. The soil type of Kulumsa is mainly sandy loam soil characterized as slightly acidic; and low in organic matter and total nitrogen contents (Table 1).

The climate of the areas during the experimental period at both locations are given in (Table 2). Holetta received a total annual rainfall of 1265.8 mm and 1289.6 mm during the 2020 and 2021 years, respectively. The mean monthly air temperature ranged from 13.2 °C to 17.1 °C with an average of 15.3 °C in the first year, and 13.3 °C–27.9 °C with an average of 16.3 °C in the second year. Whereas Kulumsa received 995.0 and 811.8 mm cumulative annual rainfall during the experimental periods. The mean monthly air temperature of Kulumsa ranged from 17.1 to 20.2 °C with an average air temperature of 18.3 °C in 2020, and 16.6–19.7 °C with an average air temperature of 17.9 °C in 2021.

2.2. Experimental treatments, design and planting

Desho grass cultivar namely 'Kulumsa DZF-592'was used as a test crop for this experiment. The treatments consisted of eight cutting heights (CH: 50 cm (T1), 60 cm (T2), 70 cm (T3), 80 cm (T4), 90 cm (T5),100 cm (T6),110 cm (T7), and 120 cm (T8). The experiment was laid out as randomized complete block design with three replications, in a total of twenty-four 3 × 4 m experimental units spaced 1 and 1.5 m apart between plots and blocks respectively followed by 0.5 m inter and 0.25 m intra-row spacing. The active root splits of the grass were planted in rows on a well-prepared and harrowed seedbed in the first week of July 2019 when soil moisture was adequate for establishing the grass. Phosphorus fertilizer was uniformly applied in the form of Diammonium phosphate (DAP, 18% N, 20% P, 1.5% S) at the rate of 100 kg ha^{-1} for all plots at the time of planting. While, after every harvest, 50 kg N ha^{-1} in the form of urea (46% N) was applied in split application with one-third during the short rainy season (May) and the remaining two-thirds at the beginning of the main rainy season (July–August). Agronomic management such as hand weeding and hoeing between rows was carried out uniformly for each plot.

2.3. Data collection

Data on agronomic characters such as: the number of leaves per plant (NLPP), and number of tillers per plant (NTPP) were counted from 6 randomly selected sample plants from each plot and their means were used for statistical analysis. Excluding the border rows, the grasses were harvested at about 5 cm above ground manually using a sickle to determine the biomass yield and nutritive value of desho grass. The total fresh biomass yield was taken from each plot to calculate the total dry matter in each year. A 500 g sample was taken immediately after harvest from each plot using a portable balance with an accuracy of 0.01 g for forage dry matter yield (DMY) determination. The representative samples from each plot and each site were dried in forced air oven-dried at 65 °C for 72 h for DM determination and quality analysis. The morphological parts (leaves and stems) were separately weighed to know their sample fresh weight, and then oven-dried for 65 °C for 72 h and separately weighed to estimate their dry proportions. The dried leaf and stem proportion were also used to estimate the leaf-to-stem ratio and determined as the ratio of the dry weight of stems in grams to the weight of leaves (g). The oven-dried samples taken from each plot were ground to pass through a 1 mm sieve pending chemical

Table 1
The soils profile of the experimental locations (the soil nutrient profile was the result of soil laboratory test).

Parameters	Holetta	Kulumsa
pH (1; 2.5H_2O)	4.94	6.1
Organic carbon (OC %)	1.90	0.18
Total nitrogen (TN %)	0.18	2.15
Available P (ppm)	5.60	7.20
K^+ (mg kg^{-1})	5.03	2.95
Ca^{2+}(mg kg^{-1})	29.50	19.80
Mg^{2+} (mg kg^{-1})	13.70	4.10
Na^+ (mg kg^{-1})	0.16	0.76
Soil texture (%)		
Clay	67	20
Sand	18	40
Silt	15	40

Table 2
Total monthly rainfall and mean air temperatures of the experimental locations.

Month	Rainfall (mm)				Temperature (^{o}C)			
	Holetta		Kulumsa		Holetta		Kulumsa	
	2020	2021	2020	2021	2020	2021	2020	2021
January	0.0	3.6	8.8	0.0	14.9	13.3	17.4	16.6
February	0.0	84.8	3.9	7.6	15.4	15.7	18.4	17.9
March	73.2	16.2	68.4	0.4	16.9	15.9	19.9	19.6
April	92.4	53.4	104.6	66.0	17.1	16.4	19.6	19.7
May	100.6	87.6	94.7	124.5	16.9	16.6	18.9	18.3
June	126.1	127.8	123.7	59.9	16.1	27.9	18.4	18.1
July	280.3	304.1	251.4	170.6	15.6	15.3	17.1	16.8
August	334.2	287.6	143.5	121.9	15.2	15.3	17.1	17.0
September	216.2	250.9	130.8	191.2	14.9	15.5	20.2	16.1
October	31.6	73.6	64.0	63.7	14.3	15.3	18.4	17.7
November	8.0	0.0	1.0	6.0	13.2	14.6	17.6	17.4
December	3.2	0.0	0.2	0.0	12.5	13.6	16.9	19.4
Total, mean	1265.8	1289.6	995.0	811.8	15.3	16.3	18.3	17.9

Source: Holetta and Kulumsa Agricultural Research Centers meteorological data report

analysis. Crude protein yield is calculated as the product dry matter yield with crude protein content divided by 100.

2.3.1. Chemical analysis and in-vitro-dry matter digestibility

The chemical composition of all samples of feed was conducted at Holetta Agricultural Research Center Animal Nutrition Laboratory. The ground samples were dried overnight at 60 °C in an oven-dry to constant moisture and 3 g from each sample was scanned by Near Infra-Red Spectroscopy (NIRS). The analyzed variables for nutritional quality were dry matter (DM), crude protein (CP), ash, neutral detergent fiber (NDF), acid detergent fiber (ADF), and acid detergent lignin (ADL) were made using a calibrated NIRS (Foss 5000 apparatus and Win ISI II software) and determined on DM basis. *In-vitro* dry matter digestibility (IVDMD) was determined using the two-stage *in-vitro* digestibility technique of [20].

2.4. Statistical analysis

The data were analyzed using the PROC MIXED procedures of SAS software [21]. We compared using the Duncan multiple range at 5% of the significant level. The general linear model used for data analysis was;

$$Y_{ijkl} = \mu + C_i + Y_j + L_k + B_l + (C_i{*}Y_{j)} + (C_i{*}L_k) + (L_{k*}\,Y_j) + (Ci{*}\,Y_j{*}\,L_{k)} + e_{ijkl};$$

WhereY_{ijkl} = Response variables; μ = the overall mean; C_i = effect due to cutting height (i = 1–8); Y_j = effect due to year (j = 2020 and 2021); L_k = effect due to location (k = Holetta and Kulumsa; B_l = effect due to block l; $(C{*}Y)_{ij}$ = effect due to interaction between ith cutting height and jth year; $(C{*}L)_{ik}$ = effect due to interaction between ith cutting height and kth location (k = Holetta and Kulumsa); $(L{*}Y)_{Kj}$ = effect due to interaction between kth location and jth year; $(C{*}\,Y{*}\,L)_{ijk}$ = effect due to interaction among ith cutting height, jth year and the kth location; e_{ijkl} = the random error.

Table 3
Mean square of analysis of variance (ANOVA) for Desho grass harvested in different plant heights during 2020 and 2021 years at Holetta and Kulumsa.

Source of variation	DF	Mean square of agronomic parameters				
		NLPP	NTPP	LSR	DMY	CPY
Treatment (Trt)	7	7.5**	596.2*	0.1^{ns}	70.7**	0.2**
Replication (Rep)	4	2.7**	384.9^{ns}	0.3^{ns}	11.1^{ns}	0.1^{ns}
Location (Loc)	1	5.4**	13468.7**	26.6**	1236.0**	29.4**
Year (yr)	1	9.6**	2532.7**	6.8**	168.4**	7.9**
Trt*Loc	7	1.4*	494.3*	0.1^{ns}	22.3*	0.3*
Trt*Yr	7	0.4^{ns}	726.0*	0.3^{ns}	11.2^{ns}	0.1^{ns}
Loc*Yr	1	21.4**	17369.3*	0.1^{ns}	143.6**	7.8**
Trt*Loc*Yr	7	1.1^{ns}	416.5^{ns}	0.2^{ns}	6.7^{ns}	0.0^{ns}
Residuals	60	0.6	212.3	0.2	8.6	0.1
Mean		7.0	92.2	1.5	11.7	1.1
CV (%)		11.5	15.8	32.9	25.0	30.5

DF = Degree of freedom; NLPP = number of leaves plant; NTPP= Number of tillers per plant; LSR = Leaf stem ratio; DMY = dry matter yield; CP = crude protein yield; CV (%) = coefficient of variation; * significant P = 0.05; ** significant P = 0.01; ** significant P = 0.001; ns = non-significant P > 0.05.

3. Results and discussion

3.1. Effect of cutting height, location, year and the interaction

The analysis of variance (ANOVA) for cutting height, location, year, and their interactions on agronomic character and dry matter yield of desho grass are illustrated in (Table 3). The number of leaves per plant (NLPP), number of tillers per plant (NTPP), dry matter yield (DMY) and crude protein yield (CPY) were significantly ($P < 0.05$) influenced by cutting height. While leaf-to-stem ratio (LSR) did not affected ($P > 0.05$) by cutting height. There was a significant ($P < 0.05$) interaction effect between cutting height and location for the agronomic traits. NLPP, NTPP, DMY and CPY were influenced ($P < 0.05$) by both cutting height and location. Only NTPP was significantly ($P < 0.05$) affected due to cutting height and year, whereas the rest of the measured agronomic character did not ($P > 0.05$) influenced by their interaction. Conversely, except leaf to stem ratio, the mean square for the interaction of location by year influenced the measured agronomic traits. There was no significant interaction effect among cutting height, location and year for the measured agronomic variables.

3.2. Effect of location on measured agronomic traits of desho grass

Location had a significant ($P < 0.001$) effect on the number of tillers per plant (NTPP), leaf-to-stem ratio (LSR), dry matter yield (DMY), and crude protein yield (CPY) in each production year (Table 4). The NLPP recorded at both locations statistically did not vary in the second year. The NLPP and LSR obtained at Kulumsa were significantly increased by 25.4% and 142.8% that of Holetta, respectively. Conversely, the NTPP, DMY, and CPY attained at Holetta significantly ($P < 0.001$) higher than that of Kulumsa in the 2020 year by 55.1, 58.8 and 103.8%, respectively. Except for LSR, the remaining agronomic traits obtained at Holetta were greater than Kulumsa in the second year. The combined effect of the two locations on the measured traits followed a similar trend as observed in the 2020 year.

The difference of the measured agronomic traits of desho grass across the testing sites might be due to the variability in temperature, rainfall and the physical-chemical propertie of the soil are the factors influencing the plant growth [22]. For instance, the greater DMY and CPY obtained at Holetta might be attributed to the greater amount of rainfall and this probably favored the grass to stimulate rapid vegetative development by increasing the amount of water accessible to the plants, mineral absorption, particularly calcium absorption increases [23]. Furthermore, the availability of minerals in the soil particularly K, Ca and Mg at Holetta probably increase the total biomass production. Geren [24] also confirmed that the variation in yield and quality of cereal forages depends on stage of growth, year, and planting location.

3.3. Effect of year on measured agronomic traits of desho grass

Table 5 indicated that the agronomic traits of desho grass significantly varied among the years within locations. Accordingly, all the measured traits achieved in the second year were consistently higher than in the establishment, year at Holetta. For instance at Holetta; NLPP, NTPP, LSR DMY and CPY obtained in the second year increased by 27.1, 17.3, 85.7, 40.2 and 100.0% respectively compared with the first year. However, only NLPP and LSR in the second year significantly increased than the first year at Kulumsa. As a result, at Kulumsa, NTPP and LSR obtained in the second year increased by 60.3 and, 17.6% compared with the first year. Similarly, the combined mean of the two years differed significantly. The accumulation of dry matter yield increased with increasing production years [25,26]. Pointed out that the dry matter yield of desho grass increased with increasing production years but the yield declined

Table 4
Mean of Agronomic traits of Desho grass harvested at different plant height over two years at Holetta and Kulumsa.

Years	Locations	Agronomic traits				
		NLPP	NTPP	LSR	DMY (t/ha)	CPY (t/ha)
2020	Holetta	5.9^b	95.7^a	0.7^b	12.7^a	1.1^a
	Kulumsa	7.4^a	61.7^b	1.7^a	8.0^b	0.5^b
	Mean	6.7	78.7	1.2	10.4	0.8
	CV (%)	12.6	20.9	38.9	18.5	18.3
	P-value	0.001	0.001	0.001	0.005	0.001
2021	Holetta	7.5	112.3^a	1.2^b	17.8^a	2.2^a
	Kulumsa	7.0	98.9^b	2.3^a	8.3^b	0.5^b
	Mean	7.3	105.6	1.8	13.1	1.4
	CV (%)	12.5	12.9	28.7	28.72	32.7
	P-value	0.081	0.001	0.001	0.007	0.001
Combined	Holetta	6.7^b	78.7^b	1.0^b	15.3^a	1.6^a
	Kulumsa	7.2^a	105.6^a	2.0^a	8.1^b	0.5^b
	Mean	7.0	92.2	1.5	11.7	1.1
	CV (%)	8.3	13.3	20.9	22.7	42.7
	P-value	0.001	0.001	0.001	0.001	0.001

Means within a column followed by different supper-script letters are significantly different ($P < 0.001$); NLPP = number of leaves plant; NTPP= Number of tillers per plant; LSR = Leaf stem ratio; DMY = dry matter yield; CPY = crude protein yield; CV (%) = coefficient of variation.

Table 5
Mean of Agronomic traits of Desho grass harvested at different cutting heights in two different locations during the study period.

Locations	Year	Agronomic traits				
		NLPP	NTPP	LSR	DMY (t/ha)	CPY (t/ha)
Holetta	2020	5.9^{b}	95.7^{b}	0.7^{b}	12.7^{b}	1.1^{b}
	2021	7.5^{a}	112.3^{a}	1.3^{a}	17.8^{a}	2.2^{a}
	Mean	6.7	104.0	1.0	15.3	1.7
	CV (%)	9.4	16.4	36.68	21.7	26.9
	P-value	0.001	0.002	0.001	0.001	0.001
Kulumsa	2020	7.4	61.7^{b}	1.7^{b}	8.0	0.52
	2021	7.0	98.9^{a}	2.0^{a}	8.1	0.52
	Mean	7.2	80.3	1.9	8.1	0.52
	CV (%)	13.1	14.1	29.6	30.4	30.1
	P-value	0.260	0.001	0.001	0.780	0.916
Combined	2020	6.6^{b}	87.0^{b}	1.2^{b}	10.4^{b}	0.8^{b}
	2021	7.3^{a}	97.3^{a}	1.8^{a}	13.0^{a}	1.4^{a}
	Mean	7.0	92.2	1.5	11.7	1.1
	CV (%)	11.5	16.1	33.6	25.2	42.1
	P-value	0.001	0.001	0.001	0.001	0.001

Means within a column followed by different supper-script letters are significantly different (P < 0.001); NLPP = number of leaves plant; NTPP= Number of tillers per plant; LSR = Leaf stem ratio; DMY = dry matter yield; CPY = crude protein yield; CV (%) = coefficient of variation.

after the third year of production.

An increase in the measured traits of desho grass in the second year might be due to the perennial nature of the grass which produces high vegetative growth in its root development system from which tillers emerge in the following growing season [27]. An increase or decrease of rainfall amount might have an increment of NLPP, NTPP, LSR, DMY and CPY in the second year both at Holetta and Kulumsa [28]. Who reported that a rise or decline in rainfall might have a negative or positive impact on plant growth and biomass production. Moreover, Nelson & Moser [16] stated that rainfall and temperature play significant roles as modulators in determining the proportion of the potential productivity achieved at a given site.

3.4. Effect of cutting height on number of leaf per plant

Means of number of leaves per plant (NLPP) of Desho grass as affected by cutting heights across two locations in 2020 and 2021 years are indicated in Table 6. The NLPP was found significantly different among cutting heights across the locations and over the year. Desho grass harvested at 120 cm (T8) constantly recorded the highest NLPP across the two locations and in both experimental years. Whereas the mean of NTPP of desho grass obtained at Holetta over the years in T3 numerically the lowest value, but statistically similar with T1, T2, and T4. Conversely, T2 scored the lowest mean value of NLPP in Kulumsa over the two experimental years but statistically did not differed with T3 and T5. The overall mean value of NLPP of desho grass across locations and over the year obtained in T1, T2, T3,T4 and T5 statistically insignificant (P > 0.05) difference among each other.

3.5. Effect of cutting height on number of tillers per plant

Means of number of tillers per plant (NTPP) as affected by cutting heights across two locations in 2020 and 2021 years are presented in Table 7. The NTPP significantly influenced by cutting height at Holetta in the second year only. NTPP in T4 was the largest

Table 6
Effect of cutting height on number of leaves per plant of *Desho* grass at Holetta and Kulumsa during 2020 and 2021 years.

Treatments	Locations						Overall mean
	Holetta			Kulumsa			
	2020	2021	Mean	2020	2021	Mean	
T1 (50 cm)	5.1^{c}	7.2^{cd}	6.2^{cd}	7.2^{bc}	6.8^{bc}	7.0^{c}	6.6^{cd}
T2 (60 cm)	5.9^{bc}	7.0^{cd}	6.4^{bcd}	5.9^{c}	5.6^{c}	5.6^{d}	6.1^{d}
T3 (70 cm)	5.6^{bc}	6.2^{d}	5.9^{d}	7.1^{bc}	6.1^{c}	6.6^{cd}	6.3^{cd}
T4 (80 cm)	5.2^{bc}	7.5^{bc}	6.4^{cd}	7.8^{ab}	6.9^{bc}	7.3^{bc}	6.8^{bcd}
T5 (90 cm)	6.2^{b}	7.2^{cd}	6.7^{bc}	6.1^{c}	7.0^{bc}	6.5^{cd}	6.6^{cd}
T6 (100 cm)	5.9^{bc}	8.5^{ab}	7.2^{b}	7.8^{ab}	6.5^{bc}	7.2^{c}	7.2^{bc}
T7 (110 cm)	6.1^{bc}	7.5^{bc}	6.8^{bc}	8.1^{ab}	8.1^{ab}	8.1^{ab}	7.5^{b}
T8 (120 cm)	7.4^{a}	8.9^{a}	8.2^{a}	8.8^{a}	9.2^{a}	9.0^{a}	8.6^{a}
Mean	5.9	7.5	6.7	7.4	7.0	7.2	7.0
CV (%)	10.3	8.0	10.1	11.4	14.1	7.4	14.2
P-value	0.012	0.002	0.001	0.011	0.013	0.001	0.001

Means within a column followed by different supper-script letters are significantly different (P < 0.01*);* CV (%) = coefficient of variation.

Table 7
Effect of cutting height on number of tillers per plant of *Desho* grass at Holetta and Kulumsa during 2020 and 2021 years.

Treatments	Locations						Overall mean
	Holetta			Kulumsa			
	2020	2021	Mean	2020	2021	Mean	
T1 (50 cm)	139.7	111.7^{bc}	125.7	62.1^{bc}	99.0^{b}	80.6	103.1^{a}
T2 (60 cm)	85.9	100.3^{bc}	93.1	57.6^{bc}	95.7^{b}	76.7	84.9^{cd}
T3 (70 cm)	82.1	96.9^{c}	89.5	61.4^{bc}	88.6^{b}	75.0	82.3^{d}
T4 (80 cm)	83.9	135.7^{a}	109.7	77.4^{a}	88.9^{b}	83.2	96.4^{abc}
T5 (90 cm)	89.2	104.5^{bc}	96.9	70.5^{ab}	98.8^{b}	84.7	90.8^{bcd}
T6 (100 cm)	94.1	112.6^{bc}	103.3	61.1^{bc}	128.9^{a}	95.0	99.2^{ab}
T7 (110 cm)	94.7	117.3^{ab}	106.0	56.2^{bc}	91.9^{b}	74.0	90.0^{bcd}
T8 (120 cm)	96.3	119.5^{ab}	107.9	47.5^{c}	99.5^{b}	73.5	90.7^{bcd}
Mean	95.7	112.3	104.0	61.7	98.9	80.3	92.2
CV (%)	21.2	10.3	18.5	13.7	13.5	10.0	24.4
P-value	0.061	0.024	0.062	0.024	0.048	0.073	0.013

Means within a column followed by different supper-script letters are significantly different ($P < 0.05$); CV (%) = coefficient of variation.

followed by T7 and T8, whereas T3 was scored the lowest value and statistical similar with T1, T2, T3, T5, and T6. Conversely, the NTPP significantly influenced by cutting height at Kulumsa in both years. The NTPP of desho grass recorded at Kulumsa over the years was significantly and inconsistently influenced by different cutting height. In the first year, the number of tillers per plant achieved in T4 was scored the highest value followed by T5, whereas T6 significantly greater NTPP than the rest of the treatments in the second year years. In contrast, the combined analysis of NTPP over the year was found non-significant at Kulumsa.

3.6. *Effect of cutting height on leaf-to-stem ratio*

The leaf-to-stem ratio is one of the indicators of nutritional quality and it is highly affected by the stage of harvesting. The result indicated that the LSR of Desho grass was significantly ($P < 0.001$) influenced by cutting height only at Holetta in the establishment year (Table 8). Accordingly, T1, T2, T3, and T4 were statistically higher LSR than the rest of the treatments. There was no significant difference among different cutting height for LSR at Kulumsa in both years and this also consistently pronounced in combined analysis. Nelson & Moser) [16] reported that when the grass became mature the leaf-to- stem ratio became decreases. The proportion of leaves in grass plants decreases as their maturity advances from the vegetative to the reproductive stage [29,30]. Likewise, leafy biomass are more nutritious and will be consumed and digested more readily than those with a higher stem biomass proportion.

3.7. *Effect of cutting height on dry matter yield*

The forage dry matter yield of desho grass was significantly ($P < 0.001$) varied due to cutting heights in both locations over the experimental periods (Table 9). Dry matter yield increased linearly with increase in cutting height. The average dry matter yield obtained in 2020 and 2021 in different harvesting height at Holetta ranged from 12.2 to 20.1 t ha^{-1}. Accordingly, T8, T7, and T6 significantly ($P < 0.001$) higher than T4, T3, T2 and T1 over the two locations. Similarly, the mean dry matter yield of desho grass achieved in Kulumsa ranged from 4.2 to 11.4 t ha^{-1}. This trends also observed in the overall means over locations and cropping years. Accordingly, T8 scored the highest dry matter yield (15.8 t ha^{-1}) whereas T1 recorded the lowest dry matter yield (8.2 t ha^{-1}).

Table 8
Effect of cutting height on leaf to stem ratio of *Desho* grass at Holetta and Kulumsa over two years.

Treatments	Locations						Overall mean
	Holetta			Kulumsa			
	2020	2021	Mean	2020	2021	Mean	
T1 (50 cm)	0.9^{a}	1.3	1.1	1.5	2.3	1.9	1.5
T2 (60 cm)	0.8^{ab}	1.4	1.1	1.6	2.3	1.9	1.5
T3 (70 cm)	0.8^{ab}	1.2	1.0	1.6	2.4	1.9	1.5
T4 (80 cm)	0.8^{ab}	1.2	0.9	2.2	2.1	2.2	1.4
T5 (90 cm)	0.7^{bc}	1.0	0.9	1.2	2.7	1.9	1.4
T6 (100 cm)	0.6^{d}	1.2	0.9	2.0	2.3	2.1	1.5
T7 (110 cm)	0.5^{d}	1.2	0.9	2.1	2.3	2.2	1.5
T8 (120 cm)	0.6^{d}	1.1	0.8	1.6	2.2	1.9	1.3
Mean	0.7	1.2	1.0	1.7	2.3	2.0	1.5
CV (%)	9.9	39.8	33.8	39.7	22.7	18.5	31.9
P-value	0.001	0.601	0.751	0.611	0.933	0.898	0.952

Means within a column followed by different supper-script letters are significantly different ($P < 0.05$); CV (%) = coefficient of variation.

Table 9
Effect of cutting height on dry matter yield of *Desho* grass at Holetta and Kulumsaover Years.

Treatments	Locations						Overall mean
	Holetta			Kulumsa			
	2020	2021	Mean	2020	2021	Mean	
T1 (50 cm)	10.7^{c}	13.7^{cd}	12.2^{c}	3.2^{d}	5.1^{c}	4.2^{c}	8.2^{e}
T2 (60 cm)	13.5^{ab}	15.9^{bcd}	14.7^{bc}	5.3^{cd}	5.9^{bc}	5.6^{bc}	10.2^{de}
T3 (70 cm)	10.5^{c}	15.0^{bcd}	12.7^{c}	7.4^{bc}	7.6^{abc}	7.5^{abc}	10.1^{de}
T4 (80 cm)	12.0^{bc}	16.5^{bcd}	14.2^{bc}	9.1^{abc}	8.9^{abc}	8.9^{ab}	11.6^{bcd}
T5 (90 cm)	11.0^{c}	12.7^{d}	11.8^{c}	11.7^{a}	7.5^{abc}	9.8^{a}	10.8^{cde}
T6 (100 cm)	14.5^{a}	21.9^{ab}	18.2^{ab}	8.1^{abc}	7.6^{abc}	7.8^{abc}	13.0^{abc}
T7 (110 cm)	15.7^{a}	20.7^{abc}	18.2^{ab}	8.9^{abc}	10.4^{ab}	9.7^{ab}	13.9^{ab}
T8 (120 cm)	14.0^{ab}	21.4^{a}	20.1^{a}	10.3^{ab}	12.4^{a}	11.4^{a}	15.8^{a}
Mean	12.7	17.2	15.3	8.0	8.2	8.1	11.7
CV (%)	11.0	24.6	22.8	27.39	34.19	28.59	29.5
P-value	0.003	0.001	0.006	0.007	0.107	0.033	0.001

Means within a column followed by different supper-script letters are significantly different ($P < 0.05$); CV (%) = coefficient of variation.

3.8. Effect of cutting height on chemical composition of desho grass

The dry matter (DM), ash, and crude protein (CP) contents were significantly ($P < 0.01$) influenced by different cutting height in both locations (Table 10). However, the combined mean DM % did not varied among cutting height. Accordingly, T1 to T5, and T8 attained the largest DM% than T6 and T7 at Holetta whereas T2, T6, and T8 statically scored the largest mean than the rest of the treatments at Kulumsa. The ash content of desho grass also significantly ($P > 0.01$) influenced by cutting height among treatments and over locations. The result revealed that as maturity stage increased the ash content of the grass decrease. Different studies confirmed that the mineral concertation of grasses significantly decreased as advancing maturity stage [31].

The crude protein content of desho grass was influenced by different cutting height. Accordingly, the CP content obtained at Holetta ranged from 8.5 to 12.2% with the mean of 10.5%. The highest CP was obtained in T1 (12.2%) at Holetta, whereas T8 scored the lowest value (8.5%). The CP content obtained at Kulumsa ranged from 5.2 to 8.3% with the mean of 6.5%. The largest CP was obtained at Kulumsa from T4 (8.3%) whereas the lowest fromT6 (5.2%). The CP content of desho grass attained in different cutting height at Kulumsa much lower than at Holetta. The result highlighted that as the grass harvesting stage increased, the CP content significantly decrease. The CP content of desho grass attained at Holetta had an overall mean value of 10.5% CP which was above the minimum CP level of 7% required for optimum rumen function for ruminant animals (Van Soest, 1984). On the contrary, the CP content obtained at Kulumsa had an overall mean value of 6.5% CP which is below the minimum recommended value. Favre et al. [32]. Found that the forage harvest occurs at a later date, forage yield is expected to increase while nutritive value is expected to decrease. Concrrent to the present study, Rambau et al. (2016) also found that stage of maturity had significant effect on crude protein content of Napier grass harvested at three stage of maturity.

The crude protein yield of desho grass achieved at Holetta location did not significantly ($P > 0.05$) influenced due to different cutting height and this trend also pronounced in the combined means of the two locations. However, the crude protein yield achieved at Kulumsa significantly influenced by cutting height. Accordingly, desho grass cut at 80 cm (T4), 90 cm (T5) and 120 cm (T8) showed statistically similar but they indicated higher crude protein yield compared to the rest of the treatments.

The neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL) and the *in-vitro* dry matter digestibility (IVDMD) of desho grass were significantly ($P < 0.01$) affected by cutting height at both locations except the NDF and ADL at Kulumsa (Table 11). The NDF content at Holetta ranged from 70.1 to 75.0% with mean value of 73.3 % The mean of NDF ranged from 69.6 to 72.9 %.The NDF content of the forage is the dominant factor in determining forage quality. However, the grass harvested in different cutting heights had greater than 60% NDF which may result in low intake and digestibility in livestock [29].

Similarly the ADF ranged from 40.1 to 42.7%. Although the ADF content of desho grass did not affected by different cutting height at Kulumsa the values obtained in each treatment were less than at Holetta. The combined mean values of ADF of the grass of the two locations showed significant ($P < 0.05$) difference among the cutting heights the values ranged from 38.4 to 40.1% with mean value of 39.3%. The ADL content of desho grass also influenced by cutting stages at both locations. There was an increment of ADL content as the cutting height advance. The concentration of the fibers (NDF, ADF, and ADL) determine the feed quality. Feeds with a lower concentration of these fibers are supposed to be more nutritious than feeds with high fibers concentration. The lower ADL content in a young and leafy forage feeds increases the digestible nutrient and thereby the amount of energy available and provided to the animal became increased [33]. Conversely, matured forage has fewer leaves, and more stems resulting in higher NDF content that is less digestible and much less capable of being consumed at a high rate of intake [32]. Woodard & Prine [34] also observed that with advancing plant maturity in elephant grass, the NDF level increased while the CP content become diminished. The invitro-dry matter digestibility (IVDMD) showed decreasing trends as the cutting height advanced. This might be due to an increase in fiber contents of the grass tends to mature. The mean the two locations of IVDMD ranged from 61.1 to 65.8%.

Table 10
Chemical composition (DM, ash, and CP percentages) of desho grass harvested at the Different cutting heights at Holetta and Kulumsa.

Trt	DM (%)			Ash (%)			CP (%)			CPY (t ha^{-1})		
	Hol	Kul	Mean	Hol	Kul	Mean	Hol	Kul	Mean	Hol	Kul	Mean
T1 (50 cm)	93.1^{a}	92.9^{cd}	93.0	6.8^{a}	6.4^{ab}	6.6^{a}	12.2^{a}	6.7^{b}	9.4^{a}	1.5	0.3^{d}	0.9
T2 (60 cm)	93.1^{a}	93.1^{abcd}	93.1	6.5^{ab}	6.8^{a}	6.6^{a}	11.3^{b}	6.7^{b}	9.0^{ab}	1.7	0.4^{cd}	1.0
T3 (70 cm)	92.9^{ab}	92.8^{d}	92.8	5.7^{bcd}	6.5^{ab}	6.1^{ab}	11.1^{b}	6.9^{b}	9.0^{ab}	1.5	0.5^{bc}	1.0
T4 (80 cm)	92.8^{ab}	92.9^{bcd}	92.9	6.1^{abc}	5.7^{bc}	5.9^{abc}	10.9^{bc}	8.3^{a}	9.6^{a}	1.6	0.7^{a}	1.2
T5 (90 cm)	92.8^{ab}	93.2^{abc}	93.0	4.8^{ef}	6.4^{ab}	5.6^{bc}	10.2^{cd}	6.8^{b}	8.5^{b}	1.2	0.7^{a}	0.9
T6 (100 cm)	92.3^{c}	93.5^{a}	92.9	5.5^{cde}	6.1^{abc}	5.8^{bc}	9.8^{d}	5.2^{c}	7.6^{c}	1.9	0.4^{cd}	1.1
T7 (110 cm)	92.7^{b}	93.2^{abcd}	92.9	5.2^{de}	5.2^{c}	5.2^{cd}	9.6^{d}	5.5^{c}	7.6^{c}	1.8	0.5^{bc}	1.2
T8 (120 cm)	93.0^{a}	93.3^{ab}	93.2	4.3^{f}	5.2^{c}	4.8^{d}	8.5^{e}	5.9^{bc}	7.2^{c}	1.8	0.7^{a}	1.2
Mean	92.8	93.1	92.9	5.6	6.1	5.8	10.5	6.5	8.5	1.6	0.5	1.1
CV (%)	0.2	0.23	0.29	9.9	9.1	10.8	4.5	10.8	8.8	26.9	30.1	42.7
P-value	0.0004	0.037	0.582	0.001	0.024	0.001	0.001	0.003	0.001	0.234	0.001	0.532

Means within a column followed by different supper-script letters are significantly different ($P < 0.01$*);* Hol = Holetta; Kul = Kulumsa; DM = Drymatter; CP = crude protein; CPY = crude protein yield.

Table 11
Chemical composition NDF), acid detergent fiber (ADF), acid detergent lignin (ADL) and The *in-vitro* dry matter digestibility (IVDMD) of desho grass harvested at the different cutting heights at Holetta and Kulumsa.

Trt	NDF (%)			ADF (%)			ADL (%)			IVDMD (%)		
	Hol	Kul	Mean	Hol	Kul	Mean	Hol	Kul	Mean	Hol	Kul	mean
T1 (50 cm)	71.3^{f}	67.9	69.6^{c}	40.8^{bc}	37.1	38.9^{bc}	4.1^{d}	2.3^{de}	3.2^{c}	68.8^{a}	62.1^{ab}	65.4^{a}
T2 (60 cm)	70.1^{ef}	67.8	69.9^{bc}	40.5^{c}	37.2	38.8^{bc}	4.2^{cd}	2.4^{bcde}	3.3^{bc}	69.2^{a}	62.3^{a}	65.8^{a}
T3 (70 cm)	73.0^{de}	68.5	70.8^{bc}	40.8^{bc}	36.1	38.4^{c}	7.3^{bcd}	2.1^{e}	3.2^{c}	69.2^{a}	61.8^{ab}	65.5^{a}
T4 (80 cm)	73.8^{abc}	69.4	71.6^{ab}	40.1^{bc}	37.2	38.9^{bc}	4.4^{bc}	2.4^{bcd}	3.4^{b}	69.5^{a}	61.1^{abc}	65.3^{a}
T5 (90 cm)	74.5^{abc}	67.2	70.9^{bc}	42.1^{ab}	36.7	39.4^{ab}	4.5^{b}	2.3^{cde}	3.4^{b}	66.8^{ab}	61.9^{ab}	64.4^{a}
T6 (100 cm)	73.6^{cd}	68.0	70.8^{bc}	42.7^{a}	37.2	39.9^{a}	4.8^{a}	2.5^{abc}	3.7^{a}	65.6^{bc}	59.4^{c}	62.5^{b}
T7 (110 cm)	75.0^{a}	70.4	72.7^{a}	41.4^{abc}	37.8	39.6^{ab}	4.9^{a}	2.6^{ab}	3.8^{a}	61.7^{d}	60.5^{bc}	61.1^{b}
T8 (120 cm)	74.8^{ab}	70.9	72.9^{a}	41.9^{ab}	38.3	40.1^{a}	4.9^{a}	2.7^{a}	3.8^{a}	62.2^{cd}	59.6^{c}	61.4^{b}
Mean	73.3	68.8	71.2	41.3	37.2	39.3	4.9	2.4	3.5	66.8	61.1	63.9
CV (%)	0.7	3.2	2.2	1.6	2.1	1.9	2.4	6.4	4.6	1.5	1.6	2.4
P-value	0.001	0.401	0.005	0.011	0.079	0.005	0.001	0.008	0.001	0.001	0.014	0.001

Means within a column followed by different supper-script letters are significantly different ($P < 0.05$); Hol = Holetta; Kul = Kulumsa; Com = combined mean; NDF = neutral detergent fiber; ADF=Acid detergent fiver; ADL = Acid detergent lignin; IVDMD= In-vitro dry matter digestibility.

4. Conclusion

Cutting height influenced dry matter yield and nutritive value of desho grass across locations. As the plant height advanced the dry matter production of desho grass increased but the crude protein content of the grass decreased. Furthermore, the finding highlighted that as the harvesting stage of the grass increased, the fibers (NDF, ADF, and ADL) concentrations of the grass increased thereby the *In-vitro* dry matter digestibility of the grass decreased. Thus, we recommend that desho grass should be harvested at 80–90 cm height for optimum dry matter yield and quality.

Data availability

The data used to support the findings of this study are available from the corresponding author upon request.

Funding the statement

This study was supported by the Ethiopian Institute of Agricultural Research.

CRediT authorship contribution statement

Gezahegn Mengistu: Writing – review & editing, Writing – original draft, Conceptualization. **Mulisa Faji:** Data curation, Conceptualization. **Kedir Mohammed:** Formal analysis, Software. **Mezgeb Workiye:** Supervision, Formal analysis, Conceptualization. **Gezahagn Kebede:** Supervision, Methodology. **Gebremariyam Terefe:** Methodology, Formal analysis. **Mesfin Dejene:** Supervision, Project administration, Conceptualization. **Fekede Feyissa:** Supervision, Funding acquisition.

Declaration of competing interest

The authors declare no conflict of interest.

Acknowledgements

The authors express their gratitude to the Ethiopian Institute of Agricultural Research for supporting the activity. The authors also highly acknowledge the feeds and nutrition research program particularly the technical and field assistance of forage and pasture of Holetta and Kulumsa Agricultural Research Centers for their contribution to this activity made possible. Furthermore, the animal nutrition staff of Holetta Research Center is duly acknowledged for their assistance in nutritional quality analysis.

References

[1] W.A. Wassie, B.A. Tsegay, A.T. Wolde, B.A. Limeneh, Evaluation of morphological characteristics, yield and nutritive value of Brachiaria grass ecotypes in northwestern Ethiopia, Agric. Food Secur. 7 (1) (2018) 1–10, https://doi.org/10.1186/s40066-018-0239-4.
[2] F. Tegegne, G. Assefa, Feed resource assessment in Amhara regional state, in: Ethiop. Sanit. Phytosanitary Stand. Livest. Meat Mark. Progr. (SPS-LMM), Texas A \&M Univ. Syst. Coll. Station. TX, USA, 2010.
[3] M. Birhan, T. Adugna, Livestock feed resources assessment, constraints and improvement strategies in Ethiopia, Middle East J. Sci. Res. 21 (4) (2014) 616–622, https://doi.org/10.5829/idosi.mejsr.2014.21.04.82406.
[4] K.J. Boote, et al., Fodder development in sub-Saharan Africa: an introduction, Agron. J. 114 (1) (2022) 1–7, https://doi.org/10.1002/agj2.20924.
[5] H.P.S. Makkar, Review: feed demand landscape and implications of food-not feed strategy for food security and climate change, Animal 12 (8) (2018) 1744–1754, https://doi.org/10.1017/S175173111700324X.
[6] A. Matope, T.J. Zindove, M. Dhliwayo, M. Chimonyo, Mitigating the effects of drought on cattle production in communal rangelands of Zimbabwe, Trop. Anim. Health Prod. 52 (2020) 321–330.
[7] E. Owen, T. Smith, H. Makkar, Successes and failures with animal nutrition practices and technologies in developing countries: a synthesis of an FAO e-conference, Anim. Feed Sci. Technol. 174 (3–4) (2012) 211–226, https://doi.org/10.1016/j.anifeedsci.2012.03.010.
[8] A. Adugna, Assessment of yield stability in sorghum using univariate and multivariate statistical approaches, Hereditas 145 (1) (2008) 28–37.
[9] S. Mengistu, et al., Livestock production challenges and improved forage production efforts in the Damot Gale District of Wolaita Zone, Ethiopia, Adv. Agric. 2021 (2021) 1–10.
[10] S. Welle, K. Chantawarangul, S. Nontananandh, S. Jantawat, Effectiveness of grass strips as barrier against runoff and soil loss in Jijiga area, northern part of Somali Region, Ethiopia, Kasetsart J./Nat. Sci. 40 (2) (2006) 549–558.
[11] G. Yakob, A. Gebremicheal, A. Aklilu, E. Melaku, Participatory evaluation of different multipurpose grass species for graded soil bund stabilization in gimbo district, south west Ethiopia, OALib 2 (6) (2015) 1–10, https://doi.org/10.4236/oalib.1101627.
[12] M. Abera, A. Tolera, A. Nurfeta, D. Geleti, "SPECIAL section : DEVELOPING FODDER RESOURCES Herbage accumulation and nutritive value of mixtures of desho grass and Vicia spp, in: Southern Ethiopia,", 2022, pp. 165–172, https://doi.org/10.1002/agj2.20891. March 2021.
[13] A. Shiferaw, R. Puskur, A. Tegegne, D. Hoekstra, Innovation in forage development: empirical evidence from Alaba Special District, southern Ethiopia, Dev. Pract. 21 (8) (2011) 1138–1152.
[14] B. Asmare, S. Demeke, T. Tolemariam, F. Tegegne, A. Haile, J. Wamatu, Effects of altitude and harvesting dates on morphological characteristics, yield and nutritive value of desho grass (Pennisetum pedicellatum Trin.) in Ethiopia, Agric. Nat. Resour. 51 (3) (2017) 148–153, https://doi.org/10.1016/j.anres.2016.11.001.
[15] M. Abera, A. Tolera, A. Nurfeta, D. Geleti, PRODUCTION, UTILIZATION AND CONSTRAINTS OF DESHO GRASS (Pennisetum glaucifolium) AS LIVESTOCK FEED IN Ethiopia, Online J. Anim. Feed Res. 11 (6) (2021) 196–205, https://doi.org/10.51227/OJAFR.2021.29.
[16] C.J. Nelson, L.E. Moser, Plant factors affecting forage quality, Forage Qual. Eval. Util. (2015) 115–154, https://doi.org/10.2134/1994.foragequality.c3.
[17] M. Abera, A. Tolera, A. Nurfeta, D. Geleti, Herbage accumulation and nutritive value of mixtures of desho grass and Vicia spp. in southern Ethiopia, Agron. J. 114 (1) (2022) 165–172, https://doi.org/10.1002/agj2.20891.
[18] Z. Tessema, A. Ashagre, M. Solomon, Botanical composition, yield and nutritional quality of grassland in relation to stages of harvesting and fertiliser application in the highlands of Ethiopia, African J. Range \& Forage Sci. 27 (3) (2010) 117–124.
[19] M.D. Rambau, F. Fushai, J.J. Baloyi, Productivity, chemical composition and ruminal degradability of irrigated Napier grass leaves harvested at three stages of maturity, S. Afr. J. Anim. Sci. 46 (4) (2016) 398–408.
[20] J.M.A. Tilley, dan R.A. Terry, A two-stage technique for the in vitro digestion of forage crops, Grass forage Sci 18 (2) (1963) 104–111.
[21] S. Sas, For Windows Version 9.3, SAS Institute Inc, Cary, NC, USA, 2011.
[22] B. Mihret, B. Asmare, Y. Mekuriaw, Effect of fertilizer type and plant spacing on plant morphological characteristics, yield and chemical composition of desho grass (Pennisetum pedicellatum Trin.) in Northwestern Ethiopia, Agric. Sci. Technol. 10 (2) (2018) 107–114, and others.
[23] F. Ludwig, H. de Kroon, F. Berendse, H.H.T. Prins, The influence of savanna trees on nutrient, water and light availability and the understorey vegetation, Plant Ecol 170 (2004) 93–105.
[24] H. Geren, Dry matter yield and silage quality of some winter cereals harvested at different stages under Mediterranean climate conditions, Turkish J. F. Crop. 19 (2) (2014) 197–202.
[25] G. Mengistu, et al., Morphological characters, dry matter production, and feed quality of three maize (Zea mays L.) varieties as influenced by milk and dough harvest stages, Ukr. J. Ecol. 13 (1) (2023).
[26] M. Faji, et al., Evaluation of ten perennial forage grasses for biomass and nutritional quality, Trop. Grasslands-Forrajes Trop. 9 (3) (2021) 292–299.
[27] T. Zewdu, Variation in growth, yield, chemical composition and in vitro dry matter digestibility of Napier grass accessions (Pennisetum purpureum), Trop. Sci. 45 (2) (2005) 67–73.
[28] S. Mishra, R. Singh, R. Kumar, A. Kalia, S.R. Panigrahy, Impact of climate change on pigeon pea, Econ. Aff. 62 (3) (2017) 455, https://doi.org/10.5958/0976-4666.2017.00057.2.
[29] K.J. Moore, L.E. Moser, K.P. Vogel, S.S. Waller, B.E. Johnson, J.F. Pedersen, Describing and quantifying growth stages of perennial forage grasses, Agron. J. 83 (6) (1991) 1073–1077.
[30] K.J. Moore, L.E. Moser, Quantifying developmental morphology of perennial grasses, Crop Sci. 35 (1) (1995) 37–43.
[31] T. Bayble, S. Melaku, N.K. Prasad, Effects of cutting dates on nutritive value of Napier (Pennisetum purpureum) grass planted sole and in association with Desmodium (Desmodium intortum) or Lablab (Lablab purpureus), Livest. Res. Rural Dev. 19 (1) (2007) 120–136.
[32] J.R. Favre, K.A. Albrecht, L. Gutierrez, V.D. Picasso, Harvesting oat forage at late heading increases milk production per unit of area, Crop. Forage Turfgrass Manag. 5 (1) (2019) 180046, https://doi.org/10.2134/cftm2018.06.0046.
[33] Y. Barrière, C. Guillet, D. Goffner, M. Pichon, Genetic variation and breeding strategies for improved cell wall digestibility in annual forage crops. A review, Anim. Res. 52 (3) (2003) 193–228.
[34] K.R. Woodard, G.M. Prine, Forage yield and nutritive value of elephantgrass as affected by harvest frequency and genotype, Agron. J. 83 (3) (1991) 541–546, https://doi.org/10.2134/agronj1991.00021962008300030005x.