



Influence of harvesting days and fertilizer levels on agronomic performance and nutritive values of Washo (*Loudetia arundinacea*) grass

Moges Boda and Yilkal Tadele*

Department of Animal Science, Arba Minch University, Arba Minch, Ethiopia. *Author for correspondence. E-mail: yilkaltadele@gmail.com

ABSTRACT. This study evaluated the effects of fertilizer levels, harvesting days and cropping years on the agronomic performance and nutritional value of Washo (*Loudetia arundinacea*) the grass. A 3×3×2 factorial arrangement in a randomized complete block design with three levels of nitrogen fertilizer (75, 100 and 120 Kg), three harvesting days (60, 90 and 120 days) and two cropping years was used. Data on number of tillers (TN), number of leaves (LN), leaf length (LL), plant height (PH), Leaf to stem ratio (LSR), herbage dry matter yield (HDMY), crude protein yield (CPY), nutritional composition, *in vitro* digestibility were recorded. The results indicated that significantly ($p<0.01$) higher values of PH (114.57 cm), LSR (0.76), LL (18.18 cm), HDMY (29.91 ton ha⁻¹) and CPY (3.54 ton ha⁻¹) at nitrogen fertilizer level of 100 Kg ha⁻¹. Fertilizer levels and harvesting days revealed significantly different ($p<0.001$) results on dry matter (DM), crude protein (CP), ash, neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL) and *in vitro* dry matter digestibility (IVDMD) contents. Cropping years had also influenced ($p<0.05$) on PH, TN, HDMY, CPY, LSR, NT and LL of the grass. From dry matter yield perspectives, harvesting of *Loudetia arundinacea* grass at 120 days is recommended.

Keywords: performances; nutrients; digestibility; grass.

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Introduction

Ethiopia has the large livestock population in Africa (Central Statistical Agency, 2021) and livestock production is an integral part of the subsistence crop-livestock systems. However, to date, the contribution of this sector is low (Central Statistical Agency, 2015). Low productivity is principally due to inefficient nutritional and management practices, high level of disease and parasitic incidence (Getahun, 2012). Among these constraints, low quality and insufficient supply of feeds are the most critical (Food and Agriculture Organization of the United Nations, 2010). The major animal feed resources in Ethiopia are natural pastures, crop residues, forage crops, agro-industrial by-products and non-conventional feeds (Ahmed et al., 2010). Though natural pastures is the main source of livestock feed, its contribution is affected by declining grazing lands, and land degradation (Berhanu et al., 2009). Overcoming animal feed shortages is crucial for livestock farming (Anele et al., 2009). According to Anele et al. (2009), indigenous forages are familiar to smallholder farmers, grow with low inputs, and are adaptable to different agro-ecological conditions.

The use of indigenous forage as a feed resource is appealing under the present Ethiopian conditions to increase livestock production and productivity (Shapiro et al., 2015). Washo is an indigenous grass species found in Ethiopia. The grass is a tufted perennial with spreading branches and conspicuously whorled (Burrows & Willis, 2005). It is also a drought-tolerant grass (Koura et al., 2022). In recent times the use of such grass as climate-resilient forage is increasing. The grass (*Loudetia arundinacea*) contains 10.84% ash, 6.5% CP, 73.88% NDF and 5.25 MJ Kg⁻¹ DM Metabolizable energy contents (Koura et al., 2022).

According to practical experience among the promising grass adaptable for the low land of Ethiopia, washo grass may have a significant role to maximize the yield and quality for animal products. The potential of indigenous forage resources like washo need research aiming in evaluation of its productivity and nutritional quality. In Kucha district, where this study was carried out, farmers traditionally use Washo grass for their livestock. However, there is no detailed information on the growth characteristics, biomass yield and nutritional value of the grass. Dry matter productivity and nutritional values of grasses can be influenced by numerous factors including plant species (French, 2017), management activities (Enoh et al., 2005), season (Xu et al., 2024), fertilizer rates (Gezahegn et al., 2024) and harvesting stages (Atis et al., 2012)

Growing of forage grasses using optimum fertilizer levels and harvesting at appropriate stages improve dry matter yield and nutritional quality. Hence, determination of appropriate harvesting days and optimum fertilizer levels for improved agronomic performances, forage yield and nutritional value of washo (*Loudetia arundinacea*) grass is imperative. Therefore, the objective of this study was to observe the effects of harvesting days, fertilizer levels and cropping years on the agronomic performances and nutritional values of washo grass (*Loudetia arundinacea*).

Materials and methods

Description of the study area

The study was conducted in Kucha district which is found in Southern Ethiopia. The district is located at 06°30' N latitude and 37°19' E longitude. The area is sub-humid climate with moderately hot temperature. It has a minimum and maximum annual rain fall of 900 and 1800, respectively (Vanden & Rowlands, 2001). In the district, there are two dominant agro-ecological zones, Woina dega (mid-altitude) and Kolla (low altitude), accounting for 50.6 and 49.4% of the total area, respectively. The district is described by a bimodal type of rainfall, namely, Belg (short rainy season) and Meher (main rainy season). The Belg rainfall starts in February and ends in March, whereas the Meher rainfall starts in July and ends in October. The areas are characterized by fertile, sandy loam soils with good internal drainage and a pH in the range of 6.3 and 7.2 and slightly acid soil but not saline soils (Kaysha et al., 2020).

Land preparation, experimental design and treatments

Land for this experiment was obtained from Kucha District Administrative Office. The land was plowed three times before sowing. The study was conducted using a 3x3*2 factorial arrangement in a randomized complete block design (RCBD) with three replications. Three harvesting days (HS1, HS2, and HS3) for 60, 90, and 120 days after planting, three levels of nitrogen fertilizer (FR1= 75 Kg ha⁻¹, FR2= 100 kg ha⁻¹, and FR3= 120 kg ha⁻¹) and two cropping years were used as factors. The study was conducted during the rainy seasons of 2022 and 2023. Root splits of Washo grass (*Loudetia arundinacea*) were used for planting. The splits were planted in a row at a depth of approximately 5 cm. The spacing between rows and plants were 50 and 10 cm, respectively. There were nine treatment combinations with three replications making a total of 27 plots. The area of each plot was 3 m length × 4 m width (12 m²), and the distances between the plot and blocks were 1 m and 1.5 meter, respectively (Asmare et al, 2017). Plots in each replicate were randomly assigned to each treatment.

Data collection procedure

Agronomic traits

Agronomic data were recorded for each parameter during harvesting. Number of tillers per plant, number of leaves per plant, leaf length (cm), plant height (cm) and dry matter yield (Kg) were recorded. Plant height and number of tillers per plant were measured from ten randomly selected plants in each plot using a measuring tape. The leaf-to-stem ratio was calculated as the weight of green leaves divided by the weight of stems. The number of leaves and internodes per plant was also recorded on ten plants in each plot. The lengths of the internodes were measured by removing the leaf sheaths. The length of a leaf was measured from the tip of the entire leaf down to the base of the lowest leaflets where they met the leaf stem.

Herbage dry matter yield (HDMY)

To determine the herbage dry matter yield, the grass was harvested from each plot 5 cm above the ground and then weighed (Ghiwot, 2019). Harvesting was carried out on a 4m² area in the middle rows of each plot. The fresh weight was taken soon after harvest in the field using sensitive balance. Based on the harvested grass at each area, the total herbage dry matter yields for each plot were thereafter converted to tons per hectare. The herbage dry matter yield was by taking 500 g sample from each harvest and dried at 60C for 72h to determine dry matter yield. The dry matter content then was determined by oven drying the subsamples at 105°C and used to calculate herbage dry matter yield (HDMY). $HDMY (t ha^{-1}) = (10 \times TFW \times SSDW) / (HA \times SSFW)$ (Gelayenew et al., 2020), Where: 10=constant for conversion of yields in Kg m⁻² to tone ha⁻¹; TFW = Total Fresh Weight from harvesting area (Kg); SSDW = Sub-Sample Dry Weight (g); HA = Harvestable Area (m²), and SSFW=Sub-sample fresh weight (g).

Chemical analysis

The treatment samples were collected at each harvesting days. Representative samples were taken from each plot at each harvest and were dried in a draft oven at 65°C for 72h before the laboratory for chemical analysis.

The dried samples were ground to pass through a 1 mm sieve (Wiley mill) and stored in airtight plastic bags until the analysis. Chemical analysis was carried out at the Animal Nutrition Research Laboratory of the Holeta Agricultural Research Center. All samples were analyzed for DM, ash, and CP, according to the procedures described by AOAC (Association of Official Analytical Chemists, 2005). Neutral detergent fiber (NDF) was analyzed according to Van Soest et al. (1991), and acid detergent fiber (ADF) and acid detergent lignin (ADL) were analyzed according to the procedure described by Van Soest and Robertson (1985). In vitro organic matter digestibility was determined using the two-stage Tilley and Terry (1963) method. Rumen liquor was collected and transported to the laboratory using thermos flasks and pre-warmed to 39°C before the daily meals of the three cannulated Boran-Friesian steers. The steers were 48 months old and weighed 500 Kg each. The steers were fed natural pasture hay (5.8% CP on DM basis) *ad libitum* supplemented with 2 Kg concentrate mixture (20% CP, DM basis) per day/head.

Metabolizable energy (ME) was estimated from digestible energy (DE) and in vitro organic matter digestibility (IVOMD) formula using the following steps: First, DE was obtained using Equation: $DE = [0.01 * (OM/100) * (IVOMD + 12.9) * 4.4] - 0.3$

Where DE is the digestible energy in calories, OM is the organic matter and IVOMD is the *in vitro* organic matter digestibility in joules. Then, $ME = 0.82 * DE$ (Mcal Kg⁻¹) was calculated and converted to SI units (MJ Kg⁻¹) by multiplying by 4.184 (National Research Council, 2001).

Economic analysis

The cost of production was analyzed in order to find out the most economic level of nitrogen fertilizer application using the procedures of Upton (1979). Total Variable costs considered were all input costs (labor, fertilizer) in producing the forage. The costs for land preparation, planting, weed control and harvesting were considered as labor cost. Gross return (GR) was calculated as the income generated from selling forage crops. The market price of forage was estimated to calculate the return. Net income (NI) was calculated as the difference between total returns (TR) and total variable costs (TVC): $NI = TR - TVC$. While, the marginal rate of return (MRR) measures the increase in net income (ΔNI) associated with each extra unit of cost (ΔTVC), i.e., $MRR = (\Delta NI / \Delta TVC)$.

Statistical analysis

All data collected on agronomic characteristics, biomass yield, and chemical composition were analyzed using the General Linear Model (GLM) procedure of SAS (Statistical Analysis System, 2009). Duncan's multiple range test was used to separate means. Differences were considered statistically significant at $p < 0.05$. The statistical model for the data analysis was as follows: $Y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \epsilon_{ijk}$; Where; α_i = is the effect of i^{th} harvesting days, β_j = is the effect of the j^{th} nitrogen level, $(\alpha\beta)_{ijk}$ = is the interaction effect of harvesting days, nitrogen levels, ϵ_{ijk} = is random error

Results and discussion

Effect of harvesting days and fertilizer levels on agronomic parameters of Washo (*Loudetia arundinacea*) grass

The effects of the nitrogen fertilizer levels, harvesting days and cropping years on agronomic performance are presented in Table 1. Significantly ($p < 0.01$) higher values of plant height (PH), leaf steam ratio (LSR), leaf length (LL), herbage dry matter yield (HDMY) and crude protein yield (CPY) were recorded at nitrogen fertilizer level of 100 Kg ha⁻¹. All the measured parameters including PH, HDMY, DDMY, CPY, IN, NL, LL, LSR, HY, and TFY were significantly ($p < 0.001$) higher at 120 days of harvesting than at the other harvesting days of washo (*Loudetia arundinacea*) grass. This might be due to the fact that these parameters are highly interconnected with the stages of growth or maturity of the grass than fertilizer treatments. Increasing nitrogen levels resulted in enhanced agronomic performances and dry matter yield of washo grass. A similar finding revealed that fertilizer application and harvest stage had a highly

significant effect on the botanical composition, productivity and nutritional quality of natural pasture in the central highlands of Ethiopia (Seyoum et al., 2020). Plant height was the most responsive parameter to nitrogen fertilizer application, and each successive increase in nitrogen dose significantly produced taller plants. This is consistent with the results of Ayub et al. (2003), who reported an increase in plant height with increasing levels of nitrogen fertilizer. A higher forage yield was observed in response to increased levels of fertilizer for oat grass in the Bale highlands of Ethiopia (Dawit & Teklu, 2014). This finding is also supported by the findings of Jayanthi et al. (2002), who reported that the application of organic and inorganic nitrogen fertilizers increased the number of tillers in oats. Harvesting stage had a noteworthy effect on all plant morphological traits, forage DM yield and quality traits of Rhodes grass (Dawit et al., 2024).

Ansah et al. (2010) also noted that numerous fine branches growing out from the leaf axils of the main stems of napier grass as the plant matures. Similarly, Wubetie et al. (2019) noted the impact of harvesting stage on agronomic parameters and nutritional values of *Brachiaria* grass Cultivars in Northwestern Ethiopia.

Table 1. Effect of nitrogen fertilizer levels, harvesting days and cropping years on agronomic parameters of *Loudetia arundinacea* grass.

Factors	Agronomic characteristics							
	PH	TN	HDMY	CPY	LSR	NL	IN	LL
Nitrogen fertilizer level (Kg ha ⁻¹)								
75	109.39 ^c	62.28	26.37 ^c	3.18 ^c	0.61 ^c	116.5 ^c	6.45	14.12 ^b
100	111.89 ^b	62.70	28.31 ^b	3.30 ^b	0.68 ^b	134.5 ^b	6.70	17.15 ^{ab}
120	114.57 ^a	62.78	29.91 ^a	3.54 ^a	0.76 ^a	157.5 ^a	7.05	18.18 ^a
SEM	11.03	3.19	0.34	0.10	0.07	0.18	0.10	0.28
P-value	0.001	0.11	0.01	0.001	0.001	0.01	0.31	0.01
Harvesting (days)								
60	107.94 ^b	59.17 ^b	28.89 ^c	3.16 ^a	0.74 ^a	135.5	6.15	14.16 ^b
90	115.58 ^a	62.08 ^a	29.25 ^b	3.01 ^a	0.70 ^{ab}	141.5	6.05	18.06 ^a
120	117.33 ^a	63.17 ^a	30.64 ^a	2.62 ^b	0.63 ^b	136.5	7.02	17.83 ^a
SEM	11.03	2.02	1.08	0.19	0.31	0.08	0.01	0.18
P-Value	0.01	0.11	0.001	0.01	0.001	0.11	0.21	0.001
Cropping Years								
Y1	101.44 ^a	57.33 ^b	26.5 ^b	2.92 ^b	70.28 ^b	126 ^b	6 ^b	14.91 ^b
Y2	118.46 ^b	66.81 ^a	31.3 ^a	3.75 ^a	75.29 ^a	137 ^a	8 ^a	18.49 ^a
SEM	10.3	0.02	0.08	0.11	0.11	0.08	0.04	0.08
P-value	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001

Means in the column with different letter(s) are significantly different, PH=Plant height (cm), TN= Tiller number, HDMY=herbage dry matter yield (ton/ha), CPY=Crude protein yield (ton ha⁻¹), LSR=Leaf steam ratio, LN= leaf number , IN=Inter node, LL=Length of leaf (cm), Ha=Hectare, SEM=Standard error of mean

All the measured parameters were significantly ($p < 0.001$) higher at 120 days of harvesting than at the other harvesting dates of *Loudetia arundinacea* grass. This might be due to the fact that these parameters are highly interconnected with the stages of growth or stages of maturity of the grass than fertilizer treatments. This finding is supported by the findings of Yidersal et al. (2019), who reported that an increased nitrogen levels per hectare increased the number of leaves and promoted good plant growth, leading to higher biomass. Longer harvesting days, along with 80 or 120 Kg N ha⁻¹ fertilizer level, was the best for attaining the maximum dry matter yield of elephant grass (Ullah et al., 2010). Compost from dairy cow manure enriched with various inorganic fertilizers (Urea and NPK) produced a largest plant height (195 cm) and number of plants of 16.37 plant stems per clump in king grass (*Pennisetum purpurhoides*) (Hendarto et al., 2022). The dry matter yield and leaf-to-stem ratio of *Brachiaria* grass in Wondogent, Ethiopia, increased with increasing NPS fertilizer but decreased with the extended harvesting stage (Mijena & Getiso, 2022). Contrary to this finding, the dry matter yield, plant height, number of leaves, and tillers of Rhodes grass were not significantly affected by the application of different fertilizer rates (Mulisa et al., 2021). In agreement with the present study, Szulc et al. (2021) reported different maize dry matter yields with respect to weather conditions.

Effect of fertilizer levels, harvesting days and cropping years on chemical composition of *Loudetia arundinacea* grass

The effects of nitrogen fertilizer levels and harvesting days on the chemical composition of *Loudetia arundinacea* grass are given in Table 2. Nitrogen fertilizer levels had a significant ($p < 0.01$) effect on ash, crude protein (CP), acid detergent fiber (ADF), acid detergent lignin (ADL) and Metabolizable energy (ME) contents. Dry

matter (DM), neutral detergent fiber (NDF) and *In vitro* dry matter digestibility (IVDMD) were not influenced by levels of nitrogen fertilizer. The highest ($p<0.01$) CP (14.38%) content was recorded at fertilizer level of 120 Kg ha⁻¹. Harvesting days also had a significant effect ($p<0.05$) on the chemical composition of the grass. The CP content and digestible parameters, including IVDMD, DOMD, and metabolizable energy, were significantly higher ($p<0.001$) on the harvesting day of 60 than on the other harvesting days, while the contents of DM, ash, and fiber fractions including NDF, ADF, and ADL were significantly higher ($p<0.001$) on the harvesting day (120 days) than on 60 and 90 harvesting days. The dry matter yield, proportion of crop fractions, leaf-to-stem ratio, and nutritional quality (CP) in guinea grass were improved through different cutting frequencies and nitrogen fertilizer application (Onyeonagu & Asiegbu, 2012). Crude protein decreased at longer harvesting intervals, and crude fiber increased because of increased stem hardness (Ullah et al., 2010). Similarly, several factors, such as year, fertilizer levels and stage of plant maturity at harvesting, can influence the nutritional values of desho grass and natural pasture (Fekede et al., 2015; Seyoum et al., 2020).

Table 2. Effect of nitrogen fertilizer levels and harvesting days chemical composition of *Loudetia arundinacea* grass.

Factors	Chemical composition (% DM)						IVDMD	IVOMD	ME (MJ Kg DM ⁻¹)
	DM	Ash	CP	NDF	ADF	ADL			
Nitrogen Fertilizer levels (Kg ha ⁻¹)									
75	90.82	6.58 ^b	13.08 ^c	69.42	37.87 ^b	5.68 ^b	67.10	56.16 ^b	9.47
100	91.15	6.78 ^{ab}	13.58 ^b	70.72	38.17 ^a	5.98 ^a	66.98	59.32 ^a	9.49
120	91.40	7.18 ^a	14.38 ^a	69.92	38.37 ^a	6.18 ^a	67.53	59.55 ^a	9.53
SEM	3.23	0.02	0.77	2.01	1.83	0.11	2.20	2.08	1.03
P-Value	0.051	0.001	0.01	0.060	0.001	0.001	0.11	0.01	0.10
Harvesting (days)									
60	89.96 ^c	6.29 ^c	13.96 ^a	66.54 ^c	34.99 ^c	4.79 ^c	68.78 ^a	57.36 ^a	7.66 ^b
90	91.56 ^b	6.81 ^b	13.34 ^{ab}	69.74 ^b	36.19 ^b	5.99 ^b	64.70 ^b	54.32 ^b	8.54 ^{ab}
120	92.97 ^a	7.33 ^a	11.42 ^b	72.79 ^a	39.24 ^a	7.04 ^a	62.63 ^c	51.54 ^c	9.93 ^a
SEM	2.83	0.02	0.71	2.44	2.01	0.11	3.08	2.28	0.91
P-Value	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.01	0.01
Cropping Years									
Y1	92.58	6.98	13.60	69.49	38.39	6.00	67.57	59.30	9.49
Y2	92.28	6.87	13.75	69.89	37.89	5.89	67.82	59.39	9.50
SEM	0.03	0.02	0.08	0.11	0.11	0.11	0.08	0.08	0.01
P-value	0.10	0.021	0.011	0.081	0.053	0.030	0.12	0.10	0.071

Means in the same column with different letter(s) indicate significant difference, DM= Dry matter, CP= Crude protein, NDF=Neutral detergent fiber, ADF= Acid detergent fiber, ADL= Acid detergent lignin, IVDMD=Invitro dry matter digestibility, IVOMD=Invitro organic matter digestibility, ME= metabolizable energy, Ha=Hector, SEM=Standard error of mean, Kg= kilogram

Correlation between agronomic data and chemical composition

The correlation values of the agronomic and nutritional values of the grasses are shown in Table 3. This relationship indicates that manipulating one of the correlated factors for improving the yield may also lead to an improvement in the other parameters. Crude protein had Positive correlations with all the measured parameters except NDF ADF and ADL contents. The NDF and ADF contents had also negative correlation with IVDMD and IVOMD of the grass.

Table 3. Pearson correlation coefficient among different parameters.

Agronomic and nutritional value parameters												
	CP	NDF	ADF	IVDMD	IVOMD	PH	NT	HDMY	LSR	NL	LL	CPY
CP	1											
NDF	-0.21	1										
ADF	-0.26	0.9	1									
IVDMD	0.28	-0.94	-0.99	1								
DOMD	0.26	-0.96	-0.97	0.99	1							
PH	0.11	0.35	-0.09	-0.02	0.11	1						
NT	0.12	0.22	-0.23	0.11	0.03	0.99	1					
HDMY	0.01	0.34	-0.09	0.02	0.2	0.96	0.94	1				
LSR	0.11	0.39	-0.05	0.06	0.15	0.99	0.98	0.96	1			
NL	0.24	0.89	0.64	0.74	0.78	0.65	0.54	0.71	0.68	1		
LL	0.11	0.46	0.04	0.15	0.22	0.98	0.98	0.94	0.98	0.73	1	
CPY	0.38	0.34	-0.06	-0.03	0.11	0.93	0.91	0.94	0.93	0.58	0.9	1

CP= crude protein; NDF=neutral detergent fiber;ADF=acid detergent fiber, IVDMD= in vitro dry matter digestibility; IVOMD= Invitro organic matter digestibility; PH=plant height; NT=number of tillers; HDMY= herbage dry matter yield; LSR= leaf stem ratio; NL=Number of leaves; LL=Leaf length; HY, herbage yield; TFY, total forage yield; DDMY, digestible dry matter yield; CPY=Crude protein yield.

Cost benefit analysis

The cost benefit analysis of using different nitrogen fertilizer levels for washo grass production (ton ha^{-1}) is presented in Table 4. The result indicated that as the application of fertilizer at 100 and 120 Kg ha^{-1} levels resulted higher marginal rate of returns (MRR). This result is consistence with the report of the pervious finding who stated that the higher inorganic and organic fertilizer application in the pasture land is profitable (Fekede et al., 2015; Seyoum et al., 2020).

Table 4. Partial budget analysis of dry matter production.

Variables	Fertilizer application (Kg ha^{-1})		
	75	100	120
Dry matter yield (ton ha^{-1})	26.37	28.31	29.91
Nitrogen fertilizer cost	1125	1500	1800
Labor cost	3200	3200	3200
Selling price of grass (Birr Kg^{-1})	8.5	8.5	8.5
Gross Return (GR)	22,414.5	24,063.5	25,423.5
Total variable cost (TVC)	4325	4700	5000
Net Income (NI)	18,089.50	19,363.50	20,423.50
MRR (%) = $(\Delta \text{NI} / \Delta \text{TVC}) * 100$	0	339.73	345.78

Conclusion

The present study showed that nitrogen fertilizer levels and harvesting days had significant effects on agronomic performance and chemical composition of washo grass. Plant height (PH), crude protein yield (CPY), leaf to stem ratio (LSR), leaf length (LL), number of leaves (NL), herbage yield (HY), and total forage yield (TFY) increased significantly as the fertilizer level increased from 75 to 120 Kg ha^{-1} . The best response for CPY (ton ha^{-1}) was obtained at a fertilizer rate (120 Kg ha^{-1}). We recommend further evaluation of Washo grass through animal feeding and in vivo digestibility trials. Policy makers, Government or any concerned body could use the finding of this research to devise and apply production of the grass for improved livestock feeding and productivity in the study district and in areas with similar agro ecologies.

Data availability

All data supporting the findings of this study are included within the article (see relevant tables). No additional datasets were generated or analyzed.

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