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Influence of fertilization and defoliation interval on forage yield and chemical composition of *Cenchrus ciliaris* under sandy soil

HAMISI S. LUGUNDI[1,2,♥], DAVID D. MALEKO[1], JONAS B. KIZIMA[2], ZABRON C. NZIKU[2], PADRAIG FRENCH[3], VALENTINO URASSA[2], WALTER MANGESHO[2], SAMSON GOODDLUCK[2], SIZYA LUGEYE[2], HOSIANA MGONJA[2], SAMWEL MNGULU[2], ISMAIL S. SELEMANI[1]

[1]Department of Animal, Aquaculture and Range Sciences, Sokoine University of Agriculture. Morogoro 3004, Tanzania. Tel.: +255-718-006-533, ♥email: lugundihammy@hotmail.com
[2]Tanzania Livestock Research Institute (TALIRI). Tanga 5016, Tanzania
[3]Teagasc, Animal and Grassland Research Centre. Moorepark, Fermoy, Co. Cork P61 C996, Ireland

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Abstract. *Lugundi HS, Maleko DD, Kizima JB, Nziku ZC, French P, Urassa V, Mangesho W, Gooddluck S, Lugeye S, Mgonja H, Mngulu S, Selemani IS. 2025. Influence of fertilization and defoliation interval on forage yield and chemical composition of* Cenchrus ciliaris *under sandy soil. Asian J Agric 9: 234-243.* Improper defoliation intervals and nutrient-deficient soil limit the yield and quality of forages, resulting in poor dairy production. Using inorganic fertilizers to improve soil nutrition is expensive and pollutes the environment. The study was conducted to assess the influence of organic fertilization and defoliation intervals on the yield and chemical composition of *Cenchrus ciliaris* L. during the rainy season. The study was designed as a 3 × 4 factorial arrangement in a Completely Randomized Design (CRD), a method that allows for a comprehensive analysis of multiple factors and their interactions. It included three cutting intervals (9, 16, and 23 days) and three fertilizer types (compost cow manure, green processed bioorganic fertilizer, and liquid processed bioorganic fertilizer), plus a control with four replications. The study revealed that all fertilizer types had a significant influence on biomass yield, metabolizable energy, and crude protein percentages. In addition, fertilizer applications significantly decreased NDF, ADF, and ADL. On the other hand, the results show that the longer the cutting interval, the higher the biomass yields, but lower protein content and metabolizable energy. *Cenchrus ciliaris* fertilized compost cow manure and cut at a 23-day interval had a higher biomass yield and reasonable nutritive value. The study suggests the importance of considering fertilization and a cutting interval as appropriate management practices for *C. ciliaris* in related soil types and climates.

Keywords: *Cenchrus ciliaris*, crude protein, defoliation interval, fertilization, forage biomass yield

Abbreviations: GDP: Gross Domestic Product, TALIRI: Tanzania Livestock Research Institute, TARI: Tanzania Agriculture Research Institute, SUA: Sokoine University of Agriculture

INTRODUCTION

The agricultural sector employs a large number of people in Tanzania. It has a high economic livelihood contribution of about 66.3% to the population of Tanzania (Country profile United Republic of Tanzania 2015). However, poverty still exists mostly in rural areas. Hence, the transformation of the sector is important. Through the revolution of the agriculture sector, including the Livestock subsector, the livelihood of most poor people, predominantly in small-scale farming, will be improved (Kinyondo and Magashi 2017). Generally, livestock is mostly important, particularly in developing countries. It contributes to the livelihood of rural areas by about 60% in developing countries (FAO-RULIS 2019). In Tanzania, the contribution of livestock is very little compared to the number of animals in the country (Engida et al. 2015).

Tanzania is the second nation after Ethiopia, with the largest livestock in Africa, having a population of 37.9 million cattle, 27.6 million goats, and 9.4 million sheep (Budget speech MLF 2024/2025). The livestock's significant gain in the country is more in the number of livestock rather than increased productivity (Waziri and Uliwa 2020). In the economy of Tanzania, livestock contributes only 7.1% of the Gross Domestic Product (GDP). The low contributions of livestock are associated with a number of factors, including low livestock productivity (Engida et al. 2015). The scarcity of forage is among the factors that affect livestock productivity (Maleko et al. 2019). The availability and quality of grazing pastures, which serve as a feed source for animals, are continuously declining, particularly during the dry season. The increased competition from other land uses, including crop production, decreases grazing land (Mengistu 2018). Additionally, an increase in livestock numbers, an increase in population, and climatic changes contribute to conflicts among land users (Mwamfupe 2015).

The scarcity of quality forages limits dairy production in Tanga. Most smallholder farmers use natural pastures, mainly collected from the roadside, and crop residues as the main forage resources for their dairy cattle. The natural pastures are normally low in quality and quantity, and hence, there is no assurance of forage availability throughout the year for sustainable milk production. To reduce the shortage of forage and improve its quality, high-yielding, and quality forages that adapt to climate change need to be recommended. *Cenchrus ciliaris* L. is among the promising forages for improvement of dairy production; it has high productivity performance, resistance to grazing, fire, and resilience to climatic change (Patidar and Mathur 2017; Maeresera 2020; Ruvuga et al. 2022). *Cenchrus ciliaris* is high temperature-resistant, surviving in an area up to 50°C (Siller-Clavel et al. 2022). In large distributed area of practiced pasture production, *C. Ciliaris* can potentially give economic benefits to farmers. (Lutatenekwa et al. 2021). Rotation grazing is one of the important systems practiced by a few farmers with established *C. ciliaris*. Yet, the proper interval of time for grazing and resting the forage was not clearly known, which might result in feeding the animal low-quality forages. Therefore, the study to document the proper defoliation interval for better yield and quality of forages by simulation grazing was inevitable.

On the other hand, soil nutrient deficiency was identified as one of the limiting factors on forage productivity and quality (Hassan et al. 2015). Kizima et al. (2015) reported the high yield performance of *C. ciliaris* when using urea in Tanzania. Nonetheless, in addition to their high cost, prolonged applications of inorganic fertilizers may lead to environmental pollution, mineral imbalances, and ecological issues (Rashmi et al. 2020). Consequently, the application of eco-friendly organic fertilizer may fulfill its intended purpose (Wu 2017).

Information on improving the yield and quality of *C. ciliaris* through a combination of organic soil fertilization and harvest management in Tanzania is lacking. It was anticipated that the application of organic fertilizers would increase the yield and quality of *C. ciliaris* in Tanga Municipal. The objective of the current study was to improve forage yields and quality through appropriate cutting intervals and the use of environmentally friendly fertilizers during the rainy season. Specifically, the study assessed the growth attributes, chemical compositions, and yields of *C. ciliaris* in response to varying levels of organic fertilizer and simulated defoliation.

MATERIALS AND METHODS

Study area

The study was conducted on the station during the rainy season, between February and May 2024, at the Tanzania Livestock Research Institute (TALIRI)-Tanga Centre, found in the Tanga Region, eastern zone of Tanzania. The institute is located at a latitude of 5°05'19.24"S and a longitude of 39°03'51.15"E, at an altitude of 60 meters above sea level, in a tropical wet and dry season with yearly temperatures varying from 26 to 33°C, with the hottest month temperatures in January and February, and receives bimodal rainfall of 1230 to 1400 mm annually (Habimana et al. 2024). An experimental site is indicated in Figure 1, where the trend of temperature and rainfall during the period of the experiment is shown in Figure 2.

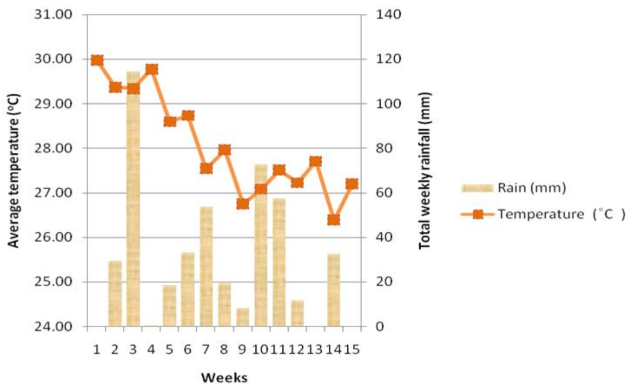

Figure 2. Trend of mean temperature and rainfall during the experimental period recorded from the HOBO data logging weather station installed at TALIRI, Tanga

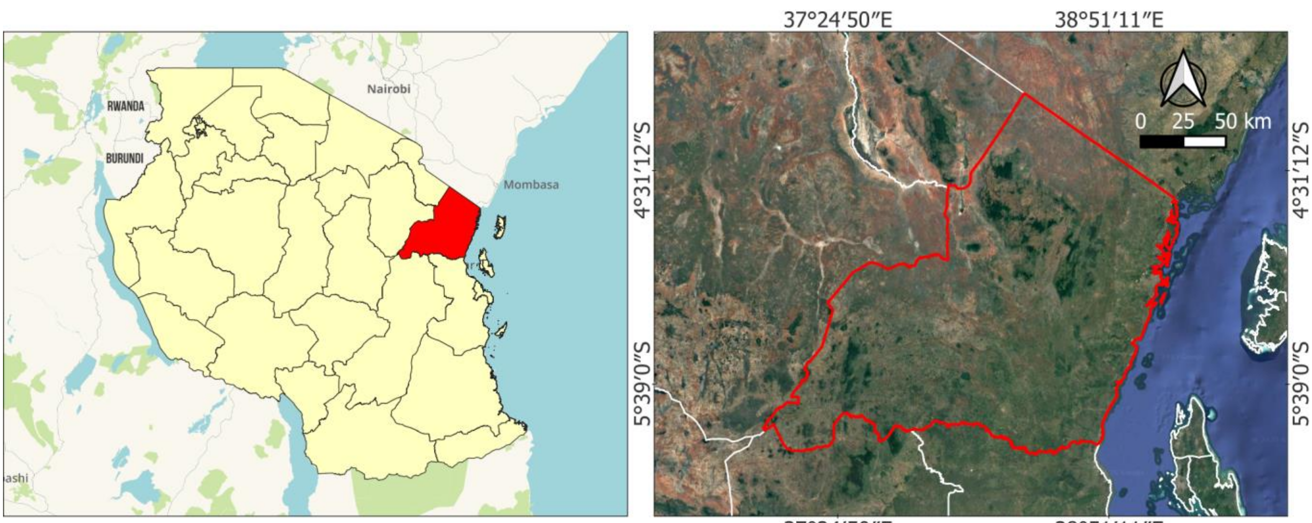

Figure 1. A study area in Tanga Municipality at TALIRI, Tanzania, indicating an experimental site

Procedures

Fertilizer collection and soil testing

The types of fertilizer used were processed bio-organic fertilizer (green and liquid fertilizers) and compost cow manure. A green fertilizer with 0.13, 0.04, 5.74, and 13.14% total nitrogen, potassium, phosphorus, and phosphate, respectively, was purchased from Afrint Bio Solution Ltd. This company supplies commercial organic products for organic farming in Tanzania. The liquid fertilizer with respectively 0.112, 0.046, and 0.0043% total nitrogen, potassium, and phosphorus was a plant source type of organic fertilizer collected from Lukwangule Organic Product Producer from Morogoro, Tanzania, which produces and supplies organic fertilizer for agricultural production.

Compost cow manure was collected and heaped for at least one year to allow decomposition. The part of the heaped manure was collected based on the amount needed for plot application and thoroughly mixed to create heaped composite manure. Subsequently, samples were obtained from five parts of the new heap and thoroughly mixed to obtain a composite sample for laboratory tests, where total nitrogen after laboratory testing was 1.55%. The source of compost cow manure was from the TALIRI cattle herds that were grazing near the station campus. The soil and compost-cow manure samples testing were done at the Tanzania Agricultural Research Institute (TARI) - Mlingano. The physical and chemical properties of the soil are shown in Table 1.

Experimental design and layout

The study was done in a 3 × 4 factorial arrangement in a Complete Randomized Design (CRD). There were two factors (the cutting interval and fertilizer type). Due to the fast re-growth of *C. ciliaris* in the coastal region during the rainy season, the data were collected in cutting intervals of three levels (9, 16, and 23 days re-growth from vegetation standardization by a homogenous cut). The fertilizer types had four levels (No Fertilizer (NF) as a control, compost cow manure (F1), green fertilizer (F2), and liquid fertilizer (F3)). These were set in four replicates to make a total of 48 subplots. Each plot had an area of 15 m² (5 × 3 m) with a spacing of 0.33 m inter-row and a 1 m path between each experimental plot. This experiment was done in two harvesting schedules in the rainy season, at early-mid rain and mid-late rain.

Site preparation and application of fertilizer

The standing sward of *C. ciliaris* established in May 2023 was used in the experiment. Pegs, manila string, and 100-meter tape were used for the plot's demarcation. The grass in all demarcated plots was cut uniformly using a grass cutter (shaving machine) at 5 cm above the ground. The full charged and sharp machine was used in uniform cut, where the blade height of the machine was adjusted to 5 cm above the ground. The grass shaving was started at one end of the plot and moved straight in overlapping rows. The consistent cutting height was highly considered to ensure the uniformity in all plots; however, any noted deviation in uneven terrain was repeated and made correct. The starting cutting time was recorded using a stopwatch, where the average cutting time used to complete all plots was about 11/2 hours, which was done in a single day. All harvested grasses were finally removed from the plots, and the plots were left clean. Throughout the time of uniform cut, no rainfall was recorded. A rate of 12 t/ha of compost cow manure (F1) was applied by broadcasting based on the nutrient deficiency of the soil on the following day after the uniform cut. This was done once throughout the experimental period. The rates of 7 kg ha^{-1} and 8 L ha^{-1} of green (F2) and liquid fertilizers (F3), respectively, were applied by spraying on the same day. Due to the leaching effect of sandy soil, three application times of the processed bio-organic (green and liquid) fertilizers with the same rate, respectively, were done in each harvesting schedule, with a seven-day interval skipped. A 7 kg and 8 L ha^{-1} of green and liquid fertilizers, respectively, were diluted in 1,400 and 4,000 L of water prior to application at each application time.

Data collection

Growth and yield

The data on growth and yield attributes for the first cut were collected based on the following parameters: plant height, tiller number, tiller diameter, biomass fresh yield, and dry matter yield. Following 9 days, subsequently data collection was repeated at 16 days and 23 days.

The data were collected in a sample size of one meter in length along a single row at the center of the plots. This was done to avoid edge effects. Plant heights were measured using a tape measure, whereby three plants (tallest, medium, and short) were measured, and an average height per plant in centimeters was calculated. Then, to obtain tiller numbers, three plants within the selected row were randomly selected and manually counted to get an average number of tillers per plant. By using a digital veneer caliper, the tiller diameter was measured from three randomly selected tillers from the randomly selected plants to obtain an average diameter per tiller per plant.

Table 1. Physical and chemical properties of the soil collected at 0-15 cm before fertilizer application on the experimental site

Particle size (%)	%textural composition	Remarks
Sand	62	
C. silt	16	
F. silt	12	
Clay	10	
Physical/chemical characteristics		
pH	6.0	Medium acid
Total nitrogen (%)	0.1	Very low
Organic carbon (%)	1.20	Low
Carbon to nitrogen ratio (C: N)	12	Good
Exchangeable bases		
Sodium (meq $100g^{-1}$)	0.15	High
Potassium (meq $100g^{-1}$)	1.41	Very high
Phosphorus (mg Kg^{-1})	6.62	Low
Calcium (meq/100g)	2.40	Medium
Magnesium (meq $100g^{-1}$)	0.32	Low
Cation Exchange Capacity (CEC) (meq $100g^{-1}$)	5.60	Low

The fresh grass sample was collected and weighed using the spring balance at 5 cm above the ground level from the sampling unit, which was one meter long along the row of the plot. The sample was then sent to the laboratory and put into an oven at 65°C for 48 hours to dry. After drying, a spring balance was used to measure the dry weight, and the yields were finally converted to t/ha. The same procedures were used at all times of data collection.

Chemical composition

The collected and dried samples were ground, sieved, and packed, ready for proximate analysis. Proximate analysis was done at the laboratory of Sokoine University of Agriculture (SUA). Total dry matter was obtained by drying the ground sample in an oven set to 105°C overnight. Ash and organic matter contents were determined after burning samples using a muffle furnace at 550°C for 3 hours, following the AOAC procedure (1990). Total Nitrogen (N) was determined using the Kjeldahl method and multiplied by 6.25 to obtain Crude Protein (CP). The ether extract (crude fat) was determined using the Tecator Soxtec extraction method. Nitrogen-free extract (%NFE) was calculated using %NFE = 100% - (%CP + %CF + %EE + %Ash) (National Research Council 2001), where CP, CF, and EE are crude protein, crude fiber, and ether extract, respectively. Neutral Detergent Fiber (NDF), Acid Detergent Fiber (ADF), and Acid Detergent Lignin (ADL) were determined using the procedure of Van Soest et al. (1991) by the Ankom fiber analyzer DELTA at the laboratory of TALIRI Tanga. Metabolizable Energy (ME) was calculated using the formula of ME = 1.549 + 0.0102 CP + 0.0275 EE + 0.0148 NFE - 0.0034 CF (Ellis 1981), where CP is crude protein, EE is ether extract, NFE is nitrogen-free extract, and CF is crude fiber.

Data analysis

Data were analyzed using the General Linear Model procedure of the Statistical Analysis System (SAS 2000), and the following model was used:

$$Yijk = \mu + A_i + B_j + (AB)ij + E_{ijk}$$

Where: Yijk: Observation (growth, biomass yield, and chemical composition), μ: Overall mean, A_i: effect due to i^{th} fertilizer types, B_j: effect due to j^{th} defoliation interval, (Ab_{ij}): effect due to interaction of fertilizer type and defoliation interval, and E_{ijk}: Sampling error.

The Duncan Multiple Range Test was used to compare the different means for all observations at a 0.05 level of significance.

RESULTS AND DISCUSSION

Growth and yield

Table 2 shows the effects of fertilizer types and cutting intervals on growth and yield parameters, as well as their interactions with each other, as shown in Table 3. All types of fertilizer were found to significantly influence plant height, tiller number, and tiller diameter of *C. ciliaris* (P < 0.05) compared to unfertilized plots. The compost cow manure influenced the highest plant height (58.9 cm) and tiller diameter (2.65 mm), followed by green and liquid fertilizers, respectively. However, there was no significant difference among the 3 types of fertilizers in the effect on tiller numbers per plant. Cutting intervals significantly influenced the plant height, tiller number, and tiller diameter (P < 0.05), where the mean values were increasing with long cutting intervals of 9, 16, and 23 days, respectively.

Higher dry matter yields (1.89 t DM ha^{-1}, 1.74 t DM ha^{-1}, and 1.69 t DM ha^{-1}) for *C. ciliaris* were recorded in the plots that received compost cow manure, green manure, and liquid fertilizer, respectively. The application of fertilizers provides essential nutrients for plant growth (plant height, tiller number, and diameter), resulting in a higher biomass yield. The same results were reported by Karydogianni et al. (2022); Alhammad et al. (2023), that the increase in yield is attributed to a considerable correlation with N fertilization.

Table 2. Effect of types of fertilizer and cutting interval on plant height, tiller number, tiller diameter, and biomass yield of *C. ciliaris*

Factors	Levels	Variables			
		Plant height (cm)	Tiller number	Tiller diameter (mm)	DM yield (t $DMha^{-1}$)
Types of fertilizer	NF	40.50^{c}	24^{b}	1.90^{c}	1.12^{b}
	F1	58.89^{a}	33^{a}	2.65^{a}	1.89^{a}
	F2	55.43^{ba}	32^{a}	2.48^{b}	1.74^{a}
	F3	52.68^{b}	33^{a}	2.42^{b}	1.69^{a}
	p-value	<0.0001	<0.0001	<0.0001	<0.0006
	SEM±	1.4	2	0.06	0.13
Cutting intervals	9 days	37.26^{c}	27^{c}	1.86^{c}	0.83^{c}
	16 days	51.63^{b}	30^{b}	2.50^{b}	1.44^{b}
	23 days	66.73^{a}	35^{a}	2.72^{a}	2.56^{a}
	p-Value	<0.0001	<0.0001	<0.0001	<0.0001
	SEM±	1.2	1	0.05	0.12

Note: Means with different superscripts within the column of the same factor are significantly different at P<0.05, SEM: Standard Error of the Mean, NF: No Fertilizer (control), F1: Compost cow manure, F2: Green processed bio-organic fertilizer, F3: Liquid processed bio-organic fertilizer

Table 3. Effect of fertilizer type and cutting interval on plant height, tiller number, tiller diameter, and dry matter yield of *C. ciliaris* and their interaction

Types of fertilizer	Cutting intervals	Variables			
		Plant height (cm)	Tiller number	Tiller diameter (mm)	DM yield (t DM ha^{-1})
NF	9 days	32.24^b	21	1.53^b	0.71^b
	16 days	41.13^a	22	2.00^a	1.05^{ab}
	23 days	48.12^a	28	2.17^a	1.59^a
F1	9 days	41.04^c	29	2.12^c	0.92^b
	16 days	53.51^b	33	2.75^b	1.47^b
	23 days	82.12^a	38	3.09^a	3.27^a
F2	9 days	39.16^c	26	1.88^b	0.83^c
	16 days	55.41^b	33	2.73^a	1.67^b
	23 days	71.71^a	37	2.82^a	2.72^a
F3	9 days	36.63^c	30	1.93^c	0.86^c
	16 days	56.45^b	33	2.52^b	1.57^b
	23 days	64.96^a	38	2.83^a	2.65^a
	p-value	<0.0001	0.9789	0.3789	0.0564
	SEM±	2.43	3	0.1	0.23
	Interaction	**			

Note: Means with the different superscript within the column of the same factor s are significantly different at P<0.05, SEM: Standard Error of the Mean; NF: No Fertilizer (control), F1: Compost cow manure, F2: Green processed bi-organic fertilizer, F3: Liquid processed bio-organic fertilizer, **: Significant interaction at p<0.05

In comparing the performance between fertilizer types, the composite cow manure performed relatively better in yield than processed bioorganic fertilizers (both green and liquid). The higher performance of composite cow manure could be due to a lower leaching effect on nutrients compared to processed bioorganic fertilizer that was in liquid form. Kang et al. (2011) reported greater leaching of nutrients when using organic liquid fertilizer compared to solid organic fertilizer, supporting this claim. Similarly, Prado et al. (2023) reported the decreased leaching of nutrients to soil through the use of manure-based fertilizer. Tan et al. (2011) also reported a high yield of corn using the solid manure organic fertilizer, more than the liquid cattle organic fertilizer.

In considering the influence of cutting interval on the grass yield, the means of growth and yield parameters were observed to differ significantly (P < 0.05) on all cutting intervals. The highest performance was recorded at 23-day cutting intervals, and the lowest was at 9-day cutting intervals. The highest performance at 23 days could be due to enough resting time for the plant before harvest, which influenced more leaves, tiller numbers, and diameter, resulting in a higher biomass yield. These results are comparable to the results of Gilo et al. (2022), who reported low yields at most harvest frequencies.

There were no significant interactions between fertilizer types and cutting intervals on the tiller number, tiller diameter, and biomass yield; however, a significant interaction (P < 0.05) was observed on plant height, where the highest mean value (82.12 cm) was recorded from the plots fertilized with compost cow manure harvested at a 23-day interval. Plots fertilized with green and liquid fertilizers, as well as unfertilized plots at the same cutting interval, performed differently in terms of plant height. This might contribute highly to biomass yield, where the highest value, 3.27 t DM ha^{-1}, was recorded from plots fertilized with compost cow manure harvested at a 23-day interval. López-Chuken (2012) reported that nitrogen fertilization and a long cutting interval yielded the highest yield, which these results agreed with.

Apart from the effects of defoliation interval and fertilization, the result reported in this study could also be influenced by the properties of sandy soil under which the study was conducted. The response of the plant to defoliation interval and fertilization can change depending on the soil properties, including water retention capacity, retention of nutrients, and microbial biomass status (Brady and Weil 2016). Therefore, the performance of *C. ciliaris* under different soil types, such as sandy soil, may respond differently to defoliation interval and fertilization, to limit the generalizability of this study. The defoliation interval and fertilization are key management practices for *C. ciliaris* discussed in this study; however, spacing, mulching, rotation grazing, and water harvest are also important to maintain soil moisture and nutrients (Ojo et al. 2020; Fenetahun et al. 2021; Mangani et al. 2022). Therefore, this management practice can be combined and implemented to enhance productivity in different climatic conditions.

Chemical composition

Percentage Crude protein (%CP)

The effect of fertilizer type and cutting interval on crude protein percentage is shown in Table 4, and their interaction is indicated in Table 5. The percentage of crude protein was significantly (P < 0.05) affected by cutting interval, fertilization, and their interactions. All types of fertilizer used in this study significantly influenced higher %Cp than unfertilized plots (P < 0.05). The highest %CP (16.73%) of *C. ciliaris* was recorded at composite cow manure, followed by liquid and green processed fertilizer, respectively. The lowest %CP (13.47%) was recorded from unfertilized plots. This indicates that the %CP of the plant increased with fertilization. This effect might be due to N applied from types of fertilizer to the soil that could be quickly absorbed and transformed into nitrate-nitrogen that is further included in the organic material of the plant (Maeresera 2020). In contrast, López-Chuken (2012) reported no significant increase in the crude protein content of *C. ciliaris* by N fertilization. However, a significant increase in crude protein content with an increase in fertilization in the current findings is agreed upon by the results reported by Kizima et al. (2015) on the same species.

The cutting interval significantly affected the crude protein content ($P < 0.05$). It was recorded higher (18.40% Cp) at a 9-day interval of cutting and lower at a 23-day cutting interval. This indicates that the percentage of crude protein decreases as plant maturity increases. The shorter cutting interval gives higher protein content than a long cutting interval. This might be due to the decrease in leaf-to-stem ratio and increase in structural carbohydrate and lignin content as the plant matures (Yigzaw 2019). The results of the present study also agree with those reported by Kisambo et al. (2023) that an increase in harvesting interval results in a decrease in crude protein content of the plant due to grass maturation.

The interaction of fertilization and cutting interval on crude protein is shown in Table 5. The crude protein was significantly affected by the interaction. The highest mean value (19.24%) for crude protein was recorded from the plots fertilized with liquid processed bio-organic fertilizer, followed by green processed organic fertilizer, compost cow manure, and control, respectively. All these higher records were at a 9-day cutting interval. From this interaction, the crude protein content was improved from 10.62% at 23 days of harvest to 19.24% at 9 days of harvesting intervals. These results are much higher than those of López-Chuken (2012), who reported 18% CP of *C. ciliaris* at a 21-day harvest.

Table 4. Effect of types of fertilizer and cutting interval on chemical composition (proximate) of *C. ciliaris*

Factors	**Levels**	**Variables**					
		DM (%)	**ASH (%)**	**OM (%)**	**CP (%)**	**EE (%)**	**NFE (%)**
Types of fertilizer	NF	94.91^{c}	13.86^{d}	81.04^{b}	13.47^{d}	2.04^{d}	36.04^{a}
	F1	95.73^{ba}	15.12^{a}	80.61^{c}	16.73^{a}	2.06^{c}	33.48^{c}
	F2	95.63^{b}	14.02^{c}	81.61^{a}	15.74^{c}	2.08^{b}	34.70^{b}
	F3	95.91^{ab}	14.13^{b}	81.79^{a}	15.88^{b}	2.09^{a}	34.71^{b}
	p-value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
	SEM±	0.08	0.02	0.08	0.02	0.002	0.09
Cutting intervals	9 days	94.98^{b}	15.39^{a}	79.59^{c}	18.40^{a}	2.12^{a}	31.61^{c}
	16 days	95.06^{b}	14.61^{b}	80.45^{b}	15.02^{b}	2.07^{b}	34.97^{b}
	23 days	96.59^{a}	12.85^{c}	83.74^{a}	12.95^{c}	2.01^{c}	37.62^{a}
	p-value	<0.0001	<0.0001	<0.0001	<0.0001	0.0001	<0.0001
	SEM±	0.07	0.02	0.07	0.02	0.002	0.08

Note: Means with the different superscript within the column of the same factor are significantly different at $P<0.05$, SEM: Standard error of the mean, DM: Dry matter, OM: Organic matter, CP: Crude protein, EE: Ether extract and NFE: Nitrogen free extract, NF: No fertilizer (control), F1: Compost cow manure, F2: Green processed bio-organic fertilizer, F3: Liquid processed bio-organic fertilizer

Table 5. Effect of fertilizer type and cutting interval on chemical composition (proximate analysis) of *C. ciliaris* and their interaction

Types of fertilizer	**Cutting interval**	**Variables**					
		DM (%)	**ASH (%)**	**OM (%)**	**CP (%)**	**EE (%)**	**NFE (%)**
NF	9 days	94.51^{b}	16.10^{a}	78.41^{c}	16.63^{a}	2.09^{a}	32.44^{c}
	16 days	94.08^{c}	13.94^{b}	80.14^{b}	13.14^{b}	2.03^{b}	36.03^{b}
	23 days	96.13^{a}	11.55^{c}	84.58^{a}	10.63^{c}	2.01^{c}	39.66^{a}
F1	9 days	95.56^{b}	16.04^{a}	79.52^{b}	18.78^{a}	2.12^{a}	30.90^{c}
	16 days	94.88^{c}	15.26^{b}	79.62^{b}	16.07^{b}	2.05^{b}	33.96^{b}
	23 days	96.73^{a}	14.05^{c}	82.69^{a}	15.35^{c}	2.00^{c}	35.59^{a}
F2	9 days	94.43^{c}	14.66^{a}	79.77^{c}	18.95^{a}	2.13^{a}	30.89^{a}
	16 days	96.04^{b}	14.33^{b}	81.71^{b}	15.16^{b}	2.09^{b}	35.77^{b}
	23 days	96.41^{a}	13.06^{c}	83.36^{a}	13.12^{c}	2.01^{c}	37.45^{c}
F3	9 days	95.40^{b}	14.75^{b}	80.65^{b}	19.24^{a}	2.14^{a}	32.23^{a}
	16 days	95.25^{b}	14.90^{a}	80.35^{b}	15.71^{b}	2.11^{b}	34.11^{b}
	23 days	97.09^{a}	12.74^{c}	84.36^{a}	12.68^{c}	2.02^{c}	37.79^{c}
	p-value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
	SEM±	0.13	0.04	0.14	0.04	0.004	0.16
	Interaction	**	**	**	**	**	**

Note: Means with the different superscript within the column of the same factor are significantly different at $P<0.05$. SEM: Standard Error of the Mean, DM: Dry Matter, OM: Organic Matter, CP= Crude Protein, EE= Ether Extract and NFE= Nitrogen Free Extract, NF: No Fertilizer (control), F1: Compost Cow Manure, F2: Green processed bio-organic fertiliser1, F3: Liquid processed bio-organic fertilizer, **: Significant interaction at $p<0.05$

This difference might be due to the significant interaction effect of both fertilizer type and cutting interval reported in the current study. The interaction of compost cow manure and cutting interval at 16 days and 23 days was recorded (16.07 and 15.35%), respectively, more than other types of fertilizer used in the current study. This indicates that compost cow manure gives better crude protein on *C. ciliaris* when harvested at these two mentioned cutting intervals.

Percentage Ether Extract (%EE)

Table 4 indicates the effect of fertilization and cutting interval on the percentage of ether extract, and Table 5 indicates the interaction of the two. All types of fertilizer significantly ($P < 0.05$) affected the percentage of ether extract (%EE) compared to unfertilized plots. The highest mean value (2.09%) of ether extract was recorded from plots fertilized with liquid bio-organic fertilizer, and unfertilized plots were recorded with the lowest value (2.04%) of ether extract. This indicates that the percentage of ether extract increases with fertilization. The current results agreed with those of Culicov et al. (2024), who used organic fertilizer on three grass species (*Agrostis capillaris* L., *Festuca rubra* L., and *Nardus stricta* L.) and reported an increase in %EE with fertilization. Furthermore, the significant increase in %EE with fertilization on rhodes grass, which is similar to the present study, was reported by Christopher (2020).

Cutting the interval significantly ($P < 0.05$) affected the percentage of ether extract. The percentage of ether extract was recorded as the highest (2.12%) at 9 days of harvest, and the lowest mean value (2.01%) of ether extract was recorded at 23 days of harvest. This indicates that the content of ether extract decreases with the increase of plant age. This might be due to plant maturation. These results are supported by Aiyesa et al. (2019), who reported a significant decrease in ether extract with plant maturity on *Cenchrus purpureus* (Schumach.) Morrone. (Mendoza-Pedroza et al. 2022) also reported a significant decrease in the content of ether extract with an increase in the harvesting age of *Pennisetum purpureum*. The interaction of types of fertilizer and cutting interval significantly ($P < 0.05$) recorded higher (2.14%) EE on liquid processed bio-organic fertilizer at 9 days of harvest, and the lowest value was recorded in 23 days of harvest on the plots harvested with compost cow manure.

Percentage nitrogen-free extract (%NFE)

The effect of fertilization types and cutting interval (Table 4) and their interaction (Table 5) significantly ($P < 0.05$) affected the percentage of nitrogen-free extract (%NFE). The highest free nitrogen extract (36.04%) on fertilization was significantly ($P < 0.05$) recorded from unfertilized plots, followed by liquid processed bio-organic fertilizer, green processed bio-organic fertilizer, and compost cow manure, respectively. This indicates that the %NFE decreases with fertilization. Mrázková et al. (2020) found a decrease in %NFE from 48.2-47.85% in the grasses by application of organic fertilizer, which supports the current finding.

The long harvest interval of 23 days was significantly ($P < 0.05$) recorded as the highest mean value (37.62%) NFE, while the harvest at 9 days recorded the lowest value (31.61%). This shows that %NFE increases with the increase in harvesting age. This might be due to the maturation effect on the nutrients of the plant. In contrast, Jagadeesh et al. (2017) found a significant decrease in %NFE of *P. purpureum* among stages of plant growth. Differences in plant species might cause this difference. However, the current finding is also supported by Jagadeesh et al. (2017), who reported the increases in %NFE of *P. purpureum* in another stage of growth.

Fiber fraction and metabolizable energy

The effect of fertilizer types and cutting intervals on the percentage of Crude Fiber (CF), Neutral Detergent Fiber (NDF), Acid Detergent Fiber (ADF), Acid Detergent Lignin (ADL), and Metabolizable Energy (ME) is shown in Table 6. The % CF, % NDF, % ADF, ADL, and I were significantly influenced by fertilizer type and cutting interval ($P < 0.05$). The application of fertilizer significantly decreased the fiber content ($P < 0.05$). The lowest 27.66, 55.92, 31.42, and 3.17% of crude fiber, neutral detergent fiber, acid detergent fiber, and acid detergent lignin, respectively, were recorded from plots fertilized with compost cow manure. The highest %CF, %NDF, %ADF, and %ADL were recorded from unfertilized plots. Hassan et al. (2015) also reported a decrease in fiber content by fertilization. Fertilizer tends to influence plant growth by increasing new leaves and shoots, which results in reduced lignification of the plant. The fiber contents were significantly increased with increasing cutting intervals ($P < 0.05$). The lowest %CF, %NDF, %ADF, and %ADL were recorded from a 9-day cutting interval, while the highest records were from the 23-day interval of cut. The increase of fiber content with increasing intervals of cut was due to the decrease in leaves-to-stem ratio, advances in structural carbohydrates, and cell wall content as the plant matures (Kefyalew and Alemu 2020). The current findings agree with Yigzaw (2019).

The application of fertilizer significantly increased the metabolizable energy of *C. ciliaris* ($P < 0.05$). The highest 5.0 MJ/kg DM Metabolizable Energy (ME) was recorded from compost cow manure, followed by green and liquid fertilizer, respectively. The lowest metabolizable energy was recorded from non-fertilized plots. This result agreed with the results of Hazary et al. (2015), who reported an increase in ME of jumbo grass with increasing N fertilization. The Metabolizable Energy (ME) was significantly decreased with increasing cutting interval ($p < 0.05$). The highest, 5.33 MJ $kgDM^{-1}$, was recorded from a 9-day interval of cutting, and the lowest was recorded from a 23-day cutting interval. Similarly, Yigzaw (2019) reported a decrease in ME with an increase in the intervals of cut. This could result from increasing the cell wall composition, which lowers plant digestibility and reflects the low ME of the grass.

This study reveals that extending cutting intervals increases forage yield while reducing nutritive values such as crude protein, ME, and ether extract. With extended cutting intervals, the fibre content increases. This indicates poor digestibility and palatability of the plant (Naseri et al. 2017; Fayos-Febrer et al. 2023), which can negatively affect livestock intake and performance. Therefore, this study suggests the importance of balancing both forage yield and quality to ensure palatability of the forage for better livestock performance.

The findings of this study reveal that the organic fertilizer improves both biomass yield and quality, particularly the use composted cow manure is used in sandy soil. Further, Reganold and Wachter (2016) reported long-term benefits on the use of organic fertilizer through enhanced soil health, decreased environmental degradation, and improved system resilience as crucial for sustainable productivity in shifting climatic patterns. Despite all these advantages of organic farming, some critics may argue that dependence on organic farming practices may fall short in satisfying the increasing demand for dairy production in a dynamically changing climate. Therefore, suggested innovative approaches, integrating organic practices with scientific advancements such as improved genetically diverse forage cultivars, exactitude nutrient management, and rotation grazing can help meet productivity demand while ensuring adaptability in the face of climate challenges without compromising environmental stewardship (Sekhar et al. 2024).

Economic analysis on the cost of fertilizers used for forage yield

The cost and benefit analysis to determine the return from forage production is shown in Table 7. The composted manure had a higher labor charge application compared to green and liquid bio-organic fertilizer; this might be due to the high volume, extra time, and physical effort required in the application of composted manure, which could reflect a high labor charge. The returns obtained from plots fertilized with composted cow manure and liquid fertilizer were higher compared to unfertilized plots. However, the application of composted cow manure had the highest return among all types of fertilizer. The application of green fertilizer yielded a low return compared to the control; this might be due to the high price of this type of fertilizer. Despite the lowest return of green fertilizer in a single aspect of forage yield, yet, the nutritive value of forage obtained from plots fertilized with green fertilizer, which was not economically analysed, was higher than that obtained from unfertilized plots. This reason explains the substantial benefit of this type of fertilizer over the non-use of fertilizer.

Compared to unfertilized plots in this study, all fertilized plots had higher nutritional value, especially crude protein, ether extract, and metabolizable energy, which are very essential to improving livestock productivity. Apart from improving the nutritional value of the forage, the ecological benefits of organic fertilizer to the soil have not been economically evaluated. Organic fertilization, especially composted cow manure, may contribute to maintaining soil structure by enhancing microbial activities and organic matter that resulting in long-term soil health and fertility (Adugna 2016).

This study reveals that the use of composted cow manure has economic advantages over other types of fertilizer. This might be the reason for the less costly and high-yielding effect in the use of compost cow manure observed in this study. Composted cow manure has a long-term effect, leading to improved productivity and resilience for sustainable farming. It is locally available with less cost and does not need frequent application as compared to commercial organic fertilizers. Commercial fertilizers need frequent application and are obtained at a high price, and with price fluctuation, which makes them economically impractical to many smallholder farmers. Since the availability of organic fertilizer varies depending on the area, the farmers have to be equipped with knowledge on how to utilize the locally available organic fertilizer for economical and sustainable farming.

Table 6. Fiber fraction and metabolizable energy of *C. ciliaris* as influenced by types of fertilizer and cutting intervals

Factors	Levels	Variables				
		CF (%)	NDF (%)	ADF (%)	ADL (%)	ME (MJ Kg DM^{-1})
Types of fertilizer	NF	29.50[a]	62.26[a]	34.80[a]	3.58[a]	4.42[c]
	F1	27.66[d]	55.92[c]	31.42[c]	3.17[b]	5.0[a]
	F2	28.49[c]	58.82[b]	32.70[b]	3.20[b]	4.88[b]
	F3	28.76[b]	58.89[b]	32.72[b]	3.24[b]	4.82[b]
	p-value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
	SEM±	0.06	0.23	0.3	0.06	0.02
Cutting intervals	9 days	26.24c	55.06c	30.06c	2.41c	5.33a
	16 days	28.41b	58.04b	33.50b	3.21b	4.70b
	23 days	31.17a	63.82a	35.17a	4.26a	4.32c
	p-value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
	SEM±	0.05	0.2	0.26	0.05	0.02

Note: Means with the different superscript within the column of the same factor are significantly different at P<0.05, SEM: Standard error of the mean, CF: Crude Fiber, NDF: Neutral Detergent Fiber, ADF: Acid Detergent Fiber, ADL: Acid Detergent Lignin and ME: Metabolisable Energy, NF: No Fertilizer (control), F1: Compost cow manure, F2: Green processed bio-organic fertilizer, F3: Liquid processed bio-organic fertilizer

Table 7. Return estimated from the total forage yield of three cuts in difference fertilizer treatments

Income and expenditure	Cutting intervals	Types of fertilizer			
		NF	F1	F2	F3
Biomass yield (t DM Ha^{-1})	9 days	0.71	0.92	0.83	0.86
	16 days	1.05	1.47	1.67	1.57
	23 days	1.59	3.27	2.72	2.65
Total biomass yield (t DM Ha^{-1})		3.35	5.66	5.22	5.08
Income Sales (USD)		319	539	497	484
Cost of fertilizer per hectare (USD)		0	83	222	129
Fertilizer application labor charge per Ha (USD)		0	25	18	18
Expenditure (USD)		0	108	240	147
Returns (USD)		319	431	257	337

In conclusion, the current study reveals that the fertilization of *C. ciliaris* by using organic fertilizer improves its quantity and quality when harvested at the proper stage. Despite the fact that all types of organic fertilizer improved the quality and quantity at all harvesting stages compared to unfertilized plots (control), the compost cow manure became superior in many parts. At a cutting interval of 23 days, plots fertilized with compost cow manure produced a 3.27 t DM ha^{-1} biomass yield and 15.35% crude protein, which are reasonable for dairy cattle production. It may accommodate many cows and supply enough protein content. The %CP produced at this stage was beyond the threshold levels: 7.5% required for rumen function, 10.6% needed for tropical grass species, as well as 15% minimum needed for animal growth and lactation, as reported by Hassan et al. (2015). Therefore, under sand soil tropical sub-humid conditions, the use of compost cow manure and grazing/cutting intervals of 23 days could be recommended for Buffel grass; this will not need to supplement crude protein-based feeds for dairy cattle. However, further study to explore the influence of defoliation and fertilization on different types of soil and agroecological zones is recommended.

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