INTL J TROP DRYLANDS
Volume 9, Number 2, December 2025
Pages: 111-119

E-ISSN: 2775-6130
DOI: 10.13057/tropdrylands/t090202

Agronomic and economic factors influence the productive performance of *Cenchrus ciliaris* under different types of organic fertilizers

HAMISI S. LUGUNDI[1,2,♥], DAVID D. MALEKO[1], JONAS B. KIZIMA[2], ZABRON C. NZIKU[2], PADRAIG FRENCH[3], SIZYA LUGEYE[2], ISMAIL S. SELEMANI[1]
[1]Department of Animal, Aquaculture and Range Sciences, Sokoine University of Agriculture. P.O. Box 3004, Morogoro, Tanzania
[2]Tanzania Livestock Research Institute (TALIRI). P.O. Box 5016, Tanga, Tanzania. Tel.: +255-718-006533, ♥email: lugundihammy@hotmail.com
[3]Teagasc, Animal and Grassland Research and Innovation Centre. Fermoy, Cork P61 C996, Ireland

Manuscript received: 23 January 2025. Revision accepted: 7 August 2025.

Abstract. *Lugundi HS, Maleko DD, Kizima JB, Nziku ZC, French P, Lugeye S, Selemani IS. 2025. Agronomic and economic factors influence the productive performance of* Cenchrus ciliaris *under different types of organic fertilizers. Intl J Trop Drylands 9: 111-119.* *Cenchrus ciliaris* L. (buffel grass) is among the essential tropical forage grasses, characterized by its high forage yield, nutritive value, grazing, drought, and fire resistance. However, nutrient deficiency in tropical sand soils is known to limit forage and seed yield, as well as the quality of *C. ciliaris.* A study was conducted to evaluate the agronomic and economic factors affecting *C. ciliaris*, focusing on seed yield and quality, forage hay yield, and its composition under different types of organic fertilizers during the rainy season. The results revealed that all fertilizer types significantly influenced seed yield, seed quality, hay biomass, and chemical composition over unfertilized plots; in comparison with other types of fertilizer, green fertilizer was found to increase crude protein content from 6.99 to 7.96% and decrease crude fiber and acid detergent fiber in harvested hay, respectively, from 32.98 to 31.7% and from 40.76 to 38.35%. On the other hand, the composted cow manure yielded the highest seed yield of 70 kg ha^{-1} and had the highest germination percentage (29%). The application of compost cow manure also increased economic return by 0.7 times. Therefore, the application of composted cow manure on *C. ciliaris* under sandy soil in a tropical sub-humid climate is the best management practice for enhancing the performance of grass pasture seeds.

Keywords: Buffel grass, compost cow manure, processed bio-organic fertilizer, seed quality, seed yield

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

INTRODUCTION

Agriculture serves as the primary engine of the sub-Saharan African economy (Erdaw 2023). It employs approximately 65 to 70% of the labor force in Africa (Roseboom et al. 2016). Approximately 20-25% of ruminant livestock globally reside in Sub-Saharan Africa, where the variety of products and services provided by livestock can help millions of impoverished individuals in the developing world earn a livelihood (Erdaw 2023). Livestock is crucial to the economy of Sub-Saharan Africa, accounting for nearly 35% of the agricultural GDP (Erdaw 2023).

In Tanzania, the livestock sector accounts for 7.1% of the country's Gross Domestic Product (GDP). The country has a population of 37.9 million cattle, 27.6 million goats, and 9.4 million sheep, of which 90% are dependent on natural pastures from open-access and communal rangelands (Budget Speech MLF 2024/2025). Due to land competition, grazing land is continuously diminishing, resulting in forage scarcity and, consequently, low livestock productivity (Mengistu 2018; Maleko et al. 2019). For these reasons, the demand for establishing high-yielding and quality pastures has increased. The pasture establishment has been promoted as an opportunity to improve the sustainable forage supply for livestock production (Muzzo and Provenza 2018).

There are many types of pasture in Tanzania, but *Cenchrus ciliaris* L. (buffel grass) is considered the best perennial grass for sandy soils in a tropical sub-humid climate. This is because it exhibits high productive performance and nutritional value (Patidar and Mathur 2017; Ruvuga et al. 2022). *C. ciliaris* is resistant to drought, grazing, and fire (Maeresera 2020). It can survive in very high-temperature areas approaching 50°C (Siller-Clavel et al. 2022). *Cenchrus ciliaris* is considered a potential perennial species that may give economic benefits to livestock keepers where widespread pasture production is practiced (Lutatenekwa et al. 2021). *C. ciliaris* is an indigenous species of African semi-arid regions and is highly favored by grazing animals, which diminishes its likelihood of becoming invasive rangeland plants and supplanting other valuable indigenous grass species (Ngenzi et al. 2024)

Despite the unique beneficial characteristics of *C. ciliaris* in tropical regions, the establishment of this species in Tanzania is limited by the poor availability of quality seeds, which forces many farmers to rely on low-quality natural pastures that are insufficient to sustain their cattle throughout the year. Several factors, including soil nutrient deficiency attributed to the lack of fertilizer use, continuous cultivation, and climate change, may impact pasture farming, including pasture seed production, in many developing countries (Tembo et al. 2024). Research has shown that most soils have experienced considerable loss of fertility and require proper management for sustained yield (Stewart et al. 2020). The yield performance of *C. ciliaris* varies in different soil types. Higher yield performance was reported in soils with high moisture retention, adequate soil nutrient availability, and sufficient drainage, such as clay-loam and loam soils (Kisambo et al. 2024). However, soil with poor aeration, such as clay soil, affects root growth and penetration, resulting in a lower pasture yield compared to clay-loam and loam soils (Kisambo et al. 2024). Despite the high influence of root penetration of sandy soil, it gives low yield performance due to low fertility and high lose of moisture in a shorter period (Kisambo et al. 2024)

To mitigate this lack of quality seeds, especially in sandy soil, studies on the proper management of established *C. ciliaris* farms are imperative. Therefore, managing soil fertility was necessary to enhance the quality and productivity of the pasture seeds. Soil fertility can be enhanced through several methods, including the application of organic fertilizers to established pastures, the use of chemical fertilizers, or a combination of both inorganic and organic fertilizers (Bader et al. 2021; Mteta et al. 2022; Tembo et al. 2024).

In Tanzania, *C. ciliaris* was reported to produce high pasture seed yields when treated with urea (Kizima 2015). However, apart from being expensive, using urea as an inorganic fertilizer over a prolonged period can have ecologically negative effects, such as mineral imbalances and environmental degradation (Rashmi et al. 2020). It was anticipated that the use of ecologically friendly organic fertilizer could serve its intended role (Wu 2017). Organic fertilizer improves physiochemical properties of the soil, increase microbial density and activities, total soluble carbon and water-soluble carbon (Wang et al. 2017). Several studies reported the improved seed yield and quality by application of different organic fertilizer in different crops. The application of bio-organic fertilizer on rice enhanced grain yield (Naher et al. 2021). The application of horse manure on *C. ciliaris* led to increased seed yield and quality (Maeresera 2020). The application of cattle manure and bioslurry enhanced seed yield in rhodes grass (Aredo et al. 2020; Getie et al. 2022) in Ethiopia. Charshanbiyev (2023) also reported the increased seed yield and quality on Alfa alfa production by application of organic fertilizer.

This study aimed to address a research gap in the use of various types of organic fertilizers to enhance *C. ciliaris* pasture seed yield and quality, a deficiency currently present in Tanzania. The objective of this study was to enhance seed yields and quality by utilizing cost-effective types of fertilizer effectively during the rainy season. Specifically, the study assessed seed yield, germination, the yield of harvested hay, its chemical composition, and economic efficacy.

MATERIALS AND METHODS

Study area

The study was conducted in 2024 at a station during the rainy season, from February to June, at the Tanzania Livestock Research Institute (TALIRI) - Tanga Centre, situated in the Tanga Region, eastern zone of Tanzania. TALIRI Tanga is 60 meters above sea level and 6 km from Indian Ocean. It is located at 5°05'19.24"S and 39° 03'51.15"E. It experiences a tropical wet and dry season, with temperatures ranging from 26 to 33°C annually, and January and February are the hottest months. It receives between 1,230 and 1,400 mm of rain annually (Habimana et al. 2024). The experimental site is illustrated in Figure 1, and the trends of temperature and rainfall during the experimental period, as recorded by the HOBO data-logging weather station at TALIRI Tanga, are shown in Figure 2.

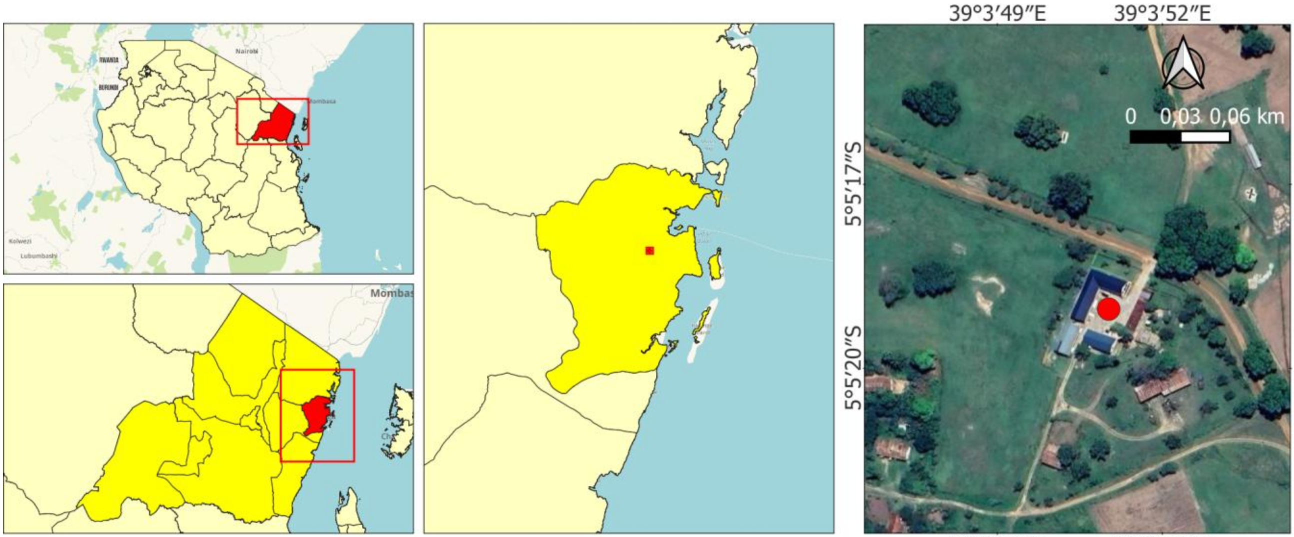

Figure 1. A study area in Tanzania Livestock Research Institute (5°05'19.24"S 39°03'51.15"E), Tanga City, Tanga Region, Tanzania

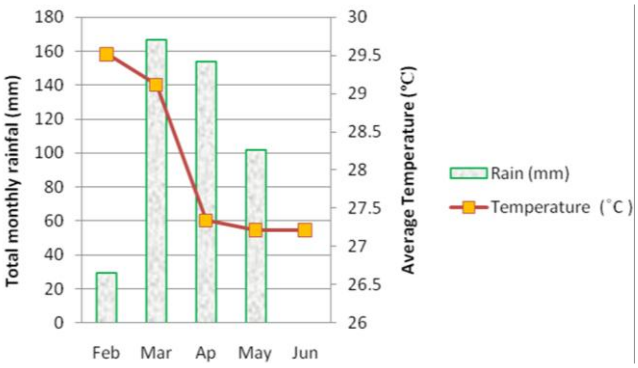

Figure 2. The HOBO data-logging weather station at TALIRI Tanga recorded the trends of mean temperature and rainfall during the experimental period

Procedures

Soil sampling and fertilizer collection

Fertilizers used in this study were processed bio-organic fertilizers (green and liquid fertilizers) and composted cow manure. A green fertilizer with 0.13% total nitrogen was purchased from Afrint Bio Solution Ltd., the company that supplies the product for organic farming in Tanzania. The liquid fertilizer, a plant-based type of bio-organic fertilizer containing 0.112% total nitrogen, was sourced from Lukwangule Organic Product Producers in Morogoro, Tanzania, which produces and supplies organic fertilizers for agricultural use.

Compost cow manure was collected and stored for at least one year prior to application, allowing for decomposition. A portion of the heaped manure was collected and thoroughly mixed to create new heaped composite manure. Subsequently, samples were collected from five different parts of the new heap and thoroughly mixed to obtain a single composite sample for laboratory testing. The total nitrogen content, as determined by laboratory testing, was 1.55%. The source of the compost cow manure was the TALIRI cattle herds, which were crossbreds of Friesian and Boran, grazing on natural pastures near the station campus.

Based on the NRC (2002) soil sampling procedures, a 15 cm V-notch hole was created using a hand hoe to sample the soil. Using a spade, two sides of the notch, approximately 2 cm thick, were sampled, and the soil was collected into a bag. The soil was then thoroughly mixed, spread onto a clean bag, and divided into four equal parts. The two diagonal parts of the soil were collected and combined to form a single sample for laboratory testing. The investigation into soil and compost cow manure samples was conducted at the Tanzania Agricultural Research Institute's (TARI) Mlingano Agricultural Research Centre. The soil type was sandy loam, with a pH of 6.0 (medium acid), a total nitrogen content of 0.1% (very low), an organic carbon content of 1.2% (low), a phosphorus content of 6.62 mg kg^{-1} (low), and a potassium content of 1.41 meq 100 g^{-1} (very high).

Experimental design and layout

The study was done in a 2 × 4 factorial arrangement in a Complete Randomized Design (CRD). There were two schedules of experiments in the rainy season: early-mid rainy and mid-late rainy, with three fertilizer types (compost cow manure (F1), green processed bioorganic fertilizer (F2), and liquid processed bioorganic fertilizer (F3), plus no fertilizer (NF) as a control) in four replicates, making a total of 32 sampling units.

Site preparation and application of fertilizer

In May 2023, a tractor plowed and harrowed the field. The seeds of *C. ciliaris* were manually sown in the field with a spacing of 0.33 meters between rows. All of the important pasture management tasks, except fertilization, were completed. Eight months later, an existing sward of established *C. ciliaris* was demarcated for the experiment. Pegs, manila string, and 100-meter tape were used for the plot's demarcation. The demarcated plots had an area of 15 m^2 (5 × 3 m) and a one-meter path between each experimental plot. The vegetation standardization was achieved by homogeneous cutting of the pasture in all demarcated plots using a grass cutter (shaving machine) at a height of 5 cm above the ground.

The fertilizer application was made to correct a 180 kg N ha^{-1} deficiency in an experimental soil. A rate of 12 t ha^{-1} of compost cow manure (F1) was applied by broadcasting the following day after the uniform cut. This was done once throughout the experimental period. Rates of 7 kg ha^{-1} and 8 L ha^{-1} of green-processed bi-organic fertilizer (F2) and liquid-processed bio-organic fertilizers (F3), respectively, were applied by spraying on the same day. Due to the leaching effect of liquid-form fertilizers in sandy soil (Kang et al. 2011), three application times of the processed bio-organic fertilizers at the same rate were conducted in each schedule of the experiment (early-mid and mid-late rainy) with a seven-day interval skipped to make a total 21 kg ha^{-1} and 24 L ha^{-1} for green and liquid bio-organic fertilizer, respectively. A 7 kg and 8 L ha^{-1} of green processed bio-organic fertilizer and liquid processed bio-organic fertilizers, respectively, were diluted in 1,400 and 4,000 L of water, respectively, prior to application at each time.

Data collection

The regrowth of the plant was visually observed from day one of the homogeneous cut, and the following parameters were recorded: days to first flowering, days to 50% flowering, and days to maturity. After seed maturity, the fertile tillers per tussock were measured by throwing a 0.5 × 0.5 m quadrat randomly into the plot, and all tillers with inflorescences within the quadrat frame of 0.25 m^2 were manually counted and designated as fertile tillers per tussock.

Next, five inflorescences were chosen at random from the randomly thrown 0.25 m^2 quadrat in the plot, and a ruler was used to measure the spike lengths to obtain the average spike length. Furthermore, the digital venier caliper was used to measure the diameter of five randomly selected inflorescences, thereby obtaining the average diameter of the spikelet per quadrat. Once everything was measured, the seeds were picked by hand, cleaned to remove any dirt, and weighed on a digital scale to determine the seed yield per quadrat at harvest. This was then changed to seed yield in kilograms per hectare.

After seed harvest, the grasses within the 0.25 m^2 quadrat in the plot were finally chopped off at a height of 5 cm above the ground. Their leaves and stems were then divided, and their fresh weights were determined by weighing them separately using a weighing balance. In the laboratory, the harvested forages and stems were subjected to an oven at 65°C for 48 hours. Soon after 48 hours, the samples were removed and weighed using a digital weighing balance to obtain the dry matter weights of the leaf and stem, which were then calculated into tons of dry matter per hectare, respectively.

The seeds were air-dried at room temperature for one month and weighed to determine the seed yield after drying, expressed in kilograms per quadrat, which was then converted to kg ha^{-1}. Next, to determine the 1000 seed weight, the 1000 seeds were manually counted and weighed using an analytical weighing balance. For the germination test, 100 seeds were placed on moist blotter paper and placed in a Petri dish at room temperature. Moisture in the seeds was monitored from the start by adding water when it decreased. Germinated seeds were counted and recorded daily from day 3 to day 28, as recommended by ISTA (2009).

Chemical composition of harvested hay

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 at 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). 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.

Economic efficacy

Next, to evaluate economic efficacy, the Total Variable Cost (TVC), Total Revenue (TR), and returns were calculated. Total variable cost includes the cost of purchasing fertilizer and labor charges for applying the fertilizer. Total Revenue (TR) included total sales of hay, dry matter yield, and seed yield value. ∑ (output x price at harvesting time) whereby the returns were calculated by subtracting the total variable cost of fertilizer application from the total revenue (TR-TVC) and expressed on a per-hectare basis.

Data analysis

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

$$Y_{ijk} = \mu + A_i + B_j + (AB)_{ij} + \sum_{ijk}$$

Where: Y_{ijk}: Observation (seed yield and quality, yield of harvested hay and quality), μ: Overall mean, A_i: Effect due to i^{th} fertilizer types, B_j: Effect due to schedule of the experiment, (Ab_{ij}): Effect due to interaction effect of fertilizer type and schedule of the experiment, $\sum_{ijk}$: Sampling error.

The Least Significant Difference (LSD) test was used to compare the means that differ at the 0.05 level of significance for all observations.

RESULTS AND DISCUSSION

Growth and dry matter yield of harvested hay

The influence of types of fertilizer on days to first flowering, days to 50% flowering, days to maturity, and dry matter yield is shown in Table 1. All parameters, except days to first flowering, were significantly influenced by the types of fertilizer at $p < 0.05$ compared to the control treatment. The plots that received fertilizers achieved 50% flowering earlier compared to the unfertilized plots. This may be due to the nutrients provided by fertilizers, which promote rapid growth and result in the flowering of many tillers. Sufficient nutrient concentration in the soil provides many plants with strong stems, robust root systems, and healthy foliage, which are essential for the plant's flowering. Plots treated with fertilizer delayed to reach seed maturity, it took 62, 63 and 66 days for plots fertilized green fertilizer, liquid fertilizer and composted cow manure respectively to reach seed maturity from the day of a homogeneous cut. However, unfertilized plots, took only 58 days. Fertilizer-ensured nutrient availability in the soil may be the cause of the delayed seed maturity from forage cuts. This could lead to strong vegetative growth and increased plant vigor, which in turn would delay reproductive activities (Kizima et al. 2015). These results align with those of Kizima (2015), who found that in a tropical, sub-humid climate, it took 66-70 days after a homogeneous cut for *C. ciliaris* treated with different fertilizer levels to reach seed maturity. These results, however, run contrary to those of Kumar et al. (2005), who reported that newly sown *C. ciliaris* seeds in India reached seed maturity in 103-118 days. This discrepancy may result from differences in the stage of the plant under management. Thus, the current findings demonstrate that, in contrast to newly established forage in semi-arid climates, which takes roughly 103-118 days, the management of existing forage can produce mature seeds in a few days, ranging from 58 to 66 days.

Table 1 indicates the yield of leaf, stem, and total forage dry matter. There was no significant influence of processed bi-organic fertilizers (both green and liquid) on forage dry matter yields, as compared to unfertilized plots. Composted cow manure significantly influenced the total forage dry matter yield compared to the control treatment at $p < 0.05$. Plots treated with composted cow manure recorded the highest dry matter yield, while unfertilized plots recorded the lowest. The higher yield from plots fertilized with cow manure compost might be due to the essential nutrients the fertilizer added to the soil, which supported plant growth. Nitrogen can support the formation of chlorophyll and enhance the plant's photosynthesis capacity. Additionally, nitrogen can help plant cells grow and promote the development of vegetative parts, such as stems and leaves, resulting in a higher biomass yield (Leghari et al. 2016). This result falls within the range of 1.9-12.6 t DM ha^{-1} reported by Kizima (2015) for *C. ciliaris*. The influence of fertilizer on biomass yield has also been reported (Nemera et al. 2017; Isa et al. 2019).

In this study, composted cow manure demonstrated the highest performance in biomass yield (12.41 t DM ha^{-1}), surpassing other bio-organic fertilizers type used in this experiment. This might be due to the low organic matter and poor water-holding capacity of sandy soil that could limit the survival and activity of nitrogen-fixing microbes in bio-organic fertilizers (Itelima et al. 2018). Given the potential of solid-form organic fertilizers to retain nutrients in the soil, this may be also the reason why the composted cow manure performed better in terms of biomass yield than processed bio-organic fertilizers. The sandy loam soil supports much leaching of nutrients (Tahir and Marschner 2017). However, nutrient leaching is less with solid organic fertilizer than with liquid organic fertilizer (Kang et al. 2011; Fan et al. 2017; Karimi et al. 2017), which aligns with the current study. Additionally, Tan et al. (2011) found that using organic fertilizer made from solid manure yielded more maize than using liquid cow manure as an organic fertilizer. According to these findings, the most effective way to increase the biomass yield of *C. ciliaris* in sandy loam soil in a sub-humid climate is to use composted cow manure. The current results of composted cow manure fall within the range of the increased forage biomass yield, ranging from 10.1 to 12.6 t DM ha^{-1}, reported by Ngenzi et al. (2023) for *C. ciliaris* when manure levels were applied in a semi-arid climate. However, the effectiveness of composted cow manure can indeed differ significantly depending on local soil health and environmental factors. Therefore, localized studies should be conducted to understand these variations better. By doing so, farmers can be provided with tailored guidance and recommendations on how to effectively utilize organic fertilizers in accordance with their specific soil conditions, ensuring optimal crop production outcomes while maintaining soil health.

On the other hand, the use of organic fertilizer is crucial, as it contributes to reduced land competition by increasing productivity per unit area and reducing the need for pasture hunting. However, it may not address deeper issues of land competition and diminishing grazing areas. Therefore, implementing integrated land management practices and agroecological approaches that balance crop production with sustainable grazing practices is important. Additionally, government policies should prioritize promoting equitable land use and protecting farmers' rights.

Seed yield and quality

Table 2 shows the influence of fertilizer types on fertile tillers, spike length, spike diameter, seed yield, 1000-seed weight, and germination percent of *C. ciliaris*. Fertilizer types had a significant influence on all parameters at $p < 0.05$. Seed yield, fertile tillers (inflorescence density), spike length, and diameters were higher in plots that received fertilizers than in unfertilized plots. These results indicate a high correlation between inflorescence density, spike length, diameter, and seed yield, as supported by Kumar et al. (2005) and Maeresera (2020). The mean value (70 > 59.4 > 53.4 kg ha^{-1}) of seed yield was recorded from plots treated with compost cow manure, liquid fertilizer, and green fertilizer. In contrast, 38.95 kg ha^{-1} was recorded from unfertilized plots. These findings fall within the range of 77.5-35.5 kg ha^{-1} seed yield reported by Kizima (2015), who researched the same species and variety using different fertilizer levels. However, these results are contrary to those of Kumar et al. (2005), who reported a high seed yield of 97 kg ha^{-1} of *C. ciliaris* by nitrogen fertilizer. This difference may be attributed to variations in climate and soil type. Kumar et al. (2005) reported an inflorescence length of 8.4-13 cm following fertilization, which is within the range of the current findings. Isa et al. (2020) also reported a high tiller density resulting from the application of fertilizer, which contributed to a high inflorescence density.

Table 1. Growth and dry matter yield of *Cenchrus ciliaris* as affected by types of fertilizer

Treatment	**Variables**					
	Days to first flowering	**Days to 50% flowering**	**Days to maturity**	**Leaf DM yield (tDM ha^{-1})**	**Stem DM yield (tDM ha^{-1})**	**Total forage yield (tDM ha^{-1})**
NF	25^{ba}	38^{a}	58^{d}	5.00^{b}	2.48^{b}	7.49^{b}
F1	24^{b}	32^{c}	66^{a}	7.95^{a}	4.46^{a}	12.41^{a}
F2	24^{ba}	35^{b}	62^{c}	6.41^{ba}	3.33^{b}	9.73^{b}
F3	25^{a}	34^{bc}	63^{b}	6.18^{b}	2.98^{b}	9.16^{b}
p-value	0.1509	0.0022	<0.0001	0.0132	0.0016	0.0036
SEM	0.3	0.96	0.34	0.57	0.31	0.82

Note: Days to first flowering: Number of days from homogeneous cut to when the first tiller starts to flower, Days to 50% flowering: Days from homogenous cut to when 50% tillers start to flower, Days to maturity: Days from homogenous cut to when the seed has straw colored. Means with the same superscript within the column are not 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 2. Effect of types of fertilizer on fertile tiller, spike length, spike diameter and seed yield, and germination percent of *Cenchrus ciliaris*

Treatment	Variables					
	Fertile tillers/tussock	**Spike length (cm)**	**Spike diameter (mm)**	**Seed yield (Kg ha^{-1})**	**1000-seed weight (g)**	**Germination%**
NF	11^{c}	7.26^{c}	9.52^{c}	38.95^{d}	0.96^{c}	24^{c}
F1	20^{a}	13.33^{a}	13.22^{a}	70.00^{a}	1.64^{a}	29^{a}
F2	14^{cb}	10.98^{b}	11.13^{b}	53.40^{c}	1.21^{b}	26.5^{b}
F3	16^{b}	11.02^{b}	11.30^{b}	59.40^{b}	1.37^{b}	26^{cb}
p-value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0007
SEM	1.15	0.33	0.29	1.96	0.08	0.71

Note: Means with the same superscript within the column are not 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

The good results of plots that were fertilized can be attributed to the essential nutrients that the fertilizer provides. These nutrients help the plant produce numerous tillers by promoting vegetative sprouting (Maeresera 2020), which leads to high inflorescence density, spike length, and diameter, ultimately resulting in a higher seed yield. On the other hand, compost cow manure outperformed other types of fertilizer. This can be attributed to its gradual release of nutrients, resulting in a longer-lasting effect. It increases substantial amounts of soil organic matter content, leading to improved nutrient retention capacity. It also helps maintain soil structure, which enhances the soil's ability to retain water and nutrients (Adugna 2016), ultimately leading to increased seed yield. Apart from high yield performance of organic fertilizer especially composted cow manure reported from the current study, using organic fertilizers results to long-term effects on the production of *C. ciliaris* pastures seeds by enhancing soil fertility and improving microbial activities, that ensure sustainable pasture production and reduced long-term environmental impact (Meena et al. 2017; Bedaso et al. 2022).

For seed quality, the 1000-seed weight and germination percentage were significantly influenced by the application of fertilizer ($p < 0.05$), compared to unfertilized plots. The seeds harvested from plots that received types of fertilizer had the highest 1000-seed weight and germination percent compared to unfertilized plots. The added essential nutrients provided by fertilizer, which enhanced effective photosynthesis and produced larger and higher-quality seeds, may be the reason for the good results in fertilized plots. These results are conversely to the finding of Kumar et al. (2005), who reported no significant influence of fertilizer on 1000-seed weight and percentage germination. This difference in findings may be caused by variations in the species diversity used in the two experiments. Yuan et al. (2022), who researched *Kengyilia melanthera*, reported a higher 1000-seed weight by applying fertilizer, which correspondingly supports the present study. Patil et al. (2018) also reported a significant influence of fertilizer on the 1000-seed weight and germination percent in perennial fodder sorghum.

Chemical composition of harvested hay

Crude fiber, protein content

The effect of types of fertilizer on crude fiber and crude protein is indicated in Table 3 below. There was a significant influence of types of fertilizer on crude protein and fiber content of *C. ciliaris* at $p < 0.05$. Unfertilized plots had 32.98% more crude fiber and 6.99% less crude protein compared to those treated with fertilizers. This implies that fertilizer application improves the crude protein content and reduces the crude fiber content in the plant. Brima and Abusuwar (2020) also reported a decrease in fiber content in rhodes grass when the level of nitrogen was increased, which supports the current study. The higher protein content recorded in fertilized plots may be due to the nitrogen (N) applied to the soil, which enhanced protein synthesis in the plant. Green fertilizer, liquid fertilizer, and composted cow manure had the highest crude protein content, at 7.96, 7.95, and 7.78%, respectively. This amount of crude protein ranges from 3.9 to 10.93%, which is the same range reported by Kizima (2015) and Mishra et al. (2010) for *C. ciliaris*. Nonetheless, the protein content value of the current study is slightly higher than the 4-6% CP range reported by Al-Dakheel et al. (2015) for *C. ciliaris* in an arid desert climate, likely due to differences in climate conditions between the two studies.

However, plots fertilized with composted cow manure had lower protein content than plots fertilized with other types of fertilizers. This might be because the stems of plants treated with compost cow manure got thicker, which makes it easier for water and nutrients to move through the plant. This helps maintain the inflorescence, ultimately leading to a high seed yield. In support of this, Kirwa et al. (2015) found a positive correlation between stem thickness and crude fiber content and a negative correlation between crude fiber and crude protein content. According to Van Soest et al. (1991), the crude protein percentage found in this study may only be sufficient to maintain rumen function. Therefore, feeding animals the harvested hay at this stage will necessitate further animal supplementation.

Table 3. Chemical composition of harvested hay of *Cenchrus ciliaris* as influenced by fertilizer types

Treatment	Variables						
	%DM	**%ASH**	**%CF**	**%CP**	**%NDF**	**%ADF**	**%ADL**
NF	93.60^{a}	13.03^{a}	32.98^{a}	6.99^{c}	70.04^{a}	40.76^{a}	4.76^{a}
F1	92.10^{b}	11.67^{b}	31.80^{b}	7.78^{b}	67.91^{ba}	38.45^{b}	4.00^{b}
F2	92.56^{b}	11.46^{b}	31.70^{c}	7.96^{a}	67.38^{b}	38.35^{b}	4.11^{ba}
F3	92.88^{ba}	10.53^{c}	31.71^{b}	7.95^{a}	68.31^{ba}	39.52^{b}	4.21^{ba}
p-value	0.0003	0.0002	<0.0001	<0.0001	0.0737	0.0014	0.0927
SEM	0.25	0.19	0.017	0.012	0.7	0.41	0.22

Note: Means with the same superscript within the column are not 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, DM: Dry Matter, CF: Crude Fiber, CP: Crude Protein, NDF: Neutral Detergent Fiber, ADF: Acid Detergent Fiber, ADL: Acid Detergent Lignin

Table 4. Returns are estimated from sales of seeds and harvested hay

Item	Types of fertilizer			
	NF	**F1**	**F2**	**F3**
Income and expenditure Hay DM yield (t/ha)	7.48	12.96	9.74	9.16
Seed yield (kg/ha)	38.95	70	53.4	59.4
Sales of hay at harvest (USD)	811	1,404	1,055	993
Sales of seed at harvest (USD)	396	711	542	603
Total revenue (USD)	1,206	2,115	1,598	1,596
Cost of fertilizer per hectare (USD)	0	94	253	147
Application labor charge per ha (USD)	0	28	20	20
Total variable cost (USD)	0	123	273	167
Returns (USD)	1,206	1,993	1,325	1,429

Note: NF: No Fertilizer (control), F1: Compost cow manure, F2: Green processed bio-organic fertilizer, F3: Liquid processed bio-organic fertilizer

Fiber contents

Table 3 also displays the influence of fertilizers on Neutral Detergent Fiber (NDF), Acid Detergent Fiber (ADF), and Acid Detergent Lignin (ADL). There was no significant influence of types of fertilizer on %NDF and %ADL at $p > 0.05$. However, %ADF was significantly influenced by fertilizer type at ($p < 0.05$). Unfertilized plots recorded the highest mean value, 40.76% ADF. Plots fertilized with green fertilizer recorded the lowest value, 38.35% ADF, followed by those fertilized with liquid fertilizer and cow manure compost, respectively. This indicates that the application of fertilizer tends to increase the N level in the soil, which decreases the %ADF of the plant, as reported similarly by Hassan et al. (2015). The results of this study fall within the range of 66.5 to 77.6% NDF and 36.6 to 47.7% ADF for *C. ciliaris* hay harvested after seed harvest, as reported by Al-Dakheel (2015). Plots that received compost cow manure fertilization had a higher ADF percentage than plots that received other fertilizers. This may be a result of the fact that composting cow manure can reduce the loss of nutrients that leach out due to its high organic matter content, which in turn supports robust, well-developed stems that produce high-quality seeds. This causes a low leaves-to-stems ratio at the stage of seed harvest and hence increases the amount of lignin.

Economic efficacy of seed and hay production

The analysis of costs and benefits was conducted to determine the expected return from producing seeds and hay (Table 4). The application labor charge for compost cow manure was slightly higher than for other types of fertilizer. The application of composted cow manure requires more physical effort, more time, and a larger volume, which may explain the high labor cost. The production of seeds and hay for *C. ciliaris*, when applied with any fertilizer used in the current study, yielded a higher return compared to non-applied fertilizers. The application of compost cow manure, green fertilizer, and liquid fertilizers, respectively, increased estimated returns by 0.7, 0.1, and 0.2 times. This study's analysis reveals that farmers can achieve greater profit by producing *C. ciliaris* seeds and hay using composted cow manure than with any other type of fertilizer. This could be due to the less costly and higher-yielding results obtained from the application of composted cow manure. The application of fertilizer further increased the nutritional value of *C. ciliaris* compared to an unfertilized one. This could also cement the economic benefits of using fertilizer if it were economically analyzed.

Organic fertilizers, especially composted cow manure, improve soil structure and microbial activity, thereby enhancing the long-term effects on soil fertility (Adugna 2016). Therefore, it reduces the need for frequent fertilizer applications. By doing so, the cost of fertilizer application is reduced while maintaining stable yields for long-run farming practices. Organic fertilizer, especially composted cow manure, is locally available, reducing purchasing expenses compared to commercial fertilizers that require frequent purchases with price fluctuations, which are economically unfeasible for smallholder farmers in Tanzania. Despite the advantages of organic fertilizer, farmers must be well-equipped with proper knowledge on how to prepare it before utilization, in order to ensure that nutrients are reserved for sustainable, economical pasture production.

On the other hand, different regions may have varying levels of access to organic resources; therefore, the need to train farmers on how to utilize locally available organic fertilizers is necessary for enhancing accessibility and easy implementation of economic and sustainable farming practices.

In conclusion, the results from the current study demonstrated that the yield and quality of seed and harvested hay of *C. ciliaris* can be improved by the application of organic fertilizer. In this manner, all types of fertilizer used in the experiment increased performance over the control. The green, processed bio-organic fertilizer outperformed others in terms of increased protein concentration and decreased fiber content in harvested hay. However, the compost cow manure increased the seed yield, germination percent, and yield of harvested hay more than all other types of fertilizer used in this experiment. The use of compost cow manure was cheaper compared to commercial green and liquid fertilizers, as it increased economic return by 0.7 times more than unfertilized ones. Therefore, to increase the pasture seed quantity and quality of *C. ciliaris* profitably and under environmentally friendly management practices, the application of composted cow manure is recommended for sandy loam soils in sub-humid tropical areas. However, further research is needed on different ecological zones, including arid and semi-arid rangelands.

ACKNOWLEDGEMENTS

The authors are grateful to acknowledge the Tanzania Livestock Research Institute (TALIRI), in collaboration with the Agriculture and Food Development Authority of Ireland, TAEGASC-Ireland, through the Maziwa Faida Project, for funding this study. We extend our gratitude to all staff members of TALIRI Tanga for their excellent cooperation during the data collection for the current study.

REFERENCES

Adugna G. 2016. A review on impact of compost on soil properties, water use and crop productivity. Acad Res J Agri Sci Res 4 (3): 93-104. DOI: 10.14662/ARJASR2016.010.

Al-Dakheel AJ, Hussain MI, Rahman AQMA. 2015. Impact of irrigation water salinity on agronomical and quality attributes of *Cenchrus ciliaris* L. accessions. Agric Water Manag 159: 148-154. DOI: 10.1016/j.agwat.2015.06.014.

Aredo TA, Chalchisa G, Wana D, Abate D. 2020. Effect of different levels of cattle manure on biomass, seed yield and crude protein content opf rhodes grass. J Nat Sci Res 10 (9): 43-48. DOI: 10.7176/JNSR/10-9-06.

Bader BR, Taban SK, Fahmi AH, Abood MA, Hamdi GJ. 2021. Potassium availability in soil amended with organic matter and phosphorous fertilizer under water stress during maize (*Zea mays* L) growth. J Saudi Soc Agric Sci 20 (6): 390-394. DOI: 10.1016/j.jssas.2021.04.006.

Bedaso NH, Bezabih M, Zewdu Kelkay T, Adie A, Khan NA, Jones CS, Mekonnen K, Wolde-meskel E. 2022. Effect of fertilizer inputs on productivity and herbage quality of native pasture in degraded tropical grasslands. Agron J 114 (1): 216-227. DOI: 10.1002/agj2.20862.

Brima FIA, Abusuwar AO. 2020. Influence of seed rate and NPK fertilizer on yield and quality of rhodes grass (*Chloris gayana* L. Kunth.) Intl J Appl Agric Sci 1 (1): 80-86. DOI: 10.52804/ijaas2020.1116.

Budget speech MLF (Ministry of Livestock and Fisheries). 2024/2025. https://www.mifugouvuvi.go.tz/speeches.

Charshanbiyev U. 2023. Effect of organic fertilizers in growing alfalfa for seed and forage. E3S Web Conf 371: 01050. DOI: 10.1051/e3sconf/202337101050.

Erdaw MM. 2023. Contribution, prospects and trends of livestock production in sub-Saharan Africa: A review. Intl J Agric Sustain 21 (1): 2247776. DOI: 10.1080/14735903.2023.2247776.

Fan J, Xiao J, Liu D, Ye G, Luo J, Houlbrooke D, Laurenson S, Yan J, Chen L, Tian J, Ding W. 2017. Effect of application of dairy manure, effluent and inorganic fertilizer on nitrogen leaching in clayey fluvo-aquic soil: A lysimeter study. Sci Total Environ 592: 206-214. DOI: 10.1016/j.scitotenv.2017.03.060.

Getie A, Asmare B, Mekuriaw Y. 2022. Effects of fertilizer type on morphological characterstics, forage yield, seed yield and qualities of rhodes grass (*Chloris gayana* K.) in Northwestern Ethiopia. Sci Papers: Anim Sci Biotechnol 55 (1): 1-12.

Habimana V, Nguluma AS, Nziku ZC, Ekine-Dzivenu CC, Morota G, Mrode R, Chenyambuga SW. 2024. Heat stress effects on physiological and milk yield traits of lactating Holstein Friesian crossbreds reared in Tanga Region, Tanzania. Animals 14 (13): 1914. DOI: 10.3390/ani14131914.

Hassan A, Zewdu T, Urge M, Fikru S. 2015. Effect of nitrogen fertilizer application on nutritive value of *Cenchrus ciliaris* and *Panicum* maximum grown under irrigation at Gode, Somali Region. J Nutr Food Sci S11:005. DOI: 10.4172/2155-9600.S11-005.

Isa MM, Ibrahim J, Bah SU. 2020. Effect of nitrogen fertilizer and inter row spacing on herbage yield and some yield components (number of leaves and number of tillers per plant) of rhodes grass (*Chloris gayana* Tan) in the dry sub humid zone of Sokoto Nigeria. Asian J Adv Res Rep 8 (1): 10-21. DOI: 10.9734/ajarr/2020/v8i130189.

Isa MM, Musa DG, Usman BS. 2019. Effect of nitrogen fertilization and spacing on growth (plant height) of rhodes grass (*Chloris gayana* Tan) in the dry sub humid zone of Sokoto Nigeria. Intl J Plant Soil Sci 31 (1): 2320-7035. DOI: 10.9734/IJPSS/2019/v31i130198.

ISTA (International Seed Testing Association). 2009. International Rules for Seed Testing 2009 Edition. Secretariat, Zürichstrasse 50, CH-8303 Bassersdorf, Switzerland.

Itelima JU, Bang WJ, Onyimba IA, Sila MD, Egbere OJ. 2018. A review: Bio-fertilizers as key player in enhancing soil fertility and crop productivity. Direct Res J Agric Food Sci 6 (3): 73-83. DOI: 10.26765/DRJAFS.2018.4815.

Kang J, Amoozegar A, Hesterberg D, Osmond DL. 2011. Phosphorus leaching in a sandy soil as affected by organic and inorganic fertilizer sources. Geoderma 161 (3-4): 194-201. DOI: 10.1016/j.geoderma.2010.12.019.

Karimi R, Akinremi W, Flaten D. 2017. Cropping system and type of pig manure affect nitrate-nitrogen leaching in a sandy loam soil. J Environ Qual 46 (4): 785-792. DOI: 10.2134/jeq2017.04.0158.

Kirwa EC, Njoroge K, Chemining'wa G, Mnene W. 2015. Nutritive composition of *Eragrostis superba* Peyr and *Cenchrus ciliaris* L. collections from the ASALs of Kenya. Livest Res Rural Dev 27 (8): 1-10.

Kisambo BK, Wasonga OV, Kipchirchir OK, Karuku GN. 2024. Effects of soil type and watering regime on performance of C4 grass ecotypes in a simulated semi-arid environment in Kenya. East Afr J Agric Biotechnol 7 (1): 399-415. DOI: 10.37284/eajab.7.1.2126.

Kizima JB. 2015. Seed Yield and Quality of *Cenchrus ciliaris* cv. Biloela Under Various Agronomic Practices in Sub-humid Eastern Zone of Tanzania. [Thesis]. Sokoine University of Agriculture, Tanga.

Kumar D, Dwivedi GK, Singh SN. 2005. Seed yield and quality of buffel grass (*Cenchrus ciliaris*) as influenced by row spacing and fertilizer level. Trop Grassl 39 (2): 107-111.

Leghari SJ, Wahocho NA, Laghari GM, HafeezLaghari A, MustafaBhabhan G, HussainTalpur K, Bhutto TA, Wahocho SA, Lashari AA. 2016. Role of nitrogen for plant growth and development: A review. Adv Environ Biol 10 (9): 209-219.

Lutatenekwa DL, Mtengeti EJ, Msalya GM. 2021. Morphological characterization of selected ecotypes of African foxtail grass (*Cenchrus ciliaris*) from selected areas of Tanzania. Tanzania J Agric Sci 20 (2): 268-277.

Maeresera T. 2020. Comparative Assessment of the Effects of Horse Manure and Urea as Nitrogen Sources on Seed Yield, Forage Production and Nutritional Quality of *Cenchrus ciliaris* Post Seed Harvesting. [Dissertation]. University of Agriculture and Natural Resources, Botswana.

Maleko D, Mwilawa A, Msalya G, Pasape L, Mtei K. 2019. Forage growth, yield and nutritional characteristics of four varieties of napier grass (*Pennisetum purpureum* Schumach) in the west Usambara highlands, Tanzania. Sci Afr 6: 00214. DOI: 10.1016/j.sciaf.2019.e00214.

Meena LR, Meena LK, Meena AL, Singh SP. 2017. Effect of organic nutrient management on intercropping systems of *Cenchrus* and *Dolichos* lab lab for quality fodder production and for improving soil health under semi-arid conditions of Rajasthan. Forage Res 43 (3): 202-207.

Mengistu H. 2018. Competitive uses of crop residues are challenging soil fertility management in Ethiopia. Intl J Curr Res 10 (2): 65139-65144.

Mishra AK, Tiwari HS, Bhatt RK. 2010. Growth, biomass production and photosynthesis of *Cenchrus ciliaris* L. under *Acacia tortilis* (Forssk.) Hayne based silvopastoral systems in semi arid tropics. J Environ Biol 31 (6): 987-993.

Mteta SK, Maleko DD, Massawe BH. 2022. Selected soil properties and small-holder dairy farmers perceptions on improved forage varieties in the Southern highlands of Tanzania. Afr J Agric Res 18 (10): 887-897. DOI: 10.5897/AJAR2022.16147.

Muzzo BI, Provenza FD. 2018. A review of strategies for overcoming challenges of beef production in Tanzania. Livest Res Rural Dev 30 (12): 1-11.

Naher UA, Biswas JC, Maniruzzaman M, Khan FH, Sarkar MIU, Jahan A, Hera MHR, Hossain MB, Islam A, Islam MR, Kabir MS. 2021. Bio-organic fertilizer: A green technology to reduce synthetic N and P fertilizer for rice production. Front Plant Sci 12: 602052. DOI: 10.3389/fpls.2021.602052.

National Research Council (NRC). 2002. Biosolids Applied to Land: Advancing Standards and Practices. National Academy of Science, Washington, DC.

Nemera F, Tessema ZK, Ebro A. 2017. Effect of organic and inorganic fertilizer application on improvement of degraded grazing land in the central highland of Ethiopia. Livest Res Rural Dev 29 (3): 1-11.

Ngenzi OD, Msalya GM, Maleko DD. 2023. Influence of seedbed type and cattle manure level on herbage characteristics and forage nutritive value of *Cenchrus ciliaris* in a semi-arid area. Trop Agric 100 (3): 191-205.

Ngenzi OD, Ruvuga PR, Msalya GM, Maleko DD, Tefera S. 2024. Participatory establishment of *Cenchrus ciliaris* forage grass among pastoralists in a semi-arid rangeland area of eastern Tanzania. Afr J Range Forage Sci 41 (1): 29-38.

Patidar M, Mathur BK. 2017. Enhancing forage production through a silvi-pastoral system in an arid environment. Agrofor Syst 91: 713-727. DOI: 10.1007/s10457-016-0033-x.

Patil B, Kumar V, Merwade MN. 2018. Effect of inter row spacing and fertilizer levels on crop growth, seed yield and seed quality of perennial fodder sorghum cv. CoFS-29. Range Manag Agrofor 39 (1): 59-64.

Rashmi I, Roy T, Kartika KS, Pal R, Coumar V, Kala S, Shinoji KC. 2020. Organic and Inorganic Fertilizer Contaminants in Agriculture: Impact on Soil and Water Resources. In: Naeem M, Ansari A, Gill S (eds.). Contaminants in Agriculture. Springer, Cham. DOI: 10.1007/978-3-030-41552-5_1.

Roseboom J, Beintema NM, Lynam J, Badiane O. 2016. Unlocking Africa's Agricultural Potential. Agricultural Research in Africa: Investing in Future Harvests (Chapter in a book), 425-438. https://www.worldagroforestry.org/ publication/unlocking-africas-agricultural-potential.

Ruvuga PR, Wredle E, Fupi GF, Mtwange CA, Kasiba BR, Selemani IS, Kronqvist C. 2022. Dry matter intake, dry matter digestibility and growth performance in goats fed grass-based diet (*Brachiaria* or *Cenchrus*) compared with a concentrate-based diet. Afr J Agric Res 18 (1): 52-57. DOI: 10.5897/AJAR2021.15785.

SAS. 2000. Stastical Analysis System. SAS/STAT users guide. Statistical Analysis Institute, Inc; Cary, Nc. USA.

Siller-Clavel P, Badano EI, Villarreal-Guerrero F, Prieto-Amparán JA, Pinedo-Alvarez A, Corrales-Lerma R, Álvarez-Holguín A, Hernández-Quiroz NS. 2022. Distribution patterns of invasive buffel grass (*Cenchrus ciliaris*) in Mexico estimated with climate niche models under the current and future climate. Plants (Basel) 11 (9): 1160. DOI: 10.3390/plants11091160.

Stewart ZP, Pierzynski GM, Middendorf BJ, Prasad PVV. 2020. Approaches to improve soil fertility in sub-Saharan Africa. J Exp Bot 71 (2): 632-641. DOI:10.1093/jxb/erz446.

Tahir S, Marschner P. 2017. Clay addition to sandy soil reduces nutrient leaching—effect of clay concentration and ped size. Commun Soil Sci Plant Anal 48 (15): 1813-1821. DOI: 10.1080/0013624.2017.1395454.

Tan CS, Zhang TQ, Welacky TW. 2011. Comparison of Organic Fertilizer with Solid and Liquid Manures vs. Inorganic Fertilizer on Water Quality and Crop Production under Free Drainage and Water Table Control Systems. In 2011 Louisville, Kentucky, August 7-10, 2011 (p. 1). American Society of Agricultural and Biological Engineers. DOI: 10.13031/2013.37737.

Tembo JA, Msalya GM, Maleko DD, Laswai GH. 2024. Influences of different types of fertilizers on the agronomic characteristics of *Chloris gayana* forage in a selected area of Tanzania. Tanzania J Agric Sci 23 (1): 48-60.

Van Soest PJ, Robertson JB, Lewis BA. 1991. Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. J Dairy Sci 74 (10): 3583-3597. DOI: 10.3168/jds.S0022-0302 (91)78551-2.

Wang J, Li X, Xing S, Ma Z, Hu S, Tu C. 2017. Bio-organic fertilizer promotes plant growth and yield and improves soil microbial community in continuous monoculture system of *Chrysanthemum morifolium* cv. *Chuju*. Intl J Agric Biol 19 (3): 563-568. DOI: 10.17957/IJAB/15.0339.

Wu Y. 2017. Chapter 9-Periphyton: A Promising Bio-Organic Fertilizer Source in Agricultural Ecosystems. Periphyton. Functions and Application in Environmental Remediation, 225249. Elsevier, Amsterdam.

Yuan S, Ling Y, Xiong Y, Zhang C, Sha L, You M, Lei X, Bai S, Ma X. 2022. Effect of nitrogen fertilizer on seed yield and quality of *Kengyilia melanthera* (Triticeae, Poaceae). PeerJ 10: e14101. DOI: 10.7717/peerj.14101.