Influences of Different Types of Fertilizers on the Agronomic Characteristics of *Chloris gayana* Forage in a Selected Area of Tanzania

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Abstract

A study was undertaken from January to April 2021 in a commercial dairy farm in Iringa, Tanzania, to determine the effects of applying different types of fertilizers on the agronomic characteristics of Chloris gayana (Rhodes grass). Four types of fertilizers, namely cattle farm yard manure (CFYM), blended Nitrogen, Phosphorus, Sulphur, and Zinc (NPSZn), Sulphate of Ammonium (SA), and Urea, were applied in experimental plots using six different combinations in a Completely Randomized Design (CRD). The combinations were control (T1) with no fertilizer, CFYM alone (T2), CFYM and NPSZn (T3), NPSZn alone (T4), NPSZn with SA (T5), as well as NPSZn with Urea (T6) allocated in four replications per treatment. The physical and chemical properties of the soil in the experimental plots and the CFYM were also determined. The application of the fertilizers followed the protocols of the manufacturers. The seeds of C. gayana were broadcasted in all the experimental plots at a rate of 20 kg/ha. On the 90th day, forages in their respective sub-plots were clipped to obtain representative samples for the determination of the agronomic characteristics. Parameters considered were plant population (PP), number of tillers per plant (NTPP), stem height (SH), number of leaves per plant (NLPP), leaf length per plant (LLPP), leaf width per plant (LWPP) and stem diameter (SD). Results showed that the soil texture was primarily sandy clay loam. The soil and manure contained total N (%) of 0.15 and 1.76 respectively. The amounts of extractable P (mg/kg) in soil and manure were 3.38 and 40.35, respectively. The study showed that the plots fertilized by a combination of NPSZn and Urea (T6) produced the highest ($p<0.05$) mean values of PP (85.7 plants/m^2), NTPP (24.5), SH (136.6 cm), NLPP (6.9), LLPP (40.9 cm), LWPP (1.5) and SD (3.1 mm) compared with other fertilizers. The control treatment (T1) with no fertilizer application had the least ($p>0.05$) mean values of PP (27.6 plants/m^2), NTPP (5.3), SH (53.9 cm), NLPP (3.7), LLPP (23.4 cm) LWPP (0.5) and SD (1.5 mm). It is concluded that a mixture of blended NPSZn and Urea could improve the soil fertility and hence promote the growth parameters of C. gayana. Further studies to determine biomass yield and quality of the forage fertilized with different fertilizers under similar soil and environmental conditions are recommended.

Keywords: Agronomic characteristics, Fertilizers, Cattle farm yard manure, *Chloris gayana.*

Introduction

Recently, the productivity of pastures in both quality and quantity in natural grassland has been deteriorating, making forage farming common and of significant importance in the tropics and sub-tropic regions (Rao *et al.,* 2015). Pasture farming in developing countries is faced with several challenges, the major ones being poor soil fertility attributed to inadequate use of fertilizers, continuous cropping systems and variations in climate (Lutatenekwa *et al.,* 2021). It has been shown that most soils have lost important fertility capacity and require good management for sustainable yield (Stewart *et al.,* 2020). Soil fertility could be improved in different ways, notably fertilizing pasture with animal manure or any other organic fertilizers, use of inorganic fertilizers, or a mixture of inorganic and organic fertilizers (Panchaban *et al.,* 2000; Bader *et al.,* 2021; Mteta *et al.,* 2022). It is of great importance therefore to investigate the means for increasing biomass from cultivated pasture through the application of appropriate types of fertilizers.

Fertilization is one of the pasture management practices commonly used for improving grass growth and development. Fertilization with manure on its side has paramount importance for successfully enhancing soil fertility and improving soil physical characteristics by adding the major and minor plant nutrients, notably Nitrogen (N), Phosphorus (P), Potassium (K), Calcium (Ca) and Magnesium (Mg) (Panchaban *et al.,* 2000). These nutrients are useful in the establishment of grasses for good agronomic characteristics, high yield and nutritive values (Gezahagn *et al.,* 2017). It is generally known that plants have different responses to various types of fertilizers and rates of application. However, the appropriate selection of the type, rate, and time for fertilizer application on the forage for its optimal growth are scarcely documented.

Therefore, this study aimed to evaluate the influence of types of fertilizers on the performance of *C. gayana* in terms of agronomic characteristics to come up with recommendations on the appropriate fertilizer combinations to be applied for increasing pasture production in a selected farm in Iringa region of Tanzania.

Materials and methods

Description of the study area

The study was carried out at Matembo pasture farm, owned by ASAS Dairies Company LTD in Iringa region of Tanzania. The farm is located 20 km East of Iringa Municipality at Kising'a Ward in Matembo village. It is situated between latitudes 6 to 7^{o}37'6" South of the Equator and longitudes 34 to 35^{o}47'41" East of Greenwich, with an altitude between 1300 and 2800 meters above sea level (Fussi, 2010 and Massawe, 2011).

Experimental design and treatments

The experiment followed a Completely Randomized Design (CRD) with six (6) different types and combinations of fertilizers. The fertilizer applications used were control (T1) with no fertilizer application, the cattle farm yard manure (CFYM) alone (T2), application of CFYM together with a fertilizer containing Nitrogen, Phosphorus, Sulphur, and Zinc (NPSZn; T3), NPSZn alone (T4), NPSZn mixed with Sulphate of Ammonium (SA; T5) and NPSZn mixed with Urea (T6). Each treatment was replicated into four, making a total of 24 sub-plots.

Source and preparation of fertilizers

The cattle farm yard manure (CFYM) was collected from the cattle house on the farm and heaped in one place for a period of 90 days, from October to December 2021. It was covered with a polythene sheet to reduce losses of nutrients, which could happen when exposed to direct sunrays and rainfall or humidity. The CFYM used was taken from the same batch because different batches could contain different concentrations of nutrients depending on sources, types of feeds eaten by the animals, and storage as reported by Murwira *et al.,* (1995). Prior to the application, a representative sample of CFYM was collected and submitted to the Soil laboratory of the Sokoine University of Agriculture (SUA) for analysis of physical characteristics and chemical composition. The SA and Urea were bought from the fertilizer companies found in the Iringa region, while NPSZn was ordered from a supplier found in Dar es Salaam. The mineral composition of the inorganic fertilizers according to the specifications of the manufacturers and that determined in the cattle farm yard manure is shown in Table 1.

Preparation of the experimental plots

An area of 2,835 m^2, measuring 63 m x 45 m, was selected, demarcated, cleared, ploughed, and harrowed at a depth of about 15 cm. Within the demarcated area, 24 plots with dimensions of 10 m wide x 10 m length and spaces between the plots of 1 m within the columns and 0.5 m rows apart from one plot to another were

Table 1: Mineral composition of the different types of fertilizers

Type of fertilizer	Mineral composition (%)			
	Nitrogen	Phosphorus	Sulphur	Zinc
Urea	46	-	-	-
SA	21	-	24	-
NPSZn	12	45	5	0.2
CFYM	1.76	40.35	0.02	6.10

formed. Around the periphery, a 1 m width was left as a path. Representative soil samples were randomly drawn from the demarcated experimental area using a 1 m^2 quadrant, which was thrown at different sites. The soil samples were drawn at depths of 0 - 20 cm and 20 - 40 cm using a soil auger, then mixed thoroughly and sub-sampled to obtain one composite sample. The sample was weighed, air-dried and sent to the soil laboratory of SUA for soil physical and chemical analyses.

Pasture establishment and management

Prior to the establishment of the pasture, fertilizers were applied to the demarcated plots based on the assigned treatments. The rates of application of CFYM and inorganic fertilizers were estimated based on the results obtained on the mineral composition (Table 1). The time and rates of application of the different fertilizers for each treatment are presented in Table 2.

Table 2: Time and rate of application of the fertilizers in different treatments and the calculated amount of the supplied nitrogen

Treatment	Time of application		Rate (kg/ha)
	Sowing	Growing	N supplied (kg /ha)
T1:Control	Nil	Nil	Nil
T2:CFYM	15 000	Nil	3.21
T3:CFYM+ NPSZn	15 000+130	Nil	18.81
T4:NPSZn	160	Nil	19.20
T5:NPSZn + SA	160 (NPSZn)	143 (SA)	49.23
T6:NPSZn + Urea	160 (NPSZn)	170 (Urea)	97.40

After land preparation and fertilization of the respective plots, the seeds of *C. gayana* were broadcasted in all the experimental plots using a chest mount hand crank seed broadcaster at a rate of 20 kg/ha. The sowing of the seeds took place in mid-January during the rainy season when the soil had sufficient moisture to enhance germination. Weeding was done using a hand hoe on the 35th day after sowing. Forty (40) days after the grass had germinated, SA and Urea were applied in the respective plots (Table 2).

Data Collection

Weather characteristics

Values of rainfall, temperature, and humidity recorded in 2019/2020 from four mini meteorological centers located in different stations at the farm were collected and summarised.

Agronomic characteristics

The agronomic characteristics of the established *C. gayana* stands were assessed on the 90th day of the plants' growth. Representative samples of the plants were obtained using a 1 m^2 quadrant, which was randomly thrown three (3) times in each plot, for all the twenty-four (24) plots, making a total of seventy-two (72) quadrants. The plants that happened to fall within the quadrant were clipped 10 cm above the ground using a sickle. All the clipped plants in each plot were counted to obtain the plant population (PP). Thereafter, the clipped plants for each quadrant in each plot were packed in separate clean bags and labelled. A systematic random sampling technique was employed for the estimation of other agronomic characteristics. The clipped plants from the quadrant were spread on the floor, whereby the first plant was chosen skipping the next two plants and the third one was selected, and so on for all plants. The selected plants were used to determine the numbers of tillers (NTPP), and leaves (NLPP) per plant by counting. The length (LLPP) and width (LWPP) of the third leaf from the newly developing top leaf in each selected plant were measured as explained by Wongsuwan (1999) and recorded. The LLPP was taken from the base of the collar region of the leaf to the tip of the leaf using a tape measure. The stem height (SH) was taken from ground level to the tip of the main stolon. The diameter of each selected plant stem (SD) was recorded at the lowest internodes using a vernier caliper.

Laboratory Analyses

Samples of soil and CFYM were air-dried in a dust-free screen house. The air-dried samples were ground to pass through a 2 mm sieve for physical analysis. The samples were subsequently oven dried at 70°C to constant weight. The oven-dried sample of CFYM was then ground to pass through a 1 mm sieve using a plant grinder and stored in clean plastic bags (zip lock bags) at room temperature for subsequent chemical analyses.

The texture of the soil was measured by the relative proportions of sand, silt and clay in the soil, which was determined by the hydrometer method as per Beretta *et al.* (2014) procedures. The samples of soil and manure were analyzed for pH using a pH meter at the ratio of 1:2.5 soils: water as described by McLean (1982). Organic carbon (OC) was determined using the Walkley and Black method (Allison, 1965), while electrical conductivity (EC) was determined using the ammonium acetate saturation method as described by Chapman (2016). Total N in soil and manure was determined by the Kjeldahl wet digestion-distillation method as described by Bremner and Mulvaney (1982) and estimated by titration with standard acid. The available phosphorus (P) was determined by the Bray 1 method (Olsen, 1954). The contents of manganese (Mn^{2+}) and zinc (Zn^{2+}) in the soil and manure were estimated following the procedures given by Lindsay and Norvell (1978). The exchangeable K^+, Ca^{2+}, Mg^{2+}, and Na+ were determined using an atomic adsorption spectrophotometer as described by Moberg (2001).

Statistical Analysis

Descriptive statistics were used to describe the weather data, levels of mineral elements in the soil and cattle farm yard manure. The collected data on the agronomic characteristics were entered in coded Excel sheets and then transferred to the Statistical Analysis System (SAS, 2010) for Windows analyzed using One-way Analysis of Variance (ANOVA) and the New Duncan's Multiple Range tests (DMRT) was used to test the significance differences between pairs of means at ($p<0.05$). The following model was used.

$$Yij = \mu + Fi + eij$$

Where:

Yij is the response variable, representing the forage growth measurement for the *i-th* fertilizer type and *j-th* replicate; μ is the overall mean; *Fi* is the effect of the *i-th* fertilizer type; eij is the random error term. The Fisher's Least Significant Difference post hoc test was used to do the pairwise comparison of the means. The means were considered to be statistically significantly different when $p<0.05$.

Results

Weather characteristics of the study area

The mean monthly (January to May) trends of rainfall, temperature and humidity for records collected in the study area for three consecutive years of 2019 to 2021 are shown in Figure 1. During the growing season of 2021, the minimum amount of rainfall was observed in May while the highest amount was in January. On the other hand, the observed temperature was lowest in January and April and highest in March. The data showed that the amount of humidity during the same period was lowest in May and highest in February and kept decreasing towards the end of the study period.

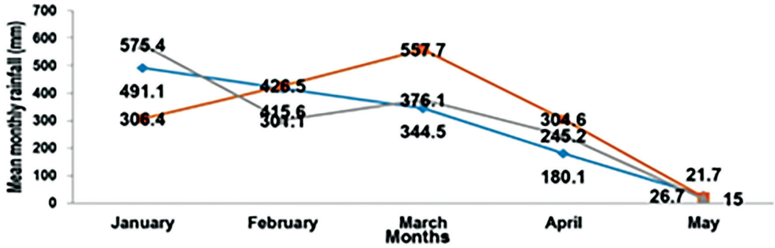

Figure a: Rainfall

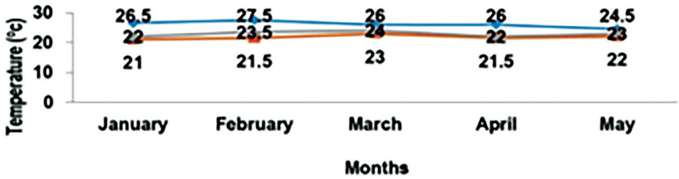

Figure b: Temperature

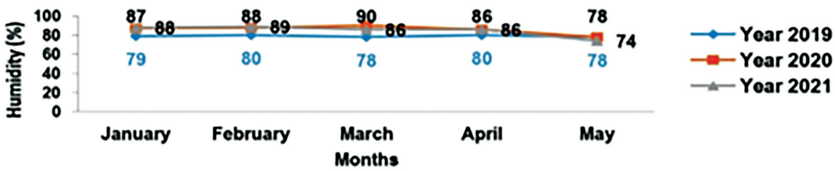

Figure c: Relative humidity

Figure 1: Weather characteristics of the study area during the years 2019 to 2021

Physical and chemical properties of the soil and manure

The data on the physical and chemical properties of soil samples collected from the experimental plots are presented in Table 3. The soil was observed to be highly dominated by sand followed by silt and clay. There were also some differences in chemical properties between soil and CFYM (Table 3). The determined values of organic carbon, total nitrogen, pH, and extractable P were generally higher in the CFYM than those of the soil samples, while the value of CEC was observed to be higher in the soil sample than in the CFYM. The values of exchangeable bases that are Ca^{2+}, Mg^{2+}, K^{+}, and Na^{+} were observed to be lower in the soil than in CFYM. The extractable base of SO_4^{2-} was observed to be higher in the soil and insignificant amount in CFYM while that of Zn^{2+} was lower in the soil than in CFYM. A similar mean value of extractable Mn2+ was observed in the soil and CFYM.

Agronomic characteristics of *C. gayana*

The LSmeans of the agronomic characteristics of the established *C. gayana* as influenced by the different types of fertilizers are presented in Table 4. The application of fertilizers resulted in a high ($p<0.0001$) increase in most of the agronomic characteristics of *C. gayana* with some variations depending on the type of fertilizer application. The plots fertilized by a combination of NPSZn and Urea (T6) produced the highest ($p<0.05$) mean values of all the agronomic characteristics, followed by those applied by NPSZn and SA (T5). The mean differences however, between T5 and T6 for the population of the plants (PP), the height of the stems (SH), and the number of leaves in each stem (NLPP), were not different ($p>0.05$). The control treatment (T1) with no fertilizer application had the least ($p<0.05$) mean values of all the parameters assessed on agronomic characteristics, followed by those fertilized with CFYM (T2).

The Lsmeans of stem height (SH) tended to increase from the control plants (T1) to the

Table 3: Physical and chemical properties of the soil and cattle farm yard manure (CFYM) used in the study

Property	Soil	CFYM
Physical property (%)		
Sand	52	NA
Silt	21	NA
Clay	35	NA
Chemical property		
Organic carbon (OC, %)	0.57	2.43
Total Nitrogen (TN, %)	0.15	1.76
Extractable Phosphorus (P, mg/kg)	3.38	40.35
Cation Exchange Capacity (CEC, cmol(+)/kg	6.90	4.90
pH	5.68	8.26
Exchangeable bases (cmol(+)/kg)		
Calcium (Ca^{2+})	0.54	1.46
Magnesium (Mg^{2+})	0.05	0.39
Potassium (K^{+})	0.28	0.45
Sodium (Na^{+})	0.03	0.08
Extractable bases (mg/kg)		
Sulphur (SO_4^{2-})	2.67	0.02
Zinc (Zn^{2+})	2.30	6.10
Manganese (Mn^{2+})	6.59	7.00

NA = Not applicable

Table 4: LSMeans of agronomic characteristics of *C. gayana* forage as influenced by the different treatments

Treatments	Agronomic characteristics						
	PP	NTPP	SH (cm)	NLPP	LLPP (cm)	LWPP (cm)	SD (mm)
T1:Control	27.62^{d}	5.25^{e}	53.9^{d}	3.69^{b}	23.43^{c}	0.54^{b}	1.49^{c}
T2:CFYM+NPSZn	55.62^{c}	9.28^{d}	92.32^{c}	5.54^{ab}	31.59^{bc}	0.85^{b}	1.91^{bc}
T3:FYM+NPSZn	62.68^{bc}	11.25^{cd}	101.49^{c}	5.53^{ab}	37.51^{ab}	0.93^{b}	2.24^{b}
T4:NPSZn	70.34^{b}	14.67^{bc}	109.89^{bc}	5.58^{ab}	32.22^{bc}	1.10^{b}	2.22^{b}
T5:NPSZn+SA	75.34^{a}	17.25^{b}	127.57^{ab}	6.33^{a}	33.84^{bc}	1.29^{b}	2.51^{b}
T6:NPSZn+Urea	85.66^{a}	24.50^{a}	136.57^{a}	6.92^{a}	40.88^{a}	1.45^{a}	3.14^{a}
SEM	6.41	2.75	11.98	0.44	2.43	0.11	0.23
P value	<.0001	<.0001	<.0001	0.052	0.0076	<.0001	0.0007

NOTE: PP - Plant population, NTPP - Number of tillers per plant, SH - Stem height, NLPP - Number of leaves per plant, LLPP - Leaf length per plant, LWPP - Leaf width per plant, SD - Stem diameter. SEM = Standard error of the means, P- Value = Probability value. Means with different superscripts in a column are significantly different at p<0.05.

plants fertilized by a combination of NPSZn and Urea (T6). However, the mean values of (SH) of plants fertilized by CFYM (T2) and those from the mixture of CFYM and NPSZn (T3) were not significantly different ($p>0.05$). The mean differences in the number of leaves per plant (NLPP) between T2, T3, and T4 and between T5 and T6 were not different ($p>0.05$). The mean differences in the length of leaves (LLPP) and diameter of stems (SD) of the plants between T4 and T5 were not different ($p>0.05$). Furthermore, the mean differences in the width of the leaves (LWPP) between all treatments were not different ($p>0.05$) except the Lsmean of LWPP in T6, which was higher ($p<0.05$) than the rest.

Discussion

The observed amount of rainfall of 1515 mm during the study period was enough to support the growth of *C. gayana* as suggested by Allah and Bello (2019). On the other hand, Cook *et al* (2005) proposed that *C. gayana* can survive well in areas where annual rainfall ranges between 300mm and 4000mm. The present result is also in agreement with the observation made by CASCAPE (2015) that *C. gayana* grows better in areas where there are necessarily supporting soil nutrients and annual rainfall above 600 mm and altitude ranges from 1400-2400 m.a.s.l. The observed range of temperature was in line with the study by Allah and Bello (2019), which shows that *C. gayana* thrives well in places where annual temperatures range from 16.5ºC to >26 ºC with a minimum of 25°C and maximum growth at 30°C during the night and day temperatures, respectively. This wide geographical and thermal distribution of growth conditions of *C. gayana* is reflected in the variety of reports in the literature for optimum growing temperatures ranging from 20ºC to 37ºC, with extremes of 5ºC and 50ºC (Mannetje and Kersten, 1992).

The observed results of the soil sample that was collected at the experiment site before the application of manure showed that the soil was slightly acidic and sandy clay loam (52% sand, 21% silt, and 35% clay) due to a high proportion of the sand in it as supported by soil textural triangle by the USDA (Gee and Or, 2002).

The observed value of organic carbon in the sample of soil (0.57 %) was lower than 0.65 %, reported by Moberg (2001). The reason could be that much of farm biomass is utilized in feeding animals through cut and carry practice without taking back the manure, hence little humus accumulates in the field. Most soil macronutrients (N, P, K, Ca, Mg, and Na) were found to be below the critical levels for optimal crop production (Sanchez, 2003), which could be due to leaching as a result of the high amount of rainfall (1617 mm) in the previous growing rain season. Thus, the use of organic and inorganic fertilizers is considered necessary for replenishing the observed soil nutrient insufficiency. The soil pH was almost within the recommended range (5.5–7.5) for the most favorable availability and plant uptake of various essential soil nutrients (Sanchez, 2003).

The observed pH of the cow farm yard manure (CFYM) was moderately alkaline and most nutrients were at sufficient levels for improving soil condition (Maleko *et al.* 2015). The observed CEC of the soil (6.9 cmol(+)/kg) and manure (4.9 cmol(+)/kg) were lower than the 15.2 cmol(+)/kg reported by Landon (1991). It shows that the low CEC levels in soil could be influenced by soil texture and the soil organic matter contents. In addition, the observed lower values of exchangeable bases in the soil than in manure could be due to the observed low organic carbon, which usually leads to the availability of exchangeable bases and determines the CEC of the soil.

The extractable base of SO_4^{2-} was observed to be relatively high as categorized by Halvin *et al.* (2003), probably due to a reduction in the use of sulphur-containing fertilizers in the previous years or burning of vegetation during land preparation and heavy rainfall. The amount of Zn^{2+} was observed to be lower in the soil than in CFYM which could be due to taking cattle farm yard manure from the cattle which were previously used to be fed by grasses fertilized by zinc containing fertilizers. High concentrations of Na and P in the soil naturally limit the availability of Zn^{2+} as described by Alloway (2009). The concentration of Mn^{2+} in the soil was observed to be higher than those recommended by Landon (1991) and this could be due to the observed low pH that favours the dissolution of Mn^{2+} in the soils (Alloway and Ayres, 1990).

The observed higher mean values of all the agronomic parameters in the plots fertilized by NPSZn+Urea (T6) than those in other treatments could be due to the higher amounts of N supplied to forage by this treatment (Table 2). Similar results were reported by Yossif and Ibrahim (2013) and Berhe and Marie (2020), who applied N-fertilizers to the growth and yield of Rhodes grass and observed an increased plant population as the amount of N content increased. The recorded lower mean values of all the agronomic parameters in the control (T1) without fertilizer application could be due to the observed low amounts of nutrients present in the soil (inherent nutrients) and the effect of low soil pH recorded in the study area, which might influence other important nutrients not to be available to plants. These results are in line with the study by Yousif and Ibrahim (2013) who reported small values of the plant population of *C. gayana* raised without fertilizer. This implies that apart from the influence of the level of N present in the soil, the other nutrients in the inorganic fertilizers (NPSZn, SA, and Urea) were also important in producing more plants per area. Each nutrient has its specific function on the growth of the forages, for instance, K present in CFYM assists in regulating the capacity of water use by the plant by controlling the opening and closing of stomata, where water is released for cooling the plant and hence gets time to grow as reported by Silva and Uchida (2000). Moreover over adequate amount of rainfall and favorable humidity present in the study area supported the dissolution of minerals in the soil to be available for plant growth as observed by Roy *et al.* (2006). Although there were differences in the amount of N contents between T5 and T6, the results on PP were shown to be not significantly different. This incidence could be supported by the ability of S in NPSZn and SA to dissolve faster than the one in Urea, becoming available for plant use.

The observed higher NTPP in T6 and T5 than in T1 and T2 could be due to the role played by the relatively higher levels of N in those treatments, having the ability to promote more tillers of the plant. The N element helps in the formation of chlorophyll and promotes the tillering rate of the plants as observed by Laidlaw (2005). An increase in the number of tillers observed with different rates and amounts of nitrogen fertilizer application in this study is supported by the study conducted by Kizima *et al.* (2015). Additionally, the present results are also supported by the study of Mushtaque *et al.* (2010) who reported that the higher rate of nitrogen supplied a high number of N nutrients in forages which triggered the activation of dormant buds to produce more tillers per plant. Moreover, the Zinc present in NPSZn mixed with SA and Urea in T5 and T6 used in the present study was an essential component of several metalloenzymes in plants (variety dehydrogenases) and therefore was necessary for different functions in plant metabolism, such as tillering. Similarly, a study by Wongsuwan (1999) observed a steady increase in the tillering rate of *Brachiaria ruziziensis* on the application of fertilizer containing nitrogen elements. According to Lafarge and Loiseau (2013), tiller production is vital for perennial grasses to sustain forage production by replacing plant parts that are lost through aging, grazing, or cutting. Sodehinde (2006) observed that nitrogen fertilizer influenced positively the number of tillers produced per stand in an experiment on the effect of nitrogen on the dry matter yield of *Pannicum maximum*. The number of tillers recorded was in agreement with what was reported in the literature by Yesihak (2008). The observed increased agronomic characteristics, such as the number of leaves and number of tillers due to different fertilizer applications are expected to increase both the yield and quality of the forage (Aderinola, 2011).

According to this study, the differences in (SH) could be due to the type of fertilizers applied and soil mineral reserve. The result could be due to the effect of the P content in soil and fertilizer as it influenced the increase in stalk and stem length. Similar results for (SH) were obtained for *C. gayana* by Arshad *et al.* (2016) who also observed the variation in plant height of *C. gayana* on application of different types of fertilizers. This result is supported by the finding of Rambau *et al.* (2016) which revealed that agronomic parameters of grass such as plant height were observed high on the use of a mixture of blended fertilizers NPS in Napier grass. This implies that at the higher rate of application to the soil, sulphur significantly improves the nitrogen absorption by plants hence significantly increasing both plant height and yield components. The results can be supported by the study of Yibarkew *et al.* (2020), who reported that stem height was affected by fertilizer type particularly those containing N applied at higher rates. The results obtained in this study were in agreement with Omer (1998), who showed that application of fertilizers containing high amounts of nitrogen urea resulted in a significant difference in plant height, leaf number per plant, and leaf area index of forage maize. Likewise, Mohammed (1990) found that, nitrogen fertilization significantly increased plant height, the number of green leaves, and the plant density of both legumes and grasses.

The P present in the T5 and T6 plus N in the Urea and SA had the metabolic function in young cells, such as shoots and root tips, where metabolism is high and cell division is rapid hence the high number of leaves. This result can also be supported by the study done by De Melo *et al.* (2010) in bana grass, where increasing P supply led to an increase in the number of leaves per plant because it enhanced the rate of leaf primordial initiation in the stem apex. The study by Koul, (1997) also reported that higher rates of nitrogen application resulted in higher values of plant height, leaf numbers, and leaf area of fodder maize. The results were in agreement with Gasim (2001) who found that the increase in the rate of N fertilizer increased the leaf number per plant of maize forage. The high amount of nitrogen applied to plots T5 and T6 made the forage in these plots have a high number of leaves per tiller.

The current result is in agreement with those reported by Mihret *et al.* (2018) on the LLPP of desho grass. The least LLPP observed in plants fertilized by CFYM (T2) was due to fewer amounts of nutrients taken by the plants from the CFYM which has resulted from delaying demineralization of CFYM. Moreover, the LLPP upon chemical fertilizer application had a significant effect ($p<0.05$) on the LLPP of Brachiaria grass as observed in the study by Yibarkew *et al*. (2020) where manure and control plot had low LLPP. Other studies showed that an increase in the nitrogen rate of fertilization significantly increased grass height and leaf length (Adam, 2004; Gasim, 2001; Mohammed, 1990). The results observed in this study were contrary to those obtained by Riyana (2018) who revealed that longer leaves were obtained from the *Elephantopus scaber* fertilized by the application of CFYM.

FAO (2014) reported that the growth of some grass yield components like the number of tillers and leaves may reduce other agronomic traits especially when competition is induced. On the other hand, the low LWPP observed in Control (T1) was due to the plots using the inherent nutrients found in the soil. The plants used much Mg^{2+} and Ca^{2+} and other micro minerals invested more on the development of stem thickness and leaf size rather than other parameters such as SH and leaf width. The treatments T2 and T3 were observed to produce no significant difference ($p>0.05$) between SH, NLPP and LWPP as it is revealed that longer stems have narrow leaves. However, the result obtained in control (T1) without fertilizer in this study was higher than the results obtained by Allah and Bello (2019) and Yesihak, (2008) whose study revealed the width of foliage to be less than 1.5 cm in the control plots.

The mean stems diameter of plants (SD) was increasing on the increase of S and associated minerals. The gradual increase in SD due to the application of fertilizer can be explained by the fact that a higher amount of sulphur and zinc contained in NPSZn and Urea promoted plant growth by activation of nitrogen uptake by the plant. On the other hand, the results obtained in the present study were in agreement with those of Elmar (2001) who observed an increase in SD due to the application of fertilizers whose sources were composed of many nutrients, such as N, P, and S. These results can be supported by the study done by Kropat *et al.* (2011) where the application of fertilizer containing a mixture of some minerals had been found to increase stem thickness and chlorophyll content. It can be revealed that the T6 had more supply of N, P, S, and Zn to the plants than the other treatments as it is known that Urea has 46% N/50kg. The NLPP, LWPP, and SD for T3 and T4 had no significant difference because of the nature of the CFYM in T3 and the low amount of N present in NPSZn which could not stimulate the production of more leaves with higher width and similar SD.

Conclusions and recommendations

It can be concluded that mineral nitrogen is the most limiting nutrient used in the growth of *C. gayana* forage in the study area. Thus, the application of a combination of fertilizers with nitrogen bases, such as blended NPSZn and Urea, and the sulphate of ammonia (SA) could improve the soil fertility and hence promote agronomic parameters of *C. gayana* forage. Further studies are recommended to determine the effects of the different types of fertilizers used in this study on the forage yield, quality and the economic benefits of using such fertilizers on the production of pastures.

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Conflict of Interest

The authors affirm that there is no personal relationship that may have in one way or another influenced them in writing this article. The expressed opinions are those of the authors and do not necessarily reflect those of the organization to which the authors are affiliated and sponsored.

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