



Short-term Effects of Cow Manure on above Ground Growth Characteristics of *Brachiaria ruziziensis* in Tropical Sub-humid Environment, Tanzania

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Authors' contributions

This work was carried out in collaboration between all authors. Author DDM designed the study, wrote the protocol, and wrote the first draft of the manuscript. Authors NJK and YAR managed data collection and the analyses of the study including performing the statistical tests. Author AZS managed the literature searches and refined the first draft and produced the submitted manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Aims: The study assessed the effects of different levels of cow manure application on above ground growth characteristics and herbage production of *Brachiaria ruziziensis* (Congo signal grass) in tropical sub-humid environment on arable land. The rationale behind being contribute to better understanding of how the growth and yield components of *B. ruziziensis* respond to varied levels of cow manure application

Study Design: Complete Randomized Block Design (CRBD).

Place and Duration of Study: Field experiment was conducted at Magadu Dairy Farm, located in Morogoro, Tanzania, from February to June, 2014.

Methodology: Three (3) blocks (replications), 4 treatments (0, 5, 10 and 15 t/ha cow manure

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levels), 3 m inter-block distance, 12 plots and 0.5 m inter-plot distance. Pre-plant spread of manure into plots at varying levels followed by planting of *B. ruziziensis* stem cuttings. Repetitive measurement of several above ground growth parameters at 2 weeks interval post planting up to the 10th week. At the end, the pasture stand was harvested and the above ground dry matter (DM) yield was estimated. One way ANOVA under SAS computer program was used to test if there was significant difference among the treatments at P = .05.

Results: Cow manure application had a significant effect on stem height, tiller and leaf number per plant (P < .0001), in which each subsequent increase in manure application was increasing growth of these parameters. Moreover, the DM yield differed significantly across all treatments (P < .001). However, there was no significant difference in DM yield between 10 and 15 t/ha manure application rates (P = .76).

Conclusion: Cow manure was found to improve productivity of *B. ruziziensis* by increasing stem growth, tiller and leaf numbers, thus DM. Moreover, cow manure application rate of 10 t/ha was found to be ideal level for maximum DM yield (13.5 t/ha) under the conditions of this study.

Keywords: Ruzi grass; congo signal grass; prostrate signal grass; dry matter yield; soil amendment; Morogoro; Tanzania.

1. INTRODUCTION

Pasture production and availability in Sub-Saharan Africa have become a big challenge as a result of soil infertility being caused by soil degradation which can be physical, chemical or biological [1,2]. Some of the processes that are accelerating soil degradation and infertility are soil erosion, nutrient leaching, overgrazing, unsustainable crop production [3], as well as gasification through denitrification and ammonium volatilization [4,5]. In turn, this soil degradation has led to soil nutrient depletion especially Nitrogen and Phosphorus in various tropical grasslands. For example, annual Nitrogen loss was estimated to be around 22 kg/ha in Sub-Saharan Africa over a decade ago [6]. Yet, it is reported that sub-Saharan Africa, Tanzania inclusive has the lowest mineral fertilizer nutrient application rate in the world with an average of less than 5 kg/ha that are applied to food crops [7]. Fortunately, sub-Saharan Africa is endowed with lots of livestock that produce a lot of nutritive manure, for example; average dung nutrient composition of 18.3 g N/kg, 4.5 g P/kg and 21.3 g K/kg on dry weight base was recorded from manures collected in Ethiopian highlands [8].

Tanzania has one of the highest densities of livestock in sub-Saharan Africa and ranks the third after Sudan and Ethiopia. Tanzania has approximately 21.3 million cattle, 15.6 million goats, and 7 million sheep; other livestock includes 2 million pigs and 60 million poultry [9]. Most of the livestock keepers in Tanzania occupy areas that are considered marginal for crop production and still rely on naturally established

pasture for feeding their animals. However, those who occupy arable lands tend to keep few high producing animals mainly dairy cows and tends to rely on established pasture such as elephant grass (*Penisetum purpureum*), napier grass (*Tripsicum andersonii*), rhodes grass (*Chloris gayana*) and Congo signal grass (*B. ruziziensis*).

Brachiaria spp are amongst highly valued forage grasses due to higher feeding values that include high palatability, high crude protein content (7 – 13%), high digestibility (55-75%) and metabolizable energy of about 7.9 MJ/kg [10]. In addition, *B. ruziziensis* is a perennial tropical grass that is highly productive ranging from 6 DMt/ha unfertilized to 20 DMt/ha under high rates of N fertilizer application [10]. However, for best performance *B. ruziziensis* needs fertile soils and adequate rainfall (over 1,000 mm mean annual rainfall) [10]; but unfortunately most high rainfall areas with fertile rich soils are densely populated with limited areas for field grazing. Alternatively, zero grazing is a common practice in densely populated areas, where smallholder farmers have opted to keep few but highly producing dairy cows. Lamentably, the culture of fertilizing pasture is still uncommon to most smallholder farming communities in Sub-Saharan Africa including Tanzania, where manure is normally used for fertilizing food crops such as maize, millet, beans and plantains [11]. Thus, this practice tends to accelerate soil nutrient mining [3,11], consequently reducing both growth and yield of various desirable pasture species including *B. ruziziensis*.

Soil nutrient mining has become critical problem in most areas that practice zero grazing system,

where forages are cut and carried to the penned animals throughout the year continuously. For example, soil nutrient mining under napier grass (*Pennisetum purpureum*) was severe from high estimated soil nutrient losses in the napier-livestock-manure cycle in Kisii, Kakamega and Embu districts, Kenya. In which, a napier herbage containing 23.2 N, 2.4 P and 30.3 K per kg was harvested with limited nutrient recycling to produce cattle milk containing 5 N, 1 P and 2 K per kg, cattle meat 30 N, 8 P and 2 K per kg and manure by products comprising of 14 N, 5 P and 11 K per kg [12]. These records imply that there was high nutrient net loss and thus unsustainability of smallholder dairy cow production under zero grazing systems in those parts of Kenya.

The current production of *B. ruziziensis* in the rural Tanzania is anecdotally very low in such a way it does not meet the pasture demand of the livestock. Soil infertility is claimed to be amongst the key factors for low pasture production. *B. ruziziensis* is reported to have good tolerance to acid soils and also responds well to nitrogen, either from fertilizer or legumes [13]. Both organic and inorganic fertilizer can be applied in the soil to add nutrients for increasing the yield of *Brachiaria ruziziensis*. It can yield up to 20 DMt/Ha when fertilized with N rich inorganic fertilizers [13,14]. However, inorganic fertilizers are too expensive for most smallholder farmers to afford purchasing [15]. Nevertheless, inorganic fertilizers do not last longer in the soil and requires frequent re-application. In contrary, organic manures like cow manure are known to last longer in the soil whilst allowing pasture to be re-grown several times without immediate replenishment [16]. Apart from the aforementioned benefits of manure application; it is also known to be a cheap and affordable way of soil fertility replenishment by smallholder farmers.

There are some related research that have been conducted on liquid manure application to soil and its effects on crop growth, yield composition and on soil properties [17,18]. However, studies that assess the response of above ground growth characteristics and DM production of *B. ruziziensis* under cow manure application in tropical areas are still limited. Cattle is the most abundant livestock in Tanzania and hence of crucial important in manure production and nutrient recycling. Thus, studies towards improving knowledge on appropriate levels of cow manure application for sustainable pasture production are worth undertaking.

Therefore, this study aimed at assessing the growth rates and dry matter yield of *Brachiaria ruziziensis* as the results of varied levels of cow manure application. This being a first step in enhancing the exploitation of the potential plenty available cow manure for increasing productivity of *B. ruziziensis*. This is expected to contribute into reducing the problem of dry season livestock feed shortages, as well as reduce poverty and food insecurity through increased milk and meat production in rural Tanzania.

2. MATERIALS AND METHODS

2.1 Study Area Description

The study was conducted at Magadu Dairy Farm (MDF) located at Sokoine University of Agriculture (SUA) 5km south west of Morogoro Municipality. The MDF is located at 37° 39'E and 06° 51'S with altitude of 545 m a.s.l. The area receives bimodal rainfall pattern ranging from 800 mm to 900 mm per annum. Long rains start in early March up to the end of May or early June of each year and short rains that are rather unreliable starts from October up to the late December. The relative humidity (RH) of the area is 81% during rainy season with the daily temperature ranging from 21°C to 30°C. Also, MDF is about 60 Ha in size and has about 150 dairy cattle and 70 dairy goats. Dominant desirable grass species found in the farm include *Brachiaria* spp, *Cynodon* spp, *Urochloa* spp and *Hyparrhenia* spp. Planted forage grasses include *Pennisetum purpurium*, *Cenchrus ciliaris*, and *Chloris gayana*.

2.2 Preparation of Experimental Site

The experimental land of approximately 18 m x 4 m was demarcated, cleared, cultivated and harrowed at the depth of about 15 cm. Three (3) blocks each 2 m wide and 12 m long were demarcated with an inter-block distance of 3 m, around the periphery a 2 m width was left as a path and outside it a wood fence was erected. Three soil samples were collected from each block at a depth of approximately 20cm, and the samples were thoroughly mixed together per block and then sent to laboratory for chemical and textural analysis. Within each block 4 plots each with 2 x 2 m² were cultivated with an inter-plot distance of 1 m, and there were a total of 12 plots. Dry cow manure was randomly collected from the cow kraal which was heaped at one point, uniformly mixed and the 5 sub-samples of

about 200 g were taken to the laboratory for moisture content determination before application. According to the laboratory results, the dry matter content of the cow manure that was used for this study was approximately 58% implying that out of 10 kg applied manure only 5.8 kg is manure and the rest is probably water and urine. Thereafter, the manure rates were calculated followed by its application into the experimental plots. The dry cow manure was uniformly mixed with the soil in the 0 to 10 cm depth at different levels namely: 0 (control), 5, 10 and 15 t/ha. Each manure level was replicated three (3) times following the complete randomized block design (CRBD) procedures [19]. Then, *B. ruziziensis*'s stem cuttings containing the rooting nodes were planted on 6th March 2014 (beginning of rain season). The planted stem cuttings/rhizomes of about 10 cm long were collected from Magadu Dairy Farm and planted at constant intra and inter row spacing of 30 cm. The plots were watered in the first two weeks (morning and evening), as well as weeded in order to ensure effective plant establishment. After two weeks following planting of *B. ruziziensis*, data on above ground growth parameters started to be recorded and there was no further irrigation of the plots until the end of the experiment.

2.3 Data Collection Method

Systematic random sampling technique was employed during measurements of growth parameters within the plots, in which the first plant was randomly chosen and there after 2 plants were skipped along the rows, the 3rd one was selected for data collection. About 20 plants per plots were measured. Parameters that were measured include culm/stem length, number of new leaves, tiller number, leaf length and width. Leaf length and width were measured from a fully developed leaf, in which the third leaf from the newly developing top leaf was consistently used [20]. Data were recorded after every 2 weeks until grazing height was reached which is 1 m (at the onset of flowering) which was at the 10th week (18th May 2014). At pasture maturity, a 0.5 x 0.5 m² quadrat frame was thrown twice in each plot and all the sward falling inside it was clipped at height of about 15 cm above ground, packed in well labeled paper bags and taken to laboratory where the sample was dried to constant weight in an oven set at a temperature of 80°C for dry matter determination.

2.4 Data Analysis

The collected data were subjected to GLM of SAS [21]. The analysis of Variance (ANOVA) was computed using the following model: $Y_{ij} = \mu + \alpha_i + \beta_j + e_{ij}$ where μ = constant, α_i = effects of manure treatments, β_j = an effect of blocks and e_{ij} is error term. The Duncan Multiple Range Test was used to compare the significant differences between the means within the treatments at $P = 0.05$.

3. RESULTS AND DISCUSSION

3.1 Rainfall and Temperature Characteristics

The monthly mean rainfall and temperature records for Magadu Dairy Farm were collected from the SUA Main Campus Meteorological Station which is located about 1 Km away from the experimental site. Rainfall records for the 2014 growing season (February - May) indicate that it was well above the average rainfall for over several years ago (Table 1). This implies that 2014 was a wet year and this might have influenced performance of *B. ruziziensis*. Also, the plots were watered twice a day during the first two weeks following planting. The observed growth of *B. ruziziensis* might also be much higher than average owing to the fact that limited rainfall is known to be amongst major constraints for pasture productivity in Tanzania. However, the mean monthly temperature records at the period of this study seem to be close to the average of previous years. This implies that temperature for Morogoro seems to be relatively stable and within desirable range for most tropical grasses. Hence, pasture management plans in areas with similar conditions to that of the study site should focus much on water related stresses such as drought and floods.

3.2 Soil and Manure Chemical Characteristics

Soil analysis results for the soil samples that were collected at the experiment site before manure application are presented in Table 2. The soil was slightly acidic and clay loam (51% clay, 12% silt and 37% sand) was the predominant soil textural class at the experimental site. Most soil macronutrients were found to be below the critical levels for optimal crop production [22]. Thus, manure addition was deemed necessary for replenishing the observed soil nutrient deficit.

However, soil pH was almost within the recommended range (5.5–7.5) for optimal availability and plant uptake of various essential soil nutrients [22]. Nutrient composition and pH of the manure that was applied in the experimental plots before pasture planting (Table 2). The pH of the manure was moderately alkaline and most nutrients were at adequate levels for improving soil condition.

3.3 Effect of Cow Manure on the Stem Height of *Brachiaria ruziziensis*

Application of cow manure was found to have overall significant effect on the stem height of *B. ruziziensis* ($P \leq .0001$). However, there was no significant effect on the stem height of *B. ruziziensis* from planting time to week 2 ($P = .81$). Also, there was no significant difference in stem height between 10 and 15 T/Ha cow manure application rates ($P=.063$) from week 4 to 10 (Fig. 1). The lack of significant difference from week 1 to 2 post-planting implies that stem growth was not influenced by the nutrients from the cow manure, rather by inherent soil nutrients. The observed significant difference in stem height post week 2 is attributed to the release of nutrients from the manure and their subsequent assimilation by *B. ruziziensis* for growth. This finding can be supported by a study on incubation of sheep manure and immature cow manure composts which revealed that only 1 to 8.2% of total added carbon was mineralized after 28 days [23]. Likewise, another study reported that it took 30 days at 30°C and under optimal soil-water content to generate 13% of plant-available nitrogen from 23 to 27 percent N of cow manure compost [24]. Moreover, peak nutrient decomposition and release of various essential nutrients from compost manure in Sahelian zone under sandy loam soils was observed to be at week 20 of the incubation period [25]. Therefore, the observed effects of cow manure on stem growth of *B. ruziziensis* from the second post planting and fourth post manure application week can be attributed to increase in availability of essential growth nutrients from the cow manure that were slowly released to the growing medium following microbial decomposition. Henceforth, the observed increase in stem growth following subsequent increase in manure application can also be attributed to this fact.

The lack of significant difference between 10 and 15 t/ha manure application rates is attributed to the fact that sufficient soil nutrients

available in the manure were supplied at the 10 t/ha level and thus further manure addition was not leading to any significant increase in stem height (Fig. 1).

3.4 Effect of Cow Manure on the Number of Tillers of *Brachiaria ruziziensis*

Cow manure was found to have a significant effect on tillering rate of *B. ruziziensis* ($P < .001$). All pairwise comparisons were significantly different ($P < .05$). In which, each subsequent increase in manure quantity was culminating into increased number of tillers per plant (Fig. 2). The tillering rate was higher at week 6 to 8 and then the rate declined as the plants started flowering. Similarly, previous studies observed a steady increase in tillering rate of *B. ruziziensis* during the vegetative phase followed by leveling off or decline during the reproductive phase [20]. Decline in tillering rate as the *B. ruziziensis* was maturing might be attributed to the fact that the plant was investing much on the reproductive and storage organs.

3.5 Effect of Cow Manure on the Number of Leaves per Plant of *Brachiaria ruziziensis*

Cow manure application did not have significant effect on number of leaves at the first two weeks after planting ($P = .087$). However, from week 2 to 10 it had a significant effect ($P < .0001$) on the number of leaves per plant (Fig. 3). The failure of cow manure to influence leaf production in the first two weeks might be attributed to manure maturation time, in which at the first two weeks mineralization was still slow and hence few nutrients were available to influence leaf production. Moreover, it might be attributed to plant root development in which the plant was still investing in root growth. The observed influence of cow manure on leaf production from week 4 onwards might be attributed to the fact that nutrients were now available and the plant was investing on photosynthetic organs which include leaves for effective growth, reproduction and tolerance to unfavorable conditions.

3.6 Effect of Cow Manure on the Dry Matter Yield of *Brachiaria ruziziensis*

Cow manure application was found to have significant effect ($P < .001$) on the DM yield of *B. ruziziensis* at flowering period that was at 10th

Table 1. Climatic mean monthly rainfall and temperature for Morogoro recorded at SUA main campus meteorological station, 2014

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul
Mean monthly rainfall (mm) for 2014	56	69.4	182.4	231	113	24	13
Climatic mean monthly rainfall (mm) 2000 - 2013	93	60	102	147	63	15	5
Mean monthly temperature (°C) for 2014	22.9	22.2	21.8	21.1	19.5	17.5	16.4
Climatic mean monthly temperature (°C) 2000 - 2013	20.5	21.5	21.5	20	20	17.5	16.5

Table 2. Selected chemical properties of the soil and dry kraal manure from Magadu dairy farm, Morogoro, Tanzania

Parameter	Soil	Dry kraal manure
pH	5.49	8.17
N ⁻¹ (%)	0.26	1.86
PO ₄ ³⁻ (%)	5.38	43.37
K ⁺ (%)	0.31	0.38
Mg ²⁺ (%)	0.06	0.29
Ca ²⁺ (%)	0.74	1.76
Na ⁺ (%)	0.01	0.05

The lack of significant difference 10 and 15 t/ha (Fig. 4) manure application rates implies that applications of cow manure beyond 10 t/ha under the conditions of this experiment are uneconomical due to additional labour and fuel for manure distribution with insignificant increase in yield. Nevertheless, excessive manure application might pose environmental problems, in particular pollution of surface water resources due to runoff and leaching of excess nutrients.

3.7 Effect of Cow Manure on the Leaf Length and Width of *Brachiaria ruziziensis*

Cow manure application was found not causing significant effect on leaf length of *B. ruziziensis* sward (P = .71). Similarly, there was no significance difference in leaf width of *B. ruziziensis* sward under different levels of cow manure application (P= .98), Figs. 5 and 6. This phenomenon is also reported in previous study that states that application of nitrogen nutrients tends to stimulate growth of some grass yield components and with a likelihood of reducing others especially when competition is induced [27]. For example, it was observed in *Paspalum plicatulum* that nitrogen application increased tiller density, tiller fertility, and raceme number on the individual inflorescence. However, percent tiller survival, raceme length, and individual seed weight decreased, while seed density per unit raceme length did not vary significantly [29]. Moreover, during this study, site specific environmental factors such as sunshine hours, soil and air temperature were not recorded and these factors may have also affected some plant growth parameters.

week post planting (Fig. 4). However, there was no significant difference between 10 and 15 T/ha manure application rates (P = .76). Previous studies have reported ruzi grass's yield of 21.5 tDM/ha in Tanzania [26], implying that the yield under this study was relatively small. Furthermore, ruzi grass's yield of 11.1 tDM/ha without fertilizer and 27.0 tDM/ha when fertilized with 600 kg N /ha /year is reported in Gualaca, Panama where mean annual rainfall is 3997 mm [27]. Moreover, ruzi grass's yield of 17.6 tDM/ha per year at 800 kg N/ha per year application was observed in Malaysian sandy loam soil [13]. The observed smaller yield of ruzi grass under this study contrary to previous studies might be due to short period of data collection in which data were recorded in only single growing season and the stand was still establishing itself. It would be of an interest to record the *B. ruziziensis*'s yield for several seasons in order determine reliable dry matter yield and for drawing firm conclusion on the effects of manure application on the *B. ruziziensis*'s dry matter yield. This suggestion is based on the fact that effects of manure on plant growth and on biological, chemical and physical properties of soil can last for many years [28].

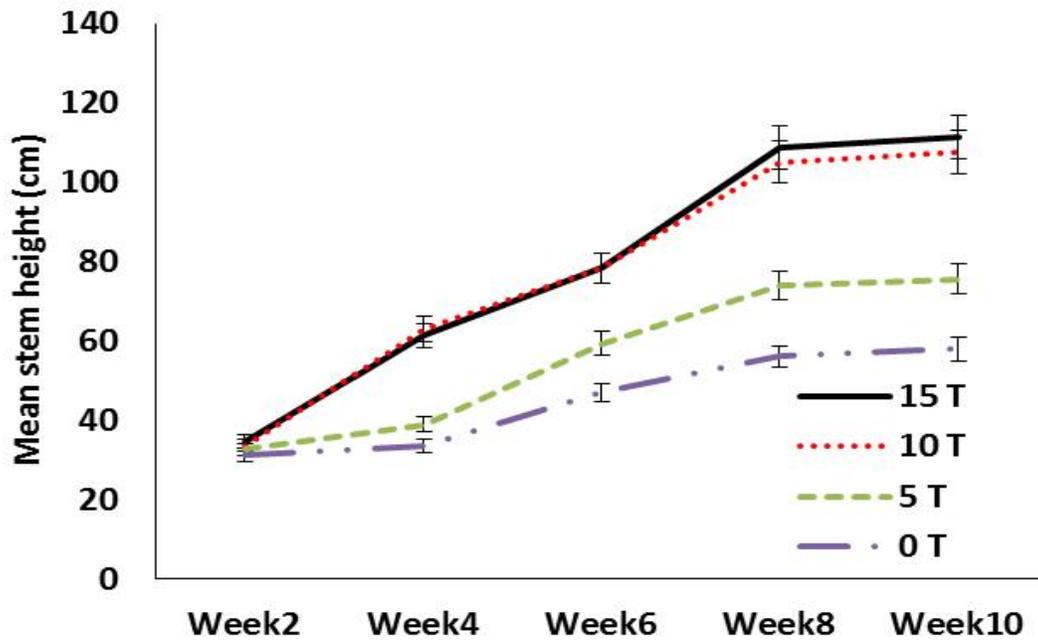


Fig. 1. Effects of cow manure application on *B. ruziziensis* stem growth at Magadu dairy farm, March – May, 2014

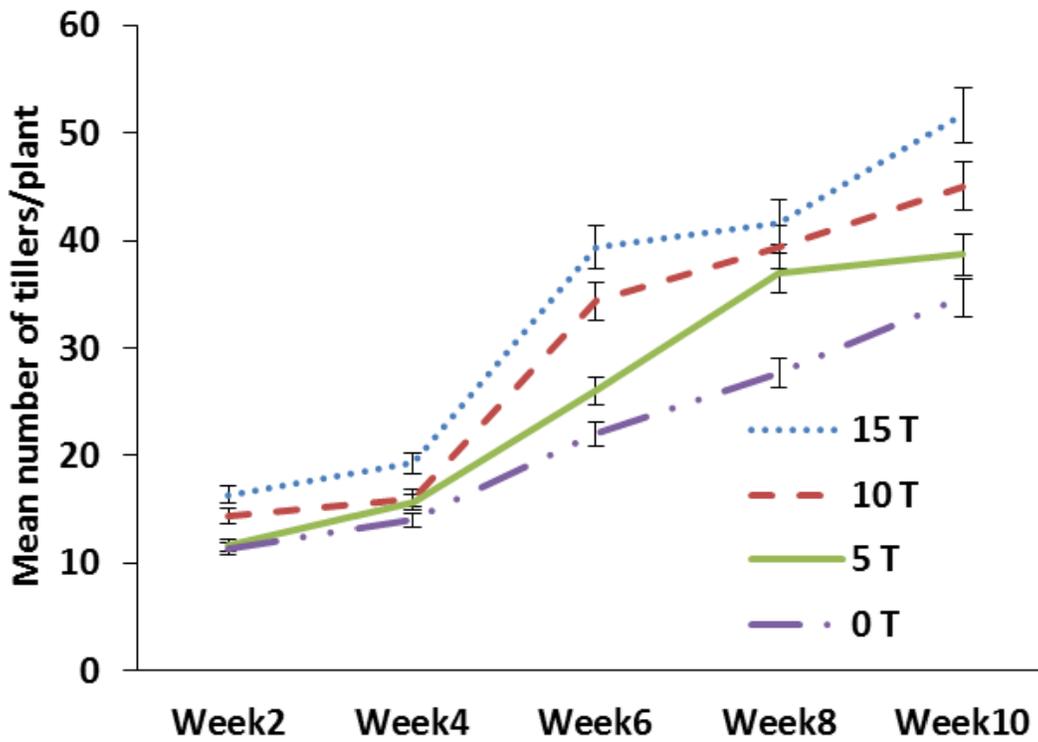


Fig. 2. Effects of cow manure application on *B. ruziziensis* mean tiller number per plant at Magadu dairy farm, March – May, 2014

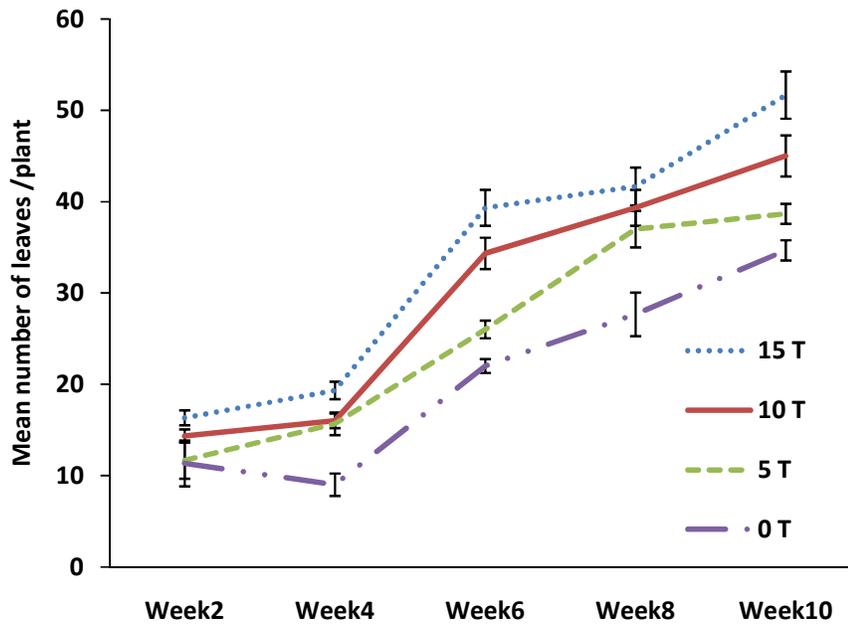


Fig. 3. Effects of cow manure application on *B. ruziziensis* mean leaf number per plant at Magadu dairy farm, March – May, 2014

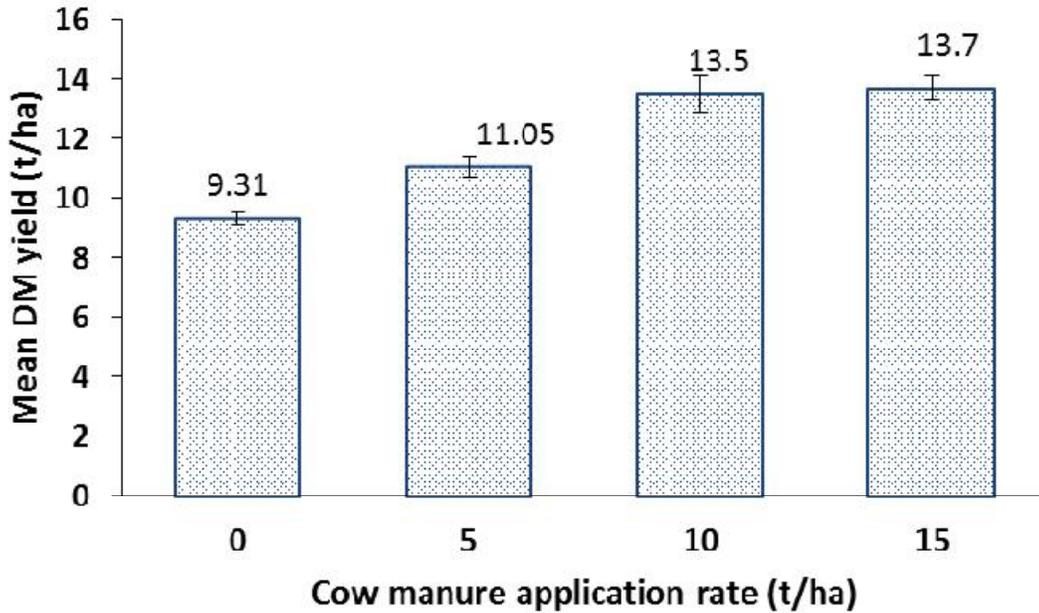


Fig. 4. Effects of cow manure application on *B. ruziziensis* dry matter yield at Magadu dairy farm, March – May, 2014

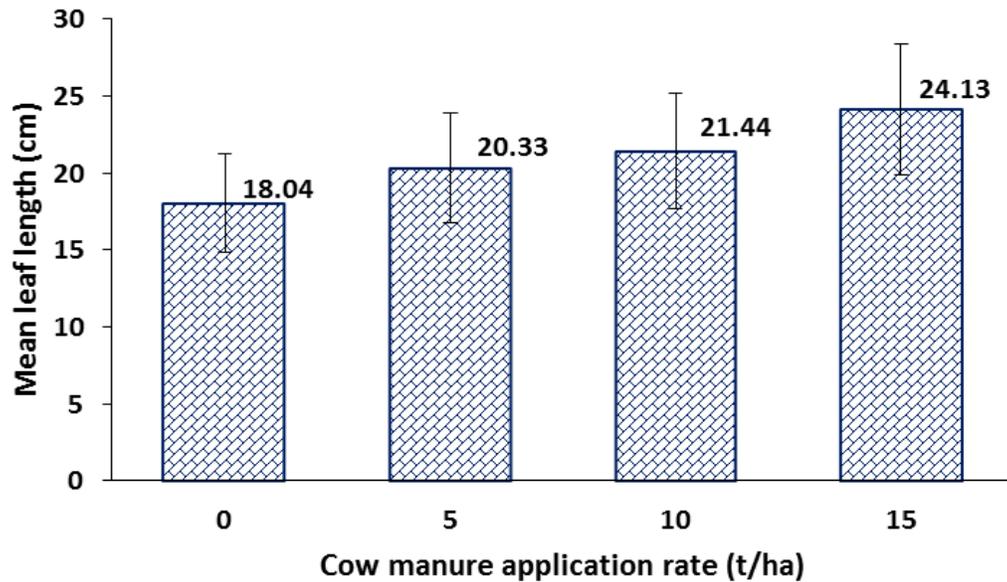


Fig. 5. Effect of manure application on leaf length at week 10 following establishment of *B. ruziziensis* stand at Magadu dairy farm, Tanzania, March – May, 2014

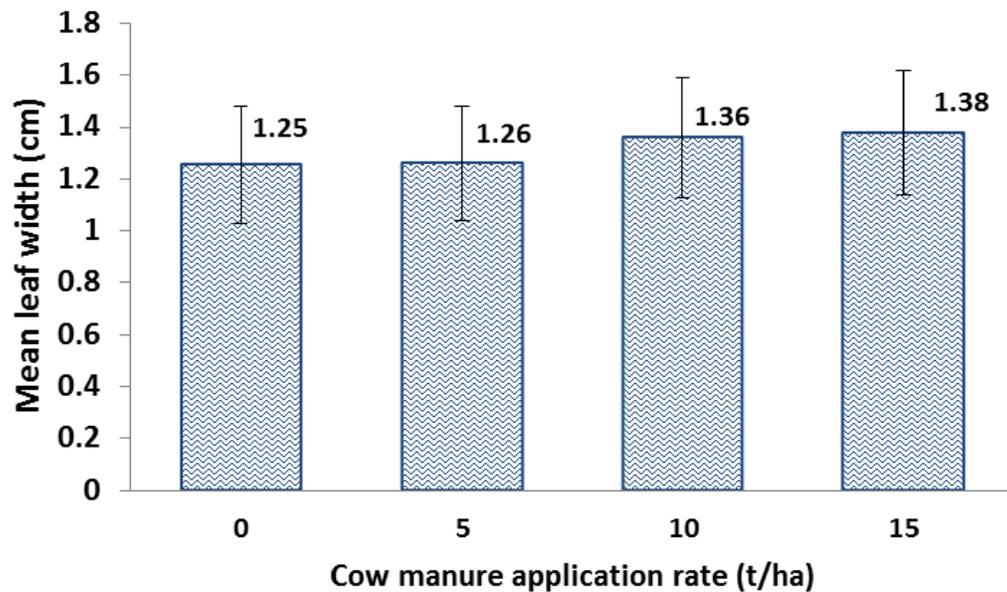


Fig. 6. Effect of cow manure application on leaf width at week 10 following establishment of *B. ruziziensis* stand at Magadu dairy farm, Tanzania, March – May, 2014

4. CONCLUSION

There is clear evidence that cow manure improves growth performance of *B. ruziziensis* through increased stem growth, number of tillers

and number of leaves per plant with eventual increment in dry matter yield. The estimated dry matter yield of 13.5 and 13.7 T/Ha at cow manure application rate of 10 and 15 T/Ha, respectively; indicates 10 T/Ha cow manure is

sufficient for fertilizing *B. ruziziensis* in areas with similar condition to this study. Moreover, it was revealed that cow manure application in pasturelands appears to be a good practice that needs to be adopted by the livestock farmers for sustainable pasture production through improved yield and fostering nutrient recycling. However, a thorough analysis of the physical and chemical properties of both manure and soil should be done in order to inform proper treatment of the manure and harness its correct application rates. Preferably, experimental manure application rates should be comparable or ideal to the farmers' field conditions and practices.

CONSENT

It is not applicable.

ETHICAL APPROVAL

It is not applicable.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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