Improved forage cultivation for increased in fodder availability and climate change mitigation in the Savanna agro-ecological zone of northern Ghana

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Abstract

The study was conducted to investigate the biomass yield and quality of two forage species *Brachiaria ruziziensis* (*B. ruziziensis*) and *Sorghum almum* (*S. almum*) in a Randomized Complete Block Design (RCBD) in two different locations (Bihinayili in the Savelugu District and Zanlerigu in the Nabdam District) in the Savanna agro-ecological zone of Ghana. Agronomic data were collected and representative samples of forage biomass taken at 60 days after planting to estimate dry matter yield and nutritive quality. The two-way interaction effect of forage species and experimental site was not significant for both agronomic and chemical parameters except for tiller number. The average leaf size was broader (P=0.006) in *S. almum* (299.0 cm^2) than *B. ruziziensis* (85.0 cm^2). Number of leaves per plant was higher (P=0.016) in *B. ruziziensis* (10.75). Number of tillers per plant in *B. ruziziensis* (9.62) was higher (P=0.001) than *S. almum* (2.88). Plant height was however, higher in *S. almum* (183.1 cm) than *B. ruziziensis* (90.1 cm). Dry matter yield of forages at 60 days after planting was higher (P<0.001) at Bihinayili (8.49 tons/ha) than that at Zanlerigu (2.23 tons/ha). The CP content of the forages at Bihinayili (89.7 g/kg DM) was also higher (P=0.018) than that at Zanlerigu (68.6 g/kg DM). Dry matter yield of *B. ruziziensis* (4.84 tons/ha) did not differ significantly from that of *S. almum* (5.88 tons/ha). In conclusion, *B. ruziziensis* and *S. almum* performed well within the Savanna agro-ecological zone and could enhance fodder supply and carbon sequestration.

Keywords: Biomass yield, *Brachiaria ruziziensis*, Crude protein, Savanna agro-ecology, *Sorghum almum*

Introduction

Farmers in Sub-Saharan Africa (SSA) depend heavily on crops and livestock products for their livelihood which are produced mainly under rain fed conditions (Agyemang, 2012; FAO, 2012). The livestock sub-sector value chain is estimated to employ about 1.3 billion people and supports 600 million farmers in developing countries in general (Thornton, 2010).

In Ghana, livestock farmers face feed inadequacy constraint. The common livestock feed resources utilized by most smallholder farmers in Ghana are natural pasture, crop residues and agro-industrial by-products (Konlan et al., 2016; Ansah and Issaka 2018). There is insignificant conservation of the natural pasture for use as hay, as well as very low adaptation of improved forage cultivation as fodder for feeding ruminants and this is largely due to low technical know-how of smallholder farmers. In the wet season, the extensive cultivation of grazing lands for food crop production limits access to the high-quality fodder by livestock. Smallholder livestock farmers often tether their animals to prevent them from encroaching on cultivated farm lands. As the dry season progresses, the major feed resources such as natural pasture and crop residues deplete in availability and quality, consequently affecting the productivity of animals. This situation results in performance below optimal levels of the indigenous livestock species often kept by farmers.

Also, the existing effect of climate change is much felt through late onset and irregular rain fall pattern that significantly reduces biomass production in both natural pasture and cultivated food crops and further compounds fodder scarcity in the dry season due to the low biomass production during the growing season (Konlan et al., 2018). The situation also has the potential to reduce the grassland carbon sequestration ability through less carbon absorption in the atmosphere. In line with climate change mitigation, Andeweg and Andy (2013) stated that, grasslands have high carbon sequestration potential and serves as carbon sink due to the large quantities of carbon it stores, while providing other ecosystem services particularly for grazing animals. Improving grassland management practices and planting improved forage species to increase vegetative cover are therefore best practices that can improve the quantity and quality of fodder available to animals and also increase soil carbon sequestration and storage. Forage cultivation will serve as an environmentally friendly practice that improves resiliency in livestock production, increase farmers output and enhance their livelihood as animals play important roles in the lives of many people in the farming communities (Thornton, 2010).

Improved forage trials in the Savanna agro-ecological zone have been ongoing to compile data on potential forages for smallholder farmer adoption. These include *Stylosanthes* sp, *Panicum maximum*, *Panicum minimum*, *Cynodon* sp, *Andropogon gayanus* and *Pennisetum purpureum* (Barnes and Addo-Kwarfo, 1996; Tenakwa et al., 2019). *Brachiaria ruziziensis* (Congo grass) and *Sorghum almum* (Forage sorghum) could be studied and added to the potential forages for cultivation in the Savanna agro-ecological zone of Ghana to augment fodder availability.

Brachiaria ruziziensis originates from East Africa specifically in Ruzizi valley in the East of Democratic Republic of Congo and spread to Rwanda and Burundi (Schultze-Kraft et all.,1992). The grass grows well in most humid tropics. Morphologically, *B. ruziziensis* is short-lived perennial forage grass (Husson et al., 2008). It is semi-prostrate and rhizomatous. The grass roots from the nodes and forms a dense canopy (Cook et al., 2005). *Brachiaria ruziziensis* has a dense system of bunched and fast growing roots that can grow down to a depth of 1.8 m (Husson et al., 2008) Culms grow from the nodes of the rhizomes and may reach a height of 1.5 m when flowering (Cook et al., 2005). The leaves are soft but hairy on both sides, lanceolate in shape and up to 25 cm long and 1-1.5 cm broad, light-green in colour. The inflorescence consists of 3-9 relatively long racemes (4-10 cm) that bear spikelets in 1 or 2 rows on one side of a broad, flattened and winged rachis (Cook et al., 2005). The spikelets are hairy and 5 mm long. The grass is a good forage with great value for livestock feeding. It is palatable and has good nutritive value (Schultze-Kraft et all.,1992). It is mostly grazed directly on pastures in the open or under plantations. *Brachiaria ruziziensis* can be cut dried as hay or fed fresh to confined ruminants (Cook et al., 2005; Schultze-Kraft et all.,1992).

Charlotte et al. (1988) reported that *S. almum* originates from South America and a hybrid between grain sorghum (S. bicolor) and Johnsongrass (S. halepense). *Sorghum almum* is an erect, robust, tussocky, short-leaved perennial grass which easily establishes from seed, and grows rapidly with numerous tillers (Charlotte et al., 1988). The grass grows up to 4.5 m tall (Muhammad, 1993). It has short, thick, upward-curving rhizomes producing new shoots near the parent clump (Ejeta and Grenier, 2005). The stems are solid / pithy, to 1 cm thick, mostly unbranched (Charlotte et al., 1988). The nodes glabrous or finely pubescent. Leaf blades linear, apex tapering, 30–45 cm long, 0.5–2.5 cm wide and has glaucescent blade and sheath usually glabrous except for hairs near the membranous ligule (Charlotte et al., 1988 Ejeta and Grenier, 2005). As a forage crop, the dry matter yield of the grass at 7 weeks after planting was reported as 1.3 tonne DM/ha (Kallah et al., 1999).

This study sought to add to the list of potential forages to enhance fodder production by investigating the growth, yield and nutrient composition of *Brachiaria ruziziensis* (Congo grass) and *Sorghum almum* (forage sorghum) in the Savanna agro-ecological zone.

Materials and methods

Location

The study was conducted in two districts within the Savanna agro-ecological zone in northern Ghana. The specific locations were; Bihinaayili (latitude 9^0 25’ N and longitude 0^0 58’W at an altitude of 183m above sea level) in the Savelugu District of Northern Region and Zanlerigu (latitude 100^0 48’ N and longitude 0^0 44’W at an altitude of 222m above sea level) in the Nabdam District of Upper East Region (GMA, 2016). The zone experiences a unimodal rainfall pattern which begins in late April and ends in October. The average rainfall volume in the area is reported to be 1043 mm per annum with an average temperature of 28.3 °C (Ampadu et al., 2019). The area experiences cool Harmattan winds that occur between November and February and warm weather conditions from March to April annually (GMA, 2016).

Experimental design

Two forage species thus *B. ruziziensis* and *S. almum* were planted on demonstration plots as a Randomized Complete Block Design (RCBD) in two different locations. Each block contained two treatments T1 (*B. ruziziensis*) and T2 (*S. almum*) and replicated four times. As an on-farm experiment, each plot was assigned to one farmer under the guidance and monitoring of the research team. In all 16 farmers were involved in the experiment in both study sites (8 farmers from Bihinayili and 8 from Zanlerigu). The participating farmers were crop-livestock farmers who willingly agreed to participate in the experiment. Certified seeds of these two forages were acquired from International Livestock Research Institute (ILRI) in Ethiopia for the experiment.

A plot size of 400 m^2 was acquired as a block and sub-divided into eight plots each measuring 50 m^2 (10 × 5 m) with 1m length between plots in each community for the experiment. The two forage species were randomly assigned to the plots for planting. *Cajanus cajan* was planted as border crop around each block. The plots were prepared by ploughing and manual harrowing of the field to allow drilling for planting.

The forage seeds were mixed with rice husk in a ratio of 1:5 forage seed to rice husk and drilled into the soil. The drilled lines were spaced 60 cm apart with 100 g of seeds per plot and making a seeding rate of 20 kg/ha. The trial span from July to November 2016 under rain-fed condition.

Data collection

Monthly rainfall data were taken from each experimental site for the 2016 rainy season. Soil samples were also taken at the experimental plots in each location and analyzed for its chemical and physical properties. Some of the specific soil parameters determined were Nitrogen, Phosphorous, Potassium and pH. Agronomic data such as days of emergence after planting, plant height, number of leaves per plant, leaf size (cm^2) and number of tillers per plant at 60 days after planting. The plant height was measured from the base of the plant to the tip of the long leaves on top of plant, held up-right using a 2m long graduated duraplast quarter inch pipe. The pipe graduation was done in centimeters (cm) with a student’s metre rule. The leave size was measured with a metre rule from the base to tip of the leave whereas the number of leaves and tiller number per plant were counted physically. To determine the biomass, yield of the forage crops, a representative cutting of the forage biomass at a stubble height of 5 cm was done in 1m^2 quadrat excluding border line plants. Sub-samples of the harvest from each treatment were preserved for the quality evaluation.

Laboratory and data Analysis

Soil analysis was done at CSIR – Savanna Agricultural Research Institute’s soil chemical laboratory at Nyankpala, Tamale, Ghana. The samples taken were ground and sieved with 2 mm mesh after air drying. Particle size analysis was done by following the hydrometer method (Anderson and Ingram, 1993). The soil pH was determined using 0.01 M $CaCl_2$ solution in a 1:2.5 soil: solution ratio, soil organic carbon was analyzed using Walkley-Black method (Nelson and Sommers, 1982), total nitrogen by Kjeldhal method (Tel and Hegatey, 1984), Available phosphorus was determined following the procedure of Bray and Kurtz (1945), exchangeable calcium, potassium, sodium and magnesium were extracted with ammonium acetate (pH 7.0) and determined by Atomic Absorption Spectrophotometry (AAS). Total exchangeable bases (TEB) were calculated as the sum of exchangeable Ca, Mg, K and Na.

Forage nutritional analysis was done in the Forage Evaluation Laboratory, Department of Animal Science, University for Development Studies, Tamale - Ghana. Sub-sample from each harvest was taken and milled to a particle size of about 1 mm after drying. The milled samples were then subjected to Dry matter (DM), Nitrogen (N), Neutral Detergent Fibre (NDF) and and Acid detergent Fibre (ADF) analysis. Nitrogen content was estimated following the Kjeldahl method (AOAC, 1990). Crude protein (CP) was calculated as N × 6.25. The NDF and ADF content were also determined according to Van Soest et al. (1994) procedure.

Metabolizable energy was calculated using the equation ME (MJ/kg DM) = 2.20 + 0.136GP + 0.057CP + 0.0029CF^2 proposed by Menke and Steingass (1988).

Where: GP= *In vitro* gas production at 24 h, CP= Crude protein, CF= Crude fat

Data Analysis

The agronomic and forage quality data collected were analyzed by ANOVA using Genstat software (14th edition; VSN International, 2011) in 2 × 2 factorial design. The factors were the two forage species and the two experimental sites. The physical and chemical soil properties were analyzed as one-way ANOVA with the two locations representing the factors. The means were separated using LSD at 5% significance level.

Results

Rainfall and soil chemical properties of experimental sites

The number of times rain fell in the experimental sites summed up to 74 and 64 in Savelugu and Nabdam districts respectively, throughout the year. This amounted to an average annual rainfall of 1127.2 and 919.3 mm in Savelugu and Nabdam Districts respectively (Figure 1).

The soils at the experimental sites were generally loamy in Savelugu District and sandy loam in Nabdam District. Nitrogen content of the soil in the experimental site at Nabdam District was higher (P<0.001) than that of Savelugu District (Table 1). The

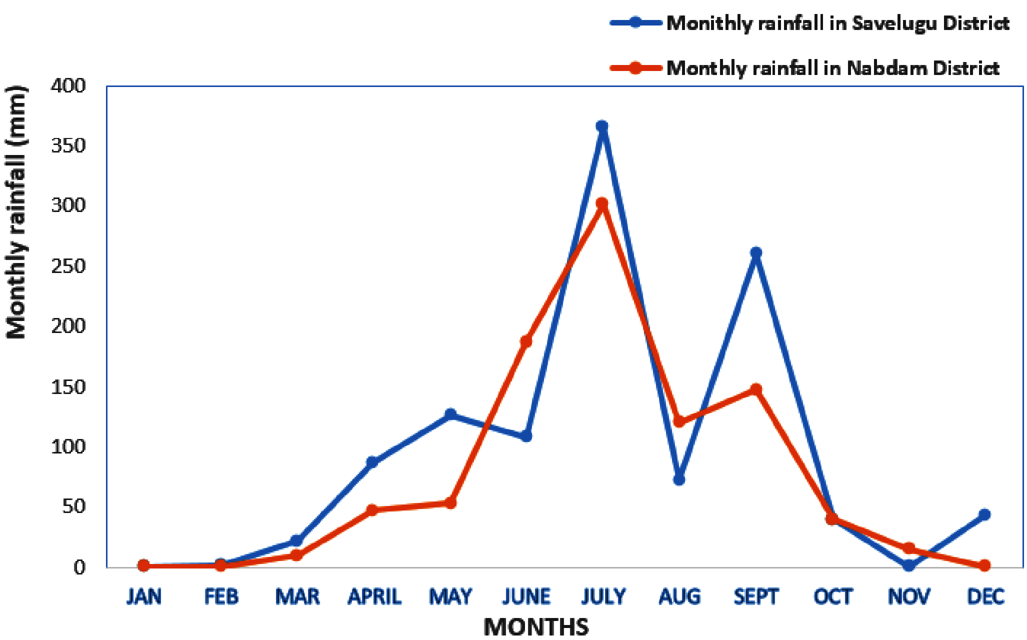

Figure 1 Monthly rainfall data in 2016 at the two experimental sites

TABLE 1
The physical and chemical properties of soil taken on the experimental plots

Soil parameter	Experimental site		SEM	P Value
	Bihinayili	Zalerigu		
Physical properties				
Sand (%)	50.4	54.9	6.08	0.469
Silt (%)	42.0	38.2	5.42	0.488
Clay (%)	7.60	6.93	1.782	0.707
Texture	Loam	Sandy loam	-	-
pH	6.3	6.6	0.10	0.011
Nitrogen (%)	0.018	0.097	0.01	0.001
Available (P) mg/kg soil	4.61	4.50	0.72	0.879
Organic carbon (%)	0.185	1.004	0.13	0.001
Exchangeable cations (cmol(+)/kg soil				
Ca^{2+}	2.6	5.2	2.04	0.228
Mg^{2+}	0.99	1.45	0.373	0.233
K^{+}	0.172	0.241	0.06	0.273
Na^{+}	0.068	0.092	0.04	0.566
CEC	4.7	7.5	2.34	0.241
Base saturation (BS) (%)	73.5	83.6	7.33	0.173
Exchange acidity (cmol/kg soil)	0.807	0.546	0.1911	0.186

SEM= Standard Errors of Means, CEC= Cation Exchange Capacity, Ca2+ = Calcium, Mg2+ = Magnesium, K+ = Potassium, Na+ = Sodium.
%BS was determined as %BS = [(Exch Ca2+ + Exch Mg2+ + Exch K+ + Exch Na+) ÷ CEC] x 100

concentration of organic compounds of the soil also followed the same trend as that of N content. The pH level of soil at the two sites differed (P=0.011) and was higher in Nabdam District.

Agronomic performance of the forage species
The forage type and location interaction did not differ significantly (Table 2). The main effect of forage type differed relative to number of days to germination. *S. almum* took the shortest (5 days) days to emerge after planting (Figure 2).
With the exception of tiller number, the two-way interaction effect of site and forage species did not differ significantly (Table 2) for the agronomic parameters. The results on leaf size, tiller number and plant height

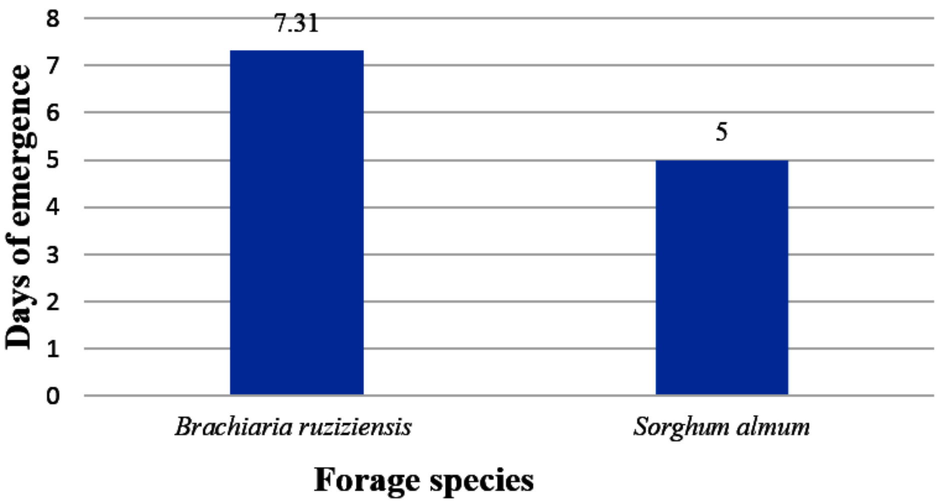

Figure 2 Average number of days to germination

TABLE 2
The interaction effect of different locations on dry matter yield and quality of two forage species within the Savanna agro-ecological zone at 60 days after planting

Biomass yield and quality Parameter	B. ruziziensis		S. almum		SEM	P values		
	Bihinayili	Zanlerigu	Bihinayili	Zanlerigu		S	F	S × F
Agronomic parameters								
Leaf size (cm^2)	102.0	68.0	328	269	9.100	0.480	0.006	0.848
No. of leaves/plant	10.50	11.00	8.75	7.25	1.392	0.621	0.16	0.330
No. of tillers/plant	10.75	8.50	7.28	5.75	1.507	0.126	0.001	0.003
Plant height (cm)	124.8	55.4	231.2	135.0	23.26	0.001	0.001	0.431
Chemical composition								
DM yield (tons/ha)	8.28	1.40	8.71	3.06	1.514	0.001	0.346	0.576
CP (g/kg DM)	85.5	65.8	93.5	71.5	11.51	0.018	0.419	0.901
NDF (g/kg DM)	590.8	632.1	629.6	654.9	25.60	0.081	0.104	0.664
ADF (g/kg DM)	327.5	343.9	365.0	390.7	16.97	0.095	0.002	0.699
ME (MJ/kg DM)	6.21	6.12	5.79	5.89	0.301	0.968	0.146	0.670

CP= Crude Protein, NDF= Neutral Detergent Fibre, ADF= Acid Detergent Fibre, ME = Metabolizable Energy, SEM= Standard errors of means, S- Site of experiment, F= Forage

TABLE 3a
Agronomic performance of *Brachiaria ruziziensis* and *Sorghum almum* in the Savanna agro-ecological zone

Parameter	*B. ruziziensis*	*S. almum*	SEM	P values
Leaf size (cm^2)	85	299	63.7	0.006
Number of leaves/plant	10.75	8.00	0.984	0.016
Number of tillers/plant	9.62	2.88	0.066	0.001
Plant height (cm)	90.1	183.1	16.44	0.001

SEM= Standard errors of mean

TABLE 3b
Agronomic performance of forages as affected by different experimental sites in the Savanna agro-ecological zone

Parameter	Bihinayili,	Zanlerigu,	SEM	P values
Leaf size (cm^2)	215	169	63.7	0.480
Number of leaves/plant	9.62	9.12	0.984	0.621
Number of tillers/plant	5.35	7.12	1.066	0.126
Plant height (cm)	178.0	95.2	16.44	0.001

SEM= Standard errors of mean

are shown in Table 2. The highest ($P < 0.05$) tiller number was obtained in *B. ruziziensis* cultivated in Bihinayili with the least recorded *S. almum* cultivated in Zanlerigu.

The main effect of forage species was found to be significantly different relative to number of leaves per plant and plant height (Table 3a). Whilst number of leaves per plant was higher ($P < 0.05$) in *B. ruziziensis* compared to *S. almum*, plant height was lower in *B. ruziziensis*.

Dry matter yield and fodder quality

The two-way interaction effect was found not to be significant for both biomass yield and fodder quality parameters (Table 2). However, there was a significant main effect of site on biomass yield and CP concentration

TABLE 4a

Dry matter yield and quality of herbage at two experimental sites within the Savanna agro-ecological zone at 60 days after planting

Parameter	Experimental site		SEM	P values
	Bihinayili	Zanlerigu		
DM yield (tons/ha)	8.49	2.23	1.071	0.001
CP (g/kg DM)	89.7	68.6	8.14	0.018
ADF (g/kg DM)	346.3	367.3	12.00	0.095
ME (MJ/kg DM)	6.00	6.01	0.213	0.968
NDF (g/kg DM)	610.2	643.5	18.10	0.081

CP= Crude Protein, NDF= Neutral Detergent Fibre, ADF= Acid Detergent Fibre, ME = Metabolizable Energy, SEM= Standard error of means

TABLE 4b

Dry matter yield and quality of two forage species within the Savanna agro-ecological zone at 60 days after planting

Parameter	Forage species		SEM	P values
	B. ruziziensis	*S. almum*		
DM (tons/ha)	4.84	5.88	1.071	0.346
CP (g/kg DM)	75.8	82.5	8.14	0.419
NDF (g/kg DM)	611.4	642.3	18.10	0.104
ADF (g/kg DM)	335.7	377.9	12.00	0.002
ME (MJ/kg DM)	6.16	5.84	0.213	0.146

CP= Crude Protein, NDF= Neutral Detergent Fibre, ADF= Acid Detergent Fibre, ME = Metabolizable Energy, SEM= Standard error of mean

(Table 4a) as well as forage species on ADF concentration (Table 4b). The combined dry matter yield obtained from the forage species at 60 days after planting was higher (P<0.001) at Bihinayili (8.49 tons/ha) in the Savelugu District of the Northern Region than that at Zanlerigu (2.23 tons/ha) in the Nabdam District of the Upper East Region. The ADF content was statistically similar between the two experimental sites but tendered to be higher (P=0.095) among forages at Zanlerigu (Table 4a). The comparative dry matter yield of the two forages did not show significant differences (P>0.05). The values obtained were 4.84 versus 5.88 tons/ha for *B. ruziziensis* and *S. almum* respectively (Table 4b).

Discussion

The higher rainfall obtained in the experimental site at Savelugu District than Nabdam District is due to slight ecological differences (GMA, 2016). The amount and pattern of rainfall recorded agreed with the report of GMA (2016) and similar to the findings of Ampadu et al. (2019). The annual rain fall recorded during the study period did not depart from the previous records in the area (GMA, 2016; Ampadu et al., 2019). The values of soil chemical properties obtained after following the standard sampling and analytical procedure were similar to the values reported by Tahiru et al. (2015) in the same ecological zone. Plant growth is greatly influenced by different levels of soil physical and chemical properties.

The agronomic parameters of the two forages in this study were good as the values obtained were comparable to similar forages produced for intensive ruminant production. Forages with higher number of leaves and broader leaf sizes contributes directly to formation of thick green canopy on soil surfaces and forage dry matter yield as well as providing larger bite size during grazing (Pedroso, 2018; Dale et al., 2018). The thick green canopy of grass on the soil surfaces stores large quantities of carbon and serves as carbon sink that reduce climate change effect, while providing other ecosystem services such as source of fodder for ruminant (Andeweg and Andy, 2013).

According to Kubota et al. (1994), high tiller production in plant as observed in *B. ruziziensis* in this study is an important trait for sustainable forage production especially when the plant is being grazed or in perennial grasses for replacement of plant parts that are lost through grazing, cuttings or ageing. Lafarge and Loiseau, (2013) reported that forage stem elongation and erection in the growth processes is vital for enhancing plant canopy light penetration and absorption. This increases the photosynthetic efficiency in plants and consequently biomass accumulation. In climate change mitigation, it increases CO_2 sequestration and reduces its concentration in the atmosphere (Opio et al., 2013) and reduces the effect of weather element that leads to climate change.

The site differences in dry matter yield in this experiment could be due to rain fall differences as observed in Figure 1. The Nabdam District in Upper East Region received lower rain fall and the area is dryer than the Savelugu District in Northern Region, although both locations are within the Savanna agro-ecological zone. This finding is in line with the observation of Konlan et al. (2018) in an estimated communal pasture dry matter yield study in the same Savanna agro-ecological zone. The growth and productivity of plants in general are influenced by magnitude of precipitation and its distribution, duration of sun shine and soil nutrient content (Haferkamp,1987; Snyman, 2002). Soil water availability is also, a major factor that determines herbage yield of forage crops (Snyman, 2002) and this might have influenced the result of this study.

The high CP content of the forage species at Bihinayili higher (P=0.018) than that at Zanlerigu despite the relatively higher soil nitrogen in Zanlerigu could be due to nitrogen accessibility differences influenced by precipitation and soil water holding capacity and other soil physical and chemical properties in the experimental site at Bihinaayili in Northern Region compared to the fields at Zanlerigu in Upper East Region (Snyman, 2002; Smith, 2002; Tahiru et al., 2015).

The dry matter yield for *B. ruziziensis* that fell slightly below the 6 tons/ha without N fertilizer and 12 tons/ ha with N fertilizer reported by Cook et al. (2005) may be attributed to soil properties (Tahiru et al., 2015). A biomass yield of between 4-12 tons/ha was reported for *S. almum* in a previous study (Cook et al., 2005). The dry matter yield obtained in this study was however, higher than the values 1.97 and 1.43 tons/ha in *Brachiaria brizantha* and *Panicum maximum* respectively, reported by Barnes and Addo-Kwarfo (1996) in their work on forages that were harvested at 63 days after planting in Coastal Savanna agro-ecological zone of Ghana. That of *S. almum* was also higher than the average 3 tons/ha reported for the local variety of *Pennisetum purpureum* initially harvested at 90 days after planting within the Savanna agro-ecological zone (Shedrack et al., 2019; Tenakwa et al., 2019).

It was observed that the ADF content of *S. almum* (367.6 g/kg DM) was higher (P<0.05) than that of *B. ruziziensis* (346.3 g/kg DM). The ADF values for both forages were slightly lower than the 393.0 g/kg DM and 389.0 g/kg DM reported for *S. almum* and *B. ruziziensis* respectively (Heuzé et al., 2015; Heuzé et al., 2017). High ADF content of forage decreases digestibility and consequently poor utilization by ruminants (McDonald et al., 1995; Thornton, 2010; Kljak et al., 2019). The CP content of *S. almum* (82.5 g/kg DM) did not differ (P>0.05) from that of *B. ruziziensis* (75.8 g/kg DM). The values obtained in this study were comparable to the reported range of 66.5 to 91.1 g/kg DM (Cook et al., 2005). Crude protein content was comaparable to *Pennisetum purpureum* CP content cultivated in the same Savanna agro-ecological zone (Shedrack et al., 2019) but was lower than the mean CP values of 100.0 g/kg DM and 115.0 g/kg DM reported for *S. almum* and *B. ruziziensis* respectively (Heuzé et al., 2015;

Heuzé et al., 2017).

Conclusion

The two forage species generally performed well within the agro-ecological zone with high potential of augmenting forage availability. The forage dry matter yield at 60 days after planting was higher at Bihinayili in Savelugu District of Northern Region than at Zanlerigu in the Nabdam District of Upper East Region. Forage quality in terms of CP, NDF and ME were within the range to support ruminant production. The experimental site soil surfaces had complete forage canopy cover with high potential of increased carbon dioxide sequestration.

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