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INTERCROPPING SYSTEMS' PRODUCTIVITY OF *BRACHIARIA DECUMBENS* WITH *STYLOSANTHES HAMATA* AND *STYLOSANTHES GUIANENSIS* IN DIFFERENT PLANTING RATIOS

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ABSTRACT

A field experiment was conducted during the wet and dry season of 2011 to 2012 at the Federal University of Agriculture, Abeokuta located in the Derived savanna agro-ecological zone of Southwest, Nigeria. The aim of the experiment was to investigate the contribution of *Stylosanthes hamata* cv. Verano and *Stylosanthes guianensis* cv. Schofield to total fodder yields, nutritive value and reduction of enteric methane gas when intercropped with *Brachiaria decumbens*. Nine treatments in all consisting of soles of a grass, legumes and grass-legume mixtures in the ratios 1:1, 1:2 and 1:3 for each legume species. The Relative yield (RY),Land Equivalent Ratio (LER), total dry matter yield, proximate composition, *in vitro* gas production and methane gas production were estimated at both seasons. *S. guianensis* gave a higher significant ($P<0.05$) relative yield when intercropped in double or triple rows with *B. decumbens* in both seasons. Planting triple rows of *S. guianensis* with a single row of *B. decumbens* produced the highest significant ($P<0.05$) total DM yield of 4.17 t/ha. The volume of gas produced after 24 hours increased significantly ($P<0.5$) as the rows of legumes increased in the mixtures. In both seasons, the volume of methane gas produced in the sole grass was higher ($P<0.05$) than in the mix swards. In all the six (6) mixtures ratios evaluated, intercropping of up to three (3) rows of *S. guianensis* within a row *B. decumbens* produced outstanding results in terms of biomass, quality and environmental impact in relation to enteric methane production.

INTRODUCTION

In the humid and sub-humid tropics, most pastures are of native species of inferior nutritional quality. As a result, livestock productivity with native pastures tends to be quite very low, and the possibilities for sustainable intensification are limited. During the dry season, the native rangelands and crop residues available for ruminants after crop harvest are usually fibrous and devoid of most essential nutrients including proteins, energy, minerals and vitamins resulting in reduced animal performance (Onwuka *et al.,* 1989). Furthermore, many of the adapted grasses matures very fast and the quality parameters decreased from the period when the plant were at a tender stage till maturity stages as a result of differences in plant composition between levels of maturity (Reling *et al.,* 2001) indicating that this forage would be best utilized at younger stages of development. Substantial reductions in annual dry matter yield have also been observed for various fodder species between successive years of establishment. Positive responses of most of tropical grasses consequentially are as a reliance on high N fertilizer application (up to 200 kg N ha^{-1}) to achieve optimum yields (Olanite *et al.,* 2009). This is unlikely to be of practical importance to the low-input farmers in Southwest Nigeria, for whom small ruminant production

is an adjunct to arable cropping. The introduction of improved forage legumes has been promoted as a possible option to improve the grassland feed resources and sustainability of livestock production in the region (Tarawali *et al.,* 1999). Yet, it is of great importance to determine the inter-specific competitiveness of each crop for accurately assessing the intercropping system productivity (NachigeraMushagalusa *et al.,* 2000).

Brachiaria decumbens is an important tropical grass because of its high productivity under intensive use, and its tolerance of low fertility and relative freedom from pests and disease. It is exceptionally tolerant to the combination of aluminium toxicity and drought (Miles *et al.,* 2004) and could play a role in smallholders' crop-livestock systems in such areas. In addition, high yields, quality and ease of propagation of improved Brachiaria grasses are central to their establishment and utilization under smallholders' crop-livestock systems for improved milk and meat production. Ndikumana and de Leeuw (1996) in their review reported that *Brachiaria decumbens is* normally established from seed and has the capacity to spreads naturally from seed and remain green long into the dry season in sub-Saharan Africa

Recent studies on climate change and greenhouse gases emission control also revealed the mitigation potential of tropical forage plants, favoured by prostrate growth habits especially *Brachiaria* species. Diets with high digestibility, energy and protein concentrations produce less Methane (CH_4) per unit of livestock product. Improving these characteristics in forages could reduce CH_4 emissions from beef production by 15– 30% (Gurian-Sherman, 2011). Legume contain less structural carbohydrates and more condensed tannins than grass, and adding legumes to the diet can further reduce methane emissions per unit of meat or milk produced (Woodward *et al.,* 2004; Waghorn and Clark 2004).

It is appropriate to assess options for pasture establishment building upon previous work using grass-legume mixtures and to introduce new options in cultivating *Brachiaria decumbens* with two species of *Stylosanthes hamata* cv. Veranoand *Stylosanthes guianensis* cv. Schofield. This paper is aimed at improving the quality and quantity of ruminant feed resources in the South west Nigeria through incorporation of legumes into sown grass pasture while mitigating GHGs by limiting the production of enteric methane.

MATERIALS AND METHODS

Site description

The experiment was conducted from April 2010 to March 2012 at the Muturu Paddock of the Institute of Food Security, Environmental Resources and Agricultural Research (IFSERAR) Farm, Federal University of Agriculture, Abeokuta. The experimental site lies within the savanna agro-ecological zone of South Western Nigeria (latitude: 7°N, longitude 3.5°E, (Google earth, 2011), with an average annual rainfall of 1037mm. Abeokuta has a bimodal rainfall pattern that typically peaks in July and September with a break of two to three weeks in August. Monthly rainfall at Abeokuta during the period of the experiment is as shown in Figure 1.

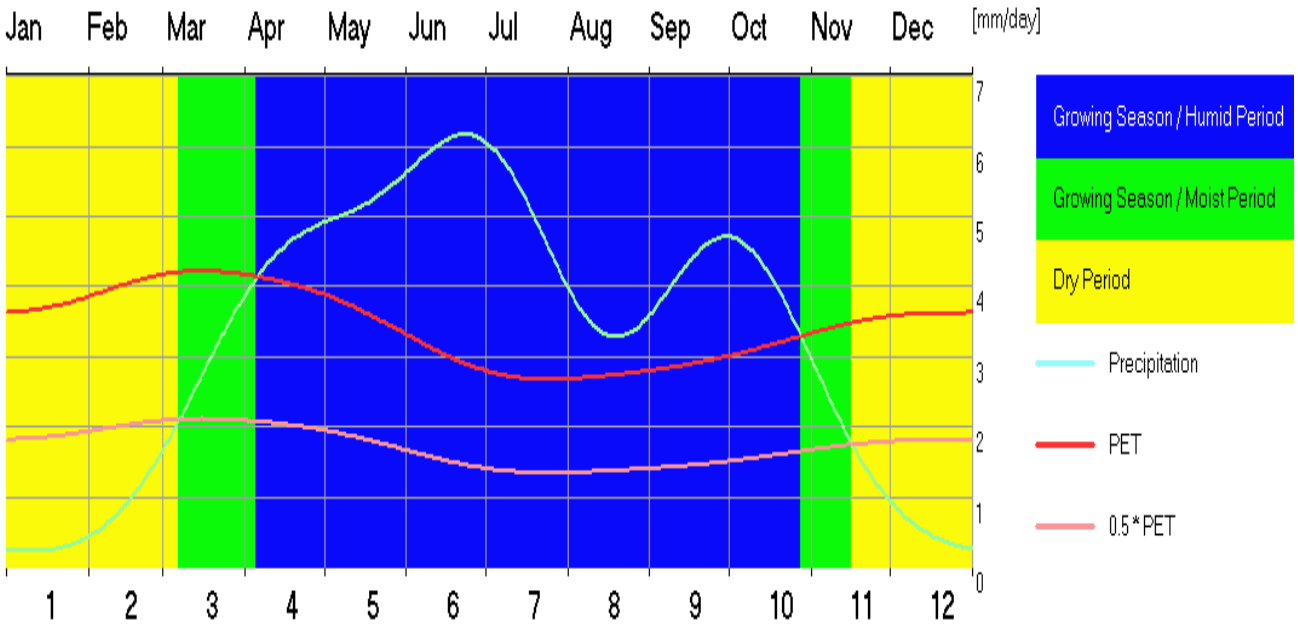


Figure 1: Agro metrological observations of the experimental location in Abeokuta, Nigeria, West Africa using New LocClim (version 1.06) (FAO 2005)

Soil at the experimental site was sandy (86% sand) with a pH of 6.5, organic carbon 1.34%, nitrogen 0.19% and phosphorus (Bray 1) 7.5 mg/kg. Other mineral element concentrations were 0.3 cmol/kg for potassium and sodium, 0.6 cmol/kg for magnesium and 2.1 cmol/kg for calcium, giving an effective cation exchange capacity (ECEC) of 3.3 cmol/kg.

A land area of 0.15 ha was ploughed, harrowed and levelled before plots layouts. The land was divided into three (3) blocks with 2m alleys to cater for the topography of the experimental site and each block represented with a replicate. Each block was later sub-divided into nine (9) plots of 7x7m^2 each, representing the number of treatments. The trial was laid in a Randomized Complete Block Design (RCBD) which comprises of two species of *Stylosanthes hamata* cv. Verano and *Stylosanthes guianensis* cv. Schofield, planted in single, double or triple rows in between *B. decumbens* grass forage with each of the legume and grass planted to give nine (9) treatments altogether: Single rows of *S. hamata* between *B. decumbens* rows, double rows of *S. hamata* between *B. decumbens* rows, triple rows of *S. hamata* between *B. decumbens* rows.Single rows of *S. guianensis* between *B. decumbens* rows, double rows of *guianensis* between *B. decumbens* rows, triple rows of *S. guianensis* between *B. decumbens* rows. Sole of *B. decumbens*, *S. hamata* and *S. guianensis.*

In May 2010, due to unavailability of seeds at the time of the trial, *B. decumbens* was established through crown splits which were sourced from the Forage Introduction Plot of the Department of Pasture and Range Management of the Federal University of Agriculture, Abeokuta, Nigeria. *B. decumbens* was planted at a spacing of 1m between and within rows to give an overall population of 10,000 stands plant population per ha. The seeds of *Stylosanthes hamata* (cv. Verano), *Stylosanthes guianensis* (cv. Cook), obtained from the National Animal Production Research Institute (NAPRI), Zaria were scarified using hot water at 80^{0}C for 10minutes and planted by drilling method at 10kg/ha four (4) weeks after planting (WAP) *B. decumbens* were

earlier established before incorporating or intercropping of legume seed. The single row of legume was drilled at the middle of the established *Brachiaria* grass row at the spacing of 50cm away from the rows of grass while the double row treatments, the legumes were sown at the spacing 30cm away from the rows of grasses and 40cm apart within the legume row. In the triple row treatment, legumes were sown at the spacing of 30cm away from grass and 20cm apart 40cm apart within the legume row. No fertilizer application was carried out but the plots were kept free of weeds throughout the period of study.

Agronomic parameters

The estimation of total yield, relative yield (RY) and land equivalent ratio (LER) was carried out by harvesting the herbage materials within the ranges of two randomly located 1m x 1m quadrat in June 2011 which coincided with the wet season and in March 2012 as the late dry season. The dry matter percentage was estimated as:

Dry matter percentage = Weight of dry sample/ weight of fresh sample x 100.

While Dry matter yield was estimated as:

Dry matter yield = dry matter percent x fresh sample from 1 m^2 which afterwards was extrapolated in tonnes per hectare.

Relative yield (RY) and land equivalent ratio (LER) and were determined following the equations of Ghosh *et al.* (2006) as:

RY = RYab = DMYab/DMYaa,

RYba = DMYba/DMYbb

LER = RYab + RYba

In the equation, the following definitions apply: ab refers to performance of *B. decumbens* (a) mixed with either *S. hamata* or *S. guianensis* (b); ba is the performance of either of the legumes (b) mixed with *B. decumbens*; aa is the performance of *B. decumbens* in sole and bb is the performance of either of the legumes as a sole.

Nutrient analysis

Nutrient compositions of the herbage samples collected in both seasons as described above was analysed. The contents of dry matter, crude protein, ether extract and ash were determined according to A.O.A.C. (1995). Fibre fraction analysis: Neutral detergent fibre (NDF); acid detergent fibre (ADF); acid detergent lignin (ADL) in accordance to procedures outlined by Van Soest *et al*., (1991). Forage samples were dried in a forced draught oven at 105^{o}C for 24 hours and were analysed for the concentration of calcium and phosphorus with atomic absorption spectrophotometry (Fritz and Schenk, 1979). The *in vitro* gas production was determined following the procedure of Menke and Steingass (1988). Organic matter digestibility (OMD) was estimated as

OMD= 14.88 + 0.889GV+ 0.45 CP + 0.651 ash (Menke and Steingass, 1988).

Short-chain fatty acid (SCFA) was estimated as:

SCFA = 0.0239GV−0.0601 (Getachew *et al.*, 2000).

Metabolizable energy (ME) was calculated as

ME= 2.20 + 0.136GV+ 0.057 CP + 0.029 CP2 (Menke and Steingass, 1988).

Total gas volume (GV) was expressed as ml/200mgDM, CP and ash as g/kg DM, ME as MJ/kgDM and SCFA as µmol/g DM.

Methane gas determination

After 24 hour of incubation, volume of gas was withdrawn from the tip of the incubation syringe using Hamilton gas tight syringe and analyzed for methane with gas chromatograph (Nucon 5700, India) fitted with stainless steel column packed with Porapak- Q (length 6';o.d.1/8" i.d. 2mm; mesh range 80-100) and Flame ionizing detector (FID). Volume of gas taken for injecting was 200µl. The standard gas for methane estimation (Spantech caliberation gas, Surrey, England) composed of 50% methane and 50% CO_2. The peak of methane gas was identified on the basis of retention time of standard methane gas and the response factor obtained was used to calculate methane percentage in the gas sample. The methane produced from substrate during 24 hour incubation was corrected for the blank values. The volume of methane produced was calculated as follows:

Methane production (ml) = Total gas produced (ml) x % methane in the sample.

Data collected were subjected to Analysis of Variance (ANOVA) using (SAS, 2003). Duncan's means separation procedure (5%) was used to test the level of significance among means (Duncan, 1955).

RESULTS

Agronomic analysis

In both season, the relative yield (RY) of *B. decumbens* reduced significantly ($P<0.05$) when the rows of *S. hamata* was doubled, while the RY of *B. decumbens* increased as the rows of *S. guianensis* increased in the mixtures. Among the legumes, only *S. guianensis* gave a higher significant ($P<0.05$) relative yield when intercropped in double or triple rows with single row of *B. decumbens* in both seasons of the experiment. The RYs of other planting ratios were less than unity, indicating that the DM yields of both grasses and legumes in the mixtures were less than those for sole stands in both seasons.

The land equivalent ratio (LER), the relative area of a sole crop or sole crops required to produce the yield achieved in intercropping and was significantly affected by the number of rows (Table 1). Planting either double rows of *S. hamata* or single row of *S. guianensis* within a single row *B. decumbens* with gave a LER less than 1 in both wet and dry season. Other planting ratios demonstrated higher yields in mixtures than the average of the sole.

Dry matter forage yields of the grass and legumes in sole and mixed plots were significantly ($P<0.05$) influenced by different number of rows (Table 1). In the wet and dry season, grass highest DM yield was recorded in *B. decumbens* when intercropped with single rows of the *S.hamata* or planted in sole. It was observed that the grass DM yield increased as the rows of *S. guianensis* increased from single to triple in both seasons while the dry matter yield of grass only increased as the rows of *S.hamata* increasedfrom double to triple rows in both wet and dry season.

The DM yield of the legumes followed an irregular pattern, however, in both seasons, highest ($P<0.05$) DM yield was recorded when *S. hamata* was planted in sole. The least legume DM yield was observed when *S. guianensis* was intercropped at single row with *B. decumbens* in the

wet season and single rows of *S. hamata* intercropped with *B. decumbens* in the dry season. The yields of *S. hamata* were higher than *S. guianensis* in wet and dry season when planted in sole.

Total yields of the mixed swards were significantly affected by the legume species and the number of rows. Planting triple rows of *S. guianensis* with single row of *B. decumbens* produced the highest (P<0.05) total DM yield of 4.17 t/ha and the least total yield was recorded when *S. guianensis* was planted at single row with *B. decumbens* during the wet season. In the dry season, total yield of all mixtures exceeded 2 t/ha with except *B. decumbens* with single row of *S. guianensis* (1.97 t/ha) and *B. decumbens* with single row of *S. guianensis*yielding significantly higher than others. Furthermore, total DM yield increased when the rows of *S. guianensis* increased in mixtures *with B. decumbens.*

Chemical analysis

In both wet and dry season, Crude protein (CP), fibre composition, and mineral concentrations were significantly affected (P<0.05) by legume species and number of rowsnumber of row (Table 2). The DM contents of the mixtures and the sole samples ranged from 775 g/kg in the mixed swards of *B. decumbens* in which a single row of *S. guianensis* to 833 g/kg recorded in sole *S. hamata* in the wet season.

The CP content of the legumes in sole *S. hamata* and *S. guianensis* (186 g/kg and 194 g/kg respectively) were higher (P<0.05) than that of mixtures of grass-legume in number of rows the wet season. Among the mixtures, increased rows of legumes resulted into increased in the CP contents. In the dry season, sole *S. guianensis* contained the highest CP contents while sole *S. hamata* contained similar CP contents as *S. hamata* when intercropped with *B. decumbens.*

Generally in both seasons, sole *B. decumbens* had the least CP contents, Neutral detergent fibre (NDF) and Acid detergent fibre (ADF) of the grass and legume mixtures at different number of rows are shown in Table 2. NDF values of the grass and legume mixture ranged between 404 to 480 g/kgDM in the wet season and 470 to 595 g/kgDM in dry season and were lower in the grass and legume mixtures than in the sole grass It was noted that the NDF contents on the mixtures decreased as the rows of legume increased in the mixture in both season. Sole *S. guianensis* and *S. hamata* contained the lowest NDF and ADF concentrations, followed by their single and double rows mixtures with *B. decumbens.* In both seasons, number of rows significantly (P<0.05) increased the mineral status of the mixtures of grass and the two legume species as shown in Table 2.

Calcium (Ca) content decreased as the rows of *S. hamata* increased in the mixtures during the wet season, but was reserved in the dry season. Ca contents of the mixtures increased significantly (P<0.05) from single row to double of *S. guianensis* then declined with triple rows in both seasons. The P contents of the mixtures were similar in the wet season and lower than in sole. In the dry season, intercropping *B. decumbens* with double or triple rows of either *S. hamata* or *S. guianensis* increased the P content of the grass- legume mixtures.

Table 1: Relative and total dry matter yield (t/ha) of grass-legume mixtures as influenced by legume species and number of rows

Single row of *B. decumbens* with	Relative yield		LER	Dry matter yield		Total dry
Wet season	Grass	Legume		Grass	Legume	matter yield
Single row of *S. hamate*	1.03^{a}	0.42^{c}	1.45^{b}	2.59^{a}	1.26^{c}	3.85^{b}
Double rows of *S. hamate*	0.14^{c}	0.38^{c}	0.52^{c}	0.40^{d}	1.14^{c}	1.54^{e}
Triple rows of *S. hamate*	0.63^{b}	0.58^{b}	1.21^{b}	1.59^{c}	1.72^{bc}	3.31^{c}
Single row of *S. guianensis*	0.19^{c}	0.09^{d}	0.28^{c}	0.47^{d}	0.16^{d}	0.63^{f}
Double rows of *S. guianensis*	0.72^{b}	1.00^{a}	1.72^{a}	1.81^{c}	1.79^{bc}	3.60^{b}
Triple rows of *S. guianensis*	0.89^{ab}	1.07^{a}	1.96^{a}	2.26^{b}	1.91^{b}	4.17^{a}
Sole *B. decumbens*	-	-	-	2.51^{ab}	-	2.51^{d}
Sole *S. hamate*	-	-	-	-	2.97^{a}	2.97^{d}
Sole *S. guianensis*	-	-	-	-	1.78^{bc}	1.78^{e}
SEM	0.11	0.08	0.23	0.31	0.22	1.01
Dry season						
Single row of *B. decumbens* with						
Single row of *S. hamate*	1.17^{a}	0.40^{c}	1.57^{a}	3.48^{a}	1.32^{d}	4.46^{b}
Double rows of *S. hamate*	0.38^{c}	0.61^{b}	0.99^{c}	1.12^{d}	2.01^{c}	3.13^{d}
Triple rows of *S. hamate*	0.68^{b}	0.55^{bc}	1.23^{b}	2.01^{c}	1.81^{c}	3.82^{c}
Single row of *S. guianensis*	0.38^{c}	0.32^{d}	0.70^{c}	1.11^{d}	0.86^{e}	1.97^{e}
Double rows of *S. guianensis*	0.71^{b}	0.75^{a}	1.46^{b}	2.10^{c}	1.98^{c}	4.08^{d}
Triple rows of *S. guianensis*	0.88^{b}	0.70^{ab}	1.58^{a}	2.60^{b}	1.86^{c}	4.80^{a}
Sole *B. decumbens*	-	-	-	2.95^{ab}	-	2.95^{d}
Sole *S. hamate*	-	-	-	-	3.29^{a}	3.29^{e}
Sole *S. guianensis*	-	-	-	-	2.65^{b}	2.65^{d}
SEM	0.04	0.01	0.02	0.32	0.28	0.32

Means followed by different letters within columns differ significantly ($P<0.05$); LER: Land equivalent ratio

Table 2: Nutrient composition of grass-legume mixtures as influenced by legume species and number of rows.

Single row of *B. decumbens* with	Nutrient content, g/kg dry matter							
Wet season	DM	CP	EE	ASH	NDF	ADF	Ca	P
Single row of *S. hamate*	815^{b}	65.5^{c}	65.8^{b}	82.0^{b}	486^{b}	232^{a}	2.20^{b}	1.21^{b}
Double rows of *S. hamata*	810^{c}	96.9^{bc}	65.2^{b}	65.9^{c}	480^{b}	205^{b}	2.17^{b}	1.22^{b}
Triple rows of *S. hamate*	823^{ab}	127^{b}	64.5^{b}	65.2^{c}	428^{d}	207^{b}	2.08^{c}	1.24^{b}
Single row of *S. guianensis*	775^{d}	47.0^{d}	63.5^{b}	99.3^{ab}	444^{c}	186^{c}	2.06^{c}	1.29^{b}
Double rows of *S. guianensis*	820^{ab}	72.0^{c}	67.1^{b}	84.0^{b}	442^{c}	181^{c}	2.30^{a}	1.30^{b}
Triple rows of *S. guianensis*	800^{b}	95.0^{bc}	66.0^{b}	65.1^{c}	422^{d}	153^{d}	2.10^{c}	1.28^{b}
Sole *B. decumbens*	830^{a}	30.2^{e}	71.3^{a}	86.9^{b}	587^{a}	239^{a}	1.92^{c}	0.22^{c}
Sole *S. hamate*	833^{a}	186^{a}	36.4^{c}	66.2^{c}	410^{e}	194^{c}	2.28^{a}	2.25^{a}
Sole *S. guianensis*	815^{b}	194^{a}	41.8^{c}	101^{a}	401^{e}	132^{e}	2.34^{a}	2.22^{a}
SEM	1.25	1.42	2.55	0.75	1.65	1.36	0.04	0.02
Dry season								
Single row of *S. hamate*	905^{d}	65.9^{d}	67.0^{b}	82.9^{ab}	592^{b}	231^{b}	1.91^{e}	1.22^{c}
Double rows of *S. hamata*	910^{c}	94.5^{c}	65.5^{c}	66.0^{c}	537^{d}	223^{b}	2.12^{d}	2.23^{b}
Triple rows of *S. hamate*	905^{d}	122^{b}	61.9^{d}	72.0^{b}	521^{e}	156^{e}	2.22^{c}	2.32^{a} ^{b}
Single row of *S. guianensis*	920^{ab}	47.7^{e}	68.9^{b}	83.6^{ab}	551^{c}	207^{c}	2.05^{e}	1.29^{c}
Double rows of *S.*	910^{c}	63.3^{d}	69.4^{b}	66.1^{c}	532^{d}	177^{d}	2.47^{a}	2.34^{a}
Triple rows of *S. guianensis*	900^{c}	94.7^{c}	67.2^{b}	63.3^{c}	510^{e}	136^{f}	2.12^{d}	2.29^{b}
Sole *B. decumbens*	919^{b}	23.9^{f}	70.3^{a}	92.5^{a}	632^{a}	255^{a}	1.85^{e}	1.20^{c}
Sole *S. hamate*	925^{a}	135^{b}	34.1^{f}	55.5^{d}	478^{f}	185^{d}	2.37^{b}	2.37^{a}
Sole *S. guianensis*	905^{d}	167^{a}	47.9e	72.0^{b}	481^{f}	135^{f}	2.41^{a}	2.22^{b}
SEM	0.10	0.22	0.81	1.02	2.13	2.08	0.04	0.14

Means followed by different letters within columns differ significantly (P<0.05)

In the wet season, the volume of gas produced after 24 hours was lower (P<0.05) in the entire sole than the grass-legume mixtures (Table 3). The mixtures of *B. decumbens* with triple rows of the legume species produced the highest gas volume after 24 hours of incubation. In the dry season however, the volume of gas produced after 24 hours the mixtures increased (P<0.5) as the rows of legumes increased. *B. decumbens* with triple rows of *S. guianensis* produced the highest (P<0.05) gas volume after 24 hours during the dry season. In both seasons, increase in the rows

of the legumes in the mixtures produced significantly higher (P<0.05) cumulative gas volume and legumes sole gave the highest cumulative gas volume (Table 3).

In results observed in both seasons, the OMD of the mixed swards increased (P<0.05) as the rows of legumes in the mixtures tripled. The estimated metabolizable energy (ME) produced by the grass-legume swards followed similar trend (Table 3). In both seasons, the volume of methane gas produced in the grass sole was constantly higher significantly (P<0.05) than the mix swards. As the rows of legumes in the mixed swards increased, the amount of methane gas produced reduced significantly in both wet and dry season.

Table 3: *In vitro* gas production characteristics, post incubation parameters and methane gas volume of the grass-legume mixtures as influenced by legume species and number of rows

Single row of *B. decumbens* with	b (ml/200mgDM)	c (ml/hr)	Absg	24 hrs. gas vol.	OMD (%)	SCFA (µmol)	ME (MJ kg^{-1}DM)	Methane (ml/gDM)
Dry season								
Single row of *S. hamata*	13.0^{d}	0.73^{a}	11.3^{b}	55.0^{b}	72.1^{ab}	1.25^{b}	9.70^{d}	8.10^{b}
Double rows of *S. hamata*	14.2^{c}	0.77^{a}	8.16^{cd}	57.5^{b}	74.7^{ab}	1.31^{b}	13.3^{b}	5.02^{c}
Triple rows of *S. hamata*	14.7^{c}	0.85^{a}	13.2^{a}	69.5^{a}	86.6^{a}	1.60^{a}	15.5^{a}	3.22^{d}
Single row of *S. guianensis*	13.5^{d}	0.78^{a}	12.3^{ab}	62.0^{ab}	78.4^{ab}	1.42^{ab}	10.5^{c}	10.1^{a}
Double rows of *S. guianensis*	14.5^{c}	0.81^{a}	12.6^{ab}	61.5^{ab}	78.3^{ab}	1.40^{ab}	11.2^{c}	5.07^{c}
Triple rows of *S. guianensis*	14.5^{c}	0.81^{a}	12.6^{ab}	66.7^{a}	82.7^{a}	1.53^{a}	14.3^{ab}	2.20^{d}
Sole *B. decumbens*e	11.5^{e}	0.72^{a}	11.3^{b}	42.5^{c}	59.7^{b}	0.96^{bc}	8.97^{g}	10.0^{a}
Sole *S. hamate*	19.4^{a}	0.44^{b}	7.41^{d}	33.5^{c}	66.8^{b}	0.74^{c}	16.7^{a}	5.11^{c}
Sole *S. guianensis*	18.6^{a}	0.59^{b}	9.13^{c}	40.5^{c}	70.7^{ab}	0.91^{bc}	15.6^{a}	6.21^{c}
SEM	0.03	0.12	0.31	3.07	2.34	0.07	3.97	0.98
Dry season								
Single row of *S. hamata*	11.5^{e}	0.46^{b}	6.37^{b}	43.0^{c}	65.8^{c}	1.09^{c}	9.30^{f}	9.00^{b}
Double rows of *S. hamata*	11.4^{e}	0.37^{c}	5.89^{c}	45.5^{c}	62.2^{c}	0.99^{c}	10.4^{e}	7.10^{c}
Triple rows of *S. hamata*	13.5^{c}	0.45^{b}	5.13^{c}	60.0^{b}	78.6^{b}	1.39^{b}	14.8^{c}	5.10^{d}
Single row of *S. guianensis*	12.5^{d}	0.12^{d}	1.92^{d}	42.0^{c}	60.5^{c}	0.94^{c}	9.73^{g}	9.20^{b}
Double rows of *S. guianensis*	12.4^{d}	0.59^{a}	9.32^{a}	56.0^{b}	73.4^{b}	1.27^{b}	10.7^{e}	5.00^{d}
Triple rows of *S. guianensis*	14.5^{b}	0.55^{a}	8.86^{ab}	67.0^{a}	83.0^{a}	1.54^{a}	13.5^{d}	4.44^{e}
Sole *B. decumbens*	08.3^{f}	0.32^{c}	5.08^{b}	44.0^{c}	61.0^{c}	0.99^{c}	9.62^{g}	13.1^{a}
Sole *S. hamate*	15.5^{a}	0.51^{a}	7.94^{b}	56.0^{b}	87.2^{a}	1.30^{b}	16.5^{a}	7.03^{c}
Sole *S. guianensis*	15.5^{a}	0.27^{d}	4.28^{c}	45.0^{c}	74.7^{b}	1.02^{c}	16.1^{b}	6.21^{c}
SEM	0.14	0.03	1.06	1.74	1.91	0.04	3.05	0.07

Means followed by different letters within columns differ significantly (P<0.05) b = Volume of gas produced in time (t); c = Fractional rate of gas production; SCFA=Short Chain Fatty Acid, DMD=Dry Matter Digestibility, ME=Metabolizable Energy, OMD = Organic Matter Digestibility

DISCUSSION

Growing two or more crops together on the same area can often produce higher yields than sole crops (Adam and Mohammed, 2012). However, the ratio of intercrop could affect the yield of the component crop when there is competition for light, water, and nutrients (Albayrak and Ekiz, 2005). The results indicated that there is a strong competition between swards of *S. hamata* and *B. decumbens* particularly as the rows of the legume increased. However, this competition seems to be weak between the swards of *S. guianensis and B. decumbens* as the relative yield of both *S. guianensis* and *B. decumbens* increase as the rows of legume increased. This implies that *S. guianensis* can be successively intercropped with *B. decumbens* without much competition (Fisher and Kerridge, 1996). Similarly, Land Equivalent ratio (LER) which indicates the amount of land needed to grow both crops together compared to the amount of land needed to grow sole stand of each. A LER less than 1.0 shows a disadvantage and any value greater than 1.0 0 indicates the presence of positive inter-specific interference (Adam and Mohammed, 2012). LER of less than 1 recorded when *B. decumbens* was intercropped in double rows of *S. hamata* and single row of *S. guianensis* shows interspecific competition among the species (Daniel *et al.,* 2001) and thus indicates the intercrop yield was less than equal of the yield of the sole. Intercropping systems productivity has revealed that the aboveground dry matter yields are positively associated with the competitive ability of component crop (Li *et al*., 2001). Thus, it is of great importance to determine the inter-specific competitiveness of each crop for accurately assessing the intercropping system productivity (NachigeraMushagalusa *et al.,* 2000). Planting *B. decumbens* and *S. guianensis* in sole would require 96% and 52% more land in wet and dry season respectively to produce the yield of both in intercropping in triple rows *S. guianensis*.

Intercropping resulted in higher cumulative total biomass yield compared to sole cropping, which resulted in higher Relative Yield Total. The higher cumulative total biomass yield was probably due to increased light use efficiency of the intercrops, which has resulted in higher cumulative leaf area of the intercrops. This finding was in agreement with that of Ibrahim *et al.* (1993) who reported a similar result in sorghum/lablab intercropping. Similarly, Jaballa (1995) also reported that intercropped treatments had higher combined leaf area than soles and the intercrops gave higher biomass yield per unit area than sole crops. Reasons for this was reported that increase in leaf area would lead to an increase in light interception and photosynthesis, which results in increased productivity (Reddy, 2000)

The use of grass-legume mixtures in temporary grassland is widely applicable and does not necessarily compromise harvest yield, thereby improving agricultural efficiency (Kirwan *et al.,* 2014 Finn *et al.,* 2013).This benefit persisted over the two season of the experiment.

The 3-4 months dry season in the Southwestern part of Nigeria is a critical period for forage production, and any species that can produce reasonable amounts of dry matter and remain leafy and green, will contribute significantly to the nutrition and performance of livestock. Incorporation up to three rows of *S. guianensis* into *B. decumbens* produced dry matter yield of over 4 t/ha which could be considered as a meaningful yields as it comparable with the yield of *B. ruziziensis* in mixtures with *S. guianensis* (5.0 t ha-1) under basal application of N.P.K. fertilizer (Olanite *et al.,* 2009). While dry matter production is a function of the nature of competition among the various species in mixtures, lower DM yield of grass in mixed plot compare with sole established could be explained as a result of competition, however, progressive increase in its DM yield as the rows of *S. guianensis* increased is noteworthy. This implies that DM yield of *B. decumbens* could maintain similar yield both in mix and sole. This

could be due to vigorous nature of grass growth and its ability to rapidly utilize the nitrogen in the soil which is released following cultivation of legume (Tessema and Baar, 2006). N fixation of legume species can also be enhanced with competition from non-legume species (Nyfeler*et al.,* 2011).

While it is desirable in agronomic systems to achieve good yields, it is important to obtain herbage of high digestibility, low fibre content and high concentration of protein, to sustain animal production (McDonald *et al.,* 2002) as sole grass established produced much lower CP contents than solely established stylo The differences between grass and legume species are well documented by Pelletier *et al.* (2010). The results obtained from these authors are similar to what was obtained in this trial. However, its combination with legumes improves the quality and hence digestibility. Forage legumes generally have higher nutritive value than grass species, slower decline in digestibility with advancing maturity and higher levels of protein (Dewhurst *et al.,* 2009) and therefore, growing mixtures of grasses and legumes can improve herbage nutritive value compared with growing sole grasses (Zemenchik *et al.,* 2002). In term of ratio of intercrop, CP contents of the grass/legume mixtures increase up to triple rows of stylosanthes in single row of *B. decumbens* in this study. However, in a similar study, incorporation of *L. pursoleus* cv. Rongai into single *A. gayanus* gave highest CP content in all the mixtures (Amole *et al*., 2015). This observation from the trial underscore the fact that ratio of grass-legume mixtures varies according to the species and should be considered in pasture establishment.

Sole established leguminous forages had lower NDF and ADF contents than the sole established grasses . This may be attributed to the fact that the amounts of cell wall constituents (NDF and ADF) in legumes are not as large as those of grasses. The proportion of cell wall constituents in grasses is larger than in legumes and also lignified quickly (Buxton 1996). This study confirms that intake and digestibility could be enhanced by the inclusion of legume in sole established grass forages particular in the dry season. NDF and ADF contents decreased as the legume proportion in the mixtures resulting from the increase in rows of legume, consequently, it indicates a potential for increasing forage intake (Amole *et la*., 2015).

The higher values of gas volume obtained when triple rows of *S. guianensis* was intercropped with *B. decumbens* may be attributed to higher nutrient composition as influenced by the ration of legume different factors in the mixtures (Dele, 2012). Thus the values obtained for the fractional rate of gas production (c) of the grasses, may indicate a better nutrient availability for rumen microorganisms (Getachew *et al.,* 2004).

From the result, although both sole and intercrop gave metabolizable energy within 6 to 13 MJ/kg DM required for optimal productivity (Steele, 2006), increasing the rows of legume within the intercrop raised the ME of the grass/legume mixtures higher than grasses planted or established sole. Increasing in weight gain by WAD goats fed the different feed has been attributed to increasing the levels of metabolizable energy in the feed (Mahgoub *et al.,* 2000). This suggests that legume inclusion is paramount particularly in the dry season for optimal productivity in ruminant livestock.

Feeding ruminant with sole grass-based forages produced more methane (CH_4) than ruminants fed sole legume forages (Eckard *et al.,* 2010). The results obtained from methane (CH_4) determination confirms that there are number of reasons to predict that methane production should be less from legumes than from grass. This includes lower fibre content, higher DM intakes and an increased passage rate from the rumen (Beauchemin *et al.,* 2008). Inclusion of

legumes in grassland management has been proposed as an important strategy for climate change mitigation in the agricultural sector (Smith *et al.,* 2008; Smith and Gregory, 2013; Bustamante *et al.,* 2014). The results of this study confirm that improving forage quality, either through feeding forage legume with a lower fibre and/or higher protein content can reduce CH_4 production (Rodríguez *et al.,* 2010). In both season, triple rows of legume in grass swards reduced the CH_4 gas production and limits higher enteric CH_4 gas production which represents a significant loss of dietary energy that could potentially be redirected towards the production of milk and meat (Eckard *et al.,* 2010).

CONCLUSION

Amongst the 6 mixtures ratios evaluated, intercropping of up to three rows of *S. guianensis* within the rows of *B. decumbens* produced an outstanding in terms of biomass, quality and environmental impact in terms of CH_4 during the experiment. It is our hope that this will help by increasing and improving livestock productivity in sub-Saharan Africa.

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