



Dry Matter Yield and Quality of Two Temperate and Two Tropical Forage Legume Hays Harvested at Early-Flowering in Jos, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. Author TTA conceived, designed and coordinated the study. Authors JTA and RJT wrote the manuscript. Author JSL assisted in data collection. Author OATN managed literature search and edited the manuscript. Author MRH managed and analyzed the data. All authors read and approved the final manuscript

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ABSTRACT

The study was designed to evaluate the dry matter yield and quality of two temperate (*T. Pratense* and *T. repens*) and two tropical forage legumes (*S. guianensis* and *C.molle*) harvested at early-flowering stage for hay in a cool tropical environment of Vom, Jos, Plateau State, Nigeria. The legumes were planted in the month of June, 2015 and 2016 in a 4 x 4 Latin Square Design with four replicates in plots measuring 5 m x 3 m. The forages were harvested at early-flowering stage for yield components, dry matter yield and nutrient quality evaluation.

The result showed that *C. molle* was significantly ($P<0.01$) higher in height in the two seasons compared to the other legumes. Number of leaves per plant was higher ($P<0.01$) significantly in *S. guianensis* (125.00) in 2015 whereas, *T. repens* had higher ($P<0.01$) value (187.25) in 2016

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cropping season. *Stylosanthes guianensis* produced significantly ($P<0.01$) higher dry matter with 10.42 t ha^{-1} in 2015, while the dry matter yield obtained from *C. molle* (2.90 t ha^{-1}) was the highest in 2016. *Trifolium pratense* and *T. repens* were scored excellent grade, while *Stylosanthes guianensis* and *Centrosema molle* were scored good in quality. Crude protein content was significantly ($P<0.01$) higher in *T. repens* (18.38%) compared to *T. pratense* (16.50%), whereas *S. guianensis* produced the least value of 13.83%. The crude fibre content of the forage materials on the other hand was significantly higher ($P<0.01$) in *S. guianensis* (37.29%) compared to the other forage legumes.

The temperate forage legumes in this trial were higher in nutrient content, but lower in dry matter yield. Therefore, the forage crops may serve as better supplementary feeds for livestock feeding especially during the dry season.

Keywords: Yield; nutrients; temperate; tropical; legumes; hay.

1. INTRODUCTION

Ruminant livestock in most parts of the tropics graze intensively on naturally growing forages which are poor in quality [1]. Natural pastures are also low in dry matter with crude protein content of about 3%, during the dry season [2]. Tropical forages are generally known to be lower in nutrient composition and digestibility. This may be due to higher lignifications of the plant leaves which is a mechanism they have developed to minimise water loss or transpiration, in order to increase their survival in hot conditions [3].

Red clover (*Trifolium pratense* L) and White clover (*Trifolium repens* L) are perennial forage legumes widely grown in the temperate regions of the world and as well as in the sub-tropical areas of Australia for extensive livestock feeding. The two legumes provide forages that are high in protein content and digestibility, which facilitates high feed intake by animals [4]. According to [5], the legumes usually have higher crude protein content, lower acid detergent fibre and neutral detergent fiber in grass stands, and especially in grasses mixed with clovers. *Trifolium pratense* is the second most important perennial forage legume after Alfalfa (*Medicago sativa* L.) and the forage crop is adapted to a wide range of climatic conditions, soil types, fertility levels and different patterns of management [6]. The forage legume is generally best adapted to a cutting system, where it can give very high dry matter production with average yield stability in different environmental conditions although the stability decreases as the stand ages [7]. *Trifolium pratense* may yield $13.0 - 18.0 \text{ t DM ha}^{-1}$ [8]. *Trifolium repens* (White clover) is a forage legume that is generally considered as the common and important grazing legume in all the temperate regions of the world [9]. It can fix as

much as 146 kg N ha^{-1} per year and give yields of $5.0- 15.0 \text{ t DM ha}^{-1}$ a year [10]. According to [11], the legume is an excellent forage for ruminants and is often used for grazing, cut-and-carry, silage and hay. It is better in quality than any tropical legume [12].

Stylo (*Stylosanthes guianensis* Cv. Cook) is one of the forage legumes well suited to the sub-humid tropical and sub-tropical zones with a marked dry season [13] In a study [14] observed that *S. guianensis* is often used as a supplement during dry season to improve the nutritive value of low quality forages, such as crop residues or by-products such as rice straw. The Organic Matter Digestibility (OMD) of *S. guianensis* ranges between 51 to 67% [15], which is lower than *T. pratense* and *T. repens*. Centro (*Centrosema molle* Mart. ex Benth.) formerly called *Centrosema pubescens* is widespread in the wet tropics from the Tropic of Cancer in the North to the Tropic of Capricorn in the Southern hemisphere and up to an altitude of 1,600 m and is one of the most palatable legumes [16]. It is considered to be a valuable feedstuff since it provides fresh green matter during the dry season [17]. Forage yield of *C. molle* is variable depending on nutrient availability in the soil. According to [18] fresh forage and forage dry matter yields of 18.9 and 7.1 t ha^{-1} , respectively, while [19] reported dry matter yields of $5.6 - 7.4 \text{ t ha}^{-1}$ and CP content of 18.9 to 22.4% in *C. molle* varieties.

Nutrient content and digestibility are higher in cold climate legumes and C_3 (temperate) grasses when compared to warm climate legumes and C_4 (tropical) grasses, respectively [20]. In a study [21] reported that cooler weather promotes neutral detergent fibre (NDF) digestibility. Tropical legumes and grasses

require more physical breakdown for degradation and their N concentration is also lower than in C₃ grasses and cold climate legumes [22]. These problems limit the productivity of animals in the tropical regions. The aim of the study was to evaluate the dry matter yield and quality of two temperate (*T. pratense* and *T. repens*) and two tropical forage legumes (*S. guianensis* and *C. molle*) harvested at early-flowering stage for hay in Vom, Jos, Plateau State.

2. MATERIALS AND METHODS

2.1 Location of the Study

The experiment was carried out at the Nigerian Institute for Trypanosomiasis Research (NITR), Vom (Lat 9° 43' 60N, Long 8° 46' 60E and 1,223 m above sea level) [23], Jos, Nigeria. Meteorological data of the study area during the 2015 and 2016 cropping seasons were obtained from the Potato Programme of the National Root Crops Research Institute (NRCRI), Vom, Jos, as shown in Table 1. The area is characterized by two major seasons (rainy and dry seasons). The rainy season starts from late-May and ends in early October each year, while the dry season starts from late-October and ends in early- May. Peak of the rain is normally observed in the month of August each year. The climate of the area is cool with tepearature ranging from 15 - 27°C during the rainy season and 7 - 18°C during the hamattam season, while temperature range of 18 - 32°C is normally observed during the late months of dry the season (March to early-May). However, the grasses found on these highlands are shorter and the trees are fewer than at lower level [24]. Soil samples of the experimental site were randomly obtained at the depth of 0-15 cm at different locations with an aid of a soil auger and its physical and chemical properties determined. Soil in this area is generally sticky when wet, has low fertility and quickly becomes hard when there is no rain for 2 - 3 days and cracks easily [24]. The analyses carried out on the soil is shown in Table 2. The experimental area was used in the year 2014 cropping season for Cocoa yam production.

2.2 Land Preparation and Experimental Design

The land was ploughed and harrowed twice using tractor mounted with implements and locally made hoes. The field was levelled and all debris were removed to provide clean seedbeds.

The four forage legumes (*T. pratense*, *T. repens*, *S. guianensis* and *C. Molle*) were used as treatments and replicated four times (columns and rows) in a 4 x 4 Latin Square Design. Total area of land for the experiment was 23 m x 13.5 m (310.5 m²) and this was divided into 16 blocks of 5 m x 3 m (13 m²) each. The spacing between each block was 1 m and 0.5 m along the rows and columns, respectively.

2.3 Sources of Planting Materials

The temperate forage legume seeds of Red clover (*Trifolium pratense* L.), AberClaret variety and White clover (*Trifolium repens* L.), AberHerald variety were obtained from the Institute of Biological, Environmental and Rural Sciences (IBERS), University of Aberystwyth, United Kingdom. The tropical forage legume seeds of Cook Stylo (*Stylosanthes guianensis*) and Centrosema (*Centrosema molle* Mart. Ex Benth) were obtained from the Feeds and Nutrition Research Programme of the National Animal Production Research Institute (NAPRI), Ahmadu Bello University, Shika, Zaria, Nigeria.

2.4 Pasture Establishment

The trials were conducted when the rains were well established in the month of June during the 2015 and 2016 rainy seasons at the seed rate of 8.44 and 7.40 kg ha⁻¹ for *T. pratense* and *T. repens*, while 8.82 and 11.62 kg ha⁻¹ seeding rates for *S. guianensis* and *C. molle*, respectively. The seed rates for the experimental legumes were determined using Pure Live Seed (PLS) index described by [25] as follows:

$$\text{PLS Index} = (\% \text{ Germination} \times \% \text{ Purity}) \div 10,000$$

$$\text{Kg of Seed per hectare} = \text{Recommended Seeding Rate} \div \text{PLS Index}$$

Where,

Kg= kilogram

PLS= Pure live seed

Seeds of *S. guianensis* were scarified by immersing in hot water at 90°C for 1 min [26] prior to sowing to reduce the hardness of seeds so as to improve germination and establishment. Seeds of *C. molle* were scarified by immersing in hot water at 80°C for 4 min. The seeds of *T. pratense*, *T. repens* and *S. guianensis* were

planted at the recommended row spacing of 0.3 m [27], while those of for *C. molle* were planted at a spacing of 0.5 m. Recommended sowing depth of 0.5 cm [27] was used for *T. pratense* and *T. repens*, while the depth for *S. guianensis* and *C. molle* were 1 and 2.5 cm, respectively [28].

2.5 Yield Measurements

2.5.1 Yield components

Five [5] plants in the middle row in each plot were tagged and used in determining the yield components of plant height, number of leaves and number of branches per plant. The height of the plants were measured from the ground level to the flag leaf with the aid of a graduated metre rule. The number of leaves and branches of the tagged plants were counted for each forage legume. Five plants within a row in each plot were harvested to determine leaf-to-stem ratio by separating the leaves of the harvested plants from the stem. Petiole was weighed as a component of the stem. The leaves and stem were weighed immediately in the field after separation, oven-dried at a temperature of 65°C for 48 h and weighed again until a constant weight was attained. Thereafter, the leaf dry weight was divided by the stem dry weight to determine leaf-to-stem ratio [29].

2.5.2 Forage yield measurement

Plants within 0.5 m² quadrant placed in the middle rows of the plots were cut at 5 cm above the ground level with a sickle to determine the forage yield at early-podding stage. The cut forages were immediately weighed to determine fresh weight after which they were oven-dried at a temperature of 65°C for 48 h to determine the forage dry matter yields. Forage dry matter yields were calculated using the formula of [30] as stated below:

Forage dry matter yield (kg DM ha⁻¹) = Fresh weight (kg) x Oven dried weight (DM%) x 40,000
There are 40,000 quadrat (0.5m²) per hectare

2.6 Preparation of Hay for Physical and Chemical Evaluation

Hay making was carried out at early-flowering stage. The forage legumes were harvested 5 cm above the ground level with the aid of a sickle. The harvested fresh forages were spread under

the shade of a tree in the field and the cut forages were turned twice daily for effective drying and to maintain the desired green colour. Sub-samples of the forage materials were oven-dried to determine dry matter content. The forage materials were removed from the field when the moisture content was less than 15%, therefore, sub-samples were taken for physical and chemical quality evaluation.

2.7 Physical and Chemical Quality Evaluation of Hay

Hay physical quality evaluation was carried out according to the Guideline for Visual Evaluation of hay described by [31]. Stage of maturity, leafiness (leaf/stem ratio), colour, odour and foreign materials were evaluated by visual scoring. Five people were used for the visual assessment of hay for the four legumes for the various parameters. An average score for each variable was taken for each forage legume. The scores from each variable was then added together and a total score was obtained from each forage legume hay from where the hays were graded as excellent, good, fair and poor. Dried forage samples of the hay materials were ground with a Thomas Willey Laboratory Mill-Model 4 and passed through 1-mm sieve. Proximate analysis was carried out using the Method of [32], while detergent fibre analysis was carried out according to the method described [33]. Mineral composition (Ca, P, Mg, K and Na) of the samples was carried out using the Atomic Absorption Spectrophotometer of [32].

Statistical model for experiment 1

$$Y_{ijkl} = \mu + ROW_i + COL_j + T_{(k)} + e_{ijkl}$$

Where,

μ = population mean

ROW_i = i^{th} effect of row

COL_j = j^{th} effect of column

$T_{(k)}$ = k^{th} effect of treatment (4 legume accession)

e_{ijkl} = Random error

2.8 Statistical Analyses

All data generated were subjected to Analysis of Variance (ANOVA). The general linear model of [34] statistical software was used for the analyses and means were separated using method of [35].

3. RESULTS

The results of yield components and dry matter yield are presented in Table 3. *Centrosema molle* was significantly ($P<0.01$) higher in height with 101.15 and 148.40 cm in 2015 and 2016 cropping season, respectively compared to the other legumes. The number of branches was higher ($P<0.01$) in *S. guianensis* (34.50) compared to other legumes, while there was no significant difference between *T. pratense* and *C. molle* in 2015. In 2016 however, *T. repens* (37.25) had higher ($P<0.01$) number of branches per plant, while *T. pratense* (7.00) was the

lowest. Similar result was obtained for number of leaves per plant as *S. guianensis* produced significantly higher ($P<0.01$) number (125.00) in 2015, whereas, *T. repens* (187.25) was higher ($P<0.01$) in 2016 cropping season. Leaf-to-stem ratio was significantly ($P<0.01$) higher in *C. molle* during the 2015 and 2016 cropping season. Dry matter yield was higher in *S. guianensis* (10.42 t ha^{-1}) compared to the other legumes, while *C. molle* (2.90 t ha^{-1}) produced significantly higher yield in 2016. The yield components and dry matter yield for the legumes were higher in 2016 than 2015 except *S. guianensis* which were higher in 2015.

Table 1. Monthly maximum temperature, relative humidity and precipitation distribution for 2015, 2016 and medium-term means (2004-2014) for Vom^a, Jos-Nigeria

Month	Max. Temp (°C)			R.H (%)			Rainfall (mm)		
	2015	2016	2004-2014	2015	2016	2004-2014	2015	2016	2004-2014
January	29	30	29	60	31	27	0.0	7.7	8.5
February	32	31	30	54	53	24	10.1	2.3	1.5
March	32	34	32	59	60	28	28.0	19.2	18.2
April	32	32	30	29	61	54	10.0	83.3	81.9
May	30	29	28	68	70	65	216.5	138.2	145.2
June	29	28	27	70	73	81	15.1	172.7	191.9
July	27	29	25	79	80	88	225.2	383.8	207.0
August	26	27	25	81	84	87	301.3	401.1	290.3
September	27	25	26	69	76	79	208.5	181.4	205.2
October	29	25	27	58	65	58	59.9	170.1	182.3
November	30	27	29	36	39	33	0.0	0.0	0.0
December	27	30	28	48	40	30	0.0	2.9	3.2

Source: National Root Crop Research Institute, Vom^a (Lat. 9° 44' 60N, Long. 08° 47' 60E. Alt. 1223m)

Table 2. Soil physical and chemical properties of the study area (0-25 cm)

Property	Value
Particle size (%)	
Clay	37.0
Silt	20.0
Sand	43.0
pH	5.5
Class of soil	sandy-clay loam
Chemical property	
Total N(%)	0.33
Organic carbon (%)	2.91
K(mg/l)	247.20
P(mg/l)	7.53
Exchangeable cation (mol/kg ⁻¹)	
P(mg/l)	
Ca ⁺⁺	14.15
Mg ⁺⁺	0.98
CAC	16.60

Table 3. Dry matter yield and yield components of four forage legumes in 2015 and 2016 cropping seasons

Forage- legumes	Height (cm)		Branche no./plt		Leaves no./plant		Leaf-to-stem ratio		DMY (t ha ⁻¹)	
	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
<i>T. pratense</i>	42.07 ^c	64.92 ^b	6.50 ^c	7.00 ^d	28.75 ^d	63.00 ^d	0.32 ^a	0.26 ^b	1.56 ^c	1.92 ^c
<i>T. repens</i>	46.90 ^c	62.65 ^b	25.50 ^b	37.25 ^a	90.00 ^b	187.25 ^a	0.23 ^b	0.24 ^b	-	1.24 ^d
<i>S. guianensis</i>	101.15 ^b	64.75 ^b	34.50 ^a	22.75 ^b	125.00 ^a	86.00 ^c	0.27 ^b	0.14 ^c	10.42 ^a	2.67 ^b
<i>C. molle</i>	111.75 ^a	148.40 ^a	9.50 ^c	19.25 ^c	41.75 ^c	90.75 ^b	0.38 ^a	0.34 ^a	1.76 ^b	2.90 ^a
SEM	3.24	3.18	3.39	1.00	4.99	3.00	0.15	0.02	0.07	0.10
LOS	**	**	**	**	**	**	**	**	**	**

^{abcd}Means with different superscript within the column are significantly different (**=P<.01), SEM= Standard error of means, LOS= Level of significant, Plt= plaqnt, DMY= Dry matter yield

Table 4. Physical characteristics of the four forage legume hays (averages of 2015 and 2016 cropping seasons)

Parameter	Forage legumes			
	<i>T. pratense</i>	<i>T. repens</i>	<i>S. guianensis</i>	<i>C. molle</i>
	Scores			
Stage of harvest	25	25	25	25
Leafiness	19	20	16	16
Colour	19	19	17	19
Odour	18	18	17	17
Foreign materials	9	9	9	9
Total scores	90	91	84	86
Remarks	Excellent	Excellent	Good	Good

Table 5. Proximate and detergent fibre composition of four forage legume hays (averages of 2015 and 2016)

Parameter (%)	Forage legume				SEM	LOS
	<i>T. pratense</i>	<i>T. repens</i>	<i>S. guianensis</i>	<i>C. molle</i>		
Crude protein	16.50 ^b	18.38 ^a	13.82 ^d	14.52 ^c	0.08	**
Crude fibre	26.33 ^c	22.61 ^d	37.29 ^a	34.51 ^b	0.06	**
Ether extract	2.09 ^a	2.23 ^b	1.09 ^d	1.57 ^c	0.02	**
Ash	9.31 ^b	10.02 ^a	6.64 ^d	7.16 ^c	0.10	**
NFE	40.40	41.58	40.68	42.09	2.96	NS
NDF	43.24 ^c	39.13 ^d	51.35 ^a	48.21 ^b	0.10	*
ADF	31.05 ^c	27.08 ^d	43.66 ^a	38.17 ^b	0.59	**

^{abcd}Means with different superscripts within the row are significantly different, SEM= standard error of means, LOS=level of significance (**P<.01 and * P<.05. NS= Not significant)

Table 6. Mineral composition of four forage legume hays (g kg⁻¹)

Parameter	Forage legume				SEM	LOS
	<i>T. pratense</i>	<i>T. repens</i>	<i>S. guianensis</i>	<i>C. molle</i>		
Calcium	14.25 ^a	12.44 ^b	8.06 ^d	9.25 ^c	0.02	**
Phosphorus	1.26 ^b	2.91 ^a	1.16 ^c	0.84 ^d	0.04	**
Magnesium	2.85 ^a	1.88 ^b	1.78 ^c	1.23 ^d	0.03	**
Potassium	15.73 ^b	19.51 ^a	14.53 ^c	10.57 ^d	0.02	**
Sodium	0.23 ^c	0.64 ^a	0.32 ^b	0.23 ^c	0.04	*

^{abcd}Means with different superscripts within the row are significantly different, SEM= standard error of mean, LOS=level of significance at **P<.01 and * P<.05

Table 4 shows the physical characteristics of the legume hays harvested at early-flowering stages. The scores for leafiness were 19 and 20 for *T. repens* and *T. pratense*, respectively compared to 16 for the tropical legume species. The scores for colour was 19 for *T. pratense*, *T. repens* and *C. molle* compared to 17 recorded in *S. guianensis*. All the forage legumes recorded the score of 9 for foreign materials. The result showed that total scores for hay physical characteristics were 90, 91, 84 and 86 for *T. pratense*, *T. repens*, *S. guianensis* and *C. molle*, respectively. Ranking the legume by their quality, *T. pratense* and *T. repens* scored excellent grade, while the other two (*S. guianensis* and *C. molle*) were scored good with respect to their physical characteristics [31].

The proximate and detergent fibre compositions of the four legume hays are presented in Table 5. Crude protein (CP) content was significantly higher (P<0.01) in *T. repens* (18.38%) than in *T. pratense* (16.50%), while *S. guianensis* had the least value of 13.83%. The crude fibre (CF) content was, however, significantly (P<0.01) higher in *S. guianensis* (37.29%) than in the other forage legumes, while *T. repens* (22.61%) had the lowest value. Ether extract (EE) content was significantly (P<0.01) lower in *S. guianensis*

(1.09%) than in the other legumes. The result showed that *T. repens* (10.02%) was significantly (P<0.01) higher in ash content compared to the other legumes. The difference between the forage legumes for nitrogen free extract was not significant (P>0.05), however, *S. guianensis* (51.35 %) was significantly higher (P<0.01) than the other three forage legumes for neutral detergent fibre (NDF) content. The result also showed that acid detergent fibre (ADF) content was significantly (P<0.05) higher for *S. guianensis* than the other forage legumes.

Table 6 shows the mineral composition of the hay from the four forage legumes. Calcium concentration was significantly (P<0.01) higher in *T. pratense* (14.28 g kg⁻¹) than in *T. repens* (12.44 g kg⁻¹), while *S. guianensis* had the least value of 8.06 g kg⁻¹. However, the P and K values for *T. repens* (2.91 and 19.51 g kg⁻¹) were significantly (P<0.01) higher compared to those for *T. pratense* (1.26 and 15.73 g kg⁻¹), while those of *C. molle* (0.84 and 10.57 g kg⁻¹) were lowest. The Mg content of *T. pratense* (2.85g kg⁻¹) was significantly (P<0.01) higher than that for *T. repens* (1.88 g kg⁻¹), while *C. molle* had the least value of 1.23 g kg⁻¹. Sodium content was significantly (P<0.05) higher in *T. repens* compared to the other three forage legumes.

4. DISCUSSION

The plant height of *T. pratense* obtained in this study fell within the range of 20 - 80 and 50 – 70 cm, but was lower than 64 cm reported by [36], [37] and [38] in six countries of Europe. The plant height of *S. guianensis* obtained in this study was similar to the result reported by [39] in Kenya, but lower than 135 cm reported by [40] in Indonesia. The number of branches in the 2016 season was higher than the result reported by [41] for *T. pratense* in Slovakia. The number of branches per plant in *C. molle* in this study was higher than 3.3 reported by [42] in the year of establishment at Shika, Zaria, Nigeria. Leaf-to-stem ratio of *T. pratense* fell within the range of 0.76 - 1.03 reported by [37] in Croatia, while that of *S. guianensis* was lower than 1.5 reported by [43] at Ibadan, Nigeria. The different in yield components between the forage legumes might be due to species differences and response of the legumes to the climate and soil conditions of the area [37]. Higher values of yield components obtained in the 2016 cropping season could be attributed to a well distributed rainfall pattern in the month of June (172.7 mm) which probably enhanced uniform field germination and plant establishment compared to 15.1mm in the same month in the 2015 cropping season as shown in Table 1. Low values of yield components of *S. guianensis* may be due to infection probably caused by *Anthraco* or leaf blight disease in the 2016 cropping season.

The highest DM yield of 3.6 t ha⁻¹ for *T. pratense* in this study was lower than the range of 7 - 13.99 t ha⁻¹ and 13.5 t ha⁻¹ reported by [41] and [44] in Slovakia and UK, respectively. Similarly, the yield of *T. repens* was lower than the 2.7 t DM ha⁻¹ as well as 6.09 t DM ha⁻¹ reported by [45] and [46] in the UK and Turkey, respectively. The DM yield of *T. repens*, however, fell within the range of 1.52 - 3.39 recorded for the same variety (AberHerald) by [47] in the UK. The lower yields of these temperate legumes in this environment compared to the temperate climate could be attributed to variety, plant population, soil and climatic differences. The established plant populations for *T. pratense* and *T. repens* were 71 and 81 plants per square meter compared to the recommended 150 and 200 plants per square meter, respectively recommended [27]. Considering the characteristics of the soil where the experiment was carried out, it could be thought that this was not favourable for higher growth and DM yield as

T. pratense and *T. repens* require a soil pH of 6 - 7.5 [27; 45] as against the 5.5 obtained in the area (Table 2). In addition, the soil was low in nutrient composition. The growing season in this environment (5 months) was too short to obtain higher yields compared to the longer growing season in the temperate region. The DM of 14.15 t ha⁻¹ in *S. guianensis* was within the range of 10 - 20 t DM ha⁻¹ reported by [48], but higher than 4.2, 5.27 and 7.73 t DM ha⁻¹ reported by [40, 49 and 50] in Australia, Indonesia and Nigeria, respectively. The DM yield of *C. molle* in the present study was lower than 7.1, 9.2 and 3.78 t ha⁻¹, reported by [18], [51] and [43], respectively. However, the DM yield of *C. molle* in this study was higher than 1.6 - 1.8 t ha⁻¹ recorded by [52]. The higher DM yield of tropical forage compared to temperate legumes agreed with [53], who observed that tropical forages accumulated more dry matter than temperate forages. This may be due to more efficient way of photosynthesis of tropical species [28, 54]. Higher forage yield obtained in the 2016 cropping season could be attributed to better plant establishment due to a well distributed rainfall pattern in the establishment month of June (172.7 mm) compared to 15.1mm in the same month in 2015 cropping season as shown in Table 1. An infection probably caused by *Anthraco*, a fungal disease might have accounted for the low values of DM yield for *S. guianensis* in the 2016 cropping season.

Ranking the legume by their quality, *T. pratense* and *T. repens* scored excellent grades, while the other two legumes (*S. guianensis* and *C. molle*) were scored good with respect to their physical characteristics [31]. In this regard, properly conserved hays made from the temperate legumes at the early-flowering stage were of better qualities compared to the tropical legumes. The CP and ash contents obtained in this study were higher, whereas CF, NDF and NDF were lower than the results (16.5%, 9.3%, 26.9%, 31% and 43%, respectively) reported by [55] for *T. pratense* in the USA. The CP content of 18.38 % was lower than 21.4%, but the CF content 22.61 % was higher than that of 20.9%, reported by [56] for *T. repens*. The CF content obtained in this study was similar, but the CP (18.4%) and EE (3.9%) were lower, while the ash (8.4%) content was higher than the result recorded by [57]. The higher nutrient compositions in hay of the temperate forage legumes agreed with the findings of [20] that the temperate forages have higher nutrient compositions. Forages growing in

the hot climate mature rapidly and have lower nutritive value than their counterparts in cooler environments [58].

Trifolium repens hay could meet the CP requirements of 15 – 17 and 18 - 19% for growth and reproduction, respectively [59] in rabbits, while *T. pratense* hay harvested at the early-flowering stage in this environment can only meet the requirement for reproduction. The CP contents in the tropical forage legume hays can not meet these requirements. Rabbits fed the tropical legume hays should, therefore, be supplemented with higher CP content feeds to meet these requirements. The legume hays can supply more than 16.0 and 30.0% for ADF and NDF, respectively, required by rabbits [60]. All the forage hays can meet the CP range of 7 – 16 % required by small ruminants for growth and productive/physiological functions [61]. The forage legume hays could also meet the CP of 7 – 14% generally required by cows and 10.5 - 14 % for heifers and steers in the tropics [62]. The temperate legume hays could also meet the 15.1 – 18.5% CP required for dairy cows [63], while animals fed with the tropical legume hays harvested at the early-flowering stage need to be supplemented with diets of higher CP content.

The values recorded for calcium and phosphorus contents for *T. pratense* hay were similar to those reported by [55] in the USA. The higher mineral composition in the temperate legumes agreed with [58] who observed that nutrient compositions were higher in the temperate forage species compared to their counterparts in the tropics due to the lower fibre contents in the temperate species. The legume hays could meet the Ca (4 -6%) and K (<18%) requirements of rabbits (59), while the other mineral elements need to be supplemented. All the forage hays can meet the Ca (0.3 - 0.8%) and Mg (0.18 - 0.4%) [61] required for growth and all productive/physiological functions of small ruminants. The hays from the legumes harvested at the early-flowering stage in this environment have the potential to supply 0.53 - 0.67% Ca, 0.22 - 0.44% P, 0.18 - 0.21% Mg, 0.22 - 0.29% Cl, 11% K, 0.22% Na and 0.11% S required for lactating cows [63].

5. CONCLUSION

The physical quality of the temperate forage legume (*T. pratense* and *T. repens*) hays was better than the tropical forage legume (*S.*

guianensis and *C. molle*) hays. Nutrient contents were higher in temperate forage legume hays than in the tropical legume hays, therefore, the legumes could be grown and conserved in this cool tropical environment as supplementary feeding especially during the dry season.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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