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Variation in Yield and Yield Components of Tropical Forage Grass Species Evaluated in the Southern Guinea Savanna of Nigeria

G. O. S. Ojo[1*], H. Madu[2] and A. I. Okwori[2]

[1]Department of Crop Production, Federal University of Agriculture, Makurdi, Nigeria.
[2]Department of Animal Production, Federal University of Agriculture, Makurdi, Nigeria.

Authors' contributions

This work was carried out in collaboration among all authors. Author GOSO wrote the protocol and first draft of the manuscript. Author GOSO managed the literature searches. Author HM performed the experiment as part of her M.Sc. research under the supervision of authors GOSO and AIO. All authors read and approved the final script.

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ABSTRACT

Seven improved tropical grass species, namely, *Andropogon gayanus* Kunth., *Brachiaria ruziziensis* Germain & Evrard, *Cenchrus ciliaris* L., *Chloris gayana* Kunth, *Panicum maximum* var. coloratum C.T, *Paspalum orbiculare* G. Forstand *Sorghum almum* Parodi were evaluated for yield and yield components at the Teaching and Research Farm of the Federal University of Agriculture, Makurdi, Nigeria in 2015 and 2016. The experiment was laid out in a randomized complete block design with three replications in each of the years. Results showed that the evaluated grass species could be cut at an early age when the leaf: stem ratio is high enough for the ruminants to derive maximum nutritional benefit and need not be delayed till 16 weeks after planting. The highest correlation between plant height and grain yield was observed at 4 weeks (r = 0.69) and 8 weeks (r = 0.70) after planting, implying that the taller the plant species at this stage of growth, the higher the probability for high grain yield. Identification and selection of tropical grass species for improvement

**Corresponding author: E-mail: gosojo2016@gmail.com;*

in grain production should, therefore, be carried out between 4 and 8 weeks of growth. All the seven tropical forage grass species performed favourably well in terms of growth and yield, with the positive response to increasing rainfall and further studies on multi-location evaluation within the Southern Guinea Savanna agro-ecologicalal zone of Nigeria is recommended.

Keywords: Tropical forage grass species; ruminants; evaluation; Southern Guinea Savanna.

1. INTRODUCTION

According to Encyclopaedia Britannica, the grass family (Poaceae) is the most important family of flowering plants in terms of abundance and provision of food/feed to man and animals. Grasses are required by livestock to meet up their nutritional need for growth, meat and milk production and are therefore very important to the development of any country.

The Southern Guinea Savanna agro – ecological zone of Nigeria receives rainfall from April to October and supports the growth of crops ranging from arable to permanent crops for most part of the year. Hence, herdsmen move their cattle from the Sudan and northern Guinea Savanna to this ecological zone in search of green pasture which is predominantly natural with low productivity. While most of the food crops grown in this ecology are improved varieties, little or no attention has been directed towards forage and fodder improvement. There is, therefore, the need for a concerted research effort that will enhance the improvement and development of forage grass species for livestock utilization and thus, contribute to the overall economy and wellbeing of Nigerians. The dearth of such information necessitated this research.

The objective of the study was to evaluate some improved forage grass species for yield and yield components in the Southern Guinea Savanna agro-ecological zone of Nigeria.

2. MATERIALS AND METHODS

Seven (7) improved tropical grass species were obtained from the National Animal Production Research Institute (NAPRI) in Ahmadu Bello University, Zaria, Nigeria and used for the experiment. The 7 species include *Andropogon gayanus, Brachiaria ruziziensis, Cenchrus ciliaris, Chloris gayana, Panicum maximum, Paspalum orbiculare and Sorghum almum.*

The experiment was conducted at the Teaching and Research Farm of the Federal University of Agriculture, Makurdi (latitude 07°41'N, longitude 08°37'E and 97 m asl) (southern Guinea Savanna agro - ecological zone of Nigeria) in 2015 and 2016. Meteorological information for Makurdi and the soil physical and chemical characteristics for the experimental site are summarized in Tables 1 and 2 respectively.

The experiment was laid out in a randomized complete block design with three replications for each of the years of study. Seeds were broadcasted into already prepared beds of 1.5 m^2 and urea fertilizer (46% N) was applied at the rate of 80 kgN/ha with 40 kgN at two weeks after planting (2WAP) and the remaining 40 kgN at 5 WAP. Manual weeding was carried out at 2 and 6 WAP, while harvesting of the fodder and grains was carried out at maturity and dried to a constant weight.

Data were taken on number of days to first flowering and 50% flowering, plant height at 4,8,12 and 16 WAP, Leaf: Stem ratio at maturity, dry matter yield of fodder and grain yield.

Data generated were subjected to analysis of variance using GLM and ANOVA procedures of SAAS 2009. Genotypic means were separated using LSD [1] while the correlation coefficient was carried out using the Pearson SPSS version 17.

3. RESULTS

The grass species were generally earlier in flowering and taller at 4, 8, 12 and 16 weeks after planting (WAP) in 2016 compared to 2015 (Table 3). *P. maximum* was earliest in flowering, while it took *Brachiaria ruziziensis* more days to flower compared to all the other species. A consistent increase in plant height across the four stages (4, 8, 12, 16 WAP) of measurement was observed for all the species evaluated. *Sorghum almum* was tallest at 4 WAP, and maintained the status till 8 WAP, before levelling to almost the same height with *P. maximum* at 12 WAP. *Sorghum almum*, however, lost its first position in plant height to *P. maximum* at 16WAP.

Table 1. Meteorological of rainfall and temperature data for Makurdi in 2015 and 2016

Year	Month	Total rainfall (mm)	Av. max temp. (^oC)	Av. min temp. (^oC)
2015	January	-	36.4	18.7
	February	-	38.3	25.9
	March	12.6	38.6	26.3
	April	31.4	37.3	26.4
	May	134.7	34.0	25.1
	June	123.6	32.7	23.6
	July	139.7	30.9	23.0
	August	213.8	30.9	23.5
	September	127.3	30.9	23.3
	October	82.9	32.4	23.8
	November	16.8	34.0	20.1
	December	0.0	33.3	17.5
	Total	882.8		
	Mean	73.6		
2016	January	-	34.3	16.5
	February	68.8	35.3	24.4
	March	-	37.0	26.2
	April	78.0	35.3	25.0
	May	142.8	33.0	25.1
	June	149.4	31.8	23.6
	July	265.6	30.9	23.2
	August	339.1	30.6	23.5
	September	268.9	30.9	23.1
	October	116.1	32.5	23.3
	November	0.0	35.3	22.4
	December	0.0	35.4	18.4
	Total	1428.7		
	Mean	119.1		

Source: Air Force Base Makurdi, Meteorological Station (TAC, 2016)

Table 2. Soil physical and chemical properties of the experimental site

Mechanical properties	
Sand	68.80
Clay	18.20
Silt	13.00
Textural Class	Sandy Loam
Chemical properties	
pH	6.63
Organic carbon (%)	1.88
Organic matter (%)	3.25
Total Nitrogen (%)	0.52
Total Phosphorous (mg/l)	6.10
Base saturation (%)	88.57
Exchangeable cation (Cmol)	
Potassium	0.34
Sodium	0.41
Magnesium	3.4
Calcium	3.6
Exchangeable Base (Cmol/kg)	7.75
Exchangeable Acid (Cmol/kg)	1.00
C.E.C (Cmol/kg)	8.75

C.E.C: Cation Exchange Capacity

Table 3. Mean values for flowering and height traits of tropical grass species evaluated in the Southern Guinea Savanna of Nigeria

Specie	Days to flowering first		Days to flowering 50%		Plant at 4WAP height		Plant at 8WAP height		Plant at 12WAP height		Plant at 16WAP height	
	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
Andropogon gayanus	83.00^{6}	86.33^{1}	95.33^{4}	90.67^{4}	8.44	13.78	54.56	62.33	111.65	121.64	192.67	200.64
Brachiaria ruziziensis	107.67^{1}	82.33^{3}	118.00^{1}	108.00^{1}	13.53	19.20	54.49	62.14	105.28	101.85	142.82	150.82
Cenchrus ciliaris	86.33^{4}	71.67^{6}	103.67^{2}	97.67^{2}	6.50	11.50	42.51	50.51	94.50	95.82	124.88	132.88
Chloris gayana	93.00^{2}	85.00^{2}	98.33^{3}	93.33^{3}	11.58	19.48	31.92	40.89	98.78	98.78	156.07	164.17
Panicum maximum	70.00^{7}	69.67^{7}	74.33^{7}	73.33^{7}	10.80	14.14	42.22	50.53	121.64	130.63	262.72	270.68
Paspalum orbiculare	83.67^{5}	72.67^{5}	88.33^{6}	79.00^{6}	8.28	13.28	43.78	52.56	97.32	89.02	112.38	120.36
Sorghum almum	88.00^{3}	77.67^{4}	92.67^{5}	87.67^{5}	15.90	20.57	62.28	70.32	122.87	132.87	202.00	212.33
Mean	87.38±6.13	77.91±2.70	95.81±7.08	89.95±6.03	10.72±2.02	15.99±1.28	47.39±1.25	55.61±1.12	107.43±1.27	110.09±1.24	170.51±1.11	178.84±0.97
$LSD_{.05}$	13.80	7.00	14.01	17.11	4.50	5.21	7.88	7.02	9.21	8.26	15.13	18.78
CV (%)	13.05	8.69	14.05	12.83	30.57	22.73	21.56	17.71	10.80	16.24	30.68	29.38

Table 4. Mean values for leaf: Stem ratio, yield and harvest index of tropical grass species evaluated in the Southern Guinea Savanna of Nigeria

Specie	Leaf: Stem ratio		DM yield of fodder (t/ha)		Grain yield (t/ha)	
	2015	2016	2015	2016	2015	2016
Andropogon gayanus	1:1.1	1:1.1	7.53	7.73	4.50	4.60
Brachiaria ruziziensis	1:1.4	1:1.4	4.87	5.00	3.67	3.73
Cenchrus ciliaris	1:1.0	1:1.1	6.01	6.13	1.87	1.90
Chloris gayana	1:1.1	1:1.1	4.18	4.27	3.53	3.63
Panicum maximum	1:1.5	1:1.6	6.87	6.97	1.47	1.47
Paspalum orbiculare	1:1.0	1:1.0	3.53	3.60	4.00	4.10
Sorghum almum	1:1.8	1:1.8	5.41	5.50	12.88	13.13
Mean			5.49±0.06	5.60±0.08	4.56±0.07	4.65±0.08
$LSD_{.05}$			0.51	0.54	0.46	0.42
CV (%)			26.06	26.16	84.07	84.41

Table 5. Correlation statistics of genotypic means for traits of tropical forage grass species evaluated in 2015 (above diagonal) and 2016 (below diagonal) within the Southern Guinea Savanna of Nigeria

TRAITS	DFF	D50F	PH4WAP	PH8WAP	PH12WAP	PH16WAP	FDMY	GY
DFF		$.93^{**}$	.39	.21	-.37	-.58	-.47	.15
D50F	.55		.12	.20	-.48	-.63	-.25	.00
PH4WAP	.52	.33		.48	.60	.35	-.19	.69
PH8WAP	.17	.17	.29		.57	.19	.30	.70
PH12WAP	.01	-.37	.25	.53		$.89^{**}$	.53	.51
PH16WAP	-.10	-.51	.14	.20	$.92^{**}$		.66	.14
FDMY	.03	-.10	-.35	.29	.67	.65		.11
GY	.20	-.01	.61	.72	.47	.15	-.11	

Keys: DFF = Days to first flowering; D50F = Days to 50% flowering; PH4WAP = plant height at 4 weeks after planting; PH8WAP = plant height at 8 weeks after planting; PH12WAP = plant height at 12 weeks after planting; PH16WAP = plant height at 16 weeks after planting; FDMY = fodder dry matter yield; GY = grain yield

The performance of the species evaluated in terms of leaf: stem ratio was almost the same in both years except for a little variation (Table 4). The leaf: stem ratio ranged from 1:1.8 for *S. almum* to 1:1 for *C. ciliaris* and *P. orbiculare* in 2015. While *S. almum* and *P. orbiculare* were consistent in maintaining the lowest (1:1.8) and the highest (1:1) leaf: stem ratio in both 2015 and 2016, *C. ciliaris* was inconsistent, recording a leaf: stem ratio of 1:1 and 1:1.1 in 2015 and 2016 respectively. All the other species (*A. gayanus*, *C. gayana, B. ruziziensis*) except *P. Maximum,* consistently maintained their leaf: stem ratio in both years.

Andropogon gayanus recorded the highest fodder dry matter yield of > 7.5 t/ha and was closely followed by *P. maximum. P. orbiculare* recorded the lowest fodder dry matter yield. Grain yield in *S.almum* was highest and about three times the yield of the next highest yielding specie (*A. gayanus*) while *P. maximum* recorded the lowest grain yield of 1.47t/ha in both years.

Highly significant positive correlation was observed between days to first flowering and 50% flowering (Table 5). Positive correlations were also observed between flowering and plant height up to 8WAP. Correlations between flowering and plant height (12WAP and 16WAP) and between flowering and dry matter yield of fodder were however negative. Correlations among all plant height traits were positive and highly significant between plant height at 12WAP and plant height at 16WAP. Correlations between dry matter yield of fodder and plant height at 12WAP and 16WAP were also positive.

Correlations between grain yield and all other traits were positive and highest between grain yield and plant height at 8WAP.

4. DISCUSSION

The variations observed for all the traits in the species evaluated could be attributed to genotypic differences in their growth habit while the generally better performance of the crops in 2016 could be attributed to the high rainfall recorded within the same period. The early flowering observed for *P. maximum* was consistent with the findings of Olubukola and Faluyi [2] who in their study of accessions of *P. maximum* observed early flowering. Early flowering is a desirable trait when producing seeds of forage species, as the grass species could be produced two to three times in a year. The implication of negative correlation between flowering and dry matter yield of fodder in the evaluated species is that early maturing tropical grass species could be selected for high dry matter yield in a breeding programme. For example, *P. maximum* flowered earlier than all the species but recorded the second highest dry matter yield of fodder in the current work. *B. ruziziensis,* on the other hand, flowered later than all species but was among the lowest dry matter yielding genotypes. The steady increase in height for all the tropical grass species evaluated was noted. In the current work, if *P. orbiculare* were to be planted in mixtures with *P. maximum*, the growth of *P. orbiculare* would be suppressed due to shading from P. maximum, which is a taller grass specie.

The significantly high correlation ($r = 0.89^{**}$ and 0.92^{**}) observed between plant height at 12 and 16 weeks after planting in both years, implied that fast tall growing grass species like *P. maximum* could be cut at 12 weeks and need not be delayed till 16 weeks after planting. This would enhance a reduction in the quantum of structural materials in the fodder, particularly lignin. The highest correlation between plant height and grain yield was observed at 4 weeks ($r = 0.69$) and 8 weeks ($r = 0.70$) after planting, implying that the taller the plant species at this stage of growth, the higher the probability for high grain yield. Identification and selection of tropical grass species for improvement in grain production should, therefore, be carried out between 4 and 8 weeks of growth.

The relatively high grain yield recorded for *S. almum* had been previously reported for *S. bicolor [*3], and could be attributed to plant density which is one of the determinants of grain yield. The lower the plant density per unit area, the higher the grain yield per plant.

Leaf: stem ratio is an important determinant of feed intake by grazing livestock. Species with higher leaf: stem ratios may improve feed intake under practical grazing conditions [4]. According to Mitchell [5], the leaf to stem ratio of grass plants caused increase in stems as they matured from the vegetative to reproductive stage. The highest leaf to stem ratio in leaves was recorded in *P. orbiculare*, *C. ciliaris* and *C. gayana* and this translated into higher herbage yield as observed previously [6].

Variations in the dry matter production of the evaluated species could be attributed to differences in their growth rate and growth habit. Dry matter productivity by all herbaceous plants holds the key to livestock productivity [7]. Grasses which yield the highest dry matter should be the most sought since they can supply the highest quantum of forage to livestock. In the current work, *A. gayanus* was superior to all the other species in terms of dry matter yield, followed by *P. maximum* and *C. ciliaris*. The low leaf to stem ratio at maturity observed in *P. maximum* may not justify its selection as a very good fodder crop. But since a lower leaf to stem ratio was encountered with increasing maturity, the harvesting of species with low leaf to stem ratio (*B. ruziziensis*, *P. maximum* and *S. almum*) should be carried out during the active vegetative phase when the growth rate of the plant is high. The value of the forage crop plant is nutritionally better with higher quality at this stage of its life cycle compared to the reproductive phase [8,9] when the percentage of structural materials (cellulose, hemicellulose and lignin) is very high. The highest rate of increase in height during the vegetative phase in all the grass species evaluated in the current work was observed between 4 and 8 WAP. This period also correlates best with grain yield, indicating that both selections for grain yield and herbage yield of the studied grass species should be within 4 – 8 WAP.

5. CONCLUSION

The seven tropical species evaluated in this research were genetically diverse and performed favourably well in terms of growth and yield, with positive response to increasing rainfall. They are therefore recommended for multi-location evaluation, before location specific recommendation within the Southern Guinea Savanna agro-ecologicalal zone of Nigeria.

Development stage of the grass directly affects quantity and quality of biomass produced and, when the plant is at its vegetative stage, the forage produced shows a better nutritional value in comparison to reproductive stage. In addition, during the transition process from one stage to the other, structural characteristics of the plant may change.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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