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RESEARCH ARTICLE

Effects of stage of growth on the forage yield, quality and nutrient uptake of three varieties of Sorghum (*Sorghum bicolor* L. Moench) in a humid zone of Edo State, Nigeria

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ABSTRACT

A field study was conducted to investigate the effects of stage of growth on the forage yield, mineral composition and nutrient uptake of three sorghum varieties. The three varieties of sorghum used were: Samsorg 16, 44 and 48 while the three stages of growth were: vegetative (6 WAP), flowering (12 WAP) and fruiting (16 WAP). Data were obtained on vegetative parameters, forage and dry matter yields. The mineral composition and nutrient uptake were also determined. The results showed that except for the number of tillersplant^{-1}, stage of growth significantly influenced the vegetative characters and yield of sorghum. Samsorg 16 at the fruiting stage had the highest forage (29.20 t ha^{-1}) and dry matter yields (14.85 t ha^{-1}). The macro-and micro-nutrients in the leaves of the crops were adequate except for Mn, Zn and Cu contents compared to the established critical levels for ruminant animal production. Samsorg 48 at fruiting and vegetative stages had the highest and least uptake of P, K, Mg, Ca and Na, respectively. However, considering the nutrient uptake, Samsorg 16 variety harvested at the fruiting stage is recommended as forage for livestock production and nutrition in this zone.

Keywords: Sorghum; Stage of growth; Variety; Forage yield; Ruminant animal

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INTRODUCTION

Sorghum is known to have originated from Ethiopia and is commonly called guinea corn in Africa's north-east region (Atokple, 2010). Sorghum is well adapted to hot climates with medium to low rainfall, performing best under light showers' conditions followed by bright sunshine during the growing periods (Rafia and Abrar, 2001). The crop is found in the region, which lies between latitudes 40˚N and 40˚S, and 1000 meters altitude above sea level (Remison, 2005). However, the optimum temperature for growth is 30˚C, with an average annual rainfall of 400-700 mm. The crop is adapted to a soil pH between 5 and 8.5 (Yousef et al., 2009). Sorghum is a short-day plant; cultivar varies in their sensitivity to photoperiods, and this character is controlled genetically. The crop can grow up to 1.5 to 6 m with single stems and produces tillers in some cultivars, which may be produced early or not until after flowering when grown as a ratoon crop (Remison, 2005).

It is the third widely cultivated cereal in Africa, accounting for about 20 % of the region's total cereal production (Yousef et al., 2009). Traditionally, sorghum is a crop mainly grown in the northern zone of Nigeria. Sorghum varieties for forages vary widely concerning agronomic characters. Forage sorghums are better harvested or grazed at about 15-31 cm in height (Msongaleli et al., 2017).

Stages of growth are the most critical factors influencing fodder's nutritional quality (Asghari et al., 2006; Ahiwale et al., 2011). As the fodder matures, the cell's cytoplasmic portion decreases the nutrients (Chaudhry et al., 2006; Atokple, 2010). Limited information is available on the effect of stage of growth on the yieldha^{-1} and nutrient availability of sorghum. Generally, forage sorghums' nutritive value is far more variable across varieties than that observed for grain sorghums (Atokple, 2010). Uzun et al. (2009) observed that dry matter content and yields increased as the crop advanced in age, with the highest dry matter content and yields being obtained at the hard dough growth stage. Ashrif et al. (1995) reported an increase in dry matter content of four sorghum varieties at different cutting heights. The differences in mineral composition and uptake may be attributed to the soil's nutrient status, stage of maturity, and other environmental factors (Nwajei et al., 2019). Choudhary et al. (2017) observed the highest uptake of macro-and micro-nutrients when sorghum was harvested 115 days after planting.

Ruminant livestock such as cattle, sheep and goat are traditionally raised on the farm grown fodders and crop residues in the study area. Green fresh fodders provide some adequate amount of protein, carbohydrates and minerals for these animals. The value of green forages depends upon the nutrient concentration in the forages and their intake by the animals. Forage crops used in the traditional farming system should be given greater concern, especially in Edo State, Nigeria's forest-savanna transition zone, as livestock population and ruminant herding have increased. Their increase and day to day search for forages have caused clashes between farmers and herdsmen, and if not managed by introducing these forage crops that are not traditionally grown here for the feeding of livestock and herdsmen, it may result in perpetual conflict (Omoregie, 2015). The low quality of the forages handicaps ruminant animal production. The available information on sorghum local cultivars' mineral composition is not available, especially the changes occurring with advancing growth. In filling this gap, the present study on the effects of stage of growth on the yield performance and mineral composition of sorghum in the forest-savanna transition zone was carried out.

MATERIALS AND METHODS

The seeds of three sorghum varieties namely Samsorg 16, Samsorg 44 and Samsorg 48 used.

The design used was a 3 x 3 factorial scheme, laid out in a RCB with three replicates. The treatments were three varieties of sorghum and three stages of growth to give nine treatment combinations. Before planting, the experimental site was cleared, debris removed, and the plot demarcated according to treatments. Planting was done on the 10th July 2019. A total of twenty-seven plots with twenty-five plants each were involved in giving a plant population of six hundred and seventy-five (675) plants, an equivalent to 66,667 plants ha^{-1}. The land area required was 9 x 13.50 m giving a total area of 121.50 m2 (0.01 ha). Manually controlled the weeds with hoe at 3 and 7 weeks after planting (WAP).

Growth and yield data were collected at the vegetative, blooming and fruiting stages of growth, including plant height (cm), leaf count (cm2), stem girth (cm), tiller count (cm), dry matter yield (cm2), and dry matter percent (dry matter yield/forage yield 100/1). The nutrient uptake was computed by multiplying nutrient content by dry matter and extrapolating to kg/ha. The AOAC defines crude protein content as the nitrogen content multiplied by 6.25.

RESULTS

Growth parameters

Plant height (cm)

The tallest plants were obtained at the fruiting stage, while those at the vegetative stage had the least (Table 1). The varieties planted did not significantly influence the plant height of sorghum. The stages of growth and variety x stage of growth interactions affected the height of sorghum significantly. Samsorg 16 had the highest plant height while Samsorg 44 had the least. Samsorg 48 at fruiting and vegetative stages of growth had the highest and least plant height values of 261.00 cm and 21.90 cm, respectively.

Number of leaves plant^{-1}

Plant^{-1} had a considerable impact on the amount of leaves it produced depending on its stage of development (Table 1). The number of leaves plant-1 of sorghum was not affected by the varieties sown. Samsorg 16 and Samsorg 44 had the most and least leaves plant^{-1}, respectively. Sorghum had the maximum and lowest number of leaves plant-1 at the fruiting and vegetative stages of growth, respectively. Variety and stage of growth had a significant interaction on the number of leaves plant-1 of sorghum. Samsorg 16 had the most leaves plant-1 (16.17) in the fruiting stage, whereas Samsorg 44 had the least in the vegetative stage (7.33).

Total leaf area (cm^2 plant^{-1})

The stage of growth, and variety × stage of growth interaction significantly affected the total leaf area produced per sorghum plant (Table 1). The highest (41,834.00 cm2) and least (2285.00 cm2) total leaf areaplant^{-1} were obtained in Samsorg 16 at fruiting and Samsorg 48 at vegetative stages of growth. Crops at fruiting and vegetative stages of growth had the highest and least total leaf areaplant^{-1}. Samsorg 48 had a higher total leaf area plant^{-1} than other sorghum varieties, although they were not significantly different.

Stem girth (cm)

The stem girth of the three sorghum varieties increased with time from vegetative (6WAP) to fruiting stage (16WAP). The growth stage had a significant on the girth of the three sorghum varieties. The impact of variety on the stem girth of the sorghum plants was not significant. There was significant ($P \leq 0.05$) variety × stage of growth interaction on the stem girth of the three varieties of sorghum, with Samsorg 16 at fruiting stage having the biggest (2.22 cm) while Samsorg 48 at vegetative stage having the least (0.87 cm) (Table 1). Samsorg 16 had the biggest stem girth while Samsorg 48 had the least. The stem girth at fruiting and flowering stages of the crops was approximately 2 cm while those at vegetative was 1cm.

The number of tillers plant^{-1}generally increased from vegetative to fruiting growth stage across varieties (Table 1). The number of tillers plant^{-1} of sorghum was not significantly affected by varieties planted. There was no consistency with the variety × stage of growth interaction on the number of tillers plant^{-1} of sorghum. Generally, the crops at different stages of growth had similar number of tillers plant^{-1}, approximately 2. Samsorg 16 and Samsorg 48 at flowering stages of growth had the highest and the least values of 2.08 and 1.42, respectively.

Table 1. Effects of stage of growth on the vegetative traits of three varieties of sorghum

Variety	Stage of growth (WAP)	Plant height (cm)	Number of leaves plant-1	Total leaf area plant-1 (cm2)	Stem girth (cm)	Number of tillers plant-1,
Samsorg16	Vegetative (6)	27.20d	7.92e	6010.00de	1.31de	1.33ns
	Flowering (12)	133.30b	11.00cd	13371.00de	1.95ab	2.08
	Fruiting (16)	252.00a	16.17a	41834.00a	2.22a	2.00
	Mean	137.50	11.69	20405.00	1.82	1.81
Samsorg44	Vegetative (6)	27.50d	7.33e	4660.00e	1.21ef	1.83
	Flowering (12)	61.60c	9.67de	16399.00cd	1.77bc	1.83
	Fruiting (16)	138.80b	15.75ab	30647.00b	2.10ab	2.00
	Mean	75.90	10.92	17235.00	1.69	1.89
Samsorg48	Vegetative (6)	21.90d	7.42e	2285.05e	0.87f	1.75
	Flowering (12)	124.70b	12.25cd	25282.00bc	1.57cd	1.42
	Fruiting (16)	261.00a	13.25bc	36075.00ab	1.71bd	2.00
	Mean	135.90	10.97	21214.00	1.38	1.72
	SL					
	V	ns	ns	ns	ns	ns
	S	*	*	*	*	ns
	Interaction (VxS)	*	*	*	*	ns

Table 2. Effects of stage of growth on the forage and total dry matter yields and dry matter % of three varieties of sorghum

Variety	Stage of growth (WAP)	Forage yield (t ha-1)	Total dry matter yield(t ha-1)	Dry matter (%)
Samsorg16	Vegetative (6)	1.20c	0.49b	40.83ac
	Flowering (12)	24.80ab	5.57b	22.46bc
	Fruiting (16)	29.20a	14.85a	50.86ab
	Mean	18.40	6.97	38.05
Samsorg44	Vegetative (6)	3.00c	0.44b	14.67c
	Flowering (12)	10.00bc	3.66b	36.60ac
	Fruiting (16)	16.90ac	7.92ab	46.86ab
	Mean	9.97	4.01	32.71
Samsorg48	Vegetative (6)	1.10c	0.16b	14.55c
	Flowering (12)	13.80ac	5.42b	39.28ac
	Fruiting (16)	22.50ab	13.47a	59.87a
	Mean	12.47	6.35	37.90
	SL			
	V	ns	ns	ns
	S	*	*	*
	Interaction (VxS)	*	*	*

Table 3. Effects of stage of growth on the mineral composition of three varieties of sorghum

Variety	Stage of growth (WAP)	CP	N	P	K	Ca	Mg	Na	Fe	Mn	Zn	Cu
		←			%			→	←	mgkg-1		→
Samsorg 16	Vegetative (6)	23.06	3.69	0.32	2.00	0.22	0.14	0.06	115.00	4.06	71.00	4.24
	Flowering (12)	21.06	3.37	0.33	1.48	0.27	0.11	0.11	98.00	2.08	62.00	1.13
	Fruiting (16)	18.94	3.03	0.25	1.32	0.18	0.11	0.10	97.00	2.01	55.00	0.97
	Mean	21.02	3.36	0.30	1.60	0.22	0.12	0.09	103.33	2.72	62.67	2.11
Samsorg 44	Vegetative (6)	23.25	3.72	0.31	1.46	0.26	0.12	0.10	111.00	4.00	65.00	2.51
	Flowering (12)	27.75	3.84	0.33	1.62	0.28	0.15	0.18	110.00	3.10	76.00	1.54
	Fruiting (16)	23.50	3.76	0.28	1.22	0.17	0.11	0.15	97.00	2.00	39.00	0.68
	Mean	24.83	3.77	0.31	1.43	0.24	0.13	0.14	106.00	3.03	60.00	1.58
Samsorg 48	Vegetative (6)	21.00	3.36	0.25	1.55	0.25	0.13	0.11	110.00	3.08	58.00	2.47
	Flowering (12)	15.38	2.46	0.33	1.41	0.21	0.12	0.11	86.00	2.11	50.00	1.33

	Fruiting (16)	13.88	2.22	0.29	1.38	0.20	0.11	0.12	85.00	2.11	44.00	0.54
	Mean	16.75	2.68	0.29	1.45	0.22	0.12	0.11	93.67	2.43	50.67	1.45

Table 4. Effects of stage of growth on the nutrient uptake of three varieties of sorghum

Variety	Stage of growth/(WAP)	N	P	K	Ca	Mg	Na	Fe	Mn	Zn	Cu
		←					Kg ha^{-1}				→
Samsorg 16	Vegetative (6)	1780.00^{c}	154.00^{b}	965.00^{b}	106.00^{b}	68.00^{b}	29.00^{c}	5.60^{c}	0.19^{d}	3.40^{c}	0.20^{b}
	Flowering (12)	3783.00^{c}	1837.00^{ab}	8239.00^{b}	1503.00^{ab}	612.00^{ab}	612.00^{bc}	54.60^{bc}	1.16^{bd}	34.50^{bc}	0.63^{b}
	Fruiting (16)	45046.00^{a}	3717.00^{a}	2676.00^{b}	2676.00^{b}	1635.0^{a}	1487.00^{ab}	144.20^{a}	2.99^{a}	81.80^{a}	1.44^{a}
	Mean	16870.0	1903.00	3960.00	1428.00	772.00	709.00	68.00	144	39.90	0.76
Samsorg 44	Vegetative (6)	1641.00^{c}	137.00^{b}	644.00^{b}	80.00^{b}	53.00^{b}	44.00^{c}	4.90^{c}	0.18^{d}	2.90^{c}	0.11^{b}
	Flowering (12 WAP)	15984.00^{bc}	1188.00^{b}	5832.00^{b}	1008.00^{b}	540.00^{ab}	648.00^{ac}	29.60^{bc}	1.11^{cd}	27.40^{bc}	0.55^{b}
	Fruiting (16)	29788.00^{ab}	2218.00^{ab}	9665.00^{ab}	1347.00^{ab}	871.00^{ab}	1188.00^{ab}	76.80^{ac}	1.47^{ad}	30.90^{bc}	0.53^{b}
	Mean	15804.00	1181.00	5380.00	812.00	488.00	627.00	40.00	0.92	20.40	0.40
Samsorg 48	Vegetative (6)	546.00^{c}	41.00^{b}	252.00^{b}	41.00^{b}	954.00^{ab}	18.00^{c}	1.80^{c}	0.05^{d}	0.90^{c}	0.04^{b}
	Flowering (12)	1352.00^{bc}	1791.00^{ab}	7653.00^{b}	651.00^{b}	651.00^{ab}	597.00^{bc}	46.70^{bc}	1.14^{cd}	27.10^{bc}	0.72^{b}
	Fruiting (16)	29908.0^{ab}	3908.00^{a}	18592.00^{a}	2694.00^{a}	1482.00^{a}	1617.00^{a}	114.50^{ab}	2.83^{ac}	59.40^{ab}	0.73^{b}
	Mean	14602.00	1913.00	8832.00	1129.00	1029.00	744.00	54.00	1.34	29.20	0.50
	SL										
	V	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
	S	×	×	×	×	×	×	×	×	×	×
	Interaction										
	V × S	×	×	×	×	×	×	×	×	×	×

Yield parameters

Forage yield

Crops harvested at the fruiting stage had the highest forage yield, while those at the vegetative stage had the least across the three varieties of sorghum. It was also observed that Samsorg 16 produced the highest forage yield with a mean of 42.70 tha^{-1}, while Samsorg 44 had the least (34.80 tha^{-1}). The highest (29.20 tha^{-1}) and least (1.10 t ha^{-1}) forage yields were obtained in Samsorg 16 at fruiting and Samsorg 48 at vegetative growth stages.

The total dry matter yields significantly varied from 0.49-14.35, 0.44-7.92 and 0.16-13.47 t ha^{-1} in Samsorg 16, 44 and 48 varieties. However, Samsorg 16 had the highest dry matter yield while Samsorg 44 had the least with mean values of 7.00 and 4.00 t ha^{-1}. Samsorg 16 harvested at fruiting and Samsorg 48 at vegetative stage, significantly, had the highest and least dry matter yield values of 14.35 and 0.16 t ha^{-1}, respectively.

Dry matter (%)

The results showed that crops cut at the fruiting stage significantly recorded the highest dry matter % while those at the vegetative stage had the least. The means ranged from 22.46-41.83 % in Samsorg 16, 14.67-46.86% in Samsorg 44 and 14.55-59.87 % in Samsorg 48. Although Samsorg 16 had the highest dry matter %, it was however not significantly different from the other varieties studied. Samsorg 48 harvested at fruiting and vegetative stages of growth had the highest and least dry matter % values of 59.87 and 14.55 %.

Mineral composition

The mineral composition, micro-and macro-nutrients, in the crops' leaves were adequate except in Na, Mn, Zn, and Cu compared to the established critical levels for ruminant animal production (Table 3). Samsorg 44 at the flowering stage had higher contents of N, P, Ca, Mg, Na and Zn than the other varieties at the other stages of growth. The Ca content in the leaves of the investigated plants was low at fruiting stage and marginal at the other stages of growth.

Nutrient uptake

The stage of growth significantly affected the uptake of both the micro-and macro-nutrients (Table 4). Samsorg 16 at the fruiting stage of growth had the highest uptake of N, Fe, Mn, Zn and Cu, while Samsorg

48 at the vegetative stage of growth had the least. Samsorg 48 at fruiting and vegetative stages of growth had the highest and least P, K, Mg, Ca, and Na uptake, respectively.

DISCUSSION

Stages of growth significantly influenced the vegetative characters of the three varieties of sorghum studied. Plant height generally increased with age and peaked at the fruiting stage (16WAP). Pahuja et al. (2014) reported a significant difference in plant height among sorghum varieties. The considerable effect of the stage of growth on the number of leaves plant^{-1} resulted from the transition from vegetative to flowering and then to fruiting stages of growth, resulting in more leaves.

The total leaf area of a plant is essential in determining the total accumulated photosynthetic materials necessary for crop growth and development (Nwajei et al., 2019). The significant differences in the total leaf area obtained among the sorghum varieties may be attributed to the leaf growth at different development stages. Samsorg 16 at flowering and vegetative stages of growth had the highest and least number of tillers plant^{-1}. In this study, it was observed that the varieties with fewer tillers gave higher forage and dry matter yields. Asghari et al. (2006) reported low yield in varieties with a higher number of tillers plant^{-1} as noted in this study. Uzun et al. (2009) in another study, observed, that number of tillers produced by the crop had no significant influence on forage and dry matter yield which agreed with the results of this present study.

The observed significant higher stem girth in the crops at flowering and fruiting stages was due to adequate food reserve accumulated during the plant growth. This may reduce the crops susceptibility and enhance resistance to lodging conditions. Yousef et al. (2009) and Nwajei et al. (2019) reported that crops with bigger girths could show resistance to factors responsible for lodging in sorghum and millet. Growth is a measure of vegetative parameters or attributes (Atokple, 2010; Nwajei and Omoregie, 2017). The results obtained from this study showed that plant height, number of leaves plant^{-1}, stem girth and total leaf areaplant^{-1}, were significantly higher in crops harvested at the fruiting stage of growth due to increased accumulation of dry matter and the development of parts which eventually transit to forage yield and quality. This result conforms with the results of Atokple (2010), Krishna (2010) and Pahuja et al. (2014), who stated that higher vegetative characters in sorghum resulted in higher forage and dry matter production.

Forage yield obtained from the crops increased from vegetative to fruiting stages of growth. The significantly higher dry matter production at flowering and fruiting stages of growth over the early vegetative stage indicates that more photosynthetic materials and digestible contents were highly accumulated at flowering and fruiting growth stages. The results agreed with those of Pahuja et al. (2014) and Ghosh et al. (2015), who reported significant higher dry matter production at the fruiting stage of growth.

Nitrogen (N) content was higher at the vegetative stage compared to the fruiting stage of growth. The highest concentration was obtained during flowering and declined at fruiting during early grain formation. N values were higher when compared to P and K. This was because N is mobile and more easily absorbed from the soil than P and K. The micro-and macro-nutrients in the leaves of the crops were adequate except for Mn, Zn and Cu contents when compared to the established critical levels for ruminant animal production. The result is in agreement with Choudhary et al. (2017) report, who observed that plants quickly absorb N than other macro-nutrients.

Nutrient uptake is directly related to the nutrient absorbed by the plant and the dry matter yield. It was observed that the variety and stage of growth with the highest dry matter yield had the highest nutrient uptake. Parihar et al. (2009), Mishra et al. (2015) and Kumarv et al. (2017) observed similar results with those of this study and attributed the higher nutrient uptake to higher dry matter yield.

CONCLUSION

Samsorg 16 variety performed best in growth and yield attributes. Therefore, it is a good source of forage for livestock production. When it is harvested at the flowering stage of growth, produced adequate mineral contents with good quality for ruminant animal nutrition in this zone.

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