YIELD AND PROFITABILITY OF SWEET SORGHUM (*Sorghum bicolor* (L) Moench cv. *saccharatum*) VARIETIES AS INFLUENCED BY VARYING NPK RATES IN NORTHERN GUINEA AGROECOLOGICAL ZONE OF NIGERIA

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ABSTRACT

Field trials were conducted to determine the response of sweet sorghum varieties to varying NPK fertilizer rates during 2018 rainy season at the Research Farm of Institute for Agricultural Research (IAR) Ahmadu Bello University, Samaru and the Research Farm of College of Agriculture and Animal Science, Division of Agricultural Colleges (DAC) Mando, both located in the Northern Guinea Savannah ecological zone of Nigeria. The treatments consisted of four NPK fertilizer rates (0:0:0, 30:15:15, 60:30:30, and 90:45:45) and three sweet sorghum varieties (NTJ-2, SW-Bungudu and SW-Daura) which were laid out in a Randomized Complete Block Design (RCBD) replicated three times. Results indicated that NPK rates significantly increased the yield and the agronomic traits studied. The highest significant yields were recorded with the application of 90:45:45 kg NPK ha^{-1} followed by 60:30:30 kg NPK ha^{-1}. The varieties significantly differed in all the parameters studied at both locations. The highest grain yield (1.4 t ha^{-1} and 1.39 t ha^{-1}) and stalk yield (20.21 t ha^{-1} and 18.48 t ha^{-1}) at both locations were obtained in varieties NJT-2 and SW-Bungudu, respectively. Significant interaction exists between NPK rate and variety on stalk and grain yields. Economic analysis of gross yields (Stalk + Grain) revealed that application of NPK fertilizer as low as 30:15:15 kg ha-^{1} to all the three varieties was viable as no loss was incurred but variety SW-Bungudu with the application of 90:45:45 kg NPK ha^{-1} was the most profitable sweet sorghum production at both locations. Thus, farmers in the Guinea savanna will get better returns on the money invested using such combination.

Keywords: Sweet sorghum; NTJ-2, SW-Bungudu; SW-Daura; NPK; yield; profitability.

INTRODUCTION

Sweet sorghum (*Sorghum bicolor* (L) Moench cv. *saccharatum*) is an annual multi-purpose crop which can be cultivated for simultaneous production of grain and stalk. The grain has high nutritional content, its ear-head is used as food and feed ingredients and sugary juice from the stalk used for making sweetener, syrup, jiggery and bio-fuel (Nahar, 2011). It is drought and salinity tolerant (Vasilakoglou *et al.*, 2011) with a short life cycle of about 4 months and is adapted to a C_4 carbon assimilation pathway mechanism. It is an ideal dedicated crop that can be put to commercial production with positive production economics under marginal conditions with promising returns (Redai *et al.*, 2018). It fits into the ecosystem with minimal negative environmental consequences (Mathur *et al.*, 2017). In Nigeria, sweet sorghum is well adapted to soils of the savannah which are inherently poor in nutrients especially the macronutrients; N, P and K (Shehu *et al.*, 2005). Despite the importance of the crop in meeting farmers' demands for food, feed and fodder, the productivity is limited by low soil fertility which in turn reduces the return on investment

The crop's productivity is greatly influenced by genotypes' response to fertilizer application (Redai *et al.*, 2018). Satpal *et al.* (2015) reported economic superiority and stability with increased level of fertilization in five sorghum genotypes where the application of 125% recommended dose of fertilizer (RDF) was the most profitable. Similarly, Mishra *et al.* (2015) reported that increasing levels of fertility up to 150% RDF significantly increased the net returns and Benefit: Cost (B:C) ratio (1.79) as compared to control. (0.6). Therefore, this experiment was carried out to evaluate sweet sorghum varieties responses to applied NPK fertilizer rates as well as the economic viability in the Northern Guinea Savanna of Nigeria.

MATERIALS AND METHODS

Field trials were conducted during 2018 rainy season at the Research Farms of Institute for Agricultural Research (IAR) Ahmadu Bello University, Samaru (Lat. 11°11'N, Long. 7°38'E at 686 m above sea level), and College of Agriculture and Animal Science, Division of Agricultural Colleges (DAC) Mando (Lat. 10°43'N, Long. 6°34'E at 508 m above sea level), both located in the Northern Guinea Savanna. Soil samples were randomly collected from nine (9) locations on the field within each of the experimental site at 0-30cm depth using hand-held soil auger and composite soil sample was taken after bulking. The composite sample was air dried, sieved through 2mm sieve and subjected to laboratory analysis according to Walkley-Black procedures at the Department of Agronomy, Ahmadu Bello University Zaria. Mean soil analysis values are presented in Table 1.

The treatments consisted of three sweet sorghum varieties (NTJ-2, SW-Daura and SW-Bungudu) and four levels of NPK (0:0:0, 30:15:15, 60:30:30 and 90:45:45 kg ha^{-1}) which were factorial combined and laid out in a Randomized Complete Block Design (RCBD) with three replications. Sowing was done manually at the rate of 5 seeds per hole, using the specified 25 cm intra and 75 cm inter row spacing respectively and emerged seedlings were later thinned to three (3) plants per stand at two weeks after sowing (WAS). NPK fertilizer was applied to the plots based on the treatment. The first half dose of nitrogen (N) and all of phosphorus (P) and potassium (K) were applied at 2 WAS using a compound fertilizer grade of NPK (15:15:15) while the remaining half of N was applied at 6 WAS using Urea (46% N). Weeds were controlled using atrazine at 0.5 kg ha^{-1} as pre-emergence herbicide followed by two hand-weeding at 3 and 6 weeks after sowing (WAS).

Ten (10) plants from the net plot were cut at the base at physiological maturity for estimating stalk (without sheath, leaves, and panicle) yields per plot. Panicles were sun dried, threshed and winnowed in the air to remove chaff and clean grains obtained were weighed as the grain yield per plot. Both yields were recorded in g $plot^{-1}$ and extrapolated to tonne per hectare. The data collected were subjected to statistical analysis of variance (ANOVA) using SAS software (Version 9.2) to test treatment effects for significance. The differences between treatments means were compared using Duncan Multiple Range Test (DMRT). Economics of different treatments were worked out in terms of cost of cultivation and gross monetary return. Data for the cost of production of the three varieties and existing market prices of fresh stalk and grain yields were analysed. The gross margin approach as described by Rahman and Lawal (2003) was used and the net return on investment was estimated as follow:

$$GM = GR - TC$$

$$B:C\ ratio = \frac{GR}{TC}$$

Where; GM= Gross margin, B:C= Benefit: Cost, GR= Gross Revenue; and TC= total cost.

$$TC = TFC + TVC$$

Where; TFC= total fixed cost and TVC= total variable cost.

RESULTS

Soil Physical and Chemical Properties

The chemical properties of the experimental sites at 0-30 cm depth are shown in Table 1. The results showed that soil at Samaru site had a loam texture, acidic (5.47) and moderate in available phosphorus (12.58 mg kg^{-1}) content while the soil at Mando is clay loam, moderately acidic (5.67) and also moderate in available phosphorus (11.5 mg kg^{-1}) content. The percentage of organic carbon was low (1.02 and 1.50) at both location and total nitrogen was lower at Samaru (0.92) and high at Mando (2.01). The exchangeable bases Mg and Na were slightly high at both locations while Ca and K were low at Samaru and high at Mando respectively. The cation exchange capacity was also low at both sites.

Table 1: Physical and Chemical Properties of Soils at the Experimental Sites during the 2018 Rainy Season

Parameters	Values	
	Samaru	Mando
Textural class	Loam	Clay loam
Chemical composition		
pH in H_2O (1:2.5)	5.47	5.67
pH in 0.01M $CaCl_2$ (1:2.5)	4.35	4.71
Organic Carbon (g kg^{-1})	1.02	1.50
Total Nitrogen (g kg^{-1})	0.92	2.01
Available Phosphorus (mg kg^{-1})	12.58	11.5
Exchangeable cations (cmol kg^{-1})		
Calcium (Ca^{2+})	1.98	2.25
Magnesium (Mg^{2+})	0.32	0.41
Potassium (K^{+})	0.12	0.16
Sodium (Na^{+})	0.20	0.18
Aluminium and Hydrogen (Al^{3+} + H^{+})	0.28	0.24
Cation Exchange Capacity (C.E.C)	2.90	3.24

Analysed at the Department of Agronomy, Ahmadu Bello University Zaria.

Stalk Yield (t ha^{-1})

Sorghum stalk yields across all the NPK rates were significantly different and increased with increasing NPK fertilizer rate from 0:0:0 - 90:45:45 kg ha^{-1} at the trial locations (Samaru and Mando) (Table 2). Variety SW-Bungudu was superior ($p \leq 0.05$) in stalk yield than the other varieties at both locations. However, at Mando, variety SW-Daura recorded comparable stalk yield to SW-Bungudu. The interaction of NPK fertilizer rates and sweet sorghum varieties on stalk yield was significant ($p \leq 0.05$) at Samaru (Table 3). Variety SW-Bungudu produced the highest stalk yield with 90:45:45 kg ha^{-1} NPK. Also, SW-Bungudu with or without fertilizer recorded the highest stalk yield.

Grain Yield (t ha^{-1})

Grain yield of sweet sorghum varieties was influenced by NPK fertilizer rates (Table 2). Each increase in NPK fertilizer rate from 0:0:0 to 90:45:45 kg ha^{-1} resulted in significant ($p \leq 0.05$) increase in total grain yield of sweet sorghum at both locations. NTJ-2 significantly ($p \leq 0.05$) outperformed all other varieties at both locations and it was followed by SW-Daura. SW-Bungudu recorded the significantly lowest grain yield at both locations. The interaction between NPK fertilizer rates and sweet sorghum varieties on grain yield was significant ($p \leq 0.05$) at both locations (Table 4 and 5). The three (3) varieties evaluated produced statistically similar grain yield when 30:15:15 kg ha^{-1} NPK fertilizer rate was applied. However, when 60:30:30 and 90:45:45 kg ha^{-1} NPK rates were applied, NTJ-2 significantly ($p \leq 0.05$) outperformed the other two varieties recording the highest grain yield with 90:45:45 kg ha^{-1}.

Economics of Production

Data on economic parameters are presented in Table 6 and 7. Cost of cultivation was the same for all treatments with the same fertilizer rate and increased with increase in NPK fertilizer rate from 0:0:0 to 90:45:45 kg ha^{-1}. Gross and net revenues increased with increase in NPK rate up to the highest dosage. The highest significant return on grain yield was recorded by variety NTJ-2 while SW-Bungudu had highest return on stalk yield. SW-Daura closely followed both varieties in their respective yields and returns.

Table 2: Stalk and Grain Yield (t ha^{-1}) of sweet sorghum varieties as influenced by NPK fertilizer rates during 2018 rainy season at Samaru and Mando

	Stalk Yield (t ha^{-1})		**Grain Yield (t ha^{-1})**	
Treatment	**Samaru**	**Mando**	**Samaru**	**Mando**
NPK (kg ha^{-1})				
0:0:0	2.76d	3.06d	0.32d	0.35d
30:15:15	9.31c	10.08c	0.80c	0.89c
60:30:30	25.83b	26.94b	1.57b	1.66b
90:45:45	29.27a	33.27a	2.12a	2.24a
SE±	0.273	0.913	0.027	0.029
Significance	**	**	**	**
Variety(V)				
NTJ – 2	15.09c	16.64b	1.39a	1.47a
SW-Bungudu	18.48a	20.21a	0.96c	1.09c
SW-Daura	16.80b	18.15ab	1.26b	1.32b
SE±	0.236	0.806	0.023	0.025
Significance	**	**	**	**
Interaction				
NPK x V	*	NS	**	**

Means followed by the same letter(s) within a treatment column are not significantly different using Duncan Multiple Range Test at 5% level of probability.
NS=Not significant. * =Significant. ** =Highly significant.

Table 3: Interaction between NPK fertilizer rates and sweet sorghum varieties on stalk yield (t ha^{-1}) at Samaru

Treatment	NTJ-2	SW-Bungudu	SW-Daura
NPK(kg ha^{-1})			
0:0:0	1.98j	3.62i	2.67ij
30:15:15	7.39h	11.36f	9.16g
60:30:30	24.49e	27.34c	25.67de
90:45:45	26.51cd	31.61a	29.69b
SE±		0.473	

Means followed by the same letter(s) within a set of treatment column are not significantly different using Duncan Multiple Range Test at 5% level of probability.

Table 4: Interaction between NPK fertilizer rates and sweet sorghum varieties on grain yield (t ha^{-1}) at Samaru

Treatment	NTJ-2	SW-Bungudu	SW-Daura
NPK (kg ha^{-1})			
0:0:0	0.33i	0.31i	0.34i
30:15:15	0.84f	0.73f	0.82f
60:30:30	1.91c	1.13e	1.68d
90:45:45	2.48a	1.68d	2.21b
SE±	0.047		

Means followed by the same letter(s) within a set of treatment column are not significantly different using Duncan Multiple Range Test at 5% level of probability.

Table 5: Interaction between NPK fertilizer rates and sweet sorghum varieties on grain yield (t ha^{-1}) at Mando

Treatment	NTJ-2	SW-Bungudu	SW-Daura
NPK (kg ha^{-1})			
0:0:0	0.36g	0.34g	0.36g
30:15:15	0.96f	0.81f	0.93f
60:30:30	1.98c	1.22e	1.80d
90:45:45	2.57a	1.97c	2.19b
SE±	0.050		

Means followed by the same letter(s) within a set of treatment column are not significantly different using Duncan Multiple Range Test at 5% level of probability.

Table 6: Gross margin analysis of production of sweet sorghum varieties with different NPK fertilizer rates at Samaru

Treatments		Yields (t h^{-1})		Revenue (₦ ha^{-1})		Gross Return(₦ha^{-1})	Costs (₦ha^{-1})		Total Cost(TC)(₦ha^{-1})	Gross Margin(₦ha^{-1})	B:C Ratio
NPK (Kgha^{-1})	Variety	Grain	Stalk	Grain	Stalk	(GR)	Total Fixed	Total Variable	(TFC + TVC)	(GR – TC)	
0:0:0	NTJ-2	0.346	1.98	18452	19800	39212	5500	124418	129918	-90706	0.302
	SW-Bungudu	0.326	3.62	17385	36200	54545	5500	124418	129918	-75373	0.420
	SW-Daura	0.348	2.67	18558	26700	45739	5500	124418	129918	-84179	0.352
30:15:15	NTJ-2	0.847	7.39	67760	105850	187330	7800	166302	174102	13228	1.076
	SW-Bungudu	0.772	11.36	61760	170400	253200	7800	166302	174102	61098	1.454
	SW-Daura	0.873	9.16	69840	137400	211240	7800	166302	174102	37138	1.213
60:30:30	NTJ-2	1.940	24.49	194000	734700	932200	13000	179410	192410	739790	4.845
	SW-Bungudu	1.177	27.34	117700	820200	942100	13000	179410	192410	749690	4.896
	SW-Daura	1.739	25.67	173900	770100	950000	13000	179410	192410	757590	4.937
90:45:45	NTJ-2	2.523	26.51	256700	795300	1052000	14500	204162	218662	833340	4.811
	SW-Bungudu	1.826	31.34	182600	940200	1137300	14500	204162	218662	918638	5.201
	SW-Daura	2.197	29.69	219700	890700	1109400	14500	204162	218662	890739	5.07

USD (1$) =NGN (₦362)

Table 7: Gross margin Analysis on production of Sweet sorghum varieties with different NPK fertilizer rates at Division of A gricultural Colleges Mando

Treatments		Yields (t h⁻¹)		Revenue (₦)		Gross Return(₦)	Costs (₦)		Total Cost(TC)(₦)	Gross Margin(₦)	B:C
NPK (Kgha⁻¹)	Variety	Grain	Stalk	Grain	Stalk	(GR)	Total Fixed	Total Variable	(TFC + TVC)	(GR – TC)	Ratio
0:0:0	NTJ-2	0.364	2.30	19412	23000	60900	5500	124418	129918	-87506	0.469
	SW-Bungudu	0.344	4.20	18345	42000	76600	5500	124418	129918	-69573	0.590
	SW-Daura	0.357	2.80	19039	28000	66900	5500	124418	129918	-82879	0.515
30:15:15	NTJ-2	0.956	8.40	76480	126000	252900	7800	166302	174102	28378	1.453
	SW-Bungudu	0.81	12.40	64800	186000	301200	7800	166302	174102	76698	1.730
	SW-Daura	0.923	9.50	72840	142500	273150	7800	166302	174102	42238	1.569
60:30:30	NTJ-2	1.975	25.50	197500	765000	1094500	13000	179410	192410	770090	5.688
	SW-Bungudu	1.219	28.70	121900	861000	1060190	13000	179410	192410	790490	5.510
	SW-Daura	1.799	26.70	179900	801000	1095730	13000	179410	192410	788490	5.694
90:45:45	NTJ-2	2.567	30.50	25600	915000	1344210	14500	204162	218660	953040	6.147
	SW-Bungudu	1.971	35.60	197100	1068000	1378720	14500	204162	218662	1046438	6.305
	SW-Daura	2.187	33.70	218700	1011000	1384190	14500	204162	218662	1011038	6.330

USD (1$)=NGN (₦362)

DISCUSSION

Effect of NPK on Stalk and Grain yield

The significant increase in stalk and grain yields of sweet sorghum with increase in NPK fertilizer input could be attributed to the combined effects of N, P and K in higher dry matter production, efficient transformation of solar energy into chemical energy that could increase carbohydrate content and transportation of sink assimilate by influencing electron transport in the transport chain of the crop and hence the increased growth and grain production of (Prajapati *et al.,* 2012; Leghari *et al.,* 2018 and Malhotra *et al,*. 2018). This is in conformity with the report of Redai *et al.* (2018), who observed that application of inorganic fertilizers resulted in higher net assimilation rate and increased yield and its components. Similarly, Wadsworth (2002) reported that increased dry matter production with increased fertilizer application was due to the role of N in optimizing the use efficiency of solar radiation thereby increasing biomass production. Nutrient deficiency reduces the photosynthetic efficiency of plants and this could account for the overall poor performance of unfertilized plants (0:0:0 kg ha^{-1}) in this study.

The significant difference between the stalk and grain yield of the varieties could be attributed to genetic make-up of the varieties and impact of genotypes interaction with the environment. Similar differences among sweet sorghum varieties and cultivars have been reported by Perazzo *et al.* (2013), Mekdad and El-sherif (2016), and Rono *et al.* (2014). The significantly higher stalk yield obtained in SW-Bungudu variety may be attributed to higher juice volume, higher plant height and nodes. This suggests its suitability for syrup production. NTJ-2 on the other hand is an improved variety bred for grain rather than syrup; this reflected in the significantly higher grain yield obtained in this variety despite the initial slow growth.

Profitability

Profitability increased with increasing Gross Return (GR) and Net Return (NR). The increase in profitability with increasing rate of NPK fertilizer application was due to significant response of sweet sorghum to NPK fertilizer which increased the crop economic yields. SW-Bungudu was the most economically viable variety with the highest net return for production. Similar results regarding the effect of levels of NPK on cost of cultivation, GMR, NMR, B:C ratio were also recorded by Mishra *et al.* (2015), Satpal *et al.* (2015).

CONCLUSION

The results obtained from this study showed that the application of NPK fertilizer enhanced the yield and profitability of sweet sorghum compared to the control. Application of 90:45:45 kg NPK ha^{-1} resulted in the best yield and profitability response. Variety NTJ-2 had the highest grain yield while SW-Bungudu had the highest stalk yield. Application of fertilizer as low as 30:15:15kg ha^{-1} would result in reasonable profitability in the areas of study as no loss was incurred unlike when no fertilizer was applied. Application of 90:45:45 kg NPK ha^{-1} to variety SW-Bungudu was the most profitable and as such recommended for adoption by farmers in the study area.

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