GROWTH AND PRODUCTIVITY OF SWEET SORGHUM (*Sorghum bicolor* (L) Moench cv. *Saccharatum)* VARIETIES AS INFLUENCED BY VARYING NPK RATES IN NORTHERN GUINEA SAVANNA OF NIGERIA

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A DISSERTATION SUBMITTED TO SCHOOL OF POSTGRADUATE STUDIES, AHMADU BELLO UNIVERSITY, ZARIA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF SCIENCE IN AGRONOMY

DEPARTMENT OF AGRONOMY,
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DECLARATION

I hereby declare that the work in this dissertation titled `` Growth and Productivity of Sweet sorghum (*Sorghum bicolor* (L) Moench cv. *Saccharatum*) Varieties as influenced by varying NPK rates in Northern Guinea Savanna of Nigeria`` was performed by me in the Department of Agronomy, under the supervision of Prof. A. B. LAWAL and Prof D. B. ISHAYA. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this dissertation has been presented to the best of my knowledge for award of degree or diploma at any institution.

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MUHAMMAD, Aminu Nuhu
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Prof. A. B. Lawal
(Chairman, Supervisory Committee)

CERTIFICATION

This dissertation entitled ``GROWTH AND PRODUCTIVITY OF SWEET SORGHUM (*SORGHUM BICOLOR* (L) MOENCH CV. *SACCHARATUM*) VARIETIES AS INFLUENCED BY VARYING NPK RATES IN NORTHERN GUINEA SAVANNA OF NIGERIA`` by MUHAMMAD AMINU NUHU meets the regulations governing the award of the degree of Master in Agronomy in the Department of Agronomy, Faculty of Agriculture, Ahmadu Bello University, Zaria and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

I dedicate this work to my parents, Alhaji Nuhu and Hajiya Ramatu Nuhu for their enormous support and guidance.

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ABSTRACT

Field trials were conducted to study 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) and replicated three times. Results indicated that NPK rates had significant effects on growth and yield components such as plant height, number of leaves per plant, shoot dry weight, number of tillers per plant, brix yield, panicle length, number of grains per panicle, 1000-grain weight and stalk yield. The highest significant yields (Stalk, Brix and Grain) were recorded with the application of 90:45:45 kg NPK ha^{-1} followed by 60:30:30 kg NPK ha^{-1}. Varieties significantly differed in all growth and yield components except for NAR, RGR, and brix yield (%). SW-Bungudu was the tallest variety (159cm and 167cm) and NTJ-2 was the shortest (145.71 and 153.34cm) at both locations. The highest grain yield (1.47 and 1.39 t ha^{-1}) and stalk yield (20.21 and 18.48 t ha^{-1}) at both locations were recorded by varieties NTJ-2 and SW-Bungudu, respectively. Significant interaction was observed on number of grains per panicle, 1000-grain weight and grain yield where the interaction of NPK rate and variety gave highest values for these characters. Correlation matrix showed positive and highly significant relationship between all yield and growth characters except days to 50% heading at both locations. The application of 90:45:45 kg ha^{-1} NPK fertilizer to variety SW-Bungudu was the most profitable sweet sorghum production at both locations.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Classification, Origin and Distribution

Sorghum (*Sorghum bicolor* (L) Moench cv. *Saccharatum)* is generally classified under the family Poaceae, tribe Andropogonaeae, subtribe *Sorghinae* and genus *Sorghum bicolor* (Clayton and Renvoize 1986; Mathur *et al*. 2017).

Although it is difficult to determine exactly when movements of sorghum to different regions occurred, these can be inferred from known trade routes and trading relationships. Improved Sorghum types were probably transported from north-eastern Africa to other parts of Africa and India (around 1500 - 1000 BC), through trade routes and human movements. It is believed that sorghum was taken from Africa to the Middle East (900 - 700 BC) and eventually into the Far East (AD 400) through shipping and trade routes (Dillion *et al*., 2007; Winchell *et al,*. 2018). In China, the crop was adapted to temperate conditions and varieties known as Kaoliangs were developed that are suited to cooler early season temperatures (Diao, 2017). Sorghum was first transported to America in the late 1800s during the slave trade (Doggett 1988; Dillion *et al*., 2007).

Though, a native to Eastern Africa, sweet sorghum has spread to other African regions, Southern Asia, Europe, Australia and the United States. Despite its tropical origin, sweet sorghum is well adapted to arid, semi-arid and temperate climates as well. The distribution of this genus, sorghum, is therefore believed to be worldwide (Wyman, 2005).

1.2 Botany

Sorghum bicolor spp. bicolor consist of all the cultivated sorghum and is described as annual, with stout culms up to 5m tall, often branched, and frequently tillering (Dogget 1988). Sweet sorghum is grown as annual crop that forms tillers, has an erect stature and can grow up to a height of 5m. The stem is hardened but the centre is usually spongy with juice and the lowest nodes form roots with the tall varieties characterized by roots above the lowest node. This ensures a good support structure for the plant, e.g. against strong winds, thereby reducing lodging incidence. There are growth rings that usually form at each node, which differentiate when needed, for example, when the plant has been floored by strong winds, an upright position may be regained through these growth rings each node also possesses a single bud that can either develop into tillers or branches (Doggett, 1988). After harvesting the stalks, most varieties will re-grow or produce ratoon. The ability to form a ratoon enables multiple harvests per season in certain environments although yields typically decrease in ratoon crops while sugar content in the juice increases with maturity, and becomes low prior to seed development (Vernerris *et al.*, 2007).

Sweet sorghum like other species of sorghum form tillers; this is variety dependent. Some varieties tiller early while others tiller post flowering. Temperature and photoperiod also play a role in tiller formation with the lowest less than 18^{o}C temperature promoting formation of tillers while short photoperiods do not. These tillers enable certain varieties to survive for a number of years (Duncan *et al.,* 1984). Sweet sorghum cultivation and practices are simple and readily adoptable (Almodares *et al.,* 1997b).

1.3 Climatic and Soil Requirements

Sorghum is adapted to C_4 carbon assimilation pathway mechanism and it is also highly water efficient (Spenceley *et al*., 2005; ICRISAT, 2015). It requires a warm, summer growing period of 4 - 5 months. A temperature of 27 - 30°C is required for optimum growth and development (Downes, 1972; FAO, 2015). Day time temperatures can be as low as 21°C and as high as 36°C without a dramatic effect on growth and yield of the crop as long as night time temperatures are low (19°C). Night time temperature affects sorghum development, with high night temperatures of around 31°C reducing the grain yield (Downes, 1972). Night time temperatures of 13°C or below can severely reduce grain production and frost can kill the plant. Seed set is also highly susceptible to cold temperature. Constant low temperatures throughout the plant’s life cycle delay flowering (Tiryaki and Andrews, 2001), induce male sterility (Downes and Marshall, 1971) and result in scarcity or a total lack of seeds in panicles (Brooking, 1979).

Day length required is 10-14 hours and relative humidity between 15% and 50%. Rainfall of 450 - 800mm per annum is sufficient for sweet sorghum production (FAO, 2015). Sorghum grows on a wide range of soils from light loams to heavy clays, but it thrives in light sandy soils (Kimber, 2000). It also tolerates a range of soil acidity from pH of 5.0 to 8.5 and has a moderate tolerance to salinity (Doggett, 1988; Kimber, 2000; Cothren *et al.,* 2000).

1.4 Production trend of Sorghum

Statistics drawn from the Food and Agriculture Organization of the United Nations (FAOSTAT, 2018 ranked the USA as the world's leading producer of Sorghum (*Sorghum bicolor spp*) with a production total of 12.2 million tonnes from approximately 2.4 million hectares of land having a yield of 4891 kg ha^{-1}. Nigeria ranks the top sorghum producing country in Africa and the 2nd largest in the world. FAOSTAT data estimates the average production of sorghum in Nigeria to be 6.9 million tonnes from 5.8million hectares of land with yield of 1193 kg ha^{-1}.

1.5 Importance of Sweet Sorghum

The crop is a multi-purpose crop which can be cultivated for simultaneous production of grain, with high nutritional content, from its ear-head as food and feed ingredients and sugary juice from the stalk used for making sweetener, syrup, jiggery and bio-fuel. In Nigeria, sorghum consumption is normally in the form of gruel, porridge, tuwo or cake. Some forms, particularly those with dark-coloured bitter grain, are used for fermenting to beer and other alcoholic beverages. Grain and crop residue also serve as poultry and cattle-feed. The stems are macerated in water and are bound together to make a sort of mat; leaf-sheaths are similarly used. Such large mats are used for covering doorways. The culms are used to make improvised beehives for taking swarming bees. As a source of paper-pulp, the product is moderately strong, but short-fibred, which could be used as filler with longer-fibred pulps. The stems contain a relatively high amount of sugar which offers possibility for production syrup. Ubiquitously the stems are chewed like sugarcane and serve as fuel and the ash is used as manure. Cultivated sweet sorghum is grown chiefly for its sweet stem and grain. In addition to the stem sugars and grains, co-products in the form of bagasse, vinasse, steam, foam, and froth are also utilized as raw material for range of purposes (Fig. 1) (Mathur *et al.*, 2017). In African traditional medicine, the seed extracts are drunk to treat hepatitis, and decoctions of twigs with lemon against jaundice; leaves and panicles are included in pant mixtures for decoctions against anaemia.

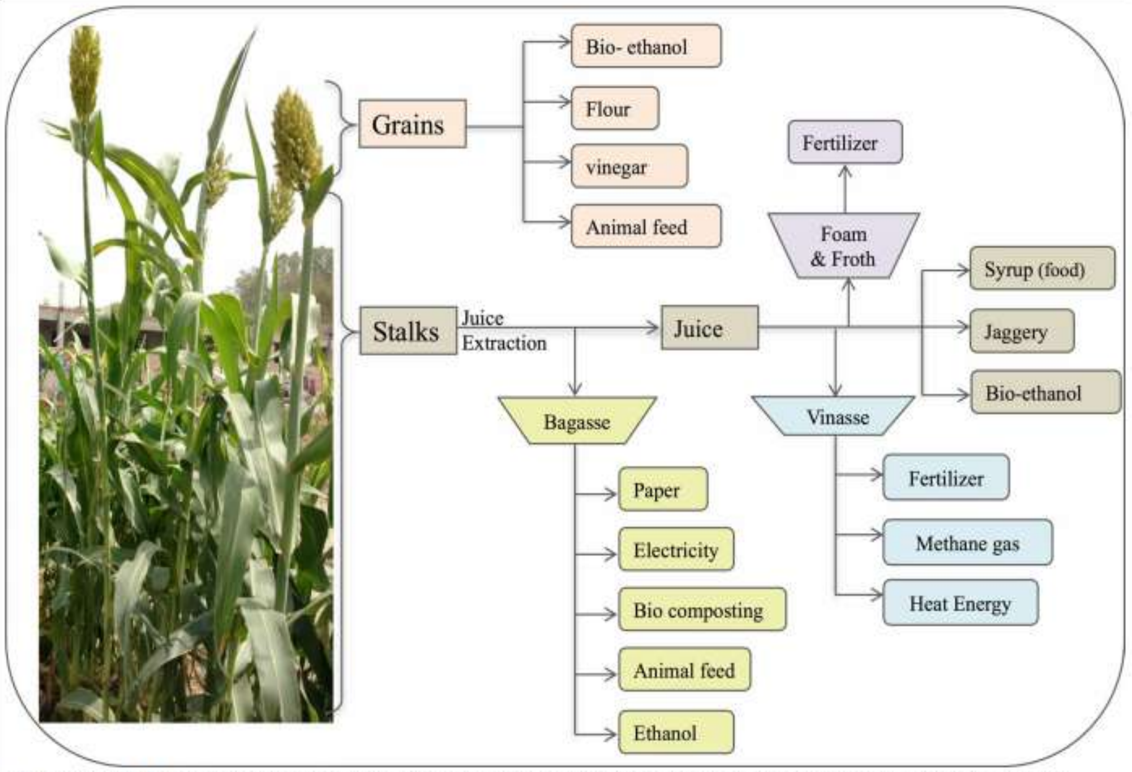

Fig. 1 Sweet sorghum as a multipurpose crop. The various uses of sweet sorghum juice, grains, and other byproducts have been illustrated

1.6 Justification

An ideal crop that can be put to commercial production with positive production economics under marginal conditions, and fits into the ecosystem with minimal negative environmental consequences is Sweet Sorghum (Mathur *et al.,* 2017). It is a crop that is increasingly utilized globally, as a sustainable and renewable source of energy (bio-fuel) which does not only fulfills the energy needs but also mitigates the adverse impact of fuel extraction on the environment. In Nigeria, sweet sorghum is mainly complementarily utilized in meeting farmers' demands for food, feed and fodder with low production output in the Savanna.

As a crop with multiple applications in meeting man's demand for food, feed and fuel coupled with its adaptation to drier environments as against other cereals, its importance cannot be over emphasized in Nigeria. This multifarious crop will need to be appropriately fertilized to produce optimally for commercial and domestic uses, but it is a well known fact that the soils of the savannah, to which the crop is adapted, are inherently poor in nutrients, especially the macro nutrients N, P and K which are usually sourced from both organic and inorganic fertilizers sources. However, the level of nutrients present in bulk of organic fertilizer are often held in complex organic chemical structures; this means organic fertilizer needs to be mineralized over time, a process which leads to delayed and inconsistent nutrient supply. This experiment seek to evaluate the crop responses to applied nutrients (NPK) from inorganic sources since nutrients from these inorganic fertilizers are made available to the plants immediately in standardized ratios from a small quantity of the inorganic fertilizer. Furthermore, as stated in previous literatures, there is trade-off between grain and stalk sugar yields in sweet sorghum, some produce more grains than juice, some produce more juice than grain while some are known to do well in respect of both. Three varieties of the crop were evaluated in this trial for response to treatments and environment in respect of their growth and yield.

The experiment was therefore conceived with the following objectives:

1. To evaluate the growth and yield characteristics responses of three varieties of sweet sorghum to varying NPK fertilizer rates with the aim of determining the most suitable rate
2. To estimate the production economics of the three varieties with a view to determining the most productive and economically viable variety.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Effects of Environmental Factors on Growth and Yield of Sweet Sorghum

Reddy and Reddi (2010) reported that, though genetic factors are mostly responsible to improve the productivity of crops but environmental factors, which consist of different weather components, soil characteristics and management practices, also play a vital role in increasing the productivity of crops. One of the most important management factors that directly influence crops performance is balanced nutrient management and it accounts for 50% effect on crop growth and yield patterns. Despite the wider adaptability of sweet sorghum to different environments, marginal change in temperature and rainfall intensity easily affects the plant at vulnerable stages. Abdulhamid *et al*. (2011) studied the influence of weather factors on yield of sorghum and reported that at pre-sowing stage, the total rainfall was found to be significantly and positively correlated with yield at 5% significant level. Relative humidity at flowering stage also showed significant and positive correlation at 1% significant level with the final yield. At total growing season, seasonality of rainfall was significantly and positively correlated with the final yield at 5% significant level. Multiple regression analysis shows that these three elements (total rainfall, relative humidity and seasonality index) accounted for 76.7% of the variation of Sweet Sorghum yield.

2.2 Growth and Yield Responses of Sweet Sorghum to NPK Fertilizer Application

All vital processes in plants are associated with protein, of which nitrogen (N) is an essential constituent. Optimum rate of N increases photosynthetic processes, leaf area production, leaf area duration as well as net assimilatory rate (Leghari *et al*., 2016). Next to N, phosphorus (P) is a vital nutrient for plant growth and productivity. It plays an important role in an array of cellular processes, including maintenance of membrane structure, synthesis of bimolecules and formation of high energy molecules. It also stimulates seed germination, development of roots, stalks and stems strength; flower and seed formation (Malhotra *et al.*, 2018). It is involved in many enzymatic reaction, CO_2 fixation, sugar metabolism, energy storage and transfer. Judicious use of phosphorus will help in increasing per hectare yield (Demkin and Ageev, 1990). Potassium is known for its role in sucrose translocation and accumulation in storage tissues of plants. Potassium (k) plays many important regulatory roles in development and it is required for numerous plant growth processes such as photosynthesis, transport of water, nutrients and sugars (Prajapati, 2012).

With sole applications of NPK, Abbas and Sayyed Hassan (2016) in Iran, and Olugbemi and Ababyomi (2016) in Nigeria, demonstrated that nitrogen significantly enhanced both growth and yield of sweet sorghum and therefore recommended the application of 150kg ha^{-1} and 120 kg N ha^{-1} for optimum performance of sweet sorghum grown in their respective areas of study. Issa-Piri (2012) reported that application of phosphorus fertilizer with micro nutrient foliar application had significant effect on plant height. From the study, it was concluded that the P is as important as N for better plant performance. Valdabadi and Farahani (2012) from Iran reported that application of nitrogen fertilizer significantly affected the total dry weight (TDW), leaf area index (LAI), relative growth rate (RGR) and crop growth rate (CGR) of maize crop. The highest total dry weight (TDW) (1910 gm^{-2}), LAI (4.2), RGR (0.08 gg^{-1}day^{-1}) and CGR (31.2 gg^{-1}m^{2}day^{1}) were obtained with application of 520kg urea ha^{-1}. The crop growth rate increased significantly with increase in fertilizer levels up to 125 percent of recommended dose of fertilizer at all the intervals. The maximum relative growth rate (RGR) in sorghum was recorded at 21-40 days and then decreased up to harvest. In sorghum at 21-40 days, RGR increased significantly with increase in fertilizer levels up to 125% recommended dose of fertilizer. Mansab *et al.* (2003), and Goma (2011) independently reported that LAI, RGR and NAR were only significantly affect by N application at later growth stages; Olubgemi and Ababyomi (2016) observed that increasing N rate from 60 to 120 Kg Nha^{-1} increased LAI, CGR and NAR while RGR was not significantly affected. The obtained results ensured the importance of N in stimulating and enhancing the photosynthetic and metabolic activities of plants which reflected on the metabolic activities of the plant and consequently the increase in the vegetative growth of sweet sorghum.

Abou-Amer and Kewan (2014) observed that in multi-cut fodder sorghum, maximum fodder yields were 16.98, 14.05 and 8.40 ton per acre by applying 120 kg N and 40kg P_2O_5 acre^{-1}, followed by 16.51, 13.46 and 8.03 ton acre^{-1} by N-P applied at the rate of 120 kg N and 30kg P_2O_5 acre^{-1} in the first, second and third cuttings, respectively. They attributed it to increasing availability of soil nutrients with the increased in N-P fertilizer rate and positive effect of N-P elements on the production of fodder crops. The maximum dry matter values were 2.68, 2.35 and 1.32 tonne acre^{-1} by applying the highest rates of N-P which was followed by 2.60, 2.26 and 1.21 tonne acre^{-1} compared to having NP at the lowest rates in the first, second and third cuttings, respectively. Almoderes *et al.* (2006) reported that the application of urea with 50 kg potassium sulfate ha^{-1} increased ($p<0.05$) stem fresh weight (24.33%), total fresh weight (25.44%), total sugar (10.50%), and juice extract (9%) at physiological maturity. They also noted that the application of N significantly increased leaf area (LA), leaf dry weight (LDW), stem dry weight (SDW), total dry weight (TDW), panicle dry weight and panicle height. K increased TDW and panicle dry weight. The highest growth parameters, carbohydrate contents and juice extract were obtained with the application of 180 kg urea ha^{-1} and 50 kg potassium sulfateha^{-1} using cultivar (cv) Keller. Almodares *et al*, (2008) also recorded highest values for stem height, stem diameter, stem fresh weight (SFW) , total dry weight (TDW) and total fresh weight (TFW) with the application of 180 kg urea ha-1 and 50 kg potassium sulphate ha^{-1}, whereas each unit increase in amount of each N or K fertilizers didn’t increase TDW. SFW and TFW had positive relation with amount of potassium fertilizer.

However, the study of Tanchev (1995) indicated that combination of NPK fertilizers showed better results on the growth, height, tillering, panicle weight and 1000-grain weight of sorghum than single applications. Khan *et al*. (2005) also studied the effects of different combinations of N, P and K fertilizers on sugarcane and found the best growth and yield of crop with combined application of NPK. In view of this, Durgesh and Chaplot (2015) observed that the crop fertilized with 80 kg N, 40 kg P_2O_5 and 40 kg K_2O ha^{-1} recorded significantly higher green and dry fodder yields on the basis of total of three cuts over control. The magnitudes of increases were 67.1, 39.9 and 12.5% in green fodder, and 64.6, 32.5 and 9.3% in dry fodder yield, respectively.

The field experiment carried by Redai *et al.* (2018) on the effect of NPK and blended fertilizers on yield and yield components of sorghum varieties during the 2016 cropping season in North-Western Ethiopia indicated phonological parameters, yield and yield components such as that number of leaves, plant height, days to 50% heading, panicle length, grain weight and 1000-grain weight were significantly affected by the main effects of variety and fertilizer and the interaction of the two factors. They also reported that the highest biomass yield was obtained with NPK application by Melkam variety (21087 kg ha^{-1}) and recommended NPK over other fertilizer blends.

Muhammad *et al*. (2018) reported from their study on the effect of poultry manure based compost and NPK fertilizer on the growth and yield of sorghum in Bauchi (Nigeria) that plant height, number of leaves and leaf area were affected by various levels of NPK. Among the three NPK levels (0, 30 and 60) observed, the application of 60 kg ha^{-1} was found to be better than all other rates. They also observed that panicle length, 1000-grain and grain yield were significantly ($p \leq 0.05$) affected by NPK rates and best results were also obtained with application of 60 kg h^{-1}.

2.3 Varietal Responses of Sweet Sorghum to Inorganic Fertilizer and Environment

Mishra *et al*. (2014) assessed the relative performance of advance open pollinated varieties (OPVs) for biomass, juice yield, quality traits, grain and bio-ethanol yields, under different fertility levels and locations. The performance of two advance OPVs (SPV 2074 and SPV 2075) was compared with check variety CSV 19SS and hybrid CSH 22SS under four fertility levels (80:40:40; 60:30:30, 40:20:20 kg N: P_2O_5: K_2O ha^{-1} and control) at Indore (Madhya Pradesh), Pantnagar (Uttarakhand) and Palem (Andhra Pradesh). They observed that plant height increased significantly ($P \leq 0.05$) with increasing fertility levels. Test genotype SPV 2075 had the tallest plant (290 cm). Application of 80:40:40 kg NPK ha^{-1} reduced the number of days required for 50 % flowering by 3 days as compared to control. Test genotypes flowered 3 days earlier than the check CSV 19SS. Application of 80:40:40 kg NPK ha^{-1} increased grain yield by 153 % over control and the test variety CSV 2074 produced 108 % higher grain yield than the check CSV 19SS. Fresh stalk yield, juice and potential ethanol yields were also increased. SPV 2074 and SPV 2075 produced higher juice yields as compared to check CSV 19SS. Juice yield was significantly ($P \leq 0.01$) and positively correlated with plant height (r = 0.667**) and fresh stalk yield (r = 0.721**). Ravella *et al*. (2016) conducted a field experiment on a North Carolina Piedmont soil to evaluate the production of sweet sorghum as a feedstock for bio-ethanol. Two varieties of sweet sorghum (Dale and M81-E) and four fertilizer treatments (T1: 0, T2: 168-56-168, T3: 84-28-84-soysoap, T4: 168-56-168-Soysoap, of N-P_2O_5-K_2O kg ha^{-1}). All the varieties of sweet sorghum studied produced significantly higher yields of tops fresh weight and stalk fresh weight from all fertilizer treatments (T2, T3 & T4) than the control (T1). Quantity of juice extracted from stalks was significantly higher for all fertilized treatments compared with the control, but was not affected by variety. No significant difference was observed in total sugar levels in all fertilized treatments and the brix (%) were statistically similar in both fertilized and unfertilized treatments.

Perrazo *et al.* (2014) evaluated the agronomic characteristics of 32 sorghum cultivars (*Sorghum bicolor* (L). Moench) in the Brazilian semi-arid region. The cultivars were cluster debased on their characteristics and five groups were hierarchically setup. Groups 3, 4 and 5 showed high potential for dry matter production, especially group 5 indicating the presence of evident variation among cultivars which allows for a selection of more productive and, thus, more suitable cultivars for silage production in the semi-arid regions. Rono *et al.* (2016) observed eight sweet sorghum genotypes at five different locations in two growing seasons of 2014 with the aim of determining the interaction between genotype and environment on cane, juice, and ethanol yield and to identify best genotypes for bio-ethanol production in Kenya. The combined analysis of variance of cane and juice yield of sorghum genotypes showed that sweet sorghum genotypes were significantly affected by environments, genotypes, and genotype by environment interaction.

2.4 Production Economics of Sweet sorghum as Influenced by Fertilization

Mishra *et al.* (2015) studied the economics of production of sorghum cultivars in response to three (3) fertility levels, viz., control (0:0:0 kg ha^{-1} of N: P_2O_5: K_2O), recommended dose of fertilizer (RDF) (80:40:40 kg ha^{-1} of N: P_2O_5: K_2O) and 150% of RDF (120:60:60 kg ha^{-1} of N: P_2O_5: K_2O). Results of which revealed that increasing levels of fertility up to 150% RDF significantly increased the net returns (25.97×103 ha^{-1}) and Benefit : Cost (B:C) ratio (1.79) as compared to control. Similarly, Satpal *et al.* (2015) noticed increase in gross return, net return and B:C in five sorghum genotypes with increasing fertility level, where the application of 125% RDF was the most profitable.

Economic superiority and stability within a price variability range of 20% were observed with increased level of N-P fertilization (i.e., 40:0 and 40:17.2 kg ha^{-1}) in the report of Buah *et al.* (2012). In corroboration, the results of the works of Meena *et al.* (2012) on effect of nitrogen levels on yield and quality of sorghum (*Sorghum bicolor* (L.) Moench) genotypes indicated 23.57, 9.10 and13.93, 4.80 per cent increase in net return and B:C ratio over 49 and 80 kg Nha^{-1} and the findings of Sawargaonkar *et al*. (2013) indicated higher economic returns and benefit cost ratio with the application of 90 kg N ha^{-1}, however, further increase in N level up to 120 and 150 kg ha^{-1} did not reflect proportionate increase in economic benefits. Application of 90 kg N ha^{-1} had 50, 35 and 18% increase in net returns compared to 0, 30 and 60 kg N ha^{-1}, respectively.

Durgesh and Chaplot (2015) compared control fertility level with 50 and 75 percent RDF, the results revealed that the crop under the influence of 100 percent RDF fetched highest net returns of Rs. 59445 ha^{-1} and B:C ratio of 2.93 registering significant increase of Rs. 28310, 20980 and 7838 ha^{-1} in net returns and 1.08, 0.86 and 0.28 in B:C ratio, respectively. Somashekar *et al.* (2015) observed among different nitrogen levels that significantly higher gross returns (Rs. 59987 ha^{-1}) and net returns (Rs. 32550 ha^{-1}) were obtained with 60 kg N ha^{-1} which was at par with application of 30 kg Nha^{-1} for each cut (Rs.57350 ha^{-1} and 31285ha^{-1}, respectively). However, significantly higher B:C ratio was obtained with 30 kg N ha-1 for each cut (2.20).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Experimental Site

Field trials were conducted during 2018 rainy season at the research farms of Institute for Agricultural Research (IAR) Ahmadu Bello University, Samaru (11^{o}11’N, 7^{o}38’E and 686m above sea level), and College of Agriculture and Animal Science, Division of Agricultural Colleges (DAC) Mando (10^{o}43’N, 6^{o}34’E and 508m above sea level), both located in the Northern Guinea Savannah ecological zone of Nigeria.

3.2 Meteorological Data

The record of rainfall, maximum and minimum temperatures, relative humidity and sunshine hours during the period of the trial were obtained from the meteorological stations of Institute for Agricultural Research (IAR) Samaru and National Water Resource Institute, Mando Kaduna.

3.3 Treatments and Experimental Design

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}). The treatments were factorially combined and laid out in a Randomized Complete Block Design (RCBD) with three replications.

3.4 Test Crop

The test crop used in the study was sweet sorghum comprising of three varieties which were obtained from sorghum breeding unit of Plant Science Department, Ahmadu Bello University Zaria and they are:

NTJ-2: Is a high yielding variety that flowers in 65 to 70 days and matures in 80 – 90 days. It grows to a height of 1.5 to 2.0m. Stem are thick and juicy with about 18.5% sugars. The variety produces mill-able cane yield of up to 50 t ha^{-1}, and gives a grain yield between 2.0 to 3.6 t ha^{-1} with bold creamy white grains. The variety is resistant to leaf diseases such as leaf rust (caused by *Puccinia purpurea*), Anthracnose, leaf blight and stalk rot (caused by *Colletotrichum graminicola*).

SW-Bungudu: Flowers in 70-75 days and matures in 85 to 105 days with an average juice content of 15% sugar. It grows to a height of 2.0- 2.5m with an average grain yield between 1.9 – 2.3 t ha^{-1} and millable cane yield of 37.5-50 t ha^{-1}.

SW-Daura: Flowers in 65-75 days, matures in 85-90 days and grows to a height of 2.0-2.5m. Stems are juicy with about 18% sugar content, produces millable cane yield of 43t $ha^{-1}$and grain yield of 2.0-2.5 t ha^{-1}.

3.5 Soil Sampling

Soil samples were randomly collected from nine (9) locations 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. Particle size distribution was determined using the hydrometer method with Calgon as a dispersing agent and the soil textural class was determined (Okalebo *et al.*, 1993). The soil pH in1:1 soil: water ratio and 1:2 soil : 0.01 $CaCl_2$ was detremied using electrometric method (Okalebo *et al.*, 1993). Organic carbon was determined by Black's wet oxidation method. Total nitrogen was determined by macro kjedahl's oxidation method involving digestion and distillation (Jackson, 1967). The readily acid-soluble forms of phosphorus as extracted with hydrochloric acid and ammpnium fluoride mixture called Bray No. 2 and phosphorus in the extract was determined by colorimetric procedure as described by Okalebo *et al.* (1993). Exchangeable were extracted with an excess ammonium acetate solution, potassium, sodium were determined using flame photometer while magnesium and calcium by atomic absorption spectrophotometer (Sparks, 1996).

3.6 Cultural Practices

3.6.1 Land preparation

The experimental site was harrowed twice to fine tilth and ridged 75cm apart using tractor at the onset of 2018 rainy season. The land was marked into plots and replications. Each plot consisted of 6 ridges of 5m length and 75cm apart (22.5m^2) with a pathway of 1.0m. The net plot was 15m^2 consisting of 4-inner ridges.

3.6.2 Seed treatment and sowing

The seeds of the three varieties (NTJ-2, Sw-Bungudu and SW-Daura) were treated with apron star (metalaxyl + carboxyl + methylthiram) at the rate of 10g of the chemical to 3kg of the seed before sowing. Sowing was done manually at the rate of 5 seeds per hole, using the specified 25cm intra row spacing and emerged seedlings were later thinned to three (3) plants per stand at two weeks after sowing (WAS). This gave a plant density of 160,000 plants per hectare.

3.6.3 Fertilizer application

NPK fertilizer was applied to the plots on treatment basis. The first half dose of nitrogen (N) and all of phosphorus (P) and potassium (K) were applied at 2WAS using a compound fertilizer grade of NPK (15:15:15) while the remaining half of N was applied at 6WAS using Urea (46%N) in accordance with the treatments. Application was by side placement at about 5cm away from the base of the plant.

3.6.4 Weed control

Glyphosate (4*l*/ha) was used to control emerged weeds on the experimental plots two weeks prior to land preparation. Thereafter, hoe weeding was done at 3, 6 and 9 weeks after sowing to keep the plots weed-free throughout the period of the trial.

3.6.5 Crop protection

Carbofuran 3G at 2.2 a.i kg ha^{-1} was applied at sowing to prevent attack from shoot fly and stem borers and birds' scarer was employed to prevent seeds/seedling removal by birds. There were no pest and disease incidence during the course of the trial.

3.6.6 Harvesting

Harvesting was carried out when the seeds were in the soft dough stage for stalk and brix yield. The stalk was cut as close as possible to the ground using cutlasses. The grains were harvested by cutting the panicle stalk. Panicles were sun dried, threshed and winnowed in the air to remove chaff and clean grains obtained.

3.7 Observations and Data Collection

Five plants were tagged within each plot at 3, 6, 9, and 12 weeks after sowing (WAS) using conspicuously colored wool tied loosely around plants ear-marked for the periodic evaluation of crop's growth, these were used to monitor the following growth parameters on per plants basis.

3.7.1 Number of leaves per plant

The number of leaves of the 5 tagged plants per plot at 3, 6, 9 and 12 WAS were counted and the mean was determined for each plot and recorded as the number of leaves per plant.

3.7.2 Plant height (cm)

The plant heights of the 5 tagged plants in each net plot were measured from the base of the culms to the tip of flag leaf and also panicle at reproductive stage using meter rule at 3, 6, 9 and 12WAS. The mean heights were recorded at each of the sampling dates.

3.7.3 Number of tillers per plant

Number of tillers from the 5 tagged plants in each net plot was counted and the average tillers per plant were recorded for each plot at 12 WAS.

3.7.4 Shoot dry matter (g)

Three plants were evaluated for the shoot dry matter production, these were carefully taken from the border rows/discard and carefully separated into leaves, shoots, enveloped and labeled appropriately at 3,6,9 and 12 WAS. The sampled plants were oven dried at 70^{o}C to a constant weight and weighed using Mettler balance (Toledo 16001). The mean shoot dry weight per plant was recorded.

3.7.5 Leaf area index (LAI)

LAI is the ratio of leaf surface area per unit of land surface per plant. This was recorded using Ceptometer (L-P80) at 3, 6, 9 and 12 WAS.

3.7.6 Crop growth rate (CGR)

CGR was determined to assess the rate of dry matter accumulation per unit area of land per unit time. It was estimated at 3, 6, 9 and 12 WAS as described by Radford, (1967); thus;

$$CGR = \frac{W_2 - W_1}{T_2 - T_1} \, (\text{g m}^{-2} \text{wk}^{-1})$$

Where W_2 and W_1 are dry weight in plant at time T_2 and T_1 in weeks, respectively

3.7.7 Relative growth rate (RGR)

This is the increase in plant materials per unit of plant materials present per unit of time. This was estimated as described by Radford (1967) thus;

$$RGR = \frac{Log_e W_2 - Log_e W_1}{T_2 - T_1} \quad (\text{g g}^{-1}\,\text{wk}^{-1})$$

Where W_2 and W_1 are dry weight in g plant^{-1} at time T_2 and T_1 in weeks respectively and $\log_e$ represents natural logarithm.

3.7.8 Net assimilation rate (NAR)

This expresses the photosynthetic efficiency of the assimilatory surface. The leaf area was recorded using L1-3100C area meter and the NAR was estimated as described by Watson (1958);

$$NAR = \frac{(W_2 - W_1)}{(T_2 - T_1)} \times \frac{Log_e A_2 - Log_e A_1}{A_2}$$

Where W_1 and W_2 are dry weight of samples in g plant^{-1}, A_2 and A_1 are the leaf area and t_2 and t_1 represent the time interval

3.7.9 Days to 50% heading

This was determined by recording the number of days from the date of sowing to the time when 50% of the plants in each net plot headed and it was expressed in days.

3.7.10 Stalk yield (t ha^{-1})

The fresh stalk weights (without leaves and panicle) after harvest of five plants per net plot were taken using Mettler balance (16001) and after harvest and thereafter expressed the average expressed in t ha^{-1} by exploration (multiplying by 10^{-6}).

3.7.11 Brix yield (%)

Brix yield was determined using a hand-held refractormeter (Master-53T) which estimated the sugar content of sap, thereafter the refractormeter was taken to the laboratory where the polarity of the sugar was determined using polarimeter and expressed in percentage.

3.7.12 Panicle length (cm)

The length of panicles from five tagged plants on each net plot were measured using meter rule from base to the tip of panicle and the average length was recorded.

3.7.13 Number of grains per panicle

The panicles from the 5 tagged plants per net plot were harvested at maturity, threshed and winnowed to obtain clean grain, thereafter the number of grains per panicle were counted and the average number of grain per panicle was recorded.

3.7.14 1000-grain weight (g)

1000-grain weight was determined by weighing three sets each of 1000 grains obtained from threshed, winnowed harvested panicle from each net plot and averaged out and recorded using a Mettler balance (Toledo 16001).

3.7.15 Grain yield (t ha^{-1})

Harvested sweet sorghum ears were further air dried, threshed and cleaned. Weight of the grains was recorded using Mettler balance (Toledo 16001) on the basis of grain yield per net plot. Grain yield per hectare was worked out and expressed in tons per hectare.

3.8 Partial Economic Analysis of Yield

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 Adegeye and Dittoh (1985), Rahman and Lawal (2003) was used and the net return on investment was estimated.

$GM = GR - TC$

Where; GM= Gross margin, GR= Gross Revenue; and TC= total cost.

3.9 Statistical Analysis

The data collected were subjected to statistical analysis of variance (ANOVA) to test treatment effects for significance using F-test as described by Snecoder and Cochran (1967). The differences between treatments means where F-test shows significant difference were compared using Duncan Multiple Range Test (DMRT) (Duncan, 1955). Correlation study was carried out to determine the association between grain yield and other yield and growth parameters as suggested by Little and Hills (1978) and regression analysis was carried out to study the pattern of response of sweet sorghum to varying NPK rates as suggested Steel and Torrie (1984).

CHAPTER FOUR

4.0 RESULTS

4.1 Soil Physical and Chemical Properties

The chemical properties of the experimental sites at 0-30 cm depth are shown in Table 1. The analysis 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 low 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.

4.2 Number of Leaves per Plant

Table 2 shows the influence of NPK fertilizer rates on the number of leaves per plant of sweet sorghum varieties: Each increase in NPK fertilizer rate from 0:0:0 to 90:45:45 kg ha^{-1} resulted in progressive and significant increase in number of leaves per sweet sorghum plant at all sampling dates at both locations except at 3 and 9 WAS at Samaru and Mando respectively, when treatments with 60:30:30 kg ha^{-1} had statistically similar effect on the number of leaves per plant as that receiving 90:45:45 kg ha^{-1} of NPK fertilizer.

Sweet sorghum variety SW-Bungudu produced significantly more leaves than other varieties of sweet sorghum evaluated for this characteristic at all sampling dates except at 3WAS at both locations and 6WAS at Mando where the effect was not significant.

Combined effect of NPK and variety was significant (Tables 3 and 4). Where observation across NPK fertilizer rates with variety constants revealed that each increase in NPK fertilizer

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

Soil Composition	Depth of Soil (0 – 30cm)	
Particle size distribution (g kg^{-1})	Samaru	Mando
Sand	450	440
Silt	440	260
Clay	110	300
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.

Table 2: Number of leaves per plant of sweet sorghum varieties as influenced by NPK fertilizer rate during 2018 rainy season at Institute for Agricultural Research Samaru and Division of Agricultural Colleges Mando

	SAMARU				**MANDO**			
Treatment	3WAS	6WAS	9WAS	12WAS	3WAS	6WAS	9WAS	12WAS
NPK(Kgha^{-1})								
0:0:0	4.51c	5.47c	5.87c	7.87d	4.91c	5.69c	6.82c	8.51d
30:15:15	4.91b	6.67b	8.11b	8.87c	4.96bc	6.56b	8.13b	10.00c
60:30:30	4.98ab	6.73b	8.49b	9.89b	5.04b	6.96b	8.64ab	10.93b
90:45:45	5.11a	7.44a	9.49a	11.13a	5.18a	7.47a	9.53a	11.82a
SE±	0.060	0.046	0.155	0.136	0.042	0.167	0.345	0.213
Significance	**	**	**	**	**	**	**	**
Variety(V)								
NTJ – 2	4.83	6.35c	7.43c	8.75c	5.05	6.58	8.58a	9.42c
SW-Bungudu	4.95	6.77a	8.55a	10.30a	5.02	6.63	8.87a	11.30a
SW-Daura	4.85	6.62b	7.98b	9.26b	5.00	6.78	7.40b	10.23b
SE±	0.052	0.040	0.134	0.118	0.036	0.144	0.299	0.185
Significance	NS	**	**	**	NS	NS	**	**
Interaction								
NPK x V	NS	NS	NS	**	NS	NS	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. WAS = Weeks after sowing.

Table 3: Interaction between NPK fertilizer and sweet sorghum varieties on number of leaves per plant at 12WAS at Samaru

Treatment		NTJ-2	SW-Bungudu	SW-Daura
NPK(Kgha^{-1})				
0:0:0		7.80f	7.93ef	7.87ef
30:15:15		8.53de	9.53bc	8.53de
60:30:30		8.87cd	11.60a	9.20bcd
90:45:45		9.80b	12.13a	11.47a
SE±	0.236			

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 and sweet sorghum varieties on number of leaves per plant at 12WAS at Mando

Treatment		NTJ-2	SW-Bungudu	SW-Daura
NPK(Kgha^{-1})				
0:0:0		8.40h	8.67gh	8.47h
30:15:15		9.27fgh	10.87cd	9.87def
60:30:30		9.67efg	12.47ab	10.67de
90:45:45		10.33def	13.20a	11.93bc
SE±	0.369			

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.

rate from 0-90:45:45 kg ha^{-1} led to significant increase in Number of leaves per plant produced at 12WAS. However, SW-Bungudu at Samaru and both NTJ-2 and SW-Bungudu at Mando produced statistically similar number of leaves per plant when 60:30:30 and 90:45:45 kg NPK ha^{-1} were applied. Keeping NPK fertilizer rates constant, no significant varietal difference was observed in the number of leaves for plants without fertilizer. At 30:15:15, 60:30:60 and 90:45:45 kgha^{-1} NPK rates, SW-Bungudu consistently produced more leaves per plant at both locations which was comparable to SW-Daura at Samaru at 90:45:45 kg ha^{-1} NPK rate.

4.3 Plant Height (cm)

The plant height of sweet sorghum varieties as influenced by NPK fertilizer rates during 2018 rainy season at Samaru and Mando is presented in Table 5. Treatments with NPK fertilizer at the highest rate of 90:45:45 kg ha^{-1} resulted in significantly taller plants at all sampling dates for both locations, except at 3 and 6WAS for Samaru and Mando when sorghum plant height on treatments with NPK at 60:30:30 kg ha^{-1} were statistically similar to those receiving fertilizer at 90:45:45 kg ha^{-1}. The shortest plant height was consistently recorded on plots receiving no fertilizer, though statistically at par with the plots receiving 30:15:15kh ha^{-1}.

The variety SW-Bungudu was significantly taller than other varieties evaluated for plant height at later stage of growth of 9 and 12WAS at Samaru. This was also true for evaluation at 12WAS at Mando. However, at other sampling dates at Mando, the height of SW-Daura was statistically comparable to SW-Bungudu.

The interaction of fertilizer rate and sweet sorghum varieties on plant height was significant only at 9WAS at Samaru. SW-Bungudu produced the significantly tallest plants with 90:45:45 kg ha^{-1} NPK. However, the heights of NTJ-2 and SW-Daura with 90:45:45 kg ha^{-1} NPK fertilizer were at statistical parity with that of SW-Bungudu fertilized with 60:30:30kg ha^{-1} NPK.

Table 5: Plant height (cm) of sweet sorghum varieties as influenced by NPK fertilizer rates during 2018 rainy season at Institute for Agricultural Research Samaru and Division of Agricultural Colleges Mando

	SAMARU				**MANDO**			
Treatment	3WAS	6WAS	9WAS	12WAS	3WAS	6WAS	9WAS	12WAS
NPK(Kgha^{-1})								
0:0:0	14.06c	20.67c	48.76d	91.84d	15.89c	26.48c	50.05d	77.86d
30:15:15	14.64bc	32.56b	91.21c	157.37c	16.51b	42.93b	97.93c	167.97c
60:30:30	15.44ab	36.69a	96.88b	171.13b	17.64a	48.74a	112.50b	184.59b
90:45:45	15.76a	37.07a	102.97a	190.41a	18.00a	53.26a	129.66a	207.92a
SE±	0.316	1.367	1.013	2.606	0.186	1.656	4.933	1.827
Significance	**	**	**	**	**	**	**	**
Variety(V)								
NTJ – 2	14.78	30.22	79.86c	145.71c	16.70b	39.67b	88.19b	153.34c
SW-Bungudu	15.35	32.22	89.33a	159.81a	17.13ab	46.17a	104.17a	167.13a
SW-Daura	14.80	32.80	85.67b	152.54b	17.20a	42.72ab	100.28ab	158.27b
SE±	0.274	1.184	0.877	2.257	0.161	1.434	4.272	1.582
Significance	NS	NS	**	**	*	*	**	**
Interaction								
NPK x V	NS	NS	*	NS	NS	NS	NS	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. WAS = Weeks after sowing.

Table 6: Interaction between NPK fertilizer rate and sweet sorghum varieties on plant height (cm) at 9WAS during 2018 rainy season at Samaru

Treatment		NTJ-2	SW-BUNGUDU	SW –DAURA
NPK(Kgha^{-1})				
0:0:0		46.93f	51.00f	48.33f
30:15:15		81.93e	98.37bc	93.33cd
60:30:30		90.27d	101.63ab	98.73b
90:45:45		100.30b	106.33a	102.27ab
SE±	1.755			

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.

4.4 Number of Tillers per plant

The effect of different NPK fertilizer rates on number of tillers per plant is presented in Table 7. Each increase in NPK fertilizer rate from 0:0:0-90:45:45 kg ha^{-1} resulted in progressive and significant increase in number of sweet sorghum tillers per plant during the course of the trial at both locations (Samaru and Mando).

SW-Daura significantly outperformed the other two varieties tested for number of tillers per plant at both locations. However, at Mando, the number of tillers recorded for NTJ-2 was statistically comparable to that for SW-Daura. Treatments interaction effect was not significant.

4.5 Shoot Dry Weight (g)

Table 8 presents the shoot dry weight (g) of sweet sorghum varieties as influenced by NPK fertilizer rates. Each increase in NPK fertilizer rate from 0:0:0 to highest rate of 90:45:45kg ha^{-1} significantly and progressively increased shoot dry weight per plant at all sampling dates at Samaru, except at 3 WAS when the difference was not statistically significant. The trend was similar at Mando for 3, 9 and 12 WAS while at 6 WAS at the same location, shoot dry weight recorded from application of 30:15:15 and 60:30:30 kg ha^{-1} were statistically comparable.

The varieties SW-Daura and NTJ-2 recorded high and comparable shoot dry weight per plant for 12WAS at Samaru and for 6 and 12WAS at Mando.

The interaction of NPK fertilizer rate and variety on shoot dry weight was significant ($P < 0.05$) at 12 WAS at Samaru (Table 9). Across the varieties, NTJ-2 and SW-Daura had the statistically highest shoot dry weights with application of 90:45:45 kg ha^{-1} NPK fertilizer. Noteworthy is the similarity observed in SDW between plants that received 60:30:30 kg NPK ha^{-1} for all the three varieties and 90:45:45 kg NPK ha^{-1} for SW-Bungudu.

Table 7: Number of Tillers per plant of sweet sorghum varieties as influenced by NPK fertilizer rates during 2018 rainy season at Institute for Agricultural Research Samaru and Division of Agricultural Colleges Mando

Treatment	**SAMARU**	**MANDO**
NPK(kg ha^{-1})		
0:0:0	0.36d	0.64d
30:15:15	1.60c	1.42c
60:30:30	2.16b	2.24b
90:45:45	2.60a	2.87a
SE±	0.134	0.196
Significance	**	**
Variety(V)		
NTJ – 2	1.63b	1.87ab
SW Bungudu	1.33b	1.45b
SW – Daura	2.07a	2.07a
SE±	0.116	0.169
Significance	**	*
Interaction		
NPK x V	NS	NS

Means followed by the same letter 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 8: Shoot dry weight (g) of sweet sorghum varieties as influenced by NPK fertilizer rates during 2018 rainy season at Institute for Agricultural Research Samaru and Division of Agricultural Colleges Mando

	SAMARU				**MANDO**			
Treatment	3WAS	6WAS	9WAS	12WAS	3WAS	6WAS	9WAS	12WAS
NPK(kg ha^{-1})								
0:0:0	1.85	6.13d	19.94d	27.26d	2.19	8.16c	22.81d	29.47d
30:15:15	1.86	10.75c	37.74c	72.94c	2.29	16.91b	44.57c	79.50c
60:30:30	1.92	12.80b	46.43b	94.18b	2.46	18.21b	60.00b	115.12b
90:45:45	1.98	14.76a	53.92a	114.15a	2.56	22.11a	69.87a	138.87a
SE±	0.067	0.463	1.537	2.227	0.116	0.500	2.370	3.197
Significance	NS	**	**	**	NS	**	**	**
Variety(V)								
NTJ – 2	1.86	11.09	39.21	76.91ab	2.31	17.35a	51.97	90.51ab
SW-Bungudu	1.91	10.86	39.13	73.28b	2.33	15.31b	46.56	86.26b
SW-Daura	1.94	11.38	40.18	81.21a	2.48	16.39ab	49.41	95.44a
SE±	0.058	0.401	1.331	1.928	0.101	0.433	2.052	2.769
Significance	NS	NS	NS	*	NS	*	NS	NS
Interaction								
NPK x V	NS	NS	NS	*	NS	NS	NS	NS

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

NS=Not significant. * =Significant. ** =Highly significant. WAS = Weeks after sowing.

Table 9: Interaction between NPK fertilizer rates and sweet sorghum varieties on shoot dry weight (g) at 12WAS at Samaru

Treatment	NTJ-2	SW-Bungudu	SW-Daura
NPK(Kgha^{-1})			
0:0:0	28.81f	31.38f	21.59f
30:15:15	69.52e	70.82e	78.48de
60:30:30	94.10bc	89.51cd	98.94bc
90:45:45	115.22a	101.41c	125.81a
SE± 3.857			

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.
WAS = Weeks after sowing.

4.6 Leaf Area Index

The leaf area indexes of sweet sorghum varieties as influenced by NPK fertilizer rates are recorded on table 10. NPK fertilizer application of 90:45:45 kg ha^{-1} at Samaru and Mando during 2018 rainy induced the highest significant values for leaf area indexes at all sampling dates except 3WAS when 30:15:15 kg ha^{-1} had statistically comparable values. Statistically similar leaf area indexes were recorded for Samaru and Mando at 6 WAS and at 9 WAS for Mando with application of 30:15:15 and 60:30:30 kg ha^{-1} NPK fertilizer.

There was no significant difference in the leaf are index of the varieties evaluated at both locations and at all sampling dates except 6 WAS, when NTJ-2 had higher leaf area index than SW-Bungudu at Mando.

The combined effect of fertilizer rates and variety on leaf area index was significant at 3WAS at both locations and 6 WAS at Mando. SW-Daura with 90:45:45 kg ha^{-1} recorded the highest significant LAI values at 3WAS for both locations (Tables 11and 12). At 6 WAS (Table 13) at Mando, combination of SW-Bungudu with 90:45:45 kg ha^{-1} NPK had the highest significant LAI, compared to other combinations.

4.7 Crop Growth Rate (CGR)

The influence of different levels of NPK fertilizer on crop growth rate of sweet sorghum varieties is presented on Table 14. With increasing levels of fertility (i.e. 0:0:0-90:45:45 kg ha^{-1} NPK) at Samaru, CGR increased significantly at all sampling dates except 3 WAS when the difference in growth rate was not statistically significant. A similar trend was observed at Mando at 9 and 12 WAS while at 6 WAS, the crop growth rates of sorghum plants receiving 30:15:15 and 60:30:30 kg ha^{-1} NPK fertilizers were statistically similar.

No significant ($P > 0.05$) varietal difference in crop growth rate of the varieties was recorded for all sampling dates except at 6 WAS at Mando and 12 WAS at both locations when NTJ- 2 and SW-Daura recorded higher and comparable CGR than SW-Bungudu.

Table 10: Leaf area index of sweet sorghum varieties as influenced by NPK rates during 2018 rainy season at Institute for Agricultural Research Samaru and Division of Agricultural Colleges Mando

	SAMARU				**MANDO**			
Treatment	3 WAS	6 WAS	9 WAS	12 WAS	3 WAS	6 WAS	9 WAS	12 WAS
NPK(kg ha^{-1})								
0:0:0	0.13b	0.17c	0.56d	1.50d	0.14b	0.19c	0.57c	1.61d
30:15:15	0.14ab	0.47b	0.91c	1.90c	0.16ab	0.48b	0.93b	2.40c
60:30:30	0.16a	0.49b	1.08b	2.43b	0.18a	0.50b	1.10b	3.20b
90:45:45	0.17a	0.65a	1.30a	2.87a	0.18a	0.73a	1.30a	3.92a
SE±	0.009	0.026	0.054	0.100	0.009	0.033	0.182	0.132
Significance	*	**	**	**	*	**	**	**
Variety(V)								
NTJ – 2	0.15	0.42	1.00	2.14	0.16	0.57a	1.03	2.75
SW-Bungudu	0.14	0.44	1.04	2.25	0.15	0.40b	1.03	2.8
SW-Daura	0.16	0.47	1.02	2.14	0.17	0.46b	1.02	2.79
SE±	0.008	0.022	0.046	0.087	0.008	0.029	0.158	0.115
Significance	NS	NS	NS	NS	NS	**	NS	NS
Interaction								
NPK x V	**	NS	NS	NS	**	**	NS	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. WAS = Weeks after sowing.

Table 11: Interaction between NPK fertilizer rates and sweet sorghum varieties on leaf area index at 3 WAS at Samaru

Treatment		NTJ-2	SW-Bungudu	SW-Daura
NPK(kg ha^{-1})				
0:0:0		0.13bc	0.12c	0.12c
30:15:15		0.14bc	0.17b	0.11c
60:30:30		0.15bc	0.15bc	0.17b
90:45:45		0.15bc	0.12c	0.23a
SE$\pm$	0.016			

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.
WAS = Weeks after sowing.

Table 12: Interaction between NPK fertilizer rates and sweet sorghum varieties on leaf area index at 3 WAS at Mando

Treatment		NTJ-2	SW-Bungudu	SW-Daura
NPK(kg ha^{-1})				
0:0:0		0.15bcde	0.13de	0.13de
30:15:15		0.16bcde	0.19b	0.12e
60:30:30		0.18bc	0.16bcde	0.19b
90:45:45		0.17bcd	0.14cde	0.24a
SE±	0.016			

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.
WAS = Weeks after sowing.

Table 13: Interaction between NPK fertilizer rates and sweet sorghum varieties on leaf area index at 6 WAS at Mando

Treatment		NTJ-2	SW-Bungudu	SW-Daura
NPK(kg ha^{-1})				
0:0:0		0.19d	0.21d	0.18d
30:15:15		0.44c	0.51bc	0.50bc
60:30:30		0.44c	0.55bc	0.50bc
90:45:45		0.52bc	1.00a	0.67b
SE±	0.057			

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.
WAS = Weeks after sowing.

Table 14: Crop growth rate ($gm^{-2}wk^{-1}$) of sweet sorghum varieties as influenced by NPK rates during 2018 rainy season at Institute for Agricultural Research Samaru and Division of Agricultural Colleges Mando

	SAMARU				MANDO			
Treatment	3WAS	6WAS	9WAS	12WAS	3WAS	6WAS	9WAS	12WAS
NPK($Kgha^{-1}$)								
0:0:0	0.66	1.52d	4.91d	2.60d	0.73	2.12c	5.21c	2.37d
30:15:15	0.66	3.16c	9.60c	12.51c	0.76	5.20b	9.83c	12.42c
60:30:30	0.68	3.87b	11.96b	16.98b	0.82	5.60b	14.86b	19.60b
90:45:45	0.70	4.54a	13.92a	21.41a	0.85	6.95a	16.98a	24.53a
SE±	0.024	0.170	0.556	0.664	0.039	0.172	0.921	0.923
Significance	NS	**	**	**	NS	**	**	**
Variety(V)								
NTJ – 2	0.66	3.28	10.00	13.40ab	0.77	5.35a	12.31	13.70b
SW-Bungudu	0.68	3.18	10.05	12.14b	0.78	4.62b	11.12	14.12ab
SW-Daura	0.69	3.36	10.24	14.59a	0.83	4.94ab	11.74	16.37a
SE±	0.021	0.147	0.482	0.575	0.034	0.149	0.798	0.800
Significance	NS	NS	NS	*	NS	**	NS	**
Interaction								
NPK x V	NS	NS	NS	*	NS	NS	NS	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. WAS = Weeks after sowing.

Table 15: Interaction between NPK fertilizer rates and sweet sorghum varieties on crop growth rate (gm^{-2}wk^{-1}) at 12WAS at Samaru

Treatment		NTJ-2	SW-Bungudu	SW-Daura
NPK(kg ha^{-1})				
0:0:0		2.43f	3.52f	1.85f
30:15:15		11.10e	12.24de	14.20cde
60:30:30		17.30bc	15.44bcd	18.18b
90:45:45		22.78a	17.36bc	24.10a
SE±	1.149			

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.
WAS = Weeks after sowing.

The interaction of NPK fertilizer rate and variety was significant ($P < 0.05$) on crop growth rate at 12WAS at Samaru (Table 15) where NTJ- 2 and SW-Daura recorded significantly higher CGR than SW-Bungudu with 90:45:45 kg ha^{-1} NPK fertilizer rate, and the rest of the combinations.

4.8 Relative Growth Rate (RGR)

Relative growth rate of sweet sorghum varieties as influenced by NPK rates during 2018 rainy season at Samaru and Mando is presented in Table 16. At both locations, treatments with fertilizer had significantly higher relative growth rate than those without fertilizer at all sampling dates except 3 and 9 WAS when all treatments had statistically similar RGR. However at 6WAS, RGR of treatments with 90:45:45 kg ha^{-1} NPK were statistically similar to those with 60:30:30 kg ha^{-1} NPK at Samaru but significantly higher than treatments with 30:15:15 and 60:30:30 kg ha^{-1} NPK at Mando which were similar at both locations.

There was no significant difference in RGR of the sweet sorghum varieties evaluated at all sampling dates at both Samaru and Mando except at 6 WAS at Mando when NTJ-2 had significantly higher RGR than SW-Daura.

The treatments interaction on RGR was significant at 6WAS at Samaru (Table 17). SW-Daura had the highest RGR with 90:45:45 kg ha^{-1} NPK fertilizer rate but still statistically similar with the other two varieties at the same rate of NPK.

4.9 Net Assimilation Rate (NAR)

Treatments effects on net assimilation rate of sweet sorghum varieties are shown on table 18. NAR of plants nourished with 90:45:45 kg ha^{-1} NPK fertilizer was statistically similar to those nourished with 60:30:30 kg ha^{-1} NPK fertilizer at all sampling dates at Samaru and Mando. While the NAR noted on application of 30:15:15 or 60:30:30 kg ha^{-1} NPK were statistically comparable at 3 and 6WAS at both locations and at 9WAS at Samaru. Plants without fertilizer consistently and significantly had the lowest NAR.

Table 16: Relative growth rate (g $g^{-1}wk^{-1}$) of sweet sorghum varieties as influenced by NPK fertilizer rates during 2018 rainy season at Institute for Agricultural Research Samaru and Division of Agricultural Colleges Mando

	SAMARU				MANDO			
Treatment	3WAS	6WAS	9WAS	12WAS	3WAS	6WAS	9WAS	12WAS
NPK(kg ha^{-1})								
0:0:0	0.08	0.18c	0.17	0.045b	0.11	0.19c	0.14	0.040b
30:15:15	0.09	0.25b	0.18	0.095a	0.12	0.29b	0.15	0.084a
60:30:30	0.09	0.28ab	0.19	0.10a	0.13	0.29b	0.17	0.095a
90:45:45	0.10	0.29a	0.19	0.11a	0.13	0.32a	0.17	0.10a
SE±	0.005	0.009	0.007	0.005	0.008	0.008	0.011	0.006
Significance	NS	**	NS	**	NS	**	NS	**
Variety(V)								
NTJ – 2	0.088	0.25	0.18	0.088	0.12	0.29a	0.15	0.072
SW-Bungudu	0.088	0.25	0.19	0.085	0.12	0.27ab	0.16	0.079
SW-Daura	0.095	0.24	0.18	0.091	0.13	0.26b	0.15	0.088
SE±	0.005	0.008	0.006	0.004	0.007	0.007	0.010	0.005
Significance	NS	NS	NS	NS	NS	NS	NS	NS
Interaction								
NPK x V	NS	**	NS	NS	NS	NS	NS	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. ** =Highly significant. WAS = Weeks after sowing.

Table 17: Interaction between NPK fertilizer rates and sweet sorghum varieties on relative growth rate (g $g^{-1}wk^{-1}$) at 6WAS at Samaru

Treatment		NTJ-2	SW-Bungudu	SW-Daura
NPK(kg ha^{-1})				
0:0:0		0.16e	0.25bcd	0.12e
30:15:15		0.27abcd	0.23d	0.26abcd
60:30:30		0.29ab	0.24cd	0.30a
90:45:45		0.29ab	0.28abc	0.30a
SE±	0.015			

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.
WAS = Weeks after sowing.

Table 18: Net assimilation rate (gm^{-2} wk^{-1}) of sweet sorghum varieties as influenced by NPK fertilizer rates during 2018 rainy season at Institute for Agricultural Research Samaru and Division of Agricultural Colleges Mando

	SAMARU				MANDO			
Treatment	3WAS	6WAS	9WAS	12WAS	3WAS	6WAS	9WAS	12WAS
NPK(Kgha^{-1})								
0:0:0	0.05b	0.05c	0.08b	0.03c	0.06	0.07b	0.09b	0.02c
30:15:15	0.05ab	0.09b	0.11a	0.07b	0.07	0.13a	0.10b	0.06b
60:30:30	0.06ab	0.10ab	0.12a	0.09a	0.07	0.13a	0.14a	0.09a
90:45:45	0.06a	0.12a	0.13a	0.10a	0.07	0.15a	0.14a	0.10a
SE±	0.002	0.008	0.007	0.005	0.004	0.008	0.012	0.008
Significance	NS	**	**	**	NS	**	**	**
Variety(V)								
NTJ – 2	0.06	0.09	0.12	0.07	0.06	0.12	0.13	0.07
SW-Bungudu	0.05	0.08	0.11	0.07	0.06	0.11	0.11	0.06
SW-Daura	0.06	0.07	0.11	0.07	0.07	0.12	0.12	0.08
SE±	0.002	0.007	0.006	0.004	0.003	0.007	0.010	0.007
Significance	NS	NS	NS	NS	NS	NS	NS	NS
Interaction								
NPK x V	NS	NS	NS	NS	NS	NS	NS	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. ** = Highly significant. WAS = Weeks after sowing.

The varieties evaluated had statistically similar NAR for all sampling periods at both locations and there was no signification interaction between fertilizer rate and variety on NAR.

4.10 Days to 50%Heading

The observation of days to 50% heading of different treatments is given in Table 19. The minimum days for 50% heading were observed by the application of 90:45:45 kg $ha^{-1}$of NPK fertilizer at Samaru and Mando. However sorghum plants supplied with 60:30:30 kg ha^{-1} NPK attained 50% heading at the same time with those supplied with 90:45:45 and 30:15:15 kg ha^{-1} NPK at both locations.

The variety SW-Daura reached 50% heading per plot significantly earlier while the variety SW-Bungudu later than NTJ-2. No significant interaction among treatments effects on number of days to 50% heading was observed.

4.11 Stalk Yield (t ha^{-1})

The influence of NPK rates on Stalk yields of sweet sorghum varieties is given in Table 20. 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. Variety SW-Bungudu was significantly ($P < 0.05$) superior 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 variety on stalk yield is presented in Table 21 and was significant only at Samaru. At fixed NPK rates across the varieties, SW-Bungudu was consistently significantly superior in stalks yield for both unfertilized (0:0:0 kg ha^{-1}) and fertilized plants (30:15:15 up to 90:45:45 kg NPK ha^{-1}). Along NPK rates, stalk yield of SW-Bungudu with 60:30:30 kg NPK ha^{-1} was statistically comparable to NTJ-2 with 90:45:45 kg ha^{-1} NPK.

Table 19: Number of days to 50% heading of sweet sorghum varieties as influenced by NPK fertilizer rates during 2018 rainy season at Institute for Agricultural Research Samaru and Division of Agricultural Colleges Mando

Treatment	**SAMARU**	**MANDO**
NPK (kg ha^{-1})		
0:0:0	73.0c	72.2c
30:15:15	67.3b	66.3b
60:30:30	67.0ab	66.0ab
90:45:45	66.7a	65.7a
SE±	0.12	0.15
Significance	**	**
Variety(V)		
NTJ – 2	67.6b	66.6b
SW-Bungudu	72.3c	71.3c
SW-Daura	65.8a	64.8a
SE±	0.10	0.13
Significance	**	**
Interaction		
NPK x V	NS	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. ** = Highly significant.

Table 20: Stalk yield (t ha^{-1}) of sweet sorghum varieties as influenced by NPK fertilizer rates during 2018 rainy season at Institute for Agricultural Research Samaru and Division of Agricultural Colleges Mando

Treatment	**SAMARU**	**MANDO**
NPK(kg ha^{-1})		
0:0:0	2.76d	3.06d
30:15:15	9.31c	10.08c
60:30:30	25.83b	26.94b
90:45:45	29.27a	33.27a
SE±	0.273	0.913
Significance	**	**
Variety(V)		
NTJ – 2	15.09c	16.64b
SW-Bungudu	18.48a	20.21a
SW-Daura	16.80b	18.15ab
SE±	0.236	0.806
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 21: 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.

4.12 Brix Yield (%)

NPK rates influence on Brix of sweet sorghum varieties is shown on Table 22. At both locations (Samaru and Mando), Brix yields recorded for 90:45:45 kg ha^{-1} NPK rates were significantly greater than the Brix yields recorded for 60:30:30 and 30:15:15 kg ha^{-1}NPK which were statistically the same at Samaru but significantly different at Mando.

Though SW-Daura consistently had the highest Brix percentages, statistically similar Brix percentages were recorded for all the varieties at both locations. There was no significant interaction between variety and fertilizer rates on brix yield (Table 22)

4.13 Panicle Length (cm)

Panicle length of sweet sorghum varieties as influenced by NPK rates at Samaru and Mando during 2018 rainy season is presented in Table 23; Each increase in NPK fertilizer application (0:0:0-90:45:45 kg ha^{-1}) led to a significant increase in panicle length of sweet sorghum plants at both locations.

SW-Bungudu developed significantly longer panicles followed by SW-Daura while NTJ-2 had the shortest panicles.

No interaction between NPK rates and sweet sorghum varieties was observed on panicle length.

4.14 Number of Grains per Panicle

Table 24 shows the number of grains per panicle of sweet sorghum varieties as influenced by NPK rates. Number of grains per panicle significantly increased with increasing NPK fertilizer rates from 0:0:0-90:45:45 kg ha^{-1} at Samaru and Mando.

Variety NTJ-2 produced more grains than SW-Bungudu and SW-Daura at the trial locations. However, the number of grains per panicle produced by SW-Daura was statistically comparable to that of NTJ-2 at Mando.

Table 22: Brix Yield (%) of sweet sorghum varieties as influenced by NPK fertilizer rates during 2018 rainy season at Institute for Agricultural Research Samaru and Division of Agricultural Colleges Mando

Treatment	**SAMARU**	**MANDO**
NPK(kg ha^{-1})		
0:0:0	8.94c	9.89d
30:15:15	12.09b	13.04c
60:30:30	12.53b	14.28b
90:45:45	13.46a	15.44a
SE±	0.247	0.221
Significance	**	**
Variety(V)		
NTJ – 2	11.78	13.12
SW-Bungudu	11.65	13.09
SW-Daura	11.84	13.28
SE±	0.214	0.191
Significance	NS	NS
Interaction		
NPK x V	NS	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 23: Panicle length (cm) of sweet sorghum varieties as influenced by NPK fertilizer during 2018 rainy season at Institute for Agricultural Research Samaru and Division of Agricultural Colleges Mando

Treatment	**SAMARU**	**MANDO**
NPK(kg ha^{-1})		
0:0:0	15.15d	15.94d
30:15:15	17.93c	18.43c
60:30:30	22.78b	23.31b
90:45:45	27.17a	27.72a
SE±	0.285	0.480
Significance	**	**
Variety(V)		
NTJ – 2	17.92c	18.64c
SW-Bungudu	23.25a	23.74a
SW-Daura	21.10b	21.67b
SE±	0.246	0.415
Significance	**	**
Interaction		
NPK x V	NS	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 24: Number of grains per panicle of sweet sorghum varieties as influenced by NPK fertilizer during 2018 rainy season at Institute for Agricultural Research Samaru and Division of Agricultural Colleges Mando

Treatment	**SAMARU**	**MANDO**
NPK kg ha^{-1})		
0:0:0	305.44d	344.89d
30:15:15	1056.89c	1159.44c
60:30:30	1856.89b	1959.44b
90:45:45	2390.56a	2574.33a
SE±	19.565	51.575
Significance	**	**
Variety(V)		
NTJ – 2	1589.00a	1687.17a
SW-Bungudu	1219.08c	1192.00b
SW-Daura	1399.25b	1649.42a
SE±	16.943	44.666
Significance	**	**
Interaction		
NPK x V	**	**

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 25: Interaction between NPK fertilizer rates and sweet sorghum varieties on number of grains per panicle at Samaru

Treatment	NTJ-2	SW-Bungudu	SW-Daura
NPK(kg ha^{-1})			
0:0:0	318.33g	188.32h	409.67g
30:15:15	1122.67e	962.67f	1085.33e
60:30:30	1922.67c	1762.67d	1885.33d
90:45:45	2992.33a	1962.67c	2216.67b
SE±	33.887		

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 26: Interaction between NPK fertilizer rates and sweet sorghum varieties on number of grains per panicle at Mando

Treatment	NTJ-2	SW-Bungudu	SW-Daura
NPK(kg ha^{-1})			
0:0:0	363.33g	210.33g	461.33g
30:15:15	1336.67e	846.00fe	1259.67e
60:30:30	2136.67c	1646.00d	2095.67c
90:45:45	2994.00a	2065.67c	2663.33b
SE±	89.33		

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.

Interaction of NPK rates and sweet sorghum varieties was significant on number of grains per panicle at both locations (Tables 25 and 26). NTJ-2 combined with 90:45:45 kg ha^{-1} NPK fertilizer produced significantly the highest number of grains per panicle at the two locations while unfertilized (0 kg ha^{-1}) and fertilized (30:15:15-90:45:45) plants of SW-Bungudu produced significantly the lowest number of grains per panicle.

4.15 1000-Grain Weight (g)

1000-grain weight of sweet sorghum varieties as influenced by NPK fertilizer rates is presented in Table 27. NPK fertilizer rates significantly influenced 1000-grain weight of sweet sorghum plants at both locations. Plants fertilized with 90:45:45 and 60:30:30 kg ha^{-1} NPK fertilizer recorded the heaviest and statistically comparable weights for 1000-grains at both locations while those without fertilizer produced significantly lighter grains compared to other rates.

Varieties NTJ-2 and SW-Daura produced significantly heavier grains than SW-Bungudu at both locations. However, NTJ-2 had statistically the same weight of grains with SW-Daura at Mando and differed significantly with the same variety at Samaru.

Treatments effect interaction on 1000-grain weight was significant at Samaru (Table 28) where SW-Daura combined with 60:30:30 and 90:45:45 kg ha^{-1} NPK rates produced the heaviest grains. SW-Bungudu, both fertilized and unfertilized plants, across the varieties had significantly the lightest grains. Noteworthy is the statistical similarity observed along the fertilizer rates in 1000-grain weight between SW-Bungudu plants that received 90:45:45 kg ha^{-1} NPK fertilizer and the grain weights of the other two varieties (NTJ-2 and SW-Daura) supplied with 60:30:30 kg NPK ha^{-1}.

Table 27: 1000-grain weight (g) of sweet sorghum varieties as influenced by NPK fertilizer rate during 2018 rainy season at Institute for Agricultural Research Samaru and Division of Agricultural Colleges Mando

Treatment	**SAMARU**	**MANDO**
NPK(kg ha^{-1})		
0:0:0	13.61c	13.77c
30:15:15	15.15b	15.43b
60:30:30	19.63a	19.92a
90:45:45	20.46a	20.59a
SE±	0.312	0.245
Significance	**	**
Variety(V)		
NTJ – 2	18.40a	18.68a
SW-Bungudu	15.09c	15.35b
SW-Daura	18.15b	18.23a
SE±	0.270	0.212
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 28: Interaction between NPK rates and sweet sorghum varieties on 1000-grain weight (g) at Samaru

Treatment	NTJ-2	SW-Bungudu	SW-Daura
NPK(kg ha^{-1})			
0:0:0	13.81c	13.11c	13.90c
30:15:15	15.98b	13.76c	15.70b
60:30:30	21.16a	16.39b	21.35a
90:45:45	22.64a	17.09b	21.65a
SE±	0.541		

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.

4.16 Grain Yield (t ha^{-1})

Grain yield of sweet sorghum varieties as influenced by NPK fertilizer rates during 2018 rainy season at Samaru and Mando is presented in Table 29. Each increase in NPK fertilizer rate from 0:0:0 to 90:45:45 kg ha^{-1} resulted in significant and successive increase in total grain yield where the application of 90:45:45 kg ha^{-1} NPK recorded significantly highest grain yield than all other rates at both locations.

NTJ-2 significantly out-yielded all other varieties at both locations and closely it was followed by SW-Daura. SW-Bungudu recorded significantly the lowest grain yield at both locations during 2018 rainy season.

The interaction of NPK fertilizer rates and sweet sorghum varieties on grain yield was significant at both locations (Tables 30 and 31). Keeping variety constant, a significant increase in grain yield was observed with increase along NPK fertilizer rates from 0:0:0 to 90:45:45 kg ha^{-1} within all the three varieties. Evaluation across fixed NPK rates indicated no varietal differences in unfertilized plants (0:0:0 kg ha^{-1}) and plants with 30:15:15 kg NPK ha^{-1} rate. NTJ-2 combined with 60:30:30 and 90:45:45 kg ha^{-1} NPK significantly outperformed SW-Daura which was also superior to SW-Bungudu at both locations.

4.17 Correlation Analysis

Correlation coefficients, shown in Table 32 and 33, depict relationship between yield (t ha^{-1}) and some growth and yield attributes at experimental locations. The tables show their relationship and effectual traits importance. Positive and highly significant ($P < 0.01$) correlations exist between grain yield and plant height, number of tillers per plant, shoot dry weight, Stalk yield, brix yield, panicle length, number of grains per panicle and 1000-grain weight in both locations. Positive correlation ($P < 0.05$) was also observed between grain yield and leaf area index. Days to 50% heading was negatively correlated with all growth and yield parameters evaluated except panicle length at both locations.

Table 29: Grain yield (t ha^{-1}) of sweet sorghum varieties as influenced by NPK fertilizer rates during 2018 rainy season at Institute for Agricultural Research Samaru and Division of Agricultural Colleges Mando

Treatment	**SAMARU**	**MANDO**
NPK(kg ha^{-1})		
0:0:0	0.32d	0.35d
30:15:15	0.80c	0.89c
60:30:30	1.57b	1.66b
90:45:45	2.12a	2.24a
SE±	0.027	0.029
Significance	**	**
Variety(V)		
NTJ – 2	1.39a	1.47a
SW-Bungudu	0.96c	1.09c
SW-Daura	1.26b	1.32b
SE±	0.023	0.025
Significance	**	**
Interaction		
NPK x V	**	**

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 30: 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 31: 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 32: Correlation matrix between yield and some growth and yield attributes of sweet sorghum varieties as influenced by different NPK rates at Institute for Agricultural Research Samaru during 2018 rainy season

	1	2	3	4	5	6	7	8	9	10	11	12
Number of leaves	1											
Plant height	0.797**	1										
Number of tiller	0.560**	0.823**	1									
Shoot dry weight	0.725**	0.916**	0.857**	1								
Leaf Area index	0.671**	0.738**	0.712**	0.776**	1							
Days 50%heading	-0.187	-0.566**	-0.739**	-0.675**	-0.355*	1						
Stalk yield	0.827**	0.869**	0.767**	0.898**	0.782**	-0.470	1					
Brix yield (%)	0.666**	0.889**	0.766**	0.880**	0.722**	-0.646**	0.801**	1				
Panicle length	0.656**	0.780**	0.793**	0.888**	0.712**	0.635**	0.928**	0.772**	1			
Grains per panicle	0.657**	0.844**	0.811**	0.928**	0.792**	-0.641**	0.901**	0.842**	0.937**	1		
1000-grain weight	0.555**	0.853**	0.809**	0.929**	0.691**	-0.734**	0.862**	0.848**	0.913**	0.942**	1	
Grain yield	0.587**	0.789**	0.792**	0.908**	0.685**	-0.649*	0.876**	0.774**	0.942**	0.960**	0.938**	1

1. Number of leaves per plant
2. Plant height
3. Numbers of tillers per plant
4. Shoot dry weight at 12WAS
5. Leaf area index at 12WAS
6. Days to 50% heading
7. Stalk yield
8. Brix yield (%)
9. Panicle length
10. Number of grains per panicle
11. 1000- grain weight
12. Grain yield

* =Significant at P = 0.05 (r = 0.325) **= highly significant at P = 0.01 (r =0.418) WAS= weeks after sowing DF (N-2) = 34

Table 33: Correlation matrix between yield and some growth and yield attributes of sweet sorghum varieties as influenced by different NPK rates at Division of Agricultural Colleges Mando during 2018 rainy season

1	2	3	4	5	6	7	8	9	10	11	12	
Number of leaves	1											
Plant height	0.762^{**}	1										
Number of tiller	0.510^{**}	0.753^{**}	1									
Shoot dry weight	0.663^{**}	0.927^{**}	0.832^{**}	1								
Leaf Area index	0.673^{**}	0.864^{**}	0.717^{**}	0.916^{**}	1							
Days 50%heading	-0.213	-0.620^{**}	-0.679^{*}	-0.673^{**}	-0.532^{**}	1						
Stalk yield	0.737^{**}	0.863^{**}	0.791^{**}	0.944^{**}	0.918^{**}	-0.472^{*}	1					
Brix yield (%)	0.755^{**}	0.926^{**}	0.782^{**}	0.898^{**}	0.843^{**}	-0.654^{**}	0.862^{**}	1				
Panicle length	0.556^{**}	0.890^{**}	0.832^{**}	0.936^{**}	0.837^{**}	0.766^{**}	0.851^{**}	0.864^{**}	1			
Grains per panicle	0.589^{**}	0.850^{**}	0.820^{**}	0.921^{**}	0.883^{**}	-0.732^{**}	0.870^{**}	0.884^{**}	0.932^{**}	1		
1000-grain weight	0.541^{**}	0.835^{**}	0.805^{**}	0.906^{**}	0.832^{**}	-0.767^{**}	0.840^{**}	0.873^{**}	0.923^{**}	0.952^{**}	1	
Grain yield	0.566^{**}	0.829^{**}	0.812^{**}	0.929^{**}	0.893^{**}	0.653^{**}	0.900^{**}	0.877^{**}	0.902^{**}	0.970^{**}	0.943^{**}	1

1. Number of leaves per plant	2. Plant height	3. Numbers of tillers per plant
4. Shoot dry weight at 12WAS	5. Leaf area index at 12WAS	6.Days to 50% heading
7. Stalk yield	8. Brix yield(%)	9. Panicle length
10. Number of grains per panicle	11. 1000- grain weight	12. Grain yield

* =Significant at P = 0.05 (r = 0.325) **= highly significant at P = 0.01 (r =0.418) WAS= weeks after sowing DF (N-2) = 34

4.18 Regression Analysis

Sweet sorghum stalk and grain yields as influenced by varying NPK fertilizer rates at experimental locations are depicted by the regression model in Figures 2 and 3 respectively. The equations for the two locations predicted that NPK fertilizer rates had positive linear effect on stalk and grain yield and also revealed that the difference in NPK fertilizer rates could account for 99% of the variation on grain yield at both sites, 94% and 96% on stalk yield at Samaru and Mando respectively.

4.19 Economics of Production

Data on economic parameters are presented in Table 34. Cost of cultivation was the same for all treatments with the same fertilizer rate and increased with increase in NPK fertilizer rate from 0:0:0-90:45:45 kg ha^{-1}. Gross and net revenues increased with increase in NPK rate up to the highest dosage.

The highest 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 and recorded the highest gross return on yields at Mando.

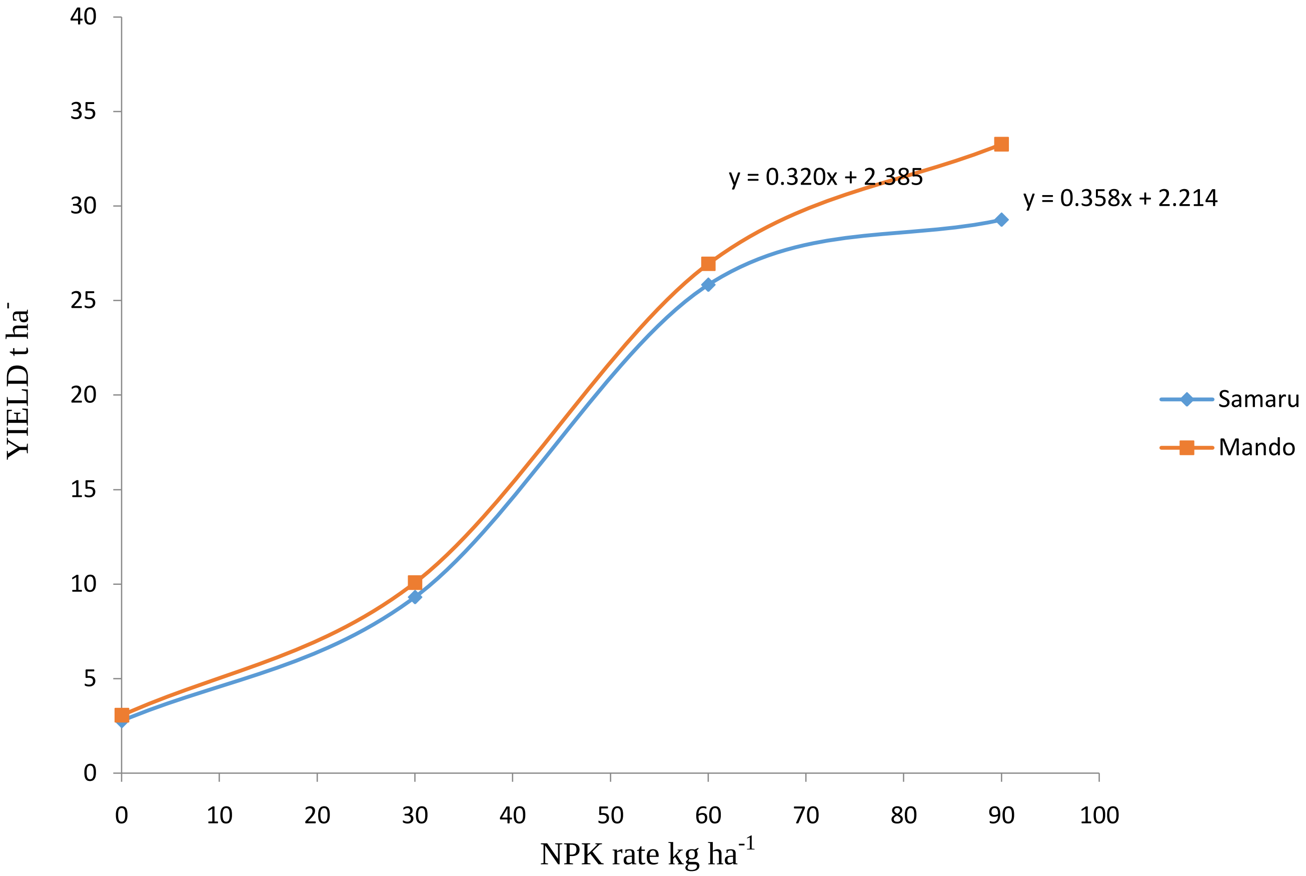

Fig. 2: Regression of NPK on stalk yield

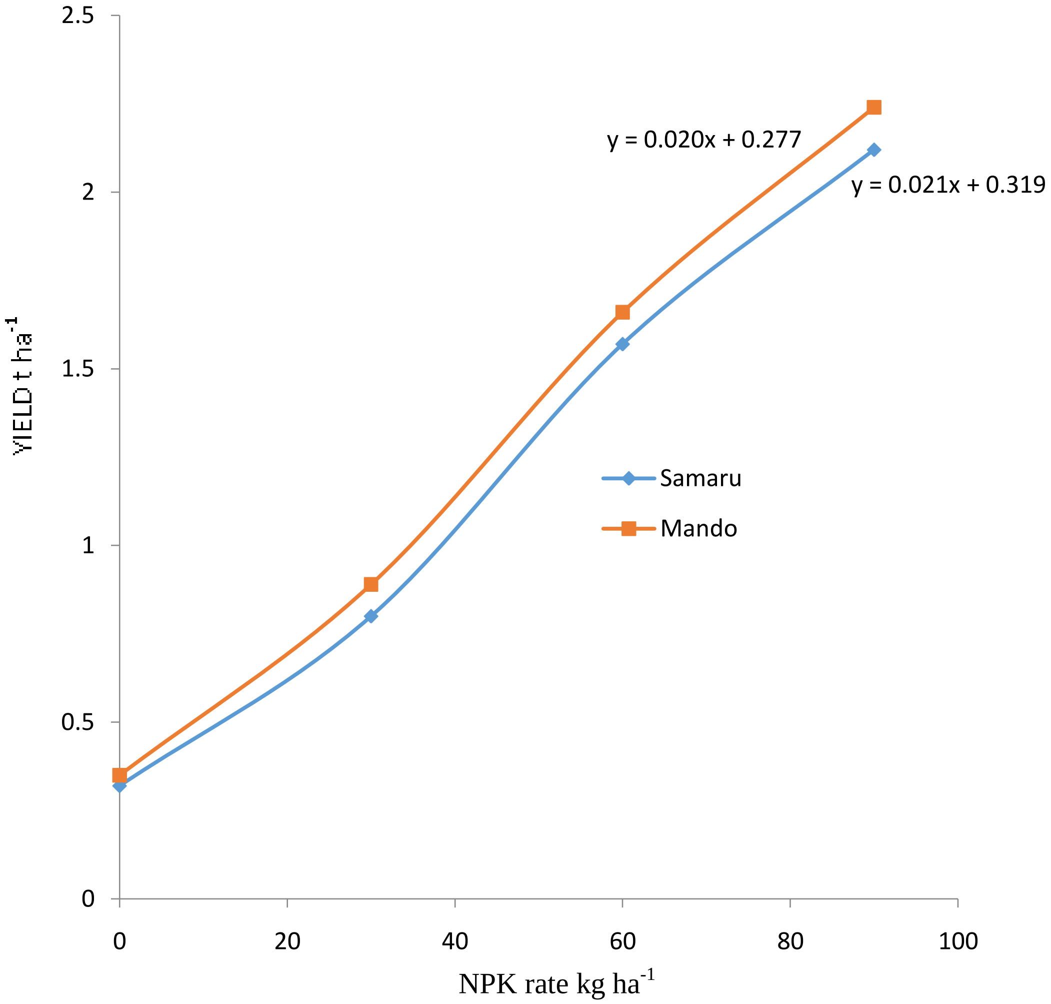

Fig. 3: Regression of NPK on grain yield

Table 34: Gross margin Analysis on production of Sweet sorghum varieties with different NPK fertilizer rates at Institute for Agricultural Research Samaru

Treatments		Yields (t h^{-1})		Revenue (₦ ha^{-1})		Gross Return(₦ha^{-1}) (GR)	Costs (₦ha^{-1})		Total Cost(TC)(₦ha^{-1}) (TFC + TVC)	Gross Margin(₦ha^{-1}) (GR – TC)	B:C Ratio
NPK (Kgha^{-1})	Variety	Grain	Stalk	Grain	Stalk		Total Fixed	Total Variable			
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 35: Gross margin Analysis on production of Sweet sorghum varieties with different NPK fertilizer rates at Division of Agricultural Colleges Mando

Treatments		Yields (t h^{-1})		Revenue (₦)		Gross Return(₦) (GR)	Costs (₦)		Total Cost(TC)(₦) (TFC + TVC)	Gross Margin(₦) (GR – TC)	B:C Ratio
NPK (Kgha^{-1})	Variety	Grain	Stalk	Grain	Stalk		Total Fixed	Total Variable			
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)

CHAPTER FIVE

5.0 DISCUSSION

Generally the growth performance of sweet sorghum plant was better at Mando than at Samaru. This could be attributed to the higher soil organic matter with higher mineralized nutrients such as nitrogen at Mando soil. Therefore, the sorghum plants could have taken up sufficient amounts of mineralized N during early growth even without any input at Mando, thereby enhancing the effect of basal N application and achieving better plant growth in 0:0:0 NPK at Mando than at Samaru. The soil factor accompanied with weather differences such as more sunshine hours, temperature and moisture could be responsible for the general better performance of sweet sorghum varieties in growth and yields at Mando than at Samaru. This is in accordance with the report of Reddy and Reddi (2010) that identified environmental factors to account for 50% effect on crop growth and yield patterns and confirmed by the work of Abdulhamid *et al.* (2011).

5.1 Effects of NPK on Growth, Yield Components and Yield of Sweet Sorghum

The initial use of seed cotyledon; as source of early plant nutrients for development of radicle and plumule to source and foray water and nutrient, accompanied with the early use of inherent soil nutrients and initial slow uptake as a result of young and developing roots and rootlets resulting in slow and seeming/non-responsiveness to applied nutrients, could be responsible for the non-significant difference in response to NPK fertilizer at early vegetative stages (0-3WAS) in this study. Almodores *et al*. (2006) suggested that it may be too early to evaluate growth parameters at this stage. Upon development of necessary apparatuses for effective photosynthesis, the effect of applied nutrient became apparent and continue throughout the crop’s active growth phase, leading up to the reproductive phase, as a result, all growth and yield parameters were eventually significantly affected by NPK fertilizer application.

Plant height, number of leaves and number of tillers per plant significantly increased with corresponding increase in NPK fertilizer rates from 0 to the highest rate of 90 kg ha^{-1} and this could be attributed to utilization of these major and some minor nutrients for cell division and elongation, proteins and chlorophyll syntheses which accelerated meristematic activity of plant that led to progressive increase in internodes length and photosynthetic area. These results corroborate with the findings of Tanchev (1995), Redai *et al.* (2018) and Muhammad *et al*. (2018) who reported significant increase in these parameters with increase in NPK dosage in sorghum.

Shoot dry weight (SDW) benefited from application of different doses of NPK fertilizer from 0-90:45:45 kg ha^{-1}. The significant increase in SDW might be due to efficient use of NPK which resulted in higher number of leaves, total leaf area, increased CGR, warranting the accumulation of assimilates to the various growth and yield organs of the crop. These results were in conformity with the finding of Almodores *et al.* (2006), Almodores *et al.* (2008) and Abou-amer and Kewan (2014). Wadsworth (2002) reported that increase in dry matter production with increased fertilizer application was due to the role of N in determining the use efficiency of sunshine by increasing biomass production, any inadequacy of nutrient reduce the sunshine use efficiency or ability to photosynthesize and this could account for the overall poor performance of unfertilized plants (0 kg ha^{-1}) in this study.

The improvement in growth as well as photosynthetic parameter (leaf area and other photosynthesizing parts) due to integration of nutrients might have resulted in better light interception and utilization of radiant energy leading to higher photosynthesis and finally more number of leaves per plant, more vigorous growth and the significant increase in leaf area index observed. Mansab *et al*. (2003), Valdabadi and Farahani (2010), observed similar trend in LAI with increase in N level. Furthermore, CGR RGR and NAR increased with the advancement of growth (3-9WAS) and then further declined toward maturity (12WAS) in line with normal sigmoid growth curve as similarly observed by Goma (2011) in grain sorghum at Samaru-Nigeria. CGR increased significantly with increasing rate of NPK application (0 - 90:45:45 kg ha^{-1}) in successive growth stages. This may be due to higher rate of dry matter accumulation with increasing amount of available NPK with successive dose of fertilizers. Similar trend was observed with RGR and NAR as both are dependent on dry matter.

The observation from this study also revealed that application of NPK fertilizer from 30:15:15 to 90:45:45 kg ha^{-1} reduced the duration to 50% heading by 6-days as compared to unfertilized plots. This could be attributed to the sufficiency of N, P and K for the synthesis of higher energy molecules and translocation of assimilate which facilitates faster differentiation of tissue and subsequent transformation into reproductive phase. Mishra *et al.* (2014) and Redai *et al.* (2018) also recorded similar observation on the effect of inorganic fertilizers on number of days to heading. Brix percentage, stalk yield, panicle length, 1000-grain weight, number of grains per panicle and grain yield of sweet sorghum increased with increase in NPK application and could be due to higher dry matter production and the role of N (Leghari *et al.,* 2018), P (Malhotra *et al,*. 2018) in efficient transformation of solar energy into chemical energy that could increase carbohydrate content, and K (Prejapati *et al.,* 2012) in transportation of sink assimilate by influencing electron transport in the transport chain processes of the crop. This is in conformity with the report of Abbas and Sayyed Hassan (2016), Muhammad *et al*. (2018), and Redai *et al*. (2018), who indicated that supply of inorganic fertilizers results in higher net assimilation rate and increased yield and its components. However the observed increase in brix with increasing NPK input in this study is contrary to the findings of Ravella *et al.* (2016) at North Carolina and

Almodores *et al*. (2007) at Iran who reported no significant difference in brix (%) between fertilized and unfertilized sweet sorghum plants at harvest.

5.2 Effect of Variety on Growth, Yield and Yield Components of Sweet Sorghum

The results obtained revealed that varieties significantly differed in plant height and number of leaves per plant, especially towards the end of the sampling period (9-12WAS), SW-Bungudu being significantly tallest with more leaves per plant and variety NTJ-2 was the shortest at both sites of the study. SW-Daura produced more tillers and reached 50% heading earlier than the short duration exotic variety (NTJ-2) while SW-Bungudu produced the lowest number of tillers per plant and matured late. Significant differences for plant height and number of leaves, number of tillers & 50% heading period could be attributed to genetic make-up of the varieties, similar differences among sweet sorghum varieties and cultivars have been reported by Perrazo *et al*. (2013), Rono *et al*. (2014) Redai *et al.* (2018). At early growth stage (6WAS), NTJ-2 recorded significantly higher LAI, CGR and RGR than SW-Bungudu at Mando, thus, produced more SDW at that stage. SW-Daura accumulated more SDW than other varieties at later growth stage (12WAS), similar trend in growth indices of sweet sorghum varieties was observed by Olugbemi and Ababyomi (2016) with different N-rates. These differences among sweet sorghum varieties could be attributed to genetic make-up and environmental conditions according to Mekdad and El-sherif (2016) and Perrazo *et al.* (2013), who also attributed sweet sorghum varietal differences to these factors. SW-Bungudu outperformed SW-Daura which was better than NTJ-2 in stalk-yield. More juice volume, higher plant height and more nodes can explain this difference. Rono *et al*. (2014) noted similar differences in stalk yield of sweet sorghum genotypes. Brix yield (%) was similar for each variety tested. SW-Bungudu developed longer panicles followed by SW-Daura with NTJ-2 having significantly shortest panicle. However, NTJ-2 out yielded the two varieties in number of grains per panicle and 1000-grain weight and therefore superior in grain yield followed by SW-Daura. The superiority of NTJ-2 in grain yield despite the initial slow growth may be attributed to its genetic make-up being a grain yield than syrup yield variety. Redai *et al.* (2018) also observed varietal superiority of sweet sorghum on yield and its components with the application of NPK fertilizer while Almodores *et al*. (2006) observed similar case with the application of N and K at Iran.

5.3 Interactions

The interaction of NPK fertilizer and sweet sorghum variety on growth indices (LAI, SDW, CGR, RGR, NAR) at vegetative stages observed at both experimental sites is evidence that there were variations in response of the varieties to the application of NPK fertilizer and it could be attributed to the degree of adaptability of the varieties and the soil condition of the growing environment. This is similar to the observation of Olugbemi and Ababyomi (2016) on the interactive effect of variety and N fertilizer on growth indices of four sweet sorghum varieties.

The significant interaction between variety and NPK rates on number of leaves per plant, plant height and stalk yield at Samaru shows that SW-Bungudu responded more to NPK fertilization (30:15:15-90:45:45kg ha^{-1}) than all other treatment combinations. It could be due to it adaptability and the impact of NPK fertilizer on it cellular growth, photosynthetic processes, assimilates production and transportation. A comparable significant interaction between variety and N-P fertilizer was found by and El-sherif (2016) and Redai *et al.* (2018) on plant height, stem weight and leaves yield of sweet sorghum.

Bilateral effects of NPK fertilizer and variety on number of grains per panicle, 1000-grain weight and grain yield shows that the exotic variety NTJ-2 in combination with NPK fertilizer application (30:15:15 to 90:45:45 kg ha^{-1}) out yielded the local varieties and it could be due to the fact that the variety has been genetically improved to produce more grains. The significant interaction also revealed that 60:30:30 and 90:45:45 kg ha^{-1} of NPK recorded similar 1000-grain weight for all the varieties, the attainment of maximum dry matter production with the application 60:30:30 or 90:45:45 kg ha^{-1} of NPK for grain filling could account for the similarity. The interactions between NPK and sweet sorghum variety on yield traits are similar to that observed by Ayat *et al*. (2014) and Redai *et al.* (2018) on plant height, panicle weight, seed index and yield between NPK and sorghum cultivars.

5.4 Correlation

Correlation coefficients observed in this study between yield (t ha^{-1}) and some growth and yield attributes at both locations have thrown the light on the relationship of effectual traits importance. The positive and highly significant relationship observed between growth and yield components such as plant height, shoot dry weight, stalk yield, panicle length, number of grains per panicle and 1000-grain weight is a confirmation that these growth characters are very important yield contributing factors. This is in agreement to the report of Goma (2011) at Samaru-Nigeria who reported positive association between plant height, number of leaves, shoot dry weight with grain sorghum yield. The negative correlation between days to 50% heading and characters such as plant height and 1000-grain weight may help in selection of early maturing local varieties for improvement. Endalamaw *et al.* (2017) observed similar relationship between days to maturity and growth traits with grain yield of sweet sorghum at Ethiopia.

5.5 Regression

The response of stalk and grain yield was linear implying that the optimum NPK rate was beyond 90:45:45 kg ha^{-1} and the application of higher rates could result in better yield responses. However, 99% r-square (r^2) on grain yield at both sites indicated the NPK requirement for grain yield was at near optimum. The curves also suggest that increase in yield in this study was not only from NPK fertilizer rates but from variety too. This corroborates results of Sawargoankar and Suhas (2016) that observed similar linear trend in the relationship between N- rates and yield of sweet sorghum and reported that the application of N beyond 90 kg ha-1 did not significantly increased grain yield but did influenced stalk yield significantly.

5.6 Profitability

Profitability increased with increasing Gross Return (GR) and Net Return (NR). The increase in GR and NR with increasing rate of NPK fertilizer application was due to more response of sweet sorghum to NPK fertilizer for increasing the crop economic yields. SW-Daura is most economically viable variety with the highest net return for production. Similar results regarding the effect of levels of NPK on cost of cultivation, Gross Margin Return, Net Margin Return, B:C ratio were also recorded by Buah *et al*. (2012), Durgesh and Chaplot (2015).

CHAPTER SIX

6.0 SUMMARY AND CONCLUSION

6.1 Summary

The field experiment was conducted to study the effect of NPK rates and variety on growth yield and productivity of sweet sorghum during 2018 rainy season at the research farm of Institute for Agricultural Research (IAR) Ahmadu Bello University, Samaru (11^{o}11'N, 07^{o}38'E and 686m above sea level), and the Research Farm of College of Agriculture and Animal Science, Division of Agricultural Colleges (DAC) Mando (10^{o}43'N, 6^{o}34'E and 508m above sea level), 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) and replicated three times.

The result of the study showed that the application of NPK fertilizer (30:15:15 – 90:45:45 kg ha^{-1}) significantly increased growth and yield parameters such as plant height, number of leaves per plant, shoot dry weight, number of tillers per plant, brix yield, panicle length, number of grains per panicle and 1000-grain weight. Grain and stalk yield were significantly influenced by NPK rates and the highest yields were recorded with the application of 90:45:45 kg ha^{-1}. The response of the sweet sorghum varieties to NPK fertilizer rates was observed to be significant on all growth and yield components except for NAR, RGR, and brix yield (%). NTJ-2 was superior in grain yield (1.39 t ha^{-1} and 1.47 t ha^{-1}) while SW-Bungudu was better at stalk yield (18.48 t ha^{-1} and 20.21 t ha^{-1}) in both locations. SW-Daura (1.26 t ha^{-1}, 1.30 t ha^{-1}) and (16.80, 18.15) closely followed the two varieties in their respective yields.

The interactive effect of NPK rate and the three sweet sorghum variety was observed on yield and some yield characters such as number of leaves per plant, number of grains per panicle and 1000-grain weight. Correlation analysis on the components of growth revealed positive and highly significant association between all yield and growth characters except days to 50% heading.

Gross margin analysis indicated increase in profitability with increase in NPK fertilizer rate from 0-90:45:45 kg ha^{-1} and the production of SW-Daura with 90:45:45 kg ha^{-1} of NPK fertilizer was the most profitable.

6.2 Conclusion

The results obtained from this study show that;

1. Application of NPK fertilizer enhanced the growth and yield of sweet sorghum compared to the control and the application of 90:45:45 kg ha^{-1} resulted in the best growth and yield response.
2. There are variations among the varieties in terms of growth and yield with NTJ-2 which is an exotic being the best at grain yield with 90:45:45 kg ha^{-1} NPK while SW-Bungudu a local variety is the best for stalk production with 90:45:45 kg ha^{-1} NPK. SW-Daura, a local variety, produced average grain and stalk yields.
3. Application of fertilizer as low as 30:15:15 kg ha^{-1} would result in reasonable performance of the crop in the areas of study as no loss was incurred economically and the application of 90:45:45 kg ha^{-1} NPK to variety SW-Bungudu was the most profitable production.

REFERENCES

Abbas, Almodares and Syyed Hassan, Hoseini (2016). Effect of Sowing dates and Nitrogen levels for Ethanol production from Sweet sorghum stalks and grains. *African Journal of Agricultural Research.* Vol. 11(4), pp. 266-275.

Abdulhamid, A., Friday, O. and Adebayo, A. (2011). Effect of Climate on the Growth and Yield of Sorghum (*Sorghum bicolor*) in Wailo, Ganjuwa Local Government Area, Bauchi State. *Research Journal of Environmental and Earth Sciences* 3(5): 469-472, ISSN: 2041-0492.

Abou-Amer, A. I and Kewan, KZ. (2014). Effect of Nitrogen and Phosphorus fertilization levels on Sorghum (*Sorghum bicolor* L.) yield and fodder quality for animals. *Alexandria Journal of Agricultural Research* 59(1): 51-59.

Adegeye, A. J. and Ditto, J. S. (1985). Essentials of agricultural economics. *Impact Publishers Nigeria Limited, Ibadan.*

Almodares A., Taheri, R., Hadi, M. R. and Fathi, M. (2006). The Effect of Nitrogen and Potassium fertilizers on the Growth parameters and the Yield components of two Sweet sorghum cultivars. *Pakistan Journal of Biological Sciences,* (9) 2350 – 2353.

Almodares, A., Hadi, M. R, and Ahmad, H. (2008). Sorghum Stem Yield and Soluble Cabohydrates under Phonological Stages and Salinity Levels. *Africa Journal of Biotechnology*. 7: 4051-4055.

Almodares, A., Sepahi, A., and Shirvani, M. (1997b). Sweet sorghum cultural practices in Iran. In: *Proceedings of the First International Sweet Sorghum Conference*. Beijing, China. 14-19 September, pp. 175-183.

Almodares, A., Teheri, R. and Adeli, S. (2007). Inter-relationship between growth analysis and carbohydrate contents of sweet sorghum cultivars and lines. *Journal of Environmental Biology* 28 527 – 531.

Ayat, B. H., Shalaby, E.M.M., Allam, A.Y., Ali, E.A. and Said, M.T. (2014). Effect of NPK Fertilization Rates and Splitting on the Grain Yield and its Components of Two Sorghum Cultivars. Asia *J. Agric. Sci.*, (45) No. (4), 1-14.

Black, C. A. (1965). Method of Soil Analysis II. Chemical and Microbiological Properties. *American Society of Agronomy.* 2:5-10

Brooking, IR. (1979). Male sterility of *sorghum bicolor* (L) Moench induced by low night temperature. II. Genetic differences in sensitivity. *Australian journal of plant physiology*, 6(2) 143-147.

Buah, S.S.J, James, MK and Luke, N.A. (2012). Grain Sorghum Response to NPK Fertilizer in the Guinea Savanna of Ghana. *Journal of Crop Improvement* 26:101–115.

Clayton, W. D. and Renvoize, S. A. (1986). Genera Graminum Grasses of the World. *Kew Bulletin Additional Series* XIII: 338–345.

Cothren, J. T., Matocha, J. E. and Clark, L.E. (2000). Integrated Crop Management for Sorghum. In: *Sorghum: Origin, history, technology and production*, Smith, C.W., Frederiksen R.A., eds. John Wiley and Sons New York. 409-442.

Demkin, V. I. and Ageev, V.V. (1990). Productivity of maize as dependent on weather conditions and fertilizers and methods of covering the in a zone of unstable moisture supply. *Agrokhimiya*, 7:73-82.

Diao, Xianmin (2017). Production and Genetic Improvement of Minor Cereals in China. *The Crop Journal of China*, Vol. 5:2, pp 103-114. https://doi.org/10.1016/j.cj.2016.06.004

Dillion, S. L., Shapter, F. M., Henry, R. J., Cordeiro, G. Liz, I. and Lee, S. L. (2007). Domestication to Crop Improvement: Genetic Resources for Sorghum and Saccharum (Andropogoneae). *Annals of Botany,* Vol. 10:5. Pp 975-989, http://doi.org/10.1093/aob/mcm192

Doggett, H. (1988). Sorghum. 2nd Edition Longman Scientific & Technical, London. 512pp

Downes, R. W. and Marshall, D. R. (1971). Low temperature induced male sterility in *Sorghum bicolor*. *Animal Production Science* 11: 352-356.

Downes, R.W. (1972). Effect of temperature on the phenology and grain yield of *Sorghum bicolor*. *Australian Journal of Agricultural Research* 23: 585-594.

Duncan, D. B. (1955). Multiple range multiple F Test. *Biometrics.* 11:1-42.

Duncan, R.R., A.J., Bockholt and F.R., Miller, (1984). Descriptive comparison of senescent and Non-senescent sorghum genotypes.*Agronomy Journal 73:849-853*

Durgesh, Kumar and Chaplot, PC. (2015). Performance of multi-cut forage sorghum genotypes to Fertility levels. *Forage Research* 41 (3):199-201

Endalamaw, C., Adugna, A. and Mohammed, H. (2017). Correlation and Path coefficient analysis of agronomic and quality traits in a bio-energy crop, sweet sorghum (*Sorghum bicolor* (L) Moench). *African Journal of Biotechnology*. ISSN 1684-5315: vol 16(47), pp. 2189-2200.

FAO (Accessed: 11-6-2018) *Sorghum bicolor* yield and production.

FAO (Accessed: 27-8-2015) *Sorghum bicolor* (L.) Moench.

Goma, L, (2011). Performance of Sorghum bicolor Varieties as influenced by Planting pattern and Nitrogen rates. Unpublished MSc Reaseach Thesis Department of Agronomy, A.B.U Zaria Nigeria. pp. 52-66.

ICRISAT (Accessed: 31-7-2015) Sorghum (*Sorghum bicolor* L. Moench). International Crops Research Institute for the Semi-Arid Tropics.

Issa, Piri. (2012). Effect of phosphorus fertilizer and micronutrient foliar application on yield of Sorghum. *Annals of Biological Research* 3 (8): 3998-4001.

Jackson L. M. (1967). *Soil Chemical Analysis*. Prentice Hall of India Private Limited, New Delhi, p. 205.

Khan, M. A., Abid, M., Hussain, N. and Massood, M. U. (2005). Effect of phosphorous levels on growth and yield of maize (*Zea mays* L.) cultivars under saline conditions. *International Journal of Agriculture and Biology* 3: 511–514.

Kimber, C. T. (2000). Origins of Domesticated Sorghum and its Early Diffusion to India and China. In: Smith C. W. and Frederiksen R. A. (eds)., *Sorghum: Origin, History, Technology, and Production*. John Wiley & Sons Inc, New York, pp 3–98

Leghari, S. J., Wahoch, J. W., Leghairi, G. M. and Leghari, A. (2016). Role of Nitrogen for Plant Growth and Development. *Advances_in_Environmental_Biology Journal* 10(9):209-218.

Little, J. M and Hills, F. J. (1978).*Agricultural Experimentation Design and Analysis.*John Willey and Sons Inc. New York. P.350.

Malhotra, H., Vandana, S., Sahrma, S. and Pandy, R. (2018). Phosphorus Nutrition: Plant Growth in Response to Deficiency and Excess. Plant Nutrients and Abiotic Stress Tolerance. ISBN 978-981-10-9043-1:171-190.

Mansab, AL., Jeffers, DL., and Henderlong, PR. (2003). Inter-relationship between Leaf area, Light interception and Growth rate in a soybean-wheat system. *Asian Journal Plant Sciences* 2:605-612.

Mathur, S., Umakanth, A.V., Tonapi, V. A., Rita, S. and Manoj, Sharma. (2017). Sweet sorghum as Biofuel Feedstock: Recent Advances and Available Resources.76 *Biotechnology for Biofuels*. 10:146 DOI 10.1186/s13068-017-0834-976.

Meena, A., Singh, P. and Kanwar, P. (2012). Effect of Nitrogen levels on Yield and Quality of [*Sorghum bicolor* (L.) Moench] sorghum genotypes. *Forage Research Journal,* 37(4):238-240.

Mekdad, A.A.A and El-Sherif, A.M.A (2016). The effect of Nitrigen and Potassium Fertilizers on Yield and Quality of Sweet sorghum varieties under Arid Regions conditions. *International Journal of current Microbiology and Applied Sciences.* ISSN: 2319-7706; Volume 5 number 11. pp. 811-823.

Mishra, J.S., Thakur, N. S., Singh, P., Kubsad, V.S., Kalpana, R., Alse, U. N. and Nemade, S. M. (2014). Tillage and Integrated Nutrient Management in rainy- season grain sorghum (S*orghum bicolor*). *Indian Journal of Agronomy*.59 (4): 619-62377

Mishra, J.S., Thakur, N.S., Singh, P., Kubsad, V.S., Kalpana, R., Alse, U. N., and Sujathamma, D.P. (2015). Productivity Nutrient use efficiency and Economics of Rainy season Grain sorghum as influenced by Fertility levels and Cultivars. *Indian Journal of Agronomy*, 60(1):7-81.

Muhammad, S. Y., Bala, R. A., Sani, K. and Zaharaddeen, S. (2018). Effect of organic and inorganic fertilizer on the growth and yield of sorghum (*Sorghum bicolor* (L.) Moench) in Bauchi state, Nigeria. *Biological and Pharmaceutical Sciences* e-ISSN: 2581-325077, 02(01), 025–031.

Okalebo, P. E. Gathua, K. W. and Woomer, P.L. (1993). Laboratory methods of soil and plant analysis: A working manual. TSBF-UNESCO. Nairobi, 88pp.

Olugbemi, O. and Abayomi, Y. A. (2016). Effect of nitrogen application on growth and yield of sweet sorghum (*Sorghum bicolor* (L.) Moench) varieties. *Advances in Agriculture*. 1–7. http://dx.doi.org/10.1155/2016/8329754.

Perazzo, A. F., Pinto de Carvalho, G. G., Edson-Mauro-Santos, E. M., Ricardo-Martins-Araujo, R. M., Campos, F. S., Oliveira, C. H., Azevêdo, J. A. and Tabosa, J. N. (2014). Agronomic evaluation of 32 sorghum cultivars in the Brazilian semi-arid region. *Journal SciELO Analytics Zootec*. Vol. 43(5). http://dx.doi.org/10.1590/S1516359.

Prajapati, Kalavati. (2012). The importance of Potassium in Plant Growth – A Review. *Indian Journal of Plant Sciences.* 1. 177-186.

Radford, D.J. (1967). Growth analysis formulae- their use and abuse. *Biology: Crop Science 7*, 171-175.

Rahman, S.A and Lawal, A. B. (2003). Economic Analysis of Maize-Based Cropping Sysytems in Giwa Local Government Area of Kaduna State, Nigeria. *Internationa Journal of Agricultural Science, Environment and Technology*. 3 (2): 139- 148.

Ravella, R., D. Ashwin, M., Reddy, R., Gehlz, R., Vangimalla, G., Godfrey, G. and Wang, L. (2016). Impact of NPK Treatments on Sweet Sorghum (*Sorghum bicolor* (L)) Yields for

Biofuel Feedstock in Piedmont Region of North Carolina. *American Journal of Experimental Agriculture.* ISSN: 2231-0606: 13(1): 1-8.

Redai Weldegebriel, Tesfay Araya and Yamane Egziaher (2018). Effect of NPK and blended fertilizer Application on Yield, Yield components and its profitability on Sorghum (*Sorghum bicolor* (L) Moench*)* under rainfed condition in North-western Tigray, Ethiopia. *International Journal of Life Sciences*. ISSN: 2320-7817; 6 (1) : 60-68.

Reddy, T. Y and Reddi, G. H. S (2010). Principles of Agronomy. Kalyani Production, New Delhi.

Rono, J. K., Cheruiyot, E. K., Othira, J. O., Njuguna, V. J., Macharia, J. A., Owuoche, J., Oyier, M., and Kange, A. M. (2016). Adaptability and Stability Study of Selected Sweet Sorghum Genotypes for Ethanol Production under Different Environments Using AMMI Analysis and GGE Biplot. *Scientific World Journal.* Volume 16. pp1-14.

Satpal, B. S., Duhan, U. N., Joshi, A. S., Godara, S., and Arya, N. (2015). Response of Yield, Quality and Economics of Single Cut forage Sorghum Genotypes to Different Nitrogen and Phosphorus Levels. *Forage Research Journal*, 41(3): pp.170-175. http://forageresearch.in

Sawargaonkar, G. L., Patil, MD., Wani, SP., Pavani, E., Reddy, BV. and Marimuthu, S. (2013). Nitrogen Response and Water use efficiency of Sweet sorghum Cultivars. *Field Crops Research,* 149:245-251.

Sawargaonkar, G. L. and Suhas P.W. (2016). Nitrogen response of of sweet sorghum genotypes during rainy season. Currest Science Association. 110 (9): 1699-1709.

Snedecor, G. W. and Cochran, W. G. (1967).Statistical Methods.6th edition. Iowa State University Press, Ames Iowa U.S.A. P. 456.

Somashekar, KS., Shekara, BG., Kalyanamurthy, KN. and Lohithaswa, HS. (2015). Growth, yield and economics of multicut fodder Sorghum (*Sorghum sudanense* L.) as influenced by different seed rates and nitrogen levels. *Forage Research* 40: 247-250.

Spenceley, J., Butler, G., Nicholas, A., Simpfendorfer, S., Holland, J., and Kniepp, J. (2005). Grain Sorghum. NSW Department of Primary Industries.

Tanchev, D. (1995). Effect of fertilizer application on the development of seed yield of sorghum. *J. Agri*., 32(3): 35-37.

Tiryaki, I. and Andrews, D. J. (2001). Germination and seedling cold tolerance in sorghum. *Agronomy Journal* 93: 1391-1397.

Valdabadi, S. A. and Farahani, H. A. (2012). Effects of planting density and pattern on physiological growth indices in maize (*Zea mays* L.) under nitrogenous fertilizer application. *Journal of Agricultural Extension and Rural Development.* 2(3): 40-47.

Vermerris, W., C. Rainbolt, D. Wright and Y. Newman, (2007). Production of Biofuel Crops in Florida: Sweet Sorghum; University of Florida. *IFAS Extension.* SS AGR 293.

Wadsworth, G. (2002). Forage maize fertilizer requirement, Potash Development Association, *Brixtarw* pp. 25-29.

Wastson, D.J. (1958). The dependence of net assimilation rate on leaf area index. *Annals of Boatany,* 22 , 37-54.

Winchell, F., Brass, M., Manzo, A., *et al.* (2018). On the Origins and Dissemination of Domesticated Sorghum and Pearl Millet across Africa and into India: a View from Butana Group of the Far Eastern Sahel. *Afrc Achaeol Rev* 35, 483-505. https://doi.org/101007/s10437-018-9314-2

Wyman, C.E., Gnansounou, E. and Dauriat, A. (2005). Refining sweet sorghum to ethanol and sugar: economic trade-offs in the context of North China. *Bio-resource Technology,* 96 985–1002.

APPENDIX I

Month	Rainfall (mm)	Temperature (^oC)		Relative Humidity (%)	Solar Radiation (sunshine hours)
		Min.	Max.		
July	232.1	20.03	30.87	85.19	5.43
August	638.1	19.61	30.2	80.12	4.96
September	256.7	18.97	31.93	76.70	6.75
October	22.0	18.09	44.09	64.45	8.09
November	0.0	19.65	38.61	13.00	6.9
December	0.0	12.48	31.32	16.90	8.85

IAR Meteorological Unit Samaru, Zaria.

APPENDIX II

Month	Rainfall (mm)	Temperature (^oC)		Relative Humidity	Solar Radiation (sunshine hours)
		Min.	Max.		
July	565.10	21.6	28.7	57.4	7.50
August	386.	21.7	27.9	61.7	6.80
September	312.0	21.1	30.2	54.0	5.30
October	182.8	21.3	31.1	51.0	8.70
November	0.0	19.2	35.1	25.0	8.01
December	0.0	17.5	35.2	12.4	8.80

National Water Resource Institute, Mando.

APPENDIX III

BIOGRAPHY

Name:	MUHAMMAD, Aminu Nuhu
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State of Origin:	Niger
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Educational Qualifications

Institution	**Certificate Obtained**	**Year Obtained**
Rahma Nursery/Primary School Suleja	Primary School Certificate	2001
Mustafa Comprehensive School Kontagora	Secondary School Certificate	2007
Ahmadu Bello University, Zaria	B. Agric.	2012
Ahmadu Bello University, Zaria	M. Sc. Agronomy in View	2018

Working Experience

Organization	**Post**	**Period**
Agricultural Research Council of Nigeria (ARCN), Abuja	Program officer II (NYSC)	2013 – 2014
Suleja Local Government Council	Agricultural I	2007-2017
Niger State Agricultural & Mechanization Development Authority (NAMDA)	Agricultural Officer II	2017-2019
Federal University of Technology Minna	Graduate Assistant	2019-Date

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