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Growth and Development of Sorghum (*Sorghum bicolor* (L.) Moench) Varieties as Influenced by Planting Pattern and Nitrogen Rates

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Abstract

This field trial was conducted during the rainy seasons of 2007 and 2008 at the Research farm of the Institute for Agricultural Research, Ahmadu Bello University, Zaria to evaluate the performance of the Sorghum varieties (*Sorghum bicolor L.*) as influenced by planting pattern, variety and nitrogen rates. The treatments were made up of three planting patterns (one plant per stand, two plants per stand and two plants per stand at both sides of the ridge), three levels of Nitrogen fertilizer (30, 60 and 90 kg N/ha) and three sorghum varieties (Samsorg 44, GPOO Malawi and Samsorg 14). Split-plot design was used with combination of nitrogen fertilizer and variety assigned to main plots, while planting patterns was allocated to sub-plot and replicated three times. The results showed that growth factors such as plant height, number of leaves/plant, leaf area index, and total dry matter per plant significantly increased with nitrogen application up to 60 kg N/ha in both seasons. Similarly planting patterns significantly influenced growth characters such as plant height, leaf area index and dry matter/plant. Number of leaves/plant was not significant; with planting at both sides of ridge significantly resulted in taller plants and higher leaf area index while planting one stand on a ridge resulted in significantly more of dry matter per plant. Sorghum variety Samsorg14 resulted in higher growth parameters compared with other varieties used. Growth and yield of sorghum at Samaru showed that application of 60 kg N/ha, planting of sorghum at both sides of the ridge interaction using Samsorg 14 supported good growth and development of sorghum.

Key words: Planting Pattern, Nitrogen level, Sorghum varieties, Samaru

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Introduction

Sorghum (*Sorghum bicolor* (L) Moench) is extensively cultivated in the tropics, sub tropics and in the temperate zone, as the major staple food grain and feeds to many people and animals. It ranks fourth in importance amongst the world cereals, coming after rice, wheat, and maize, (Dogget, 1970). Sorghum is one of the cereal crops grown under rain fed condition over an area of 42 million hectares for grain and fodder purposes mainly in the semi-arid tropics of Africa, Asia and Latin America (Reddy *et al*., 2004). Nigeria is the second largest producer of sorghum in the world, with an annual production in excess of 8 million metric tons. This energy producing plant is a basic food for mankind in regions of Africa, Asia and India. It is very hardy and can be grown in areas of the world that are too hot or too dry for other crops to be grown successfully. Grain sorghum is a small round berry which may vary in colour from yellow cream to white. According to Murty *et al*. (1994), the crop is considered as important staple food crop in Africa, South Asia and Central America. Anon. (1972) reported that, it is the principal source of nutrition for many millions of people in Africa and much of Asia. Besides providing food for humans and feeds for livestock, sorghum stems is used for a wide range of purposes, including: the construction of walls, fences and thatches; and production of brooms, mats, baskets, fish- traps, sun shades, etc. It is also used as fuel and as a soil additive to improve its fertility.

In Nigeria, sorghum is primarily use for human consumption and as a staple food in the diet of many people in many countries of the world especially sub-Saharan Africa. Sorghum is consumed boiled or popped. Sorghum is used to prepare local recipes like tuwo, akamu and kunu (Eghareba, 1979). It serves as a major raw material in the brewing industries. Some varieties of sorghum can be" malted "to produce nutritious food stuff for infants and use in bakery products. Malted sorghum can also be use in traditional beer production, an important income earning activity for village women in Nigeria. Sorghum production varies from place to place due to variation in climate, soil and agronomic practices. Difference in yields of local cultivars compared to improved varieties has been reported by several workers. The low yields are as the result of the use of unimproved local varieties, limited amount and distribution of rainfall, lack of adequate fertilization, poor planting patterns and poor pest and disease control practices coupled with the habit of planting sorghum late (Anon., 1996). Also Low yield of cereals, pulses and plantain crops were attributed to insufficient soil nutrients (Pillai, 1967). According to Lombin (1987) the most important limiting factors among the soil nutrients had been identified to be nitrogen and phosphorus. The response of improved varieties such as dwarf or semi dwarf and medium tall cultivars to fertilizer is better compared to the local tall "farafara".

In terms of nitrogen requirement of sorghum, the recommended rate is 64 kg Nha^{-1} for the northern guinea savanna (Anon., 1996). The depletion of soil nutrients and use of improved agronomic practices are as a result of introduction of improved cultivars which require more fertilizer and management compared to local cultivars that require less of these inputs. Fertilizer requirement of a crop changes with changes in crop varieties, genetic makeup and soil condition (Lombin, 1987). Planting pattern is another important agronomic factor which can cause substantial increase or decrease in yield of most crops. Hence, appropriate planting pattern is vital for the interception of adequate sunlight necessary for optimum photosynthesis. Growth and dry matter yield among sorghum varieties vary. A significant difference in plant height among varieties was observed by Chiezey (1981). Similarly Onyibe (1987) noted that, Samsorg 17 produced taller plants compared to Samsorg 28 and Samsorg 31. Stand proportion in the field is a function of plant density, as the arrangement of plants influenced the number of stands in a particular area. Tufai (1972) reported that increase in plant density from 185,000 to 520,000 plants /ha reduced the leaf area/plant in sorghum. Similarly, Wightman and Wolley (1974) reported significant decrease in leaf area/plant when plant population was increased from 133,000 to 177,000 and 49,421 to 69,189 plants/hectare respectively.

There are many forms of fertilizers which farmers use without appropriate recommendations as to the type or rates. Such inappropriate practices tend to create nutrient imbalance in the soil, which negatively affected the productivity of the soil (Anon, 1995). The quantity of Nitrogen required by crops plays an important role in plant physiology and constitutes an integral part of amino acid protein and nucleic acid (Bowman and Haris, 1974). Plants heights were observed to increase by increasing the nitrogen level from 24.7 to 98.8 kg Nha^{-1} (Singh *et al*., 1984). Increase in crop's morphological parts (root, stem, leaf and inflorescence) have been attributed to application of nitrogen (Idem, 1989). The leaf area index increased due to the fact that nitrogen enhanced protein synthesis consequently vegetative growth which resulted in increasing photosynthetic surface and stimulated further growth, as confirmed by Eltelib (2004).

Although research has been conducted on different sorghum varieties, there is limited work on sorghum varieties such as White Kaura (Samsorg 44) and GPOO Malawi in areas of nutrient requirement, and appropriate planting pattern in the northern guinea savanna of Nigeria. The increase in demand for sorghum coupled with increasing populations that are using the crop necessitated the present study with the following objectives: a. to evaluate the growth and yield of three sorghum varieties, b. to assess the effect of N fertilizer on growth and yield of three sorghum varieties and c. to determine the effect of stand proportion on growth and yield of the three sorghum varieties

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Materials and Methods

A two year field trials was conducted during the 2007 and 2008 rainy seasons at the Institute for Agricultural Research Farm, Samaru (11^0 11 N 09^0 38 E, 686m above sea level) in the northern guinea savanna ecological zone of Nigeria. The soil of the area was sandy loam with low organic matter content and exchangeable cat ions. The treatments consisted of 3 sorghum varieties (Samsorg 44, GPOO Malawi and Samsorg 14) 3 levels of nitrogen fertilizer rates (30,60 and 90 kg N/ha) and 3 planting patterns (one plant per stand, two plants /stand and two plants per stand using double row on each ridge). The treatments were laid out in a split plot design replicated three times with variety and fertilizer combinations in the main plot and the various stand proportion in the sub – plots and replicated three times.

A basal fertilizer application of 30 kg P/ha and 30 kg K/ha were applied using single super phosphate (18% P_2O_5 SSP) and murate of potash (60% K_2O MOP) as sources for P and K respectively. Nitrogen in the form of urea (46% N) was applied in two split doses as per the varied treatment rates to each plot at 2 and at 6 WAS, 5-10 cm away from the plant stand and dibbled at 5-10cm depth. The varieties used in the trial were obtained from Institute of Agricultural Research, Samaru Zaria. The SSV20043 (Samsorg 44) is a medium maturing variety (100-120 days), 1.6-1.8m in height, large grain size that is white in colour with spot, short panicle size with short exertion. It has a potential yield of 2.5 – 3.0 tons ha^{-1}. GPOO Malawi is an early maturing variety, (80-90days), 2.3-2.5m; small grain size that has creamy colour, long panicle size with long exertion. It has potential yield of 2.0 – 2.5 tons/ha. Samsorg 14 is a medium maturing variety (100-120 days), 1.5 - 2.0m in height, the grain is white in colour and medium in size, panicle with short exertion with yield potential of 2.0- 2.5 tons ha^{-1}

In the two years, the experimental fields were ploughed, harrowed twice and ridged at 75cm spacing, the land was then marked out to appropriate number of plots, the gross plot had six ridges 6m long and the net plot comprised the two inner ridges of 6m long.The seed was treated with Apron Star (a.i. 10% metalaxyl, 6% carboxyl and 34% furathiocarb) at the rate of 10g per 2.5 kg of seed before planting. Five seeds were sown per hole as per planting pattern at a spacing of 75cm × 25cm while gap filling was done at one week after sowing (WAS). The crop were thinned as per the varied planting patterns at 3 WAS to give an approximate plant population of 53,330, 106,660 and 213,330/ha. Manual hoe weeding was done at 3 and 6 WAS to control weeds. The plants were earthen up at 9 WAS. Cypermethrin was used at the rate of 2Lt/ ha to control stem borers at milking stage. The data collected were subjected to analysis of variance (ANOVA) and means were compared using Duncan multiple Range test (Duncan, 1955). Simple correlation coefficients and regression analysis were calculated from the mean of each parameter as described by Snedecor and Cochran, (1967).

Results and Discussion

Soil samples were randomly collected from 0-30cm depths across the experimental sites in 2007 and 2008 rainy seasons prior to planting and fertilizer application. The bulked soil samples were air dried, pass through 2mm mesh sieved and analyzed. Details of the soil analysis for the 2007 and 2008 are presented in Table 1. The textural class of the soil from 0-30 cm was sandy loam in both seasons. The pH in water was acidic in both years. The organic carbon and total nitrogen were low while the available phosphorus was medium. The exchangeable cat ions revealed that values for Ca and Mg were ok while that of K and Na were low. The CEC was high in both years while the concentration of H and AL were low.

Plant height was significantly affected by nitrogen application in both years (Table 1). In both 2007 and 2008 increasing nitrogen rates from 30 to 60 kg N/ha significantly increased plant height, but further increase to 90 kg N/ha was not significant in both seasons. The increase in plant height due to nitrogen fertilization may be attributed to the effect of N on cell division and tissue elongation which consequently led to increase in number of nodes and internodes elongation or both. This supported the observation reported by Miko and Manga (2008),Buah and Mwinkaara (2009).The Number of leaves/ plant was significantly affected by nitrogen application in both years (Table 2). The trend was similar with plants that received 60 and 90 kg N/ha being statistically similar in terms of number of leaves per plant, but produced significantly more leaves per plant than plants that received 30 kg N/ha. The none significant difference between application of 60 and 90 kg N/ha on dry matter production could be due the fact that the crop might have attained its optimum N requirements for dry matter production. This is consistent with the report of Miko and Manga, (2008) who reported none significant difference between application of 60 and 90 kg N/ha on sorghum dry matter production.

The leaf area index per plant was significantly affected by nitrogen application in both years (Table 2). Increasing nitrogen rates from 30 to 90 kg N/ha significantly increased LAI. Plants that received 90 kg N/ha produced significantly higher leaf area indices per plant than plants that received 60 kg N/ha which was in turn significantly higher than plants that received 30 kg N/ha in both seasons. The effect of nitrogen on LAI mainly led to an increase in leaf area per plant. Application of nitrogen increased LAI due to the fact that nitrogen enhances protein synthesis and consequently vegetative growth which resulted in increasing photosynthetic surfaces and stimulated further growth, as reported by Eltelib (2004). Similarly Spiertz and Devos (1983) reported increased LAI due to application of N. Dry Matter per plant was significantly affected by nitrogen application in both seasons (Table3). The trend in the two seasons were similar with plants that received 60 and 90 kg N/ha being statistically similar in terms of dry matter per plant, but produced significantly more dry matter/plant than plant that received 30 kg N/ha. The increase in dry matter could be due to increase in number of leaves for higher assimilating production, translocation and storage. This is consistent with the report of Miko and Manga (2008).

Increasing nitrogen level from 30 to 90 kg N/ha significantly increased CGR in both years (Table 3). The highest crop growth rate was produced by plants that received 90 kg N/ha followed 60 kg N/ha and the least was recorded on plants that received 30 kg N/ha in both years. The response of crop growth rate to the varying nitrogen levels (30, 60 and 90 kg N/ha) appeared consistent with the reports of Patil and Jawale (1977) and Eltelib (2004).Increasing nitrogen rates from 30 to 60 kg N/ha significantly increased grain yield (kg/ha) in both seasons, but further increase to 90 kg N/ha did not increase grain yield (kg/ha) in both seasons. The increase in yield could be as a result of increase of higher number of leaves per plants, LAI, total ,dry matter per plant leading to production of more assimilate which translated to higher grain yield. Increase in yield of sorghum due to nitrogen application has been reported by some workers (Obilana, 1983).

Sorghum variety Samsorg14 produced the tallest plant except, in 2008 when it was statistically similar with GPOO Malawi while Samsorg 44 produced the least. The taller plants produced by Sorghum variety Samsorg 14 could be linked to genetic make-up inherent in the variety and whether condition during the growing periods. Arunah (2004) has earlier attributed the superiority in height of Samsorg 14, to genetic make -up. The variation in plant height of

the three varieties must have also resulted in the differences in higher number and surfaces for photosynthesis (leaves) that influences the elongation of nodes and internodes as reported by Abusawar and Muhammed (1997).

Variety Samsorg 14 Significantly produced more number of leaves/Plant followed by GPOO Malawi while Samsorg 44 had the least. The higher number of leaves/plant produced by Sorghum variety Samsorg 14 could be linked to geneticmake-up that is in inherent in the crop.Consequently led to higher number and surface area for photosynthesis that influences the elongation of nodes and internodes as reported by Abusawar and Mohammed 1997). Sorghum variety Samsorg 14 produced the largest leaf area index in both seasons followed by GPOO Malawi and the least was produced by Samsorg 44. The higher LAI produced by Samsorg 14 is an indication of increase in vegetative surfaces for photosynthesis thus increased dry matter production and total dry matter per plant throughout the growing seasons.

Samsorg14 produced the highest dry matter/Plant in both years, followed by GPOO Malawi and the least was produced by Samsorg 44. The higher dry matter/Plant produced by Samsorg14 could be linked to increase in vegetative surfaces for photosynthesis thus increase dry matter production and total dry matter throughout the growing seasons. This is consistent with report of Arunah (2004). Sorghum variety Samsorg14 produced the highest CGR in both seasons followed by GPOO Malawi and Samsorg 44 had the least. The higher crop growth rate produced by Samsorg14 could be attributed to the more number of leaves per plant, more photosynthetic surfaces for assimilate production and translocation, thus affecting subsequent dry matter production and crop yield.

Sorghum variety Samsorg14 out yielded GPOO Malawi and Samsorg 44 in both seasons. The higher grain yield obtained with Samsorg14 may be due to its higher efficiency for assimilate partitioning and hence efficiency for translocation of assimilates and consequently higher grain yield as well as its higher potential for dry matter production, longer and heavier panicles, and higher grain weight per panicle. This confirms with the findings of Klidary *et al.*, (2007) Onyibe (1987), Abunyewa *et al.*, (2009) who attributed higher grain yield of Sorghum to dry matter production, Panicle weight and grain weight per panicle.

Plant height was significantly affected by planting pattern in 2007 only. Planting two Plants per stand at both side of ridge significantly produced taller plants followed by two plants per stand and planting one plant per stand had the least plant height. In 2008 varying the treatments had no significant effect on plant height. Increased Plant height as a result of high plant population possibly may be a response to greater competition for light. This supported the observation by Miko and Manga (2008) who reported increase in sorghum height with increase in Plant density. Varying planting pattern had no significant effect on number of leaves/plant in both years. The none significant difference of number of leaves/ plant might mean that adequate growth factors were equally provided to the crop at this planting patterns thereby minimizing inter-intra plant spacing competition. Similar findings were reported by Metwally *et al*.(1982) and Rowland (1993).

Planting two plants per stand at both sides of the ridge produced significantly higher leaf area index in both seasons followed by two plants per stand and the least was produced by planting one plant per stand. The higher LAI produced by two plants per stand at both sides of ridge could be attributed to efficient interception of light for the production of assimilate which largely depended on good canopy and high LAI of crop. This is consistent with the findings of (Blum and Navel, 1976,Abunyewa et al, 2009, Chaudhari, 2009 and Khalatbari et al., 2010) who reported a great decline in LAI in single rows of sorghum than double row at the later stage of growth.The highest dry matter per plant was produced at one plant per stand in both seasons followed by two plants per stand and the least was produced by planting at two plants per stand at both sides of ridge. The significant effect of planting pattern on dry matter per plant could be attributed to etiolation, since where water and nutrients are adequate radiation is the only factor likely to limit crop yield. This is consistent with the findings of Chaudhari, (2009) and Khalatbari *et al.*, 2010.

Crop Growth rate was significantly affected by planting pattern in both seasons. Planting one plant per stand significantly produced higher crop growth rate than other planting patterns followed by two plants per stand and the least was produced by two plants per stand at both sides of ridge except in 2007 when two plants per stand and two plants per stand and two plants per stand at both side of ridge were statistically similar. High plant population are necessary to intercept the maximum amount of light though after a certain point mutual shading will reduce the light available to each Plant. Planting at two plants per stand produced the highest grain yield in both seasons while plating at two plants per stand and one plant per stand were statistically similar in both seasons. The trend in grain yield response to planting pattern clearly indicated significant difference across the planting pattern in both seasons. This appeared consistent with the report of Buah et al. (2009) where they observed that sorghum planted at the highest plant density tended to grow taller, produced higher leaf area index and also flowered earlier than those planted at lower densities, but this did not significantly increased grain yield. In 2008, the significant increase in yield obtained with two plants/stand at both side of ridge over one plant/stand and two plants/stand could be linked to environmental factors such as soil moisture at the time of sowing.

Conclusion and Recommendations

Based on the results obtained in this study it could be concluded that for good growth and yield of sorghum at Samaru showed that application of 60 kg N/ha, planting of sorghum at both sides of the ridge using samsorg 14 supported good growth and development of sorghum.

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Tables

Table 1: Growth parameters of sorghum varieties as influenced by planting pattern and nitrogen rate in 2007 and 2008 rainy seasons at Samaru.

`Treatment	Plant height 12 WAS		Number of leaves per plant		Leaf area Index 12 WAS	
	2007	2008	2007	2008	2007	2008
Nitrogen Rate (kg ha^{-1})						
30	210.4b	194.1b	11.41b	9.68b	4.36c	3.70c
60	245.9a	215.9a	12.67a	10.07a	5.05b	3.89b
90	246.4a	216.5a	13.40a	10.53a	5.61a	4.11a
S.E±	0.3	0.37	0.25	0.24	0.04	0.05
Variety						
Samsorg 44	219.5c	203b	11.18c	9.09c	4.77c	3.60c
GPOO Malawi	224.5b	211.4a	12.05b	10.12b	5.03b	3.80b
Samsorg 14	230.7a	212.1a	13.91a	11.25a	5.20a	3.96a
S.E±	0.3	0.37	0.25	0.24	0.04	0.05
Planting pattern						
One plant/ stand	222.8c	207.5	12.39	10.02	4.92c	3.62c
Two plants/stand	225.2b	209.0	12.52	10.10	5.00b	3.80b
Two plants/stand at both sides of ridge.	226.7a	210.1	12.64	10.15	5.07a	3.98a
S.E±	0.43	0.59	0.33	0.42	0.02	0.03
Interaction						
N*V	NS	NS	NS	NS	NS	NS
N*P	NS	NS	NS	NS	NS	NS
V*P	NS	NS	NS	NS	NS	NS
N*V*P	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within a column are not significantly different at 5% level of significance using Duncan's Multiple Range Test (DMRT)

Table 2: Growth parameters of sorghum varieties as influenced by planting pattern and nitrogen rate in 2007 and 2008 rainy seasons at Samaru

Treatment	**Dry matter/plant 12WAS**		**Crop growth rate 12 WAS**		**Grain yield (kg/ha)**	
	2007	2008	2007	2008	2007	2008
Nitrogen Rate ($kg\ ha^{-1}$)	73.66b	58.81b	11.70c	7.66c	2096b	1779b
30	88.87a	68.87a	13.13b	9.29b	2358a	2050a
60	89.11a	69.06a	15.02a	10.59a	2378a	2073a
90	0.13	0.09	0.07	0.04	8.34	11.81
S.E±						
Variety	80.7c	64.14c	12.45c	8.60c	2204c	1807c
Samsorg 44	84.4b	65.64b	13.36b	8.98b	2243b	1965b
GPOO Malawi	86.7a	67.18a	14.03a	9.97a	2258a	2129a
Samsorg 14	0.13	0.09	0.07	0.04	8.34	11.81
S.E±						
Planting pattern	85.2a	66.19a	13.71a	9.99a	2258	1903b
One plant/ stand	83.4b	65.72b	13.09b	9.22b	2280	1908b
Two plants/stand	83.1c	65.04c	13.04b	8.24c	2295	2092a
Two plants/stand at both sides of ridge.	0.2	0.15	0.03	0.02	7.9	9.8
S.E±						
Interaction						
N*V	NS	NS	NS	NS	NS	NS
N*P	NS	NS	NS	NS	NS	NS
V*P	NS	NS	NS	NS	NS	NS
N*V*P	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within a column are not significantly different at 5% level of significance using Duncan's Multiple Range Test (DMRT)

Appendix 1: Physical and Chemical properties of soil from 0 -30 cm at Samaru during 2007 – 2008 seasons

Physical condition g/kg	**2007**	**2008**
Sand	48	53
Silt	36	35
Clay	16	12
Textural class	Sandy Loam	Sandy loam
Chemical composition		
pH in water (1:2.5)	5.20	5.45
pH in 0.1 $CaCL_2$ (1:2.5)	5.81	5.51
Organic carbon (gkg^{-1})	0.64	0.58
Total nitrogen (gkg^{-1})	0.18	0.13
Available Phosphorous ($Mg\ kg^{-1}$)	19.56	13.6
Exchangeable bases(meq/100g)		
Ca	3.70	2.76
Mg	1.49	1.15
K	0.23	0.20
Na	0.27	0.23
CEC	5.7	5.5
H + AL	0.15	0.10

Soil sample as analyzed at department of soil science ABU, Zaria.