EFFECT OF PLANT DENSITY ON THE PERFORMANCE OF TWO SORGHUM (*Sorghum bicolor* (L.) Moench HYBRIDS

BY

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A thesis submited to the Posgraduate School of Ahmadu Bello University, in partial fulfilment of the requirement for the degree of Master of Science in Agronomy

FACULTY OF AGRICULTURE
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ZARIA

OCTOBER, 1987

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DECLARATION

I hereby declare that this thesis has been written by me and that it is a record of my own research work. It has not been presented before in any previous publication for a higher degree.

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CERTIFICATION

This thesis entitled "EFFECT OF PLANT DENSITY ON THE PERFORMANCE OF TWO SORGHUM (Sorghum bicolor (L.) Moench) HYBRIDS" by Johnson Ehima Onyibe meets the regulations governing the degree of Master of Science of Ahmadu Bello University, Zaria, and is approved for its contribution to scientific knowledge and literary presentation.

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DEDICATION

This work is dedicated to my mother Mrs Comfort Onyibe for her care and to GOD for making this work possible.

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ABSTRACT

The effect of plant density on the performance of two sorghum (Sorghum bicolor (L.) Moench) hybrids, SAMSORG 28 (SSH 2) and SAMSORG 31 (SSH 5), and an open-pollinated sorghum variety SAMSORG 17 (SK5912) as a check, was studied at the Institute for Agricultural Research Farm, Samaru, during the 1986 wet season. The three cultivars were established at five plant densities (25 000, 50 000, 75 000, 100 000 and 125 000 plants/ha).

Increasing plant density from 50 000 to 100 000 plants/ha increased grain yield by 14.5%, further increase in plant density from 100 000 to 125 000 plants/ha, resulted in a 9% decrease in grain yield. Although SAMSORG 28 and SAMSORG 31 out-yielded SAMSORG 17 by 22.2% and 17.3%, respectively, and SAMSORG 28 out-yielded SAMSORG 31 by 5.9% , none of the hybrids substantially performed better than the recommended open-pollinated cultivar (SAMSORG 17). SAMSORG 31 at low plant densities of 25 000 and 50 000 plants/ha out-yielded SAMSORG 28 but showed less grain yield response to higher densities investigated.

The optimum plant densities of 98 000 and 86 000 plants/ha observed for SAMSORG 28 and SAMSORG 31, respectively, did not significantly differ from an optimum plant density of 93 000 plants/ha for SAMSORG 17. The number of panicles per square metre, leaf area index, stover yield per hectare and plant height were significantly increased by increasing plant density from 25 000 to 125 000 plants/ha. Increase in plant

density up to 75 000 plants/ha significantly increased harvest index. Also, the number of green leaves and leaf area per plant, dry weights of leaves and stem per plant, panicle weight per plant, 1000-grain weight and flag leaf area significantly decreased by increasing plant density. Apart from 1000-grain weight and number of days to 50% flowering which were higher in the open-pollinated cultivar, all the other parameters were higher in the hybrids.

Coefficient of correlation (r) between grain yield, growth and yield components, revealed that harvest index (r=0.55**) number of days to 50% flowering (r=-0.43**), grain weight per panicle (r=0.44**) and leaf area index at eleven weeks after sowing (r=0.57**) were responsible for the observed grain yield response.

Interaction between plant density and cultivar on grain yield, grain weight per panicle, lengths and weight of panicle were significant. Unlike in the two hybrids, the number of days to 50% flowering in the open-pollinated cultivar was not significantly influenced by plant density.

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Chapter 1

INTRODUCTION

In a world that is faced with an ever-growing population and limited resources for food production, grain sorghum (*Sorghum bicolor* (L.) Moench) has attracted increasing interest of both researchers and producers. It ranks fourth in importance among the world's cereals, after wheat, rice and maize (Doggett, 1970). It is grown mostly as a staple food crop in Africa and Asia and for livestock feed in America and Europe.

1.1 Production

World production of grain sorghum has been estimated at 90.6 million tonnes from about 89.5 million hectares in 1979 (Anon., 1980). In 1979, USA (the world's largest producer) had a total grain sorghum production of 27.6 million tonnes from an area of about 10.6 million hectares. Although India has the largest area sown to sorghum in the world, it ranks second to the USA in total production, with a production figure of 17.4 million tonnes from about 30.8 million hectares. Nigeria ranks third in total hectarage after India and China but sixth in total annual production after the USA, India, China, Mexico and Argentina (Anon., 1980).

Sorghum occupies about 46 % of the total land area devoted to cereal production in Nigeria, and accounts for about 50 % of the total cereal production. In 1977, about 4.8 million tonnes of sorghum grains were produced from about 6.6 million hectares, mainly in northern Nigeria (Obilana, 1981).

The total production in 1979 was about 5.5 million tonnes from about 11.6 million hectares (Anon., 1980), representing a 34.8 % drop in average production per hectare for a 75% increase in hectarage compared with the 1977 figures. In comparison with the 1979 total production for the United States, this represents approximately five times lower grain yield from an equivalent land area. The average grain yield per hectare for Nigeria in 1979 was also four times lower than those of Argentina and Mexico but half that of China (Anon., 1980).

1.2 Reasons for the Lower Average Yield of Sorghum in Nigeria

The yield of any crop is a very complex quantitative character resulting from an inter-play of different factors, many of which are agronomic. In Nigeria, increasing total annual sorghum production appears to be through increasing hectarage put to its cultivation and the adoption of recommended agronomic practices.

It is however a common practice among sorghum farmers in Nigeria to plant open-pollinated sorghum cultivars. Such open-pollinated cultivars have a low yield potential relative to the recommended hybrids. Hybrids are used in nearly all sorghum production in the United States, Mexico and Argentina and an increasing percentage in India and China (Doggett,1970). The widespread adoption of sorghum hybrids in America and its increasing adoption in Asia are as a result of their high

yield potential. For instance, the average yield potential of open-pollinated sorghum cultivars at research stations is about 2.24 t/ha (Elemo and Obilana, 1985) while that of hybrids ranges from 4.0 t/ha (Kassam, 1976) to 4.8 t/ha (Vance, 1981).

Elemo and Obilana (1985) observed that while the recommended optimum plant density for grain sorghum in Nigeria is in the range of 30 000 to 50 000 plants/ha, only about 18 000 plants/ha are commonly found on most peasant farmers' fields. Significantly higher yields are obtainable with the adoption of recommended plant densities However, the recommended optimum range is for open-pollinated varieties; a plant density range not likely to be the same for sorghum hybrids. Thus, two major reasons for the lower average yield of sorghum in Nigeria include, the absolute reliance on open-pollinated cultivars, probably due to scanty information on the agronomic requirements of the few available hybrids and the low plant densities peasant farmers often adopt.

1.3 Two Avenues for Improving Average Yield of Sorghum in Nigeria

The increasing demand for sorghum grains as an alternative or substitute for maize in poultry rations, wheat in flour mills and barley in brewing of alcoholic beverages, and as food and feed in Nigeria, calls for increased total production that cannot be met with the present low average yield of 0.633 t/ha (Elemo and Obilana, 1985). Average yield per hectare could be

improved firstly by the use of high yielding cultivars, secondly by the adoption of optimum plant density. For this reason, the usefulness of any research effort in Nigeria on any of the sorghum hybrids which are high yielding with respect to density cannot be over emphasized.

1.4 Objectives

SAMSORG 28 (SSH2) and SAMSORG 31 (SSH 5) are among the four recently developed sorghum hybrids in the Institute for Agricultural Research (I.A.R.), Samaru, which have high yield potential (Obilana, 1983). Rana and Obilana (1979), reported that their grain yield potential is about 2.9 t/ha at 37 000 plants/ha, and they emphasized that higher yields per hectare are obtainable with these hybrids at 'appropriate' (optimum) plant density. However, the optimum plant densities for the two hybrids are yet to be determined. Since sorghum cultivars could vary in their growth and yield response to different plant densities, this experiment was initiated to study among other things:

1) The effect of plant density on yield and yield components of two sorghum hybrids; SAMSORG 28, SAMSORG 31;

2) to determine the optimum plant density for the two sorghum hybrids;

3) to compare the performance of the two sorghum hybrids with an open-pollinated cultivar, SAMSORG 17 (SK5912) and

4) to study whether there are interactions between cultivars of sorghum and plant density on the various characters evaluated.

Chapter 2

LITERATURE REVIEW

The attainment of reasonable yields of grain sorghum depends, to a large extent, on adoption of good cultural practices and management. Two of the most important cultural practices reported by Doggett (1970), were adoption of optimum plant density and the use of high yielding cultivars such as hybrids. Optimum plant density is the plant density at which maximum yield is expected (Hearn, 1972). However, the optimum plant density for any given situation depends on moisture and nutrient status of the soil (Hearn, 1972), as well as on size and variability of the genotypes being sown (Wall and Ross, 1976).

2.1 Effect of Plant Density on Growth, Yield and Yield Components of Grain Sorghum

Andrews (1976), reported that the optimum plant density range for open-pollinated sorghum varieties at Samaru was 33 000 to 50 000 plants/ha. He also reported a slight decline in grain yield when plant density was increased to 66 000 plants/ha. Ogunlela and Obilana (1982) noted that plant densities of 50 000 and 100 000 plants/ha did not differ in their influence on sorghum performance except in head number, tiller number and grain number at Samaru. Also, at Samaru, Idem (1987) reported that plant density of 75 000 plants/ha significantly outyielded 50 000 and 100 000 plants/ha while Bammeke (1987) observed no grain yield response to increasing sorghum plant density up to 66 000 plants/ha. Most of the earlier works on plant density

consistently used conventional rows but varied intra-row spacings.

In India, Meliotra et al. (1979) found that increasing sorghum plant density resulted in higher grain yield up to a population level of 148 000 plants/ha, and beyond which there was a decrease. At high a population of 277 000 plants/ha and a medium population of 138 000 plants/ha, Narasiah et al. (1972), found that grain yields were statistically at par but differed significantly from a low population of 92 000 plants/ha. They obtained grain yield increases of 19.8 % and 15.4 % for 277 000 and 138 000 plants/ha respectively, over the low plant density of 92 000 plants/ha.

Thomas and French (1980) concluded that grain yield of sorghum in the range of 1.5 and 3.1 t/ha in Central Queensland, Australia, did not show a population effect on grain yield. Although they reported that densities of 80 000 to 136 000 plants/ha were equally optimum over a range of grain yield levels. Vance (1981) in Papua New Guinea, reported that grain yield increased with increase in sorghum plant density up to 281 000 plants/ha but declined at densities above this level. In Texas, a stand density thicker than 66 000 plants/ha in normal 90 - 108 cm row reduced grain yield of sorghum in a dry year (Quiby et al., 1958).

The relationship between grain sorghum yield, rainfall and optimum plant density was studied by Karper (1929). He reported that the optimum population for Kafir milo is ten times higher in wet season compared with a dry season without

irrigation. Doggett (1970) stated that competition for moisture is keenest under dry than under wet conditions. Yield is often correlated with moisture status and fertility of the soil.

Using several grain sorghum cultivars, Hoshino (1974) observed that increasing plant density reduced the number of grains per panicle. Similar result was reported by Wahua and Miller (1978), using semi-dwarf and tall sorghum cultivars. Lanjewar and Khot (1978) observed that narrow spacing between plants increased the number of panicles per net plot while Martin (1982) noted that grain yield of sorghum significantly correlated with number of panicles/m^2. However, Vance (1981) found that at a plant density of 562 000 plants/ha, 10 % of the plants failed to develop panicles. Evans (1975) stated that the size of a crop sink depends on environmental conditions at the time of its development.

While Robinson et al. (1964) observed decrease in moisture content of sorghum panicles with increase in plant density, Anon. (1982) found that the length and weight of panicles declined significantly as plant density was increased beyond 50 000 plants/ha.

Roy (1969) studied the dry matter production of the component parts of sorghum plant (CSH-1). He observed that dry matter production was essentially a function of time, irrespective of treatment. Fischer and Turner (1978) found that the total dry weight of above ground plant parts at

maturity varied from 8 t/ha at a low plant density of about 14 000 plants/ha to almost 28 t/ha at a high density of about 646 000 plants/ha. Brown and Shareder (1959), and Vecchiettini and Lambertini (1979) observed that dry matter production by a single plant leaf surface was higher at low plant density than at high plant density.

Brown and Shareder (1959) observed that row width has more effect on the height of sorghum than plant density and emphasized that spreading the plants farther apart resulted in more tillering and thus maximum leaf cover per plant. Burnside et al. (1964) reported that the heights of sorghum, planted in 25, 50, 70 and 100 cm rows were 130, 135, 137.8 and 140 cm, respectively. Their result showed decreases in plant height with increase in row width. Son (1969) reported that inter- and intra-row spacings did not influence plant height when White Collier cultivar of sorghum was sown on ridges 40-70 cm apart and at a distance of 15-40 cm within ridges.

Andrews (1976) at Samaru, observed that irrespective of row spacing, increasing plant density above 66 000 plants/ha increased the height of sorghum. He ascribed this to competition for light among the plants. Increases in the height of sorghum with increase in plant density have been reported by Clegg et al. (1970), Schulze and Clegg (1970), Wall and Ross (1976) and Vance (1981).

Tufail (1972) in Nebraska, noted that increasing plant density from 185 000 to 520 000 plants/ha reduced leaf area per plant. Raghuntha (1974) observed decrease in leaf area per sorghum plant by increasing plant density from 133 000 to 177 000 plants/ha. Reduction in leaf area per plant is sometimes suggested to be one of the reasons for decreases in dry matter production per plant with increasing plant density.

The effect of plant density on growth and yield of sorghum was studied in Mexico by Fischer and Wilson (1975). In their investigation, they found that leaf area index (LAI) for most cereal crops, often significantly correlated with total dry matter production and grain yield per hectare. However, the leaf area index for maximum dry matter yield is however different from that for maximum grain yield (Watson, 1971).

2.2 Effect of Cultivar on Growth, Yield and Yield Components of Grain Sorghum

Significant differences in grain yield potential among grain sorghum cultivars have been reported by a number of researchers. Kassam (1976) and Vance (1981) reported grain yields of 4.0 t/ha and 4.8 t/ha respectively, with the use of sorghum hybrids, while Elemo and Obilana (1985) reported an average grain yield of 2.24 t/ha with open-pollinated cultivars at a research station.

Using different sorghum varieties, Porter et al. (1960), Robinson et al. (1964), and Geraskis and Tsangeraskis (1969), reported no marked influence of cultivar on grain yield. Also, Anon. (1986), using three sorghum hybrids, found no significant effect of cultivar on grain yield. However, Chiezey (1981) who studied the physiological and morphological yield determinants of several sorghum cultivars, reported significantly different grain yield potentials of the cultivars.

Myers and Asher (1982) stated that grain yield per hectare and total dry matter yield per hectare varied greatly between cultivars having different growth durations. Goldsworthy (1970) noted that grain yield and dry matter yield per sorghum plant could depend on the height of the sorghum cultivars used. Jagannath et al.(1975) working with two sorghum hybrids, CBE-X and CSH-1, reported that CBE-X gave high grain yield because it had a higher leaf area index than CSH-1, while Prior and Russel (1976) observed that leaf area indices higher than 4.5 produced lower grain yields. Plant height, length and weight of sorghum panicle, number of days to maturity and grain size have all been reported to be significantly influenced by cultivar (Collier, 1963; Doggett, 1970 and Chiezey, 1981). In a trial with 24 sorghum cultivars, Badwal (1971) concluded that the number of green leaves per plant of each of the cultivars positively correlated with grain yield.

2.3 Interaction of Plant Density and Cultivar on Growth, Yield and Yield Components of Grain Sorghum

The performance of most of the sorghum cultivars developed at the Institute for Agricultural Research, Samaru, had often been tested by the breeders under a plant density of 37 000 plants/ha (Rana and Obilana, 1979 and Obilana, 1983). According to Tomeu and Perez (1974), who studied the effect of plant density on grain yield and its components, the practice of testing new cultivars at only one plant density could lead to erronous conclusions about their relative value. They concluded that, in order to make reliable evaluation of hybrids or varieties, different plant densities must be compared since not all varieties can be expected to respond similarly to various plant densities. Doggett (1970) was of the opinion that if sorghum genotypes respond differently to changes in plant density, genotypes selected for their superior performance under a low density might not be best for commercial production under a high density.

Tomeu and Perez (1974), and Machado et al. (1984) reported significant differences in grain yield response of different sorghum cultivars to increasing plant density up to 20 plants/m of row. In an experiment conducted by Lanjewar and Khot (1978) using two sorghum hybrids, it was observed that narrow spacing had no effect on yield of the two hybrids. Andrews (1970) reported that the best grain yield was obtained when short-statured sorghum hybrid was grown at a plant density that was

approximately twice those recommended for open-pollinated cultivars. There was a higher yield return from a hybrid 'Pioneer 846' than an open-pollinated cultivar 'Alfar' at plant densities above 188 000 plants/ha as reported by Vance (1981). Anon. (1986) and Bammeke (1987) both at Samaru, observed non-significant grain yield response of SAMSORG 31 to increasing plant density within a range of 34 000 to 100 000 plants/ha. Jagtap et al. (1983) noted that leaf area per plant, stem and leaf dry weights of sorghum increases with time (irrespective of cultivar), after which it begins to decrease. However, the number of days before decrease in leaf area and dry weight, and stem dry weight varies with varieties and may be affected by plant density (Evans, 1975 and Vance 1981).

It is however important to acknowledge that there has been enormous amount of research efforts on sorghum plant density in relation to the crop performance. The research reports so far, seem to establish the fact that response of sorghum to different plant density depends on variety and location. Perhaps, what might be optimum plant density for open-pollinated sorghum cultivars may not be for hybrids. Very little work has so far been done in Nigeria on the comparative performance of hybrids and open-pollinated sorghum cultivars at different plant densities. It is hoped that this study will serve as a pioneering work for subsequent studies into this important aspect of hybrid sorghum production.

Chapter 3

MATERIALS AND METHODS

3.1 Experimental Site

The experiment was conducted during the 1986 wet season at the Institute for Agricultural Research farm of the Ahmadu Bello University, Samaru ($11^{o}11'N$, $07^{o}38'E$ and 686 m above sea level), located in the northern Guinea savanna ecological zone of Nigeria. The climatic and soil characteristics up to a depth of 50 cm of the location are given in Appendix Table A_1 and Table 3.1, respectively. The field was sown to maize in 1983 but fallowed in 1984 and 1985. The experimental area was ploughed and disc-harrowed twice to obtain a good tilth in June, 1986.

3.2 Treatment and Experimental Design

Three sorghum cultivars, consisting of two sorghum hybrids, namely, SAMSORG 28 (SSH2) and SAMSORG 31 (SSH5), and an open-pollinated check, SAMSORG 17 (SK5912) made up the first factor. SAMSORG 28 and SAMSORG 31 have SAMSORG 17 as a common male parent. The female parent to SAMSORG 28 is the reverse cross to Farafara (RCFA) while that of SAMSORG 31 is KURGIA. The three cultivars used have drooping leaves and are semi-dwarf (Obilana, 1983). The three sorghum cultivars were established at five density levels, namely 25 000; 50 000; 75 000; 100 000 and 125 000 plants/ha at spacings of (1.0 x 0.40m), (0.75 x 0.27 m), (0.75 x 0.18 m), (0.50 x 0.20 m) and (0.5 x 0.16 m), respectively. Thus, a total combination of fifteen treatments were replicated three times in a Randomized

Complete Block Design (RCBD). The gross and net plot sizes were (9 x 6 m) and (6 x 6 m), respectively.

Table 3.1 Physico-chemical properties of the soil of the experimental site at Samaru collected up to a depth of 50 cm

Soil properties	Characteristic level Depth 0-50cm
Physical properties (%)	
Sand	60.00
Silt	25.10
Clay	14.90
Textural class - Sandy loam	
Chemical Properties	
pH in H_2O	5.8
Organic carbon %	1.15
Available phosphorus (ppm)	8.80
Total N (%)	0.063
Exchangeable cations (meq/100g soil)	
Ca	3.06
Mg	0.76
K	0.41
Na	0.13

3.3 Cultural Operations

3.3.1 Fertilizer management

Single superphosphate fertilizer (18% P_2O_5) was applied during planting at the rate of 32 kg P_2O_5/ha basally. Nitrogen fertilizer as calcium ammonium nitrate (CAN 26% N) at the rate of 90 kg N/ha was also applied, in split application with half applied at planting and the remaining half at eight weeks after sowing (WAS).

3.3.2 Planting

Planting was done on 24 June, 1986 after the rains had established. The trial was conducted on flat beds because of the variability in row width. Four seeds per hole were planted and later thinned to one plant per stand at two weeks after sowing.

3.3.3 Weed and insect pest control

Gardoprim A (atrazine and tebutylazine), a pre-emergence herbicide that was applied immediately after sowing at the rate of 4 litres/ha was not effective in controlling weeds because it rained at about an hour after it was applied. However, each plot was hoe-weeded at 4 and 8 WAS. Stem borers were controlled with carbary (Vetox 85) at the rate of 2.2 kg/ha.

3.3.4 Harvesting

Harvesting of each of the three cultivars was done at full maturity. Sorghum is matured for harvest after the development of black layer at the base of the kernels

(Chiezey, 1981). SAMSORG 28 was harvested at 132 days after sowing. SAMSORG 31 and SAMSORG 17 were harvested at 140 and 161 days after sowing, respectively. Harvesting was done by first cutting down the plants at the ground level with a cutlass, left for one day, after which the panicles were cut off with a pen knife.

3.4 Data Collection

For the purpose of determining various growth characters, samples were taken from the inner discard rows, shoot height (from the ground level to the flag leaf) at physiological maturity stage using a measuring pole from five randomly tagged plants in each plot. Leaf area per plant (Length x width at the widest point x 0.747, as described by Krishunmurthy *et al*. 1974) and leaf area index (LAI) (the ratio of leaf area per unit land area) were measured from the five tagged plants at three weeks intervals, starting from 5 WAS. For dry matter production per plant, two, four, six, eight and ten plants randomly selected (above ground level) plants parts were sampled mainly from discard rows in plots of 25 000; 50 000; 75 000; 100 000 and 125 000 plants/ha, respectively, at three weeks interval starting from five weeks after sowing. Percentage stand establishment (the ratio of actual stand count a week after thinning to expected stand count multiplied by a hundred) and the number of panicles per square meter at harvest, stem diameter and flag leaf area at milk stage were recorded.

Other parameters measured include, number of green leaves per plant (if the entire leaf surface showed up to 20% or more green coverage (visually) and the leaf was still attached to the stalk, it was considered as a green leaf), the number of days to 50% flowering, length of panicle (from flag leaf to the tip of panicle, using a metre rule) weight of panicle, grain weight per panicle, grain weight per net plot, and a thousand grain weight (by counting four sets of 250 grains from the grain yield of the net plot after grain yield figures were taken). Stover yield (weight of entire stalks of the net plot taken six weeks after harvest on the field), harvest index (ratio of grain yield to weight of unthreshed panicles plus stover yield), and threshing percentage (ratio of grain yield to weight of unthreshed panicles multiplied by a hundred) were also taken.

3.5 Statistical Analysis

All data collected were subjected to analysis of variance and the treatment means compared using the Duncan's Multiple Range Test (DMRT) (Duncan, 1955). Coefficient of correlation (r) between sorghum grain yield and growth and yield components of three sorghum cultivars were determined. Also, grain yield was regressed against plant density, and optimum plant density was determined using the equation:

$$X_{max} = \frac{-b}{2c}$$ (Thomas and Hills, 1978)

Where X_{max} = plant density at which maximum grain yield is expected i.e. optimum plant density (Hearn, 1972).

b = slope, and c = co-efficient of regression as in the quadratic equation, $Y = a+bx + cx^2$.

Chapter 4

RESULTS

4.1 Effect of Plant Density and Cultivar on Growth of Grain Sorghum

4.1.1 Number of green leaves per plant

The data on the number of green leaves per plant as influenced by plant density and cultivar at 5, 8, 11, 14 and 17 weeks after sowing (WAS) are presented in Table 4.1. Effect of plant density on the number of green leaves per plant was significant at 8, 11, 14 and 17 WAS but not at 5 WAS.

The number of green leaves per plant increased up to 14 WAS and declined thereafter. Increasing plant density significantly decreased it at 14 and 17 WAS unlike at 8 and 11 WAS. However, the differences in number of green leaves per plant at plant densities of 25 000, 50 000, 75 000 and 100 000 plants/ha at 8 WAS were not significant. The number of green leaves per plant was not influenced significantly by cultivar throughout the sampling period. Interaction between plant density and cultivar with respect to number of green leaves per plant was not significant throughout the sampling period.

4.1.2 Leaf dry weight per plant

Table 4.2 shows leaf dry weight per plant as influenced by plant density and cultivar at 5, 8, 11, 14 and 17 WAS: The data show increasing leaf dry weight per plant up to 14 WAS. Plant density had no significant

Table 4.1 Number of green leaves per sorghum plant as influenced by plant density and cultivar at Samaru, in 1986.

Treatment	Weeks after sowing (WAS)				
	5	8	11	14	17
Plant density (x1,000 plants/ha)					
25	5.6a[1]	8.8b	13.2bc	17.4a	17.0a
50	5.8a	8.8b	13.1bc	17.0a	16.2a
75	5.9a	8.8b	12.7c	15.8b	15.0b
100	6.1a	9.4ab	13.6b	15..9b	13.4c
125	6.4a	10.0a	15.3a	15.8b	12.6d
Cultivar					
SAMSORG 17*	5.5a	8.9a	13.5a	16.5a	14.8a
SAMSORG 28	6.3a	9.2a	13.5a	16.2a	14.9a
SAMSORG 31	6.0a	9.4a	13.7a	16.5a	14.8a

Table 4.2 Leaf dry weight (g) per sorghum plant as influenced by plant density and cultivar at Samaru, in 1986.

Treatment	Weeks after sowing (WAS)				
	5	8	11	14	17
Plant density (x1000 plants/ha)					
25	3.7a[1]	12.0ab	56.0a	103.3a	92.3a
50	3.8a	12.4a	48.5b	80.2b	71.3b
75	3.8a	10.3abc	50.4ab	80.4b	80.4ab
100	3.6a	10.1bc	44.9bc	54.0c	41.0c
125	3.9a	9.8c	39.8c	44.8c	42.7c
Cultivar					
SAMSORG 17*	3.6a	10.6a	45.0b	66.5b	62.5a
SAMSORG 28	3.7a	10.3a	50.9a	77.1a	66.2a
SAMSORG 31	3.9a	12.4a	47.8ab	74.1a	67.2a

[1]Means followed by the same letter(s) within a treatment and column are not significantly different at 5% level of significance using DMRT. *Open-pollinated check.

effect on leaf dry weight per plant at 5 WAS only. At 8, 11, 14 and 17 WAS, increasing plant density from 25 000 to 125 000 plants/ha decreased leaf dry weight per plant though plant densities of 100 000 and 125 000 plants/ha had statistically similar leaf dry weights per plant during the same period.

Cultivar had significant effect on leaf dry weight per plant at 11 and 14 WAS only. Leaf dry weight per plant of SAMSORG 28 was higher at 11 and 14 WAS though statistically at par with that of SAMSORG 31. SAMSORG 17 had lower leaf dry weight per plant than those of the hybrids at 11, 14 and 17 WAS. Interaction between plant density and cultivar on leaf dry weight per plant was not significant.

4.1.3 Stem dry weight per plant

The effect of plant density and cultivar on stem dry weight per plant at 5, 8, 11, 14 and 17 WAS are shown in Table 4.3. Stem dry weight of sorghum increased up to 17 WAS. Plant density effect on stem dry weight per plant was significant at 8, 11, 14 and 17 WAS but not at 5 WAS. Plant density effect did not follow any definite pattern at 8 WAS. At 11, 14 and 17 WAS, however, increasing plant density from 25 000 to 125 000 plants/ha decreased stem dry weight per plant although there was no significant difference between 100 000 and 125 000 plants/ha. Also, the differences in stem dry weight per plant at densities of 25 000, 50 000 and 75 000 plants/ha were not significant at 11 and 14 WAS. Plant density of 25 000 plants/ha nevertheless, gave significantly

higher stem dry weights at 17 WAS than higher plant densities.

Cultivar did not significantly influence stem dry weight per plant at 5 WAS compared with those at 8, 11, 14 and 17 WAS. SAMSORG 31 and SAMSORG 28 had higher stem dry weights than SAMSORG 17 throughout the sampling period. The difference in stem dry weight per plant of SAMSORG 31 and SAMSORG 28 was only significant at 17 WAS. There was no significant interaction between plant density and cultivars with respect to stem dry weight per plant.

4.1.4 *Dry matter accumulation per plant*

Table 4.4 shows the effect of plant density and cultivar on dry matter accumulation per plant. Dry matter increased up to the last sampling date. Plant density significantly influenced dry matter accumulation at all the sampling stages except at 5 WAS. Increasing plant density from 25 000 to 125 000 plants/ha decreased dry matter accumulation per plant. At 8 and 11 WAS, plant densities of 25 000, 50 000 and 75 000 accumulated the same amounts of dry matter per plant. At 14 and 17 WAS, plant density of 25 000 plants/ha had significantly higher dry matter per plant while plant densities of 50 000 and 75 000 plants/ha had similar amounts of dry matter per plant.

Cultivar effect on dry matter per plant was significant at 8, 11, 14 and 17 WAS but not at 5 WAS. SAMSORG 31 and SAMSORG 28 had significantly higher dry

Table 4.3 Stem dry weight per sorghum plant as influenced by plant density and cultivar at Samaru, in 1986.

Treatment	Weeks after sowing (WAS)				
	5	8	11	14	17
Plant density (x1,000 plants/ha)					
25	2.7a[1]	9.1ab	58.8a	174.7a	241.4a
50	2.4a	6.8c	63.8a	160.1a	210.5b
75	2.2a	10.6a	58.9a	153.4ab	190.3b
100	2.2a	8.2bc	57.3ab	124.2bc	140.9c
125	2.2a	8.7abc	45.9b	97.8c	122.0c
Cultivar					
SAMSORG 17*	2.3a	7.4b	52.3b	120.3b	150.9b
SAMSORG 28	2.3a	9.1a	58.5ab	150.6a	192.0a
SAMSORG 31	2.4a	9.6a	66.0a	156.5a	190.2a

Table 4.4 Dry matter accumulation per sorghum plant (g) as influenced by plant density and cultivar at Samaru, in 1986.

Treatment	Weeks after sowing (WAS)				
	5	8	11	14	17
Plant density (x1,000 plants/ha)					
25	6.2a[1]	21.1a	123.0a	280.0a	362.9a
50	6.2a	19.2ab	113.7ab	240.3b	313.2b
75	6.0a	21.2a	109.3ab	233.9b	297.7b
100	5.8a	18.2b	102.4b	178.2c	204.3c
125	6.0a	18.5b	85.7c	142.6d	185.2c
Cultivar					
SAMSORG 17*	5.9a	18.0b	97.3b	185.7b	242.0b
SAMSORG 28	6.0a	20.2a	109.3a	227.7a	279.9a
SAMSORG 31	6.2a	20.6a	113.9a	230.6a	296.7a

[1]Means followed by the same letter(s) within a treatment and column are not significantly different at 5% level of significance using the DMRT.

* Open-pollinated check.

matter yields per plant than SAMSORG 17. There was no significant plant density by cultivar interaction on dry matter accumulation per plant.

4.1.5 Leaf area per plant

Data on leaf area per plant as affected by plant density and cultivar are presented in Table 4.5. Plant density effect was significant only at later stages of growth (11, 14 and 17 WAS), during which increasing plant density decreased leaf area per plant. Plant density of 25 000 plants/ha had significantly higher leaf area per plant than higher densities. The leaf area per plant at plant densities of 75 000, 100 000 and 125 000 was not different significantly throughout the period of sampling. Leaf area per plant at 50 000 and 75 000 plants/ha was also statistically at par within the same period.

Cultivar had no significant influence on leaf area per plant at early (5 WAS) and late (14 and 17 WAS) stages of growth. Cultivar effect was however significant at 8 and 11 WAS. At 8 WAS, the difference between the leaf area of SAMSORG 17 and SAMSORG 28 was not significant, but both had significantly lower areas than SAMSORG 31. Similarly, at 11 WAS, the difference between the leaf area of SAMSORG 17 and SAMSORG 31 was not significant but both had significantly lower leaf area per plant than SAMSORG 28. Interaction between plant density and cultivar on leaf area per plant was not significant.

4.1.6 Leaf area index (LAI)

The result in Table 4.6 shows the leaf area index of sorghum at different sampling stages as influenced by plant density and cultivar. Leaf area index increased from 5 WAS up to 14 WAS and declined thereafter. Plant density influenced LAI significantly throughout the experimental period. Increase in plant density from 25,000 to 125 000 plants/ha increased LAI significantly.

The effect of cultivar on LAI was not significant at 5 and 11 WAS, but it was significant at 8, 14 and 17 WAS. SAMSORG 31 a had a significantly higher LAI than SAMSORG 28 and SAMSORG 17. At 8 WAS, the difference between LAI of SAMSORG 28 and that of SAMSORG 17 was not significant. At 14 and 17 WAS, SAMSORG 28 had significantly lower LAI than SAMSORG 17 and SAMSORG 31.

Interaction between plant density and sorghum cultivar on LAI was significant at 17 WAS only (Table 4.7). SAMSORG 31 at 125 000 plants/ha had the highest LAI followed by SAMSORG 17 at the same plant density. SAMSORG 28 had lower LAI than SAMSORG 17 and SAMSORG 31 at each of the five plant densities investigated. Leaf area indices of SAMSORG 31 at 75 000 plants/ha and SAMSORG 28 at 75 000 plants/ha were statistically the same. Similarly, there were no significant differences between LAI values obtained with SAMSORG 17 and SAMSORG 31 at 25 000 plants/ha on the one hand and SAMSORG 28 at 50 000 plants/ha on the other.

Table 4.5 Leaf area per sorghum plant (dm^2) as influenced by plant density and cultivar at Samaru, in 1986.

Treatment	Weeks after sowing (WAS)				
	5	8	11	14	17
Plant density (x1,000 plants/ha)					
25	12.6a[1]	24.6a	60.1a	103.9a	110.0a
50	11.8a	19.0a	46.0b	80.7b	78.4b
75	12.1a	19.8a	38.7bc	65.6bc	63.6bc
100	11.8a	19.8a	38.6c	63.9bc	58.5c
125	12.5a	20.4a	35.0c	56.9c	52.5c
Cultivar					
SAMSORG 17*	11.7a	19.6b	41.5b	78.1a	72.5a
SAMSORG 28	12.0a	19.1b	49.3a	72.2a	68.9a
SAMSORG 31	12.8a	23.5a	39.3b	78.2a	78.0a

Table 4.6 Leaf area index of sorghum as influenced by plant density and cultivar at Samaru, in 1986.

Treatment	Weeks after sowing (WAS)				
	5	8	11	14	17
Plant density (x1,000 plants/ha)					
25	0.4d	0.7e	1.6e	3.0e	3.0e
50	0.6c	1.0d	2.2d	3.8d	3.7d
75	0.9cb	1.3c	2.7c	4.5c	4.4c
100	1.1b	1.7b	3.2b	5.3b	5.0b
125	1.4a	2.3a	4.1a	6.5a	6.1a
Cultivar					
SAMSORG 17*	0.8a	1.4b	2.8a	4.8a	4.6b
SAMSORG 28	0.8a	1.3b	2.8a	4.3b	4.0c
SAMSORG 31	1.0a	1.6a	2.6a	4.9a	4.8a

[1]Means followed by the same letter(s) within a treatment and column are not significantly different at 5% level of significant using the DMRT.

*Open-pollinated check.

Table 4.7 Interaction between plant density and cultivar on leaf area index (17 WAS) of sorghum at Samaru, in 1986.

Plant density (x 1000 plants/ha	Cultivars		
	SAMSORG 17	SAMSORG 28	SAMSORG 31
25	3.0ij[1]	2.8j	3.1ij
50	3.9h	3.3i	4.0h
75	4.8ef	3.9h	4.5fg
100	5.1de	4.3g	5.4cd
125	6.0b	5.5c	6.9a

Table 4.8 Effect of plant density and cultivar on plant height, stem diameter, flag area, percentage stand establishment, and number of panicles per square metre of sorghum at Samaru, in 1986.

Treatment	Plant height (m)	Stem diameter (cm)	Flag leaf area (cm^2)	Percentage stand establishment	Number of panicles per square metre
Plant density (x1,000 plants/ha)					
25	1.5c[1]	3.8a	2.1a	95.0a	1.8e
50	1.6bc	3.7a	2.2a	94.0a	3.8d
75	1.7ab	3.4a	1.9a	94.0a	5.6c
100	1.8a	2.7b	1.5b	93.0a	7.4b
125	1.8a	2.5b	1.5b	92.4a	9.2a
Cultivar					
SAMSORG 17*	1.7ab	3.2a	1.7b	94.0a	5.6a
SAMSORG 28	1.6b	3.3a	2.0a	93.2a	5.5a
SAMSORG 31	1.8a	3.3a	1.8a	93.0a	5.6a

[1]Means followed by the same letter(s) within a treatment and column are not significantly different at 5% level of significance using DMRT.

* Open-pollinated.

4.1.7 Plant height

The effect of plant density and cultivar on the height of sorghum measured at physiological maturity is shown in Table 4.8. Increasing plant density from 25 000 to 125 000 plants/ha significantly increased plant height although, the difference in plant height at plant densities of 75 000, 100 000 and 125 000 plants/ha were not significant.

Cultivar had significant effect on plant height. SAMSORG 31 was tallest followed by SAMSORG 17 though, the difference between their heights was not significant. SAMSORG 28 was shorter than SAMSORG 17, although the difference was not significant. Plant density and cultivar interaction on plant height was not significant.

4.1.8 Stem diameter

The result on the effect of plant density and cultivar on stem diameter measured at milk stage is shown on Table 4.8. While cultivar had no significant effect on stem diameter increasing plant density from 25 000 to 125 000 plants/ha decreased stem diameter significantly. At plant densities of 25 000, 50 000 and 75 000 differences were not significant. There was no significant plant density by cultivar interaction on stem diameter at milk stage.

4.1.9 Flag leaf area

In Table 4.8 is also shown the effect of plant density and cultivar on flag leaf area of sorghum recorded at milk stage. Increase in plant density above 75 000 significantly

decreased flag area. At plant densities of 100 000 and 125 000plants/ha flag leaf area were statistically the same.

Cultivar had significant effect on flag leaf area. Flag leaf area of SAMSORG 28 was larger than that of SAMSORG 31 although not significantly. SAMSORG 17 had significantly smaller flag leaf area than each of the two hybrids. Interaction between plant density and cultivar on flag area was not significant.

4.1.10 Percentage stand establishment

The result on percentage stand establishment as influenced by plant density and cultivar recorded one week after thinning is shown in Table 4.8. Plant density, cultivar and their interaction did not significantly influence percentage stand establishment of sorghum, though there were slight decreases as plant density was increased.

4.1.11 Number of panicles per square meter

In Table 4.8 is shown the effect of plant density and cultivar on number of panicles per square meter at harvest. The three cultivars had similar numbers of panicles/m^2 at harvest while each plant density level had significantly different number of panicles/m^2. There was increased number of panicles with increase in plant density. Interaction between cultivar and plant density on the number of panicles/m^2 at harvest was not significant.

4.1.12 Number of days to 50% flowering

Table 4.9 shows the result of plant density by cultivar interaction on number of days to 50% flowering. Increasing plant density from 25 000 to 125 000 plants/ha significantly decreased the number of days to 50% flowering of sorghum. However, the difference in the number of days to 50% flowering as influenced by plant densities of 50 000 and 75 000 plants was not significant. Similarly, plant densities of 100 000 and 125 000 plants/ha had the same number of 50% flowering statistically.

Effect of cultivar on number of days to 50% flowering was significant. SAMSORG 28 attained 50% flowering at a significantly earlier date than SAMSORG31 which inturn attained 50% bloom earlier than SAMSORG 17.

Interaction between plant density and cultivar had significant effects on number of days to flowering. Number of days to 50% flowering in SAMSORG 17 was unaffected by increasing plant density in this experiment, unlike the two hybrids in which there were significant effect.

4.2 Effect of Plant Density and Cultivar on Yield and Yield Components of Grain Sorghum

4.2.1 Grain yield

Grain yield in tonnes per hectare was significantly influenced by plant density and by cultivar (Table 4.10). Increasing plant density from 25 000 to 100 000 plants/ha increased grain yield from 1.35 to 3.11 t/ha but grain yield

Table 4.9 Effect of plant density, cultivar and their interaction on the number of days to 50% flowering of sorghum at Samaru, in 1986

Plant density (x1,000 plants/ha)	Cultivars			
	SAMSORG 17*	SAMSORG 28	SAMSORG 31	Mean
25	128.7a	99.7e	113.7b	114.0a
50	128.0a	99.3d	111.0b	112.8b
75	128.0a	97.3de	111.0b	112.1b
100	127.7a	96.0e	106.3c	110.0c
125	127.7a	95.7e	106.0c	109.8c
Mean	128.0a	97.6c	109.6b	

Table 4.10 Effect of plant density, cultivar and their interaction on sorghum grain yield (t/ha) at Samaru, in 1986.

Plant density (x1,000 plants/ha)	Cultivars			
	SAMSORG 17*	SAMSORG 28	SAMSORG 31	Mean
25	1.28f[1]	1.37f	1.39f	1.35d
50	2.46e	2.63ec	2.88c	2.66c
75	2.44e	3.47ab	3.37ab	3.09a
100	2.53de	3.57a	3.24b	3.11a
125	2.48de	3.33ab	2.72cd	2.84b
Mean	2.24c	2.88a	2.71a	

[1]Means followed by the same letter(s) within a treatment are not significantly different at 5% level of significance using the DMRT.

*Open-pollinated check.

declined significantly as plant density was increased to 125 000 plants/ha. However, grain yields at 75 000 and 100 000 plants/ha were at par, though slightly higher at 100 000 plants/ha.

The hybrids significantly out-yielded the open-pollinated cultivar. Comparing the hybrids, SAMSORG 28 was significantly superior to SAMSORG 31 in terms of grain yield.

Interaction between plant density and cultivar on grain yield was significant. Grain yield of the three sorghum cultivars increased significantly with increasing plant density but declined at very high densities. With SAMSORG 28, though there was a decline in grain yield at plant density of 125 000 plants/ha, the reduction was not significant. Reduction in grain yield in SAMSORG 31 was observed as plant density was increased above 75 000 plants but significant reduction occured at a plant density above 100 000 plants/ha. Grain yield of SAMSORG 17 increased with increasing plant density up to 100 000 plants/ha although at plant densities of 50 000, 75 000, 100 000 and 125 000 plants/ha grain yields were statistically the same.

Grain yield of each of the hybrids indicated better response to plant densities than SAMSORG 17. At lower densities of 25 000 and 50 000 plants/ha, SAMSORG 31 gave higher grain yields than SAMSORG 28, but at densities above 50 000 plants/ha it gave a lower grain yield than SAMSORG 28. However, the difference between the grain yields of the two hybrids was only significant at a plant density of 125 000 plants/ha.

4.2.2 Grain weight per panicle

The result on the influence of plant density, cultivar and their interaction on grain weight per panicle is presented in Table 4.11. Increasing plant density from 25 000 to 125 000 plants/ha decreased grain weight per panicle of each of the three cultivars. There was no significant difference in grain weight per panicle of the two hybrids at each of the plant densities except at 125 000 plants/ha.

The grain weight per panicle of SAMSORG 28 was higher than that of SAMSORG 31. The hybrids had significantly higher grain weight per panicle than the open-pollinated cultivar at each of the plant densities.

4.2.3 Panicle weight per hectare

Increasing plant density increased panicle weight per ha significantly (Table 4.12). There was no significant difference in panicle weight/ha of SAMSORG 28 and SAMSORG 31 though that of SAMSORG 28 was higher. The hybrids had significantly higher panicle weight /ha than the open-pollinated cultivar.

Interaction between cultivar and plant density on panicle weight /ha was significant. Increase in panicle weight/ha with increase in plant density was higher with the hybrids than with the open-pollinated cultivar. Comparing the two hybrids, SAMSORG 28 had lower panicle weight /ha at plant densities of 25 000 and 50 000 plants/ha but had higher panicle weight /ha at densities above 50 000 plants/ha than

Table 4.11 Effect of plant density, cultivar and their interaction on grain weight per sorghum panicle (g) at Samaru, in 1986.

Plant density (x1,000 plants/ha)	Cultivars			
	SAMSORG 17*	SAMSORG 28	SAMSORG 31	Mean
25	68.5b[1]	76.8a	76.9a	74.1a
50	64.8b	71.1ab	77.5a	71.2a
75	45.3cd	65,8b	64.1b	58.4b
100	38.0ef	52.3c	47.1cd	45.8c
125	29.6g	40.5de	32.4fg	34.2d
Mean	49.3b	61.3a	59.6a	

Table 4.12 Effect of plant density, cultivar and their interaction on panicle weight per hectare (t/ha) of sorghum at Samaru, in 1986.

Plant density (x1,000 plants/ha)	Cultivars			
	SAMSORG 17*	SAMSORG 28	SAMSORG 31	Mean
25	1.5h[1]	1.6h	1.6h	1.5e
50	3.0g	3.0fg	3.3fg	3.1d
75	3.3f	4.3d	4.2d	4.0c
100	3.8e	5.0b	4.8bc	4.5b
125	4.5cd	5.6a	4.8bc	5.0a
Mean	3.2b	3.9a	3.8a	

[1]Means followed by the same letter(s) within a treatment are not significantly different at 5% level of significance using the DMRT.

*Open-pollinated check.

SAMSORG 31. However, the difference between their panicle weights/ha at each of the plant densities was not significant except at 125 000 plants/ha.

4.2.4 Panicle weight per plant

The effect of plant density cultivar and their interaction on panicle weight per plant was significant (Table 4.13). Panicle weight per plant of the three cultivars were decreased significantly with increasing plant density, but the degree of reduction was higher in the open-pollinated variety than in the hybrids. SAMSORG 28 and SAMSORG 31 had statistically the same panicle weight per plant though that of SAMSORG 28 was higher. The hybrids had significantly higher panicle weights per plant than the open-pollinated cultivar. Among the hybrids, there were no significant differences in panicle weight per plant at each of the plant densities tested except at 125 000 plants/ha.

4.2.5 Panicle length

Length of sorghum panicle was significantly influenced by plant density, cultivar and their interaction (Table 4.14). Increasing plant density above 50 000 plants/ha significantly reduced length of panicle. However, the differences between lengths of panicle at 100 000 and 125 000 plants/ha were not significant.

At each of the plant densities, the hybrids had significantly longer panicles than the open-pollinated cultivar. In the hybrids, significant reduction in length of

Table 4.13 Effect of plant density, cultivar and their interaction on panicle weight per sorghum plant(g) at Samaru, in 1986.

Plant density (x1,000 plants/ha)	Cultivars			
	SAMSORG 17*	SAMSORG 28	SAMSORG 31	Mean
25	83.2abc	89.4a	88.2ab	86.9a
50	78.8cd	81.6abcd	88.7ab	83.1a
75	61.9fg	79.6cd	81.3bcd	74.3b
100	56.0gh	74.0de	69.4ef	66.5c
125	53.8h	67.6ef	57.4gh	59.6d
Mean	66.7b	78.4a	77.0a	

Table 4.14 Effect of plant density, cultivar and their interaction on sorghum panicle length (cm) at Samaru, in 1986.

Plant density (x1,000 plants/ha)	Cultivars			
	SAMSORG 17*	SAMSORG 28*	SAMSORG 31	Mean
25	36.2c[1]	39.4a	37.1abc	37.6a
50	35.8c	39.1ab	36.6bc	37.2a
75	31.5de	37.8abc	37.4abc	35.6b
100	29.1e	36.2c	32.0d	32.4c
125	29.3e	35.1c	29.7de	31.4c
Mean	32.41c	37.5a	34.5b	

[1]Means followed by the same letter(s) within a treatment are not significantly different at 5% level of significance using the DMRT.

*Open-pollinated check.

panicle occurred at plant densities above 75 000 plants/ha while in the open-pollinated cultivar, significant reduction occurred at plant densities above 50,000 plants/ha. However, SAMSORG 28 had longer panicles than SAMSORG 31 at each of the densities investigated. The panicle length of SAMSORG 28 at the highest plant density of 125 000 plants/ha was statistically the same with those of SAMSORG 17 at the lowest plant density of 25 000 plants/ha.

4.2.6 A thousand grain weight .

SAMSORG 17 had significantly higher 100-grain weight than the hybrids (Table 4.15). One thousand grain weight of SAMSORG 31 was significantly lower than that of SAMSORG 28. Increasing plant density reduced 1000-grain weight of sorghum significantly. At lower plant densities of 25 000 and 50 000 plants/ha, 1000-grain weight was statistically the same. Also, 1000-grain weights at densities of 100 000 and 125 000 plants/ha were not significantly different. Interaction between plant density and cultivar on 1000-grain weight was not significant.

4.2.7 Threshing percentage

Increasing plant density above 50 000 plants/ha significantly decreased threshing percentage (Tabel 4.15). The hybrid had significantly higher threshing percentage than the open-pollinated. The difference between the threshing percentage of SAMSORG 28 and SAMSORG 31 was not significant. Interaction between plant density and cultivar was not significant.

Table 4.15 Effect of plant density and cultivar on a thousand grain weight, threshing percentage, harvest index and stover yield of sorghum at Samaru, in 1986.

Treatment	A thousand grain weight(g)	Threshing percentage	Harvest index	Stover yield (t/ha)
Plant density (x 1,000 plants/ha)				
25	27.4a[1]	82.2a	0.22c	4.5e
50	27.3a	84.2a	0.29a	5.9d
75	25.8b	77.4b	0.30a	6.5c
100	24.1c	68.6c	0.26b	7.6b
125	23.5c	47.0d	0.21c	8.5a
Cultivar				
SAMSORG 17*	27.4a	71.6b	0.23c	6.6a
SAMSORG 28	25.7b	77.2a	0.28a	6.5a
SAMSORG 31	23.7c	75.3a	0.26b	6.7a

[1]Means followed by the same letter(s) within a treatment and column are not significantly different at 5% level of significance using the DMRT.

*Open-pollinated check.

4.2.8 Harvest index (H.I.)

Increase in plant density significantly increased harvest index (Table 4.15). However, the increase in HI declined as plant densities were increased above 75,000 plants /ha. The hybrids had significantly higher harvest index than the open-pollinated cultivar. Between the two hybrids, SAMSORG 28 had significantly higher HI than SAMSORG 31. Plant density and cultivar interaction on harvest index was not significant.

4.2.9 Stover yield per hectare

Stover yield in tonners per hectare was significantly increased by increasing plant density from 25 000 to 125 000 plants/ha (Table 4.15). The cultivars had similar amount of stover yield per hectare. There was no significant interaction between plant density and cultivar on stover yield.

4.2.10 Correlation and regression

Combined correlation analysis (over cultivars) of some of the parameters indicated that there were significant positive correlations between grain yield and LAI at 11 WAS (r=0.57**), at 17 WAS (r=0.50**), number of panicles/m^2 (r=0.68**), harvest index (r=0.55**) (Table 4.16). On the other hand, number of days to 50% flowering, stem diameter, grain weight per panicle and 1000-grain weight were all significantly negatively correlated with grain yield (r=-0.43** -0.39**, -0.32** and -0.44**), respectively. Other parameters,

Table 4.16 Coefficient of correlation(r) between sorghum grain yield, growth, and yield components of three sorghum cultivars (SAMSORG 17, SAMSORG 28 and SAMSORG 31).

	Grain yield	LAI 11 WAS	LAI 17 WAS	No. of days to 50% flowering	Stem diameter	No. of panicle /m2	Plant height	Panicle weight/ plant	Grain weight /panicle	1000-grain weight	Harvest index
Grain yield	1										
LAI 11 WAS	0.57**	1									
LAI 17 WAS	0.50**	0.88**	1								
No. of days to 50% flowering	-0.43**	-0.18	0.10	1							
Stem diameter	-0.39**	-0.77**	-0.77**	0.07	1						
No. of panicle/m2	0.68**	0.91**	0.92**	-0.14	-0.81**	1					
Plant height	0.16	0.40**	0.51**	0.19	-0.35*	0.43**	1				
Panicle weight /plant	-0.24	-0.73**	-0.81**	-0.22	0.73**	-0.81**	-0.49**	1			
Grain weight/ panicle	-0.32*	-0.83**	-0.88**	-0.12	0.79**	-0.89**	0.50**	0.96**	1		
1000-grain weight/panicle	-0.44**	-0.50**	-.0.63**	-0.23	0.58**	-0.61**	-0.34**	0.37**	0.45**	1	
Harvest index	0.55**	-0.24	-0.33*	-0.34*	0.38**	-0.18	-0.28	0.47**	0.50**	0.16	1

* significant at 5% level of probability. Values higher than 0.31 are significant at 5% level of probability.

**significant at 1% level of probability. LAI = leaf area index. WAS = weeks after sowing.

such as flag leaf area, panicle weight per plant, panicle length did not correlate with grain yield.

Number of 50% flowering was negatively correlated with most of the yield components, harvest index was positively correlated with panicle weight per plant (r=0.47**).

Sorghum grain yield was regressed on plant density. The observed and estimated grain yield (linear and quadratic responses) at different plant densities for the three cultivars combined, and separately for SAMSORG 17, SAMSORG 28 and SAMSORG 31 are shown in Tables 4.17a, 4.17b, 4.17c and 4.17d, respectively. Grain yield responses of the cultivars to increasing plant density revealed that quadratic response was higher than linear response. The coefficient of determination (R^2) indicated that in combined analysis, linear response was 42.8% while quadratic response was 78.1%. In SAMSORG 17, linear response was 51% while quadratic response was 85%. Similarly, In SAMSORG 28 and SAMSORG 31, Linear and quadratic responses were 68% and 98.5%, and 35.1% and 94.1%, respectively. However, linear and quadratic responses were significant at 5% level of probability. The mean percentage difference between estimated (quadratic) and observed grain yields for each of the three cultivars and even for combined were less than 1% (Table 4.17a, b, c and d).

The curve of the regression analysis (Fig. 1) indicated an optimum plant density range of 75 000 to 100 000 plants/ha. Using the equation:

$$X_{max} = \frac{-b}{2c}$$

Table 4.17a Observed and estimated combined grain yield of three sorghum cultivars as influenced by plant density at Samaru, in 1986.

Plant density (x1,000 plants/ha)	Grain Yield (t/ha)		
		Estimated	
	Observed	Linear	Quadratic
25	1.35	1.93	1.41(+4.26%)
50	2.06	2.28	2.53(-5.14%)
75	3.09	2.63	3.13(1.38%)
100	3.13	2.98	3.21(3.12%)
125	2.84	3.33	2.79(-2.15%)
R^2		0.42	0.78
		Mean	(0.29%)

Table 4.17b Observed and estimated grain yield of SAMSORG 17 (Open pollinated sorghum cultivar) as influenced by plant density at Samaru, in 1986.

Plant density (x1,000 plants/ha)	Grain Yield (t/ha)		
		Estimated	
	Observed	Linear	Quadratic
25	1.28	1.75	1.41(+9.21%)
50	2.46	1.99	2.16(-13.80%)
75	2.44	2.24	2.57(+5.06%)
100	2.53	2.49	2.66(+4.52%)
125	2.48	2.74	2.40(-3.77%)
R^2		0.51	0.85
		Mean	(0.25%)

R^2 = Multiple coefficient of determination.

Figures in parenthesis indicate % difference between quadratic estimated and observed grain yields.

Table 4.17c Observed and estimated grain yield of SAMSORG 28 (Sorghum hybrid) as influenced by plant density at Samaru, in 1986.

Plant density (1x1,000 plants/ha)	Grain Yield (t/ha)		
		Estimated	
	Observed	Linear	Quadratic
25	1.37	1.91	1.37(0.00%)
50	2.63	2.39	2.66(+1.13%)
75	3.47	2.88	3.41(-1.76%)
100	3.57	3.36	3.63(+1.65%)
125	3.33	3.85	3.31(-0.60%)
R^2		0.88	0.98
		Mean	0.08%

Table 4.17d Observed and estimated grain yield of SAMSORG 31 (Sorghum hybrid) as influenced by plant density at Samaru, in 1986.

Plant density (x1,000 plants/ha)	Grain Yield (t/ha)		
		Estimated	
	Observed	Linear	Quadratic
25	1.39	2.12	1.46(+4.79%)
50	2.88	2.42	2.75(-4.73%)
75	3.37	2.72	3.38(+0.30%)
100	3.24	3.02	3.35(+3.28%)
125	2.72	3.32	2.66(-2.26%)
R^2		0.32	0.94
		Mean	(0.28%)

R^2 = Multiple coefficient of determination.

Figures in parenthesis indicate % difference between quadratic estimated and observed grain yields.

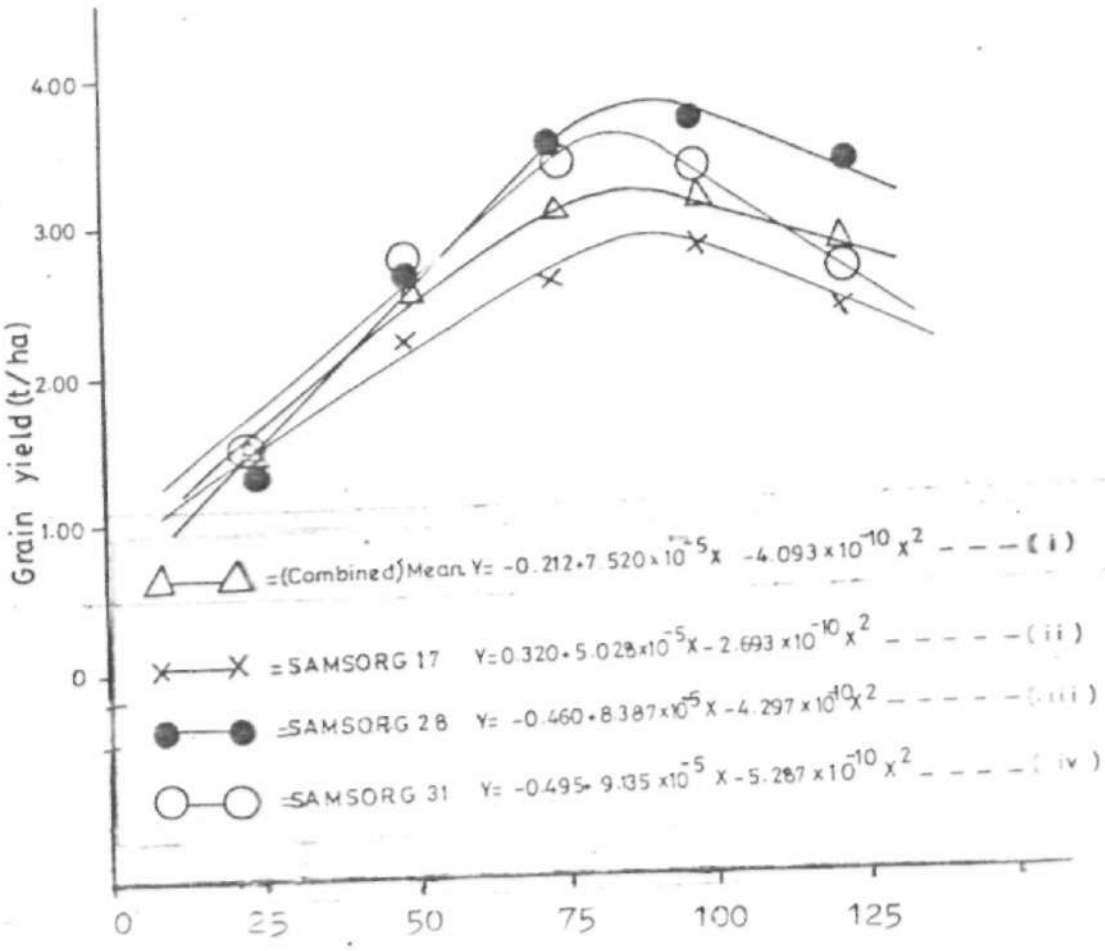


Figure 1. Regression of sorghum grain yield (estimated) on plant density at Samaru, in 1986.

(Where X_{max} = optimum plant density at which maximum grain yield is expected, b = slope and c = coefficient of the quadratic regression curve), the optimum plant density indicated for SAMSORG 17 was 93 000 plants/ha, for SAMSORG 28 was 98 000 plants/ha and for SAMSORG 31 was 86 000 plants/ha.

Chapter 5

DISCUSSION

5.1 Effect of Plant Density

The trend in grain yield response to plant density clearly indicated 14% increase in grain yield when plant density was increased from 50 000 to 75 000 plants/ha but only 0.6 % increase when plant density was in increase from 75 000 to 100 000 plants/ha. At a stand of 125 000 plants/ha, substantial loss of potential yield up to 9% was also indicated.

Reports by Andrews (1976) that loss of potential grain yield up to 19% when plant density was increased from 50 000 to 60 000 plants/ha and by Bammeke (1987) who reported insignificant response of SAMSORG 31 (SSH 5) to plant density up to 66 000 plants/ha both at Samaru, does not agree with the present finding. The difference between the result obtained in this experiment and theirs, may be due to differences in soil characteristics of the experimental sites in which each of the experiments was conducted, differences in rainfall pattern during each experimental period and differences in row spacings. For instance, Bammeke (1987) reported that the soil of the experimental site on which her experiment was conducted in 1985, had pH in water of 4.8, organic carbon percentage of 0.6 and 42% sand which were all lower than the result obtained in this experiment (Table 3.1). Availability of most crop growth elements in a soil for good crop growth often depend on the pH of the soil.

With increasing plant density, panicle weight per plant, grain weight per panicle, panicle length, 1000-grain weight, number of green leaves per plant, leaf area per plant and flag leaf area decreased. Decrease in number of green leaves at certain stages of growth with increasing plant density may be due to shading effect, which tended to make the lower leaves to senesce prematurely. The drop in number of green leaves per plant at 17 WAS was probably due to aging effect. Also, inter- and intra-plant competition for light, moisture, nutrient and assimilate could result in development of smaller leaves. Reduction in leaf size and hence decrease in leaf area per plant and flag leaf area might have occassioned the reductions in panicle length, panicle weight per plant, grain weight per panicle and 1000-grain weight that may account for low grain yield per plant or even per hectare at certain high plant densities. Results of studies elsewhere reported by Stern (1968), Schulze and Clegg (1970), Clegg et al.(1970), Andrews (1976), Wall and Ross (1976) and Vance (1981) support the present finding.

Gould and Sastry (1974), Makumbi and Rubarhayo (1978) and also Watson (1971) believed that development of a good canopy with a high LAI is vital to efficient interception of solar radiation and hence for the manufacture of assimilates. However, very high LAI has been reported to have negative consequence on grain yield as lower leaves tend to photosynthesize below compensation point and may parasitize on upper ones for assimilates meant for grain filling. This may be so pronounced as to cause a reduction in grain yield

per plant or per hectare, reduction in stem diameter at certain high plant densities as in this study or a lack of grain yield response to increase plant density (Anon., 1986 and Bammeke, 1987).

Prior and Russel (1976) found that grain yield was higher at LAI of 2.9 than at 4.6 in maize. This value is lower than the results obtained at higher plant densities in this experiment, suggesting that the decline in grain yield at these densities may be due to low rate of photosynthesis of the lower leaves. On the other hand, the high LAI obtained at higher densities might have been responsible for the high stover yield obtained at these densities. This implies that LAI required for maximum grain yield may substantially differ from that needed for maximum stover yield. The increase in LAI with increasing plant density and increase in stover yield with increasing density conforms with report by Fischer and Wilson (1975) for sorghum in Mexico.

Increase in plant density shortened the time from sowing to flowering probably because of inter-plant competition for light, nutrient and moisture, which must have been greater at higher plant densities than at lower plant densities. Clegg et al. (1970) and Vance (1981) observed that development of sorghum was not affected at plant densities below 50 000 plants /ha but showed a shortening of time to flowering with higher densities in studies which included plant density of 75 000 plants/ha. These findings are similar to the results presented in this experiment.

The observed increase in plant height with increase in plant density agrees with reports by Wall and Ross (1976), Clegg et al. (1970) and Vance (1981). Andrews (1976) ascribed increases in plant height with increase in plant density to competition for light. Goldsworthy (1970) reported that shorter sorghum cultivars were more efficient in accumulation and storage of dry matter in grain. This could be one of the reasons for the higher grain weight per plant obtained from shorter plants at lower densities than taller ones of higher densities. Reports by Graham and Lessman (1968), Saukaran and Kalliapa (1974), Pasha and Munshi (1974), and Louswan and Atkins (1978) that taller plants gave higher dry matter per plant than shorter ones is at variance with the result obtained probably because taller plants in this experiment had thinner stems.

One of the indices (harvest index) currently in use in evaluating crop partitioning efficiency which can in turn be used to predict yielding ability and tolerance to high plant density (Fischer and Kertesz, 1976), was found to increase with increasing plant density up to 75 000 plants/ha but declined at densities above this level. Overall, therefore, this seems to suggest that the tendency for plants to accumulate dry matter in plant parts other than the grain at high and at very low densities is higher than at average densities. Vance (1981) found that at very high plant density of 562 000 plants/ha most of the sorghum plants did not develop any panicle a finding that is corroborated by the result of the present experiment.

The non-significant results of plant density effect on most growth parameters observed at initial stages (5 WAS) might be explained on the basis of growth curve which is sigmoid in nature. At early stages, growth is generally slow. However, the differences became distinct at advanced growth stages. A critical look at the data revealed that leaf dry weight per plant, leaf area per plant and LAI decreased at 17 WAS while stem dry weight per plant and dry matter accumulation per plant increased progressively. The increase was due to contined increase in storage of dry matter in the stem. The reductions in leaf dry weight per plant, stem dry weight per plant and dry matter accumulation per plant as plant density increased were due to reduction in size of the plant as a result of both inter- and intra-plant competitions. Similar findings had been reported by Doggett (1970), Fischer and Wilson (1975), and Fischer and Turner (1978). Some of the older leaves had fallen off the plant at 17 WAS, thus accounting for the decline in values of parameters that were obtained from leaves at the same period.

5.2 Effect of Cultivar

The result obtained in the present experiment revealed that each of the hybrids, namely, SAMSORG 28 and SAMSORG 31, was superior to the open-pollinated cultivar; SAMSORG 17, with respect to grain yield by margins of 22.2 % and 17.3%, respectively. Yield superiority of these hybribds over SAMSORG 17 had earlier been reported by Obilana (1983) and confirmed by the present result.

The high grain yields obtained with the hybrids may be due to their higher potential for dry matter production, longer and heavier panicles, higher grain weight per panicle, larger flag leaf area than SAMSORG. 17. Also, the hybrids; SAMSORG 28 and SAMSORG 31, mature earlier by about 26 and 16 days, respectively, and both had lower 1000-grain weight than the open-pollinated cultivar (SAMSORG 17) that may have contributed to the grain yield differences. Variations in these parameters among sorghum cultivars have been reported to cause differences in grain yield (Collier, 1963; Gardener, 1966; Dalton, 1967; Goldsworthy, 1970; Clegg **et** al., 1973; Evans, 1975; Jagannath et al., 1975; Chiezey, 1981; Myers and Asher, 1982) which agrees with the present finding.

Inspite of the higher stem and leaf dry weights per plant obtained with the hybrids, their stover yields were statistically the same with that of SAMSORG 17. This occurred probably because the hybrids have a greater capacity to mobilize assimilates stored in the stem and leaves into grains than the open-pollinated cultivar, which may have accounted for their higher panicle weights. Hume and Campbell (1972) reported that the contribution of stored assimilates mobilized from the stalk of maize to final grain yield is up to 20%. Johnson and Tanner (1972) found that mobilization of assimilates into grains is higher in hybrids than in inbred, an observation which is in agreement with this result. Also, continuous storage of assimilate in the stem and leaves of SAMSORG 17

even after the hybrids had stopped accumulating dry matter could account for the lack of differences in their stover yields/ha.

Evans (1975) concluded that grain size of cereals are large when the sink is small and duration of grain filling is long. Chiezey (1981) reported that among over ten sorghum cultivars he evaluated for physiological and morphological yield determinants at Samaru, SAMSORG 17 had the longest grain filling period. In this experiment SAMSORG 17 had short panicles relative to those of the hybrids. It's larger 1000-grain weight may be explained with the case in which smalls sink (panicle) was filled in a longer period. Also its larger 1000-grain weight indicates that it has larger seeds. However, the length of panicle may depend on the conditions of the crop environment before or at the time of flowering (Evans, 1975).

Clegg et al. (1973) found that early maturing sorghum varieties out-yielded late maturing varieties because moisture became limiting at the later part of the growing season. Dalton (1967) pointed out that grain yields of late maturing sorghum varieties can be significantly lower than those of early maturing varieties, especially where there are limiting elements of the environment. These agree with the present finding because during the 1986 growing (wet) season the rains ceased 27 days before SAMSORG 17 attained 50% flowering while the hybrids had passed this stage significantly. It is thus possible that moisture stress may have developed later in the season, which adversely affected the performance of SAMSORG 17.

The harvest index values of 0.28 obtained with SAMSORG 28, 0.26 with SAMSORG 31 were significantly higher than 0.23 obtained with SAMSORG 17, respectively. According to Richard and Crookston (1976), high harvest indices are indicators of high efficiency in assimilate partitioning. This suggests that the high yields obtained with the hybrids may be due to their higher efficiency in translocating assimilates into grains than the open-pollinated cultivar.

Between the two hybrids, SAMSORG 28 gave 5.9% higher grain yield than SAMSORG 31. The slight yield difference could be due to the fact that SAMSORG 28 had longer and heavier panicles, shorter stem and lower LAI than SAMSORG 31. Jagannath et al. (1975) working with two sorghum hybrids, CBE-X and CSH-1, reported that CBE-X gave higher grain yield because it had higher LAI than CSH-1, which does not agree with the present result. On the other hand, Prior and Russel (1976) found a very high LAI to be counter productive while Goldsworthy (1970) reported that shorter cultivars are more efficient in accumulation and storage of dry matter in grain. Differences in the height, days to maturity and LAI between these two hybrid may have occassioned the slight grain yield superiority of SAMSORG 28. Also, their harvest index values seems to suggest that SAMSORG 28 was more efficient in assimilate partitioning.

5.3 Interaction Between Plant Density and Cultivar

Interaction between plant density and cultivar showed variation in grain yield response of each of the cultivars to increasing plant density. The result indicated that the grain yield of each of the cultivars increased by almost 50% when density was increased from 25 000 to 50 000 plants/ha, by 24.2% in SAMSORG 28, by 14.5% in SAMSORG 31 and by a loss of 0.8-% in SAMSORG 17 when plant density was increased from 50 000 to 75 000 plants/ha, respectively. When a plant density of 100 000 plants/ha was used, a marginal grain yield increase of 2.8% in SAMSORG 28 and a loss of 4 % in SAMSORG 31 was observed. Also, when density was increased from 100 000 to 125 000 plants/ha, loss in potential grain yield up to 19.3 % in SAMSORG 31, 6.7 % in SAMSORG 28 and 2 % in SAMSORG 17 was observed.

The present result indicates that the hybrids had higher grain yield response to increasing plant density than the open-pollinated cultivar, a finding which agrees with that of Andrews (1970), since SAMSORG 17 did not show any significant grain yield increase at plant densities above 50 000 plants/ha.

The effect of increasing plant density on LAI at 17 WAS, number of days to 50% flowering, length and weight of panicle and grain weight per panicle varied considerably among the three cultivars. At 17 WAS, LAI of SAMSORG 31 and SAMSORG 17 which were significantly higher than that of SAMSORG 28 at each of the densities except at the lowest density of 25 000 plants/ha, and the variations in the number of days to 50%

flowering and maturity may be responsible for the disparity in the grain yield response of three sorghum cultivars. However, the number of days to 50% flowering and maturity in the three cultivars was probably genetically controlled and since the female parents of the hybrids are early maturing, it is expected that changes in plant density would bring about changes in their rates of development. The non-significant effect of plant density on the number of days to 50% flowering in SAMSORG 17 seems to indicate that SAMSORG 17 is probably a photo-sensitive sorghum cultivar. Doggett (1970) reported findings that were similar to that reported in the present experiment.

The effect of increasing plant density on panicle characteristics of the hybrids was less obvious than on those of SAMSORG 17. Maybe environmental factors such as soil moisture status affected panicle development in SAMSORG 17 since there were no rains shortly before and at the time of its flowering. Evans (1975) believed that this observation could affect sink strength. The result also suggest that the hybrids could be more efficient than SAMSORG 17 in translocating assimilate into grains since their harvest indices were generally higher.

Comparing the hybrids, SAMSORG 28 had a grain yield advantage of 3% at 75 000 plants/ha, 9.2% at 100 000 plants/ha and 18.3% at 125 000 plants/ha over SAMSORG 31. However, at 25 000 and 50 000 plants/ha, SAMSORG 31 had grain yield advantages of 1.4% and 8.7% over SAMSORG 28, respectively.

This suggests that though, SAMSORG 31 out-yielded SAMSORG 28 at low plant densities, it may not be best for commercial production under high plant densities since it appeared to respond less to high densities.

5.4 Correlation and Regression

Negative correlations between some of the measured attributes and grain yield indicates that grain yield was limited by the supply of assimilate while the positive correlations indicates that sink size limited grain yield (Evans, 1975), but Adams (1967) pointed out that other explanations may hold when he found that with field beans, the negative correlations were highest in the highest yielding lines.

The positive correlation between the number of panicles /m^2 and grain yield seems to suggest that increasing plant density could increase grain yield. This agrees with the finding reported by Martin (1982). The negative correlation between grain yield on the one hand and number of days to 50% flowering on the other in the present experiment probably suggest that the longer the time to maturity the lower the yield. The hybrids matured earlier and gave higher yields compared with SAMSORG 17. However, Chiezey (1981) reported that late maturing sorghum cultivars gave higher grain yields than early maturing ones, a finding which does not agree with the present finding.

The significant positive correlation between grain yield on the one hand and LAI on the other, implies that a good canopy is necessary for efficient light interception, which is needed

in the manufacture of assimilate (Gour a and Dastry, 1978). This agrees with the present report since increasing plant density increased LAI and grain yield. Also, the significant positive correlations between harvest index and grain yield implies that high assimilate partitioning efficiency was necessary for high grain yield while the negative correlations between harvest index and number of days to 50% flowering revealed that partitioning efficiency decreased with increase in number of days to maturity. This probably accounted for the variations in yield responses among the three cultivars, which matured at different times.

The result of the correlation analysis therefore indicates that LAI, number of days to 50% flowering, partitioning efficiency and number of panicle/m^2 were critical in the overall performance of the three sorghum varieties.

The quadratic regression curve of sorghum grain yields against plant density indicates the optimum plant density for the three cultivars to be in-between 75 000 and 100 000 plants/ha (Fig 1). This optimum range falls within the optimum plant densities used in the United States for dry land sorghum, which range from 40 000 to 125 000 plants/ha (Wall and Ross, 1976) and in Australia, where 50 000 to 100 000 plants/ha are recommended (Consolidated Fertilizers, 1973). Stricker and Laude (1960) recommended a range of 40 000 to 75 000 plants/ha when moisture is limited. However, relatively higher densities have been found to be optimal

under dry-land conditions in other studies which does not agree with the present finding. For instance, little difference in grain yield have been found between 178 000 to 560 000 plants/ha by Nelson (1952), 158 000 to 760 000 plants/ha by Grimes and Musick (1960), Porter et al. (1960), Robinson et al. (1964), 100 000 to 150 000 plants/ha by Welch et al. (1966), 215 000 to 430 000 plants/ha by Clegg et al. (1970) and 188 000 to 218 000 plants/ha by Vance (1981). The optimum range is however, higher than 33 000 to 50 000 plants/ha reported by Andrews (1976), and 30 000 to 50 000 plants/ha recommended by Egharevba (1981) both at Samaru.

The optimum plant density for SAMSORG 17 (93 000 plants/ha) for SAMSORG 28 (98 000 plants/ha) and for SAMSORG 31 (86 000 plants/ha), respectively, indicated in this experiment agrees with Rana and Obilana (1979), who predicted that the optimum plant density for SAMSORG 28 and SAMSORG 31 would be higher than 37 000 plants/ha. But does not agree with Andrews (1970) that optimum plant density for hybrids could be twice as high as those of open-pollinated sorghum cultivars.

Doggett (1970) and Tomeu and Perez (1974) believed that optimum plant density of sorghum cultivars is genetically controlled, and since the two hybrids were both developed from a common male parent (i.e. SAMSORG 17), the slight differences in the optimum plant densities of these cultivars is understandable.

Comparing the grain yields (quadratic estimates) of SAMSORG 28 and SAMSORG 31 with that of SAMSORG 17 at the indicated optimum densities, there was a grain yield advantage of 26.2% with SAMSORG 28 and 22.2% with SAMSORG 31 over SAMSORG 17. These are however, lower than the 40% grain yield advantage with each of the two hybrids over SAMSORG 17 predicted by Obilana (1983). Perhaps with good management, the 40% grain yield advantage is achievable.

Chapter 6

SUMMARY AND CONCLUSION

An experiment was carried out in order to determine the effect of plant density on the performance of two sorghum hybrids (Sorghum bicolor (L.) Moench). The investigation was conducted during the 1986 wet season at the Institute for Agricultural Research (I.A.R.) Farm, Ahmadu Bello University, Samaru. The treatment consisted of two sorghum hybrids, namely, SAMSORG 28 and SAMSORG 31 and an open-pollinated sorghum variety - SAMSORG 17 as a check. The three sorghum cultivars were established at five density levels, namely, 25 000; 50 000; 75 000; 100 000 and 125 000 plants/ha at spacings of (1.0 x 0.4 m), (0.75 x 0.27 m), (0.75 x 0.18 m), (0.50 x 0.20 m) and (0.50 x 0.16 m), respectively. The treatments were replicated three times in a Randomized Complete Block Design (RCBD) in factorial arrangement. The seeds of the three cultivars were sown on June 24, 1986 after the rains had established.

The result indicated a 14.5 % increase in grain yield when plant density was increased from 50 000 to 100 000 plants /ha, and a 9% loss of grain yield when density was increased from 100 000 to 125 000 plants/ha. SAMSORG 28 and SAMSORG 31 out-yielded SAMSORG 17 by 22.2% and 17.3%, respectively. SAMSORG 28 out-yielded SAMSORG 31 by 5.9 %. The hybrids showed significantly higher grain yield response to increasing plant density up to 100 000 plants/ha. SAMSORG 31 at low plant densities of 25 000 and 50 000 plants/ha, out-yielded

SAMSORG 28 but showed less grain yield response to higher densities evaluated.

The optimum plant densities of 93 000 and 86 000 plants/ha observed for SAMSORG 28 and SAMSORG 31, respectively, did not seems to differ from an optimum plant density of 93 000 plants/ha for SAMSORG 17. All within a range of 75 000 to 100 000 plants/ha.

The number of panicles/m^2, leaf area index, stover yield/ha, plant height were significantly increased by increasing plant density from 25 000 to 125 000 plants/ha. Increase in plant density up to 75 000 plants/ha significantly increased harvest index. Also, the number of green leaves and leaf area per plant, dry weights of leaves and stem per plant and flag leaf area were significantly decreased by increasing plant density. Other parameters such as number of days to 50% flowering, length and weight of a panicle, grain weight per panicle and 1000-grain weight were significantly reduced by increasing plant density beyond 50 000 plants/ha. All the above mentioned growth and grain yield parameters except stover yield per hectare and number of green leaves per plant were significantly influenced by cultivar. Apart from 1000-grain weight and number of days to 50% flowering which were higher in the open-pollinated cultivar, all other parameters were higher in the hybrids.

Coefficient of correlation (r) between grain yield and growth, and yield components of the three cultivars, revealed that harvest index (r=0.55**), number of panicles/m^2 (r=0.68**),

number of days to 50% flowering (r=-0.43**), and leaf area index at eleven weeks after sowing (r=0.57**) and seventeen weeks after sowing (r=0.50**), respectively, were responsible for the observed grain yield response.

Interaction between plant density and cultivar on grain yield, grain weight per panicle and length of panicle were significant. Unlike in the two hybrids the number of days to 50% flowering in the open-pollinated cultivar was not significantly influenced by plant density.

The present investigation has shown firstly, that the performance of sorghum hybrids, namely, SAMSORG 28 and SAMSORG 31, as well as that of SAMSORG 17 (open-pollinated sorghum cultivar) is influenced by plant density. Secondly, that although the hybrids have a potential in increasing sorghum production, they cannot be recommended because their grain yield advantages over the open-pollinated cultivar at their indicated optimum plant densities were rather too low to justify the high cost of production and developing sorghum hybrids.

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Appendix table 1: Total rainfall, mean temperature, relative humidity, and sunshine hours at ten-day intervals during the period of the trial at Samaru, 1986.

Month	Days	Total rainfall (mm)	Mean temperature (°C)		Relative humidity (%)		Sunshine (hours)
			max.	min.	a.m.	p.m.	
June	11-20	22.6	30.2	20.6	74.3	55.8	9.1
	21-30	24.1	30.0	20.1	75.3	59.0	7.4
July	1-10	52.9	29.0	20.0	79.8	62.1	7.0
	11-20	49.4	27.8	19.5	83.4	67.3	6.5
	21-31	75.0	27.0	19.6	83.1	73.1	5.2
August	1-10	50.6	28.1	19.3	83.0	76.9	5.8
	11-20	94.9	28.5	19.7	84.3	66.0	7.1
	21-31	73.3	29.1	19.4	78.3	70.5	7.7
September	1-10	56.4	28.0	19.5	77.5	68.9	7.1
	11-20	81.2	29.3	18.6	72.6	64.2	8.6
	21-30	75.3	29.3	19.1	76.4	69.2	7.8
October	1-10	0.0	30.4	19.1	67.5	56.3	7.9
	11-20	0.0	31.5	15.8	45.4	45.3	9.6
	21-31	0.0	31.4	17.9	57.4	48.4	8.1
November	1-10	0.0	33.0	17.8	49.8	31.0	9.0
	11-20	0.0	30.0	12.0	24.9	22.4	8.5
	21-30	0.0	31.1	13.9	33.7	25.8	8.1
December	1-10	0.0	26.4	13.0	28.6	22.7	6.7
	11-20	0.0	27.0	12.4	24.3	20.4	6.0
	21-30	0.0	27.6	12.4	22.4	22.5	6.5
January	1-10	0.0	28.0	11.7	21.8	19.2	8.5

Source; Meteorological Unit, Institute for Agricultural Research, Samaru, Zaria, Nigeria.

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