THE EFFECT OF NITROGEN AND PLANT DENSITY ON THE AGRONOMIC PERFORMANCE OF A SORGHUM HYBRID

BY

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DECLARATION

I hereby declare that the report contained in this thesis is a result of my original work and was not written for me or copied from elsewhere, except where assistance and references were contacted, which have been fully acknowledged. This thesis is, therefore, a record of my work and has not been presented before in any previous application for a higher degree.

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CERTIFICATION

This thesis entitled "THE EFFECT OF NITROGEN AND PLANT DENSITY ON THE AGRONOMIC PERFORMANCE OF A SORGHUM HYBRID" by M. O. Bammeke 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 dear husband,

Adeyinka and our children, Temitope and Oluwafemi.

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ABSTRACT

A field experiment was conducted at Samaru during the 1985 wet season with a view to determining the effect of nitrogen fertilization and plant density on the agronomic performance of sorghum hybrid SAMS0RG 31 (SSH5). The treatments that were tested in the study involved the factorial combinations of five nitrogen application rates (0, 30, 60, 90 and 120kg N/ha) and three plant population levels (34 000; 50 000 and 66 000 plants/ha).

Of all the parameters considered in the present study stover yield, flag leaf area, number of leaves per plant and stand count at harvest responded to nitrogen application. However, grain quality in terms of grain crude protein content Increased by about 21% when nitrogen application rate was increased from 0 to 120 kg N/ha.

Increasing plant population from 34 000 to 50 000 plants/ha increased grain yield while a further increase from 50 000 to 66 000 plants/ha decreased grain yield. Increasing plant population from 34 000 to 50 000 and from 50 000 to 66 000 plants/ha decreased grain weight per plant by 25.5 and 14.1%, respectively. Yield attributes such as panicle length and grain number per panicle decreased with increasing plant population. Variables which decreased slightly with increase in plant population include, thresing percentage, harvest index, grain: stover ratio,

stem diameter and number of internodes. Grain quality in terms of per cent total nitrogen in the grain and crude protein content decreased with increasing plant population. Significant (P=0.05) nitrogen x population interactions were observed in respect of grain weight per panicle, 1000-grain weight, panicle length, flag leaf area, stover yield, number of panicles per m^2, number of grains per panicle, weight per panicle, panicle dry weight at 16 weeks after planting (WAP) and plant total dry weight at 12 and 16 WAP. Grain yield positively correlated with most of the important yield components such as 1000-grain weight (r=0.662**), number of grains per panicle (r = 0.702**), grain weight per panicle (r - 0.736**), panicle yield (r = 0.975**), and panicle weight (r = 0.290*).

Of the parameters considered, flag leaf area, stover yield, leaf area index, number of leaves per plant and count at harvest responded to significantly to nitrogen application up to 120 kg N/ha on this soil. It, therefore, implies that fertilizer recommendations for grain sorghum may need to take into account the native soil nitrogen Status i.e., soil test result as well as the preceding crop(s) in the rotation. There was no significant response to plant population up to 66 000 plants/ha.

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Chapter 1.

INTRODUCTION

Among the genus Sorghum Moench, cultivated species, such as bicolor, are among the most domesticated crops of the world. Grain sorghum (Sorghum bicolor L. Moench) appears to have been first domesticated in Ethiopia about 50 centuries ago and taken to West Africa at an early date across the Sudan to the Upper Niger river (Doggett, 1970). It ranks fourth to maize in terms of total world hectarage (Huckabay, 1967).

Martin et al. (1976) gave a more accurate breakdown of sorghum production in the world. He reported an annual world production figure of 72 million tonnes from 58 million hectares, giving an average of 1.3 tonnes per hectare. Leading world producers include the United States of America, India, Nigeria, Argentina, Mexico and Sudan. Yields from Africa and India vary between 300 and 2 000 kg/ha with an average of 650 to 750 kg/ha from rain-fed sorghum. Irrigated hybrid sorghum is said to yield about 1 800 kg/ha here compared to 4 500 to 6 000 kg/ha obtained in the United States (Martin et al., 1976).

Estimated total production of sorghum in West Africa in 1971 was about 58.2 million tonnes from an area of about 9.7 million hectares, corresponding to a yield of about 6 000 kg/ha (Kassam, 1976).

In the Nigerian Sevanna zone, grain sorghum is an important crop. Egharevba (1979) reported that increasing total annual production in Nigeria is mainly through increasing hectarage put to sorghum rather than through increasing yield per unit area. Nigeria's expected yield from 6.5 million hectare was 4.2 million tonnes giving an average yield of about 650 kg/ha (Anonymous, 1979). Oke (1976) also reported that about 4 million tonnes were produced in 1969/70, the northern states producing about 99% from about 6 million hectares of land. When compared to figures obtained from the United States, the average grain yield of sorghum in Nigeria is considered low. Some of the factors responsible for the low yield could be lack of adequate fertilizer application, poor crop management and the use of low-yielding varieties.

Sorghum is grown mainly for its grain for human consumption. The flour from it when milled can be made into a thick paste known as "tuwo" or thin porridge. It is also used for brewing a local beverage called "pito". Sorghum grain is higher in protein and starch but lower in fat content than maize, Zea Mays L. kernel (Komolafe et al., 1979). This crop, therefore, has good nutritional value as human and animal feed. The stalks of local cultivars are large and tall and are used as fuel, for fencing and for roofing. The vegetative parts of the plant as well as the grains are used as feeds for livestock.

Sorghum, which is adapted to a wide range of ecological conditions, grows well where the rainfall is 380 to 640 mm during the period of growth and where the weather is hot and dry when the grains are ripening. It requires a mean temperature of about 28.0^{0}C. Sorghum also performs well on a wide variety of soils, with a pH of 5.5 to 8.5.

In order to achieve maximum sorghum yield, certain agronomic factors must be at their optimum. Such factors include planting the best variety, using an optimum plant population, proper fertilizer application, adequate soil moisture supply, and diseases and insect control.

Pal et al. (1984), in an experiment designed to find out the yield response of sorghum cultivars to inorganic nitrogen, observed that sorghum hybrids yielded more than pure-line cultivars. Hybrid yield responded to the application of nitrogen up to 100 kg/ha (Chandravanshi et al., 1973). In a similar experiment, Murty (1967) observed that at the highest nitrogen level, yield response of hybrid was 7.8 kg grain per kg of applied nitrogen and that response by local cultivars was 5.0 kg grain per kg of nitrogen when levels between 0 and 200 kg N/ha were applied. He also observed that level of response to nitrogen fertilization depends on the locality and that the hybrids mature 10 to 100 days earlier than the local cultivars. He gave the economic rate of nitrogen

application for the hybrids as between 135 and 158 kg N/ha.

Sorghum is a heavy feeder on mineral nutrients, most especially nitrogen source. Earlier developed local varieties of sorghum responded poorly to fertilizer application due to their limited yield potential and as a result required a very low level of fertilization. Goldsworthy and Taylor (1970) reported 3 to 5 times higher yields of dwarf and semi-dwarf varieties of sorghum compared with the local cultivars. Among various major elements, nitrogen is the most limiting nutrient element in sorghum production (Delorit et al., 1974). This indicates that inadequate nitrogen fertilization is likely to limit the growth and productivity of improved sorghum varieties.

The National Seed Service and the Institute for Agricultural Research, Samaru, developed Nigeria's first grain sorghum hybrids, which include SAMSORG 28, SAMSORG 30 and SAMSORG 31, among others. Their common male parent is SAMSORG 17, which is a medium-tall, improved pure-line variety widely cultivated in the northern Guinea savanna (Ogunlela, 1983). While these hybrids are likely to have great potentials in improving the overall sorghum production in this country, not much research work has so far been done on them. Infact, the basic agronomic requirements of these

hybrids are yet to be determined experimentally and as a result, they have not been released to farmers for commercial production. From one of the few preliminary investigations conducted, it was reported that the most fertilizer responsive among these bybrids is SAMSORG 31 and it was also found to be among the best yielders (Ogunlela, 1983). Nitrogen application is likely to have some effects on sorghum grain quality, in aspects such as crude protein content. While it is known that the yield of sorghum may increase with increase in plant population to a certain optimal point, beyond which further yield response is not likely to occur, it is yet to be ascertained which plant population will be the optimum for the sorghum hybrid SAMSORG 31.

Information on the fertilizer requirement and the optimum population levels for sorghum hybrids in Nigeria is at present not adequate. It is, therefore, desirable to conduct investigations on these aspects of the agronomy of sorghum hybrids to provide vital information that are likely to be included in the package that would eventually accompany these hybrids to the farmers. It is in the light of the above that the present study was undertaken using sorghum hybrid SAMSORG 31 with the following objectives:

1. To study the effect of nitrogen fertilization on the performance of a sorghum hybrid.

2. To study the interaction between nitrogen and plant density on sorghum yield and yield components.

3. To study the effect of nitrogen and plant density on nutrient content and quality of the sorghum grain.

Chapter 2

LITERATURE REVIEW

2.1 Nitrogen

Sorghum is a heavy feeder on soil nutrients, especially nitrogen. Watson (1963) and Heathcote and Stockinger (1970) have reported that soil fertility of Nigerian savanna soils is generally low. Nitrogen was shown to be one of those nutrients that are most limiting to crop production (Heathcote and Stockinger, 1970). Geus (1976) reviewed the national value of tropical grain crops and the influence of fertilizers on these values. It was concluded that the production of tropical grain crops could be increased by increasing fertilizer application to high-yielding cultivars but grain protein quality should be improved primarily through plant breeding. Evans and Wilson (1956) in the southern province of the then Tangayinka (now Tanzania) observed that the effects of fertilizers varied with soil quality and the crop, but in the majority of cases, significant increases in yield were obtained when fertilization was increased. In trials conducted at various locations within India, De (1974) reported that response to nitrogen varied with the native nutrient status of the soil and with the cultivar grown and that the hybrids of all species show greater response to nitrogen than local varieties.

2.1.1 Effect of nitrogen application on sorghum growth

The effect of nitrogen application on sorghum growth has been studied and reported by many workers. Lenjewar and Khot (1978) using two sorghum cultivars and four levels of nitrogen application ranging from 0 to 75 kg N/ha observed that the values for plant height, dry weight per plant, absolute growth rate, leaf area index (LAI), leaf area ratio (LAR) and straw yields differed from cultivar to cultivar even under the same nitrogen level. In a field trial conducted by Galbiatti et al. (1977) in Latin America, where nitrogen was applied as a side dressing to sorghum at rates of 30, 60 or 90 kg/ha at 30 days after sowing, or in two equal applications at 20 and 40 days after sowing, there was a lack of response in plant development to increased levels of nitrogen application. In an experiment conducted to find the effect of rates of nitrogen application and plant population on certain growth characters of sorghum, Srivastava and Shukla (1968) observed that plant growth in terms of height, leaf number and stem diameter increased progressively as the nitrogen rates increased from 24.7 to 98.8 kg nitrogen per ha. The highest level of 98.8 kg nitrogen per ha produced the best sorghum growth.

Ram (1960) reported an increase in sorghum height with nitrogen application. The tallest plants were

produced when the highest rate of 102 kg N per ha was applied at sowing. Karve (1965) observed that soil-applied nitrogen significantly increased the height of the sorghum plant at all stages of development, although differences within the levels of 60, 120 and 180 kg N per ha were not pronounced. Reddy and Hussein (1968) reported that height of the sorghum plant increased with increasing levels of nitrogen in sorghum "CSH-1" though the differences were not significant. Using four sorghum genotypes grown under rain-fed conditions and given 0 to 200 kg nitrogen per ha., Veeranna and Patil (1978) reported increased in plant height with increasing rates of nitrogen application. Seder et al. (1976) using sorghum cultivar "Continental 2201" observed that increasing nitrogen levels from 10 to 70 kg per ha. increased plant height from 102 cm in the unfertilized control to between 122 and 129 cm. Rajput et al. (1983) observed an increase in plant height with increasing level of nitrogen when rates of 0 to 70 kg N per ha were used. The observed differences were however not significant statistically.

The total leaf area of the sorghum plant differs from cultivar to cultivar and from season to season. As the total leaf area of a plant increases, the proportion of the incident light that is intercepted increases up to an optimum before it begins to decline

and the rate of photosynthesis also increases correspondingly. Raghunathan et al. (1973) in a series of trials in the summer monsoon and winter season and also using different sorghum cultivars observed that increasing nitrogen rate from 60 kg per ha to 180 kg per ha increased total leaf area in sorghum. It was observed that leaf area per plant was greater in direct sown than in transplanted plots and in the summer monsoon crop than in the winter crop. The various sorghum cultivars also responded differently to increased nitrogen application. Karve (1965) studied the effect of graded levels of 0 to 180 kg N per ha and found that total leaf area increased with increasing level of nitrogen. Choudhari (1967) also obtained similar results when he conducted a sorghum study in India compering various levels of nitrogen ranging from 0 to 150 kg N per ha. Some other workers have also reported increases in the total area of functional leaves of sorghum with increasing levels of nitrogen application, (Patil, 1971; Lomte, 1972).

Fresh fodder yields respond to nitrogen application in the same manner as grain yield increases occur with increasing nitrogen rates. Perry and Olson (1975) studied the effect of 0 to 270 kg N per ha on irrigated sorghum and they observed that the stover yield of sorghum was significantly increased by 90 kg N per ha with no further increases at higher nitrogen rates. Dahatonde and Adhaoo

(1978) observed increases in stover yield with increase in level of nitrogen application. Stover yields were increased from 5.67 to 8.57 t/ha in 1973 and from 3.58 to 6.1 t/ha in 1974 with 200 kg N per ha. Patil and Jawale (1977) observed an increase in stover yield when nitrogen was increased from 0 to 150 kg per ha. The level of nitrogen producing the highest stover yields was given as 100 kg per ha. In a study using two sorghum cultivars, Lanjewar and Khot (1978) noted that increasing nitrogen rates from 0 to 75 kg per ha increased stover yields irrespective of the cultivar. Using a sorghum hybrid "HB3" under rain-fed conditions, Ranjodh and Gill (1963) observed that stover yields were increased from 2.65 t/ha with no nitrogen to 8.01 t/ha with 100 kg N per ha.

Variable dry matter yield responses to increases in nitrogen application rates have been reported in the literature. Increasing nitrogen rates increased dry matter yields up to an optimum when additional levels of nitrogen failed to produced corresponding increases in stover yields. Vecchiettini and Lambertini (1979) observed from an experiment on both sandy and clay soils that dry matter yields were lower at 320 kg N per ha than at 20 kg N per ha, when they used nitrogen rates which varied from 0 to 320 kg/ha. Gaya (1976) observed a significant increase in dry matter production when higher

levels of nitrogen were applied to sorghum at Nebraska in the United States. Dry matter was highest at 90 and 120 kg nitrogen per ha and this occurred between flowering and physiological maturity. Garg and Kayande (1962) observed an increase in sorghum stover yield when nitrogen application rate was increased from 0 to 22 kg per ha.

2.1.2 Effect of nitrogen application on sorghum yield

The effect of nitrogen application on grain yield of sorghum has been reported by various workers. Veeranna and Patil (1978), using four sorghum genotypes grown under rain-fed conditions, reported that different sorghum hybrids and cultivars gave their highest average yields at different nitrogen levels. The rates of nitrogen application that were tested in their study varied between 0 and 200 kg per ha. In Nigeria, yield increases in sorghum from the application of 56 and 112 kg sulphate of ammonia/ha were 11.8 and 15.6 per cent, respectively, (Obi, 1959). Dahatonde and Adhaoo (1978) in a two year experiment reported that grain yields of sorghum hybrid "CSH1" were increased from 1.66 t/ha without nitrogen to 4.25 t/ha in 1973 and from 1.36 to 3.36 t/ha in 1974 with 150kg nitrogen per ha. It was also noted that yields were not further increased when 200 kg nitrogen per ha was applied. Mehrotra et al. (1979) observed increases in the grain yield of sorghum with

increase in nitrogen application. Two-year average grain yields of 1.48, 2.45 and 2.69 t/ha were observed when they tested rates of 0, 40, 80 and 120 kg N/ha, respectively. In a similar experiment, Haripvakasrao (1978) reported an increase in grain yield from 4.42 to 5.76 t/ha with increase in rates of applied nitrogen from 68 to 136 kg/ha. Ogunlela and Obilana (1982) in a preliminary study at Samaru using three sorghum hybrids observed response to nitrogen application on a ferruginous tropical savanna soil up to 66 kg N/ha. The effect of nitrogen application on grain yield of sorghum varied with soil and climatic conditions. Turkhede and Prasad (1978) reported that sorghum hybrid "CSH1" given 0 to 150 kg N/ha gave the highest yields with 150 kg N/ha in 1969 and with 100 kg N/ha in 1970. Galbiatti et al. (1977) observed that application of 60 kg N/ha produced a higher grain yield than did the other treatments, namely 30 and 90 kg N/ha tested by them. However, it was observed that differences between treatments were not significant. Escasinas et al. (1981) reported that increasing nitrogen application rate from 30 through 200 kg/ha was associated with increased grain yield and that the 200 kg N/ha rate gave a yield of 2.32 t/ha while yield from the control was 1.32 t/ha.

Reddy et al. (1978) observed that increasing the rates of nitrogen fertilizer applied to three sorghum

cultivars from 0 to 120 kg N/ha increased average grain yield from 1.61 to 3.83 t/ha under rain-fed conditions. In an experiment to determine the effect of rate and date of nitrogen application on the production of grain sorghum, Rosolem et al. (1981) observed that nitrogen application did not significantly increase sorghum grain yield when they used rates that ranged from 0 to 120 kg N/ha. On a Mississippi River alluvial soil, Robinson and Sloane (1976) observed that application of nitrogen to grain sorghum at rates ranging from 34 to 168 kg N/ha increased yields significantly up to 68 kg N/ha only while higher nitrogen rates either decreased yields or produced non-significant further increases. In a preliminary report on the response of grain sorghum to applied nitrogen Lutrick (1970) noted an increase in yield from 5384 kg/ha with 39 kg N/ha to 5600 kg/ha with 78 kg N/ha. It was also observed that rates higher than 78 kg N/ha produced no further increases in yield. Costa (1971) observed that nitrogen application had no significant effect on grain yield when he used nitrogen rates of 0, 40 and 80 kg/ha. Tweedy et al. (1971) noted that nitrogen at 112 and 224 kg/ha increased the grain yield of sorghum by 25 and 22%, respectively, as compared with plots that had received no nitrogen fertilization. Increasing the rate of applied nitrogen from 0 to 80 kg/ha increased yields from 2200 to 4900 kg/ha at Ludhiana while at Hissar, yields increased from

3900 kg/ha on plots given no nitrogen to 7200 kg/ha with 60 kg N/ha (Singh et al., 1969). Haripraskash (1979) also observed increases in grain yield of sorghum hybrid "CSH1" when increasing rates of nitrogen fertilizer were applied. Reddy et al. (1977) in a similar experiment noted increases in sorghum grain yield with increases in rate of applied nitrogen from 0 to 150 kg/ha. Increasing nitrogen rate from 0 to 90 kg/ha was also found to have increased grain yields of sorghum from 1.47 to 3.83 t/ha. (Pawar et al., 1977). The optimum nitrogen rate of 135 kg/ha with an expected yield of 4.29 t/ha was also worked out.

In an experiment conducted to find out the effect of plant population and levels of fertilizer nitrogen on the yield of irrigated hybrid sorghum, Berna and Preston (1967) observed significantly reduced grain yields with increasing nitrogen application rate in two of the three trials while in the third trial, yields per ha were not affected by rate of nitrogen. Ramakrishnan et al. (1974) observed increase in grain yields from 5.07 to 6.54 t/ha when nitrogen rates ranging from 0 to 150 kg N/ha were tested. However, yields were decreased with 200 kg N/ha. Investigations by Berna et al. (1971) revealed that nitrogen application decreased grain yield per ha and yield per plant. It was observed that nitrogen depressed the positive effects of potassium and

phosphorus except at the highest levels and, therefore, concluded that there was no advantage in applying nitrogen to this "H160". Gill et al. (1971) worked on a red, gravely, sand-loam soil during a summer monsoon in India. They observed that increases in rates of applied nitrogen were accompanied by linear increases in grain yield from 473 to 827 kg/ha when they tested N rates ranging from 25 to 75 kg N/ha. Grain yields were consistently increased by applied nitrogen, the magnitude of increase depending on the nitrogen accumulation in the soil profile from previous fertilizer treatments (Fuehring and Finkner, 1974). In an experiment using sorghum hybrid "CSH-1", Shukla and Seth (1976) observed that increasing the nitrogen rate from 0 to 120 kg/ha increased grain yields from 1.77 to 2.91 t/ha. This was attributed to increase in number of grains per panicle from 596 to 1039 and accelerated flowering and maturity. Sotomayor-Rios and Lugo-Lopez (1970) reported significant increase in grain yield with the first increament in nitrogen application but further increases in nitrogen rate failed to significantly increase sorghum yield when rates of 56, 112, 168, 224 and 280 kg N/ha were applied in an oxisol of north-western Puerto Rico.

2.1.3 Effect of nitrogen application on sorghum yield components

Nitrogen application is expected to affect sorghum

grain yield through its effects on major components of yield such as grain number, grain weight panicle size. Shukla and Seth (1976) reported that increasing nitrogen rate from 0 to 120 kg/ha increased number of grains per sorghum panicle from 596 to 1039. Recently, Pal et al. (1984) in an experiment using different sorghum hybrids observed that hybrid "CSH-5" gave the highest yields because it has the greatest number of grains per panicle. They also noted that a nitrogen rate of 80 or 120 kg N/ha significantly increased the number of grains per panicle. A similar result had earlier been reported by Escasinas et al. (1981) in the Philippines.

Azeredo et al. (1975) reported increase in grain weight per panicle with increase in nitrogen application over a range of 0 to 100 kg N per ha. They also observed that of all the yield components studied, average grain weight per panicle gave the best correlation with grain yield. Tatwawadi and Choudhari (1976) applied different rates of nitrogen phosphorus and potassium on grain sorghum "CSH-1" in India and observed that grain weight per panicle increased with increased rates of nitrogen application. Escasinas et al. (1981) using nitrogen rates from 0 to 200 kg/ha observed that the application of nitrogen to sorghum increased grain weight per panicle and Patil and Jawale (1977) reported that 1000-grain weight was highest when the crop received a fertilizer dressing of 100 kg N/ha among various rates

of 0, 50, 100 and 150 kg N/ha that were compared. Tatwawadi and Choudhari (1976) on the other hand observed a decrease in 1000-grain weight as a result of increased nitrogen application.

In an experiment that was conducted to study the effect of different nitrogen levels on the yield and yield components of sorghum, Escasinas et al. (1981) observed that panicle length increased with the application of nitrogen fertilizer. Hariprakasrao (1970) and Rajput et al. (1983) also observed similar results when they applied different levels of nitrogen in their independent investigations. Patil and Jawale (1977) in India observed an increase in panicle length of sorghum "CSH-5" with increase in nitrogen application. When nitrogen rates were increased to 100 kg/ha, the longest and heaviest panicles were obtained. Ikeda and Nakagome (1970) on the other hand observed that panicle length of dwarf grain sorghum was slightly effected by nitrogen fertilization. Nitrogen application can also have negative effects on sorghum panicles as had been reported by Tatwawadi and Choudhari (1976) who found that panicle length decreased as nitrogen application rate was increased. In field trials using dwarf sorghum hybrid "RS610" in India, increasing the rate of nitrogen application from 0 to 100 kg/ha increased panicle weight by 125%, panicle length by 81% and percentage of harvested

panicles by 30% (Strivastava, 1970). Using nitrogen levels of 50, 100 and 150 kg/ha, Tatwawadi and Choudhari (1976) also noted that panicle weight was increased as nitrogen application rates increased.

2.2 Plant Population

Plant nutrition, growth and yield can be markedly influenced by the number of plants per unit land area. The effects of increased plant population on sorghum performance have been studied by many workers. Shepel and Aristar Khova (1982), in a study of eleven characters of grain sorghum observed that these characters fall into the following three groups in terms of the effect increased plant density has on them: (i) characters whose values increase with increased density, such as plant height, grain size and yield, (ii) characters whose values decrease with increased density such as panicle length, length of third leaf, stem diameter, tiller number and duration of growth, and (iii) characters which react little to stand density changes, such as number of internodes per plant, and length of the leaf sheath.

2.2.1 Effect of plant density on sorghum growth

Reports on the effect of increased plant density on the length of the sorghum stalk have been reported in the literature. Ikeda and Nakagama (1970), using seven plant

densities observed on increase in the length of sorghum plant as plant density increased. In a series of trials, Gikic (1972) observed the greatest plant height of sorghum with spacings of 50 cm between rows and 10 cm between plants (111 111 plants/ha) or 60 cm between rows and 10 cm between plants (166 667) plants/ha) when he used plant populations ranging from 29 600 to 200 000 plants/ha. In an experiment studying the effect of row width and plant spacing within row on sorghum yield and its components, Son (1969) reported that plant height was not effected by increased plant density. A negative effect of plant density on plant height of sorghum was reported in the Philippines by Hoshino (1974), who observed a markedly reduced plant height as a result of increased plant density. In studies to determine the effect of varying row spacings on the growth of sorghum, Garg and Kayande (1963) reported that wide spacings increased the thickness of the stem.

In a series of trials conducted during the summer Monsoon and winter season in India, Raghunathan et al. (1973) observed that when the plant population of sorghum was increased from 133 000 to 177 000 plants/ha, there was reduction in leaf area per plant. Hoshino (1974) also observed some reduction in sorghum leaf area as a result of increasing plant density.

In a series of trials using the sorghum cultivar

'White Collier', sown at inter-row spacings of 40 to 70 cm and inter-plant spacings of 15 to 40 cm. Son (1969) observed increased stover weight with increasing plant density. Vecchiettini and Lambertini (1979) worked on both sandy and clay soil and obtained higher dry matter yields at lower sowing rates than at higher sowing rates.

2.2.2 Effect of plant density on sorghum yield

Many workers have studied the effect of plant densities on the yield of sorghum. Grain yield of four sorghum cultivars in India varied significantly between plant densities of 30, 40 or 50 plants/m^2 (Desideric and Mowotti, 1985). They observed in just one year out of a number of years during which their experiment was conducted under rain-fed conditions that the higher the plant density, the lower was the grain yield. Increasing levels of sorghum plant density gave significantly higher grain yields up to a population level of 140 000 plants/ha in India, beyond which there occurred a decrease in grain yield (Mehrotra et al., 1979). In a series of experiments conducted at Samaru during 1960-70 to study the effect of plant density changes on long season dwarf photosensitive sorghum varieties and hybrids, Andrews (1976) found that the optimum plant density for the crop was 65 000 plants/ha. Elsewhere, a plant density of 200 000 plants/ha gave the highest sorghum grain yield of 2.07 t/ha in Philippines

(Escasinas et al., 1981) and the work of Bhalerao and Choudhari (1978) in India produced a result which showed an optimum plant population level of 135 000 plants/ha. Using two sorghum hybrids grown at between plant spacings of 15 or 22.5 cm. Lenjewar and Khot (1978) observed that narrowing spacings between plants produced no effect on grain yield. Solorzano (1982) conducted an experiment testing the effect of population levels on the performance of grain sorghum in Venezuela from which he observed increased grain yield with increasing plant population when he used plant populations of 200 000, 320 000 and 390 000 plants/ha.

Increasing plant density of three dwarf sorghum cultivars from 600 000 to 1 200 000 plants/ha increased grain yield. However, there were yield differences among the various cultivars (Malinovskii and Vakhonskii, 1977).

Yield decreases with plant population at less than 80% of the optimum population level which was 150 000 plants/ha irrespective of planting pattern on red shallow soils in India (Chetty and Reddy, 1979). These workers also reported that as long as this optimum plant population level and row width of 45 cm were maintained, the pattern of plant distribution within row had no significant effect on grain yield. Ivanov (1922), using a sorghum hybrid 'NK-120' grown at a stand density of 71 400 to 285 720 plants/ha observed that the highest average grain yield of 6.26 t/ha was obtained with 142 850 plants/ha and that

further increase in stand density decreased yield, especially in dry years. Choudheri and Mahalle (1971) used three population levels of 150 000 100 000 and 75 000 plants/ha and observed that 150 000 plants/ha gave higher grain yield than any of the other two plant densities tested. In Brazil, Costa (1971) observed non-significant increase in grain yield as a result of increased plant density. During 1977-78 season, grain yield but not stover yields and in 1979 stover yields, but not grain yields, increased significantly with increased plant density (Postiglione and Basso, 1980). Their result demonstrated the significance of seasonal variation in yield response to plant population changes in grain sorghum.

2.2.3 Effect of plant density on sorghum yield components

The effect of plant density on the number of grains per panicle of sorghum has been reported by a number of workers. Using semi-dwarf and tall sorghum cultivars in a study conducted in Illinois, United States, Wahua and Miller (1978) observed that increasing sorghum plant density from 1.30 to 33 plants/m^2 reduced the number of grains per panicle. Ogunlela and Obilana (1982) observed that plant density did not influence sorghum performance at Samaru except to increase the head and grain numbers. Molina et al. (1977) reported reductions in number of grains per

panicle when they used seven sorghum cultivars at plant population of 120 000, 200 000 and 280 000 plants/ha. Escasines et al. (1981) investigated the effect of different plant densities on sorghum yield components and reported that when sorghum plant population increased number of grains per panicle decreased.

Lanjewar and Khot (1970) in a study with sorghum cultivars grown at between plant spacings of 15 or 22.5 cm noted reduction in grain weight per panicle as a result of increased plant density. Son (1969) on the other hand reported increases in grain weight per 100 m^2 with increasing plant density in sweet sorghum (Sorghum Vulgare Pers.). Landsberg (1964), who compared different sorghum plant populations in Rhodesia, observed that heavy panicles produced higher yields than did a larger number of lighter heads.

Srivastava (1970), studied the yield-contributing characters of dwarf sorghum as influenced by intra-row spacing. He observed that increasing the distance between plants from 10 to 30 cm in rows spaced 50 cm apart increased panicle weight by 25% and percentage of harvested panicles by 16%.

Wahua and Miller (1978) observed that increasing plant densities from 1.30 to 33 plants/m^2 only slightly influenced 1000-grain weight in semi-dwarf and tall

sorghum cultivars. In a series of trials, Son (1969) observed that the 1000-grain weight of sorghum cultivar 'White Collier' decreased with increased plant density.

The effect of increased plant density on the number of panicles per plant was reported by Hoshino (1974) and Wahua and Miller (1978). They both observed that when plant density was increased, number of panicles per plant in sorghum was reduced. Using two sorghum cultivars sown at inter plant spacing of 15 or 22.5 cm. Lanjewar and Khot (1978) noted increases in number of panicles per plot with increased plant density. Escasinas et al. (1981) studied the effect of different population densities on the yield and yield components of sorghum. They noted a reduction in panicle length with increasing plant density. Using three different sorghum hybrids, Gikic (1972) observed that the shortest panicles came from plants spaced 10 or 10 cm apart when he used plant densities which ranged between 29 600 and 200 000 plants/ha.

2.3 Effect of Nitrogen Application and Plant Density on Grain Quality

The effects of nitrogen application and plant density on grain quality have been extensively studied by many workers. Sotomayor-Rios and Lugo-Lopez (1978) studied the effect of nitrogen fertilization on sorghum grain quality. They observed that grain nitrogen content increased with increasing nitrogen application in Puerto Rico and that

grain crude protein content was higher with split application of nitrogen than when this nutrient was applied in a single dose. Pal et al. (1983) also noted that application of nitrogen to newly developed hybrids and varieties of sorghum increased nitrogen uptake. Khatoon (1978) reported that the content of crude protein, true protein, non-protein nitrogen and prolamine in grains of hybrid sorghum increased with increasing nitrogen application rates. In trials with grain sorghum in both wet and dry seasons, Azeredo et al. (1976) reported increases in grain protein yield with application of nitrogen and that grain protein yield per ha is more dependent on grain yield than on grain protein content, which varies inversely with grain yield. Geus (1976) studied the nutritional value of tropical grain crops including sorghum. He reported that application of nitrogen fertilizer increased the protein content of sorghum grains and concluded that grain protein quality should be improved mainly through plant breeding. Application of 150 kg N/ha significantly increased crude protein and true protein contents of sorghum grain mainly by increasing the prolamine fraction in the protein (Gupta and Gupta, 1972). In the same experiment, it was observed that applied nitrogen increased the content of lysine, leusine, methionine and tryptophan in the grain. Protein nitrogen in the grain increased steadily from 8.60% for the control, which was not given nitrogen, to 11.30% with 160 kg N/ha (Lutrick, 1970). Rao and Reddy

(1973) noted that grain protein content increased with increasing nitrogen rates when they applied nitrogen levels of 0 to 150 kg/ha to four sorghum cultivars. It was also observed that the major protein fraction was glutelin followed by albumin, globulin and prolamine. Tweedy et al. (1971) observed an increase in total protein content of grain from 49 to 52% when they applied nitrogen rates of 112 to 224 kg N/ha. In an experiment to investigate the effect of nitrogen levels on nitrogen uptake, Joshi and Morey (1970) observed increased values of nitrogen contents and nitrogen uptake by organs as a result of increased nitrogen application rate. Application of nitrogen at rates of 60 and 136 kg N/ha gave significant increases in both content and yield of protein in grain and forage in Texas (Burleson, 1956). Using nineteen sorghum cultivars at both high and low fertility levels, Campbell and Pickett (1960) reported that nitrogen application significantly influenced the grain protein content at low fertility level. Warsi and Wright (1973) in India studied the effect of various levels of nitrogen on the quality of grain sorghum. They reported that nitrogen application increased the grain content and yield of protein and that higher protein content observed from the application of 60 kg N/ha reflected increases in prolamine and glutelin contents. At rates of 120 and 180 kg N/ha, it was only the prolamine content that was increased, and also at an application rate of 180 kg N/ha both the grain protein and

amino acid contents were increased but the proportion of essential to non-essential amino acids was lower compared to the unfertilized control. Ater and Bains (1973) observed increases in grain protein content as a result of increased nitrogen application when they used rates of nitrogen ranging from 0 to 100 kg/ha. Veeranna and Patil (1978) using grain sorghum grown under rain-fed conditions observed increased nitrogen uptake and grain nitrogen content when they compared the effects of nitrogen application rates which ranged between 0 and 200 kg N/ha.

Grain protein content decreased with increasing plant population when plant population ranging from 91 000 to 272 000 plants/ha were tested using sorghum cultivars 'CSH-1' and 'Swarna' (Ater and Bains, 1973).

2.4 Interaction between Plant Density and Nitrogen in Sorghum

Very few interactive effects of plant density and nitrogen have been cited in the literature.

In a field trial using three sorghum hybrids, namely, 'RS626', 'RS671' and 'NB634', Gaya (1975) observed that yields of 'RS626' were highest at the lowest population density of 100 000 plants/ha and at the highest nitrogen rate of 120 kg/ha, while 'NB634' and 'RS671' produced their highest yields under a combination of high population levels and high nitrogen rates. In an experiment

conducted by Morril and Ashlock (1975), it was observed that grain yield of sorghum varied between years but that the average data indicated that yields were highest at 80 000 plants/ha and 36 kg N/ha. Joshi and Upadhyay (1977) studied three sorghum cultivars and reported that grain and fodder yields per ha increased with increasing nitrogen application at the highest plant density. They also reported that maximum yields were obtained at inter-plant spacings of 10 cm under a fertilizer treatment of 150 kg N/ha. In a similar experiment using sorghum hybrid 'GS764', Tatero and Ojima (1973) observed a maximum dry matter production rate at 42 g/m^2/day and that this occurred at a high plant density under a heavy fertilizer application at 300 kg N/ha at 14 days before heading.

2.5 Correlations

Grain yield in sorghum has been shown to be more positively correlated with the number of heads per unit area than with the size of the head or weight of grain per head (Martin, 1928). In two trials with grain sorghum under both rain-fed and irrigated conditions in Brazil, Azeredo et al. (1975) reported that of all the yield components studied, average grain weight per panicle gave the best correlation with grain yield. The rates of nitrogen tested were 0, 50 and 100 kg/ha.

In a sorghum/wheat rotation using nitrogen levels of 50, 100 and 150 kg/ha, Decau et al. (1977) observed a negative correlation between grain protein content and yield. In a field trial with sorghum cultivar 'Funk's G. 522', Armero and Brambila (1977) observed a highly significant positive correlation between rate of applied nitrogen and grain crude protein content when they tested nitrogen rates of 0, 80, 120, 160 and 200 kg/ha. In a dry season, sorghum cultivars 'Cosor 3' and 'UPLB SG-5' were sown after low-land rice using zero or conventional tillage at plant densities of 200 000, 250 000, and 300 000 plants/ha and nitrogen rates of 0, 50, 150 kg N/ha. Leaf area index (LAI) was found to be closely correlated with grain yield (Pascual et al., 1978). In an experiment conducted to study the effect of striga and fertilizer application on hybrid sorghum performance in the Nigerian savanna, Ogunlela (1983) observed positive correlations between grain yield and stover yield, weight per head, plant height and grain number per head. Stover yield was also found to be positively correlated with these yield components and plant height. However, grain yield negatively correlated with number of days to 50% flowering.

Chapter 3

MATERIALS AND METHODS

3.1 Experimental Site

A field experiment was conducted at the Institute for Agricultural Research experimental farm in Samaru (11^{0} $11^{'}$ N, 07^{0} $38^{'}$ E, 606 m above sea level), Nigeria, during the 1985 cropping season. Samaru lies within the northern Guinea savanna zone (Keay, 1959). It receives a mean annual rainfall of 1007 mm during the months of April to September (Kowal and Knabe, 1972). The field used had been left fallow for several years before it was cropped with soyabean (Glycine max L.) during the 1984 rainy season.

3.2 Soil Samples

After plowing and harrowing and prior to fertilizer application, two composite soil samples were taken from 0 - 20 cm and 20 - 40 cm depths at the experimental site. Each sample was analysed for chemical and physical properties using standard procedures and the results of these are shown in Table 3.1

3.3 Crop Used

The crop used was sorghum hybrid SAMSORG 31, a high yielding cultivar of medium height.

Table 1: Physico-chemical properties of composite soil samples taken from two depths at the experimental site at Samaru, 1985.

Soil property	Soil depths	
Physical property	0 - 20 cm	20 - 40 cm
Sand %	42	40
Silt %	44	34
Clay %	14	26
Textural class	Sandy loam	Sandy clay loam
Chemical property		
pH 1:1 H_2O	4.8	5.6
pH 1:25 ($Cacl_2$)	4.2	5.0
Total nitrogen %	0.046	0.046
Organic carbon %	0.60	0.48
C : N ratio	1:10	1:13
Available P (ppm)	3.5	1.4
Exchangable bases		
K (meq/100g soil)	0.23	0.10
Ca (meq/100g soil)	3.25	3.00
Mg (meq/100g soil)	0.95	0.66
Na (meq/100g soil)	0.07	0.06
CEC (meq/100g soil)	6.0	7.2

3.4 Experimental Design

The experiment was laid out in a randomized complete block design. The five rates of nitrogen and the three plant populations were in factorial combinations to give fifteen treatments. Each treatment was replicated four times.

3.5 Plot Size

The gross plot size was 4.5 m x 9.0 m (40.5 m^2) and the net plot size was 3.0 m x 9.0 m (27.0 m^2).

3.6 Treatments

3.6.1 Nitrogen

Nitrogen (N) was applied as calcium ammonium nitrate (26% N) at the rates of 0, 30, 60, 90 and 120 kg N/ha. Each rate of nitrogen was applied in two split doses, half at three weeks after planting (WAP) and the other half was applied eight weeks after planting. The first and second doses of nitrogen fertilizer were applied by side-dressing in a groove along the ridge and covered with soil immediately after uniform application.

3.6.2 Plant population

Three plant population levels were compared, namely, 34 000, 50 000 and 66 000 plants/ha. Rows were spaced 75 cm apart and inter-plant spacing was varied to maintain the

desired plant population levels. All possible factorial combinations making up the treatments tested are as follows:

T_1	=	N_0P_1
T_2	=	N_0P_2
T_3	=	N_0P_3
T_4	=	N_1P_1
T_5	=	N_1P_2
T_6	=	N_1P_3
T_7	=	N_2P_1
T_8	=	N_2P_2
T_9	=	N_2P_3
T_{10}	=	N_3P_1
T_{11}	=	N_3P_2
T_{12}	=	N_3P_3
T_{13}	=	N_4P_1
T_{14}	=	N_4P_2
T_{15}	=	N_4P_3
T_{16}	=	N_5P_1

Where N_0 = 0, N_1 = 30, N_2 = 60, N_3 = 90 and N_4 = 120 kg N/ha and P_1 = 34 000, P_2 = 50 000 and P_3 = 66 000 plants/ha.

3.7 Cultural Practices

The land was ploughed and harrowed. A blanket application of muriate of potash and single supper phosphate at rates of 40 kg K_2O/ha and 60 kg P_2O_5/ha

respectively, was carried out before ridging. Ridging was done at a row distance of 0.75 m with each plot consisting of six ridges. The seeds were treated with Aldrex T at 5 g/kg of seeds before planting. About four seeds were sown per hole at interplant spacings of 40, 26 and 20 cm (depending on the desired plant population). It was later thinned to one plant per stand at three weeks after planting, ensuring that the most vigorous seedling was retained. There was an attack of stem borer and this was controlled by spraying carbaryl (Vetox 85WP) at the rate of 1.02 kg a.i./ha. The experiment received three weekly sprays of Vetox. A pre-emergence herbicide, Gardoprim A 500 FW was applied at the rate of 2.0 kg a.i./ha for the control of early weeds. Supplementary hoe-weeding was done during the cropping season as was found necessary.

3.8 Measurements and Observations

3.8.1 Meteorological data

The meteorological data for Samaru during the 1985 cropping season, consisting of rainfall figures, are shown in Appendix Tables A.1 and A.2. Appendix Table A.1 consists of daily rainfall figures during May to October, 1985; while Appendix Table A.2 shows 10-day rainfall totals during the same period.

3.8.2 Plant height

Ten plants were randomly selected within the net

plot area and their individual heights to the tips of the panicles were measured at 14 weeks after planting. The average plant height for each plot was later calculated.

3.0.3 Leaf area measurement

The leaf area was measured at 15 weeks after planting. This was done by selecting four plants from each net plot area and measuring the length and the maximum width of every leaf on each of the four plants. To compute the leaf area, the product of length and maximum width was multiplied by a factor of 0.75 (Stickler et al., 1961). The sum of the leaf area of all the leaves on a plant gave the total leaf area for that plant. The flag leaf area at 10 WAP was determined using the same procedure.

3.0.4 Plant dry weight

Four plants from the discard area were sampled three times during the growing season at fortnightly intervals, namely, at 12, 14 and 16 weeks after planting. Harvested plants were separated into leaves, panicles and stems. Samples were then dried in an oven at 70^{0}C to constant weights and weights were recorded. The weights obtained were then expressed as dry weights per plant.

3.0.5 Number of panicles per net plot

The number of panicles in the plots were counted at harvest and these values later used to calculate the number of panicles per m^2 and per hectare.

3.8.6 Stand count at harvest

The total number of stands per net plot at harvest was counted.

3.8.7 Panicle length

At maturity, the lengths of ten randomly selected panicles per net plot were measured. On the basis of this, the average panicle length for each plot was determined.

3.8.8 Number of internodes

The numbers of internodes for ten randomly selected plants per plot were recorded at 19 weeks after planting and the average number of internodes per plant for each plot was later determined.

3.8.9 Stem diameter

The stem diameter at the first internode above the ground level was measured for ten plants selected randomly within each plot at 10 weeks after planting using a pair of calipers.

3.8.10 Stover yield

After harvesting the panicles, the plant stalks were cut at ground level, left on the field for some time to sun dry and later weighed.

3.0.11 1000-grain weight

A sample of 1000-grains was taken from each plot harvest and weighed.

3.0.12 Number of leaves

The number of fully expanded leaves on ten randomly selected plants in each plot was determined at 16 weeks after planting.

3.0.13 Grain yield and components of yield

The grain yield, panicle yield, number of grains/panicle, test weight, harvest index, grain: stover ratio and threshing percentage were obtained as follows:

1. Grain yield

   The grain yield was obtained by weighing the grains got from the net plot. This weight was then multiplied by 370.37.

2. Panicle yield

   This was obtained by harvesting the panicles within the net plot and then weighed. This was then multiplied by 370.37.

3. Number of grains/panicle

$$= \frac{\text{grain yield/plot}}{\text{No. panicle/plot}} \times \frac{1000}{\text{1000 grain weight.}}$$

4. Test weight

$$= X \times \frac{1}{0.33L}$$

X = known weight of grain

L = known volume of grain

5. Harvest index

$$= \frac{\text{total grain weight}}{\text{stover wt. + total panicle wt.}}$$

6. Grain : stover ratio

$$= \frac{\text{grain yield/ha}}{\text{Stover yield/ha}}$$

7. Threshing percentage

$$= \frac{\text{wt. grain}}{\text{wt.panicle}} \times 100$$

3.0.14 Chemical analysis of grain

Samples were taken from grain harvest for each plot and ground with a Wiley mill to pass through a 2mm screen. Care was taken to avoid any contamination of the sample. Duplicate sub-samples were taken and analysed for total nitrogen content using the standard micro-Kjeldahl method (Bremner, 1965). Crude protein content was determined by multiplying the total nitrogen content by a factor of 6.25 (Gurragossian et al., 1977). Total protein yield values were arrived at by using the followin formula:

Protein yield (kg/ha)

$$= \frac{\text{crude protein (\%)} \times \text{grain yield (kg/ha)}}{100}$$

3.0.15 Statistical analysis

The data collected were analysed as a randomized complete block design. Analysis of variance to test treatment effects was done for each of the observed parameters. Main and interaction effects were also determined for each of the observed parameters. Significance of mean differences was tested using the new Duncan's Multiple Range Test described by Steel and Torrie (1960).

Chapter 4

RESULTS

4.1 Effect of Nitrogen Rate and Plant Population on Yield and Yield Components of Grain Sorghum

4.1.1 Grain yield

Increasing nitrogen application rate from 0 to 120 kg N/ha did not increase sorghum grain yield significantly. Similarly, increasing plant population levels from 34 000 to 66 000 plants/ha had no significant effect on grain yield. There was virtually no yield response as plant population was increased from 34 000 to 50 000 plants/ha while a further increase to 66 000 plants/ha seemed to depress yield marginally, (Table 4.1).

4.1.2 Stover yield

Significant differences in stover yield were observed among the various nitrogen rates. Application of 90 kg N/ha produced significantly higher stover yield than 30 kg N/ha. Lower stover yield was obtained with 30 kg N/ha compared with any of the other three nitrogen rates. The effects of 0, 30, 60 and 120 kg N/ha rates on stover yield were almost at par (Table 4.1).

Increasing the plant population levels from 34 000 to

Table 4.1: The effect of nitrogen and plant population on grain yield, stover yield, 1000-grain weight and number of grains per panicle of sorghum hybrid SAMSORG 31 at Samaru, 1985.

Treatment	Grain yield (kg/ha)	Stover yield (kg/ha)	1000-grain wt. (g)	No. grains per panicle
Nitrogen rate (kg/ha)				
0	2433a	6092ab	26.9a	2474a
30	2104a	5027a	25.3a	2354a
60	2485a	6515ab	26.1a	2730a
90	2672a	7034b	26.1a	2759a
120	2255a	6549ab	25.5a	2475a
SE±	251.3	516.6	0.93	283.5
Plant population (plants/ha)				
34 000	2419a	6530a	26.7a	2971c
50 000	2429a	6715a	25.5a	2435b
66 000	2321a	6446a	25.7a	2224a
SE±	194.6	400.1	0.72	157.6
Mean	2309.8	6563.5	25.90	2560.0

Means followed by the same letter(s) within the same column and treatment are not significantly different at 5% level of probability according to the new Duncan's Multiple Range Test.

66 000 plants/ha had no significant effect on stover yield. However, there was a tendency for stover yield to increase when plant population was increased from 34 000 to 50 000 plants/ha while a further increase to 66 000 plants/ha seemed to decrease yield (Table 4.1).

4.1.3 Thousand-grain weight

Grain weight was significantly affected by neither nitrogen application rate nor by plant population in the present study. However, grain weight was slightly higher with 34 000 plants/ha than with any of the higher plant population levels of 50 000 and 66 000 plants/ha (Table 4.1).

4.1.4 Number of grains per panicle

As seen in Table 4.1, the effect of nitrogen application rate on the number of grains per panicle was not significant.

The effect of plant population levels on number of grains per panicle was however significant. Increasing plant population decreased the number of grains per panicle. Plant population at a level of 34 000 plants/ha produced significantly more grains per panicle than did any of the other levels. Significantly lower number of grains per panicle was obtained with the highest plant population level of 66 000 plants/ha tested in the present study.

4.1.5 Number of panicles per square metre

The effect of nitrogen application on the number of panicles per m^2 was not significant when nitrogen rate was varied between 0 and 120 kg N/ha.

There were significant differences in number of panicles per m^2 due to increase in plant population. The 50 000 and 66 000 plants/ha which were at par, produced significantly higher numbers of panicles per m^2 than the 34 000 plants/ha level. The first 16 000 plants/ha increment in plant population gave 27% increase in number of panicles per m^2 (Table 4.2).

4.1.6 Panicle length

The influence of nigrogen application on panicle length was not significant when nitrogen rate was varied between 0 and 120 kg N/ha. The length of panicle was however affected by increasing plant population. When plant population was increased from 34 000 to 50 000 plants/ha, panicle length was decreased slightly but remained unaffected by a further increase in plant population to 66 000 plants/ha. The shortest panicles were observed with the higher plant population levels (Table 4.2).

4.1.7 Panicle yield

Neither nitrogen application rate nor plant population level affected panicle yield significantly.

Table 4.2: The effect of nitrogen and plant population on number of panicles per m^2, panicle length, panicle yield, grain weight per panicle and weight per panicle of sorghum hybrid SAMSORG 31 at Samaru, 1985.

Treatment	No. panicles per m^2	Panicle length (cm)	Panicle yield (kg/ha)	Grain wt. per plant (g)	Wt. per panicle (g)
Nitrogen rate (kg/ha)					
0	3.7a	35.2a	3243.8a	59.0a	97.7a
30	3.6a	34.9a	2913.6a	52.2a	87.9a
60	3.5a	35.5a	3305.6a	61.0a	103.6a
90	3.8a	35.0a	3549.4a	59.4a	97.5a
120	3.6a	35.1a	3114.2a	52.3a	88.3a
SE±	0.19	0.41	285.12	6.10	10.14
Plant population plants/ha					
34 000	3.0a	35.9b	3205.6a	71.4a	106.1b
50 000	3.0b	35.0a	3270.4a	53.2a	86.4a
66 000	4.1b	35.0a	3200.0a	45.7a	83.9a
SE±	0.15	0.32	220.05	4.72	7.80
Mean	3.64	35.30	3225.33	56.70	92.73

Means followed by the same letter(s) within the same column and treatment are not significantly different at 5% level of probability according to the new Duncan's Multiple Renge Test.

However, application of nitrogen fertilizer at the rate of 60 and 90 kg/ha tended to increase panicle yield slightly relative to the panicle yields produced when fertilizer was applied at 30 kg N/ha or the unfertilized control (Table 4.2).

4.1.8 Grain weight per plant

The effect of nitrogen application on the grain weight per plant of sorghum was not significant in the present study.

Plant population had no significant effect on this parameter when plant population was increased from 34 000 plants/ha through 66 000 plants/ha. Grain weight per plant decreased as plant population was increased. Plant population of 34 000 plants/ha produced a higher yield than the other two plant population levels. The magnitudes of decrease in this parameter due to increasing plant population were 25.5 and 14.1 per cent when plant population was increased from 34 000 to 50 000 plants/ha and from 50 000 to 66 000 plants/ha, respectively.

4.1.9 Test weight

Neither nitrogen application nor plant population had significant effect on test weight of grain sorghum. Despite the increases in the rate of nitrogen application in the present study, test weight of sorghum remained

virtually unchanged.

There were also no differences amongst the plant population levels with respect to their effects on this parameter. Plant population of 66 000 plants/ha seemed to produce a slightly higher test weight than either 50 000 or 34 000 plants/ha, (Table 4.3).

4.1.10 Threshing percentage

Neither the effect of nitrogen application nor that of plant population was significant on threshing percentage. However, threshing percentage in sorghum tended to decrease as plant population was increased from 34 000 to 66 000 plants/ha. The highest threshing percentage of 75 per cent was observed with a population of 34 000 plants/ha while the lowest threshing percentage was observed with 66 000 plants/ha, (Table 4.3).

4.1.11 Harvest index

There were no significant differences among the various rates of nitrogen application or plant population levels in terms of their effects on harvest index of sorghum.

Although there were no significant differences among the plant population levels, increased plant population seems to have caused some decrease in the harvest index. The lowest population of 34 000 plants/ha gave the highest

harvest index compared with the other two plant populations (Table 4.3).

4.1.12 Grain: stover ratio

Increasing nitrogen rate as well as plant population did not significantly affect grain:stover ratio. However, there was a slight tendency for grain: stover ratio to decrease when plant population was increased from 34 000 to 50 000 plants/ha. Also, when nitrogen rate was increased to 60 or 90 kg N/ha, grain:stover ratio seemed to increase.

4.2 Effect of Nitrogen Rate and Plant Population on Growth Characteristics of grain Sorghum

4.2.1 Stand count

Table 4.4 shows the effect of nitrogen and plant population on the stand count of sorghum. Significant differences in stand count were observed among nitrogen rates. Rates of 90 and 120 kg N/ha gave higher stand counts than did other rates. A lower stand count was observed with 30 kg N/ha.

Increasing the plant population increased stand count per unit area. Plant population of 66 000 plants/ha gave a significantly higher stand count than either 34 000 or 50 000 plants/ha. The lowest stand count was observed with a plant population of 34 000 plants/ha. The levels of

Table 4.4: The effect of nitrogen and plant population on stand count per net plot at harvest, stem diameter, number of internodes and plant height of sorghum hybrid SAMSORG 31 at Samaru, 1985.

Treatment	No. stands per net plot	Stem diameter (cm)	No. internodes per plant	Plant height (cm)
Nitrogen rate (kg/ha)				
0	114.9ab	3.40a	21.4a	240.5a
30	111.5a	3.41a	20.0a	240.0a
60	114.5ab	3.50a	21.1a	240.0a
90	121.3b	3.37a	21.1a	240.0a
120	120.6b	3.37a	21.5a	242.1a
SE±	3.93	0.007	0.54	4.20
Plant population (plants/ha)				
34 000	90.0a	3.57a	21.9a	244.0a
50 000	122.6b	3.39a	21.0a	244.0a
66 000	137.1c	3.32a	20.6a	240.7a
SE±	3.04	0.067	0.42	3.25
Mean	116.56	3.426	21.10	245.11

Means followed by the same letter(s) within the same column and treatment are not significantly different at 5% level of probability according to the new Duncan's Multiple Range Test.

increase due to plant population were 36 and 12 per cent when plant population was increased from 34 000 to 50 000 and from 50 000 to 66 000 plants/ha, respectively.

4.2.2 Stem diameter

Nitrogen application and increasing plant population did not affect stem diameter significantly. However, stem diameter decreased slightly with increasing plant population (Table 4.4).

4.2.3 Number of internodes per plant

The effect of nitrogen and plant population on number of internodes was not significant. All the levels of nitrogen produced virtually the same number of internodes. The same was true in the case of plant population effects on this parameter.

4.2.4 Plant height

Plant height was affected by neither nitrogen application nor by plant population in the present study. Plant population of 66 000 plant/ha however, gave the tallest plants, although it was not significantly different from the others.

4.2.5 Flag leaf area

There were significant differences in flag leaf area among the different rates of nitrogen application.

Application of 90 kg N/ha produced a significantly larger flag leaf area than the 30 kg N/ha rate. The flag leaf area at 0, 30, 60 and 120 kg N/ha were similar statistically (Table 4.5).

Increasing plant population resulted in reduction in flag leaf area. Plant population at the level of 34 000 plants/ha produced the largest flag leaf area while the smallest flag leaf area was obtained at a plant population level of 66 000 plants/ha. Flag leaf area was reduced by a magnitude of about 8 per cent when plant population was increased from 34 000 to 66 000 plants/ha (Table 4.5).

4.2.6 Number of leaves per plant

Number of leaves per plant was slightly affected by nitrogen application. There was a marginal significant reduction in the number of leaves per plant when nitrogen rate was increased from 0 to 30 kg N/ha. However, further increases in the rate of nitrogen to 120 kg N/ha had no significant effect on this variable.

Increasing the plant population from 34 000 to 66 000 plants/ha had no significant effect on the number of leaves per plant (Table 4.5).

4.2.7 Total leaf area per plant and leaf area index

The effect of nitrogen application on leaf area per plant was not significant in the present study.

Table 4.5: The effect of nitrogen and plant population on flag-leaf area at 10 WAP, number of leaves at 16 WAP, leaf area per plant at 15 WAP and leaf area index of sorghum hybrid SAMSORG 31 at Samaru, 1985.

Treatment	Flag-leaf area (sq.cm) 10 WAP	No. leaves per plant 16 WAP	Leaf area per plant (Sq. cm) 15 WAP	Leaf area index
Nitrogen rate (kg/ha)				
0	140.8ab	20.2b	104.6a	4.32c
30	142.7a	19.4a	103.3a	4.17a
60	152.9ab	19.9ab	105.2a	4.21ab
90	164.4b	19.8ab	97.5a	4.23b
120	155.5ab	19.9ab	93.8a	4.21ab
SE±	6.98	0.40	5.1	0.212
Plant population (plants/ha)				
34 000	150.2b	20.2a	110.2b	3.61a
50 000	154.1ab	19.6a	92.7a	4.13b
66 000	146.2a	19.7a	99.7a	4.44c
SE±	5.40	0.37	4.0	0.164
Mean	152.05	19.84	100.9	4.333

WAP = Weeks after planting

Means followed by the same letter(s) within the same column and treatment are not significantly different at 5% level of probability according to the new Duncan's Multiple Range Test.

However, slight differences were observed in leaf area index (Table 4.5).

The effect of plant population on the total leaf area was significant. The total leaf area at a plant population level of 34 000 plants/ha was found to be significantly larger than at 50 000 or 66 000 plants/ha. A 16 per cent reduction in total leaf area per plant was observed by increasing the plant population from 34 000 to 50 000 plants/ha. The leaf area index at 50 000 or 66 000 plants/ha was significantly greater than at 34 000 plants/ha. A 26 per cent decrease in LAI was observed between the lowest and the highest plant population levels.

4.2.0 Leaf dry weight

Nitrogen application did not have any significant effect on sorghum leaf dry weight at 12, 14 or 16 weeks after planting. There was however a tendency for this variable to be increased by higher rates of nitrogen application.

Increasing plant population caused leaf dry weight per plant at 12 weeks after planting to decline significantly. Leaf dry weight decreased by 9 and 11 per cent with increase in plant population from 34 000 to 50 000 and 66 000 plants/ha, respectively (Table 4.6).

At 14 weeks after planting, leaf dry weight was

Table 4.6: The effect of nitrogen and plant population on leaf dry weight of sorghum hybrid SAMSORG 31 at 12, 14 and 16 WAP at Samaru, 1985.

Treatment	Leaf dry weights (g/plant)		
	12 WAP	14 WAP	16 WAP
Nitrogen rate (kg/ha)			
0	67.7a	72.6a	59.9a
30	72.1a	77.4a	50.1a
60	72.1a	70.1a	60.6a
90	73.9a	70.4a	70.0a
120	76.3a	71.0a	64.2a
SE±	4.31	7.09	5.49
Plant population (plants/ha)			
34 000	79.9b	02.0b	69.6c
50 000	72.6a	71.0ab	64.5b
66 000	64.0a	60.4a	53.6a
SE±	3.34	5.49	4.25
Mean	72.43	74.06	62.56

WAP = Weeks after planting.

Means followed by the same letter(s) within the same column and treatment are not significantly different at 5% level of probability according to the new Duncan's Multiple Range Test.

observed to have decreased with increasing plant population. The lowest plant population level of 34 000 plants/ha gave a significantly higher dry weight of leaves than 66 000 plants/ha. The magnitudes of decrease in leaf dry weight when plant population was increased from 34 000 to 50 000 and from 50 000 to 66 000 plants/ha were 12 and 6 per cent, respectively. Leaf dry weight at 16 weeks after planting followed a similar trend. A plant population of 34 000 plants/ha gave a significantly higher leaf dry weight than 50 000 plants/ha and 66 000 plants/ha (Table 4.6). Leaf dry weight per plant declined as sorghum plants aged past 14 weeks after planting.

4.2.9 Stem dry weight

As shown in Table 4.7, the effect of nitrogen application on sorghum stem dry weight was not significant at 12 and 14 weeks after planting. However, stem dry weight per plant tended to increase as nitrogen application rate increased from 0 through 120 kg N/ha. At 16 weeks after planting, significant differences in the stem dry weight were observed between nitrogen rates. The lowest stem dry weights were obtained from the application of 30 kg N/ha while the highest stem dry weights per plant were obtained by the application of 90 and 120 kg N/ha.

Plant population had a negative effect on the stem dry weight of sorghum at 12, 14 and 16 weeks after planting in

Table 4.7: The effect of nitrogen and plant population on stem dry weights of sorghum hybrid SAMSORG 31 at 12, 14 and 16 WAP at Samaru, 1985.

Treatment	Stem dry weights (g/plant)		
	12 WAP	14 WAP	16 WAP
Nitrogen rate (kg/ha)			
0	152.4a	210.0a	210.0b
30	159.1a	206.5a	185.6a
60	163.9a	220.1a	191.1ab
90	164.0a	205.9a	214.2b
120	169.6a	110.0a	219.0b
SE±	13.03	10.51	15.69
Plant population (plants/ha)			
34 000	181.1b	243.4b	241.3c
50 000	162.0a	206.9a	206.3b
66 000	142.3a	186.5a	169.7a
SE±	10.09	14.34	12.15
Mean	161.80	199.76	204.75

WAP = Weeks after planting.

Means followed by the same letter(s) within the same column and treatment are not significantly different at 5% level of probability according to the new Duncan's Multiple Range Test.

the present study. At 12 weeks after planting, increasing plant population level from 34 000 to 50 000 plants/ha significantly reduced the stem dry weight. However the decrease in stem dry weight caused by a further increase in plant population from 50 000 to 66 000 plants/ha was not significant. Reductions of 11 and 12 per cent were observed by increasing the plant population levels from 34 000 to 50 000 and from 50 000 to 66 000 plants/ha, respectively.

The effect of increasing plant population levels on the stem dry weight of sorghum at 14 weeks after planting followed the same trend as that of 12 weeks. Reductions of 15 and 10 per cent were observed when plant population levels were increased from 34 000 to 50 000 and from 50 000 to 66 000 plants/ha, respectively. At 16 weeks after planting, significant reductions in stem dry weight were observed when plant population levels were increased from 34 000 to 50 000 plant/ha and from 50 000 to 66 000 plants/ha. The magnitudes of reductions that were observed were 15 and 10 per cent, respectively (Table 4.7).

4.2.10 Panicle dry weight

The application of nitrogen did not produce any significant effect on panicle dry weight at both 14 and 16 weeks after planting (Table 4.8).

Table 4.8: The effect of nitrogen and plant population on panicle dry weights of sorghum hybrid SAMSORG 31 at 14 and 16 WAP at Samaru, 1985.

Treatment	Panicle dry weight (g/plant)	
	14 WAP	16 WAP
Nitrogen rate (kg/ha)		
0	34.3a	96.4a
30	34.6a	88.8a
60	36.1a	92.1a
90	32.6a	97.3a
120	35.0a	94.0a
SE±	3.05	6.50
Plant population (plants/ha)		
34 000	35.5a	104.6b
50 000	35.2a	93.2a
66 000	33.4a	83.3a
SE±	2.36	5.04
Mean	34.69	93.71

WAP = Weeks after planting

Means followed by the same letter(s) within the same column and treatment are not significantly different at 5% level of probability according to the new Duncan's Multiple Range Test.

Increasing plant population levels resulted in a non-significant reduction in the panicle dry weight of sorghum at 14 weeks after planting. The heaviest panicles were produced at the lowest population level. Increasing plant population level decreased panicle dry weight at 16 weeks after planting. A significant reduction in panicle dry weight was observed by increasing plant population level from 34 000 to 50 000 plants/ha. The level of reduction in panicle dry weight for the first 16 000 plants/ha was 11 per cent while a non-significant reduction of 10.6 per cent was observed for a further 16 000 plants/ha increment in plant population level.

4.2.11 Total plant dry weight

The effect of nitrogen on the total dry weight per plant was not significant at 12, 14 and 16 weeks after planting. However, there seems to be a tendency for this variable to be increased by higher rates of nitrogen application.

There were significant differences in the total dry weight per plant among plant population levels at the three growth stages used in the present study. At 12 weeks after planting increasing plant population reduced the total dry weight of the sorghum plant. The highest population level tested i.e. 66 000 plants/ha produced the lowest total dry weight per plant while the highest

dry weight was produced at the lowest plant population level. At 14 weeks after planting, significant differences in the total plant dry weight were observed among the plant population levels. The first 16 000 plants/ha increment in plant population level produced 13 per cent decrease in total plant dry weight while a further 16 000 plants/ha increment resulted in 0 per cent decrease in the total dry weight per plant.

At 16 weeks after planting highly significant differences in the total dry weight per sorghum plant were observed among the plant population levels. Reductions in the plant total dry weight as a result of increment in plant population levels from 34 000 to 50 000 and from 50 000 to 66 000 plants/ha were 12 and 16 per cent, respectively (Table 4.9).

4.3 Effect of Nitrogen Rate and Plant Population on Grain Quality

4.3.1 Grain crude protein

Increasing nitrogen application rate increased the grain crude protein. Significant differences in this parameter were observed among the different nitrogen rates. A 21 per cent difference in the grain crude protein was observed between the lowest and highest nitrogen application rates. Increasing the plant population from 34 000 through

Table 4.9: The effect of nitrogen and plant production on total plant dry weight of sorghum hybrid SAMSORG 31 at 12, 14 and 16 WAP at Samaru, 1985.

Treatment	Total plant dry weights (g/plant)		
	12 WAP	14 WAP	16 WAP
Nitrogen rate (kg/ha)			
0	220.1a	316.9a	366.3a
30	231.2a	310.5a	332.5a
60	236.0a	334.3a	351.0a
90	237.9a	300.9a	301.5a
120	245.9a	326.4a	370.0a
SE±	16.94	26.92	25.35
Plant population (plant/ha)			
34 000	261.1b	360.9b	415.5c
50 000	234.6ab	313.9ab	364.0b
66 000	207.1a	288.3a	306.6a
SE±	13.12	20.86	19.64
Mean	234.24	321.01	357.20

WAP = Weeks after planting

Means followed by the same letter(s) within the same column and treatment are not significantly different at 5% level of probability according to the new Duncan's Multiple Range Test.

66 000 plants/ha decreased the grain crude protein in the present study. Plant population levels of 34 000 and 50 000 plants/ha produced grain crude protein values which were at par but significantly higher than that produced at a plant population level of 66 000 plants/ha (Table 4.10).

4.3.2 Crude protein yield

There were significant differences in grain crude protein yields observed among different rates of nitrogen. Higher rates of nitrogen seemed to have produced higher crude protein yield than did the lower nitrogen rates.

Increasing plant population levels caused slight but non-significant reductions in crude protein yield. The highest yield of crude protein was obtained at the lowest plant population tested in the present study (Table 4.10).

4.4 Interactive Effect of Nitrogen and Plant Population on Grain Sorghum

4.4.1 Plant total dry weight

As shown in Table 4.11, significant differences were observed in this variable as a result of interaction between nitrogen application and plant population. At 12 weeks after planting the highest total plant dry weight was observed at the lowest population level and highest nitrogen rate tested. The lowest dry weight on the other

Table 4.10: The effect of nitrogen and plant population on grain crude protein and crude protein yield of sorghum hybrid SAMSORG 31 at Samaru, 1985.

Treatment	Grain crude protein (%) (Nx6.25)	Crude protein yield (kg/ha)
Nitrogen rate (kg/ha)		
0	12.22a	296.0a
30	13.22b	277.9a
60	14.06c	349.3ab
90	14.33d	303.1b
120	14.72e	331.0b
SE±	0.092	34.55
Plant population (plants/ha)		
34 000	14.05b	366.4a
50 000	13.92b	342.4a
66 000	13.16a	304.2a
SE±	0.071	26.76
Mean	13.710	331.30

Means followed by the same letter(s) within the same column and treatment are not significantly different at 5% level of probability according to the new Duncan's Multiple Range Test.

hand was obtained at the highest plant population level and highest nitrogen rate. At 16 weeks after planting, the lowest dry weight was obtained at 60 kg N/ha at the highest population while this parameter was highest at the lowest population level without the application of nitrogen (Table 4.11).

4.4.2 Thousand-grain weight and grain weight per plant

Significant differences due to interaction between nitrogen application and plant population were observed in these two parameters.

Table 4.12 shows that at the lowest plant population of 34 000 plants/ha and nitrogen rate of 60 kg N/ha the highest grain weight per plant was obtained. That weight was however comparable with those obtained at any other nitrogen rate under the same plant population level of 34 000 plants/ha.

The highest value of thousand-grain weight was obtained at a combination of the lowest plant population and the lowest nitrogen application rate. This grain weight value was however comparable with those obtained with higher nitrogen rate at the same plant population level (Table 4.12).

Table 4.11: Interactive effects of nitrogen and plant population levels on plant total dry weights of sorghum SAMSORG 31 at 12 and 16 WAP at Samaru, 1985.

Nitrogen rate (kg/ha)	Plant total dry weights (g/plant) at 12 WAP			Plant total dry weights (g/plants) at 16 WAP		
	Plant population (plants/ha)			Plant populations (plants/ha)		
	34 000	50 000	66 000	34 000	50 000	66 000
0	253.3abcdef	204.6ab	205.0abc	455.1gh	335.3abcdef	300.7abcde
30	236.0abcdef	255.4abcdef	206.6abcd	429.4fgh	279.6ab	200.0abc
60	261.7abcdef	237.7abcdef	200.0abcde	379.5bcdefgh	395.0defgh	274.0a
90	259.0abcdef	226.6abcdef	224.3abcdef	400.1defgh	390.5cdefg	354.1abcdefg
120	291.4f	240.5abcdef	195.4a	407.1defgh	413.4fgh	306.4abcd
SE±		29.35			43.91	

WAP = Weeks after planting.

Means followed by the same letter(s) within the same column are not significantly different at 5% level of probability according to the New Duncan's Multiple Range Test.

Table 4.12: Interactive effects of nitrogen and plant population levels on grain weight per plant and 1000-grain weight of sorghum hybrid SAMSORG 31 at Samaru, 1985.

Nitrogen rate (kg/ha)	Grain weight per plant (g)			1000-grain weight (g)		
	Plant populations (plants/ha)			Plant populations (plants/ha)		
	34 000	50 000	66 000	34 000	50 000	66 000
0	73.2fgh	51.3abcdefh	52.4abcdefgh	27.9b	25.2ab	27.5ab
30	60.0bcdefgh	44.2abc	44.5abcd	26.6ab	23.8a	25.3ab
60	76.6h	59.5abcdefgh	47.1abcde	26.4ab	27.3ab	24.4ab
90	75.4fgh	59.9abcdefgh	42.9ab	26.5ab	25.2ab	26.6ab
120	64.0abcdefgh	51.2abcdef	41.7a	25.9ab	26.8ab	24.5ab
SE±		10.56			1.61	

Means followed by the same letter(s) within the same column are not significantly different at 5% level of probability according to the new Duncan's Multiple Range Test.

Table 4.13: Interactive effects of nitrogen and plant population levels on number of panicles per sq. metre and number of grains per panicle of sorghum hybrid SAMSORG 31 at Samaru, 1985.

Nitrogen rate (kg/ha)	Number of panicles per m^2			Number of grains per panicle		
	Plant population (plants/ha)			Plant population (plants/ha)		
	34 000	50 000	66 000	34 000	50 000	66 000
0	3.2abcd	3.7cdef	4.2f	2730.4abcdefgh	2422.0abcdefgh	2269.0abcde
30	3.0abc	3.5abcdef	4.2f	2914.1abcdefgh	2191.0ab	1962.3a
60	2.9ab	3.0cdef	3.0def	3145.4fgh	2613.0abcdefgh	2454.9abcdefgh
90	3.3abcde	4.0ef	3.9ef	3266.4gh	2703.6abcdefgh	2222.0abcd
120	2.0ab	3.0cdef	4.2f	2799.2abcdefgh	2416.0abcdef	2200.6abc
SE±		0.33			352.41	

Means followed by the same letter(s) within the same column are not significantly different at 5% level of probability according to the new Duncan's Multiple Range Test.

planting was significant. The highest panicle dry weight was obtained from either the 0 or 30 kg N/ha under the lowest plant population.

Significantly heavier panicles were obtained with a combination of a plant population of 34 000 plants/ha and 90 kg/ha nitrogen application rate. Although this treatment combination produced the heaviest panicles, it was statistically similar to those obtained under the same plant population at all other nitrogen rates.

4.4.5 Panicle length and flag leaf area

The longest panicles were obtained under a combination of a nitrogen rate of 90 kg/ha and a plant population of 34 000 plants/ha, the lowest plant population tested in the present study. However, the lengths of panicles obtained at a higher nitrogen rate and the same plant population level were comparable with this length (Table 4.15).

The flag leaf area was higher under a plant population of 66 000 plants/ha and nitrogen applications rate of 90 kg/ha, compared to other combination of factor levels.

4.4.6 Stover yield

This parameter showed some differences due to

Table 4.14: Interactive effects of nitrogen and plant population levels on panicle dry weights at 16 WAP and weight per panicle of sorghum hybrid SAMSORG 31 at Samaru, 1985.

Nitrogen rate (kg/ha)	Panicle dry weight (g) at 16 WAP			Weight per panicle (g)		
	Plant population (plants/ha)			Plant population (plants/ha)		
	34 000	50 000	66 000	34 000	50 000	66 000
0	114.6f	83.9abcd	90.7abcdef	105.4ab	105.0ab	81.9ab
30	114.7f	76.9abc	74.7a	101.0ab	75.6ab	71.2ab
60	97.0abcdef	103.6def	75.9ab	107.7ab	92.7ab	110.2ab
90	101.0abcdef	106.0abcdef	90.1abcdef	113.5b	69.3a	79.2ab
120	95.9abcdef	100.0abcdef	85.2abcde	101.6ab	80.5ab	76.3ab
SE±		11.27			17.57	

WAP = Weeks after planting

Means followed by the same letter(s) within the same column are not significantly different at 5% level of probability according to the new Duncan's Multiple Range Test.

interaction between nitrogen application and plant population. The highest stover yield was obtained at a plant population of 50 000 plants/ha and a 90 kg/ha nitrogen application rate (Table 4.16).

4.5 Simple Correlation Studies

Simple correlation studies involving pairs of various important parameters were made and the results of these are shown in Table 4.17. These important parameters include plant height, panicle length, grain yield, stover yield, 1000-grain weight, flag leaf area, number of grains per panicle, panicle yield, weight per panicle, grain weight per panicle and plant total dry weight.

Among these parameters, only total dry matter at 12 and 14 weeks after planting were positively correlated with panicle length; one of all the others had significant correlation with panicle length.

Plant height was positively correlated with grain yield, stover yield, panicle yield, 1000-grain weight, grain weight per panicle and total dry matter at 16 weeks after planting. Grain and stover yields were positively correlated with flag leaf area, number of grains per panicle, panicle yield, weight per panicle, and total dry matter at 16 weeks after planting. Thousand-grain weight was positively correlated with all the parameters with the exception of flag leaf area and panicle length.

Table 4.15: Interactive effects of nitrogen and plant population levels on panicle length and flag leaf area of Sorghum hybrid SAMSORG 31 Samaru, 1985.

Nitrogen rate (kg/ha)	Panicle length (cm)			Flag leaf area (cm^2)		
	Plant populations (plants/ha)			Plant populations (plants/ha)		
	34 000	50 000	66 000	34 000	50 000	66 000
0	36.1cde	35.1abcde	34.4abc	154.0ab	147.0ab	130.0ab
30	35.4abcde	34.7abcd	34.6abcd	140.5ab	154.0b	124.7a
60	35.6abcde	36.2de	34.8abcde	162.6b	148.1ab	140.0ab
90	36.5e	34.8abcd	35.9cde	164.6b	160.0b	137.7b
120	35.0abcde	34.1a	35.5abcde	155.3b	159.3b	151.0ab
SE±		0.72			12.09	

Means followed by the same letter(s) within the same column are not significantly different at 5% level of probability according to the new Duncan's Multiple Range Test.

Table 4.16: Interactive effects of nitrogen and plant population levels on stover yield of Sorghum hybrid SAMSORG 31 at Samaru, 1985.

Nitrogen rate (kg/ha)	Stover yield (kg/ha) Plant populations (plants/ha)		
	34 000	50 000	66 000
0	7629.6b	6105.2ab	6061.1ab
30	5777.0ab	5435.2a	6260.5ab
60	6351.9ab	6796.3ab	6390.1ab
90	6851.9ab	7796.3b	6453.7ab
120	6037.0ab	7361.1ab	6250.0ab
SE±		094.71	

Means followed by the same letter(s) within the same column are not significantly different at 5% level of probability according to the new Duncan's Multiple Range Test.

Table 4.17: Correlation matrix of panicle length, plant length, grain yield, stover yield, 1000-grain we flag leaf area, no. grains per panicle, panicle yield, weight per panicle, grain weight per and total dry matter at 12, 14 and 16 WAP.

	Panicle length	Plant height	Grain yield	Stover yield	1000-grain wt.	Flag leaf area	No. grains per panicle	Panicle yield(kg/ha)	Weight per panicle	Grain weight per panicle
Plant height	0.164									
Grain yield	0.025	0.412**								
Stover yield	-0.004	0.617**	0.630**							
1000-grain wt.	0.109	0.402**	0.662**	0.554**						
Flag leaf area	-0.045	-0.033	0.319*	0.009	0.219					
No. grains/ panicle	0.120	0.132	0.702**	0.233	0.472**	0.402**				
Panicle yield (kg/ha)	0.010	0.464**	0.975**	0.695**	0.643**	0.273*	0.610**			
Wt./panicle	-0.004	0.101	0.298*	0.153	0.384**	0.206	0.480**	0.281*		
Grain wt./ panicle	0.170	0.281*	0.736*	0.434**	0.676**	0.459**	0.874**	0.684**	0.499**	
Total dry matter at 12 WAP	0.200*	0.103	-0.034	0.241	0.090	0.093	0.105	=0.018	0.024	0.261*
Total dry matter at 14 WAP	0.273*	0.000	0.037	0.109	0.428**	0.030	0.423**	0.029	0.220	0.283*
Total dry matter at 16 WAP	0.230	0.260*	0.310*	0.415**	0.474**	0.274*	0.470**	0.283**	0.336**	0.526**

0.365

0.493

* = Significant at 5% (0.254)

** = Significant at 1% (0.330)

WAP = Weeks after planting.

Flag-leaf ere was positively correlated with all thc parameters with the exception of plant height, panicle length, stover yield, weight per panicle and total dry matter at 12 and 14 weeks after planting.

Number of grains per panicle was positively correlated with all the selected variables, with the exception of panicle length, plant height and total dry matter at 12 weeks after planting. A highly significant correlation was found between number of grains per panicle and grain yield, 1000-grain weight, panicle yield, weight per panicle, grain weight per panicle and total dry weight at 14 and 16 weeks after planting.

Panicle yield was positively correlated with all the variables except total dry weights at 12 and 14 weeks after planting and panicle length.

Weight per panicle was positively correlated with other variables except panicle length, plant height and total dry matter at 12 weeks after planting. A highly significant correlation was observed between panicle weight and 1000-grain weight, number of grains per panicle, grain weight per panicle and total dry weight at 16 weeks after planting.

Grain weight per panicle was positively correlated with all the selected variables except with panicle length.

Highly significant correletion was observed between grain weight per panicle and grain yield, 1000-grain weight, flag leaf area, number of grains per panicle, panicle yield, weight per panicle and total dry weight at 16 weeks after planting.

The total dry weight at 12, 14 and 16 weeks after planting were positively correlated with other variables except that total dry weight at 12 weeks after planting was negatively correlated with panicle yield and grain yield. Some of the variables that had highly significant correlations with total dry weight at 12, 14 and 16 weeks after planting are stover yield, 1000-grain weight, number of grains per panicle, panicle yield and grain weight per panicle.

Grain yield was positively correlated with all parameters measured except total dry weight at 12 weeks after planting.

Chapter 5

DISCUSSION

5.1 Nitrogen

Grain yield was not significantly affected by nitrogen application in the present study. The lack of response by this hybrid (SAMSORG 31) to nitrogen application may be due to several factors, which are likely to include the fact that the soil nitrogen status of the experimental site on which the trial was conducted (with a value of 0.046 per cent) was fairly higher than the average value (0.038 per cent) for the savanna cultivated soils (Balasubramania et al., 1984). It is most likely that the level of soil total nitrogen would meet a substantial proportion of the nitrogen required for the production of maximum grain yield in grain sorghum. Also the organic carbon content as well as the C:N ratio of the soil were high. It is also possible that much of the assimilates produced by the plant at some critical growth stages were translocated to straw resulting in higher stover yield at the expense of higher grain production. It may also be due to the fact that the crop soy bean (Glycine max L.), that preceded sorghum on the experimental area is a nitrogen fixing legume. According to Lombin and Abdullahi (1981), a field previously cropped with legumes, especially groundnut, may fix up to 100 - 150

kg N/ha. Although part of the nitrogen fixed in the soil may be leached out of the root zone before the sowing of sorghum, the remaining nitrogen adequately supplements any fertilizer added and reasonably meets the crop's need. Adams (1974) in Texas also reported similar findings. He failed to observe significant response of sorghum yield to nitrogen fertilizer application up to 69 kg N/ha due to preceding sweet clover crop. Lack of grain yield response to high level of nitrogen application in the present study can also be attributed to the low pH of the soil, which reduced the availability of applied nitrogen. Acid soils are not likely to bring about significant response to nitrogen fertilization in cereals.

The increased stover yield due to the application of 90 kg N/ha which was observed in the present study confirms the observation reported by Perry and Olson (1975), who reported increase in stover yield with application of 90 kg N/ha. The observed increase in stover yield could be explained on the basis of intra-plant competition. Assimilates instead of being translocated to the panicles for grain development, were used for straw formation, which resulted in higher stover yield.

The non-significant effect of nitrogen on number of grains per panicle, weight of grains per panicle and grain size may partly explain the observed non-significant

effect of nitrogen application on grain yield. Most of the assimilates were used for vegetative growth and relatively less was left for grain formation and grain-filling. The observed result may also be associated with the delay in planting the sorghum crop. Ogunlela (1985) observed a progressive decline in grain number/panicle when planting was delayed beyond 3 June at Samaru, Nigeria.

Number of panicles per m^2, panicle length and panicle yield were not affected by the application of nitrogen. However, the tendency for these varibles to decrease at high nitrogen rates may be due to the negative effect of nitrogen application, which in turn may be due to increase in susceptibility of sorghum to pest attack with nitrogen application (Hayward, 1973). This is because at high nitrogen application level, the plant parts have succulent tissues, which will likely attract and support the growth of pests and diseases.

The non-significant effect of nitrogen application rate on test weight, threshing percentage, and harvest index confirms the findings of Anonymous (1986, 1987), who had earlier reported the non-significant effect of increased nitrogen application to sorghum hybrids SAMSORG 20, SAMSORG 29 and SAMSORG 31 with respect to these variables. Test weight is influenced by grain size as well as density. Since nitrogen had no significant

effect on grain size, it consequently had no effect on the test weight of sorghum grain.

The failure of grain: stover ratio to increase in response to nitrogen rates higher than 60 kg N/ha could be as a result of the use of more assimilates for the production of other plant parts rather than for grain due to intra-plant competition for nutrient and moisture.

There was no significant effect due to nitrogen application on plant height. This could be as a result of the fact that nitrogen application, especially when supplied in large quantities, encourages vegetative growth by increased leaf cell number and cell enlargement with an overall increase in size and leaf production rather than height (Morton and Watson, 1940). It may also be as a result of the acidic nature of the soil at the experimental site, which tended to fix some of the nutrient applied to the field. The result is similar to that of Ram (1960), who recorded a significant response in plant height only when the highest level of nitrogen (102 kg N/ha) was applied to sorghum. Narayan (1967) however, reported significant response even at 60 kg N/ha application. The disparity between these two results could be due to differences in the fertility levels of the experimental sites. However, non-significant response to nitrogen application had also been reported by Anonymous (1986; 1987) and Gaya (1975).

The lack of response of stem diameter and number of main stem internodes to nitrogen application may be due to the fact that the fertility level of the experimental soil was adequate for this hybrid (SAMSORG 31) to exploit its growth potentials.

Although differences due to nitrogen application were observed for flag leaf area, number of leaves per plant and leaf area index, there was no clear-cut pattern in their response to the rates applied. This observation may be due to a lack of response of the hybrid sorghum to nitrogen application, a fact that could be occasioned by factors that have earlier been discussed.

The non-significant effect of nitrogen application on the dry weight of leaves may be due to the general poor response of this hybrid to nitrogen application. However, the increase observed in the dry weight of the leaves with increase in nitrogen application at 12 WAP may be due to the fact that the entire nitrogen quantity was applied before the determination of this parameter and also because no panicles had been formed up to the time the determination was done. All the available photosynthate was, therefore, used for vegetative growth. At 16 WAP, the lack of significant increase in dry weight of leaves per plant in response to nitrogen application could be due to abscission of lower older leaves where the earlier

mentioned differences may have occurred. Dry weights of stem was significantly affected by nitrogen application only at 16 WAP. At this growth stage, sorghum plants were at their advanced stage of growth and much of the assimilates were translocated to the stem as reserve products. The dry weights of the panicles at 14 and 16 WAP were not significantly affected by nitrogen application but the panicle dry weights at the latter stages trebled these at 14 WAP. This result may be due to fact that panicles were at the stage of active growth and, therefore, more assimilate had to be translocated to the panicles for grain filling purposes.

The slight and, therefore, non-significant increase in total dry matter with nitrogen application confirms the report of Gaya (1976), who had earlier observed increased dry matter in sorghum varieties with high levels of nitrogen application at Nebraska in the United States. This is because nitrogen application to annual crops is expected to promote a more vigorous growth of the plant.

5.2 Plant Population

In the present investigation, the non-significant decrease in grain yield at the highest plant population (66 000 plants/ha) was probably due to intra and inter-plant competition for nutrient and moisture by sorghum plants. The high population may have produced some mutual shading effect, thereby limiting the photosynthetic

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activities of leaves and thereby resulting in decreased dry matter production. Since plants at high population levels are usually smaller in size, they probably develop less extensive root system, with a consequent lower capacity for maximum moisture, as well as nutrient, uptake than plants at the lower populations. This result is in agreement with the findings of Costa (1974), who observed non-significant increase in grain yield with increasing plant populations in grain sorghum in Brazil.

Grain number per panicle was reduced by as much as 25% when plant population was increased by about 32 000 plants/ha. This was because plots with plants grown under low plant population levels produced individual plants which had better and more vigorous growth and higher yielding ability, which was reflected in greater grain number per panicle. Molina et al. (1977), Wahua and Miller (1978) and Escosima et al. (1981) also observed similar reductions in number of grains per panicle in direct response to increase plant population.

Although the differences were not significant statistically, a plant population of 34 000 plants/ha produced heavier grains. This could be associated with a situation of less competition for light, moisture and nutrients among plants, resulting in more vigorous plants, which in turn produced heavier seeds. This result

is in agreement with the findings of Sun (1969).

A significant increase in number of panicles per m^2 confirms the report of Lanjewar and Khot (1970) to the effect that narrow spacings between plants tended to increase the number of panicles per m^2. This was probably due to the greater numbers of plants in closer spaced plots since the sorghum hybrid used in the study is not a tillering type.

The decreased panicle length which resulted under increased plant population levels as observed in this study might be due to the fact that wider spacings resulted in less competition for most of the growth factors and consequently better growth and healthy individual plants and hence significantly longer heads. Escasinas *et al.* (1981) have reported a reduction in length of sorghum panicles with increase in plant population in the Philippines.

The 36% reduction in the weight of grain per plant observed as a result of 32 000 plants/ha increase in plant population could be due to both intra and inter-plant competion for moisture, light, and nutrients. Since these factors significantly affect the size and the number of grains, by reducing these at high population, ultimately, the grain weight per plant will be reduced. Lanjewar and Khot (1970) had earlier observed that increasing plant

population decreased grain weight per panicle. The present result, therefore, lends further credence to their finding.

Failure of the panicle yield to increase at the highest plant population (66 000 plants/ha) may be due to the severe competition for nutrients and moisture at a population higher than that which was considered to be optimum (50 000 plants/ha).

The slight and non-significant reduction in test weight due to increased plant population could be as a result of the negative effect of high population on grain size. This is because test weight is influenced by the grain size as well as grain density.

The non-significant reduction in harvest index and grain:stover ratio under increased plant population was probably due to the fact that the assimilates instead of being translocated to the panicles for grain filling, were directed to vegetative growth and hence the observed higher stover yield relative to the grain. Under high plant population levels, plants tended to compete for sunlight and, therefore, grew taller. Anonymous (1987) observed non-significant effect of increased plant population on grain: stover ratio in grain sorghum. Non-significant effect of increased sorghum plant population on harvest index when grown in mixture with maize (Zea mays L.) was

reported by Lere (1984).

The decrease in stem diameter and number of internodes per plant in response to plant population increase observed in this study agrees with the findings of Shapal and Arister Khova (1982). Competition for moisture, light and nutrient resulting in some stress probably caused the production of plants which were weak and with slender stems. Shading effect at high population may cause the production of less photosynthates which could have made the production of thick stems possible.

Although there was no significant increase in plant height due to increased plant population, the slight increase at the highest plant population level may be due to greater mutual shading of the plant canopy under high leaf area index. The plants might have used the assimilates in bringing about increase in height in an attempt to reach for more sunlight. Son (1969) observed that intra-row spacing did not influence plant height in sorghum. El-Sebaaic (1979) reported from his studies conducted at Samaru that changing plant distance within the row did not effect plant height except when the inter-row spacing was made narrow (60 cm).

A significant reduction in the area of the flag leaf as a result of increased plant population observed in the present study agrees with the findings of Anonymous (1977)

who reported a decrease in flag leaf area with increased population. Competition for light, carbon dioxide, nutrients and moisture probably partly explains the reduction in the area of the flag leaf with increase in plant population.

The effect of increased plant population on the number of leaves per plant was not significant, however, there was a tendency for this variable to decrease at higher plant population levels. By increasing plant population, a greater competition among the sorghum plants resulted, consequently less plant growth was recorded, which was reflected in the number of leaves per plant.

The decrease in leaf area per sorghum plant with increase in plant population observed in this study confirms the findings of Raghunathen et al. (1973) and Hoshino (1974). This was so because increased plant population resulted in greater competition among the individual plants for different growth factors. That competition probably resulted in reduction in the total leaf area of the plant. This result is similar to the response in the number of leaves per plant to plant population changes, since this parameter is a function of number of leaves.

The decrease in LAI at the highest population level tested (66 000 plants/ha) may probably be due to the

significant reduction in the total leaf area of individual plant at high plant populations.

Leaf dry weight at 12, 14 and 16 WAP were significantly affected by plant population changes in this study. By increasing plant population, competition for photosynthates was increased and this is reflected in lower dry weights of leaves per plant. The significant increase in dry weights of stems, panicles and total dry weights at a lower plant population level can be attributed to the generally good performance in terms of plant vegetative growth or dry matter production at low plant population levels. The plants in plots sown at low densities grew vigorously and this most likely encouraged the development of larger stem diameter and larger heads, which seemed to have compensated for the higher number of plants per unit land area at the higher populations. At high plant population levels, there is likely to be mutual shading and thus less light is able to penetrate the crop canopy and reach the lower.older leaves. Such leaves being devoid of adequate sunlight are likely to photosynthesize below the point of compensation. The outcome of this is greater total dry matter per sorghum plant under low plant population levels. Also at high population levels, there was competition for space moisture and nutrient elements, a situation which also effected the physiology or general performance of the crop. Vecchiettini and Lambertinii (1979) observed higher dry matter

yields at low sowing rates, a finding that agrees quite closely with the present result.

The reduction in panicle weight due to increase in plant population levels may be attributed to increased plant competition. At high plant population more competition for growth requirements will ultimately result in less vigorous plants, which in turn would produce lighter panicle. Mercer-Quarshie (1972) observed that panicle in late maturing sorghums in Ghana were reduced by increasing plant population.

5.3 Grain Quality

The grain crude protein content and crude protein yield increased with increasing nitrogen rate. This might be due to the vigorous growth of the plants and larger leaf area per plant, which resulted in more protein synthesis and storage. The rather high value of crude protein obtained may be due to increased nitrogen uptake by the plants and also the fairly high nitrogen content in the experimental site. Gangaseran and Prasad (1979) observed increased nitrogen uptake with increased nitrogen application. Nitrogen is a mobile nutrient and its availability and concentration in the plant parts are usually associated with its degree of uptake by the plant.

The decrease in grain crude protein due to increased plant population may be explained in the light of more competition for the available nitrogen in the soil. The non-significant effect of population on the protein yield may mainly be due to the variation in grain yields rather than protein content per se since the differences in the grain yield were insignificant. Gupta and Gupta (1972), Rao and Reddy (1973) and Khatoon (1978) had also observed and reported various levels of decreases in grain protein content with increased plant population. Azeredo et al. (1976) observed that grain protein yield per hectare was more dependent on grain yield rather than on grain protein content.

5.4 Nitrogen - Population Interaction

The significant nitrogen x population interaction for total dry weights at 12 and 16 WAP revealed that nitrogen at high rates and low plant population would seem to increase total plant dry weights. This result shows that at high nitrogen application rates, nutrients are more available to the plants when under less competition due to the low plant population level.

Grain weight per plant of sorghum was at its highest value at nitrogen rate of 60 kg N/ha and at plant population level of 34 000 plants/ha. This is comparable with those at any of the other nitrogen rates tested under a plant population of 50 000 plant/ha. This may be due to the lack of response in grain weight per plant to nitrogen application in the present study.

Although the heaviest grains were obtained without the application of nitrogen and at the plant population level of 34 000 plants/ha, this is still comparable to those obtained at any of the other nitrogen rates and plant population levels tested. This may be due to the non-significant effect of both nitrogen rate and plant population level on this variable. As would be expected, the highest number of panicles per m^2 was observed at the highest population level tested irrespective of nitrogen level. This may be due to the significant effect of plant population on this variable and to the non-significant effect of nitrogen application.

A combination of 90 kg N/ha and 34 000 plants/ha produced the highest number of grains. This may have been as a result of reduced competition among plants and greater nutrient availability per plant under low plant population level and high fertilizer application.

The heaviest and the longest panicles were obtained with a combination of the lowest population and high nitrogen rate. Minimal inter-plant competition coupled with adequate nutrient may, therefore, explain the observed results.

The area of the flag leaf revealed that high population coupled with high nitrogen application rate produced the largest flag leaf areas. This may be due to the vigorous growth of the plant that resulted from the application of nitrogen at this rate.

The production of the highest yield of stover at a plant population of 50 000 plants/ha and 90 kg N/ha fertilizer rate may be due to a combination of nutrient supply to the root medium which was used for the production of stalks, in addition to the fact that there was a high number of plants per unit land area.

5.5 Correlation Studies

The significant positive correlations observed between plant height, stover yield, 1000-grain weight, number of grains per panicle, panicle yield, and grain weight per panicle with grain yield shows that an increase in any of these variables would contribute to increase in grain yield. Pasha and Munshi (1974), Louswan and Atkins (1975) and Chiezey (1981) observed positive correlations between plant height and grain yield in grain sorghum. The negative

correlation between grain yield and total dry weight at 12 WAP may be due to the fact that at this stage of growth, there were no panicles and, thefore, there were no grain formed.

The high positive correlation between number of grains per panicle, panicle yield, weight per panicle grain weight per panicle, total dry weight at 14 WAP and 1000-grain weight could be explained on the basis that each of these variables influenced in one way or the other sorghum grain size. The significant positive correlation observed between 1000-grain weight, number of grains per panicle, weight per panicle and total dry weights at 12, 14 and 16 WAI was so probably because these variables are considered to be major components of yield while the dry weight of the plant is a good indication of the final biological yield.

Chapter 6

SUMMARY AND CONCLUSION

The effect of nitrogen and plant population on the performance of a sorghum hybrid SAMSORG 31 was investigated during the (1985) wet season at the Institute for Agricultural Research farm, Samaru, (11^{0} 11'N, 07^{0} 38'E and 686 m above sea level), Nigeria. The rates of nitrogen compared were 0, 30, 60, 90 and 120 kg N/ha and the population levels tested were 34 000, 50 000 and 66 000 plants/ha.

Most of the variables considered in this study were not significantly effected by nitrogen application. It could be as a result of the fertility level of the experimental site which was able to meet much of the nutrient requirement of this hybrid SAMSORG 31 for purposes of growth as well as yield. However, grain per cent total nitrogen and grain crude protein were increased significantly by about 21% when nitrogen rate was increased from 0 to 120 kg N/ha. Crude protein yield also increased with increasing rates of nitrogen application up to 120 kg N/ha.

Grain weight per plant decreased by 25.5 and 14.1% when plant population was increased from 34 000 to 50 000 and from 50 000 to 66 000 plants/ha, respectively. Other yield attributes such as panicle length and grain number per panicle

also decreased with increase in plant population. The dry weights of the stem, leaves and panicles as well as the total dry weight of the plant decreased with increasing plant population. Other variables which decreased slightly with increase in plant population include threshing percentage, harvest index, grain: stover ratio, stem diameter, and number of internodes.

Interactions between nitrogen and plant population were observed with respect to number of panicles per m^2, weight per panicle, number of grains per panicle, grain weight per panicle, stover yield, flag leaf area, panicle and total dry weight at 16 DAF. The highest number of grains per panicle, the heaviest and the longest panicles were obtained with a combination of 34 000 plants/ha and 90 kg N/ha. High plant population and high nitrogen rate when in combination tended to favour increased flag leaf area and stover yield while the number of panicles per m^2 was highest at high plant population irrespective of nitrogen rate. The grain nitrogen content as well as crude protein content decreased with increasing plant population levels.

Grain yield was observed to have significantly correlated with most of the important yield components such as grain weight, number of panicles per m^2 and panicle yield.

In conclusion, the present investigation has shown that sorghum hybrid SAMSORG 31, may be less responsive to nitrogen application rate due to a number of factors. This aspect however, needs further investigation on farmers' field. There was also no significant response to plant population up to 66 000 plants/ha.

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Appendix Table A.1: Daily rainfall (mm) during the 1985 cropping season at Samaru.

Days of the Month	May	June	July	August	Sept.	Oct.
1.	Tr.	-	-	24.3	0.2	1.1
2.	-	1.3	-	20.5	-	
3.	-	6.6	-	Tr.	5.5	
4.	-	-	-	-	-	
5.	-	-	30.6	7.3	22.7	
6.	3.4	-	-	13.7	23.2	
7.	-	-	3.0	2.2	-	
8.	23.7	-	5.8	-	-	
9.	-	-	104.2	Tr.	-	
10.	-	0.6	-	0.7	0.9	
11.	-	-	13.5	2.0	-	
12.	-	-	-	2.0	6.6	2.2
13.	-	-	11.0	17.2	10.6	
14.	-	30.7	-	23.4	0.9	
15.	-	-	42.2	16.3	4.6	
16.	10.3	0.7	-	2.6	19.0	
17.	-	-	6.1	10.9	25.7	
18.	Tr.	22.1	1.3	0.5	-	
19.	-	-	1.0	-	-	
20.	4.4	-	1.1	-	-	

Appendix Table A.1 (Cond.): Daily rainfall (mm) during the 1985 cropping season at Samaru

Days of the Month	May	June	July	August	Sept.	Oct.
21.	-	-	2.5	17.3	-	
22.	-	-	Tr.	-	-	
23.	0.6	17.5	25.0	2.0	-	
24.	-	-	-	-	1.6	
25.	17.5	2.2	10.0	11.2	10.5	
26.	-	-	2.0	2.0	0.6	
27.	34.3	-	-	-	14.7	
28.	Tr.	-	6.0	-	-	
29.	40.0	52.5	47.0	-	-	
30.	-	-	-	-	-	
31.	6.5	-	-	51.6	-	
Total	140.7	142.2	313.3	247.3	163.3	3.3

Source: = Department of Soil Science, I.A.R., Samaru.

Tr. = Trace