THE EFFECT OF RATE, TIME AND METHOD OF NITROGEN APPLICATION ON THE PERFORMANCE OF GRAIN SORGHUM (*Sorghun bicolor* L. Moench) HYBRID SSH5 (SAMSORG 31)

BY

TARFA, I. G.

SEPTEMBER 1987

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THE EFFECT OF RATE, TIME AND METHOD OF NITROGEN APPLICATION ON THE PERFORMANCE OF GRAIN SORGHUM (Sorghun bicolor L. Moench) HYBRID SSH5 (SAMSORG 31)

BY

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A thesis submitted to the Postgraduate School, Ahmadu Bello University, Zaria, in partial fulfilment of the requirement for the Degree of Master of Science Agronomy.

DEPARTMENT OF AGRONOMY

FACULTY OF AGRICULTURE

AHMADU BELLO UNIVERSITY, ZARIA,

NIGERIA.

SEPTEMBER, 1987

DECLARATION

I, Ishaku G. Tarfa, hereby declare that the thesis herein presented, has been written by me and that it is a record of my own research work. It has not been presented in any previous application for a higher degree. All quotations are indicated and the sources of information are specifically knowledged by means of references.

Ishaku Garga Tarfa

Date: 16th October 1987

The above declaration is confirmed.

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Date: 16 October 1987

C E R T I F I C A T I O N

This thesis entitled 'THE EFFECT OF RATE, TIME AND METHOD OF NITROGEN APPLICATION ON THE PERFORMANCE OF GRAIN SORGHUM (Sorghum bicolor L. Moench) HYBRID SSH5 (SAMSORG 31)' by Ishaku Garga TARFA meets the regulations governing the award of 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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ZARIA, NIGERIA.

D E D I C A T I O N

This thosis is dodicated

to

Mariyam Tintak Madziga

A C K N O W L E D G E M E N T

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Ishaku G. Tarfa

ABSTRACT

A field experiment was conducted during the wet season of 1985 on the Institute for Agricultural Research Farm at Samaru, Zaria, to study the effect of rate, time, and method of nitrogen application on the performance of grain sorghum (Sorghum bicolor L. Moench) hybrid SSH5 (Samsorg 31) and to also evaluate the nitrogen fertilizer Use that would result in improvement of it's performance•

Nitrogen fertilization in sorghum significantly increased plant height, stem diameter, number of internodes per plant and total number of leaves per plant but reduced the number of days to 50 per cent flowering. Yield parameters and yield components that were increased by nitrogen application include grain yield, stover yield, weight of grains per panicle, 1000-grain weight, panicle length, number of primary branches in panicle, threshing percentage, total dry matter production, grain protein yield, and number of functional leaves at 14 and 16 weeks after; sowing (WAS). However, nitrogen application had *no* significant effect *on* number of plants per square metre, number of panicles per square metre, weight per panicle, grain number per panicle$_n$ total length of ear, grain; stover ratio, harvest index, number of days to hard dough stage, number of days to grain filling, number of functional (green) leaves at 10, 1?, and 18 WAS, and total nitrogen and crude protein content of grains due to the moderate initial nitrogen status of the soil of the experimental site. Application of 120 kg N/ha resulted in significantly higher yields than did the application of 30 kg N/ha

"but not that of 60 kg N/ha with respect to grain and stover yields in sorghum.

Method of nitrogen application had no significant effect-on all plant growth parameters, yield and yield attributes considered but the broadcast method of nitrogen application appeared to be slightly superior to that of the groove method of application. This may be attributed to uniform application of fertilizer which resulted in efficient utilization of nitrogen by the crop.

With timing of nitrogen application on sorghum, significant effect was observed with respect to number of days to hard dough stage, stover yield, panicle length, total length of ear, number of primary branches in panicle, total dry matter production, and panicle dry weight per plant at physiological maturity, but no significant effect was observed on other growth, yield and yield components considered in this study. Application of nitrogen in two equal splits at three and eight weeks after Bowing was however, beneficial in terms of grain yield.

For the attainment of high grain yield in serghum hybrid SSH5, up to 60 kg N/ha should be broadcasted and split applied, half dose at three weeks and remaining half at eight weeks after sowing.

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LIST OF ABBREVIATIONS

Abbreviation	Full Meaning
F.A.O.	Food and Agricultural Organization of the United Nations.
N	Nitrogen
$P(P_2O_5)$	Phosphorus (Phosphorus Pentoxide)
$K(K_2O)$	Potassium (Potassium Oxide)
Na	Sodium
Ca	Calcium
Mg	Magnesium
CEC	Cation exchange capacity
Meq	Milliequivalent
WAS	Weeks after sowing
FW	Flowable
ppm	Parts per million
ai	Active ingredient
kg/ha	Kilogramme per hectare
t/ha	Tonne per hectare
ml	Millilitre
l	Litre
mm	Millimetre
cm	Centimetre
m	Metre
^oC	Degree centigrade
NS	Not significant
SIG	Significante
SE	Standard error
LSD	Least significant difference

Chapter 1

INTRODUCTION

Grain sorghum (Sorghum bicolor L. Moench) is classified under the tribe Andropogoneae, of the Graminae family, and probably originated in tropical Africa, specifically in the North-East quadrant, where the greatest variability in both the wild and cultivated forms exists (Purseglove, 1972). Doggett (1970) believed that the crop was first domesticated in Ethiopia 4,000 - 3,000 B.C. and reached West Africa at an early date across the Sudan to the upper part of the Niger river. In Nigeria, the greatest diversity occurs in the North-East towards Lake Chad (Curtis, 1965).

Sorghum ("guinea corn") is grown as a staple food crop in most parts of northern Nigeria, where it is extensively cultivated. It was produced on about 5.3 million hectares in 1973 but increased to an estimated land area of 6.0 million hectares in 1984, when it occupied about 44 per cent of the total hectarage devoted to growing of cereal crops. As much as about 96 per cent of the area put under sorghum cultivation was in the savanna ecological zone of Nigeria. Annual production of sorghum in 1973 was about 3.0 million tonnes (F.A.O., 1976), which reached a peak of 3.9 million tonnes in 1984 (F.A.O., 1984), accounting for about 38 per cent of the total cereal production in the country.

Although total annual production of sorghum is experiencing an upward trend, this can be primarily attributed to increasing total hectarage put to sorghum rather than from and increase in yield per unit area accomplished through the adoption of improved technology. Average yield of local varieties under traditional farmers' practice is about 643 kg/ha (F.A.O., 1984) while the yield potential of sorghum under improved crop management practice is about 3.5 to 4.5 tonnes per Hectare (Kassam et al., 1976). Yields of 8.5 to 10.0 tonnes per hectare have been recorded with commercial hybrids elsewhere (Pickett and Oswalt, 1971). Similarly yields of up to 14 tonnes per hectare have been reported by Goldsworthy (1970).

Sorghum, unlike other cereals, is adapted to a wide range of ecological conditions. It grows well on heavy soils, even when subjected to temporary water-logging and also performs well on light sandy soils (Kramer and Ross, 1970) but is preferably grown on well-drained fertile loams, with a pH range of 5.0 to 8.5. Although sorghum can be grown in areas with rainfall as low as 400mm per annum, it thrives best in places where annual rainfall ranges between 650 and 1250mm. Leaky and Wills (1977) reported that serious losses in yield have been associated with water deficit occurring during anthesis. Optimum temperature requirement for sorghum growth is in the neighbourhood of 27^{o}C, with higher temperatures being tolerated but it does not grow at temperatures below 16^{o}C.

Only recently did the Institute for Agricultural Research, Ahmadu Bello University, Samaru, Zaria, and the National Seed Service developed Nigeria's first grain sorghum hybrids, three of which, namely, SSH2 (Samsorg 28), SSH4 (Samsorg 30), and SSH5 (Samsorg 31), have a common male parent, Var. SK-5912 (Samsorg 17). Although these hybrids are yet to be widely grown by Nigerian farmers, the potential for hybrid sorghum production is nevertheless very high. Among the hybrids so far developed, SSH5 (Samsorg 31) has been found to be one of the most high yielding (Ogunlela, 1983). However, information on the responsiveness of this and other hybrids to nitrogen fertilization in the savanna is still very much lacking. It is in the light of the foregoing that the present study was undertaken with the following objectives:

1. To study the effect of nitrogen applied at various rates on grain sorghum yield and yield components.
2. To study the effect of time, method of nitrogen fertilizer application and their interaction on the performance of grain sorghum.
3. To assess the improvement in nitrogen fertilizer use by grain sorghum that is likely to be brought about by the better fertilizer placement and appropriate timing of application.

Chapter 2

LITERATURE REVIEW

2.1. Effect of Nitrogen on Growth, Yield and Yield Components of Grain Sorghum

Nitrogen application has a remarkable effect on plant growth and development and on yield and yield components of grain sorghum. Nitrogen has been described as a major nutrient likely to generally bring about increased grain yield in sorghum (Genter et al., 1956). Curtis (1965), using ammonium sulphate as a source of nitrogen, obtained sorghum yield increases of 11.8 and 15.4 per cent from the application of 68 and 122 kg N/ha. The effect of nitrogen fertilization, however, becomes more pronounced with application of phosphorus and/or potassium than with the application of nitrogen alone. Highest grain yields have been obtained with 50 kg N and 50 kg P_2O_5 on sorghum cultivars given combinations of 25 - 75 kg N, 0 - 50 kg P_2O_5 and 0-50 kg K_2O/ha compared to yields obtained from applying 50 kg N/ha alone (Nagre and Sahasrabuddhe, 1977). Goldsworthy (1970) also found that the application of a combination of 120 kg N/ha and 80 kg P_2O_5/ha as fertilizer dressing produced as high as 4,000-5,000 kg/ha grain yield in sorghum in northern Nigeria.

According to Brady (1974), nitrogen aids in the utilization of phosphorus and potassium from the soil. Application of phosphorus (Dahatonde and Adhaoo, 1978; Owenya,

1979) or potash (Nagre and Sahasrabuddhe, 1977· Balasundaram and Rumulu, 1980) alone has been shown to have had no significant effect on grain yield of sorghum. Also, application of both phosphorus and potash did not increase sorghum yields significantly (Tatwawadi and Choudhari, 1970; Bathkal et al., 1971) but in combinations with nitrogen, significant yield increases resulted (Gahlot et al., 1979). Nitrogen, phosphorus and potash have been reported to account for 41.7, 30.7 and 33.4 per cent respectively of the variations in grain yield (Ali et al., 1980), while responses of sorghum cultivars to various combinations of nitrogen, phosphorus and potash have been reported to decrease in the treatment order of NPK > NP > NK > MK (Ali and Salih, 1972; Gahlot et al, 1979).

Since observations from field experiments have shown that the accumulation of nitrogen and phosphorus increased almost linearly until maturity while potassium accumulation was more rapid in the early stages of plant growth (Ray and Wright, 1974), the most widely adopted practice is the application of phosphorus and potassium before sowing so as to promote root development and good stand establishment in early crop life (Ogunlela and Egharevba, 1981).

2.1.1. Effect of nitrogen on sorghum root growth and development

Only limited information is available on the effect of nitrogen fertilization on root growth and development in the

sorghum plant. Root growth and development occur mostly in the first half of the growth cycle (Myers, 1980) whilst maximum root activity occurs in the top 15 cm of the soil profile and within 20 cm radius of the plant (Lavy and Eastin, 1969). Root growth has been reported to consistently increase, especially in the early growth stages of sorghum plant with application of nitrogen fertilizer. Most of the roots of sorghum plants supplied with nitrogen are found within the top horizon of the soil but root growth has been observed to consistently increase with depth down to 180 cm, especially in the post-flowering stages (Warsi and Wright, 1973a), while root development reaches a maximum at 44 days after seedling emergence (Myers, 1980). Maximum root depth attained by both the fibrous primary and secondary root systems in sorghum was 182 cm with a lateral spread of 90cm (Miller, 1966) but in isolated sorghum plants lateral spread may reach 240 cm (Lavy and Eastin, 1969). With mineral absorption, activity is rarely found below 90cm but appreciable water absorption by the roots occurs at depths of up to 180cm (Miller 1966).

Myers (1980) found that when the root mass of sorghum was measured through the soil profile to a depth of 150 cm, about 53-65 per cent of the mass was located in the 0-10cm layer, 76-79 per cent in the 0-20cm layer and 86-87 per cent in the 0-40cm layer. Corresponding figures for root length were 42, 60-63 and 77-78 per cent respectively.

2.1.2. *Effect of nitrogen on sorghum shoot growth and development*

Nitrogen application enhances plant growth and development in cereals. This nutrient increases growth of tops (shoot) without markedly affecting root growth (Myers, 1980). Sadar *et al.* (1976) working with sorghum cultivar 'Continental 2201' given a basal dressing of 50 kg P_2O_5 and 30 kg K_2O per hectare observed that increasing nitrogen levels from 10 to 70 kg/ha increased plant height from 102cm in the control to between 122 and 120 cm. The length of stem to the first rachis of the panicle also increased from 10.5cm to between 13.8 and 15.7cm. Veeranna and Patil (1978) also observed similar increases in plant height with the application of nitrogen. However, Gaya (1975) observed no significant effect of applied nitrogen on plant height in sorghum in a study he conducted in Nebraska, United States.

Nitrogen application has also been reported to result in thickers stems, longer peduncles, more leaves per plant (Krishnamurthy *et al.*, 1975) and increased panicle length (Haripiakasrao, 1978; Veeranna and Patil, 1978). Roy and Wright (1973) observed that although application of phosphorus and nitrogen produced longer panicles in sorghum, it had no effect on the numbers of primary panicle branches and of whorls per panicle. Myers (1978) observed no significant effect on head number with application of nitrogen but grain number per head and individual grain weight were increased

Nitrogen and phosphorus fertilization of sorghum favours faster ear emergence (Srivastava and Singh, 1971; Krishnamurthy et al., 1975). Flowering is delayed in the sorghum plant not given nitrogen (Sotomayor-Rios and Lugo-Lopez, 1978) while the supply of this nutrient accelerated flowering and maturation (Shukla and Seth 1976; Haripiakasrao, 1978). While the application of nitrogen was said to have reduced the number of days to 50 per cent flowering (Venkateswarlu et al., 1977; Boon-Ampol et al., 1980), it increased the number of days between flowering and maturation in grain sorghum (Venkateswarlu et al., 1977).

2.1.3. Effect of nitrogen on sorghum grain yield

Sorghum cultivars vary in their response to nitrogen application levels with respect to grain yield and total dry matter production (Gupta and Gupta, 1975). Application of nitrogen has been reported to increase grain and fodder yields (Joshi and Upadhyay, 1977). Ogunlela (1983) working with three grain sorghum hybrids derived from a common male parent (var. SK - 5912) observed up to 74 per cent increase in grain yield with the application of a fertilizer dressing of 66 kg N and 22 kg P_2O_5 per hectare relative to the unfertilized control. Some researchers have reported almost linear increases in sorghum grain yield with the application of nitrogen (Haripiakasrao, 1978; Balasundaram and Rumulu, 1980; Escasinas et al., 1981) while some others observed a lack of response in yields with nitrogen rates above a given optimum requirement (Gupta and Gupta, 1976; Kulkarni et al.,

1978). There have also been some instances in which no significant yield increases were obtained (Sader et al. 1976). Sotomayor-Rios and Lugo-Lopez (1978) having applied nitrogen rates varying from 56 to 280 kg N/ha on grain sorghum obtained significant increase in grain yield with the application of the first rate of nitrogen, but higher rates gave no further increase in yield.

2.1.4. Effect of nitrogen on sorghum dry matter production

Although application of nitrogen at increasing rates did not produce differences in sorghum plant growth and development (Galbiatti et al., 1977), amongst the macronutrient elements, nitrogen is the most effective in increasing dry matter production in all parts of the plant and at all stages of growth, followed by phosphorus, while potassium significantly increased it only in the panicle and grain (Power and Narkhede, 1981). Naphade and Choudhary (1976) working with sorghum hybrid PSH-2 observed that application of nitrogen in different froms not only increased the dry matter production of sorghum at all growth stages but also the grain and stover yields. Roy and Wright (1973) obtained highest dry matter yields of whole sorghum plants with the application of 120 kg N and 26 kg P_2O_5/ha fertilizer dressing.

Application of nitrogen has been reported to increase nitrogen concentrations of sorghum plant parts (Myers, 1978). Sotomayor-Rios and Lugo-Lopez (1978) observed an increase in the nitrogen content of sorghum leaves with the application of

nitrogen. However, Gupta and Gupta (1976) in an experiment using two sorghum cultivars noted that the dry matter content of stems increased with age up to three months while the nitrogen content of leaves and stems decreased with age, but leaf dry matter content increased only up to two months of age.

2.1.5. Effect of nitrogen on chemical composition of sorghum grain

There exists a positive and highly significant correlation between rates of applied nitrogen and crude protein content in sorghum (Armero and Brambila, 1977). Campbell and Pickett (1968) reported that not only grain yield but also grain protein content increased with increase in nitrogen application rates. Mirhadi *et al.* (1979) raising sorghum plants on a nutrient solution observed that by increasing nitrogen concentration in the nutrient solution from 17.5 to 220 ppm, crude protein content of grain was increased from 10.3 to 14.6 per cent. Nitrogen application has also been found to increase grain nitrogen content in maize (*Zea mays* L.) (Deckard *et al.*, 1973), and in wheat (*Triticum aestivum* L.) (Croy and Hageman, 1970; Batey and Reynish, 1976).

When nitrogen is supplied in amounts that are adequate for vegetative growth but inadequate during grain formation, yield is very little affected but protein content of grain is reduced, especially the protein content of the endosperm (Kramer and Ross, 1970). Veeranna and Patil (1978) reported that nitrogen application increased nitrogen uptake and grain nitrogen content. Waggle *et al.* (1967) observed that as the

level of nitrogen fertilizer was increased, levels of crude protein and seventeen nutritionally essential amino acids increased significantly. Mirhadi et al. (1979) found that although the percentage of crude protein in grains increased remarkably with increasing nitrogen application, other components such as crude fat, were little affected. Pickett and Oswalt (1971) observed increase in the protein content of several commercial sorghum hybrids from 9.1 to 12.6 per cent with increasing nitrogen application rate. Rai (1965) in a study on rainfed sorghum and maize observed that applied nitrogen increased crude protein content in grain and straw of both crops. Nitrogen application has also been reported to increase crude protein and ash contents of sorghum grain but reduced the grain starch content (Dechev, 1973).

2.2. Effect of Time and Method of Nitrogen Application on Yield and Yield Components of Grain Sorghum

2.2.1. Effect of time of application on grain sorghum: response to nitrogen fertilization

Time of nitrogen application on sorghum has been reported to significantly influence grain yield (Anonymous 1975). Kulkarni et al (1978) found that application of 40 kg N/ha at sowing increased grain yield by 34 per cent compared with the unfertilised control. Srivastava and Singh (1971) using 100 kg N/ha recommended an application of 10-15 kg N/ha at sowing and the remaining 85-90 kg N/ha at 20-30 days later,

during the grand growth stage.

Doughton (1971) observed no difference in grain yield of sorghum when nitrogen was applied at or just prior to planting and when applied 20 days after planting. Optimum time of application after sowing was 20-21 days while a yield reduction of 15 per cent was observed when nitrogen was applied 10 days earlier or later than the optimum time.

Ogunlela and Egharevba (1981) found that when nitrogen fertilizer was applied to two early maturing sorghum at 4, 6, 8, and 10 weeks after sowing, 10 - 15 per cent increase in yield resulted from application at 8 weeks after sowing. Similar results were obtained by Jones (1973) on maize at Samaru, where the application of 224 kg of nitrogen per hectare at both seedbed and side dressing at 7 weeks produced a grain yield that was 10 per cent higher. Maximum grain yield was obtained with the application of 72 kg N/ha at 30 days after germination while for the most efficient use of nitrogen application of 40 kg nitrogen per hectare at 20 days after germination was suggested by Doggett (1970).

2.2.2. Effect of method of application on grain Sorghum response to nitrogen fertilization

Split application of nitrogen are likely to be more beneficial to sorghum than a single application owing to the long duration of growth, although no one method of fertilizer application has been found to be superior over the other (Egharevba, 1979), Doughton (1971) reported that provided sorghum is row-spaced at 36cm, there were little differences in grain yields for the different methods of fertilizer application.

Doggett (1970) stated that there is often an advantage accruing from splitting fertilizer dressing and applying at seedbed preparation and as top dressing one to two weeks before floral initiation. Turkhede and Prasad (1978) found that yields were higher when nitrogen was applied in two split dressings, both at sowing and as top dressing than when applied in a single dressing or in three split dressings. Singh et al. (1971) observed no significant differences in yield between single and split applications of nitrogen at rates of 40 kg and 80 kg N/ha but single application proved better at rates exceeding 80 kg N/ha. Balasundaram and Rumulu (1980) using rates in the range of 0-200 kg N/ha with basal application of phosphate and potash observed significant increase in grain yield with application of nitrogen half at sowing time and the remainder 30 days later.

Higher grain yields have been obtained with broadcast application of nitrogen after emergence of seedlings than either an earlier broadcast of nitrogen or application of nitrogen with the seed (Myers, 1978). Myers (1979) in a study on nitrogen uptake in dryland grain sorghum in the Northern Territory of Australia, observed that grain yield and nitrogen uptake increased in the order of band > mixed > split application of nitrogen.

Nitrogen uptake by sorghum crop was higher with nitrogen placed 10 cm deep in the soil and the remainder applied as foliar spray than when applied as broadcast (Singh and Prasad, 1975). Singh (1976) observed increase in yield of sorghum and millet (Pennisetum americanum) with 20-80 kg/ha of NPK fertilizer drilled 10cm into the furrow than when applied by broadcast method. Umarni et al. (1978) noted that yields were slightly higher

with nitrogen placed 10 cm deep and 5cm away from the seedbed at sowing than when applied in four split dressings both at sowing time and as three foliar sprays. According to Das and Subbiah (1975) placement of nitrogen in the form of ammonium sulphate fertilizer at 15cm depth was more effective in increasing sorghum yields, by ensuring more efficient utilization of applied nitrogen than either of 7.5 and 22.5cm depths.

Crude protein content of grain is usually higher with split applications of nitrogen than with a single application (Sotomayor-Rios and Lugo-Lopez, 1978), while nitrogen application later in the season has been found to give greater accumulation of grain protein than an earlier application (Warsi and Wright, 1973b).

2.3. Optimum Rate of Nitrogen Fertilizer for Grain Sorghum

Abundant information exist in the literature with regard to the optimum rate of nitrogen fertilization for grain sorghum but these are as varied as are sources of information. Kulkarni et al. (1977) reported an optimum rate of 25 kg N plus 25 kg P_2O_5/ha for sorghum. Hiremath et al. (1977) gave the optimum rate as 40 kg N, 40 kg P_2O_5, plus 20 kg K_2O/ha. Sotomayor-Rios and Lugo-Lopez (1978) reported that near maximum yield was obtained with the application of nitrogen fertilizer at 56 kg N/ha. Gahlot et al. (1979) observed that application of 60 kg N, 30 kg P_2O_5 and 30 kg K_2O per hectare to sorghum crop grown under rained conditions gave the highest yields but yields from the application of 40 kg N and 20 kg P_2O_5/ha were similar to those obtained from 60 kg N/ha. Ali et al. (1980) suggested an optimum

fertilizer dressing of 76 kg N, 33 kg P_2O_5 and 50 K_2O/ha for grain sorghum.

According to Bhalerao et al. (1979) not more than 80 kg N/ha should be applied to sorghum crop grown under rainfed conditions. Krishnamurthy et al. (1975) noted that although yield increased with nitrogen rates up to 120 kg N/ha, the optimum rate for sorghum was 100 kg N/ha. Powar et al. (1977), obtained an optimum nitrogen rate of 135 kg N/ha for this crop in India.

Highest grain yield was obtained from sorghum hybrid CSH-1 with the application of fertilizer dressing consisting of 120 kg N, 120 kg P_2O_5, and 60 K_2O/ha in the Bundelkhand region of India (Gill and Abichandani, 1976). Maximum grain yield was however obtained with the application of 150 kg N/ha in various parts of India under rainfed conditions (Joshi and Upadhyay, 1977; Singh and Singh, 1978; Srivastava and Singh, 1980).

Optimum rate of nitrogen application for sole crop sorghum in the Nigerian savanna was found to be 64 kg N/ha (Singh et al., 1983) and 160 kg N/ha for improved United States varieties (Anonymous, 1970). Recommendations of nitrogen fertilizer for grain sorghum are usually sufficient to supply 56 kg N/ha depending on the type of fertilizer used (Doughton, 1971). Higher levels of nitrogen fertilizer above the optimum requirement generally depresses sorghum yield, particularly in the case of long duration cultivars.

2.4. Cultivar Effect on Sorghum: Response to Nitrogen Fertilization

Hybrids of sorghum and pearl millet generally show greater linear responses to nitrogen fertilization than do the local varieties (Murty, 1967). Singificant yield differences amongst sorghum varieties have been reported by Bhalerao et al. (1977). Seshadri and Peter (1972) working with four sorghum hybrids and two local varieties observed highest grain yields with the hybrids. Similar results were observed by Krishnamurthy et al. (1975) using three sorghum cultivars given 60-180 kg N/ha, where sorghum hybrid CSH-1 and a high yielding cultivar (Swarna) out-yielded the local variety by 39 and 35 per cent respectively.

Sorghum cultivars also vary markedly in their individual nitrogen requirements. Singh et al. (1971) working with three sorghum varieties and up to 200 kg N/ha observed maximum grain yield with the application of 140 kg N/ha but the most economic level ranged from 112.3 to 114.9 kg N/ha depending on the variety. Mishra and Singh (1978) in a trial involving the use of two sorghum cultibars (CSH-1 and Mau T-1) given nitrogen ranging from 0 to 160 kg N and phosphorus from 0 to 40 kg P_2O_5/ha observed the highest grain yield with the application of a combination of 120 kg N and 40 kg P_2O_5/ha on CSH-1 while with Mau T-1, the application of 80 kg N and 40 kg P_2O_5/ha gave the highest yield. Veeranna and Patil (1978) also reported a similar result using sorghum genotypes supplied with 0-200 kg N/ha and a basal dressing of 50 kg P_2O_5 and 50 kg K_2O/ha,

where highest grain yields were obtained in sorghum hybrids CSH-2 with application of 200 kg N/ha; with the application of 150 kg N/ha to sorghum hybrid CSH-1; and finally , in the case of both cultivars Swarna and C 2-3-1 high grain yields were obtained with the application of 100 kg N/ha.

Response of sorghum cultivars to nitrogen application is highly dependent on the seasons (Myers, 1978). Purkhede and Prasad (1978), working with sorghum hybrid CSH-1 to which was applied nitrogen rates varying from 0 to 150 kg N/ha, obtained the highest grain yield with the application of 150 kg N/ha in 1969 but in 1970, highest grain yield was obtained with 100 kg N/ha. Similar work by Bathkal et al. (1971) using fertilizer rates of 50, 100, and 150 kg N/ha applied to the same sorghum hybrid showed significant yield increases in the first year with both 100 and 150 kg N/ha over the 50 kg N rate but only the application of 150 kg N/ha rate significantly increased grain yield in the second year. Gangasaran and Prasad (1979) in a study on irrigated sorghum obtained an optimum nitrogen rate of 84 kg N/ha in 1969 with a yield response of 6.44 kg grain/kg N but in the following year the optimum nitrogen rate was 130.7 kg N/ha with a response of 13.64 kg grain/kg N. Conversely, Sheshadri and Peter (1972) working with six sorghum cultivars to which nitrogen rates in the range of 0 to 200 kg N/ha were applied observed significant grain yield response to the application of 50 kg N/ha in 1971 but observed no response to applied nitrogen the following year, Ogunlela and Egharevba (1981) also noted that response to nitrogen application by sorghum crop in the savanna zone of Nigeria was a function of both location and year.

Chapter 3

MATERIALS AND METHODS

2.1. Experimental Site

A field experiment was conducted during the wet season of 1985 at the Institute for Agricultural Research Farm, Samaru ($11^{o}11'N$, $07^{o}38'E$; 686m above sea level), Kaduna State, situated in the northern Guinea savanna zone of Nigeria.

Samaru has a long-term average annual rainfall of 1054mm, occuring essentially during the months of May - October, and a mean monthly temperature range of 20 - $30^{o}C$. Rainfall data for Samaru recorded by the Meteorological Unit of the Institute for Agricultural Research during 1985 cropping season are presented in Appendix Table A.1.

The experimental site had been left fallow for a number of years before it was cropped with soyabeans the preceding year (1984). The soil is moderately deep, well-drained and leached classified as ferruginous tropical sandy loam. Soil samples were augered randomly from the experimental area at a 0 - 20cm depth, bulked and the composite sample analised for it's chemical and chemical characteristics. Organic carbon content was determined by the Walkley-Black method and total nitrogen by Kjeldhal distillation method. All other determinations were carried out by standard procedures (Black, 1965). Cations were extracted with 1N NH_4 OAC (pH 7.0) and determined by atomic absorption spectrophotometry.

3.2. Variety

Hybrid sorghum SSH5 (Samsorg 31) was used for the experiment at the recommended plant population of about 50,000 plants per hectare, using ridges 75cm apart and intra-row spacing of 26cm.

3.3. Treatments

Treatments tested include three nitrogen rates, two placement methods, and four times of application. Details of treatments are as follows:

Nitrogen levels

Calcium ammonium nitrate (26% N) was used as source of nitrogen and applied at three rates to supply, 30, 60, and 120 kg N/ha.

Placement methods

Nitrogen fertilizer was applied using two methods, namely:

(i) Broadcast application: Where a weighed quantity of fertilizer was evenly broadcast by hand throughout a given plot depending on the treatment and incorporated into the soil immeidately.

(ii) Groove application: Which involves construction of grooves along the ridge at a distance of about 5cm from the plants. Fertilizer was then uniformly placed within the grooves in continous bands and then covered with soil immediately.

Time of Application

Times of nitrogen application that were compared are as follows:

T_1 = All fertilizer dose applied at seedling emergence.

T_2 = Half dose of fertilizer applied at 3 weeks and the remaining half dose at 8 weeks after sowing.

T_3 = All fertilizer dose applied at 3 weeks after sowing.

T_4 = All fertilizer dose applied at 6 weeks after sowing.

3.4. Experimental Design and Plot Size

A randomised complete block design with three replications was used with a uniform gross plot size of 4.5m x 9.0m ($40.5m^2$), each having six rows per plot. The net plot size, the area from which yield data were collected, was 3.0m x 9.0m ($27.0m^2$).

3.5. Field Operations

3.5.1. Land preparation

The experimental area was ploughed, harrowed once and ridged to 75cm apart. Prior to ridging, the field recieved a basal fertilizer dressing of single superphosphate (18% P_2O_5) and muriate of potash (60% K_2O) uniformly broadcast using a tractor-mounted fertilizer spreader at rates of 60 kg P_2O_5 and 40 kg K_2O per hectare.

3.5.2. Sowing

Seeds dressed with Aldrex T at the rate of 2g per 15 kg of seeds were sown on 20 June, 1985, as soon as rains were established. About 5 - 6 seeds were sown along the ridge in holes 2.5cm deep and spacing of 26cm apart. Missing stands were supplied one week after sowing.

3.5.3. Thinning

Thinning of stands was done at three weeks. Seedlings were thinned to one plant per stand leaving the most vigorous seedling.

3.5.4. Weed control

Experimental field was sprayed after planting with the herbicide Gardoprim A 500 FW pre-emergence using a CP3 knapsack sprayer at a concentration of 250 ml/15l water (i.e. 2.0 kg a.i/ha) as a weed control measure. Supplementary hoe-weeding was done a few times to keep the plots weed free.

3.5.5. Harvesting

Harvesting was done after the sorghum crop had fully matured. The stalks were cut at ground level and ripe panicles were severed at their base (neck node) from plants within four middle rows of the plots. The panicles were counted, bagged and further sun-dried until they attain a constant weight and their final weights recorded.

3.5.6. Threshing

Threshing was done using wooden mortar and pestle. Threshed grains were cleaned by winnowing, bagged and subsequently weighed.

3.6. Data Collection

3.6.1. Pre-harvest data

Crop data recorded during the vegetative phase of sorghum development include number of functional (green) leaves per plant, total number of leaves per plant, and stem diameter at 50 per cent flowering using twenty plants per plot. Others include plant height (at physiological maturity) measured from base of plants to the tip of the last internode, number of internodes per plant, flag leaf area at 50 per cent flowering, and stand count at crop maturity.

Data on number of functional leaves per plant were collected every fortnight commencing at ten weeks and these include leaves that were still green at more than 50 per cent of their total leaf area while total number of leaves include both green leaves and senescent leaves, which have lost their photosynthetic ability. Measurement of stem diameter at 50 per cent flowering was done at the third internode from ground level; whereas number of internodes per plant refers specifically to those internodes above-ground, but excluding the last internode (peduncle) bearing the panicle. Computation of flag leaf area was based on

measurement of the length of flag leaf from tip to its ligule, and maximum width. The product of length x width multiplied by a factor of 0.75 gave the individual flag leaf area (Stickler et al., 1961).

$$LA = 0.75 \times L \times W$$

Where LA = flag leaf area (cm^2)

L = length of flag leaf in cm

W = Maximum width of flag leaf in cm

Crop data collected during the reproductive phase of sorghum growth include number of days to 50 per cent flowering, number of days to hard dough stage, number of days to grain filling, and total dry matter production using four plants per plot.

Number of days to 50 per cent flowering include days between sowing date and the date at which about 50 per cent of plants within a specified plot bloomed. Number of days to hard dough stage includes days between sowing date and the date of attainment of grain filling. To verify physiological maturity, grains from middle portion of the panicle were tested because flowering and grain maturity in sorghum progresses downwards from the apex of the panicle. Number of days between 50 per cent flowering and day of attainment of hard dough was referred to as days to grain filling.

Sampling for dry matter production was done after heading stage of the sorghum crop. Four plants were sampled randomly from the two outermost ridges of a plot and dissected into component parts of stem, leaves and panicles, then dried to constant weight in an oven at 70°C.

3.6.2. Post-harvest data

Yield and yield attributes measured include total length of ear, panicle length from the base (neck node) to the tip, and number of primary branches in panicle. Also recorded were number of panicles per plot, weight of panicles per plot, weight of grains per plot, stover weight per plot, and 1000-grain weight. Other variables derived and their formulae are as follows:-

(i) $\text{No. panicles/m}^2 = \frac{\text{No. panicles per plot}}{\text{Net plot size (m}^2\text{)}}$

(ii) $\text{Wt. per panicle (g)} = 1000\text{x} \frac{\text{Wt. of panicles per plot (kg)}}{\text{No. panicles per plot}}$

(iii) $\text{Wt. grains per panicle(g)} = 1000\text{x} \frac{\text{Wt. grains per plot(kg)}}{\text{No. panicles per plot}}$

(iv) $\text{No. grains per panicle} = 1000\text{x} \frac{\text{Wt. grain per panicle (g)}}{\text{1000 - grain weight (g)}}$

(v) $\text{Grain yield (kg/ha)} = 10{,}000\text{x} \frac{\text{Wt. grain per plot (kg)}}{\text{Net plot size (m}^2\text{)}}$

(vi) $\text{Stover yield (kg/ha)} = 10{,}000\text{x} \frac{\text{Wt. Stover per plot (kg)}}{\text{Net plot size (m}^2\text{)}}$

(vii) $\text{Threshing percentage (\%)} = 100\text{x} \frac{\text{Wt. grains per plot (kg)}}{\text{Wt. panicles per plot(kg)}}$

or $= 100 \text{ x } \frac{\text{Wt. grains per panicle (g)}}{\text{Wt. per panicle (g)}}$

(viii) Grain: stover ratio = $\frac{\text{Wt. grains per plot (kg)}}{\text{Stover weight per plot (kg)}}$

(ix) Harvest index = $\frac{\text{Wt. grains per plot (kg)}}{\text{Wt. panicles per plot (kg)} + \text{Wt. stover per plot (kg)}}$

3.6.3. Chemical analysis of sorghum grains

Grain samples from individual plots were collected and ground with a Wiley mill to pass through a 2mm mesh screen, the grinding machine and receptacle bag being thoroughly cleaned between grinding of samples to prevent contamination of flour; from each ground grain sample were taken deplicate sub-samples that were analysed for total nitrogen content. Determination of total nitrogen content of grain was done using the micro-K[illegible]hl method (Bremner, 1965). The percentage total nitrogen content of grains was converted to crude protein using a conversion factor of 6.25 as recommended by A.O.A.C., (1975) and described by Guiragossian et al. (1977).

Protein yield was computed from the following relationship:

Protein yield = $\frac{\text{Crude protein (\%)} \times \text{Grain yield (kg/ha)}}{100}$

3.7. Statistical Analysis

Data collected from field observations and after harvest were subjected to analysis of variance to test significance treatment effects. Where the F-value showed significance, the treatment means were compared using the test of least significant differences (L.S.D.) at the 5% level of probability as described by Steel and Torrie (1960).

Chapter 4

RESULTS

4.1. Soil Analysis

Details of the physico-chemical properties of the composite soil sample collected from the experimental site are presented in Table 4.1. The soil has low organic carbon content, high phosphate content and moderate content of nitrogen and potash.

4.2. Effect of Rate, Method, and Time of Nitrogen Application on Yield and Yield Components in Grain Sorghum

4.2.1. Number of plants/m^2 and number of panicles/m^2

Application of nitrogen had no significant effect on the number of plants per square metre and number of panicles per square metre in sorghum. However, there was a tendency for number of panicles per square metre to decline slightly as nitrogen rate was increased from 60 to 120 kg N/ha (Table 4.2.). The number of plants and of panicles per square metre varied from 4.8 to 4.9 and from 4.1 to 4.4 respectively as nitrogen rates were increased from 30 to 120 kg N/ha.

Method and time of nitrogen application also has no significant effect on either number of plants per square metre or number of panicles per square metre. Application of nitrogen fertilizer by the broadcast or the groove method made no difference with respect to these two variables in sorghum. Similarly, single or split application of nitrogen made no difference whatsoever.

Table 4.1. Physico-chemical properties of the composite soil sample collected at 0-20cm depth from the experimental site.

Soil property	Value
Physical property	
Clay (%)	18.0
Silt (%)	26.0
Sand (%)	56.0
Textural class	sandy loam
Chemical property	
pH in H_2O	5.20
pH in 0.01 $CaCl_2$	4.60
Organic carbon (%)	1.52
Total nitrogen (%)	0.170
Available phosphorus (ppm)	3.5
Exchangeable cations (meq/100g soil)	
Na	0.16
K	0.28
Ca	7.13
Mg	1.89
CEC	9.6

Table 4.2. Effect of rate, method and time of nitrogen fertilizer application on number of plants/m^2, number of panicles/m^2, grain yield (kg/ha), and stover yield (t/ha) in sorghum at Samaru 1985.

Treatment	No. plants/m^2	No. panicles/m^2	Grain yield (kg/ha)	Stover yield (t/ha)
Nitrogen rate (kg/ha)				
30	4.90	4.35	2422.1	8.91
60	4.88	4.28	2865.1	10.41
120	4.79	4.10	2945.5	11.09
SE (±)	0.073	0.125	225.17	0.413
LSD (0.05)	NS	NS	452.50	0.829
Method				
Broadcast	4.87	4.22	2824.2	10.44
Groove	4.84	4.27	2664.3	9.83
SE (±)	0.060	0.102	183.85	0.337
LSD (0.05)	NS	NS	NS	NS
Time				
All dose at emergence	4.92	4.35	2872.4	10.84
½ dose at 3 WAS+ ½ at 8 WAS	4.86	4.31	2989.1	10.25
All dose at 3 WAS	4.86	4.26	2545.3	9.44
All dose at 6 WAS	4.78	4.06	2570.2	10.01
SE (±)	0.084	0.144	260.00	0.476
LSD (0.05)	NS	NS	NS	0.957
Mean	4.86	4.3	2744.3	10.14

NS = Not significant.

4.2.2. Grain yield

Application of nitrogen on sorghum significantly ($p = 0.05$) increased grain yield from 2,422 kg/ha with 30 kg N/ha to 2,946 kg/ha with 120 kg N/ha fertilizer rate. The difference resulting from application of 30 and 60 kg N/ha rate was not statistically significant but application of 120 kg N/ha gave significantly higher grain yield than the 30 kg N/ha rate (Table 4.2). The application of 60 and 120 kg N/ha resulted in 18.3 and 21.6% increase in grain yield over that of 30 kg N/ha respectively.

Method and time of application of nitrogen had no significant effect on grain yield of sorghum. Broadcast method of nitrogen application, however, gave a slightly higher grain yield than groove method but the difference was not significant statistically. With timing of nitrogen application, highest grain yield was obtained with split application of nitrogen (i.e. application of half dose at three weeks after sowing and remaining half at eight weeks), followed by full application at seedling emergence, and full application at six weeks after sowing or at three weeks after sowing respectively.

4.2.3. Stover yield

Stover yield of sorghum increased significantly ($p = 0.05$) with application of nitrogen, although both the 60 kg and 120 kg N/ha rates resulted in significantly higher stover yields than

30 kg N/ha, the difference between these two rates was not significant statistically (Table 4.2). Response to nitrogen application was therefore significant only up to 60 kg N/ha.

Method of nitrogen application had no significant effect on the stover yield of sorghum although the broadcast method of application produced a higher stover yield than did the groove method. Time of nitrogen application however, significantly ($p = 0.05$) influenced stover yield of sorghum. With respect to timing of nitrogen, full application at seedling emergence gave significantly higher stover yield (by about 14.9%) than the lowest yield which was obtained with application of nitrogen three weeks after sowing. Stover yields obtained with split application of nitrogen and full application at six weeks after sowing were similar and not significantly different from that obtained when nitrogen was applied as full dose at three weeks after sowing.

4.2.4. Weight per panicle

Weight per panicle in sorghum was increased slightly by 11.3% as the rate of nitrogen application was increased from 30 kg to 60 kg N/ha but this was not significant statistically. Application of 120 kg N/ha resulted in the heaviest sorghum panicles but the increase in weight was not significant statistically over either the 30 kg or the 60 kg N/ha rate (Table 4.3).

Table 4.3: Effect of rate, method and time of nitrogen fertilizer application weight per panicle, grain weight per panicle, 1000-grain weight, and grain number per panicle in sorghum at Samaru, 1985.

Treatment	Wt./ panicle (g)	Wt. grain/ panicle (g)	1000-grain Wt.(g)	Grain/ No. Panicle
Nitrogen rate (kg/ha)				
30	85.1	55.7	23.63	2375
60	94.7	67.4	25.48	2619
120	96.6	70.9	26.27	2684
SE(±)	5.27	4.74	0.972	151.5
LSD (0.05)	NS	9.52	1.953	NS
Method				
Broadcast	95.0	67.0	25.77	2593
Groove	89.2	62.3	24.48	2526
SE(±)	4.31	3.87	0.793	123.7
LSD (0.05)	NS	NS	NS	NS
Time				
All dose at emergence	95.8	66.7	25.47	2610
½ dose at 3WAS+ ½ at 8WAS	96.6	69.7	24.74	2767
All dose at 3 WAS	85.9	59.4	25.40	2326
All dose at 6 WAS	90.3	63.0	24.89	2534
SE (±)	6.09	5.47	1.122	174.9
LSD (0.05)	NS	NS	NS	NS
Mean	92.1	64.7	25.13	2559.3

NS = Not significant

Effect of method and time of nitrogen application on panicle weight in sorghum was not statistically significant. However, the broadcast fertilizer application method resulted in a slightly higher weight per panicle than the groove method. With time of nitrogen application, highest weight per panicle was obtained with split application of nitrogen followed by nitrogen application at seedling emergence, application at six weeks, and application at three weeks after sowing in that order

4.2.5. Weight of grains per panicle

Weight of grains per panicle in sorghum increased significantly ($p = 0.05$) with nitrogen application up to 60 kg N/ha (Table 4.3).

Application of a higher nitrogen rate of 120 kg N/ha significantly increased weight of grains per panicle in sorghum compared with the 30 kg N/ha rate, but there was no significant increase when the 60 kg N/ha rate was applied (Table 4.3).

Neither method nor time of nitrogen application had significant effect on weight of grains per panicle in grain sorghum. However, broadcast application of nitrogen tended to result in higher weight of grains per panicle than groove method, while with time of nitrogen application, highest weight of grains per panicle was attained with split application of nitrogen followed by nitrogen application at seedling emergence, application at six weeks, and finally application of nitrogen at three weeks after sowing.

4.2.6. Thousand grain weight

Application of nitrogen significantly ($p = 0.05$) increased 1000-grain weight up to 60 kg N/ha rate (Table 4.3). Increasing nitrogen rate to 120 kg N/ha produced a grain size that was not significantly larger than that produced by the 60 kg N/ha rate. Method and time of nitrogen application had no significant effect on 1000-grain weight of sorghum.

4.2.7. Grain number per panicle

Increasing nitrogen application rate from 30 kg to 120 kg N/ha increased grain number per panicle from 2375 to 2684 but that increase was not significant statistically (Table 4.3). Also the different methods and times of nitrogen application had no significant difference in grain number per panicle. Broadcast and groove methods of nitrogen application produced similar grain number per panicle. However, the highest number per panicle was obtained when nitrogen was applied in two equal doses at three and eight weeks after sowing. Application of all dose of nitrogen at three weeks after sowing produced sorghum grains that were fewer in number than split application.

4.2.8. Panicle length

When nitrogen application rate was increased from 30 kg N/ha, panicle length in sorghum increased significantly ($p = 0.05$) but further increase to 120 kg N/ha produced no significant increase in panicle length (Table 4.4).

Table 4.4. Effect of rate, method and time of nitrogen fertilizer application on panicle length, total length of ear, and number of primary panicle branches at maturity in sorghum at Samaru, 1985.

Treatment	Panicle length (cm)	Total ear length (cm)	No. primary panicle branches
Nitrogen rate (kg/ha)			
30	34.4	75.4	89.0
60	36.2	76.5	91.7
120	36.4	74.5	92.3
SE(±)	0.30	1.34	1.06
LSD (0.05)	0.60	NS	2.13
Method			
Broadcast	35.7	75.7	90.5
Groove	35.7	75.3	91.4
SE(±)	0.24	1.10	0.86
LSD (0.05)	NS	NS	NS
Time			
All dose at emergence	36.0	78.1	89.1
½ dose at 3 WAS+ ½ at 8WAS	36.2	76.8	91.1
All dose at 3 WAS	35.3	74.3	89.9
All dose at 6 WAS	35.3	72.7	93.8
SE (±)	0.35	1.55	1.22
LSD (0.05)	0.69	3.12	2.45
Mean	35.7	75.5	91.0

NS = Not significant

Method of nitrogen application had no significant effect on panicle length in sorghum. Both broadcast and groove method of application gave similar panicle lengths. Time of application of nitrogen however significantly ($p = 0.05$) affected panicle length with split application of nitrogen and application at seedling emergence resulting in similar but significantly longer panicle than those obtained with application of nitrogen all at either three or six weeks after sowing.

4.2.9. Total length of ear

By increasing nitrogen rate from 30 kg N to 60 kg N/ha the total length of ear in sorghum was not increased and ev[illegible] futher increase in nitrogen rate to 120 kg N/ha produced sorghum ears that were not longer than those of the two application rates (Table 4.4).

No significant effect on total length of ear was observed with respect to method of nitrogen application. Both broadcast and groove application of nitrogen produced similar total lengths of ear in sorghum. Timing of nitrogen application however significantly ($p = 0.05$) increased total length of ear in sorghum. Application of nitrogen at seedling emergence resulted in the longest ear in sorghum followed respectively by split application of nitrogen, application at three weeks and finally, application of nitrogen at six weeks after sowing. Total length of ear obtained with application of nitrogen at seedling emergence was significantly higher than application of all nitrogen at either three or six weeks

after sowing while application of nitrogen in two equal splits at three and eight weeks after sowing significantly increased total length of ear than application of all nitrogen at six weeks after sowing.

4.2.10. Number of primary branches in panicle

Number of primary branches in panicle was increased significantly ($p = 0.05$) with nitrogen application at least up to 60 kg N/ha rate. Higher rate of nitrogen (120 kg N/ha) did not increase number of primary branches in panicle over the 60 kg N/ha rate but resulted in significantly higher number of panicle branches when compared to the 30 kg N/ha rate (Table 4.4).

Method of nitrogen application had no significant effect on number of primary branches in panicle, with no difference observed between broadcast and groove application methods. Time of nitrogen application had a significant influence on the number of primary branches in panicle of grain sorghum. Nitrogen application at six weeks after sowing resulted in significantly higher number of primary branches in panicle than any of the other times of nitrogen application. However, no significant difference was observed in number of primary branches in panicle with either nitrogen application at seedling emergence, application at three weeks, or the split application. Delayed application of nitrogen fertilizer appears to have favoured the production of primary panicle branches.

4.2.11. Threshing percentage

Application of nitrogen significantly increased threshing percentage in sorghum up to the 60 kg N/ha rate but when nitrogen rate was increased to 120 kg N/ha, threshing percentage did not increase beyond that of the 60 kg N/ha rate as further increase in this parameter was rather marginal (Table 4.5).

Method and time of application of nitrogen had no significant effect on threshing percentage in sorghum. Broadcast method of nitrogen application produced a threshing percentage that was similar in magnitude to that of the groove method of application. With respect to time of nitrogen application, the split application of nitrogen had no particular advantage over the other times of nitrogen application.

4.2.12. Grain: stover ratio

Grain: stover ratio was virtually unaffected by increasing rates of nitrogen application from 30 kg N/ha through 120 kg N/ha (Table 4.5). Similarly, method and time of application of nitrogen also had no significant effect on grain: stover ratio in sorghum. Application of nitrogen in two equal split dose at three and eight weeks after sowing seemed to have produced a slightly higher grain: stover ratio in sorghum compared to applying all nitrogen dose at six weeks.

Table 4.5: Effect of rate, method and time of nitrogen fertilizer application on threshing percentage, grain: stover ratio, and harvest index in sorghum at Samaru, 1985.

Treatment	Threshing percentage (%)	Grain: stover ratio	Harvest index
Nitrogen rate (kg/ha)			
30	65.5	0.276	0.193
60	70.4	0.274	0.198
120	72.7	0.266	0.183
SE(±)	1.88	0.0192	0.0176
LSD (0.05)	3.78	NS	NS
Method			
Broadcast	70.0	0.272	0.194
Groove	69.0	0.271	0.195
SE (±)	1.54	0.0157	0.0143
LSD (0.05)	NS	NS	NS
Time			
All dose at emergence	68.8	0.264	0.193
½ dose at 3WAS+ ½ at 8WAS	71.3	0.291	0.205
All dose at 3 WAS	68.8	0.274	0.194
All dose at 6 WAS	69.1	0.258	0.186
SE (±)	2.17	0.0222	0.0203
LSD (0.05)	NS	NS	NS
Mean	69.5	0.272	0.195

NS = Not significant.

4.2.13. Harvest index

Nitrogen application had no significant effect on harvest index in sorghum SSH5. Although application of nitrogen at 30 kg N/ha rate resulted in a harvest index that was exactly the same as that for the 120 kg N/ha rate, there was a slight edge in the case of the 60 kg N/ha rate (Table 4.5).

Method and time of nitrogen application also had no significant effect on harvest index of sorghum. Broadcast method of application produced a harvest index that was not different from that of the groove application method. However, with respect to time of application, slightly higher harvest index was obtained when nitrogen fertilizer was applied in two split doses as against applying this in a full dose at 6 weeks after sowing.

4.2.14. Interactions

First and second order interactions between rate, method and time of nitrogen application on sorghum were not significant with respect to number of plants per square metre, number of panicles per square metre, weight per panicle, weight of grains per panicle, 1000-grain weight, and grain number per panicle.

Neither were interaction effects significant with respect to panicle length, total length of ear, threshing

percentage, grain: stover ratio, and harvest index. However, grain yield, stover yield, and number of primary panicle branches in sorghum were significantly ($p = 0.05$) influenced by nitrogen x time interaction. Highest grain yield (3717 kg N/ha) resulted from application of 120 kg N/ha in two split doses consisting of the application of half dose at 3 weeks and remaining half at 8 weeks after sowing, whereas, the application of 30 kg N/ha at three weeks after sowing produced the lowest grain yield (2232 kg/ha) (Table 4.6). Among the three rates of nitrogen application, the 60 kg N/ha rate was the least affected by time of application. Stover yield of sorghum which resulted from the application of 30 kg N/ha at three weeks after sowing was lowest whereas nitrogen application at the rate of 120 kg N/ha at time of seedling emergence resulted in the highest stover yield (Table 4.7). With number of primary panicle branches in sorghum, application of 30 kg N/ha at seedling emergence produced the lowest number of primary panicle branches while the 120 kg N/ha rate applied at six weeks after sowing gave highest number of primary panicle branches (Table 4.8).

Table 4.6: Interaction betwwon nitrogen rates and time of application on grain yield (kg/ha) of sorghum at Samaru, 1985.

	Nitrogen rates (kg/ha)		
T i m e	30	60	120
All doses at emergence	2649.4	2904.3	3063.6
½ dose at 3WAS+½ at 8 WAS	2379.6	2870.4	3717.3
All dose at 3 WAS	2232.1	2804.9	2598.8
All dose at 6 WAS	2427.2	2880.9	2402.5
LSD (0.05)	905.00		

Table 4.7. Interaction between rates and time of application on stover yield (t/ha) of sorghum at Samaru, 1985

Time	Nitrogen rates (kg/ha) 30	60	120
All dose at emergence	9.95	11.01	11.55
½ dose at 3 WAS + ½ at 8 WAS	8.74	10.56	11.43
All dose at 3 WAS	7.74	10.28	10.30
All dose at 6 WAS	9.20	9.77	11.08
LSD (0.05)	1.658		

Table 4.8 Interaction between nitrogen rates and time of application on the number of primary panicle branches in sorghum at Samaru, 1985.

Time	Nitrogen rates (kg/ha)		
	30	60	120
All dose at emergence	86.1	91.1	90.1
½ dose at 3 WAS + ½ at 8 WAS	89.1	90.9	93.2
All dose at 3 WAS	88.2	90.9	90.6
All dose at 6 WAS	92.5	93.7	95.2
LSD (0.05) 4.25			

4.3. Effect of Rate, Method, and Time of Nitrogen Application on Growth of Grain Sorghum

4.3.1. Plant height

Increasing nitrogen rate from 30 kg to 60 N/ha significantly ($p = 0.05$) increased plant height in sorghum but further increase to 120 kg N/ha produced no additional increase in plant height over the 60 kg N/ha rate.

There was no difference between applying nitrogen fertilizer using the broadcast or the groove method with respect to plant height. Time of application of nitrogen had no significant effect on plant height (Table 4.9).

4.3.2. Stem diameter

Application of nitrogen to sorghum significantly ($p = 0.05$) increased stem diameter of sorghum at least up to the 60 kg N/ha rate (Table 4.9). Higher rate of 120 kg N produced significant increase in stem diameter over the 30 kg N/ha rate but produced no further increase in diameter over the 60 kg N/ha rate.

There was no significant effect of either method or time of nitrogen application on stem diameter in grain sorghum. The magnitude of stem diameter obtained with the broadcast method of application was basically the same with that of groove application of nitrogen fertilizer. Applying

Table 4.9: Effect of rate, method and time of nitrogen fertilizer application on plant height, stem diameter and number of internodes in sorghum at Samaru, 1985

Treatment	Plant height (cm)	Stem diameter (cm)	No. internodes
Nitrogen rate (kg/ha)			
30	244.0	2.54	20.5
60	260.0	2.69	21.0
120	258.9	2.70	21.5
SE(±)	4.70	0.070	0.25
LSD (0.05)	9.44	0.140	0.50
Method			
Broadcast	257.4	2.66	21.1
Groove	251.3	2.63	20.9
SE(±)	3.83	0.057	0.20
LSD (0.05)	NS	NS	NS
Time			
All dose at emergence	255.6	2.52	20.6
½ dose at 2 WAS + ½ at 8 WAS	255.7	2.66	21.3
All dose at 3 WAS	252.2	2.71	21.4
All dose at 6 WAS	253.6	2.68	21.0
SE (±)	5.43	0.081	0.29
LSD (0.05)	NS	NS	NS
Mean	254.3	2.64	21.0

nitrogen fertilizer all at 3 weeks after sowing would seem to have favoured stem diameter as against applying this fertilizer all at seedling emergence.

4.3.3. Number of internodes per plant

Significant increase ($p = 0.05$) in number of internodes per plant in sorghum occured with the application of nitrogen up to the highest rate of 120 kg N/ha. Application of nitrogen at 120 kg N/ha produced more stem internodes than either 30 or 60 kg N/ha (Table 4.9).

Method of nitrogen application had no significant effect on the number of internodes per plant in sorghum. The broadcast application produced the same number of internodes as the groove application of nitrogen fertilizer. Time of application of nitrogen also had no significant effect on the number of internodes per plant in sorghum.

4.3.4. Number of days to 50% flowering

Number of days to 50 per cent flowering in sorghum was significantly reduced ($p = 0.05$) with application of higher rates of nitrogen (Table 4.10). Significantly lower number of days to 50 per cent flowering resulted when nitrogen rate was increased from 30 kg N to 60 kg N/ha. Further increase in nitrogen rate to 120 kg N/ha gave significant lower number of days to 50 per cent flowering than either the 30 kg N/ha or 60 kg N/ha rate.

Table 4.10: Effect of rate, method and time of nitrogen fertilizer application on the number of days to 50% flowering and hard dough stage, and grain filling period in sorghum at Samaru, 1985.

Treatment	No. days to 50% flowering	No. days to hard dough stage	Grain filling period (days)
Nitrogen rate (kg/ha)			
30	108.3	138.4	30.2
60	106.4	139.1	32.7
120	104.6	140.6	36.0
SE(±)	0.83	1.21	3.58
LSD (0.05)	1.67	NS	NS
Method			
Broadcast	106.2	139.8	33.7
Groove	106.7	138.9	32.2
SE(±)	0.68	0.98	2.92
LSD (0.05)	NS	NS	NS
Time			
All dose at emergence	107.7	137.2	29.6
½ dose at 3WAS + ½ at 8 WAS	105.2	138.9	33.7
All dose at 3 WAS	106.6	139.6	33.0
All dose at 6 WAS	106.2	141.8	35.6
SE(±)	0.96	1.39	4.13
LSD (0.05)	NS	2.80	NS
Mean	106.4	139.4	33.0

NS = Not significant

Method of nitrogen application had no significant effect on number of days to 50 per cent flowering in sorghum. Both the broadcast and the groove methods of nitrogen application gave similar numbers of days to 50 per cent flowering in sorghum. Time of nitrogen application also had no significant effect on number of days to 50 per cent flowering in sorghum. Highest number of days resulted with the application of nitrogen fertilizer at seedling emergence whereas the lowest number of days to 50 per cent flowering was obtained with split application of nitrogen. There was no difference between number of days to 50 per cent flowering with fertilizer application at both three and six weeks after sowing, but these were slightly higher than days obtained with split application of nitrogen.

4.3.5. Number of days to hard dough stage

There was a progressive increase in the number of days to hard dough stage in sorghum with an increase in fertilizer rate from 30 kg N to 120 kg N/ha but such differences were not significant statistically (Table 4.10).

Number of days to hard dough stage obtained with broadcast application of nitrogen was similar to that for the groove application method and as such were not significantly different. Time of nitrogen application however, significantly ($p = 0.05$) influenced the number of days to hard dough stage in sorghum, although no significant difference was observed

seedling emergence, and application at three weeks after sowing. Application of nitrogen at six weeks after sowing gave significantly higher number of days to hard dough stage than those for both application of nitrogen at seedling emergence and using split application, but not significantly different from that for nitrogen application at three weeks after sowing. Fewest number of days to hard dough stage resulted from nitrogen application at seedling emergence with progressively higher days obtained with split application of nitrogen, application at three weeks, and application at six weeks after sowing.

4.3.6. Length of grain filling period

Increasing nitrogen rate from 30 kg N to 120 kg N/ha increased the length of grain filling period from 30 to 36 days but these differences were not significant statistically.

Method of application of nitrogen had no significant effect on this parameter although the groove application of nitrogen seems to have resulted in a slightly shortened duration of sorghum grain filling period than the broadcast application method. Time of nitrogen application also had no significant effect on the duration of grain filling. The shortest grain filling period resulted from fertilizer application at seedling emergence while the longest duration occurred with fertilizer application at six weeks after sowing (Table 4.10).

4.3.7 Total number of leaves per plant

Application of nitrogen, at least up to 60 kg/ha

increased number of leaves per plant in sorghum significantly ($p = 0.05$). Higher rate of 120 kg N/ha resulted in significant increase in number of leaves per plant over the 30 kg N/ha rate but not over the 60 kg N/ha rate. The number of leaves per plant for the 60 and 120 kg N/ha rates were quite similar (Table 4.11).

Both groove and broadcast application of nitrogen produced similar number of leaves per plant in sorghum. Time of nitrogen application also had no significant effect on number of leaves per plant in sorghum.

4.3.8. Flag leaf area

Flag leaf area in sorghum was significantly ($p = 0.05$) increased by nitrogen application up to 60 kg N/ha. Increasing nitrogen rate to 120 kg N/ha produced no further increase in flag leaf area when compared to the 60 kg N/ha rate, but there was a significantly larger flag leaf area than for the 30 kg N/ha rate.

Flag leaf area was slightly larger when nitrogen was applied by broadcast method than when groove method was used. However, their difference was not significant statistically (Table 4.11). Time of nitrogen application had no significant effect on flag leaf area. The magnitude of flag leaf area for the various times of nitrogen application were virtually the same.

Table 4.11: Effect of rate, method and time of nitrogen fertilizer application on number of leaves per plant at physiological maturity and flag leaf area at 50% flowering in sorghum at Samaru 1985.

Treatment	No. Leaves/ plant	Flag leaf area (cm^2)
Nitrogen rate (kg/ha)		
30	21.6	161.6
60	22.2	204.9
120	22.5	203.1
SE(±)	0.19	5.65
LSD (0.05)	0.38	11.35
Method		
Broadcast	22.2	194.5
Broove	22.0	185.2
SE(±)	0.15	4.61
LSD (0.05)	NS	NS
T i m e		
All dose at emergence	22.0	189.9
½ dose at 3 WAS + ½ 8 WAS	22.0	190.8
All dose at 3 WAS	22.4	186.2
All dose at 6 WAS	22.1	192.5
SE(±)	0.22	6.52
LSD (0.05)	NS	NS
Mean	22.1	189.9

NS = Not significant.

4.3.9. Number of functional leaves per plant

When nitrogen rates was increased from 30 to 120 kg/ha, number of functional (green) leaves per plant in sorghum increased but such increases were statistically significant only at 14 and 16 weeks after sowing but not at 10, 12 and 18 weeks after sowing (Table 4.12). At 10 and 12 weeks after sowing, number of functional leaves increased slightly up to 60 kg N/ha rate only. Significant increase ($p = 0.05$) in this parameter was observed at 14 weeks after sowing, the stage at which maximum number of functional leaves per plant was attained. As nitrogen rate was increased, number of functional leaves per plant at 14 weeks after sowing increased up to the 60 kg N/ha rate. Higher nitrogen rate of 120 kg N/ha although producing number of functional leaves that were significantly higher than the 30 kg N/ha rate, it did not differ from that of the 60 kg N/ha rate. At 16 weeks after sowing, there was significantly increase in number of functional leaves per plant but the average number was fewer as compared with that at 14 weeks after sowing. Increasing nitrogen rate did not result in increased number of functional leaves until the highest nitrogen rate (i.e. 120 kg N/ha) had been applied. At 18 weeks after sowing, number of functional leaves per plant declined drastically compared to that observed at 16 weeks after sowing. Increasing nitrogen rate from 30 to 120 kg N/ha failed to produce any significant increase in number of functional leaves at 18 weeks after sowing. When number of functional leaves per plant as influenced by nitrogen rates of 30, 60 and

Table 4.12: Effect of rate, method and time of nitrogen fertilizer application on the number of functional (green) leaves per plant in sorghum at Samaru (1985)

Treatment	Weeks after sowing				
	10	12	14	16	18
Nitrogen rate (kg/ha)					
30	11.3	13.1	15.0	13.4	6.1
60	11.8	13.8	16.2	13.8	6.6
120	11.8	13.7	16.5	14.1	7.2
SE(±)	0.30	0.35	0.26	0.27	0.65
LSD (0.05)	NS	NS	0.52	0.53	NS
Method					
Broadcast	11.9	13.7	16.1	14.0	7.0
Groove	11.4	13.3	15.7	13.3	6.3
SE(±)	0.25	0.29	0.21	0.22	0.53
LSD (0.05)	NS	NS	0.43	NS	NS
T i m e					
All dose at emergence	11.5	13.8	15.8	13.7	6.8
½ dose at 3WAS+ ½ at 8 WAS	11.9	13.6	16.1	14.0	6.9
All dose at 3 WAS	11.7	13.2	15.6	13.3	6.8
All dose at 6 WAS	11.4	13.5	16.1	14.0	6.6
SE(±)	0.35	0.40	0.30	0.31	0.75
LSD (0.05)	NS	NS	NS	NS	NS
Mean	11.6	13.5	15.9	13.8	6.7

NS = Not significant

120 kg N/ha were considered it was observed that number of leaves increased from 10 weeks to 14 weeks after sowing, when maximum number was attained. It thereafter declined gradually at 16 weeks before becoming drastically reduced at 18 weeks after sowing, when plants were closer to maturity stage.

Method of nitrogen application had no significant effect on number of functional leaves at 10, 12, 16, and 18 weeks but only at 14 weeks after sowing. With respect to all observations, the numbers of functional leaves obtained with broadcast method of nitrogen application were slightly higher than groove application.

Time of nitrogen application had no significant effect on the number of functional leaves per plant in sorghum. At 10 weeks after sowing, there was no difference among the various times of nitrogen application with respect to this parameter. Irrespective of the growth stage, the difference in number of functional leaves among the various times of nitrogen application were not significant statistically. When numbers of functional leaves per plant for various nitrogen rates of 30, 60 and 120 kg N/ha were considered with respect to the effect of method and time of application of nitrogen, it was found that number of leaves also increased between 10 and 14 weeks after sowing, when maximum number was attained, but declined rapidly thereafter.

4.3.10. Interactions

There was no significant effect of the first and second

order interactions with respect to stem diameter, number of internodes per plant, number of days to 50 per cent flowering, number of days to grain filling, flag leaf area, total number of leaves per plant and number of functional leaves per plant. However, interaction effects were observed for total plant height in sorghum and this was significant ($p = 0.05$) statistically. The 30 kg N/ha rate when split applied, half dose at three weeks and remaining half eight weeks, resulted in the shortest plants, whereas split application of 120 kg N/ha resulted in the tallest plants (Table 4.13). Nitrogen x time interaction on number of days to hard dough stage was significant ($p = 0.05$) with the lowest number of days to hard dough stage being attained with application of 30 kg N/ha at seedling emergence while the highest number was obtained with application of 120 kg/ha at six weeks after sowing (Table 4.14).

4.4. Effect of Rate, Method and Time of Nitrogen Application on Dry Matter Production in Grain Sorghum

4.4.1. Stalk dry weight

Sorghum stalk weight increased significant ($p = 0.05$) as nitrogen rate was increased from 30 to 120 kg N/ha. Increasing nitrogen rate from 30 to 60 kg N/ha increased stalk weight by 41%, while the application of 120 kg N/ha produced an additional 18% increase over the 60 kg N/ha rate (Table 4.15).

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Table 4.13: Interaction between nitrogen rates and time of application on plant height at physiological maturity (cm) in sorghum at Samaru 1985.

Time	Nitrogen rates (kg/ha)		
	30	60	120
All dose at emergence	244.1	260.0	262.8
$\frac{1}{2}$ dose at 3 WAS + $\frac{1}{2}$ 8 WAS	242.2	257.7	267.5
All dose at 3 WAS	242.7	261.3	252.6
All dose at 6 WAS	247.0	261.1	252.8
LSD (0.05)	18.88		

Table 4.14: Interaction between nitrogen rates and time of application on the number of days to hard dough stage in sorghum at Samaru, 1985.

T i m e	Nitrogen rates (kg/ha)		
	30	60	120
All dose at emergence	134.3	136.0	141.3
½ dose at 3 WAS + ½ at 8 WAS	138.0	139.3	139.3
All dose at 3 WAS	139.7	140.0	139.0
All dose at 6 WAS	141.7	141.0	142.7
LSD (0.05) 4.85			

Table 4.15: Effect of rate, method and time of nitrogen fertilizer application on dry matter production at physiological maturity of sorghum at Samaru, 1985.

Treatment	Stalk wt/ plant (g)	Leaf wt/ plant (g)	Panicle wt/plant (g)	Total dry matter/ plant (g)
Nitrogen rate (kg/ha)				
30	139.7	56.1	88.8	286.3
60	196.9	73.8	1111.0	381.7
120	222.1	76.9	128.0	427.1
SE(±)	7.93	3.36	2.72	10.70
LSD (0.05)	15.94	6.76	5.47	21.50
Method				
Broadcast	194.1	71.5	111.7	377.4
Groove	178.3	66.3	106.8	352.6
SE(±)	6.48	2.75	4.90	8.67
LSD (0.05)	13.02	NS	NS	17.42
T i me				
All dose at emergence	182.3	68.2	114.1	366.3
½ dose at 3 WAS + ½ at 8 WAS	184.5	66.6	111.7	363.1
All dose at 3 WAS	184.3	67.8	104.8	356.9
All dose at 6 WAS	193.8	73.1	106.5	373.5
SE(±)	9.16	3.89	3.11	12.42
LSD (0.05)	NS	NS	6.25	NS
Mean	186.2	68.9	109.3	365.0

NS = Not significant.

Method of nitrogen application influenced stalk dry weight in sorghum significantly with greater stalk dry weight being obtained with the broadcast method. Time of nitrogen application had no significant effect on stalk dry weight. The greatest stalk dry weight was attained with the application of nitrogen at six weeks after sowing while application at seedling emergence resulted in the lowest stalk weight.

4.4.2. Leaf dry weight

Higher rates of nitrogen application produced greater leaf dry weights in sorghum but this effect was significant only up to 60 kg N/ha rate. Application of the 120 kg N/ha rate resulted in a significantly greater leaf dry weight compared to the 30 kg N/ha rate but the value for this was not different from that of the 60 kg N/ha (Table 4.15).

Method and time of nitrogen application had no significant effect on leaf dry weight in sorghum. However, broadcast application produced slightly greater leaf weights than the groove application method. With respect to time of application, the lowest dry weight of leaf was obtained with split application of nitrogen in two equal doses at three and eight weeks after sowing while nitrogen application at six weeks after sowing produced a slightly greater leaf dry weight.

4.4.3. Panicle dry weight

Panicle dry weight per plant increased significantly ($p = 0.05$) as nitrogen rate was increased from 30 to 120 kg N/ha. Application of 60 kg N/ha resulted in a significantly greater panicle dry weight than 30 kg N/ha rate while further increase in nitrogen rate to 120 kg N/ha produced a significantly greater panicle weight than both the 30 and 60 kg N/ha rate (Table 4.15).

Method of nitrogen application had no effect on the dry weight per panicle in sorghum although the broadcast method tended to have a slight edge over the groove application method. Time of nitrogen application had a significant effect on panicle dry weight in sorghum. The greatest dry weight of panicle was attained with nitrogen application at seedling emergence while lowest weight was obtained with application of nitrogen at three weeks.

Application of nitrogen at seedling emergence and split application of nitrogen produced a significantly higher dry weight of panicle than both nitrogen application at three and six weeks after sowing. Also , nitrogen application at seedling emergence produced a panicle dry weight that was greater than those for application of nitrogen at both three and six weeks after sowing. However, no significant difference in panicle weight was observed between either nitrogen application at seedling emergence and split application of nitrogen or nitrogen application at three weeks and six weeks after sowing.

4.4.4. Total dry matter accumulation

Application of higher rates of nitrogen increased total dry matter in sorghum significantly. Application of 60 kg N/ha produced a significantly greater total dry matter than the 30 kg N/ha rate, and also increasing nitrogen rate to 120 kg N/ha resulted in a significant increased in total dry matter accumulation as against both the 30 kg N or 60 kg N/ha rate (Table 4.15).

Method of nitrogen application had a significant effect on total dry matter accumulation in sorghum. Broadcast method of nitrogen application resulted in total dry matter accumulation that was significantly greater than the groove method of nitrogen application.

4.5. Effect of Rate, Method, and Time of Nitrogen Application on Chemical Composition of Sorghum Grain

4.5.1. Total nitrogen and crude protein content of grain

Application of higher rates of nitrogen had no significant effect on either total nitrogen or crude protein content of sorghum grain (Table 4.16). However, increasing nitrogen rate from 30 to 120 kg N/ha increased the total nitrogen content of sorghum grain from 1.8 per cent to 2.0 per cent and crude protein content from 11.2 per cent to 12.3 per cent.

Table 4.16 Effect of rate, method and time of nitrogen fertilizer application on total nitrogen and crude protein content of grain, and protein yield in sorghum at Samaru, 1985.

Treatment	Total nitrogen (%)	Crude protein (%)	Protein yield (kg/ha)
Nitrogen rate (kg/ha)			
30	1.79	11.19	267.8
60	1.88	11.76	327.8
120	1.97	12.32	366.0
SE(±)	0.120	0.684	31.97
LSD (0.05)	NS	NS	64.24
Method			
Broadcast	1.86	11.64	328.3
Groove	1.90	11.87	312.7
SE(±)	0.090	0.559	26.10
LSD (0.05)	NS	NS	NS
Time			
All dose at emergence	1.81	11.30	322.1
½ dose at 3 WAS + ½ at 8 WAS	1.90	11.89	357.4
All dose at 3 WAS	1.89	11.80	287.8
All dose at 6 WAS	1.92	12.03	304.8
SE(±)	0.127	0.790	36.91
LSD (0.05)	NS	NS	NS
Mean	1.88	11.76	320.6

NS = Significant.

The effect of method and time of nitrogen application was not significant with respect to both total nitrogen and crude protein contents of sorghum grain. The groove method of nitrogen application resulted in a slightly higher total nitrogen and crude protein contents than the broadcast method. With respect to timing of nitrogen, application at six weeks after sowing produced the highest total nitrogen and crude protein contents of sorghum grain followed respectively by application of nitrogen in split dose (i.e. half at three weeks and remaining half at eight weeks after sowing), application at three weeks after sowing , and finally, application at seedling emergence.

4.5.2. Grain protein yield

Increasing rates of nitrogen fertilizer significantly ($p = 0.05$) increased the grain protein yield of sorghum. The highest nitrogen rate of 120 kg N/ha produced significantly higher grain protein yield than did the 30 kg N/ha rate but the differences between the 30 and 60 kg N/ha rates, and between the 60 and 120 kg N/ha rates were not significant statistically (Table 4.16).

Method and time of nitrogen application had no significant effect on the grain protein yield of sorghum. However, the broadcast method of application produced a higher protein yield than did the groove method. With respect to time nitrogen application , the highest protein yield was attained with split application of nitrogen fertilizer followed by application at seedling emergence, six weeks after sowing and three weeks after sowing.

4.5.3. Interactions

Effect of the first order and second order interactions on total nitrogen and crude protein content of grain in sorghum were not significant statistically (Table 4.17). Interaction effects of nitrogen x time on grain protein yield of sorghum was however significant ($p = 0.05$). Lowest protein yield resulted from application of 30 kg N/ha at three weeks after sowing while the highest protein yield was obtained with split application of 120 kg N/ha.

Table 4.17: Interaction between nitrogen rates and time of application on crude protein yield (kg/ha) in sorghum at Samaru, 1985.

Time	Nitrogen rates (kg/ha)		
	30	60	120
All dose at emergence	271.0	328.0	367.2
½ dose at 3 WAS + ½ at 8 WAS	264.4	341.4	466.5
All dose at 3 WAS	261.6	312.0	319.9
All dose at 6 WAS	274.0	330.1	310.3
LSD (0.05) 128.47			

Chapter 5

D I S C U S S I O N

4.1. Effect of Nitrogen Application Rate on Grain Sorghum

Nitrogen application had no significant effect on number of sorghum plants per square metre at maturity or number of panicles per square metre at harvest. Number of panicles per square metre was also lower compared to number of plants per square metre at maturity.

Sorghum grain yield was significantly increased with application of 120 kg N/ha compared to the 30 kg N/ha rate. Application of 60 and 120 kg N/ha resulted in 18.3 and 21.6% increase in grain yield over the 30 kg N/ha rate respectively. This is in agreement with the findings of Roy and Wright (1973b); Shukla and Seth (1976); Escasinas et al. (1981). Basuvaraju and Bomegowda (1982) and Pal et al. (1984), who observed increases in grain yield of sorghum with increase in nitrogen rates but contradicts that of Sader et al. (1976), who found no significant increase in grain yield with application of 10 - 70 kg N/ha on sorghum cultivar 'Continental 2201.' The relatively lower response of sorghum in terms of grain yield to various rates of applied nitrogen in the present study may be due to the medium initial nitrogen status (0.17%) of the soil of the experimental site, a condition that might have resulted from either a long fallow and/or previous cropping of a leguminous crop. Lombin and Abdullahi (1981), in an experiment conducted on sorghum at Samaru, noted that on fields previously cropped with legumes,

especially groundnuts, up to 100 - 150 kg N/ha may be fixed in the soil, and even though part of the nitrogen fixed in the soil may be leached out of the root zone before sowing of sorghum, the remaining nitrogen adequately supplements any fertilizer addition and reasonably meets the crop's needs.

Stover yield of sorghum was significantly increase with application of 60 and 120 kg N/ha resulting in 16.8% and 24.5% increase respectively over the 30 kg N/ha rate. This conforms with the observations of Naphade and Choudhary (1976); Patil and Jawale (1977); Dahatonde and Adhaoo (1978); Gahlot et al. (1979); and Ithal et al. (1980), who had reported increased in sorghum stover yields with application of nitrogen. The higher percentage increase attained with stover yield at 120 kg N/ha compared to that of grain yield suggests a slightly greater response of sorghum stover to nitrogen application than did the grain yield. Increase in grain and stover yields resulting from the application of higher nitrogen rates were 18 - 22 per cent and 17 - 25 per cent respectively.

Weight of grains per panicle increased significantly with application of nitrogen on sorghum. This agrees with earlier reports of Tatwawadi and Choudhary (1976) and Esesinas et al. (1981), who observed similar increase in weight of grains per panicle with nitrogen fertilization.

Nitrogen application significantly increased 1000-grain weight (seed size) in sorghum. Although application of 60 kg N/ha had no significant effect on 1000-grain weight in sorghum relative to 30 kg N/ha, the 120 kg N/ha rate resulted in

significant increase over the 30 kg N/ha rate. Similar increased in sorghum 1000-grain weight with nitrogen application have been reported elsewhere (Roy and Wright, 1973b; Naphade and Choudhary, 1976; Patil and Jawale, 1977; Myers, 1978; Powar et al., 1980; Basuvaraju and Bommegowda, 1982) and in Nigeria (El-Sabaaie, 1979) but this result contradicts the findings of Tatwawadi and Choudhary (1976) and Ogunlela (1983) who found no significant effect of nitrogen fertilization on seed size in sorghum. They claimed that sorghum grain size is strongly under the influence of genetic control rather than that of the environment.

Application of nitrogen had no significant effect on weight per panicle in sorghum, although this variable tended to slightly increase with increase in nitrogen application rate. This result conflits with the findings of Tatawawadi and Choudhary (1976); Powar et al., (1980) and Ogunlela (1983) who observed significant increase in panicle weight with nitrogen application. Also, nitrogen application had no significant effect on grain number per panicle although there was an increase from 2375 to 2684 when nitrogen was applied at the rate of 30 kg and 120 kg N/ha respectively. The increase in grain number per panicle observed with nitrogen fertilization may have resulted from an increase in production of assimilates contributed to grain. This observation partly conforms with the findings of Shukla and Seth (1976); Tatawawadi and Choudhary (1976); Myers (1978); El-Sabaaie (1979); Escasinas et al. (1981) and Ogunlela (1983) who had reported significant increase in grain number per panicle. The increase in weight of grains per panicle with consequent increase in grain yield of sorghum may be due to increases in the seed size of sorghum and the

number of primary branches in panicle bearing grains. Pal et al. (1984) have attributed the high grain yields of sorghum hybrids specifically to their greater number of grains per panicle compared to that of local cultivars which are relatively low yielding.

Application of nitrogen on sorghum significantly increased panicle length. The longest panicles were obtained with application of either 60 or 120 kg N/ha. This is in agreement with the findings of Roy and Wright (1973b); Patil and Jawale (1977); Haripiakasrao (1978); El- Sabaaie (1979); Powar et al. (1980) and Escasinas et al. (1981) who reported increase in panicle length with higher nitrogen rates but was contrary to the findings of Sadar et al. (1976) who observed no significant increase in panicle length with nitrogen application on grain sorghum.

Nitrogen application on sorghum had no significant effect on total length of ear sorghum whatsoever. This conflicts with the observation of Veeranna and Patil (1978) who had reported significant increase in total length of ear in sorghum with nitrogen application. Reduction in total length of ear, which is compensated for by the heavy panicles that resulted from the application of 120 kg N/ha, suggested that shorter and thicker peduncles are required to adequately support the heavy heads of sorghum which are likely to result from heavy nitrogen dressings. A decrease in peduncle length in sorghum hybrid (CSH-1) has been reported by Tatawawadi and Choudhary (1976) but in contrast Krishnamurthy et.al.(1975) noted an increase in peduncle length with nitrogen fertilization.

Number of primary branches in panicle significantly increased from 89 to 92 with application of 120 kg N/ha in comparison to 30

kg N/ha. Both 60 kg N/ha and 120 kg N/ha rates resulted in significantly higher number of primary branches in sorghum panicle compared to the 30 kg N/ha rate. Roy and Wright (1973b) found no significant effect of applied nitrogen on number of primary branches in sorghum panicle. The increase in grain number per panicle may be attributed to an increase in number of primary branches in panicle bearing grains in sorghum with nitrogen fertilization rather than from increase in number of grain per primary panicle branch in sorghum.

Threshing percentage, which represents the proportion of total dry grain weight to total head weight, was significantly increased from 65.5 to 72.7% with application of 30 and 120 kg N/ha respectively. Application of nitrogen up to 60 kg N/ha also significantly increased threshing percentage over the 30 kg N/ha rate. Further increase in nitrogen rate to 120 kg N/ha although resulting in significantly higher threshing percentage than the 30 kg N/ha rate produced only slight increase over that obtained with 60 kg N/ha. This may suggest that increase in nitrogen level from 30 to 60 kg N/ha had resulted in a proportionately greater increase in grain weight than in total head weight whereas further increase in nitrogen level had no significant effect on number of grains.

Grain: stover ratio was not significantly influenced by nitrogen fertilization although there was a slight decline as nitrogen level was increased to 120 kg N/ha. This observation corroborates that of Welch et al. (1966) who had reported decline in grain: stover ratio with the application of nitrogen. Application of higher rates of nitrogen on sorghum also had no significant effect on harvest index in sorghum. The significant increase in threshing percentage

observed with increasing rate of applied nitrogen may be attributed to increase in weight per head as a result of increase in panicle length, number of primary panicle branches and seed size in sorghum while the slight decline in grain: stover ratio may perhaps be due to the preferential increase in vegetative growth in sorghum with increase in nitrogen rate at the expense of grain production. With harvest index, it appears that application of 60 kg N/ha was the optimum nitrogen fertilizer rate for sorghum hybrid SSH5 since increase in nitrogen rate to 120 kg N/ha, although producing an increase in sorghum biomass, did not result in any appreciable increase in economic yield in sorghum.

Plant height was significantly increased from 244 cm to 260cm application of nitrogen from 30 kg N to 60 kg N/ha but failed to increased any further with the application of 120 kg N/ha. This finding agrees with the reports of Sadar et al. (1976); Veeranna and Patil (1976); and Escasinas et al. (1981), who observed increase in plant height with application of nitrogen but contrasts with that of Gaya (1975) who observed no significant increase in sorghum plant height with nitrogen application.

Stem diameter in sorghum was also significantly increased from 2.5 to 2.7cm with application of 30 and 120 kg N/ha respectively. This corroborated the observation by Krishnamurthy et al. (1975), who noted that nitrogen application on sorghum resulted in thicker stems.

Number of internodes per plant was significantly increased

from 21 to 22 while number of leaves per plant at maturity was increased from 22 to 23 with application of 30 and 120 kg N/ha respectively. Krishnamurthy et al. (1975) and El-Sabaaie (1979) also noted some increase in number of leaves in sorghum with nitrogen fertilization. Number of leaves obtained was slightly higher than number of internodes per plant suggesting that a few leaves of the sorghum plant originated from nodes that were located in the telescoped part of the stem forming the shoot apex.

Flag leaf area in sorghum increased from 161.6cm^2 to 204.9cm^2 with application of 30 kg N/ha and 60 kg N/ha but remained relatively unchanged with additional increment in nitrogen application to 120 kg N/ha. Increase in flag leaf area may partly explain the increase in grain yield of sorghum observed with nitrogen application since in cereal crops, dry matter produced in the grain is partly determined by the amount of assimilate produced after ear emergence for which the flag leaf plays an important role. Rao and Singh (1982) reported that the contribution of the flag leaf of sorghum to yield was up to 16%.

Number of days to 50 per cent flowering was significantly reduced by about 2 and 4 days relative to 30 kg N/ha when 60 and 120 kg N/ha rates were applied respectively but no significant effect of nitrogen application was observed on number of days to hard dough stage and number of days to grain filling in sorghum. However, increasing nitrogen application rate from 30 to 120 kg N/ha increased the number of days to hard dough stage from 138 to 141 days while the number of days to grain filling was increased from 30 to 36 days respectively. This finding is in

aggreement with a report by Boom-Ampol et al. (1980), who observed up to 10 days decrease in number of days to 50 per cent flowering with nitrogen fertilization relative to the unfertilized control. Some other workers such as Shukla and Seth (1976). Venkateswarlu et al. (1977), Haripiakasrao (1978), and Sotomayor-Rios and Lugo-Lopez (1978) had earlier also found that increasing nitrogen application rate reduced the number of days to 50 per cent flowering in sorghum but increased the number of days to hard dough stage. Reduction in number of days to 50 per cent flowering with nitrogen fertilization resulted in longer period of grain filling and consequently, more assimilates were translocated to the grains.

Nitrogen application had no significant effect on the number of functional leaves of sorghum at 10, 12, and 18 W.S except at 14 and 16 WAS. Increase in the number of functional leaves in sorghum would represent an increase in the assimilatory material and consequently an increase in amount of assimilate that is available for translocation to the grains.

Stalk dry weight in sorghum was significantly increased with the application of 60 kg N/ha over the 30 kg N/ha rate. Further increase in nitrogen rate to 120 kg N/ha resulted in significant increase in stalk dry weight over both the 30 and 60 kg N/ha rates. Application of 120 kg N/ha resulted in 13.3 and 59.0% increaseds over the 60 and 30 kg N/ha rates respectively.

Leaf dry weight of sorghum was also significantly increased with nitrogen application. Both the 60 and 120 kg N/ha rates significantly increased leaf dry weight in sorghum over the 30 kg N/ha rate. This conforms with the report of Gupta and Gupta (1976), who had observed increase in both stalk and leaf dry weight in sorghum with nitrogen application. The increases observed in respect of both stem and leaf dry matter could be associated with the enhancement in growth of the sorghum plant, which resulted from

improved manufacture of photosynthates.

Panicle dry weight in sorghum was significantly increased with increase in nitrogen application. Application of 120 kg N/ha resulted in 44.1 and 15.3% increases in panicle dry weight over the 30 and 60 kg N/ha respectively. As an important component of yield in grain sorghum, the increase in panicle dry weight that resulted from higher rates of nitrogen application would likely account for part of the favourable response to fertilization shown by grain yield.

Above ground total dry matter production was also significantly increased with increasing rate of nitrogen applied in sorghum. Application of 60 kg N/ha resulted in significant increase in above ground total dry matter when compared with the 30 kg N/ha rate. Further increase in nitrogen application rate to 120 kg N/ha also significantly increased the total dry matter produced relative to the 60 kg N/ha rate. This observation comforms with those of Roy and Wright (1973a) and El-Sabaaie (1979), who observed the highest total dry matter production in sorghum with the application of 120 kg N/ha. Similar results had been reported by a number of other workers (Gaya, 1975; Gupta and Gupta, 1976; Naphade and Choudhary 1976).

Although application of nitrogen had no significant effect on total nitrogen content and crude protein content of sorghum grain, there was a clear and definite trend of increased nitrogen and crude protein content of grain with increase in nitrogen application rate. This report seems to be in line with the results of Welch et al. (1966), Roy and Wright (1973a), Gaya (1976) and Veeranna and Patil (1978), who observed significant increase in total nitrogen content of grain with increase in nitrogen application rate. Dechev (1973), Warsi and Wright (1973), Armero et al. (1978) and Mirhadi et al. (1979), also found significant increase in grain crude

protein content with increase in nitrogen application. Nitrogen application has also been reported to increase grain protein content in maize (Haggar and Couper, 1972) and in wheat (Hamid, 1973). In sorghum, an increase in grain crude protein content from 10.3 to 14.6% have been reported by Mirhadi et al. (1980) when nutrient solutions having concentrations ranging from 17.5 ppm to 220 ppm nitrogen were applied. Pickett (1969) had stated that grain protein content of sorghum generally ranges from 8 to 15 per cent.

Grain protein yield of sorghum was significantly increased from 268 to 366 kg/ha with application of 30 and 120 kg N/ha respectively, resulting in about 37% higher grain protein yield over that of 30 kg N/ha. However, differences in total grain protein yield resulting from either between 30 and 60 kg N/ha or between 60 and 120 kg N/ha was not significantly statistically. Warsi and Wright (1973) had reported similar increase in total grain protein yield with application of nitrogen fertilizer on sorghum. The significant increase in total grain protein yield observed is attributed to the significant increase in grain yield resulting with application of nitrogen rather than from increase in crude protein content of grain per se.

5.2. Effect of Method of Nitrogen Application on Grain Sorghum

Broadcast method of nitrogen fertilizer application resulted in slightly higher grain yield, stover yield, weight per panicle, weight of grains per panicle, and 1000-grain weight than the groove method but no apparent difference was observed with respect to the

other yield components considered in the present study. The broadcast method resulted in about 6% increase in both grain and stover yields in sorghum while weight per panicle, weight of grains per panicle, and 1000-grain weight were increased by 6.5, 7.5, and 5.3% respectively over the groove method of nitrogen application.

Broadcast method of nitrogen application was also superior to the groove method with respect to growth attributes considered. Plant height was increased by about 2.4% while flag leaf area increased by about 5% when nitrogen was applied by broadcast method. Number of functional leaves per plant at 14 WAS was also enhanced by the broadcast method of nitrogen application relative to the groove method. The effect of broadcast method was manifested when the number of functional leaves per plant in sorghum reached its peak at 14 weeks.

Broadcast application of nitrogen significantly increased stalk dry weight and total dry matter production in sorghum compared to the groove method of nitrogen application but had no significant effect on leaf and panicle dry weights.

Broadcast application of nitrogen resulted in higher dry weight of various plant parts suggesting its superiority over the groove method of application with respect to dry matter yield.

Method of nitrogen application had no significant effect on total nitrogen and crude protein contents of sorghum grain and total grain protein yield in sorghum. However, the groove method of nitrogen application resulted in slightly higher total nitrogen and crude protein content of sorghum grain than the broadcast

method. The broadcast method was, of course, marginally superior in terms of total grain protein yield. The higher total grain protein yield observed with broadcast application of nitrogen is as a result of its favourable influence on grain yield as against the groove method rather than due to increase in crude protein content of grain.

With the exception of number of primary panicle branches, harvest index, and total nitrogen and crude protein content of grain, the broadcast method nitrogen application was superior to the groove method with respect to its effect on all growth attributes, yield and yield components considered. It was therefore, apparent that the broadcast method of nitrogen application would be preferred over the groove method in grain sorghum fertilization at Samaru. However, this finding contradicts that of Agboola (1967), who in an experiment in the rainforest zone of Nigeria noted that the ring application of ammonium sulphate fertilizer and banding of fertilizer on both sides of maize crop were superior to other methods of fertilizer application. The superiority of the broadcast method of nitrogen application may perhaps be attributed to the achievement of uniform placement of fertilizer, which facilitates speedy uptake of applied nitrogen through root interception resulting in an improvement in the efficiency of nitrogen utilization by sorghum. This may be explained on the basis of nitrogen mobility and availability in the soil. Bray (1954) defined mobility as "the overall process whereby nutrient ions reach sorbing root surfaces, thereby making possible their sorption into the plant, and involves solution or exchange of the nutrient as well as its movement to root surfaces".

The calcium ammonium nitrate fertilizer applied in this study contains nitrogen in the forms of nitrate and ammonium in equal proportions. When this nitrogenous fertilizer is incorporated into the soil, it dissolves in the soil solution. The nitrate form moves freely with the soil solution to root surfaces largely by mass flow and diffusion (Reisenauer, 1978) while the ammonium form is adsorbed onto the clay particles (miscellos). Therefore, the widespread nature of sorghum roots (Singh, 1978; Myers, 1980) may have facilitated the uptake of nitrogen applied through broadcast method since roots are in close proximity with nutrients in the soil solution. With the groove method of placement, some portion of the applied nitrogen may have been lost through leaching and volatilization since placement of nitrogen is localised resulting in a reduction in the efficiency of nitrogen utilization by sorghum crop. Apart from the high mobility of nitrogen, leaching losses may have been facilitated by the acid nature of the soil (pH 4.6). Reisenauer (1978) had reported that absorption of nitrate nitrogen is favoured by lower pH (increased acidity) whereas absorption of ammonical nitrogen increases with increase in pH (alkalinity). Therefore, the localised placement achieved through groove method of application may enhance leaching of nitrate nitrogen. Bray (1963) enumerated five factors which govern the response of crops to applied nutrients and these include, the kind of crop, the planting pattern and rate of planting, the form of the nutrient, and the distribution pattern of the nutrient relative to the planting pattern.

5.3. Effect of Time of Nitrogen Application on Grain Sorghum

Time of nitrogen application on sorghum had no significant effect on grain yield and several yield components but significant effect was observed on stover yield, panicle length, total length of ear, and number of primary branches in panicle. The split application of nitrogen fertilizer (half dose applied at three weeks and remaining half at eight weeks after sowing) resulted in higher yield and yield components compared to other times of application. Nitrogen application at six weeks after sowing resulted in the highest number of primary panicle branches whereas the effect of time of nitrogen application on 1000-grain weight was unclear. Also, no apparent effect of time of nitrogen application was observed with respect to number of plants per square metre and number of panicles per square metre although application at seedling emergence result in highest stover yields.

Split application of nitrogen fertilizer therefore proved superior to other times of application in terms of its effect on yield and yield components. Higher grain yield obtained with split application is in agreement with the findings of Fayemi (1966), Fayeni (1968), Agboola (1968), Jones (1973), and Haque (1979) in studies conducted on maize, and Hamid (1973) in a study on wheat, where appreciable yield increases were observed with split application of nitrogen over that of single application. The higher stover yield observed with application of nitrogen at seedling emergence may perhaps be due to utilization of applied nitrogen for vegetative growth since sorghum is a relatively long

duration crop and potential for vegetative growth and development is established during the earlier part of the plant's life cycle.

Number of days to hard dough stage was significantly influenced by timing of nitrogen on sorghum. Nitrogen application at six weeks after sowing resulted in significantly higher number of days to hard dough stage than application of nitrogen at seedling emergence or in split applications, but no significant difference over nitrogen application at three weeks after sowing. This observation suggests that a delay in nitrogen application on sorghum delays attainment of the hard dough stage in sorghum. This finding agrees with that of Guo and Wang (1980), who observed a delay in ripening when nitrogen was deficient during the seedling stage of sorghum.

Application of nitrogen at seedling emergence resulted in the highest number of days to 50 per cent flowering suggesting that plants utilized most of the applied nitrogen during vegetative development, a condition which subsequently resulted in delayed flowering. The fewest number of days to 50 per cent flowering was attained with split application of nitrogen suggesting that a better spread of nitrogen resource to plants during the growing season promotes the attainment of flowering stage in sorghum. In terms of number of days to grain filling, application of nitrogen at seedling emergence resulted in the shortest grain filling period while nitrogen application at six weeks after sowing lengthens this period. This observation suggests that application of nitrogen late in the season

contributed more assimilates to grain filling in sorghum than an earlier application. Venkateswarlu et al. (1977) also found that timing of nitrogen application on sorghum had no significant effect on both the number of days to 50 per cent flowering and grain filling.

It appears that increase in plant height of sorghum was accompanied by reduction in stem diameter while shorter plants produced thicker stems. The taller plants obtained with nitrogen application at seedling emergence and split applications may be due to an enhancement in growth and development resulting from early application of nitrogen. Andrews (1956) had reported that young corn plants grew more rapidly when ammonium form of nitrogen was present than with nitrate nitrogen. This may explain why grain yield and plant height in sorghum were better with both split application and application of nitrogen at emergence of seedling.

Time of nitrogen application significantly influenced panicle dry weight of grain sorghum but had no effect on stalk dry weight, leaf dry weight and total dry matter production. With panicle dry weight, application of nitrogen at seedling emergence although similar to split application resulted in significantly higher panicle dry weight than nitrogen application at either three or six weeks after sowing. The greater panicle dry weight obtained with both application of nitrogen at seedling emergence and split application may be attributed to advanced grain filling at time of sampling. Earlier application of nitrogen to sorghum might have resulted in faster grain filling compared to application of nitrogen at either three or six weeks

after sowing. Application of nitrogen at six weeks after sowing resulted in higher dry weights of stalk and leaves and total dry matter production but no appreciable differnces were observed with respect to other times of nitrogen application. This seems to suggest vigorous growth of the sorghum plant with nitrogen application at six weeks, and consequently an increase in the dry matter produced.

No significant effect of nitrogen application was observed on total nitrogen and crude protein contents of grain and protein yield. However application of nitrogen at six weeks after sowing resulted in greater total nitrogen and crude protein contents of grain followed respectively by application of nitrogen fertilizer in split dose, application of nitrogen at three weeks after sowing, and finally, application of nitrogen at emergence of seedlings. With protein yield, split application of nitrogen was superior, followed respectively by application of nitrogen at six weeks, nitrogen application at seedling emergence and finally, nitrogen application at three weeks after sowing.

The low values for total nitrogen and crude protein content of sorghum grain observed with nitrogen application at seedling emergence suggest that most of the applied nitrogen was utilized for vegetative growth, whereas the high percentage obtained with nitrogen application at six weeks after sowing may be attributed to preferential translocation of the applied nitrogen to the developing grain. Accumulation of nitrogen within sorghum plant has been reported to increase almost linearly up to maturity stage being high during the stages of jointing (35 - 42 days of sorghum growth) and grain filling stage (70 - 91 days after sowing) (Srivastava and Singh, 1971.

Warsi and Wright, 1973; Roy and Wright, 1974 Guo and Wang, 1980). This may have resulted in the greater total grain protein yield obtained with split application of nitrogen and also explains the lower yield of grain protein obtained with nitrogen application at three weeks after sowing.

5.4. Effect of Interactions Between Nitrogen, Method and Time of Application on Grain Sorghum

Interaction effects between nitrogen rate, method and time of application on all the growth and yield attributes considered in the present study, with exception of nitrogen x time interaction on grain yield, stover yield number of primary panicle branches, plant height, number of days to hard dough stage, and protein yield in sorghum were not significant statistically. This suggests that nitrogen rate and method of application may be acting independently of each other in sorghum but with appropriate timing of nitrogen application, grain yield, stover yield, and total protein yield could be significantly increased.

Chapter 6

SUMMARY AND CONCLUSSIONS

Application of nitrogen on sorghum significantly increased most of the growth and yield attributes considered. Application of 60 and 120 kg N/ha had significant and positive effects on plant height, sten diameter, number of internodes, number of days to hard dough stage, total number of leaves per plant, flag leaf area number of functional leaves at 14 and 16 WAS, and total dry matter accumulation. Also significantly increased by nitrogen fertilization were grain yield, stover yield, weight of grains per panicle, 1000-grain weight, panicle length, number of primary branches in panicle, threshing percentage, and total protein yield.

With the exception of stalk dry weight, total dry matter accumulation and number of functional leaves at 14 WAS, the method of nitrogen application had no significant effect on other growth and yield attributes studied. However, the broadcast method of nitrogen application proved to be marginally superior to the grooves method of application in sorghum.

Time of nitrogen application significantly influenced number of days to hard dough stage panicle dry weight, total length of ear, and number of primary branches in sorghum panicle but had no effect on the other parameters considered. Application of nitrogen fertilizer in two equal split at three and eight weeks after sowing resulted in highest grain yield, weight per panicle,

weight of grains per panicle, grain number per panicle, panicle length, threshing percentage, grain: stover ratio, harvest index, protein yield, and plant height when compared with any of the other times of nitrogen application in grain sorghum.

It is concluded from the present study that for attainment of high yield in sorghum hybrid SSH5 (Samsorg 5), nitrogen fertilizer should be applied in two equal splits at three and eight weeks after sowing each time at the rate of about 60 kg N/ha using broadcast method of application.

As the response to nitrogen application in this study was linear up to 120 kg N/ha, it is suggested that for future work on this hybrid, highest level of nitrogen fertilizer likely to increase grain yield significantly should be determined in order to evaluate the most economic rate of application.

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APPENDIX

Table: A.1: Rainfall Data for Samaru - Zaria, 1985 (mm)

	MONTH							
Date	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT
1	-	-	Tr	-	-	24.3	0.2	1.1
2	-	-	-	1.3	-	39.5	-	-
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	-	8.7	0.9	-
TOTAL	-	-	27.1	8.5	143.6	95.7	52.5	1.1
11	-	-	-	-	13.5	2.8	-	-
12	-	-	-	-	-	2.0	6.6	2.2
13	-	-	-	-	11.0	17.2	18.6	-
14	-	-	-	30.7	-	23.4	0.9	-
15	-	Tr	-	-	42.2	16.3	4.6	-
16	-	-	10.3	8.7	-	2.6	19.0	-
17	-	-	-	-	6.1	10.9	25.7	-
18	4.5	-	Tr	22.1	1.3	0.5	-	-
19	Tr	-	-	-	1.0	-	-	-
20	-	-	4.4	-	1.1	-	-	-
TOTAL	4.5	-	14.7	61.5	76.2	75.7	75.4	2.2
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	2.8	-	-
27	-	-	34.3	-	-	-	8.6	-
28	Tr	-	-	-	6.8	-	14.7	-
29	27.7	-	40.0	52.5	47.0	-	-	-
30	-	-	-	-	-	-	-	-
31	0.7	-	6.5	-	-	51.6	-	-
TOTAL	28.4	-	98.9	72.2	93.3	84.9	35.4	-
GRAND TOTAL	32.9	0.0	140.7	142.2	313.2	256.3	163.3	3.3

TOTAL RAINFALL FOR THE YEAR = 1051.8mm

Source: Meteorological unit, Institute for Agricultural Research, Ahmadu Bello University, Samaru - Zaria.