Chapter One

Introduction

Grain sorghum (*sorghum bicolor*-L-M Moench) is an important cereal crop. It ranks fifth among the world's cereals. It is grown mainly in semi arid areas of the tropics and subtropics. Grain sorghum is a basic human food crop in many developing African and Asian countries. It is also used as an animal feed. The sorghum stalks are used as construction material and fuel (Taha.1998).The total area under sorghum production in the world is more than 52 million hectares with an average grain yield of about 1.09 metric tons per hectare. In Africa sorghum is important in the region from Ethiopia and south wards through east and central to south Africa. Africa produces less than 1/4 of the world total production with average yield of less than 1/3 of the world average. Sorghum is a basic food crop in many developing African countries. It is also used as animal feed and for industrial purposes (Abdalla, 1987).

In Sudan, grain sorghum is the most important cereal crop in terms of acreage, total production and as a main dietary stable of Sudanese people. (Ejeta , 1988). Traditionally sorghum was a peasant grain crop grown for local consumption by hand methods. In the last few years, more lands have been brought into mechanized crop production schemes, most of which lie in the central rain land areas (Gadarif, Dalli, Mazmoom, Habila and Damazin) (ELhassan, 1986). The sorghum is mostly consumed in form of Kisra (unleavened bread). It is also used to make, Asida (Thick porridge) and Abreih (a popular beverage) (Ejeta, 1988).Sorghum production in Sudan takes place in all three production systems. The irrigated sub-sector, the mechanized rain fed sector and the traditional rain fed sector (Taha, 1998).

In the Sudan, It is the main staple food and ranks first among cereals in importance and production. It is grown mainly as a rain fed crop because it tolerates heat, drought and low soil fertility. Under these harsh environmental conditions, its average grain yield in Sudan is low (539 Kg/ha) compared to that of the world (1288Kg/ha) (Abdalla, 1999). The rain fed sector produces 90% and only 10% of sorghum is produced in irrigated sector for food security to guard against risk of drought and environmental hazards. Sorghum is grown annually in an area ranging between 4.3 to 7.1 million hectares (ELamin and ELzein, 2006).Besides the economic importance of sorghum, farmers in the Sudan prefer to grow sorghum if they have the freedom of decision making, especially in irrigated schemes. Some of the reasons for that preference are included in the largest agricultural scheme in the Sudan.

The reasons include:

1. Drought resistance, which is important given Sudan's relatively arid climate.
2. The relative simplicity of sorghum's cultural practices.
3. Relatively short maturity periods.
4. The possibility of storage for home consumption and for feeding hired laborers . (Sid Ahmed, 1985).

Increase of yield of sorghum should be initiated within the national sorghum improvement program of the Agricultural Research Corporation in the Sudan. Also the optimum sowing date and the best nitrogen rate of sorghum in Sudan are one of the key components for a better sorghum grain yields. One of the most important cultural practices is sowing date. It has a pronounced effect on the growth and development of cereal crops. The suitable date for cereals mainly depends on many factors particularly weather conditions (sunshine, temperature and humidity). Either early or late planting can result in lower yield because the probability exists that unfavorable climatic conditions can occur after planting or during the growing season (Ahmed, 2013).

Nitrogen is an important nutrient element. Sorghum reacts favorably to nitrogen fertilization both in terms of the yield and protein content (Munteann et al, 2012). Nitrogen plays a key role in several physiological crop processes. As a result of increasing nitrogen dose , the photosynthetic a activity leaf area index (LAI) and leaf area duration (LAD) increased (Adrienn et al , 2012) .

The objectives of this study were:

1. To study the effect of sowing time on growth and yield of sorghum.
2. To determine the best nitrogen dose.
3. To calculate the nitrogen use efficiency.

Chapter Two

Literature Review

2.1 Grain Sorghum

Grain sorghum (*sorghum bicolor* (L) Moench) is a major crop in many parts of Africa that is noted for its versatility and diversity. Grain sorghum was the basic food crop for the ancient farmers more than 10000 years ago. Today, grain sorghum is still the most basic food crop. Grain sorghum is important for two reasons. First, it is the major source of food for the world's population. Secondly, it is used to feed livestock, which provide meat, dairy products, wool, and eggs. Grain sorghum is easy to store and will not spoil if properly stored. It is easy to convert into food. Sorghum is an excellent source of essential nutrients, particularly the carbohydrates which provide energy. They are also easy to grow in many different parts of the world (Douglas, et al, 1983). There are many verities of sorghum bicolor. Ranging in color from white through red to brown and mixed types in the grain standards (Baidab, 2012).

2.2 Sorghum origin:

The beginning of sorghum culture, as that of the most other crops is shrouded in Mistery. Evidence indicates that it started in eastern Africa (probably Ethiopia or Sudan) in prehistoric times perhaps 5000 to 7000 or more years ago (Wall and Ross, 1970).

Doggett (1988) analyzed species without regard for the taxonomic validity but as an indication of variability. He found that out of the cultivated sorghum, 20 species out of a total of 28 in Africa occurred in the northeast quadrant. Similarly, 87 of species had been collected in this region, out of a total of 128 in Africa. Collections has been very uneven, and Sudan appears to show greater variability than does Ethiopia according to the data in the world collection (Doggett, et al, 1970). From Ethiopia and Sudan, cultivated sorghum spread south wards in to Kenya, Tanzania and Uganda (Doggett, et al, 1970). Sorghum do mastication has been associated with human migration, trade and shipping routes through Africa and through the Middle East to India, 3000 years ago. Nowadays, cultivated sorghum is found in a wide range of environments in Africa, Asia, Australia, North, South and Central America (Mohamed, 2011).

2.3 Sorghum importance:

Sorghum is the fifth most important cereal crop after wheat, rice, maize and barley. It is the staple food in many of the drier tropical areas of Africa, India and China as it is resistant to drought and can consistently out yield maize under rain fed conditions in areas with variable annual rainfall. 90% of the sorghum food grain in the dry tropics is utilized in five main ways.

1. Unleavened bread (Kisra).
2. Gruel/porridge .
3. Boild whole grain or pieces after removal of the per carp.
4. Beer.

Sorghum flour can also be added to wheat or maize flour in different proportions (Gibbon and pain, 1985). Furthermore, sorghum is used to make syrup, ethanol, silage (sweet sorghum) and brooms from the branches of broom corn seed clusters. Besides all the uses mentioned, sorghum has a great number of morphological and physiological characteristics that gives it a great advantage over other cereals being able to produce a harvestable crop where many other cereal crops would fail.

These characteristics include an extensive root system and a waxy bloom on the leaves, which reduces water loss and the ability to stop growth during periods of drought and resume growth when conditions become favorable this contribute to sorghum adaptation to harsh environments, where water availability and soil fertility are marginal. These unique advantages of sorghum must be considered for the future, especially in the presence of an increasing world population that demands more food with an efficient use of water and land resources (Rooney et al, 1980, Murty and Kumar, 1995).

2.4 Sorghum production:

Sorghum is broadly adapted and grown in a great range of environments. One of its strongest traits is its great adaptability to tropical and subtropical areas of the world where water availability and soil conditions are considered marginal for other grain crops. Under optimal conditions, sorghum has a high yield potential comparable to other cereals such as rice, maize or wheat (Mohamed, 2011).

Sorghum grain yield can be as high as 15 mt. ha^{-1} , and a good yield is usually between 7 and 9 mt. ha^{-1} when rainfall is not a limiting factor. Under average conditions, sorghum yield can vary between 3-4 mt.ha^{-1} under drought (House, 1982). This drastic variation in grain yield among different sorghum production systems throughout the world is mainly due to the use of hybrids and improved equipment and production techniques in developed countries, compared to use of landraces and subsistence agriculture that predominate in the developing world (Moncada, 2006). Asia and Africa each account for about 25 to 30% of global production. Nigeria and Sudan are the major producers in Africa. Production in

Africa remains characterized by low productivity and extensive low-input cultivation (Abdelrahman, 1998).

2.5 Sorghum in Sudan:

Sudan is located within the region where sorghum is believed to be domesticated for the first time and where the largest genetic variation for both cultivated and wild sorghum is found. A large collection of Sudanese landraces from different parts of Sudan was collected at the Agricultural Research Corporation Gene Bank. Today this collection amounts to more than 400 accessions (Mohamed, 2011).

Sorghum is grown in an area ranging between 4.3 and 7.1 million ha with an average of 5.2 million ha. In 2009, the total annual sorghum production in Sudan was 4.192 million metic tons from approximately 6.653 million ha, with an average yield of 0.63 $mt.ha^{-1}$. (FAO STAT, 2010). The rain-fed production in the mechanized rain-fed sector accounts for most of the yield and only 10% of sorghum is produced in the irrigated sector for food security to guard against risk of drought and rainfall.

Sorghum contributes to about 65% of Sudan consumption of grain, 70% of the calories in the diet, and to considerable amount of protein. Sorghum is also mixed with wheat in composit flour. There is an increasing demand for feed for livestock which contributes to foreign exchange reserues. Sorghum is grown throughout the country in all agricultural sub-sectors (irrigated, Mechanized and traditional) during the rainy season, from June to October.

Sorghum research programs focus on varietal improvement with objective of developing high yielding varieties with good quality traits for consumer and market demand. Research also focuses on resistance to biotic and a biotic factors such as striga, insect, disease, drought etc. (Noureldin and Elamin, 2006) to produce high yield potential cultivars, such as Tabat and WadAhmed. In addition hybrid development with emphasis on striga management. The most significant outcome of Sudan's cooperative program with ICRI SAT (1977) was the release of commercial hybrid sorghum in 1982 by ICRISAT and the Agricultural Research corporation (ARC) (Doggett, 1988).

Sorghum production increased by 39% between 1960 s and the 1970s from 1.297 million MT to 1.801 million metric tons, by 29% between the 1970s and the 1980s from 1.801 million MT to 2.33 million metric tons, and by 38% between the 1980s and the 1990 from 2.33 to 3.213 million metric tons. Sorghum production increase during the 1990s is mainly attributed to the major increases in sorghum planted area, stimulated by high prices at planting time, in addition to better than average supplies of fuel and fertilizer and in the greater use of high potential cultivars which provided the conditions for the highest sorghum crop in recent years (FAO, 1997).

2.6 Adaptation:

Sorghum has a wide range of adaptation but prefers hot warm conditions and is killed by frost. It can grow well from sea level to 2000m altitude and between 40^{o} N and40^{o} S Latitudes. It grows best in fertile soils but is one of the best cereals for poor conditions and uncertain rainfall. Sorghum is better able than maize to with staid drought periods because:

1. The root system is very deep and extensive and becomes well established before stem and leaf growth acceleration.
2. The roots contain silica which maintains them during drought period.

3. The leaf area is limited and can be reduced further by inward rolling during drought.
4. Sorghum usually has much greater water use efficiency than maize.
5. The plant can suspend growth during periods of drought and resume growth when conditions become more favorable (Gibbon and pain, 1985).

Sorghum is a short day plant but the mechanism of its flowering response to photoperiod is not clearly understood. (Cobley and Steels, 1977). Sorghum shows a wide range of sensitivity to photoperiod and temperature changes but it is generally thought that the timing of the flowering of a sorghum cultivar is determined by the interaction between genotype, photoperiod and temperature. Sorghum can grow well on heavy soils and can mature entirely on stored residual moisture in deep clays. It also grows well on lighter soils, (Gibbon and pain, 1985). Also sorghum is grown successfully on nearly all types of soils with range of pH 5.5-8.5. Sorghum will tolerate considerable salinity and alkalinity fairly well. (Warm and John, 1987).

2.7 Effect of sowing date on growth and grain yield of sorghum.

In Sudan Ali (2005) reported that the highest grain yield was produced by first July sowing, followed by Mid June sowing. Late planting (August) reduced grain yield of sorghum by 76.7% compared to the recommended sowing date (15 June – 21 July). Ishag and Farah (1963) reported that the optimum planting time for the late maturing varieties (Wad akar and Fahal) was the first half of June. The early Dwarf White Milo and Medium variety Dwarf Feterita 7028 responded better to planting in the second half of June. They also reported that grain yield was increased by early planting while the straw yield declined with later planting. Elrayah (1977), in Sudan found that grain yield was high with June15 and July1 sowings and was reduced by delaying sowing to July 15.

Faddal (1963) found that sowing on August25 led to lower grain yield (662 kg/ha) compared with 1042 kg/ha obtained from July27 sowing. Fadlel Mula. (2009) reported that the grain yield was higher (498-689 kg/fed) when the sowing date of sorghum starts early as from the first week to the 3rd week of July.Gaikwad et al. (1984) in India reported that RabiSorghum crops were better that sorghum grown in Kharif(Monsoon) season. They also reported that the ratoon sorghum gave grain yield ranging between 1110 and 2380 kg/ha and the forage yield of 3550-3590 kg/ha. According to Gorbet (1985) in U.S.A, planting in April and harvest in November gave the highest yield for both the main and ratoon crops (7060 and 5030 kg/ha respectively). Chielle and Chielle(1990) in Brazil reported that sowing date had greater effect on yield than cultivar. They also reported that grain yield from regrowth ranged from 60-80% of the main crop depending on weather conditions than on sowing dates. The grain yield response of Rabi sorghum to sowing date was in favour of early sowing (15 September to 15 October) rather than late sowing (beyond 1 November) (Patel et al, 1990). From their study they reported average Rabi grain yield of 4.6t/ha (early sowing) as against 3.4 t/ha (Late sowing).

2.8 Effect of Nitrogen rate on growth and grain yield of sorghum:

Fertilizer nitrogen has contributed more than any other fertilizer towards increasing yield of grain crops, including sorghum. Studies in the U.S.A and other parts of the world in the past 30 years, showed that nitrogen fertilizer increases yield of crops more than any other single factor. Consequently, nitrogen has become the foremost input in relation to cost and energy requirement in advanced agricultural production systems (Yousif, 1993). Nitrogen is one of the expensive nutrients to supply. Simultaneously it is important factor limiting crop productivity. Approximately 85 to 90 Millia metric tons of nitrogenous fertilizers are added to soil world wide each year (Maduraimuthu and Desikan, 2013).

In Sudan, Ishag and Farah (1963) found that 86 kg N/ ha in form of urea or sulphate of ammonium gave straw yield of 6133kg/ha and 5909 kg/ha, respectively. They also found that broadcasting of urea was better than side dressing. Application of nitrogen at flowering gave low grain yield, while addition of nitrogen between sowing and flowering increased the grain yield to 2473kg/ha. They also found the bestapplication time for increasing grain yield was one month after planting.

According to Ali (1981) , application of 86 and 43 kg N/ha significantly increased grain yield over the control. Also application of 86 kg N/ha significantly increased grain yield over 43kg N/ha.

Elrayah (1976) studying the effect of different rates of nitrogen (0.0, 43, 86, and 130 Kg N/ha) found that nitrogen had a significant effect on grain yield which was constantly increased up to 130 kg N/ha.Shukla et al.(1976), found that increasing nitrogen rate from 0 to 120 kg N/ha increased grain yield from 1.77 to 2.91 t/ha by mainly increasing number of grains / panicle from 596 to 1039. Patel et al. (1990), reported a significant interaction between number of irrigations and nitrogen level on yield. They also reported that 150 kg N/ha and 6 irrigations gave better yield than 50 kg N/ha and three irrigations (4780 kg/ha). Ravoof and Chua (1978), found that 134 kg N/ha was optimum for grain and roughages yields. They reported that forage dry matter and crude protein yields were greater in the ratoon crop (9000 and 910 Kg/ha, respectively) than in the plant crop (6200 and 780 kg/ha,respectively). According to lomete and Dabahade (1990) grain yield of 4100 kg/ha was obtained by addition of 180 kg N/ha to the ratoon crop.

In Australia, Wad et al. (1992) reported that application of 100 kg N/ha increased grain yield of the ratoon crop at one site from (1500 to 1760 kg/ha). Furthermore, Balasubramaniam and Manick Sundram (1993) reported that grain yield of the ratoon crop ranged from 300 to 600 kg/ha due to addition of mineral fertilizer containing 75% N,100% P and 100% K applied for both the sown and ratoon crops. According to Viomlsut jarit (1987) in Philippines, the yield components, grain and stover yields were increased as the level of nitrogen was increased from 0.0 to 180 kg N/ha.Duncan (1987) reported that tropically adapted hybrids produced 610 - 620 kg/ha more grain yield with 95 kg N/ha than temperately adapted hybrids. In Sudan Fadlelmula (1987), obtained a grain yield ranging between 315 to 932 kg/ha in the ratoon crop with application of 86 kg N/ha as urea applied immediately after the removal of the main crop stubble.

2.9 Nitrogen use efficiency:

Mol et al. (1982) defined NUE as the yield of grain per unit of available N in the soil including the residual N present in the soil and fertilizer. NUE can further be divided into two processes: nitrogen uptake efficiency and nitrogen utilization efficiency. Nitrogen uptake efficiency is defined as a quotient of plant nitrogen uptake (Nupt) and total crop nitrogen supply (NSUP) (Fertilizer plus soil mineral nitrogen) (Samborski et al., 2008). Nitrogen uptake efficiency is also called nitrogen recovery efficiency (REN) which defines the capacity of the plant to acquire nitrogen from the soil. According to Baligar et al. (2001) nitrogen uptake efficiency is attributed to morphological, physiological and biochemical processes in plants and their interaction with climate, soil, fertilizer, biological and management practices. Improved NUE can help to enhance yield under low nitrogen and thus improve crop nutritional quality and it will also reduce ground water contamination by excess nitrates (Hirel and Lemaire, 2005). Nitrogen use efficiency for production of cereals such as wheat , rice , corn , barley , sorghum , pearl millet is a approximately 33% and the remaining 67% goes as loss (Maduraimuthu and Desikan , 2013) . Nitrogen use efficiency is necessary to secure staple food source for the increasing population of the world, especially when there are challenges from global climate change and higher cost of energy, fertilizers and water (Smith et al, 2012).

Chapter Three

Materials and Methods

3.1 Location:

This study was carried out during July – December for two consecutive seasons (2011/2012 and 2012/2013) at the Demonstration Farm of the College of Agricultural Studies, Sudan University of Science and Technology, Shambat. (Latitude 15^0-$40^/$N, Longitude 32^0- $32^/$E and 375 meters above sea level)(Sayed 2012).

3-2 Climate:

The climate of the site is described as tropical semi arid with only three months of rainfall during July, August and September. Maximum temperature is above 40C^o in the summer and the minimum is around 20C^o in the winter season. The relative humidity ranging between 14-27% during dry season and 31-51% during the wet season (Sayed 2012). The records of temperature, relative humidity and rainfall for the experimental period for the two seasons is shown in (Appendix -1).

3.3 Soil analysis:

The soil is typical clay soil (Appendix-2), it is beep cracking, moderately alkaline clays, low permeability with low nitrogen content and pH ranging between 7.5 – 8.0. Its low permeability is related to both high pH content and high exchangeable sodium percentage (ESP) in sub soils (Azrag, 2010).

3.4 Source of seeds , Experimental design and treatments.

Hybrid (Wad Ahmed) seeds used in the experiment were obtained from the Gezira Research Station. Split plot arrangement in a randomized complete block design (R.C.B.D), with three replications was used. The treatments components were as follows:

a. Variety Faterita wad Ahmed (FWA).

   This is a local commercial name for the new release (Osman and Mahmoud, 1992) pedigree A/239: 1/2/3 X Gadam ElHamam. Its grain hardness is medium (70-80%) it stays green even after grain harvesting.

b. Sowing dates:(main plot)

   1. 1st July (S1).
   2. 15th July (S2).
   3. 1st August (S3).
   4. 15th August (S4).

c. Rates of Nitrogen fertilizer.(sub-plot)

   Four nitrogen rates were applied, namely:

   1. Control(N0).
   2. 45 Kg N/ha(N1).
   3. 90 kg N/ha(N2).
   4. 135 Kg N/ha(N3).

3.5 Sowing and Fertilizer application.

Sowing was done by hand where five seeds per hole were sown on top of the ridge at 4-5 cm depth. The spacings between ridges and hole were 70 and 20 cm respectively. The plot size was 3x3 meters and each plot consisted of four ridges. The fertilizer was side-dressed in the form of urea (46% N) 4 weeks after effective sowing i.e. at tillering.

3.6 Watering, Thinning and weeding.

The watering interval was 7-10 days in both seasons and the plants were thinned to two plants per hole after two weeks from planting. Three manual weedings in each season were carried out. Stem borer was observed when the crop was 50 days old in the first sowing date (1st July) in first season and 27, 75 days old in the second. The crop was sprayed with pychovex 480 EC and Deltaplan 250 EC in first season and Zork a.i. Carbosulfan 25% EC and Fastac 100 EC in second season. (Sudan University, crop protection).

3.7 Measurements of growth attribute:

Measurements of growth attributes were taken after 65 days from sowing. Four plants were selected randomly from each plot after leaving 50 cm at each end of the plot. The selected plants were tagged.

3.7.1 Plant height (Cm):

Plants height was measured from the soil surface to the collar of the last leaf on the plant, then the mean plant height was calculated for each plot.

3.7.2 Leaves number per plant.

The four plants used for the measurement of plant height were also used for counting the leaves per plant and the average numbers of leaves were recorded.

3.7.3 Leaf area (cm^2):

Leaf area for three leaves per plant of each of the four plants per plot was measured. For each leaf, the maximum length was multiplied by the maximum width and then multiplied by 0.75 to obtain the leaf area (Sticker, 1961).

3.8 Yield and Yield components:

Measurements of yield components were taken when signs of maturity were clearly observed on the plants (complete yellowing of leaves and partial shedding of leaves).

3.8.1 Length of head (cm):

The heads of four selected plants in each plot were measured and the average head length was recorded.

3.8.2 Weight of seeds per plant (g):

The harvested heads of four plants were air dried and threshed and bulk weight and the average weight of seeds was calculated.

3.8.3 100- seeds weight (g):

100-seeds were counted randomly then weighed for each plot of the four selected plants.

3.8.4 Grain yield (t/ha):

The harvest plants from each plot were threshed and seed yields for each plot were recorded, yield per hectare was then estimed. Yield (t/ha)

$$= \frac{\text{weight. of seeds per plot}}{\text{Area of the plot}} \times \frac{10000\ m^2}{1000\ kg}$$

3.8.5 Harvest index:

It was calculated as the ratio of grain to total biological yields as follows:

$$\frac{\text{Grain yield (t/ha)}}{\text{Biological yield (t/ha)}} \times 100$$

3.8.6 Nitrogen use efficiency (kg seeds/kgN):

This was determined by dividing the grain yield by the N fertilizer applied, i.e., grain yield obtained per Kg N applied:

$$\frac{\text{Grain yield (k/ha)}}{\text{Kg N/ha}}$$

3.9 Analysis of data:

The data was analyzed by computer, using the Mstat .C program. The treatment means were compared using Duncan multiple range test (DMRT).(Gomes and Gomes 1984)

Chapter Four

Results

4.1 Vegetative growth:

4.1.1 Plant height (Cm).

From the statistical analysis of variance (Appendix 3,4) it was clear that there were no-significant effect of sowing date and nitrogen fertilizer on plant height in both seasons, but nitrogen fertilizer dose of 135 K gN/ha recorded the tallest plants (Table 1).

There were no significant differences in Interaction between sowing date and fertilizer. But the tallest plants were recorded by the treatment S_2 (15^{th} July) with fertilizer dose 45 KgN/ha (table 1). In 2^{nd} season.

4.1.2 LeaF number / plant.

Statistical analysis (Appendix 3,4) showed that sowing date had significant effect on leaf number / plant in first season (P = 0.05) when, S_1 (1^{st} July) a sowing date gave highest leaf number (Table 2).

Leaf number / plant was significantly affected by nitrogen Fertilizer in the 2^{nd} season ,application 135 KgN/ha gave highest leaves number (Table 2).

Table 1: Effect of sowing date and nitrogen rate on plant height (Cm) of sorghum.

1st season | **2nd season**

Fertilizer	Sowing-date									
	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean
No	91.00^{ef}	95.53^{abcdef}	93.43^{cdef}	95.33^{bcdef}	93.82^{b}	99.30^{ab}	99.47^{ab}	98.87^{ab}	100.8^{ab}	99.61^{a}
N_1	90.30^{f}	96.77^{abcdef}	96.27^{abcdef}	94.87^{bcdef}	94.55^{ab}	99.10^{ab}	103.1^{a}	99.53^{ab}	100.3^{ab}	100.3^{ab}
N_2	94.43^{bcdef}	98.87^{abc}	94.03^{cdef}	95.33^{bcdef}	95.67^{ab}	95.27^{b}	95.10^{b}	95.10^{b}	99.03^{ab}	99.03^{ab}
N_3	91.77^{def}	100.3^{ab}	101.7^{a}	101.7^{a}	101.7^{a}	102.1^{ab}	98.53^{ab}	101.5^{ab}	99.03^{ab}	100.29^{a}
Mean	91.88^{a}	97.87^{a}	96.36^{a}	95.78^{a}		98.94^{a}	99.05^{a}	100.68^{a}	99.79^{a}	
C.F					6.18					7.79

Means in the same column followed by different letters are significantly different at $p = 0.05$ (DMRT).

Key S_1 = sowing date at 1st July, S_2 = 15th July, S_3 = 1st August, S_4 =15th August,

Fertilizer N_O, N_1, N_2 and N_3 control, 45, 90 and 135 KgN/ha (urea) respectively and C.F= critical factor.

There were no significant differences in interaction between sowing date and nitrogen fertilizer. The highest leaves number were recorded for the treatment S_2 (15thJuly) with fertilizer dose 45 Kg N/ha in 1st season and S_2 (15thJuly) with fertilizer dose 135 Kg N/ha in 2nd season (table 2).

4.1.3 Leaf area (Cm^2):

According to statistical analysis it was clear that sowing date had significant effect on leaf area in both seasons. In the 1st season means of S_3 (1stAug.) gave the largest area of leaf area and in 2nd season means of S4 (15thAug.) was the best (Table 3).

Leaf area was not significantly affected by fertilizer and interaction between sowing date and fertilizer in both seasons (Appendix 3,4). The largest area of leaf was recorded for the treatment S_4 (15thAug.) with fertilizer dose 135 Kg N/ha in both seasons. (table 3).

Table 2: Effect of sowing date and nitrogen rate on leaf number/plant of sorghum.

1st season **2nd season**

	Sowing-date									
Fertilizer	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean
No	12.93 ^{b}	14.10 ^{ab}	13.60 ^{ab}	13.20 ^{b}	13.46^{a}	14.60 ^{abc}	14.20 ^{abc}	14.20 ^{abc}	12.87 ^{c}	13.97^{a}
N_1	12.93 ^{b}	14.60 ^{a}	13.03 ^{b}	12.77 ^{b}	13.33^{a}	14.00 ^{abc}	14.50 ^{abc}	13.20 ^{c}	13.33 ^{c}	13.76^{b}
N_2	13.93 ^{ab}	13.70 ^{ab}	13.87 ^{ab}	13.03^{b}	13.63^{a}	14.37 ^{abc}	13.30 ^{c}	14.20 ^{abc}	13.93 ^{bc}	13.95^{b}
N_3	13.30 ^{ab}	13.87 ^{ab}	13.67 ^{ab}	13.70 ^{ab}	13.64^{a}	15.43 ^{ab}	15.97 ^{a}	14.27 ^{abc}	13.63 ^{bc}	14.83^{a}
Mean	13.27^{b}	14.07^{a}	13.54^{ab}	13.18^{b}		14.60^{a}	14.49^{a}	13.97^{a}	13.4^{a}	
C.F					2.00					1.99

Means in the same column followed by different letters are significantly different at $p = 0.05$ (DMRT).

Key S_1 = sowing date at 1st July, S_2 = 15th July, S_3 = 1st August, S_4 =15th August,

Fertilizer N_O, N_1, N_2 and N_3 control, 45, 90 and 135 KgN/ha (urea) respectively and C.F= critical factor.

4.2 Yield and Yield components:

4.2.1 Length of head (cm).

From the analysis of variance it was clear that sowing date had significant effect (P=0.05) on length of heed in 2nd season (Appendix 4). The means of S_4 (15th Aug.) gave the highest significantly bigger head in 2nd season (Table 4).

On the other hand, the effect of fertilizer and interaction between sowing date and fertilizer were not significantly on length of head in both seasons (Appendix 3,4). But the nitrogen dose N3 (135 kgN/ha) was recorded the higher length of head .The tallest length of head was recorded by the treatment S_3 (1st Aug.) with fertilizer dose 135 KgN/ha in 1st season and S_4 (15th August) with fertilizer dose 135 KgN/ha in 2nd season.(table 4).

4.2.2 Weight of seeds / plant (g).

Statistical analysis (Appendix 3,4) showed that sowing date and fertilizer had no significant effect on weight of seeds/plant in both seasons. Sowing date S_4 (15st Aug.) gave highest significant weight and the nitrogen dose 135kgN/ha was recorded higher weight of seeds/plant (Table 5).The analysis showed that the interaction between sowing date and fertilizer had a significant effect on weight of Seeds/plant in both seasons (Appendix 3,4).

Table 3: Effect of sowing date and nitrogen rate on leaf area (Cm^2) of sorghum.

1^{st} season **2^{nd} season**

	Sowing-date									
Fertilizer	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean
No	208.5^{k}	248.3^{hijk}	312.4^{abcd}	260.0^{ghij}	257.3^{a}	306.2^{a}	357.6^{fg}	415.0^{cdef}	538.3^{ab}	413.25^{a}
N_1	235.3^{ijk}	268.7^{efghi}	328.1^{abc}	302.3^{cdefg}	283.6^{a}	343.4^{fg}	410.2^{cdef}	454.1^{bcde}	487.2^{abcd}	423.73^{a}
N_2	223.2^{jk}	264.1^{fghij}	306.9^{bcdef}	308.7^{bcde}	275.73^{a}	297.0^{g}	404.0^{def}	487.9^{abcd}	502.3^{abc}	422.8^{a}
N_3	244.3^{hijk}	283.0^{defgh}	349.6^{ab}	353.8^{a}	307.68^{a}	373.8^{efg}	425.0^{cdef}	455.7^{bcde}	549.1^{a}	450.9^{a}
Mean	227.83^{b}	266.03^{b}	324.25^{a}	306.2^{a}		339.08^{d}	399.20^{c}	453.18^{b}	519.23^{a}	
C.F					42.96					93.18

Means in the same column followed by different letters are significantly different at $p = 0.05$ (DMRT).

Key S_1 = sowing date at 1st July, S_2 = 15th July, S_3 = 1st August, S_4 =15th August,

Fertilizer N_O, N_1, N_2 and N_3 control, 45, 90 and 135 KgN/ha (urea) respectively and C.F= critical factor.

The highest weight of seeds/plant was recorded by the treatment sowing date (15^{th} August) with fertilizer dose 135 KgN/ha in 1^{st} season and sowing date (15^{th} July) with fertilizer dose 45 KgN/ha in 2^{nd} season (table 5).

4.2.3 Weight of 100 seeds (g).

According to statistical analysis it was clear that sowing date had highly significant effect on weight of 100 seeds in 2^{nd} season (Appendix4), S_2(15^{th}July) recorded highest weight of 100 seeds . On the other hand, the fertilizer had not significant effect on weight of 100 seeds in both seasons but the dose 135 kg N/ha was recorded higher 100 seeds weight (Appendix 3,4).

The analysis showed that the interaction between sowing date and fertilizer had a significant effect on weight of 100 seeds in 1^{st} season (Appendix3) . The highest weight of 100 seeds was recorded by the treatment S_4 (15^{st}Aug.) with N_2 (90kgN/ha) in 1^{st} season and S_2 (15^{th}July) with N_3 (135 kgN/ha) in 2^{nd} season (Table 6).

4.2.4 Grain yield (t/ha):

From the analysis of variance it was clear that sowing date and fertilizer had a significant effect on grain yield, while the interaction is not significant in 1^{st} season (Appendix 3) . The means of S_4 (15^{th}Aug.) had the highest yield in the second season (5.27t/ha) .135 KgN/ha gaved highest grain yield in 2^{nd} season (Table 7).

Table (4): Effect of sowing date and nitrogen rate on length of head (cm) of sorghum.

	1st season					2nd season				
	Sowing-date									
Fertilizer	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean
No	14.63 bc	15.80 abc	15.77 abc	15.90 abc	15.53a	15.82a	14.83 e	15.03 de	17.63 a	15.72a
N_1	15.07 bc	15.23 bc	16.20 ab	15.97 abc	15.62a	16.53 abcd	16.43 abcd	16.33 abcde	17.23 ab	16.63a
N_2	15.07 bc	15.00 bc	15.30 bc	15.67 abc	15.26a	16.57 abc	15.97 bcde	16.53 abcd	16.93 ab	16.5a
N_3	14.37 c	14.97 bc	17.37 a	15.73 abc	15.61a	16.87 abc	16.07 bcde	16.20 abcde	17.40 ab	16.64a
Mean	14.79a	15.25a	16.16a	15.82a		16.34ab	15.83b	16.02b	17.3a	
C.F					1.81					1.52

Means in the same column followed by different letters are significantly different at p = 0.05 (DMRT).

Key S_1 = sowing date at 1st July, S_2 = 15th July, S_3 = 1st August, S_4 =15th August,

Fertilizer N_O, N_1, N_2 and N_3 control, 45, 90 and 135 KgN/ha (urea) respectively and C.F= critical factor.

The interaction between sowing date and fertilizer had affected significantly grain yield in 2nd season (Appendix 4). The highest grain yield was recorded by the treatment sowing date S_3 (1st Aug.) with fertilizer dose 135 kg N/ha in both seasons (table 7).

4.2.5 Harvest index (%):

Statistical analysis (Appendix 3,4) showed that the sowing date had significantly affected Harvest index in both seasons. The means of S_3 (1st Aug.) and the means of S_4 (15th Aug.) gave the higher significant Harvest index in 1st season and 2nd season respectively (Table 8).

The analysis showed that fertilizer and interaction between swing date and fertilizer had not effect significantly the Harvest index in both seasons (Appendix 3,4). The highest Harvest index was recorded by the treatment S_3 (1st August) with fertilizer dose 90 Kg N/ha and sowing date S_4 (15th August) with fertilizer dose 135 KgN/ha in 1st season and 2nd season respectively (table 8).

4.2.6 Nitrogen use efficiency.

From the analysis of variance (Appendix 3,4) it was evident that, sowing date had no significant effect on Nitrogen use efficiency in both seasons. But S2 (15th July) recorded higher nitrogen use efficiency in 2nd season .

The fertilizer had highly significant effect on Nitrogen use efficiency in both seasons. The application of 45KgN/ha gave the higher significantly Nitrogen use efficiency in both seasons (Table 9).

Table (5): Effect of sowing date and nitrogen rate on weight of seed (cm) of sorghum.

	1st season					2nd season				
	Sowing-date									
Fertilizer	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean
No	84.30 [e]	113.40 [bcde]	135.80 [abcde]	146.40 [abc]	119.98[a]	177.60 [ab]	171.97 [ab]	176.57 [ab]	184.87 [a]	177.75[a]
N_1	117.9 [bcde]	104.40 [cde]	164.40 [ab]	140.80 [abcd]	131.88[a]	169.13 [b]	185.13 [ab]	174.30 [ab]	183.80 [ab]	178.09[a]
N_2	116.3 [bcde]	89.43 [de]	150.80 [abc]	123.10 [bcde]	119.91[a]	172.83 [ab]	175.97 [ab]	181.80 [ab]	178.50 [ab]	177.28[a]
N_3	86.13 [e]	117.9 [bcde]	180.80 [a]	148.30 [abc]	133.28[a]	183.20 [ab]	181.57 [ab]	184.30 [ab]	179.37 [ab]	182.11[a]
Mean	101.16[c]	106.28[bc]	159.45[a]	139.65[ab]		175.69[a]	178.66[a]	179.24[a]	181.64[a]	
C.F					53.96					17.44

Means in the same column followed by different letters are significantly different at $p = 0.05$ (DMRT).

Key S_1 = sowing date at 1st July, S_2 = 15th July, S_3 = 1st August, S_4 =15th August,

Fertilizer N_O, N_1, N_2 and N_3 control, 45, 90 and 135 KgN/ha (urea) respectively and C.F = critical factor.

The statistical analysis (Appendix 4) showed that the interaction between sowing date and fertilizer had significant effect on Nitrogen use efficiency in 2^{nd} seasons. The higher nitrogen use efficiency recorded by the treatment sowing date S_3 (1^{st} August) with fertilizer dose 45 Kg N/ha in 1^{st} season and sowing date S_2 (15^{th}July) with fertilizer dose 45 KgN/ha in 2nd season (table 9).

Table (6): Effect of sowing date and nitrogen rate on weight of 100 seeds (g) of sorghum.

	1st season					2nd season				
	Sowing-date									
Fertilizer	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean
No	3.87^{abc}	3.93^{abc}	4.03^{abc}	4.43^{abc}	4.07^{a}	4.53^{cde}	4.93^{abc}	4.07^{e}	4.90^{abc}	4.61^{a}
N_1	3.90^{abc}	4.03^{abc}	4.23^{abc}	3.87^{abc}	4.01^{a}	4.17^{de}	4.93^{abc}	4.13^{de}	4.63^{bcd}	4.47^{a}
N_2	3.83^{bc}	3.67^{c}	3.60^{c}	4.77^{a}	3.97^{a}	4.27^{de}	5.13^{ab}	4.17^{de}	4.60^{cd}	4.54^{a}
N_3	3.87^{abc}	4.17^{abc}	4.00^{abc}	4.60^{ab}	4.16^{a}	4.27^{de}	5.33^{a}	4.43^{cde}	4.60^{cd}	4.66^{a}
Mean	3.87^{a}	3.95^{a}	3.97^{a}	4.42^{a}		4.31^{c}	5.08^{a}	4.2^{c}	4.68^{b}	
C.F					0.91					0.53

Means in the same column followed by different letters are significantly different at p = 0.05 (DMRT).

Key S_1 = sowing date at 1st July, S_2 = 15th July, S_3 = 1st August, S_4 =15th August,

Fertilizer N_O, N_1, N_2 and N_3 control, 45, 90 and 135 KgN/ha (urea) respectively and C.F= critical factor

Table (7): Effect of sowing date and nitrogen rate on grain yield (t/ha) of sorghum.

	1st season					2nd season				
	Sowing-date									
Fertilizer	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean
No	2.10 e	2.83 bcde	2.60 cde	3.50 abcde	2.76b	4.33 ab	3.67 b	4.23 ab	5.47 ab	4.43c
N_1	3.37 abcde	3.20 bcde	4.33 abc	3.50 abcde	3.6a	3.70 ab	5.70 ab	4.30 ab	5.17 ab	4.72bc
N_2	3.40 abcde	3.00bcde	4.63 ab	3.60 abcde	3.66a	4.50 ab	5.00 ab	5.80 ab	5.27 ab	5.14ab
N_3	2.27 de	3.63 abcde	5.17 aA	4.03 abcd	3.78a	5.73 ab	5.50 ab	5.87 a	5.17 ab	5.57a
Mean	2.79b	3.17ab	4.18a	3.66ab		4.57a	4.97a	5.05a	5.27a	
C.F					1.83					2.19

Means in the same column followed by different letters are significantly different at p = 0.05 (DMRT).

Key S_1 = sowing date at 1st July, S_2 = 15th July, S_3 = 1st August, S_4 =15th August,

Fertilizer N_O, N_1, N_2 and N_3 control, 45, 90 and 135 KgN/ha (urea) respectively and C.F= critical factor

Table (8): Effect of sowing date and nitrogen rate on Harvest index (%) of sorghum.

	1st season					2nd season				
	Sowing-date									
Fertilizer	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean
No	24.53 bcde	24.60 bcde	30.73 abc	30.33 abcd	27.55a	29.40 def	32.30 cdef	30.63 cdef	37.53 abcde	32.47a
N_1	27.93 abcd	21.43 cde	32.60 ab	33.90 ab	28.97a	26.73 f	32.97 cdef	38.07 abcde	36.77 a	36.14a
N_2	25.43abcde	18.23 e	34.60 a	33.20 ab	27.87a	30.33 cdef	33.77 bcdef	34.10 bcdef	39.33 abcd	34.38a
N_3	21.23 de	24.80 bcde	34.33 a	27.50 abcde	26.97a	30.67 cdef	28.83 ef	39.90 abc	43.30 ab	35.68a
Mean	24.78ab	22.27b	33.07a	31.23a		29.28c	31.97bc	35.68ab	41.73a	
C.F					9.46					10.34

Means in the same column followed by different letters are significantly different at $p = 0.05$ (DMRT).

Key S_1 = sowing date at 1st July, S_2 = 15th July, S_3 = 1st August, S_4 =15th August,

Fertilizer N_O, N_1, N_2 and N_3 control, 45, 90 and 135 KgN/ha (urea) respectively and C.F= critical factor.

Table(9): Effect of sowing date and nitrogen rate on Nitrogen use efficiency (kgSeeds/kgN) of sorghum.

	1st season					2nd season				
	Sowing-date									
Fertilizer	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean
No	0.00 f	0.00 f	0.00 f	0.00 f	0.00d	0.00 f	0.00 f	0.00 f	0.00 f	0.00d
N_1	74.83 b	71.10 b	96.33 a	77.77 b	80.01a	50.00 bcd	126.70 a	95.57 abc	114.80 ab	104.82a
N_2	37.80 cd	33.33 de	51.50 c	40.00 cd	40.66b	50.00 de	55.57 de	64.47 cde	58.53 de	57.14b
N_3	17.53 e	26.93 de	38.30 cd	29.83 de	28.15c	42.47 e	40.77e	43.47 e	38.27 e	41.25c
Mean	32.54a	32.84a	46.53a	36.9a		43.67a	55.76a	50.88a	52.90a	
C.F					17.39					33.38

Means in the same column followed by different letters are significantly different at $p = 0.05$ (DMRT).

Key S_1 = sowing date at 1st July, S_2 = 15th July, S_3 = 1st August, S_4 =15th August,

Fertilizer N_O, N_1, N_2 and N_3 control, 45, 90 and 135 KgN/ha (urea) respectively and C.F= critical factor.

Chapter Five

Discussion

The general trend was that Sowing date and nitrogen rate had a significant effect on some vegetative and Yeild parameter of sorghum.

Sowing at mid July and 1th August increased all vegetative growth and yield component, compared to other sowing in both seasons. Temperature was similar in both growing season. Decrease of all assessed morphological traits, yield and yield components of sorghum at delayed sowing date can be attributed to unfavorable climatic conditions (Temperature) during vegetative growth .

In the first season stem borer infestation occurred which greatly reduced yield and yield components. Under the conditions of this study in the two seasons plant height, leaves number, leaf area, length of head, weight of seed, 100 seed weight, grain yield and harvest index increased as the amount of nitrogen fertilizer increased from 0Kg N/ ha to 135Kg N/ha . This could be attributed to the fact that nitrogen fertilizers result in vigorous plant growth and enhance photosynthesis and dry matter production.

Interaction between sowing date and nitrogen rate had significant effect on weight of seeds / plant in both seasons, 100seed weight in 1st season , grain yield, nitrogen use efficiency in 2nd season . From the statistical analysis of variance it was clear that there were no significant effect of sowing date and nitrogen fertilizer on plant height in both seasons. These results did not agreed with the results obtained by Ishag (1963) who reported that plant height was more effected by later sowing date than the earlier sowing date. This might be a photo- periodic effect. Abdel Rahman et al (2005) reported that sowing date had significant effect on plant height. Venkates et al (1977) found that July sowing date gave the greater plant height. Ali (2007) reported that sowing date effect was highly significant for plant height.

In this study there were significant differences in plant hight among the four levels of nitrogen rate in 2nd season, nitrogen dose 135KgN/ha recorded the tallest plants. This might be attributed to the fact that nitrogen fertilizer will give healthy vigorous plant. These results were in agreement with Yousif (1993) findings who reported that the application of 86 Kg N/ha gave the greatest plant height. Mohamed (1990) stated that nitrogen significantly increased plant height. Elasha (2007) stated that, applying no nitrogen resulted in a significantly shorter plants compared to nitrogen fertilization. Plant height was not significantly affected by interaction between sowing date and nitrogen rate in both seasons in this study. These results did not agree with Ali (2006) who reported the significance of interaction effects of sowing date and nitrogen rate on plant height.

The results showed that sowing date had significant effect on leaves number / plant in 1st season. Sowing at 15th July gave highest leaves number. Nitrogen fertilizer had significantly affected leaves number / plant in 2nd season. Application of 135KgN/ha gave highest leaves numbers.

Sowing date had a significant effect on leaf area in both season. August sowing gaved the largest leaf area in both seasons. This might be due to favorable climatic conditions during vegetative growth. Interaction between sowing dates and nitrogen rates had no significant effect on leaf area. The largest leaf area was recorded by the treatment 15th August with fertilizer dose 135 Kg N/ha in both seasons.

In the present study in the two seasons, it was clear that sowing date had significant effect on length of head in 2nd season. In this connection, Abdel Rahman et al (2005) reported that sowing date had significant effect on length of head. On the other hand, the effect of interaction between sowing date and nitrogen rate was not significant on length of head in both seasons. But there were significant differences between levels of nitrogen rates. Application 135 kgN/ha higher length of head. This result was in agreement with Elasha (2008) who reported that nitrogen levels had significant effect on length of head.

The results obtained in both seasons, showed no significant effect of sowing date and nitrogen fertilizer on weight of seeds / plant. 15th August sowing gave the highest weight. Reduction of weight of seeds / plant on early sowing might be attributed to shorten vegetative growth period, lower amounts of carbohydrates and reduce translocation assimilation to grains. On the other hand, the interaction between sowing dates and nitrogen rates had significant effect on weight of seeds / plant in both seasons. The highest seed weight/plant was recorded by treatment S_2 with N_1 in 2nd season. This might be due to more photosynthetic resulted from different seasons.

Sowing date no significant effect on 100 seeds weight. Sowing at 15th July recorded highest weight of 100 seed. However Abdel Rahman et al (2005). They found that sowing date had significant effect on 100 seed weight. Ali (2007) reported that sowing date treatment was highly significant for 100 seed weight. The non –significant effect of nitrogen application on 100 seed weight which was obtained in this study contradicted findings of Mohamed et al (1998), and Elhassan (1986). However Yousif (1993) obtained increased 100 seed weight from application of 86 Kg N/ha. The highest 100 seed weight was recorded by the treatment S_2 with N_3 in 2nd season. This might be due to the different in the weather in 2nd season.

From the analysis of variance, it was clear that the sowing date significantly affected grain yield in 1st season. Similar results were reported by Ali (2007) who obtained significant effects for sowing date on grain yield. Ishag and Farah (1963) reported that optimum planting time for the medium varieties which responded better to planting was in the second half of June. Elrayah (1977) found that grain yield was high with 15th June and 1st July sowing. Fadda (1963) found sowing on July 27 gave highest grain yield. Chielle and Chielle (1990) reported that sowing date had greater effect on yield than cultivar. The influence of fertilizer on grain yield was significant in both seasons. Fertilizer dose 135 Kg N/ha gave the highest grain yield(5.57 t/ha). This might be due to increase of leaf area, greater length of head and increase weight of seeds / plant .Which are the most important components of grain yield . This result was in agreement with Atar and Pains (1973) who reported that application of 120 Kg N/ha gave the highest grain yield. Babiker (1999) found that highest grain yield was obtained by applying 86 Kg N/ha. Mohamed (1998) reported that grain yield was increased significantly with increasing nitrogen dose. Farah and Faki (1991) obtained the grain yield of HD-1 which was significantly affected by application of 86 Kg N/ha. Bebawi and Abdel Aziz (1983) reported the application of 172 Kg N/ha gave the highest grain yield. Shukla et al (1976) found that 120 Kg N/ha increased grain yield. Gono (1990) reported that application of 100 Kg N/ha significantly increased the grain yield. In a similar study Patel et al (1990) reported that application of 150 Kg N/ha and 6 irrigations gave the highest grain yield.

Statistical analysis showed that sowing date had a significant effect on harvest index in both seasons. Sowing at $1^{st\ and}$ 15^{th} August gave the highest significant harvest index in 1^{st} and 2^{nd} season respectively. The interaction between sowing date and nitrogen rate had not significantly affected Harvest index in both seasons. The highest harvest index was recorded by the treatment sowing at 15^{th} August with fertilizer dose of 135 kgN/ha in 2^{nd} season. This is due to the higher grain yield with favorable climatic conditions in the 2^{nd} season. These results agree the results of Elasha (2008) who reported that nitrogen levels had significant effect on Harvest index.

In this study sowing date had no significant effect on nitrogen use efficiency in both seasons. This result did not agree with Elasha (1997) who found that the early planting of sorghum had significantly larger effects on nitrogen use efficiency (% IN). The nitrogen fertilizer had highly significant effect on Nitrogen efficiency in both seasons. These results However Babiker et al

(1999). reported that nitrogen use efficiency was decreased by increasing the rate of nitrogen and the highest value was obtained within (43 Kg N/ha). Simth et al (2012) found that improved nitrogen use efficiency can enhance yield under low nitrogen and thus improve crop nutritional quality and it will also reduce ground water contamination by excess nitrates. The interaction between sowing date and nitrogen rate had a significant effect on nitrogen use efficiency in 2nd season. The best nitrogen use efficiency was recorded by the treatment sowing at 15th July with fertilizer dose 45 Kg N/ha in 2nd season . This is due to the efficient use of nitrogen at the growth stages which was then reflected on the grain yield and the extra amount of nitrogen was not utilized by the plant 45kgN/ha had the highest nitrogen use efficiency in both seasons .

Summary and Conclusion

A field experiment was undertaken in 2011/12 and 2o12/2013 Summer seasons at the College of Agricultural Studies, Sudan University of Science and Technology in Khartoum (Shambat) to study the effect of sowing date, nitrogen rate and nitrogen use efficiency on growth and yield of sorghum (*Sorghum bicolor* L.).

Sowing in mid July to first week of August significantly increased all growth parameter and yield components in both seasons. This was mainly attributed to the optimum sowing date.

The application of fertilizer 135 Kg N/ha resulted in greater plant height, higher leaf number, greater leaf area, more length of head, higher weight of seed, higher 100 seed weight and higher grain yield in both seasons than other nitrogen levels used .

The application of 45 Kg N/ha gave significantly highest nitrogen use efficiency in both season. This clearly revealed that nitrogen use efficiency was decreased by increasing the rate of nitrogen over 45 Kg N/ha although grain yield increased for up to 135 kgN/ha.

The application of 135kgN/ha with 1st August sowing date was recorded the highest grain yield in both seasons .

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APPENDIXES

Appendix (1) Monthly average of some meteorological data at Shambat Station for two Seasons 2012 /2013

Month	Meant temperature		Relative	Total	Wind	
	Max	Min	Humidity %	Rainfall (MM)	Dir	Speed
July 2012	38.2	27.1	5.8	20.9	SW	10
August 2012	36.3	25.7	6.8	57.7	SW	10
September 2012	40.0	27.7	9.0	TR	SW	8
October 2012	39.8	27.5	10.3	8.0	N	6
November 2012	36.1	23.3	9.8	TR	NNW	8
July 2013	40.4	25.9	33	35.1	S	5
August 2013	35.4	25.8	57	99.9	S	5
September 2013	38.8	26.4	41	11.6	S	5
October 2013	38.4	24.5	27	TR	N	5
November 2013	35.3	19.6	27	0.0	N	3

Max = Maximum, Min = Minimum, Dir = Direction

HP = Hecto Pasecal (Pressure Units), N= North, S = South

W = West, E= East, TR = Trace, N/E = North by East

Knot = 1.85 Km/hr = 0.5 M/S

1.15 Mile /hr = 1069 feet /S

Source: Shambat Meteorological Station

Appendix (2): Chemical and Physical Properties of the Field Soils

PH Phaste	8.2
ECe (M_3 / M^2)	1.05
CEC (meg / loog)	43.78
Sar	5.59
O.M (%)	0.46
Available P(PPM)	2.58
Ca Co_3 (%)	4.00
Ca (meg/L)	2.00
Mg (Meg/L)	1.50
Na (Meg/L)	7.39
K (Meg/L)	0.0213
Co_3 (Meg/L)	NA
Hco_3 (Meg/L)	5.80
CL (Meg/L)	7.50
Fe(Mg/L)	4.742
2n (Mg/L)	0.085
Cu (Mg/L)	0.305
Sand (%)	32.7
Silt (%)	32.7
Clay %	42.8

Source Azrag: (2010)

Appendix 3: Summary of the ANOVA table for sowing date and fertilizer of sorghum 2012 season.

Source of variation	D.F	F. Value								
		Plant height (cm)	Leaf number /plant	Leaf area (cm2)	Length of head(cm)	Weight of seed/plant(g)	100.seeds wt (g)	Grain yield(t/ha)	Harvest index (%)	Nitrogen use efficiency
Replication	2	53.36	2.00	3396.3	0.73	498.23	0.32	0.12	58.71	219.9
Sowing date (s)	3	78.22 ns	1.90*	26413.6*	4.44 ns	9232.24ns	0.74 ns	4.29*	316.95*	509.3 ns
Error A	6	39.35	0.49	2925.8	2.18	1411.50	0.54	1.18	76.93	205.4
Fertilizer (F)	3	36.86 ns	0.26 ns	2889.4 ns	0.34 ns	734.53 ns	0.08 ns	2.67*	8.47 ns	13250.0* *
Sowing date Fertilizer (SxF)	9	11.19 ns	0.57 ns	377.6 ns	0.96 ns	853.39*	0.24*	0.98 ns	26.24 ns	88.5 ns
Error B	24	16.08	0.78	1790.0	1.40	925.14	0.10	0.85	35.91	153.5
SE ±	-	1.57	0.18	20.27	0.37	9.39	0.18	0.27	2.19	3.58
C.V %	-	4.20%	6.53%	17.40%	7.64%	24.02%	7.84%	26.73%	21.53%	33.28%

** Significant at 1% level (highly significant)

* = significant at 5% level (significant)

ns = Not significant.

Appendix 4: Summary of the ANOVA table for sowing date and fertilizer of sorghum 2013 season.

Source of variation	D.F	F. Value								
		Plant height (cm)	Leaf number /plant	Leaf area (cm2)	Length of head(cm)	Weight of seed/plant(g)	100.seeds wt (g)	Grain yield(t/ha)	Harvest index (%)	Nitrogen use efficiency
Replication	2	161.03	0.51	938.2	0.80	43.30	0.26	0.63	13.22	108.0
Sowing date (s)	3	7.54 ns	3.41 ns	70745.5**	5.13*	66.15 ns	1.93**	1.03 ns	354.64*	319.4 ns
Error A	6	43.24	1.72	2773.0	0.99	160.49	0.13	2.68	38.31	338.5
Fertilizer (F)	3	15.00ns	2.72*	3150.6 ns	2.27 ns	62.75 ns	0.08 ns	2.99**	38.09 ns	22520.1**
Sowing date Fertilizer (SxF)	9	17.80 ns	1.16 ns	2545.1 ns	0.67ns	85.78*	0.08 ns	1.41*	37.36 ns	326.7 *
Error B	24	15.01	0.92	3926.0	1.33	34.10	0.13	0.61	40.45	111.8
SE ±	-	1.64	0.33	13.16	0.25	3.16	0.09	0.41	1.49	4.60
C.V %	-	3.89%	6.80%	14.65%	7.05%	14.43%	10.05%	15.77%	25.19%	20.82%

** Significant at 1% level (highly significant)
* = significant at 5% level (significant)
ns = Not significant.