EVALUATION OF THE PERFORMANCE OF SEVEN FORAGE SORGHUM (*Sorghum* species) IN KHARTOUM STATE, SUDAN.

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DEDICATION

To the soul of my brother, the martyr Husham Abdelgadir Ahmed,

To memory of my niece Ahmed Salih,

To my father who lights me the candles of love and support.

To my mother to every mother anywhere beat of her heart provides generosity warmth.

To my faithful husband for his patience and constant encouragement during the study period.

To all family members and friends and to every one who contributed to the success of this work.
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ABSTRACT

The experiment was conducted in the Experimental Farm of Shambat Research Station in the late of the winter season (Feb., 2005), with the objective of investigating the magnitude of genetic variability among seven forage sorghum selections isolated from the local population of the traditional cultivar Sudan grass (Garawia), traditional cultivar used by farmers (farmer check) and Kambal which was isolated from the traditional cultivar ‘Abu Sab’in’ (Aliab type) using Randomized Complete Block Design (RCBD).

The study showed significant differences among the studied entries for the first cut and the second cut of GMY (green matter yield), DMY (dry matter yield) for the second cut, days to 50% flowering, plant density, plant height, number of leaves per plant and leaf/stem ratio. The selection S. (32-2)A gave the highest forage yield followed by Kambal (Abu Sab’in), with respective yields of about 41.75 and 40.30 t/ha in the first cut. Whereas Kambal was superior to S. (32-2)A in the second cut, with respective yields of about 24.99 and 23.65 t/ha. The latter selection S. (32-2)A was considered the best since it was earlier in flowering than the former (Kambal).
The overall mean of GMY of the first cut (35.78 t/ha) was higher than that of the second cut (18.88 t/ha). This was attributed to the fact that sowing date has been late of winter season with its favourable conditions represented by the increase in temperature and day length, which are generally favourable for forage sorghum production, whilst the second cut coincided with the unfavourable conditions for forage sorghum production, which is reflected in water stress and diseases. It is suggested that farmers should benefit from the second cut when forage sorghum is grown in winter season.

The unique performance noticed for most selection in forage yield and related attributes indicated that selection within the local stocks could result in isolation of improved versions of the traditional populations.
لا يمكنني قراءة النص العربي المقدّم بشكل طبيعي حاليًا.
لا يمكنني قراءة النص العربي بشكل طبيعي. من فضلك قدم النص باللغة الإنجليزية.
CHAPTER ONE
INTRODUCTION

The production of forage crops is very important for livestock production in the Sudan. This is due to the fact that, Sudan owns a huge herd of animal wealth estimated to be around 116 million heads. It ranks first in the Arab World and second in Africa in livestock population. The natural pasture sector and crop residues are responsible for supporting more than 90% of this wealth (National Comprehensive Strategy “N.C.S.”, 1999). The stocking rate is far in excess of the stock carrying capacity of the range land. The rangeland is diminishing due to the law expansion of rain fed agriculture. This encourage a seasonal migration of animals, reduces land available for grazing and assists in the desertification of such lands. Nomads are always faced by uncertainties which include diseases, climatic changes and lack of forage. On the other hand, forage is necessary for dairy farms, poultry farms and fattening centres found around cities such as Khartoum, Medani and Kosti.

Most of the animals in Sudan are greatly dependent on the natural vegetation as their main source of feed for maintenance and production. This attitude is clearly reflected on the poor output and performance of animals resulting from the poor quality of forages, and
the problems of over grazing. The expansions of the demarcated and non
demarcated mechanized crop production schemes constitute a potential
threat to the grazing lands in the Sudan. establishment and development
of irrigated pastures can alleviate the heavy burden on natural pasture in
addition to the encouragement of the utilization of agricultural by
products and residues that are produced in huge amount for animals
feeding in the Sudan.

Despite the meager contribution of irrigated forage (4%) in
maintaining the national herd, however, its role is maximized by the high
quality value of green forages as compared to feed stuff provided by
other sources. Green forages play unique role in upgrading and finishing
of animals for export. The number of animals to be exported is
sometimes limited by the quantity available of green forages. The
importance of the irrigated forage sector in the economy of the Sudan
could be outlined in the following points:

- The sharp increase in the demand for animal products created by
  the ever rising population densities in urbanized centers.
- The growing market of animal export to the Arab World as
could be seen from the large flows of animals to Khartoum State
  (Appendix 1). The N.C.S. aims at boosting animal products
exports by twenty times compared to the present level. It also aims at increasing the livestock population by three folds through upgrading the conventional methods employed by the traditional herd owners to more modernized techniques.

• Sudan can be recognized as having potential as a forage exporting country particularly to the Gulf States. The bad need for forages to meet the flourishing of animal products in these countries was further accentuated by the policy of some of these countries to reduce the area under forage production.

As a result, the area under forage crops has recently witnessed a rapid increase both in the small holders and large specialized systems. Reliable records of acreage and tonnage at the national level are not available in the literature. However, taking Khartoum State as an example, the statistics of the Ministry of Agriculture and Animal Wealth for 2003 showed that the total area devoted to forage crops amounted to 120,000 feddan representing around 52% of the total area cultivated. A forage gap of about 809 thousand metric ton still exists despite this expansion (Appendix 2).

Selected forage crops in this study were *Sorghum bicolor* (L.) Moench (Kambal or Abu Sab’in) and *Sorghum Sudanese* (Piper) Stapf
Garawia (Sudan) Sudangrass (Australia, United State). They are a member of the family Graminae, the tribe is Andropogoneae (Doggett, 1970). Sorghum forage is considered as a main cereal forage in the Sudan for the following characteristic that make them especially valuable as fodders:

- Sorghum forage is quite resistant to drought and is well adapted to regions of limited rainfall e.g. Nile State, Northern State and Khartoum State.
- Sorghum forage is produced successfully on all types of soil and is more tolerant to salinity and alkalinity.
- Sorghum forage dry matter production is greater compared to other fodder crops.
- The feed is more palatable when young.
- Sorghum forage has the ability to regrow after grazing or cutting.
- Sorghum forage in some areas cut for hay and put up in large piles during the dry season of the year and later stacking.

Sorghum (Sorghum bicolor (L.) Moench) is the most important irrigated forage crop in the Sudan. A part form the natural vegetation, the sorghum straw “qassab” constitutes the bulk of the animal feed in the country (Bacon, 1948). Areawise, sorghum (mainly the traditional
cultivar “Abu Sab’in”) covers the majority of the land cropped to forage. Abu Sab’in is a farmer bred cultivar that has been exclusively grown for forage in areas near towns for many decades. Being a traditional cultivar, it is a highly mixed variety, with dry non sweet stems and suffers from yield depression during winter season. Nevertheless, Abu Sab’in is a well adapted cultivar with some good agronomic characteristic.

Development of improved types of grain sorghum has been the main focus of research efforts in the Sudan during the past decades. Little or no attempts have been exerted to improve forage types.

Considering the unique role of forage sorghum in sustaining the animal wealth of the country, and the great diversity of sorghum known to exist in the Sudan, it seems unrealistic to rely on Abu Sab’in as the sole forage sorghum type in the Sudan.

The dominant pattern of fodder crop production in the state is the green chopping or cut and carry system. Other systems like production of forage for storage or grazing and haymaking are less adopted or even not existing. Absence of different forage varieties and the traditional dependent on one or two varieties resulted in a poor quality and yield.
Moreover, it should be mentioned that, research on fodder crops, especially breeding programs, are not as much as those given to other cash crops such as grain, vegetables and fruits crops.

The above mentioned problems have an impact on the process of domestic and international marketing of the crop, and resulted in a feed gap.

Therefore, the process of scientific research is very much in need for the following:

1. Improving of forage crops which require a huge scientific and specialized research to upgrades the quality, and improves the production and adapting local mode of cross-breeding by using the most sophisticated technology.

2. Cultural practices: It’s also a very important part as it include the guidance aspect for the farmers who ignore the basic and scientific method of production such as seed rate, level of cutting the crops, sowing date, the importance of crop rotation in protection soil fertility and reducing pests and diseases.

Recent studies are focused on improving sorghum forage quality and quantity. Recently an improved version of the traditional cultivar Abu Sab’in (Kambal) has been released by the Agriculture Research
Corporation (ARC). Some promising selections isolated from the
traditional Sudan grass (Garawia) were also developed by the forage
improvement program at Shambat Research Station. Abu Sab’ın is know
of giving one cut of high yield whereas Sudan grass types are known to
give numerous cuts but with lower yield per cut compared to Abu Sab’ìn.

The objective of this study was to investigate the following
aspects:

1. To evaluate the performance of the newly developed Sudan grass
   selections as compared to the traditional checks (Garawia).

2. To evaluate the comparative performance of some introduced
   forage sorghum selections, using the newly released Abu Sab’ìn in
   variety (Kambal) as check and to see whether the multi cuts
   provided by Sudan grass will compensate to the highly yield of
   Abu Sab’ìn.
CHAPTER TWO
REVIEW OF LITERATURE

2.1 General Background

Sorghum (*Sorghum bicolor* ‘L.’ Moench) is believed to have originated in Africa (Hughens, *et al.*, 1951). The leading countries in sorghum production are the USA, India, China, Nigeria, Merico, Sudan and Australia.

It is the fifth most important world cereal crop coming after wheat, maize, rice and barley (Onwueme and Sinha, 1991). The crop is mostly ground for human consumption. However, in U.S.A. it is grown primarily for livestock and poultry consumption (Hughens, *et al.*, 1951).

In Khartoum State, irrigated forages rank first in total area cultivated. According to the statistics of the Ministry of Agriculture, the total area cropped to forage in 1997/98 amounted to about 102,000 feddans representing around 48% of the total area cultivated. Almost 100% of this area is covered by local forage cultivars. Of these, the most widely grown are Abu Sab’in (forage sorghum), maize (open pollinated) and Berseem (alfalfa). Other forage include *Lubia afin*, *Clitoria* and *Phillipesara*. 
Very limited efforts have been made to improve the productivity of forage sorghum. There is an obvious need for an improved forage programme. This improved forage programme is expected to result in a “package” of recommendations for increasing production starting from seeding to harvest operations. At the moment the variety most widely grown for forage is “Abu Sab’in”. The implication of Arabic name is that it will be ready for cutting as a fodder in about seventy days (Bacon, 1948). However, this may be restricted to fertile soils with adequate soil moisture retention and release characteristic like silty soils. In soils of marginal productivity (e.g. salt affected or poor in physical condition) the period for cutting may be about 80-85 days from sowing. Kambal (1972), reported that the variety of sorghum grown in Khartoum area is a mixed variety but adapted to local conditions.

2.2 Forage Sorghum Research in the Sudan

Very few research efforts have been exerted to develop improved forage sorghum cultivars from the local stocks. Kambal (1972) studied the performance of two local forage types, namely, Abu Sab’in and Ankolib together with four forage plant selections. Abu Sab’in was more productive than the introduced varieties, averaging higher in dry matter production per day. The introduced varieties, on the other hand, were
characterized by higher tillering capacity and finer juicy-sweet stems. The yield components that contributed most to the higher yield of Abu Sab’in were stem height and thickness. It was concluded that selection in Abu Sab’in was effective in isolating lines earlier in flowering, more productive and better in quality (juiciness and sweetness) than the original stock. In other trial Kambal (1984) studied the performance of Abu Sab’in, two introduced sweet sorghum, one local maize and pearl millet varieties during summer kharif and winter seasons. The introduced sweet sorghum variety ‘Kansas Orange’ over yielded Abu Sab’in during summer and winter seasons. It was concluded that, 50% increase in yield over the present practice of growing Abu Sab’in could be attained by growing the maize variety in winter, Kansas orange in summer and the millet variety in kharif.

Ibrahim and Orfi (1996) studied variability in forage yield over two sowing dates and two locations in ten sorghum cultivars. Eight of them were grain cultivars while the other two were forage cultivars namely, Abu Sab’in and the hybrid pioneer 988. They presented data based on ranking procedure showing that Abu Sab’in and some grain cultivars were superior in forage yield compared to the hybrid pioneer 988. Among grain cultivars, Saffra and Gadam Elhamam were considered
the best yielders. They noticed a wide range of variability for most characters. The effect of sowing date was most pronounced compared to that of location especially for days to flowering and plant height.

2.3 Forage Sorghum Hybrids in the Sudan

No evidence in the literature pointing to the release of a locally developed forage hybrid sorghum in the Sudan. Research work on forage hybrids was mainly confined to introduction and testing of exotic hybrids. Up to date four grain sorghum of Sudan grass hybrids were tested and released by the Agricultural Research Corporation (ARC) viz. Pioneer 988, from Pioneer International Co. (Ishag, 1989) followed by Speedfeed and Jumbo from Pacific Seed Co. (Kair, et al., 1995), Panner 888 from Panner Seed Co. (Nour, et al., 1998) and Safed Moti from Proagro Seed Co. (El Ahmadi, et al., 2003).

Mohammed (2001) studied the agronomic performance of the introduced hybrids Panner 888, Speedfeed and Safed Moti in comparison to the local cultivar Abu Sab’in. the results showed that, the introduced hybrids were superior in yield compared to Abu Sab’in. Panar 888, though was not the best yielding hybrid, but was the earliest in flowering and showed the best average dry matter production per day. However,
Abu Sab’in showed increased seedling vigor compared to the introduced hybrids.

2.4 Potential for Forage Sorghum Improvement in the Sudan

There is strong evidence in the literature pointing to the great genetic diversity of Sorghum spp. in the Sudan (Bacon, 1948; Tahir, 1964; Abu El Gasim and Kambal, 1975 and Yasin, 1978). The most important types of forage in the Sudan include:

**Grain Sorghum:** Bacon (1948) reviewed forage crops in the Sudan. Many of the grain sorghum varieties can be grown as forage crops. According to Harlan and de Wet’s (1972) classification, the most widely grown forage cultivar ‘Abu Sab’in’ belongs to the race Caduatum-Dura. Abu Sab’in is a farmer-bred cultivar. According to Bacon (1948) the needs for fodder influence farmers to choose vigorous plants with finer stems which upon growing at higher seed rate produce a better forage crop. Kambal (2003) reported that the name of Abu Sab’in is used for two distinct sorghum cultivars grown for grain production at Rubatab and Alyab areas in Northern Sudan. Abu Sab’in tolerates a wide range of salinity under which the forage quality is further improved (Khair and Jarrel, 1987). Some heterogeneity exists with in both types of Abu Sab’in (Kambal, 2003). The present seed stock was subjected to
great mechanical mixing with other dura seed leading to an obvious less of the initial agronomic features of the variety. Selection with in such population may result in isolation of lines with better yield and quality. This had been demonstrated by Kambal (1972).

**Wild Sorghum:** Bacon (1948) stated that wild sorghums represent a wealth of good fodder grasses in the Sudan. Rao and Mengesha (1979) reported that wild sorghums, which are lacking in the present world collection, are particularly abundant in the central Sudan. Bacon (1948) gave some details about wild sorghum in Sudan. This group comprises a number of annual and perennial grasses. The annual grasses comprise different types under the local name ‘adar’. The traditional cultivar ‘Garawi’ is one of the adar types. According to Bacon (1948), Garawia provides excellent green forage or hay, does well in salty soil, less affected by the stem borer and has better persistence or longevity. In addition, Mc Donald and Dale (1983) pointed that the risk of the hydrocyanic acid poisoning tends to be less with Sudan grass as compared to perennial grasses or grain sorghum. Sudan grass (*Sorghum sudanense*), the widely cultivated annual forage in the United States is one of the annual adar or garawia types. As reported by Manuder (1983) it’s original seed lot had been introduced to the United States from Sudan.
in 1909 mainly to replace the perennial type Johnson grass. As pointed by Bacon (1948) the perennial grasses are similar in appearance to the annual adar, but have a perennial rhizome.

**Sweet Sorghum Forages:** Ankolib is the general term used for sweet sorghums in the Sudan. Rao and Mengesha (1979) conducted a germ plasm collection expedition in eastern Sudan. they reported that Ankolib is *Adura bicolor* characterized by sweet stalk just like sugar cane. It is a mixed land race variety grown mainly for chewing the juicy sweet stem (Kambal, 1972). Ankolib was rarely mentioned in the literature as a forage crop. However, sweet sorghum are highly recognized for forage and syrup production in other parts of the world (Dwayne, *et al*., 1999).

### 2.5 Agronomic Management

**Seed Rate:** Gautam and Chopre (1962) in India, reported that the optimum seed rate for forage sorghum range from 50 to 60 kg/ha and the crop was ready for harvest in 60 to 70 days. the crop gave about 275 to 375 quintals/ha of green fodder and under favourable condition, yields as high as 550 quintals/ha were obtained, Bebawi and Mezloum (1986) studied the effect of sowing pattern and seed rate on the yield of forage
sorghum and they found that yields were greater when plants were sown at 70 kg seeds/ha than when traditionally sown at 35 kg seed/ha. On the other hand, Stickler and Laude (1960) observed that less tillers and fine stems were produced under high plant population of 78000 plant/ha. Several workers (Throne, 1962; Laude, et al., 1967 and Cannel, 1959) reported that in temperate cereals, the number of tillers reaches a peak then decline to a minimum before ear emergence. When a crop is grown at different seed rates, the high seed rates tend to produce higher biomass yield than the low seed rate during the vegetative stages. As forages are usually harvested at stage of flowering, high seed rates would result in early high biomass yields. High seed rates usually tend to produce thinner plants, which are considered as a high quality attribute of forages, however, Juskiw, et al. (2000) reported that higher seed were associated with higher forage yields.

Burnside, et al. (1964) concluded that narrow row spacing (10 to 20 inches) increased lodging, forage yields, sorghum population and sorghum heads per acre. Moreover, plant density has a considerable influence on the number of tillers per plant and per unit area. It has been shown that increasing plant density would increase tiller number per plant in barley (Kirby, 1967; Kirby and Fari, 1972).
Holt (1970) in Texas, USA reported that in several studies a decrease in stem size of hybrid Sudan grass with narrow rows and/or increased seeding rates within row spacings. Plant size decreased as plant population increased. Several workers (Porter, et al., 1960; Gautam and Chopra, 1962; Govil and Prasad, 1971; Rai, et al., 1984; Prasad, et al., 1984 and Sharma, et al., 1984) concluded that narrow spacing produced higher forage yield than wider spacing. Burger and Campbell (1961) at Illinois Agric.Exp. Sta. studied the effect of rates and methods of seeding on the original stand, tillering, stem diameter, leaf stem ratio and yield of Sudan grass. They concluded that drilled Sudan grass produced higher original stand counts, smaller original stem diameter and more herbage than when seed broadcasting. There was no increase in yield resulting from increasing rates of seeding with either 12, 18 and 24 lb/acre or 48 lb/acre. The tillering habit of Sudan grass will compensate for a comparatively low initial population. On the other hand, Martin and Kelleher (1984) in New South Wales, reported that sweet sorghum increased yield with increasing plant population from 8-16 plants/m². Gautam and Chopra (1962) and Relwan (1968) in India, reported that garavia sown at the rate of 20 to 25 kg/ha, in rows 60 cm a part. Sudan grass was ready for the first cut after 50 to 60 days from sowing, and
subsequent cuttings were available at intervals of 40 days. Several workers (Sullivan, 1961; Koller and Scholl, 1968; Martin and Kellaher, 1984) reported that in Sudan grass, narrow spacing resulted in significantly greater yields than wider spacing. Contrary to that Burger and Cambell (1961) reported that there was no significant difference in yield of Sudan grass at different row width. Quiby and Karper (1963) concluded that when plants were thick in the row, tillers were suppressed or never developed. With respect to tillering there was a tendency, especially in some varieties, for the lateral buds at the lower most nodes to develop into tillers.

2.6 Irrigation Effects on Fodder Sorghum

The objective of irrigation is to supply sufficient water to keep the plant growing normally. This is usually accomplished by keeping the soil moisture within the root zone somewhere between the wilting point and field capacity. Odell (1959) reported that if too much water is applied during the period of early vegetative growth, lodging may occur, adversely affecting yield.

According to Norman (1962), the most important information generally needed about soil water is the amount of it in the soil around the rooting system. This amount varies in humid regions where irrigation
is not commonly practiced as compared with dry regions. In arid regions, where irrigation is practiced, rainfall must be considered. Paul, *et al.* (1959) stated that the available water in the soil at seeding, or the depth to which soil was wet, was an indicator of wheat yield prospects. He also concluded that this relationship could be applied for sorghum provided row spacing and plant population were considered.

Saeed (1984), showed that soil moisture increased with decreasing the irrigation interval. Similar results were reported by Mansour (1981), and by El Nadi (1980 and 1981), working on broad beans.

Mustafa, *et al.* (1982), concluded that dry matter of forage sorghum increased with the decreased in irrigation interval. This was also supported by Saeed (1984), and Kambal (1984), working on sorghum, and by Whitt and Van Bavel (1982) who reported that plant height of sorghum increased with decreasing irrigation frequency or interval. This is also supported by Saeed (1984), and by Mansour (1981), for the same crop.

Shorter irrigation interval resulted in bigger leaf area but here nitrogen and gypsum were considered (Mustafa, *et al.*, 1982). Similar findings on leaf area index of forage sorghum were reported by Hussein,
et al. (1974); Mansour (1981) and by Saeed (1984). Further work on irrigation interval was reported by Mustafa, et al. (1982). They stated that water use efficiency by forage sorghum increased as they decreased irrigation interval. Similar results were reported by Saeed (1984) working on sorghum. However, Carlson (1959) added fertilizer to achieve the same results.

2.7 Growth Attributes of Sorghum

Plant Height: Is an important growth parameter which influences both fodder quantity and quality. Long slender fine stems are often preferred by animals than short thick stems as they affect palatability of the forage. With respect to height, generally tall plants yielded more than short types (Casady, 1965; Hadley, 1965; Graham and Lessman, 1966; Stickler and Younis, 1966), but these were under low population densities and wide row spacing which could be judged to favour tall plants. The time that some visible radiation penetrated to the soil is approximately 20% longer for the short plant type at a yield disadvantage both from stand geometry and light distribution. Stickler and Laude (1969) concluded that plant height increased with decreasing the spacing and increasing the seed rate and they attributed this to the light effects on internode elongation. Burnside, et al. (1964) also gave the
same conclusion. However, Robinson and Bernat (1964); Reddy and Husain (1968) reported that sorghum plant height increased as a result of decreased population. In India Dwivedi, *et al.* (1988) studied the effect of row spacing on forage yield, they showed that row spacing didn’t affect plant height and tillers per plant. On the basis of average yield, the spacing of 50 cm x 30 cm, 50 cm x 15 cm and 30 cm x 30 cm were optimum for getting maximum plant height. In an investigation carried out at Shambat to study the performance of some local and introduced varieties of forage sorghum. Kambal (1972) found that the introduced varieties were characterized by high tillering and fine stems. He recorded plant height of 174 cm for Ankolib, while the mean height of Abu Sab’in was 173 cm. Yield components that contributed most to the high yield of Abu Sab’in are stem height and thickness. Several workers (Elamin, 1980; Mustafa and Abdelmagid, 1982) found that plant height in forage sorghum increased with nitrogen fertilization and reduction of irrigation intervals from 15 to 7 days. Reddy and Husain (1968) in India stated that sorghum height, number and size of leaves and the leaf area were not influenced significantly by nitrogen levels. Pursglove (1972) in USSR, showed that the plant height of sorghum ranged from 50 to 200 cm divided into several internodes, and the stem may produce few branches
from the crown buds at the base, but tillering varies with the variety and growing conditions. In east Africa Goldson (1977) reported that good dry matter yields of Napier grass were obtained when the grass was about 60 to 100 cm height, which coincided with a cutting interval of six to ten weeks. Gosnell and Weiss (1965) working on Napier grass, stated that regular cutting at low height resulted in a lower yield of dry matter and reduced life time.

**Number of Green Leaves:** Green leaves play an important role in the vegetative habits of plants. Photosynthetic active leaves receive the sunlight and oxygen and produce the chlorophyll which is distributed to the different parts of the plants for maintaining the plant duration. Moreover, it is a major component of plant which contributes much to forage quality.

In an experiment carried at Shambat, Kambal (1972) reported, an average of 14.1 green leaves for Ankolib and 12.5 green leaves for Abu Sab’in. Elsayed and Abdel karim (1968) studied Abu Sab’in under Shambat conditions found that the proportion of leaves (on dry matter basis) decreased from the first stage through the last stage of growth, while the proportion of the stems followed the opposite direction. Reddy and Husain (1968) reported that the difference in the mean number of
leaves per plant due to nitrogen at various level was not statistically significant. Furthermore, they found that seed rate significantly influenced the number of leaves per plant.

**Plant Density (Population):** Plant density is an important feature in forage production as it influences both fodder quality and quantity especially in cereal forages.

Plant density is defined as number of plants per unit area of land (Willey and Health, 1968). Plant density can affect many aspects of growth and development (Baker and Briggs, 1982). It was also reported that with increasing planting density and competition for light, plant height may be markedly increased (Arnon, 1975; Singh, *et al*., 1988). Determination of the lowest plant population necessary for optimal yield is a major agronomic goal (Carpenter and Board, 1997). Therefore it is desirable to define the relationships between plant population and crop yield quantitatively (Willey and Health, 1969).

All available evidence indicates that as plant density increases to a certain limit, the crop will continue to respond to higher level of added nutrient (Arnon, 1972). Bebawi (1987) in a work carried out at Shambat, Sudan, found that number of tiller density of Pioneer 988 was significantly superior to that of Abu Sab’in at all harvests and number of
tiller of Abu Sab’in and Pioneer 988 declined significantly with harvests. Downes (1967) in Australia, reported that buds did not expand into tillers in grain sorghum when the average daily temperature exceed a threshold of about 18°C. Plants were stimulated to tiller if they spent a period below this threshold at four to six leaf stage, though normally grown at a temperature higher than 18°C. In India Reddy and Husain (1968) showed that plant density of sorghum had influenced plant height, number and size of leaves and leaf area more than nitrogen application. Plant growth was more pronounced at low density than at high density, and an increase in the dose of nitrogen reduced the number of days to flowering significantly. Reddy and Husain (1968), Thangamuthu and Sundrow (1974) and Bebawi (1987) found that nitrogen application had no effect on plant population. In Hyderabad, Rao (1970) stated that, the total absence of the practice of fertilizer application and the traditional growing of sorghum only under low population had been the major limiting factor in having higher forage yields. Stickler and Laude (1960) showed that there was no difference in forage sorghum silage yield in row spacing of 51 to 102 cm, and there was an increase in plant as a result of increased population.
2.8 Quality Attributes of Forage Sorghum

Pasture and fodder grasses in the tropics are poor in quality when compared with well-managed pastures in temperate countries. While yields are often very high in terms of dry matter, the fodder is deficient in protein and relatively high in fibre. According to Sen (1952), the feeding standards recommended for maintenance in temperate countries can be reduced by about 20 percent under Indian condition. The composition of herbage changes with the season. The rapid drop in the crude protein content of the herbage at the end of the rains is accompanied by an increase in the fibre content which brings it to a very high level, (Sen, 1952). Similar results have been obtained in Australia, the Sudan and elsewhere in the tropics.

The factors affecting the quality of forage are generally related to the nutritive value of the crop. High nutritive value for most forages is found in the leaf, which is considered a desirable characteristic. In general, the most nutritious grasses are those which have a high proportion of leaf to stem and maintain this high proportion even when nearly mature. Schofield (1945), found that comparative figures for four species in the mature seeding stage are shown in (*Brachiaria brizantha*, *Chloris gayana*, *Cynodon plectostachyus*, *Panicum maximum*), which
retained a high proportion of leaf even when mature. This accounts partly for the good reputation of this grass, even though the protein content is comparatively low.

Khair and Elobeid (1991), found that, in those of the forage sorghum (the farmer experiments) the crude protein percentage (CP%) of the leaf were over twice that of the stems. Khair (1991) found that no significant differences were found among the genotypes of cultivar Abu Sab’in versus three sorghum/Sudan grass hybrids, whether in the crude protein, yields or CP%. The CP% of the leaves on all genotypes was more than twice that of the stem in both cuts Palatability of forage depends on kind of animals and forage species and is related to the chemical composition of the forage, such as presence of alkaloids. Some forages may contain compounds that are either lethal or toxic to animals. Sudan grass is dangerous when young, because it may contain prussic acid. The accumulation of nitrate nitrogen may be toxic to livestock. Mohamed, et al. (1988) stated that crude fibre and non structural carbohydrate content were higher at higher seeding rate.

The percentages of crude protein and crude fibre are often used to estimate the nutritive value of forage crops. Farhoomand and Weddin (1955; cited by Kambal, 1984) reported that the protein content depends
chiefly on, the species, the time of cutting or growth stage at the time of harvest, the level of nitrogen fertilization and the leaf content. Protein content is higher at early than late stage of growth, while the opposite is true for crude fibre in Abu Sab’in (El Sayed and Abdel Karim, 1968). RAO and House (1972) mentioned that cereal forages are rich in carbohydrates and low in protein, their nutritive value depends mainly on the stage of the growth when harvested. The crude protein content of dry matter is generally within the range of 8-12% and at the time of ear formation, the percentage of crude fibre falls with the increase in soluble carbohydrates. Burns and Wedin (1964), found that forage sorghum (Abu Sab’in) was significantly higher in crude protein percent than Sudan grass and the crude fibre percent increased in both with advance in maturity. Owen and Wesbster (1963), showed that advance maturity resulted a significant decrease in moisture content, crude protein, crude fibre but an increase in nitrogen free extract (NFE) in sorghum silage.

Bolhuis (1960), Ram 1960; Burleson (1965) and Reddy and Hussein, (1968) pointed out that protein production was increased by application of nitrogen fertilization in forage sorghum. The same trend was found in cereal forages (e.g. sorghum) (Vijay Kumar, 1962; Miaki, 1969) and in grasses (Cowling and Lockyer, 1967).
Ramage, *et al.* (1958); Woelfel and Poulton (1960); Groot and Keuning (1965) and Reid, *et al.* (1966), reported that the fibre content of herbage dry matter is little influenced by nitrogen fertilization.

### 2.9 Proximate Analysis

Investigators throughout the world are interested to conduct proximate analysis for different forage species to identify their nutritive value and hence their importance as reliable forage for different classes of animals.

In an experiment to compare the performance of some varieties of sorghum, maize and pearl millet at Shambat in Sudan, Kambal (1984) showed that the highest yield was produced by sorghum variety in summer, the percent crude protein for sorghum was 8.0% and the crude fibre content was 39.90 percent. Gautam and Chopra (1962) and Kambal (1972) found that forage sorghum requires 70 days to reach maturity stage. On the other hand at Shambat, Osman and El Saeed (1968) studied some aspects of the nutritive value of (*Sorghum vulgare*) var. Abu Sab’in and they concluded that the crude protein content of the dry matter decreased with the advance in growth and crude fibre reached a peak at the maturity stage. Their chemical composition showed that when Abu Sab’in ranged between 70 to 80 days age. The crude protein was 5.44%,
crude fibre 35.35%, ether extract 1.70%, ash content 10.65% and dry matter was 53.10%.

In Sudan Osman and Osman (1982) studied the performance of a mixture of cereal and legume forage and their monoculture. They used different seed rates with four fertilizer levels and they harvested after 90 days from sowing. They found that the mixture treatment together with some other yielded more total crude protein than Abu Sab’in alone. On the other hand, Osman, et al. (1968) at Shambat reported that the crude protein contents in the leguminous forages were higher than in grasses. They concluded that, the crude fibre, soluble carbohydrates and nitrogen free extract (NFE) in the grasses were higher than in leguminous forages.

El Awad (1983) in Shambat (personal communication) found the following nutritive values for some forage crops: Abu Sab’in 5% CP, 55.2 TDN; clitoria 14% CP, 56% TDN, Lubia fodder 19.30% CP and phillipesara 12% CP, 56% TDN.

Thomas, et al. (1980) in India, studied the effect of nitrogen and cutting intervals on quality of guinea grass and they found that the protein content decreased in the plant cut at 45 days intervals, and they attributed this to an increase in fibre content. In India Patel, et al. (1962) investigated the effect cutting treatments on the yield and composition of
forage in grass land, and they noticed that, when the forage was harvested at monthly intervals, the protein content remained at a higher level, and when the stage of the first harvest was prolonged the protein content decreased.

2.10 Salt Affected Soils in Sudan

Sudan, the largest country in Africa, comprising an area of 2.56 million square kilometers or 630 million feddans (262.5 million ha), extending from latitude 4°N to a point very close to the tropic of cancer. Consequent, different climate prevail in the different parts of the country. This includes the very humid tropics in the south to a completely arid zone in the north. The degree of the soil salinity and/or sodicity in the country seems to follow an opposite pattern to that of the rainfall.

Beraymah (1998) reported that, the saline sodic soils (% total area) increase from the south to the north. Soil surveys 63121 ha in Northern Sudan, have shown that 11% of the area is salt-affected to variable degree. The salt-affect soils comprise 10 series extending over sizable areas between latitudes 14°N and the northern frontier of the country including the White Nile (2.3%), North Gezira (2.3%), East Khartoum (Elsilait) (40%), South Kartoum (Elbagair) (33%), Northern east Khartoum (22%), Shendi (4.2%), Dongola (62.2%).
Most areas around Khartoum are uncropped due to their salinity and/or sodicity. The most common crop in these areas is a forage sorghum variety (Abu Sab’in) which is a moderately salt tolerant crop (Khair and Jarrel, 1987). The same picture exists in the Northern State. The net result of the salinity/sodicity problems is that, large areas are left uncropped.

2.11 Crop Salt Tolerance

The cereal crops are moderately tolerant to salt and some reports indicated that they are more tolerant as forage than as grain crops (Magistad and Christiansen, 1994). *Sorghum bicolor* L. is grouped as a semi-tolerant crop (Dregne, 1973) or as a medium salt tolerant (Metha and Desai, 1957; Mehrotra and Gangwar, 1964; Ogra and Baijal, 1978), while Abichandani and Bhatt (1965), on the basis of relative percentage germination of different varieties of sorghum, reported the crop to be highly susceptible to salt stress. An F.A.O. report (FAO, 1979) showed that grain yield decreases in sorghum due to soil salinity under irrigation were zero percent at an E.C. of 4, 10% at 5.1, 25% at 7.2 and 50% at 11 millimhos/cm. Bains and Fireman (1964) reported that sorghum is found to be sensitive to the increase in E.S.P. and is generally responsive to
fertilization by N, P, K and Zn. Thus, it seems to be a promising test crop for investigations involving alkali, saline and fertility interaction.

2.12 Cutting

By cutting at or before the early flowering stage, it is possible to make a good-quality hay from at least some types of natural pasture in the tropics. In the Sudan, *Sorghum purpureo-sericeum* cut just before flowering gave a hay containing 11.5 percentage crude protein compared with 1.4 percent for the mature grass. Studying the effect of cutting at one-, two- and three-month intervals on the yield and chemical composition of 19 grasses over a period of two years. Schofield (1944 and 1945), found that, while monthly cutting resulted in the highest protein content, maximum dry matter yields were obtained with the three months frequency. At the end of two years, the vigour of the plants on plots cut at one-month intervals been markedly reduced. Similar results were recorded by Paterson (1933, 1935) in Trinidad, and by Nordfeldt, et al. (1951) in Hawaii.

Khair (1991), found that no significant differences were found between Pioneer 977F and Abu Sab’in, neither in the first cut nor in the total yields. In the second cut, however, Abu Sab’in significantly out-yielded Pioneer 877F.
According to Rahman, et al. (1999-2000) forage sorghum produced higher biomass under single cut than multi cut irrespective of sowing date, when cut 50 days after sowing, than at 35 days intervals. They concluded that single cut produced higher biomass in all conditions, and regrowth was affected more than single cut due to sub-optimal solar radiation and thermal conditions.

2.13 Dry Matter Production

Webster (1963) studied the effect of harvesting dates on forage sorghum yields, percentage of dry matter and protein content. He found that with advance in maturity, yield and dry matter production increased whereas crude protein percentage decreased. Jung, et al. (1964) reported that yield of Sudan grass increased, and digestibility decreased with advance in maturity. They also found that the ratoon yielded was greater than the first crop and attributed this to the effect of tillering. Their results showed that plants growing under higher levels of nitrogen fertilization were slightly more advanced in maturity than plant at lower levels. Moreover, their results indicated that, the digestible crude protein content and yield of dry matter were increased by the nitrogen fertilization.
El Sayed and Abdel Karim (1968), studied Abu Sab’in under Shambat conditions, found that the proportion of leaves (on dry matter basis) decreased from the first stage of growth (30-40 days) to the second stage (50-60 days) and from the second stage to the third stage (70-80 days), while the proportion of the stems followed the opposite direction.

Both fresh and dry matter yields increased appreciably as the seed rate increased, and sowing on shoulders always resulted in higher yields than sowing on top of ridges in saline soil (Abusuwar, 1981). Porter, et al., (1960) they found that heavier plantings produced the high yield of forage. Raheja and Krantz (1957); Reddy and Husain (1968) in their work on sorghum; Hinkle and Garret (1961) working on corn reported that high yield of straw was produced under high plant population.

Fertilizer treatments increased both fresh and dry matter yields. Nitrogen fertilization is found to increase the dry matter yield (Porter, et al., 1960; Jung, et al., 1964; Rumburg, et al., 1964 and Naik, et al., 1979).
CHAPTER THREE
MATERIALS AND METHODS

The study was carried out in the Experimental Farm of Shambat Research Station (latitude 15°37’, longitude 32°32’, altitude 380m). The soil of the experimental site was vertisol with high clay content (52-61%), a pH of 7.9. The electrical conductivity ranges between 1.0 to 2.5 ds/m Silt percentage ranges between 16.1 to 15.0. The climate of the area is semi-desert with average annual rainfall of 160 mm, occurring mostly during July and August (Whiteman, 1971). Average minimum and maximum temperatures range between 14°C and 27°C in January (winter season) and between 25°C and 41°C in May (summer season). The relative humidity ranges between 14%-25% during the dry months and between 31%-51% during the wet months of the year. Solar radiation is high and is always exceeding 450 cal cm\(^{-2}\) in all months of the year. Temperature, rainfall and relative humidity during the growing season are presented in Appendix 3.

The land was ploughed using disc plough, disc harrowed, leveled with scraper to option a more leveled seed bed, and then plots were ridged at 75 cm apart.
3.1 Treatments

Seven entries of forage sorghum were studied Appendix 4. Five of them were Sudan grass selections, namely: S. (32-2) A, S.51, S 10-1, S.18SG and S. 50, isolated from the local variety Sudan grass (*Sorghum sudanense*), obtained from the Shambat Research Station developed by forage improvement program by Dr. Maarouf. Wide range of variability has been observed for most characters, specially growth vigor, plant height, flowering time, leafiness, head characteristics, culm color, tillering capacity and seed-yielding ability. The two other were composed of Kambal and Garawia (check cultivars), Kambal which was isolated from the traditional cultivar, Abu Sab’in line S.19, Aliab type, was released under the name Kambal by the Variety Release Committee (VRC) in 2004, obtained by Dr. Maarouf, Agricultural Research Corporation. The traditional cultivar “Garawia” a common type of Sudan grass, makes excellent green forage or hay, do well on salty soils and has better persistence or longevity.

A randomized complete block design with three replications was used. The experimental plot consisted of four ridges each 6 meter long. Spacing between ridges was 75 cm and between plants along the ridge was 15 cm. Five seeds were planted in each hole spaced at 5 cm along
both sides of the ridge. Weeding was done three weeks after sowing and at various stages of growth. Nitrogen fertilizer at a rate of 55 N kg/ha was applied at second irrigation. The experiment was irrigated every 7 to 10 days. harvesting was practiced two weeks after completion of 50% flowering for each treatment. The two middle ridges were harvested to estimate fresh matter yield (FMY).

yield of the second cut. The following parameters were measured:

1. **Plant population (plant density)**

   Three counts were recorded at 15 and 30 days after sowing for each treatment and immediately before harvested for each treatment. One meter length was randomly located and permanently marked from the two middle ridges in each treatment. So that in each sampling the plants in the same area were counted. Then the plant population in this area was determined.

2. **Number of Leaves per Plant**

   Ten plants were randomly selected from each plot. All leaves of the ten plants were counted, and mean number of leaves per plant was obtained. The data recorded after 30 days from sowing and immediately before harvesting from each plot.
3. Plant Height (cm)

At harvested, a sample of three plants were randomly selected from the two middle ridges in each plot to measure plant height.

Plant height is measured from the ground level to the tip of the panicle.

4. Days to 50 Percent Flowering

Taken as the average number of days from sowing date to the day on which 50 percent of the main panicles in the plot reached anthesis.

5. Percent of Leaves Plant

Estimated from a sample of three plants that was randomly chosen from each plot and separated to leaf and stem, and air dried until a constant weight was reached to obtain the dry weight. Then calculated leaf/stem ratio according to the following formula:

\[
\text{Percent of leaves plant} = \frac{\text{dry weight of leaves}}{\text{Dry weight of leaves} + \text{dry weight of stem}} \times 100\%
\]

6. Fresh Matter Yield (FMY) – First Cut (ton/ha)

The fresh matter yield was estimated from the two middle ridges of each plot.
7. **Dry Matter Yield (DMY) – First Cut (ton/ha)**

Estimated from 500g fresh sample taken from the harvested plot and air dried until a constant weight was reached to obtain the dry weight.

8. **FMY and DMY – Second Cut (ton/ha)**

After the first cut, nitrogen fertilizer was added and the experiment was irrigated to evaluate the yield of the second cut. Plants in six meters from the middle of the plot were harvested and weight to get FMY per ha. Dry matter yield was obtained similar to the first cut mentioned before.

9. **Crude Protein and Crude Fibre**

Proximate analysis was performed to determine the nutritive value of the fodder in term of C.P. and C.F. percentages of the fodder. Crude protein was determined by the Micro Kjeldhll method as outlined in Appendix I. Expressed on dry matter basis. Macro digestion of the samples and the calculation of the nitrogen percentage of the fodder were done according to the recommendations of the Association of Official Agricultural Chemists (A.O.A.C.) (1965). Crude fibre was determined using Modified Acid Detergent Fibre Test (MADF), method as shown in Appendix 5.
3.2 Statistical Analysis

The analysis of variance was carried out for data analysis. The ANOVA table for the randomized complete block design as shown in Appendix 7.

Duncan’s Multiple Range Test at 0.05 probability level, as used for means separation. Coefficient Variability (C.V.) was obtained (Appendix 7)
CHAPTER FOUR
RESULTS AND DISCUSSION

Mean squares for different characters of the entries in the first cut and second cut were given in Appendix 8 and 9, respectively. Highly significant differences between entries were detected for most of the characters studied. Only four characters; namely plant density 15 days from sowing and immediately before harvest in the first cut, crude protein, crude fibre in both cuts, and dry matter yield in the first cut, were not significant, (Plate 1).

4.1 Plant Density (Population)

Highly significant differences ($P \leq 0.01$) were detected among entries for plant density at 30 days from sowing. Fifteen days from sowing and immediately before harvest showed no significant differences in plant density (Table 1).

The number of plants increased from 15 days up to 30 days from sowing, then decreased immediately before harvest. These results are in agreement with those of Bebawi (1987), who found that plant density in Abu Sab’in, declined significantly at harvest. The increase in number of plants from 15 days to 30 days from sowing, then dropped at harvest is normal, as with advance in growth, tillers are produced but later due to
Plate (1)  General view of the field

Plate (2)  First cutting
Table 1: Plant density at different growth stages of five Sudan grass selection, and checks, Kambal (Abu Sab’in) and Farmer check. At Shambat 2005 Khartoum State.

<table>
<thead>
<tr>
<th>Entry</th>
<th>Plant density after (15 days)</th>
<th>Plant density after 30 days</th>
<th>Plant density immediate before harvest</th>
</tr>
</thead>
<tbody>
<tr>
<td>S. (32-2)A</td>
<td>71.00 a</td>
<td>102.67* ab</td>
<td>55.67 a</td>
</tr>
<tr>
<td>S. 51</td>
<td>53.33 a</td>
<td>55.33 d</td>
<td>48.33 a</td>
</tr>
<tr>
<td>S. 10-1</td>
<td>75.67 a</td>
<td>112.00 a</td>
<td>65.33 a</td>
</tr>
<tr>
<td>S. S. 18 SG</td>
<td>71.00 a</td>
<td>90.00 b</td>
<td>74.67 a</td>
</tr>
<tr>
<td>S. 50</td>
<td>70.90 a</td>
<td>105.67 a</td>
<td>62.00 a</td>
</tr>
<tr>
<td>Kambal (check)</td>
<td>73.69 a</td>
<td>73.33 c</td>
<td>71.33 a</td>
</tr>
<tr>
<td>Garawi (check)</td>
<td>61.67 a</td>
<td>74.33 c</td>
<td>50.00 a</td>
</tr>
<tr>
<td>GM</td>
<td>68.18</td>
<td>87.62</td>
<td>61.05</td>
</tr>
<tr>
<td>Sig. level</td>
<td>N.S</td>
<td>**</td>
<td>N.S</td>
</tr>
<tr>
<td>S.E±</td>
<td>5.188</td>
<td>4.481</td>
<td>7.053</td>
</tr>
<tr>
<td>C.V%</td>
<td>13.18</td>
<td>8.86</td>
<td>20.01</td>
</tr>
</tbody>
</table>

N.S, ** = non-significant and significant at 0.01 probability level.

Figure in each column means with letters in common are not significantly different at 0.05 probability level according to Duncan’s Multiple Range Test (DMR).
competition and failure of some tillers to reach maturity, the density dropped.

The entry S.10-1 resulted in the highest plant density at 15 days and 30 days from sowing, giving 76 and 112 plant/0.75 m² after 15 and 30 days from sowing, respectively. The entry S.18SG recorded the highest plant density of (75 plant/0.75 m²), followed by Kambal (71 plants/0.75 m²) immediately before harvest. The entry S.51 gave the lowest plant density at three counts (15 days, 30 days and immediately before harvest); giving (53, 55, 48 plant/0.75 m²), respectively, followed by the traditional cultivar (Garawia) at two counts (15 days and immediately before harvest), giving 62, 50 plant/0.75 m², respectively. No significant differences between Garawia and Kambal (74, 73 plant/0.75 m²), respectively, which followed by the entry S.51 at the plant count 30 days from sowing. Garawia and Kambal gave highly significant difference from the entry S.51. A similar result was obtained by Ibrahim and Rashid (1996) who found that Abu Sab’in gave least number of tillers per plant. Similar findings were reported by Khalifa (1988). With respect to plant density at 30 days from sowing, higher plant density was obtained by all selection of Sudan grass, with exception
of S.51, i.e. Sudan grass selection were superior in plant density than that of the Kambal and Garawi.

Generally, it was observed that plant density was affected by the environmental condition (Downes, 1967), the seed rate (Burnside, et al., 1964); (Stickler and Laude, 1960), type of crop (Pursglove, 1972)) and the stage of crop harvest, (Throne, 1962); (Laude, et al., 1967) and (Canne, 1959).

4.2 Number of Green Leaves

Green leaves are major components of yield that affect forage quality. Generally number of leaves per plant increased during the seedling stage up to vegetative stage and stop before flowering stage.

There were significant difference (P≤ 0.05) between entries at 30 days from sowing in the number of leaves per plant (Table 2). The Sudan grass entries resulted in high number of leaves per plant than that of the traditional cultivar Garawia, (6.47 leaves/plant) and Kambal (6.13 leaves/plant). The Sudan grass entries showed no significant differences between them. Moreover, no significant differences between Garawia and Kambal were detected. The entry S. (32-2)A gave the highest number of leaves per plant (7.38 leaves/plant), and there are highly significant (P≤ 0.05) differences between it and Kambal and Garawia.
Table 2: Number of leaves per plant, after one month from sowing and immediately before harvest of five Sudan grass selection, Kambal and Farmer check at Shambat (Feb., 2005) Khartoum State, Sudan.

<table>
<thead>
<tr>
<th>Entry</th>
<th>No. of leaves/plant</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>After one month</td>
<td>Before harvest</td>
<td></td>
</tr>
<tr>
<td>S. (32-2)A</td>
<td>7.38 a</td>
<td>8.78 ab</td>
<td></td>
</tr>
<tr>
<td>S. 51</td>
<td>7.27 ab</td>
<td>8.63 ab</td>
<td></td>
</tr>
<tr>
<td>S. 10-1</td>
<td>6.70 abc</td>
<td>8.70 ab</td>
<td></td>
</tr>
<tr>
<td>S. 18 SG</td>
<td>7.00 ab</td>
<td>8.28 bc</td>
<td></td>
</tr>
<tr>
<td>S. 50</td>
<td>6.53 abc</td>
<td>7.63 c</td>
<td></td>
</tr>
<tr>
<td>Kambal (check)</td>
<td>6.13 c</td>
<td>8.63 ab</td>
<td></td>
</tr>
<tr>
<td>Garawi (check)</td>
<td>6.47 bc</td>
<td>9.33 a</td>
<td></td>
</tr>
<tr>
<td>G.M</td>
<td>6.78</td>
<td>8.57</td>
<td></td>
</tr>
<tr>
<td>Sig. level</td>
<td>*</td>
<td>**</td>
<td></td>
</tr>
<tr>
<td>SE±</td>
<td>0.256</td>
<td>0.235</td>
<td></td>
</tr>
<tr>
<td>C.V%</td>
<td>6.55</td>
<td>4.75</td>
<td></td>
</tr>
</tbody>
</table>

*=** = Significant at 0.05, 0.01 probability level respectively.

Figure in each column, means with letters in common are not significant different at 0.05 probability level according to Duncan’s multiple range test (DMR).
No significant differences between Garawia and the Sudan grass entries with exception of S. (32-2)A had been recorded.

Before harvesting there were highly significant ($P \leq 0.01$) differences among entries. The traditional cultivar Garawia was superior in number of leaves per plant (9.33 leaves/plant), followed by the entry S. (32-2)A (8.78 leaves/plant), were no significant differences were detected. On the other hand, Kambal (8.63 leaves/plant), had no significant ($P \leq 0.01$) differences with other entries with exception of the entry S. 50, which gave lower number of leaves per plant (7.63 leave/plant). No significant differences between Garawi and all entries with exception of the entries S.18SG and S. 50 (8.27 and 7.63 leaves/plant, respectively), and there were no significant differences between the entry S. (32-2)A, Kambal and traditional cultivar at the count of number of leaves per plant immediately before harvest.

Average number of leaves per plant for Kambal after one month and immediately before harvest were 6.13 and 8.63 leaves/plant, respectively. Opposite result were obtained by Kambal (1972), who found that the average number of leaves was 12.5 leaves per plant for Abu Sab’in. This result may be referred to seasonal effect. The number of leaves per plant increased from one month after sowing to
immediately before harvest (harvested practiced after 15 days at 50% flowering) Table 2.

Evidently this leaf production was due to the production of new leaves at the early stage of the plant growth and to natural senescence of lower leaves as the plant advances in age (El Sayed and Abdel Karim, 1968). Generally, there is a relationship between the number of leaves per plant and the seed rates and fertilization with urea (Reddy and Husain, 1968).

4.3 Plant Height (cm)

Effect of treatments on plant height is presented in Table 3. Highly significant ($P \leq 0.05$) differences between treatments in plant height at both cuts (Feb. and May) were detected.

In the first cut taller plants for all entries were recorded in comparison to the second cut (plate_2). This can be attributed mainly to environmental condition differences between, Feb. (winter) and May (summer) where the lower temperature in Feb. favours the growth of hybrids. Also denser population which were observed in Feb. resulted in high competition and consequently taller plants. These results are in agreement with those of Arnin, (1975) and Singh, et al., 1988.
Table 3: Plant height of five Sudan grass selection and two checks, Kambal (Abu Sab’in) and Farmer check. At Shambat 2005 Khartoum State.

<table>
<thead>
<tr>
<th>Entry</th>
<th>Plant height (cm)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>First cut (Feb.)</td>
<td>Second cut (May)</td>
</tr>
<tr>
<td>S. (32-2)A</td>
<td>226 a#</td>
<td>174 ab#</td>
</tr>
<tr>
<td>S. 51</td>
<td>199 ab</td>
<td>192 ab</td>
</tr>
<tr>
<td>S. 10-1</td>
<td>179 abc</td>
<td>144 bc</td>
</tr>
<tr>
<td>S. 18 SG</td>
<td>209 ab</td>
<td>170 ab</td>
</tr>
<tr>
<td>S. 50</td>
<td>181 b</td>
<td>147 bc</td>
</tr>
<tr>
<td>Kambal (check)</td>
<td>191 b</td>
<td>172 ab</td>
</tr>
<tr>
<td>Garawi (check)</td>
<td>185 b</td>
<td>128 c</td>
</tr>
<tr>
<td>G.M</td>
<td>196</td>
<td>161</td>
</tr>
<tr>
<td>Sig. level</td>
<td>*</td>
<td>**</td>
</tr>
<tr>
<td>SE±</td>
<td>0.818</td>
<td>11.073</td>
</tr>
<tr>
<td>C.V%</td>
<td>8.69</td>
<td>11.92</td>
</tr>
</tbody>
</table>

* = Significant at 0.05 probability level.

Figure in each column, means with letters in common are not significant different at 0.05 probability level according to Duncan’s multiple range test (DMR).
reported that increasing planting density and competition for light, plant height may be remarkably increased. Similar trends were observed by Stickler and Laude (1969), who concluded that plant height increased with seed rate, and they attributed this result to the light effects on internode elongation. Burnside, et al. (1964), also gave the same conclusion. Similar results were obtained by Reddy and Husain (1968), who showed that plant density of forage sorghum had influenced plant height. Opposite results happened in the second cut due to lower plant density and consequently less competition between plants was expected. Therefore, plants were shorter at the second cut than the first cut. In the first cut, the tallest plants range between (226 to 179 cm), obtained by the entry S. (32-2)A and the entry S. 10-1, respectively. Kambal (Abu Sab’in) and the traditional cultivar (Garawia) recorded 191 and 185 cm, respectively. No significant differences between them, but highly significant differences between them and the entry S. (32-2)A was observed. Taller plants in Feb. cut could also be due to less water loss through evapotranspiration as it coincided with winter season which means enough moisture was available in plant roots compared to summer cut. This result is in line to the results reported by Whitt and Van Bave (1982), who reported that plant height of sorghum increased with
decreasing irrigation frequency and interval, which means more moisture in the root zone. This is also supported by Saeed (1984), and by Mansour (1981), for the same crop. Moreover, Elamin (1980), Mustafa and Abdelmagid (1982), found that plant height in forage sorghum increased with reduction of irrigation intervals from 15 to 7 days.

In the second cut the height of the plant range from (192 to 128 cm) which were obtained by the entry S. 51 and the traditional cultivar (Garawia). Kambal (Abu Sab’in) recorded 172 cm. These results are in agreement with those of Kambal (1972), who reported that the introduced varieties of forage sorghum were characterized by high tillering and fine stems, while the mean height of Abu Sab’in 173 cm. Similar results were obtained by Pursglove (1972), who showed that the plant height of sorghum ranged from 50 to 200 cm divided into several internodes, but tillering varies with the variety and growing conditions. This results of plant height could be attributed to the favourable environmental condition for crop growth during this season (Feb.).

In the second cut the entry S. (32-2)A recorded 174 cm which was taller than Kambal (172 cm), but no significant (P ≤ 0.05) differences between them. The entry S. (32-2)A resulted in a significant (P ≤ 0.05) difference compared to traditional cultivar (Garawia).
4.4 Days to 50% Flowering

Flowering time of sorghum is affected by the sowing date (Andrews, 1973), photoperiod (Elbakri, 1990), temperature (Caddel and Weibal, 1972) and the interaction of day length and temperature (Doggett, 1988).

Because of the trait, days to 50% flowering, is highly positively related to maturity (Khalifa, 1988), delay in flowering as the temperature was lowered to 11 hours photoperiod treatment was reported by Imrie and Lawn, (1990).

Highly significant ($P \leq 0.01$) differences among entries were detected for days to 50% flowering (Table 4). The entry S. (32-2)A was the earliest to flower (55 days) followed by the S. 51 (56 days) traditional cultivar (57 days) and the entry S.18 SG (58 days). The entry S. 10-1 (65 days) was the latest to flower.

The entry S. (32-2)A was significantly ($P \leq 0.05$) early flowering than Kambal (60 days). From these results Kambal (Abu Sab’in) ranks in the middle of the list for maturity. Similar results were obtained by Khalifa (1988) who classified that Abu Sab’in is a medium maturity crop.
Table 4: Days to 50% flowering, in first cut of five Sudan grass selection, Kambal and Farmer check at Shambat 2005, Khartoum, Sudan.

<table>
<thead>
<tr>
<th>Entry</th>
<th>Days to flower</th>
</tr>
</thead>
<tbody>
<tr>
<td>S. (32-2)A</td>
<td>55 d</td>
</tr>
<tr>
<td>S. 51</td>
<td>56 cd</td>
</tr>
<tr>
<td>S. 10-1</td>
<td>65 a</td>
</tr>
<tr>
<td>S. 18 SG</td>
<td>58 c</td>
</tr>
<tr>
<td>S. 50</td>
<td>61 b</td>
</tr>
<tr>
<td>Kambal (check)</td>
<td>60 b</td>
</tr>
<tr>
<td>Garawi (check)</td>
<td>57 cd</td>
</tr>
<tr>
<td>G.M</td>
<td>59</td>
</tr>
<tr>
<td>Sig. level</td>
<td>**</td>
</tr>
<tr>
<td>SE±</td>
<td>0.535</td>
</tr>
<tr>
<td>C.V%</td>
<td>-</td>
</tr>
</tbody>
</table>

** = Significant at 0.01 probability level.

Figure in each column, means with letters in common are not significant different at 0.05 probability level according to Duncan’s multiple range test (DMR).
The traditional cultivar (Garawi) was the earliest to flower compared to Kambal (Abu Sab’in) and the difference was highly significant \((P \leq 0.01)\). In this study it was observed that, there is a relationship between plant density and days to 50% flowering. The lower plant density, the earlier plant to flower. The plant density of the traditional cultivar (Garawia), the entry S. (32-2)A and S.51, were the lowest, immediately before harvest (50, 56 and 48 plants/0.75 m\(^2\)), respectively, therefore, they were the earliest to flower (57, 55 and 56 days), respectively. However, no significant \((P \leq 0.01)\) differences was detected between these entries on the days to 50% flowering. Generally plant density has a negative effect on days to 50% flowering as it delayed flowering.

**4.5 Percent of Leaves in plant**

It is ratio representing the average fraction of the total dry weight in form of leaf. It is related to leaf canopy and structure. Leaves to plant ratio, which was recorded only in the first cut, showed a highly significant \((P \leq 0.01)\) difference between treatments (Table 5). The entry S. 50 was the best in leaves to plant ratio (42.82%) followed by farmer check (37.73%, with a significant differences between them. On the other hand, no significant difference in leaves to plant ratio between farmer
Table 5: Leaves to plant ratio in first cut of five Sudan grass selection, Kambal and Farmer check at Shambat 205, Khartoum State, Sudan.

<table>
<thead>
<tr>
<th>Entry</th>
<th>Leaf/stem ratio (Percentage)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S. (32-2)A</td>
<td>37.00 b</td>
</tr>
<tr>
<td>S. 51</td>
<td>34.45 c</td>
</tr>
<tr>
<td>S. 10-1</td>
<td>36.84 b</td>
</tr>
<tr>
<td>S. 18 SG</td>
<td>37.56 b</td>
</tr>
<tr>
<td>S. 50</td>
<td>42.82 a</td>
</tr>
<tr>
<td>Kambal (check)</td>
<td>33.89 c</td>
</tr>
<tr>
<td>Garawi (check)</td>
<td>37.73 b</td>
</tr>
<tr>
<td>G.M</td>
<td>37.18</td>
</tr>
<tr>
<td>Sig. level</td>
<td>**</td>
</tr>
<tr>
<td>SE±</td>
<td>0.736</td>
</tr>
<tr>
<td>C.V%</td>
<td>3.43</td>
</tr>
</tbody>
</table>

** = Significant at 0.01 probability level.

Figure in each column, means with letters in common are not significant different at 0.05 probability level according to Duncan’s multiple range test (DMR).
check (Garawia) and the entry S.18 SG, the entry S. (32-2)A and the entry S. 10-1, which gave 37.56%, 37.00%, 36.84% leaves to plant ratio, respectively. With the exception of the entry S. 51 (34.45%), the Sudan grass entries were better in leaves to plant ratio than Kambal (33.88%). A highly significant (P ≤ 0.01) difference between Kambal and Garawia was observed.

4.6 Yield

4.6.1 Green Matter Yield

Highly significant (P ≤ 0.01) differences in forage production were detected between all entries tested in both cuts, (Table 6).

Green matter yields were higher in the first cut compared to the second cut at all treatment, i.e. The first cut yields were double that of the second cut yields. This is probably because of the better environmental conditions such as light and temperature (winter) as they were reflected in higher plant growth parameter (height, number of leaves, leaves to plant ratio) reported during the first cut. In addition to yield component which contributed to increase the Green Matter Yield (GMY). In this trait the yield component contributed to increase the yield include plant height, stage of harvest, and plant density. All these results are in agreement with those of Rahman, et al. (2000), they found that, for the
Table 6: Green matter yield (GMY) of dry matter yield (DMY) of five selection of Sudan grass, Kambal and Farmer check, in the first cut and second cut, at Shambat (Feb., 2005) Khartoum State, Sudan.

<table>
<thead>
<tr>
<th>Entry</th>
<th><strong>First cut</strong></th>
<th></th>
<th><strong>Second cut</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GMY (T/ha)</td>
<td>DMY (T/ha)</td>
<td>GMY (T/ha)</td>
<td>DMY (T/ha)</td>
</tr>
<tr>
<td>S. (32-2)A</td>
<td>41.76 a</td>
<td>9.99</td>
<td>23.65 a</td>
<td>6.47 ab</td>
</tr>
<tr>
<td>S. 51</td>
<td>36.10 abcd</td>
<td>9.04</td>
<td>22.94 a</td>
<td>6.26 abc</td>
</tr>
<tr>
<td>S. 10-1</td>
<td>34.71 bcde</td>
<td>9.95</td>
<td>17.19 b</td>
<td>5.18 c</td>
</tr>
<tr>
<td>S. 18 SG</td>
<td>36.46 abc</td>
<td>9.18</td>
<td>20.92 ab</td>
<td>5.84 bc</td>
</tr>
<tr>
<td>S. 50</td>
<td>29.73 d</td>
<td>8.25</td>
<td>11.38 c</td>
<td>3.36 d</td>
</tr>
<tr>
<td>Kambal (check)</td>
<td>40.30 ab</td>
<td>10.57</td>
<td>24.99 a</td>
<td>7.21 a</td>
</tr>
<tr>
<td>Garawi (check)</td>
<td>31.41 cd</td>
<td>8.48</td>
<td>11.11 c</td>
<td>3.08 d</td>
</tr>
<tr>
<td>G.M</td>
<td>35.28</td>
<td>9.35</td>
<td>18.88</td>
<td>5.34</td>
</tr>
<tr>
<td>Sig. level</td>
<td>**</td>
<td>N.S</td>
<td>**</td>
<td>**</td>
</tr>
<tr>
<td>SE±</td>
<td>1.948</td>
<td>0.507</td>
<td>1.582</td>
<td>0.354</td>
</tr>
<tr>
<td>C.V%</td>
<td>9.43</td>
<td>9.38</td>
<td>14.51</td>
<td>11.46</td>
</tr>
</tbody>
</table>

N.S, ** = non-significant and significant at 0.01 probability level.

Figure in each column means with letters in common are not significantly different at 0.05 probability level according to Duncan’s Multiple Range Test (DMR).
forage sorghum, single cut produced higher biomass in all conditions, and that regrowth (multi-cut) was affected more than single cut due to suboptimal solar radiation and thermal conditions. Similar results were obtained Casady (1965), Hadly (1965), Graham and Lessman (1966), Stickler and Younis (1966). They reported that, tall plants yielded better than short types, but these were under low plant density and divided row spacing. Carpenter and Board (1997) reported that lowest plant populations are necessary for optimal yield. Similar results were obtained by Willey and Health (1969). They reported about the relationships between population and crop yield quantitatively.

Kambal (Abu Sab’in) which produced 40.30 ton/ha outyielded all selection of Sudan grass and the traditional cultivar, with exception of the entry S. (32-2)A (41.75 ton/ha), in the first cut, but the difference was not significant. Whereas in the second cut, Kambal was the highest yielding among all entries tested, followed by the entry S. (32-2)A, but with no significant ($P \leq 0.05$) differences between them at both cuts. Highly significant ($P \leq 0.05$) differences between Kambal, the entry S. (32-2)A and the traditional cultivar, at both cuts were detected. Traditional cultivar (Garawia) ranked lowest in GMY (11.11 ton/ha) in the second cut, whereas the entry S. 50 was the lowest (29.73 ton/ha) in the first cut,
followed by farmer check (31.41 ton/ha), but the difference was not significant ($P \leq 0.05$) between them in both cuts. The results of high GMY obtained by Kambal (Abu Sab’in), are probably due to its good performance which is attributed to taller plant, thicker stems and medium maturity. In addition to the better adaptability to the environmental factors which favours crop growth. These results are in agreement with those of Ibrahim and Orfi (1996). They showed that Abu Sab’in and some grain cultivars were superior in forage yield compared to the hybrid Pioneer 988. Similar results were obtained by Kambal (1972), who reported that Abu Sab’in was more productive than the introduced varieties. Moreover, he concluded that the yield components that contributed most to the high yield of Abu Sab’in were stem height and thickness.

Generally, for yield and yield component, the entry S. (32-2)A gave the highest yield compared to Kambal (Abu Sab’in), due to high tillering, early flowering, taller plants, high leaf to stem ratio and the presence of extra leaves. In addition to these characters better vigor and strong regrowth, which enhances multi cut (Plates 3 to 4).
Plate (3)  Selection (32 - 2) A (Sudan Grass)

Plate (4)  Second cutting of Kambal (Abu Sab'in)
4.6.2 Dry Matter Yield

The dry matter yield (DMY) of all entries tested, were higher in the first cut compared to the second cut (Table 6). This is expected since growth parameters and fresh yields were superior during the first season. If green matter yield (yields) is high, dry matter yield is expected also to be high. The yield component affected dry matter yields in this experiment were plant height and plant density, in addition to the cutting time of the crops. These results are in agreement with those of Goldson (1977) who reported that good dry matter yield of Napier grass were obtained when the grass was about 60 to 100 cm height (plant height effect), by the same crop reported that regular cutting at low height resulted in lower yield of dry matter and reduced life time, this results obtained by Gosnell and Weiss (1965). Similar results were obtained by Webster (1963) who found that with advance in maturity, yield and dry matter production increased whereas crude protein percentage decreased, for the forage sorghum. Jung, et al. (1964), reported the same results in Sudan grass. Regarding the effect of less water loss through evapotranspiration similar trends were observed by Mustafa, et al. (1982), who reported that dry matter of forage sorghum increased with
the decrease in irrigation interval which means enough moisture was available in plant roots.

In the first cut, there were no significant differences among all entries tested. Whereas, the differences in dry matter yields were highly significant \( (P \leq 0.01) \) at the second cut.

Dry matter yield decreased from first cut to second cut. This is due to the reduction occur to fresh yield, yield component and water stress due to increased evapotranspiration; in addition to effect of environmental conditions (summer season).

In both cuts, Kambal (Abu Sab’in) dry matter yield was superior compared to all selections of Sudan grass and farmer check (Garawia), (10.57, 7.31 ton/ha, respectively), followed by the entry S. (32-2)A (9.99, 6.47 ton/ha), respectively, at both cuts. Kambal gave these highest values due to higher green matter yields and to the high yield component (plant height, number of leaves per plant and tillering). This result was comparable to result obtained by Kambal (1972) who found that Abu Sab’in is more productive than introduced varieties averaging higher dry matter per day.

In the first cut, with exception of the entry S. 50, all selections of Sudan grass gave higher dry matter yield than the traditional cultivar
Plate (5) Selection 50 (Sudan Grass)

Plate (6) Selection (10 - 1) (Sudan Grass)
“Garawia) (8.48 ton/ha), while in the second cut farmer check (Garawia) ranked the lowest for dry matter yield (3.08 ton/ha), but the difference was not significant when compared to the entry S. 50 (3.36 ton/ha). At second cut, the dry matter yield obtained by Kambal (7.31 ton/ha) was not significantly different (P ≤ 0.01) than that of the entry S. (32-2)A and the entry S. 51 (6.47 - 6.26 ton/ha), respectively.

From the results of dry matter yield it can be concluded that the better entries were Kambal (Abu Sab’in) and the entry S. (32-2)A, whereas farmer check (Garawia) and the entry S. 50 were the worst.

4.6 Crude Protein and Crude Fibre

Fodder grasses in the tropics are low in quality, while dry matter yield is high. The fodder is deficient in protein and relatively high in fibre.

There were no significant differences detected among all entries tested at both cuts in the percentages of Crude protein (C.P) and crude fibre (C.F.) as shown in Table 7.

In the first cut the entries S.(32-2)A, S.51, S10-1 and S.50 showed relatively high protein contents in comparison to S. 18 SG; Kambal and Garawia (Plates 5 to 6). Similarly, in the second cut, S. (32-2)A, S. 51, S. 10-1 in addition to Garawia showed relatively high protein percentages in comparison to other entries.
Table 7: Crude protein (C.P) and crude fibre (C.F) in first cut and second cut of five Sudan grass selection, Kambal and Farmer check, at Shambat (Feb., 2005), Khartoum State, Sudan.

<table>
<thead>
<tr>
<th>Entry</th>
<th>C.P (percentage)</th>
<th></th>
<th>C.F (percentage)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>First cut</td>
<td>Second cut</td>
<td>First cut</td>
</tr>
<tr>
<td>S. (32-2)A</td>
<td>7.88</td>
<td>6.57</td>
<td>36.44</td>
<td>40.37</td>
</tr>
<tr>
<td>S. 51</td>
<td>7.00</td>
<td>6.57</td>
<td>38.69</td>
<td>39.23</td>
</tr>
<tr>
<td>S. 10-1</td>
<td>6.57</td>
<td>6.57</td>
<td>36.79</td>
<td>37.89</td>
</tr>
<tr>
<td>S. 18 SG</td>
<td>5.26</td>
<td>5.69</td>
<td>41.30</td>
<td>38.02</td>
</tr>
<tr>
<td>S. 50</td>
<td>6.13</td>
<td>5.69</td>
<td>40.09</td>
<td>38.62</td>
</tr>
<tr>
<td>Kambal (check)</td>
<td>5.69</td>
<td>6.13</td>
<td>41.19</td>
<td>37.66</td>
</tr>
<tr>
<td>Garawi (check)</td>
<td>5.25</td>
<td>6.57</td>
<td>38.59</td>
<td>40.83</td>
</tr>
<tr>
<td>G.M</td>
<td>6.27</td>
<td>6.26</td>
<td>39.00</td>
<td>38.94</td>
</tr>
<tr>
<td>Sig. level</td>
<td>N.S</td>
<td>N.S</td>
<td>N.S</td>
<td>N.S</td>
</tr>
<tr>
<td>SE±</td>
<td>0.497</td>
<td>0.415</td>
<td>1.733</td>
<td>1.592</td>
</tr>
<tr>
<td>C.V%</td>
<td>11.2</td>
<td>9.39</td>
<td>6.29</td>
<td>5.78</td>
</tr>
</tbody>
</table>

N.S = Non-significant
For the crude fibre percentage during the first cut S. 18 SG, S. 50 and Kambal showed relatively high fibre contents in comparison to other entries. Whereas in the second cut Garawia and S. (32-2)A were relatively high in crude fibre percentages in comparison to other entries.

From these results the differences in values between the first cut and second cut in crude protein and crude fibre could be due to the change in the environmental conditions. i.e., the changes between the two season (winter season and summer season). These results are in agreement with those of Sen (1952), who reported that, the composition of herbage changes with the season.

The low percentage of crude protein compared to high percentage of crude fibre in both cuts could be because this parameter were measured in dry matter of entries after plants were over mature, so that crude protein was low and crude fibre was high in dry matter yield. This result was similar to that observed by Osman and El Saeed (1968). They concluded that the crude protein content of the dry matter decreased with the advance in growth and crude fibre reached a peak at the maturity stage. Crude protein content of dry matter is generally within range of 8-12% and at the time of ear formation, the percentage of crude fibre falls with the increase in soluble carbohydrates.
The differences occur between Kambal ‘Abu Sab’in’, traditional cultivar (Garawia) and all selection of Sudan grass in crude protein and crude fibre may be due to high percentage of leaf to stem ratio which resulted in high nutritive value. In addition to the changes with the season, the species, the time of cutting and the leaf content. These results are in agreement with those of Khair and Elobeid (1991), who found that, in forage sorghum the crude protein percentages (C.P%) of the leaves was twice as that of the stems. Similar results were obtained by Farhoomand and Weddin, 1958 (cited, Kambal, 1975), who reported that the crude protein content depends chiefly on the species, the time of cutting or growth stage at the time of harvest, the level of nitrogen fertilization and the leaf content. Moreover, El Sayed and Abdel Karim (1968) found that, protein content is higher at early stages than late stages of growth, while the opposite is true for crude fibre in Abu Sab’in and in the cereal forages (RAO and House, 1972). Opposite trends were observed by Burns and Wedin (1964), who found that forage sorghum (Abu Sab’in) was significantly higher in crude protein percent than Sudan grass and the crude fibre percent increased in both with advance in maturity.
No significant differences among all entries, in both cuts, were reported. These results are in agreement with those of Khair (1991), who found that no significant differences were found among the genotypes of cultivar Abu Sab’in versus three sorghum and Sudan grass hybrids, and the crude protein percent of the leaves on all genotypes was more than twice of that of the stem in both cuts.

In general the entry S. (32-2)A was the best for crude protein percent compared to Kambal ‘Abu Sab’in’ and traditional cultivar (Garawia).
CONCLUSIONS AND RECOMMENDATION

The results of this study indicated that:

- There was significant variability among entries. Ranking procedure showed that Sudan grass selection (32-2)A has the higher value for all triats. Kambal followed S. (32-2)A in most triats. Whereas the traditional cultivar (Garawia) has the lower value for all traits with exception to leaf/stem ratio.

- Generally the first cut out yielded second cut. First cut yields were twice as much of that of the second cut yields, which indicated that seasons of plantings for these entries is important (summer and winter).

- Single cut produced higher biomass under all conditions and that regrowth (multi cut) was affected more than single cut due to sub-optimal solar radiation and thermal condition.

- Forage dry yield of sorghum harvested after flowering was highest during the first cut compared to the second cut due to the better growth environments of the winter and summer season.
• The performance of some elite Sudan grass selections were superior to Kambal (Abu Sab’in). So that the multi cuts provided by Sudan grass can be compensated by the high yield of Abu Sab’in.

• DMY increased where as crude protein percentages decreased. And the DMY of forage sorghum increase with decrease in irrigation interval.

• DMY of Kambal was higherr, followed by S. (32-2)A. Whereas the traditional cultivar (Garawia) was poor in DMY.

• Farmers in marginal areas, growing landraces which are characterized by low yield, it may be necessary for them to introduce some selection of Sudan grass and Kambal (Abu Sab’in) in such area to increase their productivity.

• It is suggested that farmers should benefit from the second cut when forage sorghum is grown during winter season. This recommendation is specific for the field in the winter season, because in the summer season the second cut coincided with the winter season which is not favourable for sowing forage sorghum.

• The unique performance noticed for most selection in forage yield and related attributes indicated that selection within the local stocks could result in isolation of improved versions of the traditional populations.
• Further research work is needed to obtain more information on the
effect of some characters on yield. And the relationship between
characters.
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Mohamed, A.A.H. and Hamed, Y.N. (1988). The effect of cutting stage, nitrogen fertilization and seeding grate on yield and quality of


Appendices


<table>
<thead>
<tr>
<th>Animal</th>
<th>Settled animals</th>
<th>Incoming animals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cattle</td>
<td>204 000</td>
<td>300 000</td>
</tr>
<tr>
<td>Sheep</td>
<td>424 000</td>
<td>2000 000</td>
</tr>
<tr>
<td>Goats</td>
<td>617 000</td>
<td>300 000</td>
</tr>
<tr>
<td>Camels</td>
<td>5 400</td>
<td>5 000</td>
</tr>
<tr>
<td>Total</td>
<td>1 250 400</td>
<td>2 605 000</td>
</tr>
</tbody>
</table>

Source: Dr. Lo’ai Osman Hashim. The present status of Agriculture in Khartoum state (in Arabic). General Director, Ministry of Agriculture and Animal Wealth, Khartoum State.


<table>
<thead>
<tr>
<th>Crop</th>
<th>Production</th>
<th>Demand</th>
<th>Forage gap</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forage crops</td>
<td>1 378</td>
<td>2 187</td>
<td>- 809</td>
</tr>
<tr>
<td>Vegetables</td>
<td>1 118</td>
<td>663</td>
<td>+455</td>
</tr>
<tr>
<td>Fruits</td>
<td>138</td>
<td>410</td>
<td>-272</td>
</tr>
</tbody>
</table>

Source: Dr. Lo’ai Osman Hashim. The present status of Agriculture in Khartoum state (in Arabic). General Director, Ministry of Agriculture and Animal Wealth, Khartoum State. (rearranged)
Appendix 3

Monthly means of temperature (C°), rainfall (mm) and relative humidity (R.H.%) during the growing season at Shambat Meteorological Observatory (2005).

<table>
<thead>
<tr>
<th>Month</th>
<th>Monthly means</th>
<th>Rainfall (mm) total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Max.</td>
<td>Min.</td>
</tr>
<tr>
<td>February</td>
<td>37.0</td>
<td>17.4</td>
</tr>
<tr>
<td>March</td>
<td>37.3</td>
<td>18.6</td>
</tr>
<tr>
<td>April</td>
<td>41.2</td>
<td>23.0</td>
</tr>
<tr>
<td>May</td>
<td>40.7</td>
<td>22.9</td>
</tr>
<tr>
<td>June</td>
<td>41.7</td>
<td>27.3</td>
</tr>
<tr>
<td>July</td>
<td>34.3</td>
<td>24.5</td>
</tr>
</tbody>
</table>
### Appendix 4

Local stock, seed color, mid-rib color of seven selection, Shambat (2005).

<table>
<thead>
<tr>
<th>Selection</th>
<th>Local stock</th>
<th>Seed color</th>
<th>Mid-rib color</th>
</tr>
</thead>
<tbody>
<tr>
<td>S. (32-2)A</td>
<td>Sudan grass</td>
<td>Brown</td>
<td>Green</td>
</tr>
<tr>
<td>S. 51</td>
<td>“</td>
<td>White</td>
<td>“</td>
</tr>
<tr>
<td>S. 10-1</td>
<td>“</td>
<td>Light brown</td>
<td>“</td>
</tr>
<tr>
<td>S. S. 18 SG</td>
<td>“</td>
<td>Black</td>
<td>“</td>
</tr>
<tr>
<td>S. 50</td>
<td>“</td>
<td>White</td>
<td>“</td>
</tr>
<tr>
<td>Kambal (check)</td>
<td>Abu Sab’in</td>
<td>White</td>
<td>“</td>
</tr>
<tr>
<td>Garawia</td>
<td>Sudan grass</td>
<td>Mix color</td>
<td>white</td>
</tr>
</tbody>
</table>
Appendix 5

Determination of Crude Protein

Using Micro-Kjeldhal method

Calculation = Wt. of dried (Crucible + Fibre) – Wt. of dried crucible x 100 = % fibre in dried material.

Laboratory Procedure

1. 1 gm of plant sample was taken to Kjeldhal flask.
2. 25 ml of conc. Sulphoric acid was added.
3. The sample was digested for three hours at fall heat.
4. The sample was cooled, distilled water was added to complete 100 ml of solution and then distillated as the following:
   (a) 25 ml of 4% boric acid was put on a conical flask and an indicator was added, the colour become purple.
   (b) 10 ml of 40% NaOH solution was added to sample the receiver colour change to blue.
   (c) Titration is the receiver was titrated against .02 HCl to the end point. The amount of HCl used was recorded.
   (d) Calculation = N% = \( \frac{T - B}{V} \) x \( \frac{V}{S - B} \) x \( \frac{A x W}{C.P.} \) = % N x 6.25
$T = \text{The sample}$

$S = \text{The standard titre}$

$B = \text{The blank titre}$

$V = \text{The volume of sample digest}$

$A = \text{The aliquot of sample digest taken for distillation.}$

$W = \text{The weight of dry matter present in the sample.}$
Appendix 6

Crude Fibre (MAFD) Methods

- 1 gram of freshly dried ground herbage is weighed on tarred scope and transferred carefully to number conical quick fit flask.

- 100 ml of cold co/n of C.T.A.B. (1% w/v) in/n – H₂SO₄ are added. The mixture is rapidly brought to boil (0.3 min) and then boil gently and evenly for exactly 2 hours under reflux. The contents of flask are filtered through a previously dried and weighed sintered glass crucible of porosity (pore size = 100-200 u). The fibre is washed thoroughly on the crucible with minimum of 200 ml of hit distilled water.

**N.B.** A vacuum, allowed to cool in a desiccator and weighed.

Calculation:

\[
\text{Wt. of dried (crucible + fibre)} - \text{wt. of dried (crucible)} \times 100
\]

= % fibre in dried materials.
Appendix 7

The form of analysis of variance and the mean squares of the experiment.

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>d.f.</th>
<th>M.S.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replication</td>
<td>(r-t)</td>
<td>M1</td>
</tr>
<tr>
<td>Treatments</td>
<td>t-1)</td>
<td>M2</td>
</tr>
<tr>
<td>Error</td>
<td>(r-1)(t-1)</td>
<td>M3</td>
</tr>
<tr>
<td>Total</td>
<td>(rt-1)</td>
<td>M1 + M2 + M3</td>
</tr>
</tbody>
</table>

Where: r = Number of replications  
t = Number of treatments  
M1+M2+M3 = mean squares for replication, treatments and error respectively.

\[ \text{C.V.} = \sqrt{\frac{\text{MSE}}{\text{GM}}} \times 100 \]

Where; C.V. = Coefficient Variability  
MSE = Mean Square of Error  
GM = Grand mean.
Appendix 8

Mean square of “F” values for various characters of five Sudan grass selection, Kambal farmer check obtained from first and second cuts. Sown in the Shambat Research Station of Shambat Farm during 2005 season.

<table>
<thead>
<tr>
<th>Characters</th>
<th>Degree of freedom</th>
<th>Mean squares</th>
<th>F-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant count of 15 days of sowing</td>
<td>6</td>
<td>186.152</td>
<td>2.3051</td>
</tr>
<tr>
<td>Plant count of 30 days of sowing</td>
<td>“</td>
<td>1287.603</td>
<td>21.3724**</td>
</tr>
<tr>
<td>Plant count before harvest</td>
<td>“</td>
<td>311.603</td>
<td>2.0878  N.S</td>
</tr>
<tr>
<td>Plant height at first cut</td>
<td>“</td>
<td>863.270</td>
<td>2.9855*</td>
</tr>
<tr>
<td>Plant height at second cut</td>
<td>“</td>
<td>1456.825</td>
<td>3.9609*</td>
</tr>
<tr>
<td>Number of leaves/plant after one month</td>
<td>“</td>
<td>0.612</td>
<td>3.1052*</td>
</tr>
<tr>
<td>Number of leaves/plant before harvest</td>
<td>“</td>
<td>0.165</td>
<td>4.8971**</td>
</tr>
<tr>
<td>Leaf/stem ratio at first cut</td>
<td>“</td>
<td>25.340</td>
<td>15.5750**</td>
</tr>
<tr>
<td>Days to 50% flower</td>
<td>“</td>
<td>38.190</td>
<td>44.5556**</td>
</tr>
<tr>
<td>Crude protein (first cut)</td>
<td>“</td>
<td>1.873</td>
<td>3.7999  N.S</td>
</tr>
<tr>
<td>Crude protein (second cut)</td>
<td>“</td>
<td>0.346</td>
<td>1.0048  N.S</td>
</tr>
<tr>
<td>Crude fibre (second cut)</td>
<td>“</td>
<td>7.541</td>
<td>1.2549  N.S</td>
</tr>
</tbody>
</table>

N.S = Non-significant at 5% level.
*-* = Significant at 5% and 1% levels respectively
Appendix 9

Mean square and “F” values for various characters of five Sudan grass selection, Kambal and Farmer check (Garawi) obtained from yield. Sown in the Shambat Research Station of Shambat Farm during 2005 season.

<table>
<thead>
<tr>
<th>Characters</th>
<th>Degree of freedom</th>
<th>Mean square</th>
<th>F-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>FMY (first cut)</td>
<td>6</td>
<td>56.752</td>
<td>4.9880**</td>
</tr>
<tr>
<td>FMY (second cut)</td>
<td>“</td>
<td>100.044</td>
<td>13.3229**</td>
</tr>
<tr>
<td>DMY (first cut)</td>
<td>“</td>
<td>2.175</td>
<td>2.8242</td>
</tr>
<tr>
<td>DMY (second cut)</td>
<td>“</td>
<td>7.470</td>
<td>19.9231**</td>
</tr>
</tbody>
</table>

N.S = Non-significant at 5% level.
** = Significant at 1% level.