**Sudan University of Science and Technology**

**College of Graduate Studies**

# EVALUATION OF FODDER PRODUCTION AND NUTRITIONAL QUALITIES OF SOME SORGHUM (*Sorghum bicolor* (L.) Moench) GENOTYPES UNDER RAIN-FED AND IRRIGATION IN NORTH KORDOFON STATE.

تقييم إنتاج العلف والخصائص النوعية لبعض الطرز الوراثية من الذرة الرفيعة تحت ظروف الأمطار والري بولاية شمال كردفان.

**Thesis Submitted to Sudan University of Science and Technology in Fulfillment of the Requirements for the Degree of Philosophy Doctor in Agronomy**

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## *DEDICATION*

***To the Soul of my sister: Asia Ismail Ahmed (ALLAH mercy her).***

***To my affectionate and lovely parents,***

***To my faithful wife and lovely sons Mohammed and Haitham,***

***To my dear brothers, sisters, friends, colleagues and every one contributed to the success of this work***

***With love and respect***

*Salah-eldeen*

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# ABSTRACT

Field experiments were conducted for two successive rainy seasons (2014/15 and 2015/16) and for two successive irrigated winter seasons (2014/15 and 2015/16) in sandy soil at experimental Farm, Faculty of Natural Resources and Environmental Studies, University of Kordofan, Elobeid. The aim of this study was to evaluate 10 forage Sorghum genotypes under rain-fed and to investigate the effect of these 10 genotypes and watering interval (7 and 10 days) under irrigation on growth, yield and quality of forage sorghum. A randomized complete block arrangement with three replications was used in rainy experiment and split-plot design with three replications was used in the irrigated experiment. The water intervals were assigned as main plots, while genotypes assigned as sub-plots. Characters studied included vegetative attributes (plant height, stem diameter, number of leaves per plant, number of tillers per plant, number of leaves per tiller and leaf area index (L.A.I.). Phonological attributes (Number of days to 50% flowering) and yield attributes (fresh and dry forage yield (g/plant) and (ton/ha), leaf to stem ratio,), and percentage of dry weight) and quality parameters (dry matter percentage, ash%, crude protein%, ether extractable fats (E.E), Crude fiber %). The results showed that the hybrid Pioneer and local performed better with regard to growth traits moreover, local genotype Nabig and hybrid Pioneer produced highest fresh forage yield (26.5 and 21.3) and dry weight (ton/ha) and high percentage of dry weight. Local genotypes Aish-Baladi and Gassabi reached days to 50 % flowering earlier than other genotypes. The results of irrigated experiment (winter season) showed that, genotypes, irrigation intervals and their interaction generally had slightly differences in most of the studied parameters. Irrigation every 7 days produced better in growth and yield compared to irrigation every 10 days. The cultivar Pioneer had the highest fresh forage (9.7 and 11.3 ton/ha), and dry weight (ton/ha), highest Leaf to stem ratio (LSR), and Leaf area index (LAI). Differences in crude protein percentage were highly significant ($P \geq 0.05$).Genotype Taqqat.9A had the

highest values (12.0 and 13.2 %) during rainy season, whereas hybrid Pioneer obtained the highest values of (11.6 and 11.4 %) under irrigation. The lowest fiber content was obtained by genotypes Gassabi during both conditions. Genotypes showed significant differences for ash, and ether extractable fats percentage.

# ملخص البحث

أجريت تجارب حقلية لمدة موسمين متتالين ( 2015/2014- 2016/2015) بالأمطار وموسمين متتالين (2015/2014- 2016/2015) شتوى بالرى في تربة رملية بالمزرعة التجريبية ،بكلية الموراد الطبيعة والدراسات البيئية،جامعة كردفان- الأبيض. .بهدف تقيم عشرة أصناف من الذرة العلفية تحت ظروف الأمطار ومعرفة أثر تلك الاصناف وفترة الرى ( 7 و10 أيام) علي النمو و الأنتاجية والنوعية في محصول الذرة العلفية. أستخدم تصميم القطاعات العشوائية الكاملة بثلاث مكررات فى التجربة المطرية وتجربة القطع المنشطرة بثلاث مكررات للتجربة المروية. الصفات التى تم دراستها شملت مؤشرات النمو (طول النبات، قطر الساق، عدد الاوراق/النبات وعدد الخلف /النبات وعدد الأوراق/الخلفة ودليل مساحة الاوراق والسمات الفينولوجية (عدد الأيام لـ 50% إزهار) ومؤشرات الإنتاجية (انتاجية العلف االرطب والجاف جرام / للنبات وطن / للهكتار ، نسبة الأوراق للساق والنسبة للوزن الجاف) ومؤشرات الجودة (النسبة المئوية للمادة الجافة والرماد والبروتين والدهون والالياف). أ ظهرت النتائج أن الصنف الهجين بايونير كان الأفضل من حيث معايير النمو. كما أن الصنف الهجين بايونير و الصنف المحلي نابغ سجلا أعلي انتاجية للعلف الرطب (26.5 و 21.3) والجاف (طن/هكتار) وأعلي نسبة للوزن الجاف. الصنف المحلي عيش بلدي والقصابي سجلت أقل عدد لأيام 50 % إزهار مقارنة بالأصناف الأخري. أظهرت نتائج الموسم الشتوي (المروى) أختلافات معنوية للأصناف وفترات الري ، والتفاعل المشترك في أغلب الصفات المدروسة. الري كل 7 أيام أعطي أفضل نمو و إنتاجية مقارنة مع الري كل 10 أيام .الصنف بايونير حقق أعلي إنتاجية للعلف الرطب والوزن الجاف ( 11.3 و 9.7) (طن/هكتار) وأعلي نسبة أوراق للساق وأعلى دليل مساحة أوراق.الأختلافات بين الاصناف في نسبة البروتين الخام كانت عالية المعنوية ( $P \geq 0.05$) ، الصنف المحلي طقت 9 .أ كان الأعلي في نسبة البروتين الخام ( 13.2 و 12.0 %) في الموسم المطري. بينما الصنف الهجين بايونير سجل أعلي القيم ( 11.6 و 11.4 %) خلال الموسم الشتوي. أقل نسبة ألياف خام سجلت في الأصناف قصابي والجراوية في الموسمين معاً. كما أظهرت الأصناف فروقاً معنوية في نسبة الرماد والدهون الخام . .

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# CHAPTER ONE
# INTRODUCTION

Sorghum (*Sorghum bicolor. (*L.) Moench) is the main staple food crop for a large section of population in Africa and India. Besides being a major source of staple food for humans, it serves as an important source of feed and fodder for animals.

In Sudan, it constitutes the first crop in term of area and production. Sorghum is a warm season crop growing well in tropical and subtropical climates. It is well adapted to drought in arid and semi areas with 400 – 600 mm rain fall. The crop thrives well in a wide range of temperature (16-40°C). In Sudan, it is grown in nearly 92% of the total area devoted to whole crops (Fadlelmula, 2009). Crop adaptability to soil is also wide; it grows in sandy soil " Goz " to heavy black cracking clays (Skerman and Riveros, 1989). It is extensively grown under rain-fed and irrigated conditions for grain and forage production. (FAO, 2011).

Sorghum plant has a potentiality of quick growth to produce grain yield and good fodder (Ullah *et al*., 2007). Fodder sorghum is used as a pasture crop in United States of America. In Sudan, forage sorghum is usually consumed as green fodder or after drying to be used in summer season where availability of fodder to cows and sheep is rare. Sorghum forage is also known as a rich source of nutrients, it contains 5% crude protein and 55-% total digestible nutrients (Osman *et al*., 1968).

In Sudan, sorghum forage production is primarily concentrated in the central and eastern states. Its production system is mainly under irrigation. The average of fresh yield of forage Sorghum in Sudan was 22.3 – 43.3 ton/ha (Mosa, 2010).

And the average dry yield ranges between 6.55 and 10.08 ton/hectare. Vegetation in general and forage in particular serve and important functions in the Sudan, the irrigated forage occupy about 121.00 hectares (Khair, 2011). The irrigated green forage production in the Sudan is about 4 million tons per year. Sorghum forage production is small compared with other forages, it, production is only about 4% of the total forage produced in the Sudan (*Khair*, 1999). As a result of crop improvement program, a number of promising strains with diversified morphological and quality traits are available for general cultivation over the world. (Hussain *et al.,* 1995). The genotypes mainly determine the nutrient composition of a feed stuff, but the different factors like soil fertility, status of a soil, location, temperature, season, and stage of maturity of a crop also influence the chemical composition of a feed stuff (Harris, 1960).Also fodder yield, dry matter yield, crude protein, and crude fiber contents revealed differential performance of the same genotypes in the diverse environment (Hussain *et.al*, 2007).

Animal production in traditional sector in the Sudan depends mainly on natural ranges, which had been threatened by the encroachment of mechanized crop production schemes, seasonal bush fires, overgrazing around watering sites and drought. In North Kordofan State, where it is characterized by a large number of animal wealth, the demand for forage and fodder is continuously increasing due increasing numbers of animals. Lack of cultivars with high yield, good quality and well adapted to Sudan environments is the most important problem facing forage sorghum production in the Sudan (Idris and Mohammed, 2012). Moreover, very few efforts, with regard to selection or evaluation of known forage sorghum, were exerted. This imposed a crucial need to practice evaluation and selection for good forage sorghum suitable for the State to be cultivated under irrigation or rain-fed. Therefore, the main objectives of this study are:-

1- To study the performance of the genotypes in terms of forage yield and its nutritional values in North Kordofan under rain-fed and irrigation conditions.
2- To identify the earlier forage sorghum genotypes suitable to marginal rain fall areas.
3- To compare between two watering interval of seven and ten days on growth and yield of sorghum forage in sandy soil.

# CHAPTER TWO

# LITERATUER REVIEW

## 2.1General Background

Sorghum (*Sorghum bicolor* (L.) Moench) is a cereal plant member of the family Poaceae (Adeyeye and Adesina, 2013). It is the fifth important cereal in the world after maize, rice, wheat and barley (Sher, *et.al*, 2013). It is extensively grown under rain-fed conditions for grain and forage production. (FAO, 2011), with a worldwide production. In Africa, especially in Sudan sorghum is a large subsistence food, forage and ethanol production crop for more than 75 % of the population (Dawelbeit *et. al*, 2010). It can be grown as important dual purpose crop for grain and forage yields in many arid and semi-arid regions of the world, due to its advantages. These advantages include high water use efficiency and could be a good alternative to maize under limited water in the semi-arid conditions (Marsalis *et al.*, 2010).

It also had low consumption of nitrogen (Olanite *et.al.* 2010); adapted to hot and dry environments and high salt tolerance (Yan *et al.,* 2012; Saberi, 2013).Sorghum has great potential for fodder production under limited resource conditions compared to other cereals, especially maize. Sorghum is more drought tolerant, less input demanding and thrive better under harsh condition (Mohammed, 2010). Sudan is endowed with a wealth of genetic variability in sorghum (Yasin, 1978). The total forage yield in Sudan available for animal consumption is estimated as 105.2 million ton of dry matter (Abuswar and Drag, 2002).The natural rangeland shares about 78 million ton and irrigated forage produces about 4 million ton only and the crop produce provide about 21.8 million ton. The production of forage crops is very important for livestock in Sudan; this is due to the fact that there is a huge animal resource in the country. Animals have a social value which leads to the buildup of their population to reach about 132 millions of cattle, sheep, goats and camels (Ministry of Animal Resources, 2003). Locally the latest estimates of the livestock population of Kordofan (MOA, 2007) indicated that, there are now 31 million heads, composed of 8, 12.5, 8, and 3 million of cattle, sheep, goats and camels respectively, totaling about 13 million animal units. According to Ahmed, (1999), evaluation and selection within the sorghum forage local stocks could result in isolation of improved versions of the traditional populations.

## 2.2 Climatic requirement and adaptability.

### 2.2.1 Climatic requirement.

Temperature, photoperiod, rainfall and rainfall distribution and the interaction of theses climatic factors driving forage interact with the biological range and exert selective pressure among sorghum species to affect adaptation in a particular area (Maiti, 1996). Sorghum is well adapted to tropical climates with several traits making it a drought-tolerant crop that survives under adverse climatic conditions, (FAO, 2011).

### 2.2.2 Adaptability

Sorghum is one of the most widely adapted forage crops and grown extensively during summer season and has a significant role in livestock production (Amandeep, 2012).It is generally cultivated in dry, hot areas with an average annual rainfall of 400-700 mm, though it can be grown where rainfall is much higher (House, 1995). Sorghum is a short-day plant but most of our forage varieties are relatively insensitive to photo-period .Sorghum will proceed successfully on all types of soils, growth being dependent upon relative fertility and soil moisture supply .It is more tolerant to alkali or salts than most cultivated crops (Quinby and Karper, 1981). It is generally accepted that sorghum is a versatile crop capable of growing in a wide range of climatic and soil conditions, according to Swindale (1985), sorghum offers proven versatility, hardness, dependability, and stability of yield under very adverse climate. Sorghum is becoming an increasingly important forage crops in many regions of the worlds (Bhatti, *et.al,* 2008). It has a good potential to tolerate adverse environmental conditions which make it a suitable crop for semi-arid areas. Its rapid growth and high biomass production helps to overcome unfavorable environmental conditions (Zerbini and Thomas, 2003).

**2.2.3 Soil requirement of forage sorghum.**

Forage sorghum does well on a large variety of sandy to clayey soils and can be planted more successfully on marginal soils than other crops, like maize (Donaldson 2001). Forage sorghum can produce high yields even on low fertility soils, but responds very well to good fertilization practices, especially nitrogen. Sorghum is often relegated to poor soils and low-input management, it is extensively grown under rain-fed conditions for grain and forage production (FAO, 2011). Sorghum is grown successfully in variable soils with pH ranges from 5.5 to 8.5, but fertile soil is important to optimize yield (Folliard, *et.al*, 2004).Loamy soil shows best performance for sorghum growth (Maiti,1996).

**2.2.4 Temperature requirement of forage sorghum.**

As sorghum can perform the best at higher temperature and dry land ecologies, it serves as to provide substantial amount of fodder of outstanding quality during summer season. (Azam *et al.*, 2010). The optimum temperature for sorghum growth ranges from 25 to 30 °C (Kettering, *et.al.* 2007).Thomas and Miller (1979) reported that sorghum seedlings respond differently when exposed to varying temperatures, and genetic variation for thermal tolerance in sorghum has been shown to exist in certain lines that are capable of emerging at soil temperature of about 55°C.The base temperature for sorghum germination Is 10.5 C°.The average maximum temperature varies from 35 C° in northern Upper Volta, Niger and Sudan to 22.5 C° in Ethiopia highland (Maiti, 1996).

Generally, the optimum temperature is about 27 C°, maximum temperature of up to 37C° while maturity can be retarded when temperature drop below 15 C°,(Malala,2010).High soil --surface temperature is one of the reasons for poor seedling emergence (Maiti,1996). Peacock *et.al*. (1993) and Howarth (1989) have discussed the need for greater diversity in sorghum seedling tolerance to heat in superior genotypes, as this will improve the crop establishment in the semi-arid tropics. While Onwueme and Sinha (1991) reported that, the optimum temperature during growing season ranges from 27° to 32°,while the minimum and maximum temperatures are 15° and 45°.

### 2.2.5 Moisture and irrigation requirement of forage sorghum.

Forage sorghum has been proved to be more economical than other cereal forages due to fewer requirements of irrigations and fertilizers. It is short season forage achieving its full bloom in 52-60 days after sowing if harvested at 50% flowering or heading stage (Iqbal, *et.al*. 2015).Availability of water is one of the limiting factors determining plant distribution and survival in natural ecosystem. Soil moisture deficiency in sorghum forage may also affect the growth of the root apparatus, which is responsible for establishing the soil-plant-atmosphere continuum in the flow of water (Kuchenbuch et al., 2006).

Aulakh *et.al*, (2004) concluded that, water deficit affected growth and yield of forage and re-growth. Sorghum is better suited to, and physiologically withstands high temperatures and low moisture conditions than C3 cereals (Downes, 1992). Sher, *et.al*, (2013) recommended that, sorghum forage cultivars had different abilities under the effects of water shortage. The amount of moisture needed to produce an acceptable yield of grain sorghum is approximately 400 to 500 mm, which may be provided from a combination of stored soil moisture, rainfall and irrigation. Fresh weight yields of forage sorghum ranged from 38.3 t ha-1 with no irrigation to 88.4 t ha-1 with 560 mm of irrigation (Amaducci, *et al*. 2000; Naescu and Nita, 1991). Good management of crop, soil and water could raise productivity by increasing root penetration and improving water use efficiency and photosynthetic capacity (Athar and Ashraf, 2005). Zakria (2010) practiced watering in Abusabeen every 10 to 15 days. Watering most probably depends upon soil type and characteristics and climatic requirement during the growing season. Hussein and Alva, (2014) stated that, omitting the middle irrigation significantly decreased the fresh and dry yield of sorghum forage as compared to those of the plants grown under optimal irrigation. In similar studies, Ehrlich *et al*. (2003)

pointed that reducing the frequency and total volume of irrigation resulted in a reduced level of soil water and pasture yields of Rhodes grass. Forage sorghum performs best with an annual rainfall of more than 600 mm, but it can be successfully cultivated in areas a rainfall as low as 400 mm. Forage sorghum is able to tolerate drought better than most other grain crops because it possess xerophytic characteristics, physiological and morphological attributes that allow them to be resistant or tolerant to moisture stress (Miller and Stroup, 2003). Forage sorghum has the ability to enter a so-called growth dormancy phase during periods of stress.

Moisture consumption is curtailed and physiological development is retarded. According to Miller and Stroup, (2003) this can be attributed to an exceptionally well-developed and finely branched root system, which is very efficient in the absorption of water and small leaf area per plant, which limits transpiration. In addition to, water can affect crop performance not only directly but also indirectly by influencing nutrient availability, timing of cultural operations, and other factors. Sorghum can respond to additional irrigation by stem elongation and increase of yield (Saeed and El-Nadi 1998, Singh and Singh 1995). Nassar, *et.al*. (2000), studied the effect of water interval on forage sorghum, and reported that, prolonging irrigation intervals from 5-10 days caused a depression in growth and yield of forage.

## 2.3 Importance of forage sorghum.

Forage plays important role through the history of mankind .Vegetation in general and forage in particular serve and important functions in the Sudan, the irrigated forage occupy about 121.00 hectares (Khair, 2011).The most important strategic objective in any forage throughout the entire year and especially during the summer months, when drought period occur , or following severe winter killing of perennial forge species ,emergency of summer –annul forage such as sorghum play an important role in the overall forage program .Some of the characteristics of summer annual grasses are :rapid establishment high-yielding capacity in a very short period of time and production of a leafy ,high- quality, nutritious palatable forage that many be grazed or stored as silage or hay (Miller,1984).

An important summer forage in many countries is sorghum, belongs o the family Poaceae, it includes both wild and cultivated species all of which cross easily with one another. Sorghum is believed to have originated in Africa and India .All cultivated types are grouped under the species (*Sorghum bicolor* (L) Moench, this species is divided into sub species bicolor which includes all the domesticated grain sorghum and two wild subspecies .The cultivated sorghum is divided into five basic race :bicolor ,guinea, can datum ,kafir, and dura (Anonymous,2013). Sorghum fodder is a basic feed for livestock; Cattle use sorghum better than sheep. Properly cured sorghum fodder with little protein supplement ill maintain cattle in good condition .Fodder sorghum is utilized as stover, fodder, silage hay and pasture (Mustafa and Abdelmagid, 1982 and Abuswar, 1994).

## 2.4 Genetic diversity of sorghum forage and improvement in the Sudan.

The genetic diversity within the *Sorghum* forms the basis of the thousands of years' natural and farmer/user selection and the grain and forage sorghum breeding programs that have occurred internationally during the last century. In this regard, the Sudanese sorghums have been very useful as sources for traits such as drought resistance (Rosenow.*et.al.*1999).And have been reviewed by Mahmoud *et.al*. (1996).The Sorghum germplasm in Sudan has been utilized extensively in USA and other parts of the world. Apart of karif of southern Africa, no sorghum conducted to the crops current high international status as did Sudan's Feterita, Milo, and Hegari, Mugud, Ziraizeera, and Sudan grass type. In contrast local efforts to exploit such variability to developed improved sorghum feed types have been very limited and mostly directed towards improving food grain types. The first fully devoted forage improvement program in the country started in 2000 (Mohammed, *et.al,* 2008).One of the program objectives was developed improved fodder types from local stock of forage sorghum. Under this program, the first improved forage cultivar “Kambal” (Improved Abu Sab’in) and Sudan-1(Improved Garawi) have been released in year 2004 and 2009.respectively (Mohammed, 2010). There is strong evidence in the literature pointing to the great genetic diversity of *Sorghum* spp. in the Sudan (Bacon, 1948; Tahir, 1964; and Yassin, 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 tolerates a wide range of salinity under which the forage quality is further improved (Khair and Jarrel, 1987). 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), Grawia 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 sudanensis*), the widely cultivated annual forage in the United States is one of the annual “Adar” or Grawia types. As reported by Manuder (1983) its original seed lot had been introduced to the United States from Sudan in 1909 mainly to replace the perennial type Johnson grass.

**Sweet Sorghum Forages:** Ankolib is the general term used for sweet sorghums in the Sudan. Rao and Mengesha (1979) conducted a germplasm collection expedition in eastern Sudan, they reported that Ankolib is Ad*ura 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 is highly recognized for forage and syrup production in other parts of the world (Dwayne, *et al*., 1999).

## 2.5 Problems facing sorghum forages production in the Sudan.

Although, the importance of forage sorghum as a grain crop in the Sudan was stated by many workers, the information on its importance as forage is meager (EL-Ahmadi, 2003). Mohammed (2005) stated that, very few efforts have been exerted to develop improved forage cultivars from local stock. In addition, no evidence in the literature pointing the release of locally developed forage hybrid sorghum in the Sudan. Research work for devolving forage hybrid was only confirmed to introduction and testing of exotic hybrids. Khair (1999) reported that, shortage in forage seeds ,poor knowledge about forage sorghum production technique among farmers ,the method of making up forage into silage or hay are another problems need to be solved. Lack of cultivars with high yield, good quality and well adapted to Sudan environments is the most important problem facing forage sorghum production in the Sudan (Idris and Mohammed, 2012).

## 2.6 Research of sorghum forage in Sudan.

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. 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 AbuSab'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. Mohammed (2001) studied the two varieties of Abu Sabeen, Aliab and Rubatab, and compared them. He found that a wide range of variability could be observed between both populations for flowering time, plant height, juiciness and panicle characteristics, Aliab type was taller and later in flowering compared to Rubatab. Bedawi.*et al*.(1986) studied the effect of sowing methods found that green – chop yield was less from the broadcast plots than from the drilled plots at all harvests from January and October sowings, also he found that no differences between regular rows, double rows and triple rows.

## 2.7 Sorghum forage cultivars grown in Sudan.

According to Bogdan (1977), sorghum type with finer, more numerous and more leafy stems are grown especially for fodder and this is partly supported by House (1985),who gave some plant characteristics to be selected for in forage development as being leafy, good tillering, thin stemmed, juicy sweet, reasonably good grain yield ,palatable, digestible and low in HCN.

The forage sorghum (*Sorghum bicolor* L. Moench (Cultivar Abusabein) is considered as the principal cereal and forage crop grown in the Sudan(Khair,1999 and Abusuwar, 2005), it is grown as an annual summer cereal crop because of its short growing season. The implication of the Arabic name Abusabien is that it matures in about seventy days as stated by (Bacon, 1948). The name of Abusabien is used from two distinct grown in the Northern part of the River Nile State, particularly in Rubatab area, which is usually grown as summer crop, cultivar Dibeikri is the other one which dominates in the southern part of the State particularly in Aliab area and is usually grown as a flood season crop and harvested in about 105 days after sowing (Kambal, 2003). Recently, a new cultivar of Abusabein was released under the name of Kambal for commercial production in Khartoum and Nile States as an irrigated forage cultivar (Mohammed, *et al*, 2008).

Also in the Sudan the major grasses include Sudan grass (*Sorghum sudanensis)* is a recently introduced fodder species by organizations to improve the production of fodder from appropriate plant varieties. Sudan grass is easily grown, usually leafier, has fine stems and tillers extensively, with very quick re-growth (Richard, 2008; Guangyao and Kurt, 2010).It is best used for pasture or in multiple cut systems. Its forage quality will be high due to low fiber content if cut frequently (IITA, 2010). Sudan grass, with a high ability to withstand drought and relatively poor soil fertility, has much promise as forage which can fill the ‘‘gap” of poor yielding ones and is more productive because of its high-yielding capacity and resistance to foliar diseases (Jung and Reid 1996). It is more suited to pasturing than other types of sorghum, and it is more popular for annual hay and late summer (in time of scanty rainfall) pasture offering relief in fodder shortage (Richard, 2008; Guangyao and Kurt, 2010). It is also an excellent pasture plant with no danger of bloat which can be produced under irrigated or dry farming conditions (Richard, 2008).The collected data and research work of forage sorghum hybrid pointed that, hybrids where introduced to Sudan and released by Agricultural Research Corporation (ARC). These cultivars include pioneer 988 (Ishag, 1989), speed feed and Jumbo (Khair., *etal*-1995), Pannar 888 (Nour., *et.al,* 1998). El-

Ahmadi., *et.al*, (2003), observed that, the introduced forage sorghum hybrids have greater dry matter yield as compared to the traditional cultivar Abusabien.

## 2.8 Effect of cutting system and time on forage.

Defoliation of grasses mean the removal of varying amount of top growth frequently including portions of stem as well as leaf (Younger, 1972).Defoliation pattern resulting in the application of various combination of these aspects, determines the productivity and persistence of grasses (Brayan,*et.al.*,2000).High of cutting influence the ratoon capacity of sorghum since it affects both carbohydrates reserves and the number of potential tiller buds in the stubble after harvesting (Ahmed,2013).King *et.al,*(1979) reported that increasing cutting height at initial harvest greatly increased regrowths of ryegrass in terms of increased weight of green chop and attributes this pattern to amount of residual leaf area index after cutting. Crop should be cut 5 – 8 cm high from ground for fast sprouting (Doggett, 1988). Bedawi (1988) reported contradicting results which showed that, tiller density of pioneer and Abu sabeen was significantly greater at 10 cm cutting height compared to 30 cm height. On the other hand, shorter cutting height increased forage green chop yield at the first and second harvest. The quality of forage is directly related to the time of harvest. Many studies evaluating the satiability of varieties for grazing, grass-chop, or silage have involved clipping frequency comparisons. Single cut varieties should be cut at 50% flowering stage. In multi cut varieties first cut taken after 50 - 60 days of sowing. Subsequent cuttings should be taken at an interval of 35 – 40 days. Crop should be cut 5-8 cm high from ground level for fast sprouting (Doggett, 1988).

Zaroug (2005) found that tillers and thinner stems were obtained from row sowing as compared to broad casting which is the normal farmers practice. Abu Sabeen has low regrowths capacity and is suitable for single cut system (Khair, 1999).Sparrow and Masiak (2008) studied the effect of second harvest timing on yield and forage quality of some forage crops and found that, yield increased with increasing time to second harvest. Mc Cormic *et.al*. (1995) reported that, first cut dry matter yields of some sorghum cultivars significantly increased as the plant matured from the mid-vegetative-harvested sorghum. In similar studies also, Atis *et al.* (2012).reported that, there were obvious forage and dry yields reduction in the second growths compared to the first growths at the three cutting systems.

On the other hand, fodder cutting at the flowering stage, ensures a produce with good protein content and the best nutritional value (Hussain, *et al*., 2004), where cutting should be in several times (Multi cut) during the growing season, which increases the amount of production per unit area (Akash and Saoub, 2000; Mosimann, 2004). Suhaibani (2003) found that, the first cut (after 60 days from sowing) produce a largest fodder production than the second cutting, (nearly 30% for both seasons).While the content of dry matter, and crude fiber, increased when fodder cuttings late (Selahattin and Rashid, 2002).

## 2.9 Yield of sorghum forage under various agronomic practices.

Forage yield is influenced by tiller density, plant height, stem diameter, number of leaves and leave area (Ping, *et.al*, 2005).As these agronomic traits increased, forage yield also increased .However, the performance of different forage crops is primarily based on the type of forage based on type of forage crop variety grown as well as prevailing growing environment (Maiti and Soto, 1990).

Early work in the Sudan reported first harvest yields of 71 tons $ha^{-1}$ green–chop from forage sorghum on fertile ground and with heavy irrigation and the second and third harvests adding another 59 tons $ha^{-1}$ (Bacon, 1948). The increase in fresh and dry forage yields was mainly due to greater plant height, number of green leaves per plant, stem diameter, leaves area per plant and number of tillers per plant consequently (Raki *et al.*, 2013).This value have been stated by Sarafa, *et.al* (2012) recorded that, there were a considerable variations in the performance of varieties with respect to years in green forage yield, and this variation due to varietal potential. Anonymous, (2013) found that, the green- chop was 46.8, 36.3 and 16.4 ton/ha for pioneer 988 and 40.8, 29.8 and 13.8for Abusabeen at the first, second and third cut respectively. More recently, lower yields of 8 and 3.9 tons $ha^{-1}$

dry matter have been reported in non–saline and saline soils, respectively (Kambal, 1972; El-Karouri and Mansi, 1980).Fresh and dry matter yield of forage sorghum exceeded that of the leguminous forages especially in the first cut, depending on soil fertility and water, the average fresh yield of forage sorghum was 25-27 tons/ha (Bowman, *et al.*, 2000). Many workers found that, increased seed rate gave maximum yield (Orak and Kavdr, 1994) and also significantly increased the green fodder and dry matter yield (Ayub *et al.*, 2003).

The significant variations among sorghum genotypes for dry matter production have already been reported in studies conducted by Yousef *et al*. (2009), Palta and Karadavut, (2011). Although the crop as forage is very palatable, especially when young and at flowering stage, it should be used carefully because it produces prussic acid which is poisonous to livestock. The risk is high when it is young and under water stress. Toxicity danger varies between cultivars (Bowman *et al.*, 2000). Lower forage yield were obtained when the planting was delayed until the end of October (Abusuwar, 2005). Consistent with Kambal (1983),Who studied the performance of different varieties in different season and found that the dry matter yield of the crop when sown in winter, summer and the rainy seasons were 0.9, 2.8 and 2.0 ton /ha, respectively. While higher yields of 8.8 and 7 tons/ha were obtained when the crop was sown in July and August. Abusuwar and Mohamed (1997), they also reported that nitrogen fertilization significantly increased forage fresh and dry yields of the graminaceous forages for the first and ratoon crops. On the other hand, nitrogen application did not affect growth attributes of these forages for the second crop, except Napier grass. Ahmed, (2016), concluded that, forage yield in sandy soil of north kordofan, had wide range of variation in growth attributes, and yield during dry season and kharif, yields of Abusabin was significantly improved by using seed rate of 71(kg/ha).

## 2.10 Factors affecting sorghum forage quality.

The factors affecting the quality of forage are generally related to the nutritive value of the crop. High nutritive value for most forage 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 (Ahmed, 2007).

For any crop the meaning of quality is difficult to define, for forages, quality has been defined as amount of nutrient material that an animal can obtain from a feed in the shortest possible time (Walton, 1983). Thus the quality reveals the level of nutrient (chemical) composition, palatability and intake, many factors influence forage quality, some of them are forage cultivar, stage of maturity at harvest and storage method. Secondarily environmental factors such as soil type and fertility, day length, temperature during plant growth are also important (Ball, 2000). Abusuwar and Elzilal (2010),concluded that, Summer sowing increased forage productivity and improved quality in cereal forages than winter sowing and they found that, pioneer cultivar seemed to be more nutritious than Abu' Sabein. Also Glamoclija, *et al*. (2011).Observed that, fodder quality of sorghum depends on many factors such as fertilization, irrigation, genotype, plant density and harvesting time. Type of cultivars and soil fertility considered as secondary factors that, affecting sorghum forage quality (Collins and Frtiz, 2003).

In terms of forage quality, therefore, the higher the crude protein (CP), total digestible nutrient (TDN), the lower the Crude fiber (CF), hydrocyanic acid (HCN) and lignin the better quality of the forage material. Fribourg (1985) investigated that, good quality forage has a large leaf to: stem ratio, a large concentration of protein and digestible nutrients and small concentration of fiber and lignin. Walton, (1983) reported that, the digestibility of CP in forages varies widely, ranging from 35 – 80 %. In view of its high digestibility, the percentage of protein in forage is frequently regarded as index of digestibility .Crude protein digestibility is connected to its content in the forage,i.e,the higher crude protein content ,match with higher digestibility (Bogadan,1977).

## 2.11 Quality attributes of sorghum forage.

Fodder quality is of great importance as well as higher forage yield. Quality of sorghum forage genotypes can be improved by harvesting earlier. (Ayub, *et.al*, 2010). Elseed, *et. al.*, (2007) indicated that, forage quality with more leaf material to stem was probably higher for the first cut. Sorghum forages produce a tonnage of dry matter having digestible nutrients (50 %), crude protein (8 %), fat (2.5 %) and nitrogen free extracts (45 %) (Azam *et al*., 2010). 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 .Mohammad, (1989) reported variation in fodder yield, and quality traits of sorghum under diverse environments. With advance in maturity, yield and dry matter production increased whereas crude protein percentage decreased, for the forage sorghum. (Webster.1963).Maximum green fodder yield, acid detergent fiber, forage yield and stover yield were observed at the optimum environment (irrigated) while maximum crude protein was produced under rain-fed conditions. Also Mohammad *et .al* (1990) supported these results, and found a significant differences in sorghum and maize for crude protein, crude fiber ,green fodder yield and dry matter yield due to different genotypes and locations. The forge quality of different species or cultivar may vary significantly .This is attributed to difference in anatomy, morphology and chemical composition. Leafier genotypes have significant digestibility (Reddy *et.al*, 2002). Ayub *et al.* (2010) and Abusuwar and Hala (2010) also confirmed that there was a significant difference among sorghum varieties regarding crude fibre. Mohamed, *et al.* (1988) stated that crude fibre and non structural carbohydrate content were higher at higher seeding rate. The forage quality of different species or cultivars of the same species may vary significantly; this is attributed to differences in anatomy, morphology and chemical composition (Reddy, 2002). Silungwe, (2011) found, a significant differences among sorghum forage cultivars in crude protein percentage. Also the significant differences among sorghum forage genotypes have been reported by many workers (Carmi *et al*. (2006); Miron *et al*. (2007) and Tauqir *et al*. (2009). Sen (1952) reported that, the composition of herbage changes with the season. The significant differences in ether extractable fat percentage among the sorghum cultivars have also been reported by Ayub *et al*. (2002). Differences among sorghum cultivars for ash contents have been reported by Mehmud *et al*. (2003) and Ayub *et al*. (2002).

### 2.1.2 Growth attributes of forage sorghum and phenology.

Planting density and irrigation were important agronomic factor in fodder production which largely influences sorghum growth (Cho *et al*. 2001).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 plant height, generally taller plants yielded more than short types (Stickler and Younis, 1966). Bhattis, *et al.* (1991) reported that, taller plants produced more number of leaves/plant.

Environmental conditions caused variation in the hormonal balance and cell division rate that resulted in changes in the plant height of the different varieties. Sartaj *et al.* (1984).Okiyos *et al.* (2011) found that highest plant height was recorded on watered in comparison to no water treatment. Saeed and El-Nadi (1998) found that plant height of forage sorghum decreased at heavy infrequent irrigation in comparison to other two regimes. 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 AbuSab'in was 173 cm. Yield components that contributed most to the high yield of Abu Sab'ins are stem height and thickness. Elamin, (1980) found that plant height in forage sorghum increased with nitrogen fertilization and reduction of irrigation intervals from 15 to 7 days. Ahmed, (2016), reported that, high estimates of plant height and leaf area produced by the seed rate (36 Kg/) in sandy soil.

Green leaves play an important role in the vegetative habits of plants. In this respect forage sorghum plants are larger and leafier compared to grain sorghum (Bowman, *et al*., 2000). Thus an increase or decrease in number of leaves per plant has a direct effect on the green forage yield of forage crops (Afzal, *et.al*, 2013). In an experiment carried at Shambat, Kambal (1972) reported, an average of 14.1 green leaves for Ankolib and 12.5 green leaves for AbuSab'in. In several studies, Reddy and Hussein (1968) reported that the difference in the mean number of leaves per plant due to nitrogen at various levels were not statistically significant. Furthermore, they found that, seed rate significantly influenced the number of leaves per plant. Olanite *et al*. (2010), Samia *et al*. (2010), Akram *et al.*, (2010), and Khalid *et al*., (2010), reported that, numbers of leaves per plant are more in line sowing as compared to broad cast due to better resources available in line sowing to the crop plant. Significantly higher number of leaves per plant in sole crop of sorghum might be due to low plant population which resulted less competition among the plant to utilized resources for growth and minimum number of leaves per plant was due to more population and less availability of space for CO2. Number of leaves per tiller is an important growth factor and yield component that affects the second harvest of sorghum forage (Shakoor *et.al.*, 1983). They observed that, leaves and tiller had positive relationship with plant height i.e. taller plants produced more leaves/tiller and vice versa. Difference in number of leaves /tiller due to varieties was indicated by Faridullah, (2010).

Leaf to stem ratio of forage sorghum is vital for forage yield and quality. Leaf and stem biomass increased, the leaf to: stem ratio deceased with maturity, the leaf to stem ratio decreased because there is higher increase in proportion of the stem than the leaf, this decrease in L: S ratio partly explains why there is a decrease in quality with maturity. (Khallah, 1981). Njamba, (1998), supported that, the leaf to stem ratio decreased with maturity, the vegetative growth had the highest leaf to: stem ratio, while the grain filling stage had the lowest. High temperature reduced leaf to stem ratio (Lascano, *et.al*., 2001).Abd-Elbakheit (2007), found that, leaf to stem ratio for Abu Sabin was slightly higher than that of Sudan grass .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, (1999).

### 2.1.3 Effect of irrigation interval on growth and yield attributes of forage 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. Saeed (1984) showed that soil moisture increased with decreasing the irrigation interval. Similar results were reported by Mansour (1981).Aishah *et al.* (2011) reported that the irrigation frequency was found to affect growth and yield of the forage sorghum. However, Abdalla, *et.al*. (2004) found that the narrow irrigation recorded insignificant increases in growth and forage yield except number of tiller/unite area in both cuts. Plant heights and leaf area index of forage sorghum were higher in the frequently watered plots than in plots where irrigation water was delivered less frequently. Results suggest that in such semiarid environments, WUE of forage sorghum could be increased by combining light irrigation with a short interval (Saeed and El-Nadi 1998). The irrigation intervals had a significant effect on the yield and yield component of forage sorghum (Moosavi, *et.al,* 2011).Atem (2007) concluded that, forage fresh and dry weights produced under irrigation every seven days were higher than those under irrigation every ten days. This was, also reflected in higher average growth rate/day.

Generally tall plants yielded more than short types (Casady, 1965). Elamin, (1980) found that plant height in forage sorghum increased with nitrogen fertilization and reduction of irrigation intervals from 15 to 7 days. Whitt and Van Bavel (1982), also, reported that, plant height of sorghum increased with decreasing irrigation frequency and interval, which means more moisture in the root zone. Plant height differed significantly due to genotypes and irrigation regimes. (Sher, 2013). Okiyo *et al.* (2011) reported that, there was significant interaction between genotypes and water treatments for plant tallness. Nassar, *et.al*, (2000), noticed that widening the irrigation intervals led to increase the water use efficiency. Plant heights and leaf area indices of forage sorghum were higher in the frequently watered plots than in plots where irrigation water was delivered less frequently.LAI reduction under water deficit condition is a main reason for forage yield reduction (Moosavi, *et.al*. 2011).While Saeed and El-Nadi (1998) stated that, leaf area of forage sorghum decreased at heavy infrequent irrigation in comparison to other two regimes.

In other works Saifullah *et al.* (2011) stated, no variation in number of tillers per plant among the varieties but only irrigation level significantly affected. Similar findings reported by Sher, (2013) who stated that, number of tillers differed significantly due to genotypes, maximum number of tillers registered at high water regime.

Other findings, Asgharipour and Mahmood, (2011) reported maximum stem diameter at different irrigation regimes, and Abdelmula and Salih (2007) found significant differences among genotypes in stem diameter under well water conditions. Mustafa, *et al*. (1982), in similar studies reported that, dry matter of forage sorghum increased with the decrease in irrigation interval which means enough moisture, was available in plant roots.

Further works Mohammedien,(2005) found that, in fodder maize less frequent irrigation (14 days) resulted in remarkable reduction in the attributes of vegetative growth e.g. plant height, number of leaves, stem diameter; this reduction was naturally reflected in lower fresh and dry matter yield. The best water use efficiency and relative growth for fodder maize was recorded for frequent irrigation (7 days) intervals and lower water use efficiency, relative growth at infrequent irrigation (14 days). Moosavi, *et.al,* (2011) reported that, the irrigation intervals had a significant effect on the leaf to stem ratio and protein yield, the comparison, mentioned that, increase of irrigation intervals, caused an increase in leaf to stem ratio but protein yield decreased significantly.

# CHAPTER THREE
# MATERIALS AND METHODS

## 3.1 Experimental site and plant material.

Field experiments were conducted in the Demonstration Farm of Crop Sciences Department, Faculty of Natural Resources and Environmental Studies, University of Kordofan, at Sheikan locality latitude (11-15$^{\circ}$) and (16-30$^{\circ}$) N and longitude (27-32$^{\circ}$) E for two successive rainy seasons (2014/015 and 2015/016) and for two successive irrigated winter seasons (2014/016 and 2015/016).The climate of the area is arid and semi-arid. The soil is sandy, annual rain fall ranges between 350-450 mm (Ahmed, 2009). Average maximum daily temperature ranges between 30-40 C$^{o}$ throughout the year.

The plant material used in this study consisted of ten different genotypes of forage sorghum, six local tested sorghum genotypes were selected from “Zinnari ”,namely Taqqat.7B, Taqqat.9A Taqqat.5A, Gasabi, Geshaish and Nabig these were early to medium maturing genotypes which were collected from Khortaqqat area, North Kordofan State, and three genotypes which were cultivated in the irrigated area include:-Pioneer (introduced hybrid), Abu70-Aliab from Hudeiba (ARC) and Sudan grass “Grawia” obtained from Sudanese Arab Seed company (ASSCO),which represent the improved sorghum forages, and Aish-Baladi which was collected from Merowi area.(Table3.1).

## 3.2 Experimental layout and implementation.

### 3.2.1 Rain-fed experiments.

The ten genotypes genotype forage sorghum were arranged in a Randomized Complete Block Design (RCBD) with three replications. The plot size was (3×3) $m^2$ consisted of four rows. Sowing was on 10$^{th}$ of July, 2014 and 20$^{th}$ of July 2015(according to the effective rains). The crop was sown manually on line 70 cm apart with seed rate of 30 kg/fed. Manual weeding was practiced three times during both seasons. Measurements of vegetative growth attributes were carried on sample size of ten plants chosen randomly from the two inner rows when plants reached 50% flowering, with yield attributes.

### 3.2.2 Irrigated (winter season) experiments.

The field experiment was conducted under irrigated conditions in winter and its layout was randomized complete block design (RCBD) in a split - plot arrangement with three replications. The treatments consisted of two water irrigation intervals (7 and 10 days, designated as $W_1$, and $W_2$ respectively), and the 10 forage sorghum genotypes. Irrigation interval treatments were assigned to the main plot whereas genotypes treatments were assigned to the sub –plot, land was disc harrowed and leveled. The individual plot size was (2×2 $m^2$) and 70 cm apart consisted of three rows. The main plots were isolated by the guard area of 1.5 m apart to avoid lateral movement of irrigation water or lateral precipitation to adjacent experimental plots. The irrigation adopted in this trial was surface irrigation out, and was applied by using pumping machine through a valve and tube of 2-inches diameter and the amount of irrigation water was added at the rate of 50 mm /irrigation, according to (F.A.O, 2012) recommendation. The total amount of irrigating water for the first irrigation treatment was 550 mm, while the second one was 400 mm (Table 3.2). The crop was sown manually on 1st of February 2015 and 2016. Manual weeding was practiced two times during both seasons; the first one was after two weeks from sowing and the second weeding after a month from the first. Irrigation water was equally applied at seven days intervals to all experimental plots for establishment of plants till they were 21 days old. Irrigation intervals treatments were applied thereafter.

**Table 3.1**Origin of **10** genotypes used in the study.

| Entry | Genotype name | Origin |
|---|---|---|
| 1 | Taqqat.9A | Local tested genotype collected from Taqqat area. |
| 2 | Pioneer | Introduced hybrid. |
| 3 | Taqqat.7B | Local tested genotype collected from Taqqat area. |
| 4 | Aish –Baladi | Local genotype collected from Merowi area. |
| 5 | Abu70 (Aliab) | ARC-Hudeiba. |
| 6 | Taqqat.5A | Local tested genotype collected from Taqqat area. |
| 7 | Nabig | Local tested genotype collected from Taqqat area. |
| 8 | Sudan grass “Grawia” | ASSCO. |
| 9 | Geshaish | Local tested genotype collected from Taqqat area. |
| 10 | Gasabi | Local genotype. |

**Table 3.2** Total numbers of applied irrigations for the two irrigation treatments.

| Watering interval Treatments | Before Treatment were applied | After treatment were applied | No.of irrigation | Total amount of irrigation water |
|---|---|---|---|---|
| $W_1$ | 3 | 8 | 11 | 550 mm |
| $W_2$ | 3 | 5 | 8 | 400 mm |

$W_1$: for irrigation interval 7 days. $W_2$: for irrigation interval 10days.

## 3.3 Data collection.

**Vegetative growth parameters.**

The vegetative parameters were measured at 50 % flowering stage. A random sample of ten plants was selected from inner rows during both rainy and irrigated experiments to measure the followings:-

**Plant height (cm).**

It was measured from soil surface to the tip of the main panicle.

**Stem diameter (cm).**

It was measured by using a Vernier (caliper) at the third internode.

**Number of leaves/plant.**

Was determined by counting all number of leaves per plant at flowering stage.

**Number of tillers/plant.**

Were obtained before the second cut (30 days) by counting the number of tillers for the five selected plants and then the average was calculated.

**Number of leaves/tiller.**

This character was determined by counting and summation of the number of leaves per each tiller in the plant, and then the averages were calculated.

**Leaf area index (L.A.I)**

Leaf area index (L.A.I), a dimensionless quantity, is the leaf area (upper side only) per unit area of soil below. It is expressed as $m^2$ leaf area per $m^2$ ground area. Leaf area was determined using the following formula:-

Leaf area = maximum leaf length x maximum leaf width x (0.75*).*

Maximum leaf length was measured from the base of leaf blade up to its tip while maximum leaf width was estimated from the middle of the leaf blade. These calculations were taken from upper (flag), middle, and the lower leaf and average was estimated, and then the average was multiplied by the number of leaves per plant, according to Stickler *et al*. (1961). And leaf area index (L.A.I) was determined as follows:

$$\text{Leaf area index (L. A. I)} = \frac{\text{Leaf area per plant}}{\text{Plant ground area}}$$

**Number of Days to 50 % flowering.**

Days to 50% flowering were recorded as the number of days from the effective sowing date to the day on which 50% of the plants in a plot reached anthesis at least halfway down the panicle.

## 3.3.2 Yield attributes:-

**Fresh forage yield (g/plant).**

Was estimated two times from five tagged plants at 50% flowering and at 30 days from first cutting. The harvest process was done to the whole plant (15 cm from ground level), and the yield from the harvesting was recorded as (g) plant.

**Dry forage yield (g/plant).**

The yield of every cut mentioned above was subjected to sun drying and separately weighed to gain the dry forage yield at every cut.

**Fresh forage yield (ton/ha).**

It was calculated by harvesting one meter length from central rows; cutting was practiced at 15 cm above soil surface in each plot, and then weighed immediately in the field by using a spring balance, and final fresh weight expressed in ton/ha.

**Dry forage yield (ton/ha).**

The green forage cut of the one meter was sun dried for three weeks and weighed by spring balance again to get the dry forage yield (ton / ha).

**3.3.2.5 Dry matter percentage.**

The percentage of the dry matter was recorded by the dry matter % of the respective plots computed by using the following formula :( Herrera, 2006):-

Dry matter (%) = (Dry forage yield / Green forage yield) ×100.

**Leaf to stem ratio.**

Five plants were cut from each plot and leaves were detached out from the main stems, leaves and stems were sun dried and then weighed separately to determine leaf to stem ratio as follows :-

$$\text{Leaf to stem ratio } (LSR) = \frac{\text{mean of leaves dry weight}}{\text{mean of stems dry weight}}.$$

### 3.3.3 Quality determination.

Fodder samples collected at 50 % flowering stage from experiments were analyzed for proximate composition according to AOAC (1990).The laboratory analysis was carried out at laboratory of animal research center (Hillat Koko) Khartoum during 2014/015-2015/016 to determine the following measurements:-

#### 3.3.3.1 Determination of dry matter (dm %).

A dry crucible was placed in a forced- draught oven for a minimum of 1 hour, and transferred to desiccators and allowed to cool at room temperature and then weighed, then accurately. The weight of 5 (g) sample was put in a dish and was heated in the drying oven at 105 $C^{\circ}$ for 12 hours to remove moisture from the sample, the dish with the sample was removed from the oven and placed in desiccators to cool, then was reweighed to get the dry weight.

Calculations:

$$\text{Dry matter } \% = \frac{(\text{Wt of the dried sample +dish}) - (\text{Wt of the dish})}{(\text{Wt of original sample})} \times 100.$$

#### 3.3.3.2 Ash determination (ash %).

A metal dish was cleaned and heated for 1 hour in an oven, cooled and weighed. Exactly weight of 5 (g) in to the dish was taken and placed in muffle furnace and then ashed the sample at 550 $C^{\circ}$ for 14 hours to burn off all organic material, then the muffle was turn off and leave to cool , the dish was removed from muffle and transfer to desiccators to cool, then was reweighed. Ash content was calculated using the following formula:-

$$\text{Ash } (\%) = \frac{(\text{Wt of ash + dish}) - (\text{Wt of dish})}{(\text{Wt of original sample 5gm})} \times 100$$

### 3.3.3.3 Determination of crude protein (CP %).

As per semi – micro kjeldal distillation method, accurate weight of 0.5 g dried sample weighted was transferred to kjeldal flask digestion of 10 ml of concentrated. Sulphuric acid then, the flask was placed in the digestion unit, brought to temperature of 350 $C^{\circ}$.The reaction became black due to the dehydration action of sulfuric acid and the formation of free carbon and the contents were digested for 1.5 – 2 hours until color changed to light or colorless. The flask was removed from the digestion block and allowed to cool, 20 ml of distilled water was added to digestion flask and then transferred to 75 ml kjeldal tube and diluted to volume of distilled water which was treated with 3 ml of Na OH solution and distilled ammonia was received into 10 ml of boric-acid plus indicator (2-3 drops of methyl red) in 50 ml a conical flask, then and started heating for 3 minutes to collect ammonia steam ($NH_3$). The titration of the distillated ammonia started against standard acid (0.01 N – HCL) until the color changed to light pink with end point occurring.

Calculations:-

$$CP\,\% = \frac{(Titrate - Blank)}{(Standard - Blank)} \times \frac{75\,ml}{3\,ml} \times \frac{1}{0.5\,g} \times 6.25 \times \frac{1}{1000} \times 100.$$

### 3.3.3.4 Determination of ether extractable fats (E.E %).

A dry sample empty extraction flask was weighed ,Exactly 2.5 g of sample was weighed into thimble free from fat and covered with cotton wool to the top to stop loss of sample and the thimble was inserted in extractor tube , 100 ml of petroleum spirit was added to the volume of 250 ml in the flask and was attached to the apparatus, heat was adjusted to produce regular boiling, the extraction was carried out for 5 hr with petroleum spirit boiling point (60 – 80 $C^{\circ}$).The thimble was placed to collect evaporated solvent for re-distilling, then extraction flask was moved to oven (105 $C^{\circ}$) till drying was complete and cooled in desiccators .Weight of the fat content was calculated using the following equation :-

$$\% \text{ Crude fat (EE \%)} = \frac{(\text{Wt of the flask + oil}) - (\text{Wt of flask})}{\text{Wt. of original sample (2.5 g).}} \times 100$$

### 3.3.3.5 Crude fiber determination (CF %).

About 1 g of dried ground herbage was weight and transferred carefully to numbered 500 ml conical quick-fit flask. 100 ml of acid detergent fiber (A.D.F) was added, the mixture was rapidly brought and boiled exactly for 1 hour, the contents were filtrated by using vacuum pump, then inserted into glass crucible and fiber was washed on the crucible with minimum 200 ml of hot distillated water, the crucible and contents were dried over night at 105 C° in an oven, allowed to cool in desiccators and weighed. The residues was ashed in muffle furnace at 550 C° for 4 hours till alight grey ash was formed ,then the crucible was removed from furnace when the temperature was (100C°) and put in desiccators to cool to get the weight of the crucible + ash. Calculations:-

$$\text{CF \%} = \frac{(\text{Wt of crucible +dried residues}) - (\text{Wt of crucible + ash})}{(\text{Wt. of the original sample 1g}).} \times 100$$

## 3.4 Statistical Analysis Procedure:

The data recorded on various morphological traits, yield and its components, and quality traits were statistically analyzed using (RCBD) with three replications and by statistical package for spilt – plot trial ,as described by Gomez and Gomez (1984), using computer program (MSTATC), Duncan’s multiple range test was used to separate the differences between treatment means.

# CHAPTER FOUR
# RESULTS

## 4. Rainy Experiments.

### 4.1 Growth attributes.

#### 4.1.1 Plant height (cm).

The analysis of variance showed that, plant height (cm) was significantly different between the different genotypes in both seasons (Table.1).The highest plant heights (159.9 and 149.1cm) were recorded by Pioneer and Nabig genotypes followed by Grawia during the 1$^{st}$ season. However' hybrid Pioneer had higher plant height of (172.5 cm) than other genotypes during 2$^{nd}$ season. While the lowest plant heights of (92.0 and 100.1cm) were observed by genotype Taqqat.9A in both seasons. Generally the 2$^{nd}$ season, had higher means of plant height (cm) compared to the 1$^{st}$. (Appendices 1and 2).

#### 4.1.2 Stem diameter (cm).

Significant differences were observed among sorghum genotypes for stem diameter (cm) in both seasons (Table 1).The maximum stem diameter was given by Taqqat.5A (1.90 cm) followed by Taqqat.7B, Taqqat.9A and Pioneer in the 1$^{st}$ rainy season, whereas Taqqat.7B had highest stem diameter (1.70 cm) in the 2$^{nd}$ season followed by Pioneer and Grawia. The minimum stem diameter was obtained by Aish-Baladi in both seasons (1.23 and 1.25 cm) successively. The mean of stem diameter was relatively higher in 1$^{st}$ rainy season than 2$^{nd}$ seasons (Appendices 1and 2).

#### 4.1. 3 Number of leaves /plant.

Analysis of variance revealed a significant difference in number of leaves/plant, in the two seasons, local sorghum forage Taqqat.7B and Taqqat.5A produced maximum number of leaves per plant (12 and 11.7) respectively followed by hybrid Pioneer during 1st rainy season, while hybrid forage cultivar Pioneer, had highest number of leaves per plant in the 2nd rainy season, (10.70) followed by Taqqqat.7B, Abu70 (Aliab), Grawia and Taqqat.9A, in comparison with other genotypes. Also the results showed that, local sorghum forage Aish-Baladi produced (7 and 6) less number of leaves/plant during both years (Table.1). The mean of number of leaves was relatively higher in the first season than the second (Appendices 1and 2).

### 4.1.4 Number of tillers/plant.

Differences among studied genotypes were found in number of tillers per plant during 1st rainy season (Table 2), local genotype Geshaish had a higher number of tillers per plant (2.33), followed by Gassabi and Pioneer. Whereas the lowest value (1.1) was recorded by Abu70. Although the data of 2nd rainy season were not significant, the mean number of tillers per plant in the 2nd season was better than the 1st season, (Appendices 1and 2).

### 4.1.5 Number of leaves /tiller.

Statistical analysis of the data revealed that, differences in number of leaves per tiller were significant (Table 2). In the 1st rainy seasons, local tested genotype Geshaish produced maximum number of leaves/tiller (9.78) followed by Gassabi and Taqqat.9A.Genotypes. Grawia, Nabig and Taqqat.5A had the highest number of leaves per tiller (19.0, 18.0, and 18.67) respectively during 2nd rainy season, followed by Geshaish and Gassabi, while genotype Abu70 (Aliab) produced minimum number of leaves per tiller (4.20) during both seasons. The mean number of leaves per tiller was relatively higher during 2nd rainy season than the first one. (Appendices 1 and 2).

### 4.1.6 Leaf area index (L.A.I).

Leaf area index, showed highly significant differences for the two rainy seasons (Table.3), maximum (L.A.I), was recorded by local genotypes Nabig (2.6) and

Taqqat.7B (2.5), followed by Grawia and Abu 70 (Aliab) in $1^{st}$ rainy season. Also genotypes Pioneer and Taqqat.7B produced maximum (L.A.I) during the $2^{nd}$ rainy season (2.0 and 1.9) respectively, whereas local genotypes Aish-Baladi and Gassabi recorded minimum L.A.I of (1.1 and 1.2) and (1.0 and 0.9) over the two rainy seasons respectively. The mean of leaf area index was relatively highest in the first rainy season (Appendices 1and 2).

### 4.1.7 Number of days to 50% flowering.

Results indicated significant differences among genotypes in number of days to 50 % flowering during the two rainy seasons (Table.2).The genotypes Grawia, Taqqat.5A,Abu70(Aliab), Taqqat7B and Pioneer took more days to reach 50 % flowering (76,76,71,76 and 75 days ) respectively during the $1^{st}$ rainy season . While the genotypes Grawia, Taqqqt.5A, Taqqa7.B, and Pioneer showed the same results (74, 72, 74 and 72 day) in the second rainy season respectively. The genotypes Geshaish and Aish-Baladi were the earlier to flower (50 and 54 day) in both seasons (Appendices 1and 2).

## 4.2 Yield attributes.

### 4.2.1 Fresh forage yield (g/plant).

The analysis of variance showed that, there were significant differences in fresh forage yield /plant (g) for the two seasons, (Table 3). The highest value was given by local genotype Nabig (120.5 g) followed by genotypes, Taqqat.7B and Geshaish in the $1^{st}$ rainy season. While in the $2^{nd}$ season hybrid genotype (Pioneer) had the same result (120.5g), followed by Grawia, Nabig, Taqqat.5A, Abu70 (Aliab) andTaqqat.7B.

The lowest value was given by genotype Aish-Baladi (37.3g) during the $1^{st}$ season. However, in the $2^{nd}$ season, the lowest value was obtained by genotypes: Gassabi, Geshaish and Taqqat.9A which attained 30, 30 and 33g respectively. The mean of fresh yield was greater in season (2014/2015), than that obtained during the rainy season (2015/2016) (Appendices 1and 2).

**Table** 1.Effect of genotypes on plant height, stem diameter and number of leaves per plant of fodder sorghum (*Sorghum bicolor* L. Moench) grown during rainy seasons (2014/2015-2015/2016).

| | Rainy Season (2014/2015). | | | Rainy Season (2015 / 2016). | | |
|---|---|---|---|---|---|---|
| Treatment (Genotypes) | Plant height (cm). | Stem diameter (cm) | No. of Leaves/plant | Plant height (cm) | Stem diameter (cm) | No. of Leaves/plant |
| Taqqat.9A | 92.0$^{e}$ | 1.7 $^{abc}$ | 10.0 $^{c}$ | 100.1 $^{e}$ | 1.6 $^{d}$ | 9.7 $^{ab}$ |
| Pioneer | 159.9 $^{a}$ | 1.7 $^{abc}$ | 11.0 $^{b}$ | 172.5 $^{a}$ | 1.7 $^{a}$ | 10.7 $^{a}$ |
| Taqqat.7B | 109.0 $^{cd}$ | 1.8 $^{ab}$ | 12.0 $^{a}$ | 128.7$^{bcde}$ | 1.7 $^{a}$ | 10.3 $^{ab}$ |
| Aish –Baladi | 97.6 $^{de}$ | 1.2 $^{e}$ | 7.7 $^{e}$ | 105.7 $^{e}$ | 1.3 $^{f}$ | 7.3 $^{d}$ |
| Abu70(Aliab) | 116.3 $^{c}$ | 1.7 $^{bc}$ | 10.7 $^{bc}$ | 141.5 $^{bcd}$ | 1.5 $^{de}$ | 10.0 $^{ab}$ |
| Taqqat.5A | 106.7 $^{cd}$ | 1.9 $^{a}$ | 11.7 $^{a}$ | 116.0 $^{de}$ | 1.6 $^{bc}$ | 9.3 $^{abc}$ |
| Nabig | 149.1 $^{a}$ | 1.7 $^{bc}$ | 10.7 $^{bc}$ | 148.4 $^{abc}$ | 1.6 $^{cde}$ | 8.7 $^{bcd}$ |
| Grawia | 131.6 $^{b}$ | 1.7 $^{abc}$ | 10.0 $^{c}$ | 154.3 $^{ab}$ | 1.7 $^{ab}$ | 10.0 $^{ab}$ |
| Geshaish | 104.9 $^{cd}$ | 1.6 $^{cd}$ | 10.7 $^{bc}$ | 125.1 $^{cde}$ | 1.6 $^{cd}$ | 8.7 $^{bcd}$ |
| Gassabi | 100.9 $^{de}$ | 1.4 $^{de}$ | 9.0 $^{d}$ | 113.0 $^{e}$ | 1.5 $^{e}$ | 7.7 $^{cd}$ |
| Grand mean | **116.79** | **1.6** | **10.3** | **130.53** | **1.6** | **8.2** |
| SE± | 2.03 | 0.04 | 0.12 | 4.72 | 0.038 | 0.30 |
| C.V% | 5.45 | 7.26 | 3.58 | 11.43 | 7.74 | 10.17 |

* Values having the same letters are not significantly different at5% levels according to Duncan΄s multiple range test (DMRT).

**Table** 2. Effect of genotypes on number of tillers per plant, number of leaves per tiller and days to 50% flowering of fodder sorghum (*Sorghum bicolor* L. Moench) grown rainy during seasons (2014/2015-2015/2016).

| | Rainy Season (2014/2015). | | | Rainy Season (2015 / 2016). | | |
|---|---|---|---|---|---|---|
| Treatment (Genotypes) | No.of tillers/plant | No.of Leaves/tiller | Days to50% flowering | No.of tillers/plant | No.of Leaves/tiller | Days to50% Flowering |
| Taqqat.9A | 1.8 $^{abcd}$ | 8.4 $^{ab}$ | 65.0 $^{b}$ | 3.0 $^{a}$ | 13.7 $^{bc}$ | 62 $^{b}$ |
| Pioneer | 1.9 $^{abc}$ | 7.1 $^{bc}$ | 75.0 $^{a}$ | 3.0 $^{a}$ | 13.3 $^{bc}$ | 72 $^{a}$ |
| Taqqat.7B | 1.2 $^{de}$ | 6.7 $^{bc}$ | 76.0 $^{a}$ | 3.0 $^{a}$ | 16.7 $^{ab}$ | 74 $^{a}$ |
| Aish –Baladi | 1.3 $^{cde}$ | 5.0 $^{cd}$ | 54.0 $^{cd}$ | 2.0 $^{a}$ | 10.7 $^{cd}$ | 50 $^{c}$ |
| Abu70(Aliab) | 1.1 $^{e}$ | 4.2 $^{d}$ | 71.0 $^{a}$ | 2.0 $^{a}$ | 8.3 $^{d}$ | 63 $^{b}$ |
| Taqqat.5A | 1.3 $^{cde}$ | 6.7 $^{bc}$ | 76.0 $^{a}$ | 3.0 $^{a}$ | 18.7 $^{a}$ | 72 $^{a}$ |
| Nabig | 1.5 $^{bcde}$ | 6.3 $^{bcd}$ | 65.0 $^{b}$ | 3.0 $^{a}$ | 18.0 $^{a}$ | 63 $^{b}$ |
| Grawia | 1.3 $^{e}$ | 6.5 $^{bcd}$ | 76.0 $^{a}$ | 3.0 $^{a}$ | 19.0 $^{a}$ | 74 $^{a}$ |
| Geshaish | 2.3 $^{a}$ | 9.8 $^{a}$ | 53.0 $^{d}$ | 3.0 $^{a}$ | 16.7 $^{ab}$ | 53 $^{c}$ |
| Gassabi | 1.9 $^{ab}$ | 7.8 $^{ab}$ | 59.0 $^{c}$ | 4.0 $^{a}$ | 16.0 $^{ab}$ | 55 $^{c}$ |
| Grand mean | **1.2** | **6.9** | **67.0** | **2.9** | **15.0** | **65.00** |
| SE± | 0.16 | 0.39 | 0.94 | 0.18 | 0.67 | 0.85 |
| C.V% | 22.04 | 18.35 | 4.41 | 19.57 | 14.11 | 4.20 |

* Values having the same letter are not significantly differing at 5% levels according to Duncan´s multiple range test (DMRT).

### 4.2.2 Dry forage yield (g/plant).

The differences among sorghum forage genotypes with respect to dry forage yield per plant (g) in both rainy seasons were significant (Table.3). The highest value of dry forage yield /plant the 1$^{st}$ was recorded by Nabig (41.0 g) followed by hybrid cultivar Pioneer (40.9 g). While cultivar Pioneer had the highest dry weight (33.0 g) in the second season compared to others, whereas the local genotype Asih-Baladi had the lowest values in both seasons, (16.3 and 10.3 g) respectively, followed by Gassabi and Geshaish in the 2$^{nd}$ rainy season. The mean of dry forage yield per plant of the 10 sorghum forage genotypes was higher during 1$^{st}$ season (Appendices 1and 2).

### 4.2. 3 Fresh forage yield (ton/ha).

Data regarding fresh forage yield (ton/ha) during the two rainy seasons showed, significant differences among genotypes (Table 4).Maximum fresh forage yield of (26.50ton/ha) was recorded by the hybrid cultivar Pioneer, followed by Nabig (23.28), Taqqat.5A(20.39) and Taqqat.7B(18.00) during the rainy season (2014/2015). Also cultivar Pioneer produced highest fresh forage yield (ton/ha) (21.31) during the 2$^{nd}$ season, followed by genotypes Taqqat.7B (17.90), Nabig (16.44), and Taqqat.5A (16.12) compared to the other genotypes. The lowest fresh forage yield (ton/ha) was produced by local genotype Gassabi, Taqqat.9A, Aish-Baladi and Geshaish, (10.44, 10.78, 12.65 and 13.22) respectively in 1$^{st}$ season. In contrast, minimum fresh forage yields (ton/ha) in the 2$^{nd}$ season (5.29, 6.47 and 7.23) were recorded by genotypes Gassabi, Aish-Baladi and Geshaish, respectively. Seasonality effect has produced (16.8 ton/ha). There was higher fresh forage yield (ton/ha) during the 1$^{st}$ rainy season than the 2$^{nd}$ season (12.8 ton/ha) (Appendices 1and 2).

### 4.2.4 Dry forage yield (ton/ha).

Data represented in Table.4 revealed that, the genotypes had significant difference

**Table 3**. Effect of genotypes on leaf area index (L.A.I), fresh forage yield (g/plant) and dry forage yield (g/plant) of fodder sorghum (*Sorghum bicolor* L. Moench) grown during rainy seasons (2014/2015-2015/2016).

| | Rainy Season (2014/2015). | | | | Rainy Season (2015 / 2016). | | |
|---|---|---|---|---|---|---|---|
| Treatment (Genotypes) | L.A.I | F.F.Y (g/plant) | D.F.Y (g/plant) | | L.A.I | F.F.Y (g/plant) | D.F.Y (g/plant) |
| Taqqat.9A | 1.9 $^{c}$ | 66.7 $^{e}$ | 27.7 $^{g}$ | | 1.2 $^{cd}$ | 33.0 $^{c}$ | 13.3 $^{bc}$ |
| Pioneer | 2.2 $^{bc}$ | 98.3 $^{bc}$ | 40.9 $^{b}$ | | 2.0 $^{a}$ | 120.5 $^{a}$ | 33.0 $^{a}$ |
| Taqqat.7B | 2.5 $^{a}$ | 112.0 $^{b}$ | 36.0 $^{d}$ | | 1.9 $^{ab}$ | 66.7 $^{b}$ | 29.7 $^{ab}$ |
| Aish –Baladi | 1.1 $^{d}$ | 37.3 $^{f}$ | 16.3 $^{j}$ | | 1.0 $^{d}$ | 43.3 $^{c}$ | 10.3 $^{c}$ |
| Abu70(Aliab) | 2.4 $^{b}$ | 77.7 $^{de}$ | 34.8 $^{e}$ | | 1.5 $^{abc}$ | 63.3 $^{b}$ | 20.3 $^{abc}$ |
| Taqqat.5A | 2.3 $^{bc}$ | 90.7 $^{cd}$ | 37.0 $^{c}$ | | 1.5 $^{abc}$ | 66.7 $^{b}$ | 22.7 $^{abc}$ |
| Nabig | 2.6 $^{a}$ | 120.5 $^{a}$ | 41.0 $^{a}$ | | 1.6 $^{abc}$ | 66.7 $^{b}$ | 23.0 $^{abc}$ |
| Grawia | 2.4 $^{b}$ | 84.7 $^{cde}$ | 34.4 $^{f}$ | | 1.3 $^{bcd}$ | 76.7 $^{b}$ | 23.0 $^{abc}$ |
| Geshaish | 2.0 $^{bc}$ | 110 $^{b}$ | 20.9 $^{h}$ | | 1.2 $^{cd}$ | 30.0 $^{c}$ | 10.3 $^{c}$ |
| Gassabi | 1.2 $^{d}$ | 73.7 $^{de}$ | 19.7 $^{i}$ | | 0.9 $^{d}$ | 30.0 $^{c}$ | 10.3 $^{c}$ |
| Grand mean | **2.1** | **78.92** | **30.9** | | **1.4** | **59.6** | **19.7** |
| SE± | 0.07 | 2.51 | 0.15 | | 0.07 | 2.1 | 0.2 |
| C.V% | 11.28 | 10.07 | 1.50 | | 20.66 | 26.87 | 29.52 |

* Values having the same letters are not significantly different at 5% levels according to Duncan's multiple range test (DMRT).
-***F.F.Y** and **D.F.Y** denotes fresh forge yield and dry forage yield respectively.

in dry forage yield (ton/ha) in both rainy seasons. The maximum dry yield (9.7 and 7.12 ton/ha) was recorded by Pioneer and Taqqat.5A respectively, whereas Taqqat.9A, Gassabi, Geshaish and Grawia produced the lowest dry forage yield (ton/ha) in 1st rainy season, while the cultivar Pioneer and genotype Taqqat.7B registered the highest values of dry forage yield (9.45 and 8.29 ton/ha) successively in the 2nd rainy season followed by Grawia, Taqqat.5A and Nabig. Contrarily, minimum dry forage yield (1.90, 2.42 and 3.25 ton/ha) was obtained by local genotypes Gassabi, Geshaish and Taqqat.9A during the respective years (Appendices 1and 2).

### 4.2.5 Percentage of dry matter.

Significant differences among genotypes were shown in this trait in (Table.4). Maximum dry matter percentages were recorded in cultivar Abu70 (37.4%) followed by cultivar Pioneer (36.9%) and genotype Taqqat.5A (35.09%), in the 1st rainy season. The lowest dry matter percentages during the same season (23.30%, 23.35% and 25.21%) were recorded by local genotypes Geshaish, Nabig and Aish-Baladi, respectively. The highest value (47.3 %) has also been recorded by genotype Taqqat.7B, followed by cultivar Pioneer (43.3 %) in the 2nd rainy season, while genotypes Geshaish, Grawia and Nabig registered the lowest values. The performance of the 1st season was greater compared to the second season (Appendices 1and 2).

### 4. 2.6 Leaf to stem ratio (LSR).

Genotypes differed significantly from each other for leaf to stem ratio in both rainy seasons (Table 5).The maximum LSR was observed by local genotype Geshaish (1.48) followed by Taqqa.5A (1.30) in 1st rainy season. In contrast minimum leaf to stem ratio was recorded in Aish-Baladi (0.71).Cultivar Pioneer recorded the highest value of LSR (0.92) during the 2nd rainy season, while the lowest values (0.63 and 0.64) were obtained by genotypes Taqqat.9A and Gassabi respectively during the same season (Appendices 1and 2).

#### 4.2.7 Fresh forage yield (g/plant) during the 2nd cut.

Data presented on Table 5, indicated significant differences for the genotypes in the two successive rainy seasons, the highest yield in 1st rainy season was recorded by local genotype Nabig (19.0 g) followed by Taqqat.7B (18.0 g), whereas the lowest value (15 g) was observed by cultivar Abu70 and genotype Gassabi during the same season. A maximum value (50 g) of same trait was recorded by local genotypes Grawia, and Nabig during rainy season (2015/2016), followed by cultivar Pioneer (33.0 g), while the lowest value (20.0 g) was recorded by genotypes Abu70 and Aish-Baladi in the same season. The performance of second rainy season was greater, compared to the first one (Appendices 1and 2).

#### 4.2.8 Dry forage yield (g/plant) during the 2nd cut.

Differences in dry forage yield (g) per plant for the 2nd ratoon crop were found among the studied genotypes in two rainy seasons (Table.5).Genotype Taqqat.7B scored the highest value (9.8 g) followed by cultivar Pioneer (6.6 g) during the 1st rainy season , while the lowest value (4.2 g) was recorded by local genotype Gassabi. In the 2nd rainy season, genotypes Nabig and Grawia registered maximum dry yield/plant (24 and 18 g) respectively, the lesser value of (10 g) was observed by genotypes Abu70, and Aish-Baladi, in the same season. In spite of the dry weight per plant (g) during 2nd cut was very poor, the mean of dry yield (g) during season (2015/2016) was higher than rainy season (2014/2015), Appendix (1and 2).

## 4.3 Winter experiments.

### 4.3.1 Vegetative attributes.

#### 4.3.1.1 Plant height (cm).

The effect of genotypes and watering intervals on plant height is shown in table (6) and Appendix (3and 4). A significant difference among genotypes was found on visual data. Cultivar Pioneer had the highest plant height (120.3cm), while the lowest value (82.1 cm) was recorded by genotype Gassabi. Also irrigation interval was significant and water interval $W_1$ had a higher value in this trait

**Table** 4. Effect of genotypes on green forage yield (ton/ha), dry forage yield (ton/ha) percentage of dry matter of fodder sorghum (*Sorghum bicolor* L. Moench) grown during rainy seasons (2014/2015-2015/2016).

| | Rainy Season (2014/2015). | | | | Rainy Season (2015 / 2016). | | |
|---|---|---|---|---|---|---|---|
| Treatment (Genotypes) | F.F.Y (ton/ha) | D.F.Y (ton/ha) | % . of the dry matter | | F.F.Y (ton/ha) | D.F.Y (ton/ha) | % . of the dry matter |
| Taqqat.9A | 10.8 $^{f}$ | 2.7 $^{e}$ | 25.0 $^{d}$ | | 10.0$^{de}$ | 3.5 $^{bcd}$ | 34.3 $^{bc}$ |
| Pioneer | 26.5 $^{a}$ | 9.7 $^{a}$ | 36.9 $^{ab}$ | | 21.3 $^{a}$ | 9.5 $^{a}$ | 43.3 $^{ab}$ |
| Taqqat.7B | 18.0 $^{c}$ | 5.5 $^{c}$ | 31.9 $^{abc}$ | | 18.0 $^{ab}$ | 8.3 $^{a}$ | 47.3 $^{a}$ |
| Aish –Baladi | 12.7 $^{ef}$ | 4.2 $^{de}$ | 25.2 $^{d}$ | | 6.5 $^{e}$ | 2.5 $^{cd}$ | 38.3 $^{abc}$ |
| Abu70(Aliab) | 17.3 $^{cd}$ | 6.4 $^{bc}$ | 37.4 $^{a}$ | | 12.7 $^{cd}$ | 4.5 $^{bc}$ | 34.7 $^{bc}$ |
| Taqqat.5A | 20.4 $^{bc}$ | 7.1 $^{b}$ | 35.1 $^{ab}$ | | 16.1 $^{bc}$ | 5.5 $^{b}$ | 34.0 $^{bc}$ |
| Nabig | 23.3 $^{ab}$ | 5.4 $^{c}$ | 23.3 $^{d}$ | | 16.4 $^{bc}$ | 5.1 $^{b}$ | 31.3 $^{c}$ |
| Grawia | 16.0 $^{cde}$ | 4.8 $^{d}$ | 30.1 $^{bcd}$ | | 14.5 $^{bcd}$ | 4.7 $^{b}$ | 32.0 $^{c}$ |
| Geshaish | 13.2 $^{def}$ | 3.1 $^{e}$ | 23.5 $^{d}$ | | 7.3 $^{e}$ | 2.4 $^{cd}$ | 33.0 $^{c}$ |
| Gassabi | 10.4 $^{f}$ | 2.9 $^{e}$ | 27.6 $^{cd}$ | | 5.1 $^{e}$ | 1.9 $^{d}$ | 33.7 $^{bc}$ |
| Grand mean | **16.9** | **5.2** | **29.6** | | **12.8** | **4.8** | **36.2** |
| SE± | 0.76 | 0.28 | 1.19 | | 0.85 | 0.42 | 1.60 |
| C.V% | 14.19 | 16.65 | 12.66 | | 21.00 | 27.84 | 14.01 |

* Values having the same letter are not significantly differ 5% levels according to Duncan's multiple range test (DMRT).

***F.F.Y** and **D.F.Y** denotes for fresh forage yield and dry forage yield respectively.

**Table** 5. Effect of genotypes on leaf to stem ratio, fresh forage yield (g/plant) and dry forage yield during 2nd cut (g/plant) of fodder sorghum (*Sorghum bicolor* L. Moench) grown during rainy seasons (2014/2015-2015/2016).

| | Rainy Season (2014/2015). | | | | Rainy Season (2015 / 2016). | | |
|---|---|---|---|---|---|---|---|
| Treatment (Genotypes) | Leaf to Stem ratio | F.F.Y (g/plant) during 2nd cut | D.F.Y (g/plant) during 2nd cut | | Leaf to Stem ratio | F.F.Y (g/plant) during 2nd cut | D.F.Y (g/plant)/ during 2nd cut |
| Taqqat.9A | 0.76 bc | 17.0 c | 4.4 h | | 0.63 c | 30.0 c | 14.0 c |
| Pioneer | 0.82 bc | 17.0 c | 6.6b | | 0.92 a | 33.0 b | 14.0 c |
| Taqqat.7B | 1.04 abc | 18.0 b | 9.8 a | | 0.72 bc | 30.0 c | 11.0 f |
| Aish –Baladi | 0.71 c | 16.0 d | 4.7 g | | 0.70 bc | 20.0 e | 10.0 g |
| Abu70(Aliab) | 0.90 bc | 15.0 e | 5.1 e | | 0.82 ab | 20.0 e | 10.0 g |
| Taqqat.5A | 1.30 ab | 17.0 c | 5.3 d | | 0.74 bc | 23.0 d | 11.0 f |
| Nabig | 0.73 bc | 19.0 a | 6.4 c | | 0.77 bc | 50.0 a | 24.0 a |
| Grawia | 1.12 abc | 17.0 c | 4.8 f | | 0.82 ab | 50.0 a | 18.0 b |
| Geshaish | 1.48 a | 10.0 f | 4.3 i | | 0.74 bc | 30.0 c | 12.0 e |
| Gassabi | 1.16 abc | 15.0 e | 4.2 j | | 0.64 c | 30.0 c | 13.0 d |
| Grand mean | **1.00** | **16.1** | **5.6** | | **0.75** | **31.6** | **13.7** |
| SE± | 0.09 | 0.41 | 0.20 | | 0.29 | 0.51 | 0.34 |
| C.V% | 29.31 | 7.99 | 11.39 | | 12.09 | 5.09 | 7.98 |

* Values having the same letter are not significantly differ 5% levels according to Duncan῾s multiple range test (DMRT).
***F.F.Y** and **D.F.Y** denotes for green forage yield and dry forage yield respectively.

Genotypes and water interval (GxW) showed a statistically significant interaction on plant height. The highest plant height was (138.3cm) produced at the lesser irrigation water interval ($W_1$) with cultivar Pioneer, while the lowest plant height was (77.87cm) recorded by genotype Aish-Baladi under irrigation interval ($W_2$). However, in the 2[nd] season, the highest value (159.9 cm) was recorded by cultivar Pioneer followed by local cultivar Nabig, while Taqqat.9A recorded the lowest value (92.6 cm). Watering interval one ($W_1$) had the highest value in this character (Figures.1 and 2). The interaction between watering interval and sorghum cultivars was not significant (Table.7).

**4.3.1.2 Stem diameter (cm)**.

Statistical analysis indicated that, there were significant differences between genotypes (Table.1). The highest values were (1.48 and 1.43 cm) recorded by genotypes Taqqat.7B and Taqqat.5A respectively, whereas the minimum value was (1.13 cm) registered by genotype Aish-Baladi. Watering treatments had significant effect on mean of stem diameter (cm), watering interval ($W_{1)}$, gave (1.34 cm) as the highest value. Whereas the maximum stem diameter/cm (1.70) was registered by local genotypes Taqqat.5A and 7.B followed by cultivar Abu70 in the 2[nd] winter season, the minimum value (1.21cm) of the same trait was recorded by the genotype Aish-Baladi. Watering intervals were not significant (Figure.3 and 4). There were no significant differences among interactions in the tow seasons (Table.7) (Appendices 3and 4).

**4.3.1.3 Number of leaves /plant.**

Statistical analysis of variance (Appendix, 3and4) showed that there were no significant differences on mean number of leaves among genotypes during 1[st] winter season. Whereas the results of the 2nd season were significant, hybrid Pioneer had the highest number (12.3) of leaves followed by cultivar Abu70, while the lowest value (7.2) was recorded by the local cultivar Aish-Baladi

(Figure.5) and the differences between the two irrigation intervals and their interaction were not significant in both seasons (Table 6 and 7).

**4.3.1.4 Number of tillers /plant.**

Data presented on Tables (8 and 9) and Appendices (3 and 4) indicated that, there were no significant differences on mean number of tillers per plant between genotypes for the 1st season; in contrast the analyzed data for the 2nd season showed significant differences for the same traits. Genotype Nabig scored the highest value (2.9) followed by cultivar Pioneer (2.6), while the lesser (1.5) number of tillers was recorded by cultivar Abu70 (Figure.6). The main effect of watering interval and their interactions (GxW) was not significant in both seasons.

**4.3.1.5 Number of leaves / tiller.**

Data regarding the number of leaves per tiller recorded during winter seasons, showed significant differences among genotypes (Tables.8, and 9). Genotype Nabig had higher (13.8) number of leaves per tiller followed by Taqqat.9A, Taqqat.7B, Pioneer and Gassabi in 1st season. The same result was attained by genotype Nabig which had the highest value (12.7) of the same trait followed by genotype Taqqat.5A in the 2nd season, whereas cultivar Abu70 recorded the lowest values (7.7 and 9.2) respectively in both seasons (Figure.7). The effect of irrigation intervals was not significant. Genotypes and irrigation intervals (W x G) were not statistically significant in the same trait for the tow consecutive seasons (Appendices 3 and 4).

**4.3.1.6 Leaf area Index (L.A.I).**

The results showed that, there were significant differences amongst studied genotypes (Tables10 and 11). Maximum leaf area indices (1.88 and 5.4) were given by cultivar Pioneer for the two seasons, and minimum values of (1.34 and 2.4) were recorded by genotypes Aish-Baladi during both seasons (Figure.10). Analysis of variance showed that, there were no significant differences between water intervals, and their interactions in both seasons (Appendices 3 and 4).

#### 4.3.1.7 Number of days to 50% flowering.

Statistical analysis showed significant differences with respect to the number of days to 50% flowering between genotypes (Tables, 8 and 9). Taqqat.7B reached this period later (64.17 and 65.7 day) respectively in both seasons, than the other genotypes except genotype Aish-Baladi which had reached this period in shorter days (54.33 and 53.2 day) and followed by Gassabi and Nabig in 1st winter season and by Geshaish and Gassabi 2nd winter season(Figure.8). The interaction (W x G) was not statistically significant in both seasons Appendix (3and 4).

### 4.3.2 Yield attributes.

#### 4.3.2.1 Fresh forage yield (ton/ha).

The effect of irrigation watering intervals and genotypes on fresh forage yield (ton/ha) is shown on tables (10and11), and Appendices (3and 4). There were significant differences among genotypes on fresh forage yield during both seasons. The highest value (9.66 ton/ha) was obtained by cultivar Pioneer followed by Abu 70 and genotype Taqqat.7B during the 1st season; also cultivar Pioneer had the highest (11.3 ton / ha) fresh weight during the 2nd season followed by genotype Taqqat.5A, while the lowest values (4.32, 6.7) and (4.45, 4.7) ton /ha were recorded by genotypes Gassabi and Aish-Baladi, respectively in both seasons (Figure.11).There was a significant difference due to watering interval treatments, the higher values in both seasons were recorded by $W_1$ (Figure.12). Also the interaction (W x G) was significant during both seasons, the highest fresh forage yield (14.14) and (12.9) ton /ha was obtained by cultivar Pioneer followed by cultivar Abu70 and genotype Nabig with lesser watering interval frequent ($W_1$) during the 1st season, while the lowest fresh forage yield (3.9 ton/ha) was produced by genotype Taqqat.5A with most frequent irrigation ($W_2$) during the 1st season and by genotype Aish-Baladi (4.6 ton/ha) during 2nd season.

#### 4.3.2.2 Dry forage yield (ton/ha).

Data regarding the dry forage yield (ton/ha) recorded during the tow winter seasons (2014/2015 and 2015/2016), showed significant differences among genotypes (Tables.12 and13). Cultivar Pioneer produced the highest weight (4.62ton/ha) during the 1st season than the other genotypes followed by genotype Taqqat.7B, Abu70 and Nabig, whereas the lowest values (1.52, 1.66 and ton/ha) were given by genotypes Aish-Baladi and Gassabi .While local genotype Taqqat.5A recorded maximum value (3.8 ton/ha) followed by cultivar Pioneer (3.3 ton/ha) during the 2nd season ,and local genotypes Aish-Baladi and Geshaish recorded the lowest values of (1.77 and 2.2 ton./ha), respectively during the same season. Watering intervals were significantly different. Watering interval $W_1$ gave the highest value in both seasons (Figurers. 13 and 14). Interactive effect of watering interval and genotypes during the 1st season was significantly different. The highest dry weight (5.25 ton/ha) was given by cultivar Pioneer with lesser irrigation watering interval $W_1$ followed by the same cultivar in watering interval $W_2$. While genotypes Aish-Baladi, Gassabi, and Taqqat.5Aobtained the lowest values (1.62, 1.67 and 1.72 ton/ha) respectively with frequent watering interval ($W_1$) treatment. In contrast watering interval ($W_2$) gave the minimum values (1.43, 1.64, 1.70 and 1.79 ton/ha) with genotypes Aish-Baladi, Gassabi, Geshaish and Grawia respectively. The interaction (GxW) effect of season (2015/2016) was not significant (Appendices 3and 4).

#### 4.3.2.3 Percentage of dry matter.

The (ANOVA) table (Appendices.3and4) showed that, there were no significant differences between all treatments (genotypes and watering intervals) in percentage of dry matter in both seasons. Likewise, the irrigation intervals x genotypes for percentage of the dry matter was not significant (Tables, 11and 13).

**Table** 6. Effect of genotypes and watering intervals on vegetative parameters of forage sorghum (*Sorghum bicolor* L. Moench) grown during winter season (2014/ 2015).

| | Parameters | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | plant height (cm). | | | stem diameter (cm). | | | no. of leaves/plant | | |
| (Treatments) Genotypes. | $W_1$ | $W_2$ | Mean | $W_1$ | $W_2$ | Mean | $W_1$ | $W_2$ | Mean |
| Tagat.9A | 94.0 [cdefgh] | 92.9 [defgh] | 93.5 *[c]* | 1.4 | 1.4 | 1.4 *[abc]* | 9.3 | 9.0 | 9.2 |
| Pioneer | 138.3 [a] | 102.4 [bcde] | 120.4 *[a]* | 1.4 | 1.4 | 1.4 *[ab]* | 8.7 | 7.7 | 8.2 |
| Tagat.7B | 92.0 [efghi] | 95.5 [cdefg] | 93.7 *[c]* | 1.6 | 1.4 | 1.5 *[a]* | 7.3 | 8.7 | 8.0 |
| Aish –Baladi | 96.0 [cdefg] | 77.9 [i] | 87.0 *[cd]* | 1.1 | 1.1 | 1.1 *[f]* | 7.3 | 7.3 | 7.3 |
| Abu70 (Aliab) | 98.4 [cdef] | 89.6 [efghi] | 93.1 *[c]* | 1.3 | 1.3 | 1.3 *[bcde]* | 8.3 | 8.7 | 8.5 |
| Tagat.5A | 85.7 [fghi] | 84.7 [fghi] | 85.2 *[cd]* | 1.5 | 1.4 | 1.4 *[a]* | 7.7 | 8.3 | 8.0 |
| Nabig | 114.9 [b] | 107.7 [bc] | 111.3 *[b]* | 1.3 | 1.2 | 1.3 *[def]* | 8.3 | 8.0 | 8.2 |
| Grawia | 107.9 [bcd] | 104.1 [bcde] | 105.7 *[b]* | 1.4 | 1.4 | 1.4 *[abcd]* | 7.0 | 7.7 | 7.3 |
| Geshaish | 92.3 [efghi] | 82.9 [gh] | 87.6 *[cd]* | 1.2 | 1.3 | 1.3 *[cdef]* | 7.0 | 7.3 | 7.2 |
| Gasabi | 84.3 [fghi] | 79.8 [hi] | 82.1 *[d]* | 1.4 | 1.1 | 1.2 *[ef]* | 7.3 | 7.3 | 7.3 |
| Mean | 100.3 **[a]** | 91.8 **[b]** | | 1.3 **[a]** | 1.3 **[b]** | | 7.8 | 8.0 | |
| C.V% | 7.98% | | G.M :96.04 | 8.05% | | G.M :1.33 | 8.37% | | G.M :7.92 |
| SE± | SE (w)= 0.50, SE (g)= 0.41, SE (w×g) = 3.86 | | | SE (w)=.025 ,SE (g) = 0.021,SE = (w×g) = 0.046 | | | SE (w) =0.10 ,SE (g) = 0.85 ,SE (w×g) = 0.36 | | |

* $W_1$ and $W_2$ denote watering interval every 7 and 10 days, respectively.* G.M denote for grand mean *SE (w), SE (g) and SE (w×g) denote for of water interval, genotype and their interaction respectively.*Values having the same letter are not significant differently at5% (using Duncan multiple range test) italic letter denote genotypes, bold letter denote watering interval and normal for their interaction.

**Table** 7. Effect of genotypes and watering intervals on vegetative parameters of forage sorghum (*Sorghum bicolor* L. Moench) grown during winter season (2015/ 2016).

| | Parameters | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | plant height (cm). | | | stem diameter (cm). | | | no. of leaves/plant | | |
| (Treatments) Genotypes. | $W_1$ | $W_2$ | Mean | $W_1$ | $W_2$ | Mean | $W_1$ | $W_2$ | Mean |
| Taqqat.9A | 100.6 | 84.6 | 92.6 *j* | 1.6 | 1.6 | 1.6 *e* | 9.8 | 8.1 | 8.9 *f* |
| Pioneer | 176.6 | 143.4 | 159.9 *a* | 1.6 | 1.6 | 1.6 *d* | 13.0 | 12.3 | 12.3 a |
| Taqqat.7B | 123.7 | 111.2 | 117.5 *h* | 1.7 | 1.7 | 1.7 *a* | 10.0 | 9.9 | 10.06 *c* |
| Aish –Baladi | 115.0 | 113.0 | 114.0 *i* | 1.2 | 1.2 | 1.2 *i* | 7.0 | 7.3 | 7.2 *j* |
| Abu70 (Aliab) | 145.3 | 120.5 | 132.9 *d* | 1.7 | 1.7 | 1.7 *b* | 10.3 | 10.0 | 10.2 *b* |
| Taqqat.5A | 128.7 | 111.2 | 120.0 *g* | 1.7 | 1.7 | 1.7 *a* | 9.8 | 9.7 | 9.8 *e* |
| Nabig | 155.8 | 134.2 | 144.9 *b* | 1.4 | 1.3 | 1.4 *h* | 8.1 | 7.7 | 7.9 *i* |
| Grawia | 146.4 | 132.9 | 139.7 *c* | 1.6 | 1.6 | 1.7 c | 9.9 | 9.7 | 9.8 *d* |
| Geshaish | 133.9 | 115.3 | 124.6 *e* | 1.4 | 1.5 | 1.5 *g* | 8.5 | 9.0 | 8.7 *g* |
| Gasabi | 129.6 | 117.8 | 123.7 *f* | 1.6 | 1.4 | 1.5 *f* | 9.4 | 7.6 | 8.5 *h* |
| Mean | 135.6 **a** | 118.4 **b** | | 1.6 | 1.6 | | 9.6 | 9.1 | |
| C.V% | 8.58% | | G.M **:**126.9 | 4.71% | | G.M **:**1.55 | 9.30% | | G.M **:**9.3 |
| SE± | SE (w)= 2.09, SE (g)= 1.71, SE (w×g) = 3.06 | | | SE (w)=.023 ,SE (g) = 0.018,SE = (w×g) = 0.042 | | | SE (w) =0.16 ,SE (g) = 0.13 ,SE (w×g) = 0.38 | | |

***** $W_1$ and $W_2$ denote watering interval every 7 and 10 days, respectively.***** G.M denote for grand mean *****SE (w), SE (g) and SE (w×g) denote for of water interval, genotype and their interaction respectively.*****Values having the same letter are not significant differently at5% (using Duncan multiple range test) italic letter denote genotypes, bold letter denote watering interval and normal for their interaction.

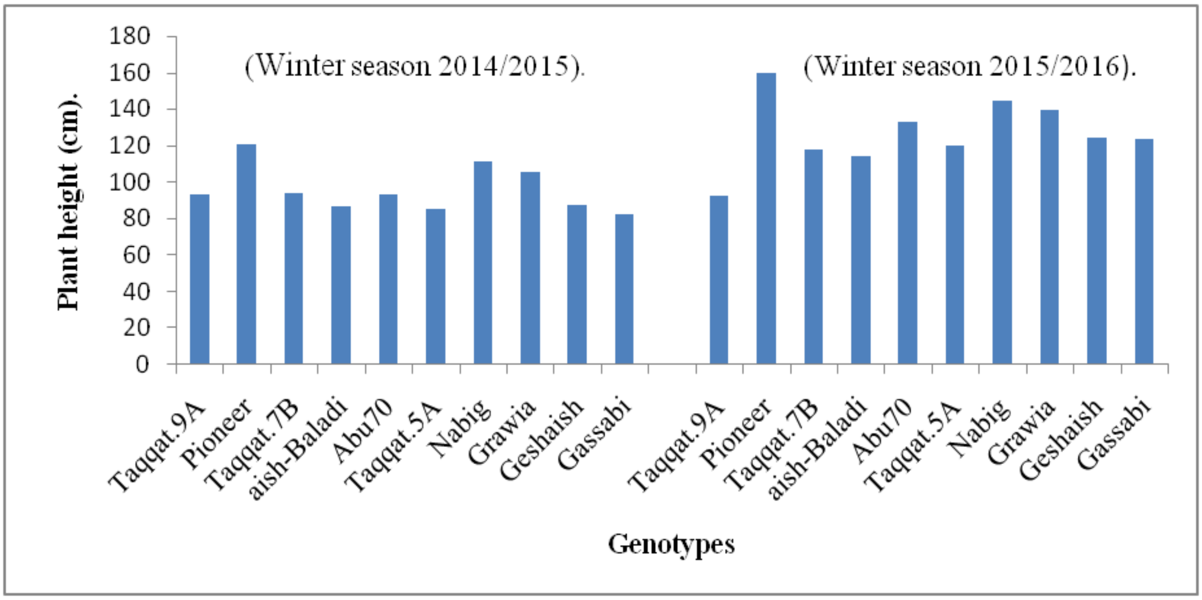


**Figure.1** Plant height (cm) of 10 sorghum forage genotypes during winter season.

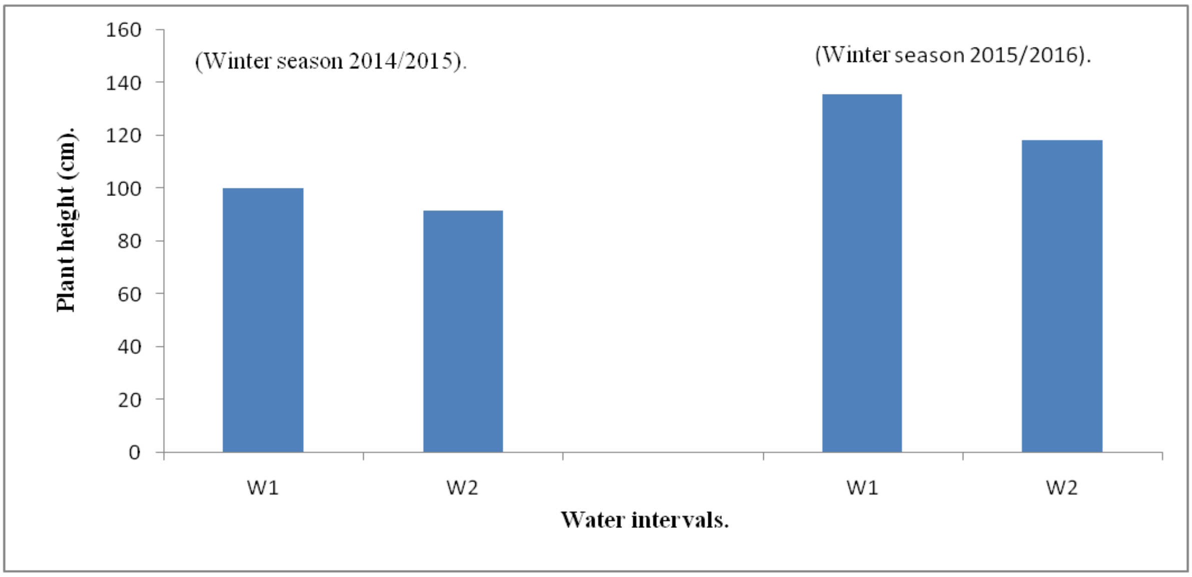


**Figure .2** Effect two watering intervals on plant height (cm) during winter season.

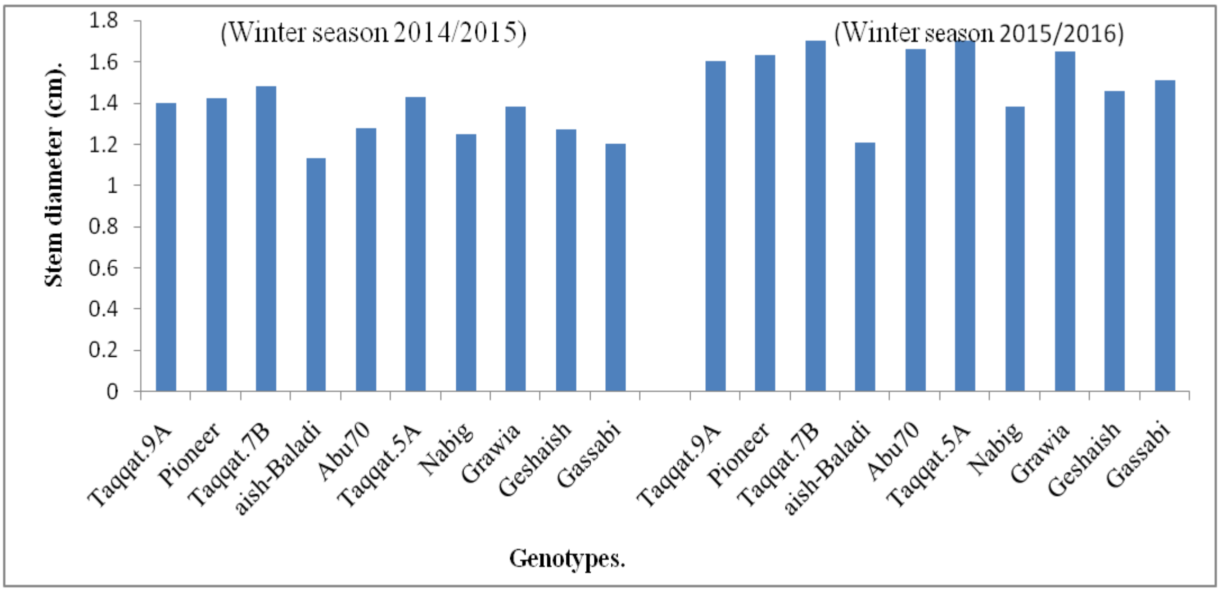


**Figure.3** Stem diameter (cm) of 10 forage sorghum genotypes, during winter season.

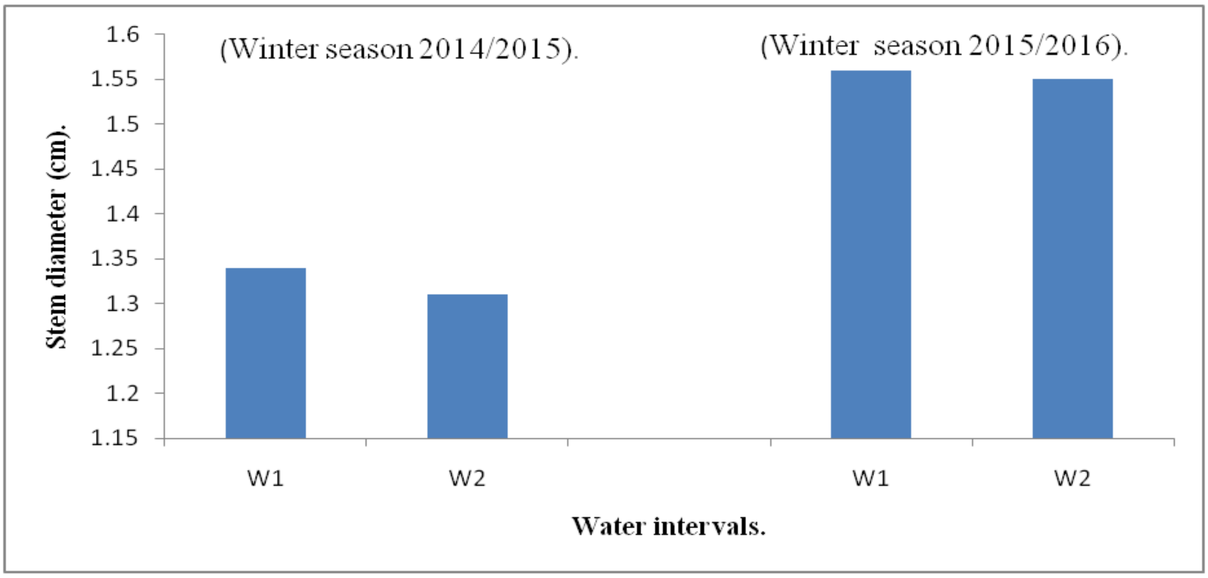


**Figure .4** Effect of two watering intervals on stem diameter (cm) during winter season.

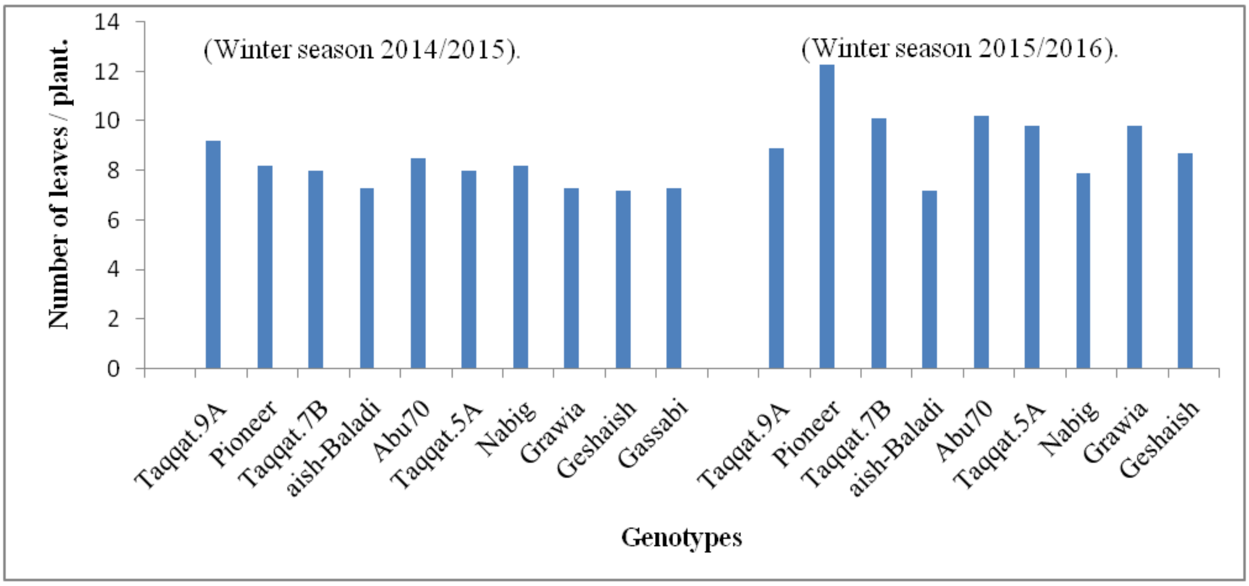


**Figure.5** Number of leaves/plant of 10 forage sorghum genotypes, grown during winter season.

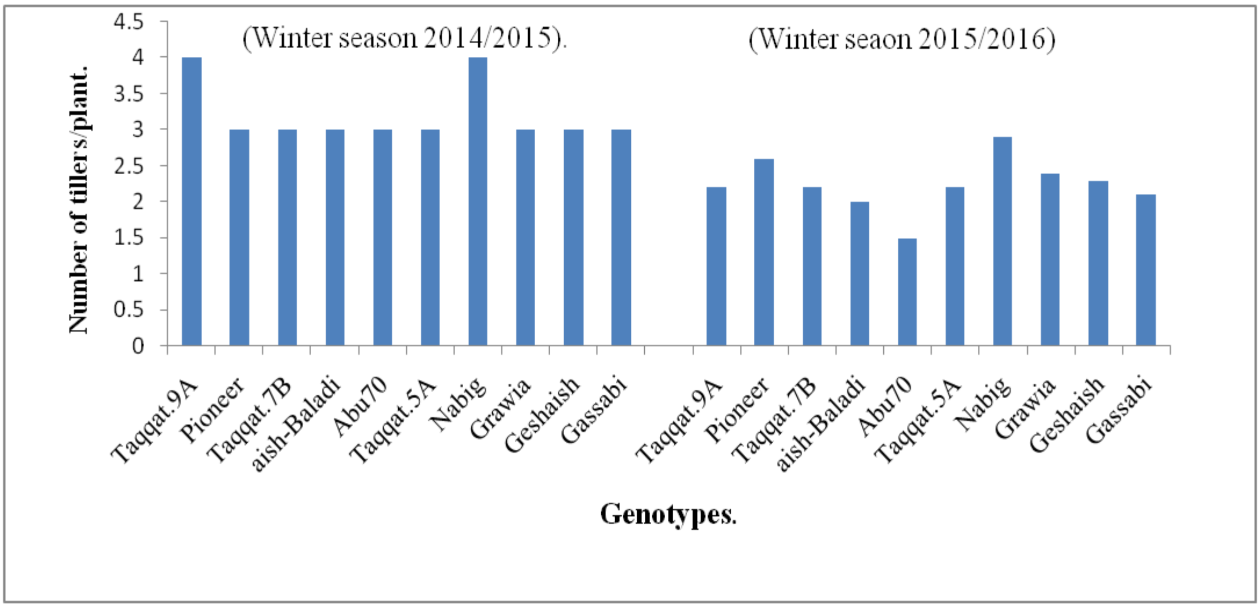


**Figure. 6** Numbers of tillers / plant of 10 forage sorghum genotypes, grown during winter season.

### 4.3.2.4 Leaf to stem ratio.

Hybrid cultivar Pioneer had the highest (0.97) leaf: stem ratio, followed by cultivar Abu70 Aliab (0.95) which were significantly ($P \geq 0.05$) higher than the other genotypes during the 1$^{st}$ season. Likewise genotype Pioneer had the maximum value (1.40) followed by genotype Taqqat.5A (1.23) during the 2$^{nd}$ season. Whereas genotype Geshaish recorded the lowest values (0.55 and 0.78) respectively during both seasons (Figure.9). The variation between watering intervals was not significant during both seasons. The combined effect of the two factors (W x G) was significant during 2$^{nd}$ season, $W_1$ with hybrid Pioneer had the highest value (1.5), whereas the lesser value of (0.71) was obtained by genotype Aish-Baladi with watering interval $W_2$, The interaction (W x G) was not significant during 1$^{st}$ season (Tables,10 and 11) and (Appendices 3 and 4).

### 4.3.2.5 Fresh forage yield (g/plant).

Statistical analysis of variance (Appendices.3 and 4) showed that there were significant differences among genotypes in fresh forage yield per plant (g) in both seasons. The highest values (44.0 and 88.3 g) were obtained by cultivar Pioneer for the both respectively, followed by local genotypes Taqqat.7B and Nabig (43.0g) during 1$^{st}$ season and by genotype Nabig during season (2015/2016), while the lowest weight of (26.0 and 26.8 g) was recorded by genotypes Aish-Baladi for the both season respectively (Figure.15) . Also the interaction (W x G) was significant for the same trait during the 1$^{st}$ season. Cultivar Pioneer produced maximum weight (57.0 g) followed by genotype Nabig with watering interval $W_1$, while genotypes Gassabi, Taqqat.5A and Aish-Baladi registered lesser values (23.0, 27.0 and 27.0 g) successively with irrigation interval ($W_1$). Whereas the lowest values (23.0 and 27 g) were recorded by genotypes Gassabi and Aish-Baladi, respectively with watering interval treatment $W_2$ during the 2nd season. The interaction effect was not significant during the 2$^{nd}$ season.

**Table 8.** Effect of genotypes and watering intervals on vegetative parameters and phenology of forage sorghum (*Sorghum bicolor* L. Moench) grown during winter season (2014/ 2015).

| Parameters | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | no. of tillers/plant. | | | no. of leaves / tiller. | | | days to 50 % flowering | | |
| Treatments) Genotypes. | $W_1$ | $W_2$ | Mean | $W_1$ | $W_2$ | Mean | $W_1$ | $W_2$ | Mean |
| Tagat.9A | 4.0 | 3.0 | 4.0 | 11.0 | 11.0 | 11.0 b | 62.5 | 62.7 | 62.5 *abc* |
| Pioneer | 3.0 | 3.0 | 3.0 | 11.0 | 10.7 | 10.8 c | 63.0 | 63.0 | 63.2 *ab* |
| Tagat.7B | 4.0 | 3.0 | 3.0 | 11.0 | 10.7 | 10.8 c | 64.2 | 66.7 | 64.2 *a* |
| Aish –Baladi | 3.0 | 3.0 | 3.0 | 9.8 | 9.7 | 9.7 e | 54.3 | 53.0 | 54.3 *e* |
| Abu70 (Aliab) | 2.0 | 3.0 | 3.0 | 7.3 | 8.0 | 7.7 g | 61.8 | 61.7 | 61.8 *abcd* |
| Tagat.5A | 3.0 | 3.0 | 3.0 | 9.3 | 9.3 | 9.3 f | 60.7 | 59.3 | 60.7 *bcd* |
| Nabig | 4.2 | 4.0 | 4.0 | 14.0 | 13.7 | 13.8 a | 58.8 | 59.0 | 58.8 *d* |
| Grawia | 3.0 | 4.0 | 3.0 | 11.0 | 10.3 | 10.7 d | 62.5 | 63.7 | 62.5 *abc* |
| Geshaish | 3.0 | 3.0 | 3.0 | 9.8 | 9.0 | 9.3 f | 59.5 | 59.7 | 59.5 *cd* |
| Gasabi | 3.3 | 3.0 | 3.0 | 11.3 | 10.7 | 11.0 b | 58.8 | 58.7 | 58.8 *d* |
| Mean | 3.0 | 3.0 | | 10.53 | 10.30 | | 60.6 | 60.6 | |
| C.V% | 23.00 % | | G.M : 3.30 | 8.68 % | | G.M:10.42 | 4.24 % | | G.M :60.63 |
| SE± | SE (w) = 0.18, SE (g) = 0.15, SE (w×g) = 0.28 | | | SE (w) = 0.20, SE (g)= 0.17, SE (w×g) = 0.34 | | | SE (w)= 0.18, SE (g) = 0.15, SE (w×g) = 1.13 | | |

***** $W_1$ and $W_2$ denote watering interval every 7 and 10 days, respectively.***** G.M denote for grand mean *****SE (w), SE (g) and SE (w×g) denote for standard error of water interval, genotypes and their interaction respectively.*****Values having the same letter are not significant differently at 5% (using Duncan multiple range test) italic letter denote genotypes, bold letter denote watering interval and normal for their interaction.

**Table** 9. Effect of genotypes and watering intervals on growth and phenology of forage sorghum (*Sorghum bicolor* L. Moench) grown during winter season (2015/ 2016).

| Parameters | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | no. of Tillers/plant. | | | no. of leaves/tiller. | | | days to 50 % flowering | | |
| Treatments) | $W_1$ | $W_2$ | Mean | $W_1$ | $W_2$ | Mean | $W_1$ | $W_2$ | Mean |
| Taqqat.9A | 2.4 | 2.0 | 2.2 *e* | 9.3 | 9.7 | 9.6 *h* | 62.3 | 61.7 | 62.0 *d* |
| Pioneer | 2.4 | 2.8 | 2.6 *b* | 11.2 | 11.6 | 11.4 *c* | 62.0 | 64.0 | 63.0 *b* |
| Taqqat.7B | 2.2 | 2.2 | 2.2 *e* | 11.4 | 10.7 | 11.1 *e* | 67.3 | 64.0 | 65.7 *a* |
| Aish –Baladi | 2.1 | 1.9 | 2.0 *g* | 11.2 | 11.1 | 11.2 *d* | 55.7 | 50.7 | 53.2 *j* |
| Abu70 | 1.5 | 1.4 | 1.5 *h* | 9.1 | 9.2 | 9.2 *i* | 63.7 | 59.0 | 61.3 *e* |
| Taqqat.5A | 2.3 | 2.1 | 2.2 *e* | 12.0 | 11.2 | 11.6 *b* | 60.0 | 60.7 | 60.3 *f* |
| Nabig | 3.1 | 2.7 | 2.9 *a* | 13.1 | 12.2 | 12.7 *a* | 59.7 | 60.3 | 60.0 *g* |
| Grawia | 2.3 | 2.4 | 2.4 *c* | 10.7 | 10.7 | 10.7 *f* | 62.7 | 61.7 | 62.2 *c* |
| Geshaish | 2.6 | 2.1 | 2.3 *d* | 10.2 | 11.0 | 10.6 *g* | 58.7 | 58.3 | 58.5 *i* |
| Gasabi | 2.3 | 1.9 | 2.1 *f* | 10.7 | 10.7 | 10.7 *f* | 58.7 | 59.7 | 59.2 *h* |
| Mean | 2.3 | 2.2 | | 10.9 | 10.8 | | 61.1 | 60.0 | |
| C.V% | 14.65 % | | G.M : 2.25 | 3.24 % | | G.M**:**10.8 | 4.93 % | | G.M **:**60.5 |
| SE± | SE (w) = 0.074, SE (g) = 0.016, SE (w×g) = 0.017 | | | SE (w) = 0.10, SE (g)= 0.08, SE (w×g) = 0.16 | | | SE (w)= 0.61, SE (g) = 0.49, SE (w×g) = 1.31 | | |

***** $W_1$ and $W_2$ denote water interval every 7 and 10 days, respectively.***** G.M denote for grand mean *****SE (w), SE (g) and SE (w×g) denote for standard error of water interval, genotypes and their interaction respectively.*****Values having the same letter are not significant differently at 5% (using Duncan multiple range test) italic letter denote genotypes, bold letter denote watering interval and normal for their interaction.

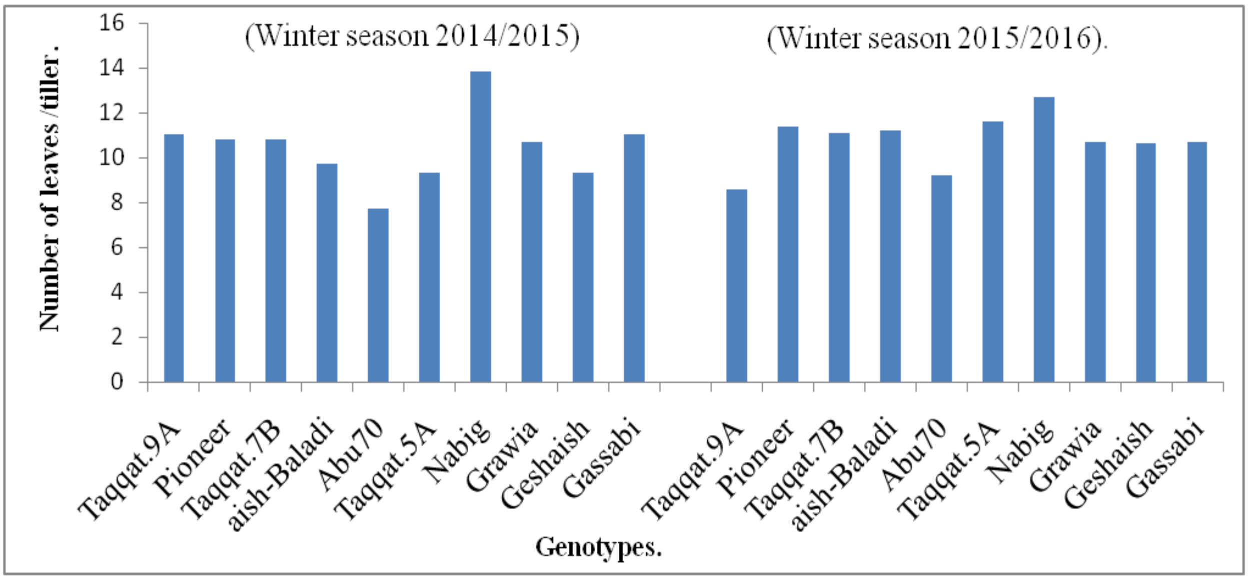


**Figure .7** Number of leaves/ tillers of 10 forage sorghum genotypes, grown during winter season.

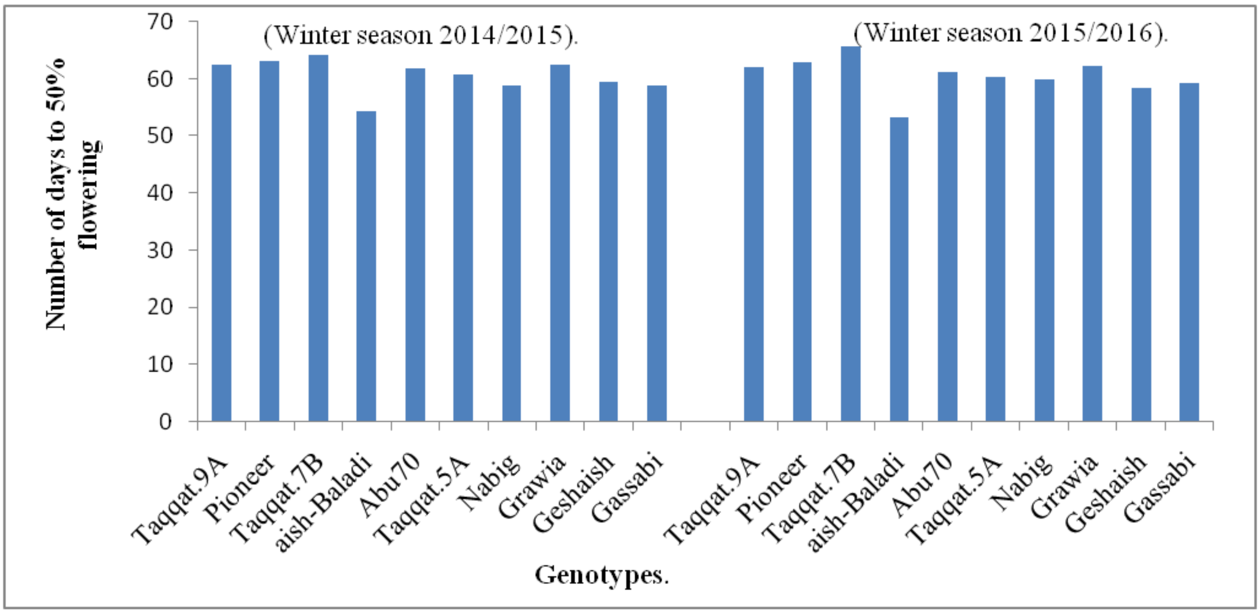


**Figure .8** Number days to 50% flowering of 10 forge sorghum genotypes, grown during winter season.

Whereas the effect of water treatment was significant during both seasons, lesser water interval ($W_1$) had the highest values (Figure16), Tables (12 and 13).

**4.3.2.6 Dry forage yield (g/plant).**

Data presented in Tables (14 and 15) and Appendices (3and 4), showed significant effect of the studied genotypes during seasons (2014/2015 and 2015/2016), and their interaction (W x G) in dry forage yield per plant (g). Cultivar Pioneer had the highest (13.8 g) dry weight (g) per plant, followed by local genotype Taqqat.7B, Taqqat.5A and Nabig, while the lowest value (7.7 g) was given by genotype Gassabi during the $1^{st}$ season .Likewise genotype Taqqat.5A produced the highest value (26.0 g) followed by the local tested genotype Taqqat.7B, and minimum value of (11.8 g) was produced by genotype Aish-Baladi during the $2^{nd}$ season (Figure.16). The (genotypes x irrigation interval) interaction was significant. In this respect hybrid cultivar Pioneer produced the highest (16.7 g) dry forage yield per plant (g) followed by the local genotype Taqqat.5A, whereas genotype Gassabi had the lowest value (7.7g), followed by genotype Aish-Baladi with watering interval ($W_2$) during the $1^{st}$ season. The irrigation intervals were significant during both seasons, in this respect $W_1$ was greater than $W_2$ (Figure18).

**4.3.2.7 Fresh forage yield (g/plant) during the $2^{nd}$ cut.**

Analysis of variance indicated that, there were no significant differences among genotypes in fresh forage yield per plant at the second cut during the $1^{st}$ season (Table, 14).The data revealed significant differences among genotypes during the $2^{nd}$ season (Table.15). Genotype Nabig produced the highest (52.3 g) fresh weight. While the local genotype Aish-Baladi had the lowest (29.9 g) fresh weight. The interaction (W x G) was significant during the $2^{nd}$ season, genotype Nabig had the highest value (59.0g) with watering interval $W_1$, whereas the genotype Aish-Baladi had the lowest value (29.2 g) compared to other treatments (Fiure.19). Watering treatments were significant, the highest value of fresh forage yield (g) per plant during the second cut was obtained by water irrigation interval $W_1$, Figure (20) .The combined effect (W x G) significant during the 1st season (Appendices .3 and 4).

#### 4.3.2.8 Dry forage yield (g/plant) during the 2nd cut.

The effect of genotype and irrigation interval on dry forage weight (g) per plant at second cut was shown in table (14 and 15). There were no significant differences in dry forage yield (g) per plant 2nd cut among genotypes and due to water irrigation intervals, also irrigation interval and genotype interaction for dry forage yield per plant was not significant during both seasons( Appendices .3and 4).

## 4.4 Quality Parameters.

### 4.4.1 Performance of quality traits during rainy season (2014/2015) and winter season (2014/2015).

Table (16) showed the performance of different genotypes for dry mater percentage (DM %), ash % , crude protein (CP %), Ether extractable fats (E.E) and crude fiber (CF %), during the 1st rainy season and the 1st winter season.

### 4.4.2 Dry matter (DM %).

Data revealed significant differences in dry matter percentage during the rainy season; the highest percentage was shown by genotype Aish-Baladi (94.70%) followed by genotypes Taqqat.9A and Abu70, whereas the lowest value was recorded by genotype Grawia (93%). Genotypes were not significant during winter season for dry matter percentage, but the dry matter % in winter season was better than rainy season (Appendix 5).

### 4.4.3 Ash %.

Analysis of variance was significant in ash percentage during both seasons. Genotype Gassabi gave maximum percentage (7.91%) followed by Nabig, while genotype Taqqat.7B registered the lowest percentage (5.68%) in the 1st rainy season. Highest percentages (12.41, 11.29, and 10.69 %) were obtained by genotypes Gassabi, Geshaish and Grawia, respectively in winter season; in contrast the lowest

**Table** 10. Effect of genotypes and watering intervals on vegetative parameters and yield of forage sorghum (*Sorghum* L. *bicolor* Moench) grown during winter season (2014/ 2015).

| Parameters | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | leaf to stem ratio. | | | L.A.I | | | fresh forage yield (ton/ha) | | |
| (Treatments) Genotypes. | $W_1$ | $W_2$ | Mean | $W_1$ | $W_2$ | Mean | $W_1$ | $W_2$ | Mean |
| Tagat.9A | 0.77 | 0.80 | 0.78 *bcd* | 1.8 | 1.8 | 1.8 b | 6.6 bcde | 4.5 de | 5.6 *cd* |
| Pioneer | 1.1 | 0.88 | 0.97 *a* | 1.9 | 1.9 | 1.9 a | 14.1 a | 5.2 de | 9.7 *a* |
| Tagat.7B | 0.71 | 0.89 | 0.80 *abcd* | 1.59 | 1.6 | 1.6 f | 8.4 bc | 7.5 bcd | 7.9 *ab* |
| Aish –Baladi | 0.62 | 1.0 | 0.65 *de* | 1.3 | 1 .4 | 1.3 h | 4.4 de | 4.5 de | 4.5 *d* |
| Abu70 (Aliab) | 0.89 | 0.59 | 0.95 *ab* | 1.7 | 1.7 | 1.7 d | 9.2 b | 6.8 bcde | 8.0 *ab* |
| Tagat.5A | 0.92 | 0.69 | 0.75 *cd* | 1.7 | 1.7 | 1.7 c | 6.2 bcde | 3.9 e | 5.0 *d* |
| Nabig | 0.97 | 0.86 | 0.92 *abc* | 1.7 | 1.7 | 1.7 e | 9.0 b | 6.1 bcde | 7.5 *bc* |
| Grawia | 0.88 | 0.77 | 0.82 *abcd* | 1.7 | 1.7 | 1.7 c | 6.5 bcde | 5.0 de | 5.7 *cd* |
| Geshaish | 0.56 | 0.54 | 0.55 *e* | 1.5 | 1.5 | 1.5 g | 6.3 bcde | 5.3 de | 5.8 *cd* |
| Gasabi | 0.83 | 0.82 | 0.83 *abcd* | 1.3 | 1.3 | 1.4 h | 4.3 de | 4.2 de | 4.3 *d* |
| Mean | 0.82 | 0.78 | | 1.6 | 1.6 | | 7.4 **a** | 5.3 **b** | |
| C.V% | 16.99 % | | G.M **:** 0.80 | 6.71 % | | G.M**:**1.6 | 24.84 % | | G.M **:**6.40 |
| SE± | SE (w) = 0.045, SE (g)= 0.036, SE(w×g) = 0.075 | | | SE (w)= 0.03 , SE (g)= 0.02 , SE (w×g) = 0.06 | | | SE (w)= 0.29, SE (g) = 0.24, SE (w×g) = 0.79 | | |

*****$W_1$ and $W_2$ denote watering interval every 7 and 10 days, respectively.***** G.M denote for grand mean *****SE (w), SE (g) and SE (w×g) denote for standard error of water interval, genotype and their interaction respectively.*****Values having the same letter are not significant differently at5% (using Duncan multiple range test) italic letter denote genotypes, bold letter denote watering interval and normal for their interaction.

**Table** 11. Effect of genotypes and watering intervals on vegetative parameters and yield of forage sorghum (*Sorghum bicolor* L. Moench) grown during winter season (2015/ 2016).

| | Parameters | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | leaf to stem ratio. | | | L.A.I | | | fresh forage yield (ton/ha) | | |
| (Treatments) Genotypes. | $W_1$ | $W_2$ | Mean | $W_1$ | $W_2$ | Mean | $W_1$ | $W_2$ | Mean |
| Taqqat.9A | 0.95 gh | 0.79 n | 0.87 *f* | 3.6 | 2.7 | 3.1 *f* | 8.8 g | 7.3 k | 8.0 *e* |
| Pioneer | 1.5 a | 0.88 k | 1.2 a | 5.6 | 5.2 | 5.4 a | 12.9 a | 9.8 e | 11.3 *a* |
| Taqqat.7B | 0.96 g | 0.77 o | 0.86 *g* | 4.7 | 2.7 | 3.7 *d* | 8.4 h | 6.5 m | 7.4 *f* |
| Aish –Baladi | 0.87 k | 0.71 p | 0.79 *I* | 1.9 | 2.9 | 2.4 *i* | 4.9 p | 4.6 q | 4.7 *j* |
| Abu70 (Aliab) | 1.1 c | 1.0 f | 1.0 *c* | 3.7 | 3.7 | 3.7 d | 7.8 i | 6.1 n | 6.9 *h* |
| Taqqat.5A | 1.3 b | 1.00 c | 1.2 . b | 4.3 | 3.9 | 4.1 *b* | 10.9 c | 9.2 f | 10.0 *b* |
| Nabig | 1.0 e | 0.92 i | 0.98 *d* | 3.3 | 2.8 | 3.1 *g* | 10.4 d | 8.5 h | 9.4 *d* |
| Grawia | 0.91 i | 0.95 h | 0.93 *e* | 4.4 | 3.5 | 3.9 *c* | 12.3 b | 6.9 l | 9.6 *c* |
| Geshaish | 0.66 q | 0.90 j | 0.78 *j* | 2.7 | 3.0 | 2.8 *h* | 7.5 j | 6.5 m | 6.9 *g* |
| Gasabi | 0.83 l | 0.82 m | 0.83 *h* | 4.2 | 2.5 | 3.4 *e* | 7.8 i | 5.7 o | 6.7 *i* |
| Mean | 1.0 | 0.89 | | 3.83 | 3.32 | | 9.2 **a** | 7.1 **b** | |
| C.V% | 17.07 % | | G.M **:** 0.97 | 24.51% | | G.M:3.58 | 15.31% | | G.M **:** 8.1 |
| SE± | SE (w) = 0.049, SE (g)= 0.040, SE(w×g) = 0.050 | | | SE (w)= 0.17 , SE (g)= 0.14 , SE (w×g) = 0.38 | | | SE (w)= 0.22, SE (g) = 0.18, SE (w×g) = 0.93 | | |

***$W_1$** and $W_2$ denote watering interval every 7 and 10 days, respectively.* G.M denote for grand mean *SE (w), SE (g) and SE (w×g) denote for standard error of water interval, genotype and their interaction respectively.*Values having the same letter are not significant differently at5% (using Duncan multiple range test) italic letter denote genotypes, bold letter denote watering interval and normal for their interaction.

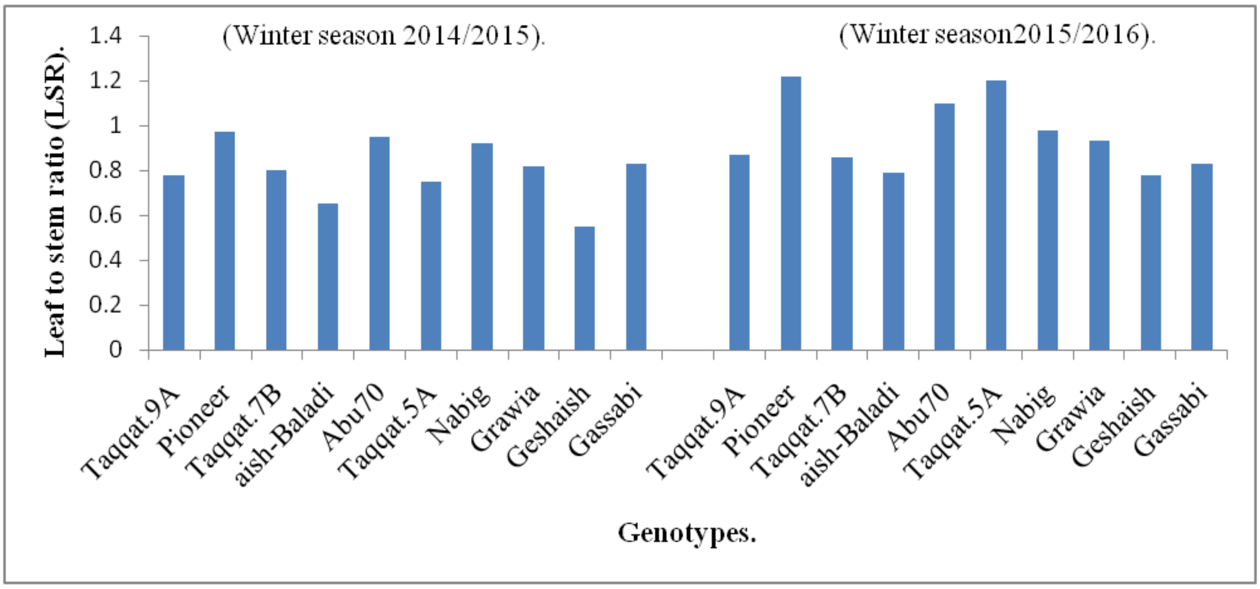


**Figure .9** Leaf to stem ratio (LSR) of 10 forage sorghum genotypes grown during winter season.

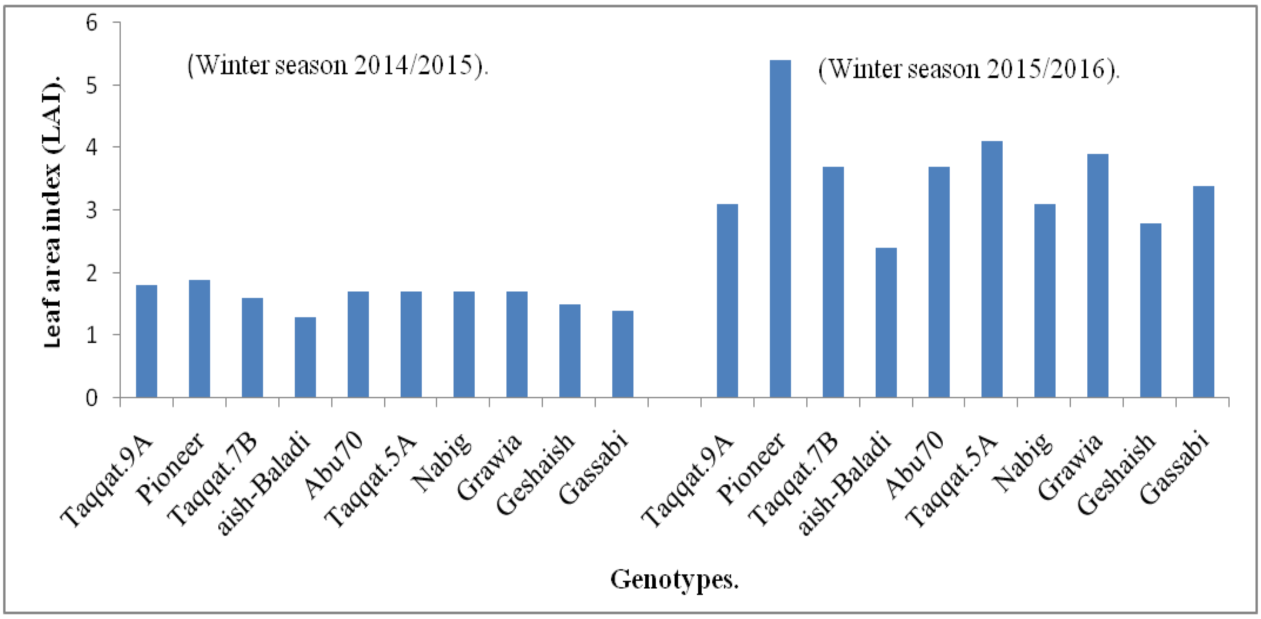


**Figure .10** Leaf area index (LAI) of 10 forage sorghum genotypes, grown during winter season.

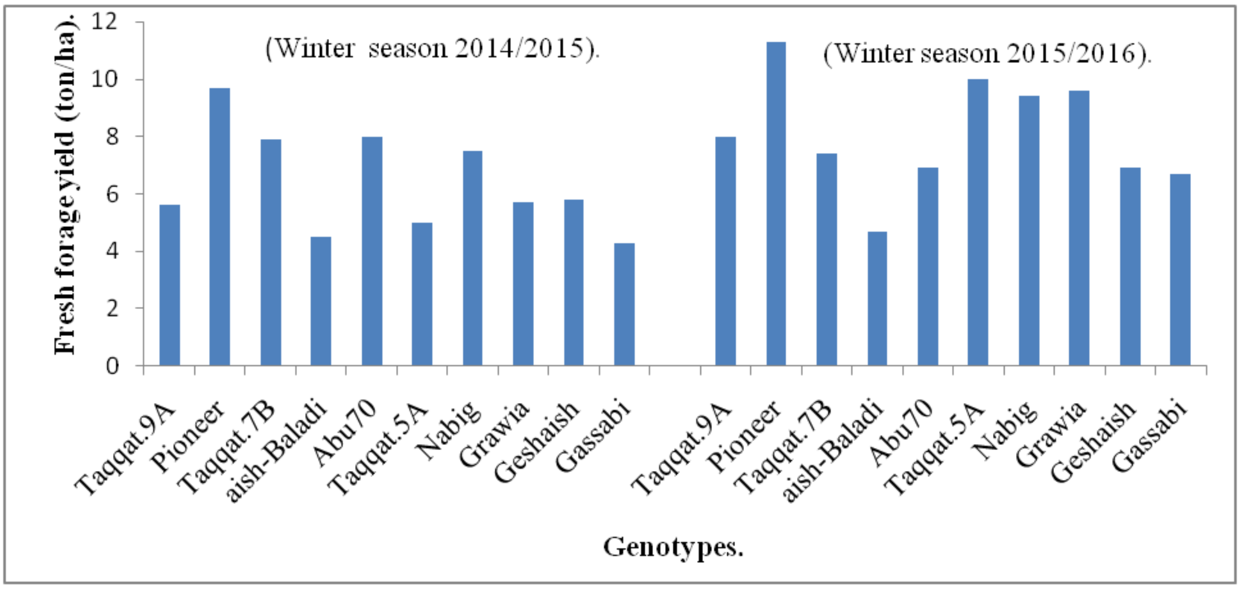


**Figure .11** Fresh forage yield (ton/ha) of 10 forage Sorghum genotypes, grown during winter season.

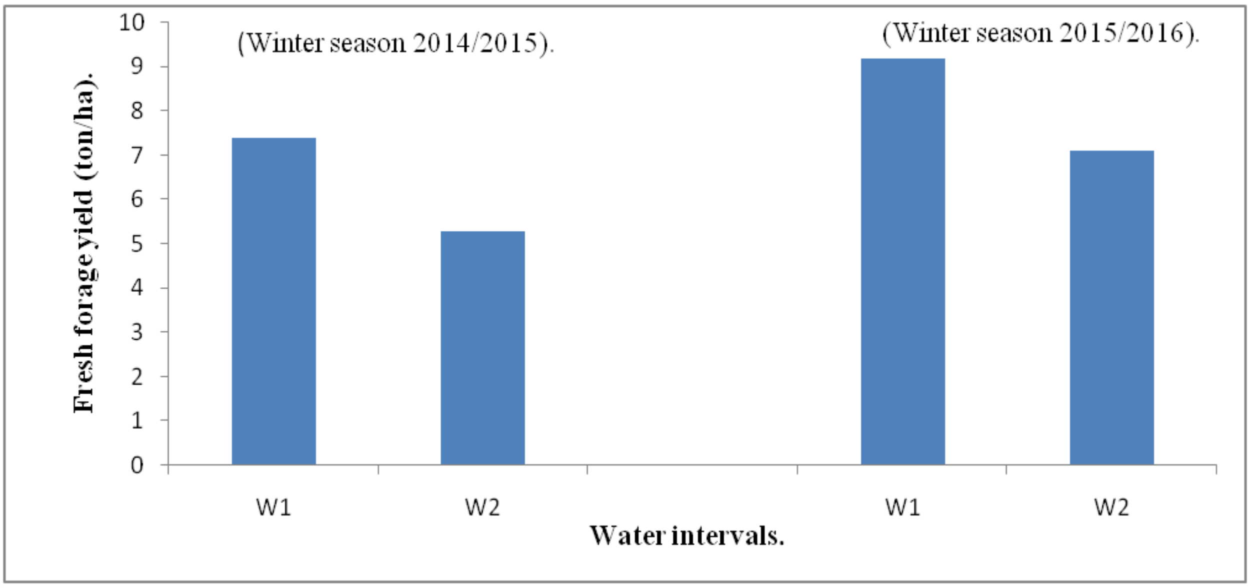


**Figure .12** Effect of two watering intervals on fresh forage yield (ton/ha), during winter season.

percentage (3.5) was recorded by Taqqat.9A, 1st winter season was greater than rainy season for ash percentage (Appendix 5).

**4.4.4 Crude protein (CP %).**

Statistical analysis, showed significant differences among genotypes, during both seasons. The highest percentage was obtained by genotype Taqqat.9A (12.0 %) followed by Gassabi, and the lowest percentage was recorded by genotypes Aish-Baladi and Abu70 (6.51 and 7.16 %) respectively in the rainy season. While at winter season high percentages (11.6, 11.4, and 11.1 %) were produced by cultivar Pioneer, Abu70 (Aliab) and genotype Aish-Baladi, followed by genotypes, Taqqat.7B, Taqqat.9A, Nabig, Taqqat.5A and Geshaish. The Lesser percentage (5.5%) was obtained by Local genotype Gassabi (Appendix 5).

**4.4.5 Ether extractable fats (E.E %).**

During both season, the genotypes differed significantly for ether extractable fats percentage, (Appendix 5). Genotypes Aish-Baladi and Taqqat.5A had the highest percentage (4.50 and 4.00 %) respectively followed by cultivar Abu70, while the lowest value was obtained by genotype Taqqat9A (0.10 %) during the rainy season, whereas at winter season genotypes Abu70, Taqqat5A, Grawia and Pioneer recorded the highest values (3.20, 3.0, 2.80, and 2.80%) successively, followed by Taqqat.9A. The lesser percentage of (1.40 %) was produced by genotype Taqqat7B.

**4.4.6 Crude fiber (CF %).**

Significant differences were detected among genotypes for crude fiber during both seasons. Crude fiber at rainy season ranged between 32 – 45 %. The highest percentage was given by cultivar Abu70 followed by local genotype Nabig (38.50 %), on the contrary the minimum percentage (32 %) was registered by genotype Gassabi. At winter season crude fiber ranged between (29 – 49 %).The maximum CF % was obtained by local genotype Nabig (49%) followed by Abu70 (36%) and Aish-Baladi (35.17%), while the lowest percentage at winter season (29 and 30.5%) was given by genotype Grawia and Gassabi respectively (Appendix 5).

### 4.4.2 Performance of quality traits during rainy season (2015/2016) and winter season (2015/2016).

Table (17) showed the performance of different genotypes for dry mater percentage (DM %), ash %, crude protein (CP %), Ether extractable fats (E.E) and crude fiber (CF %), during rainy and winter seasons.

#### 4.4.2.1 Dry matter (DM %).

The data presented in Table.17 revealed that cultivar Abu70 produced the highest dry matter percentage (93.4 %); it was followed by local genotype Geshaish, while the genotype Taqqat.7B produced the lowest (90.9%) dry matter % during the 2$^{nd}$ rainy season. Whereas the tested genotypes were not significant during the 2$^{nd}$ winter season with respect to dry matter percentage. The overall mean of winter season was greater than the rainy season (Appendix 5).

#### 4.4.2.2 Ash %.

The maximum ash percentage (7.44%) was recorded in case of genotype Taqqat.7B followed by cultivar Pioneer, while the minimum value of (5.82%) was recorded by cultivar Abu70 during the 2$^{nd}$ rainy season. while, the genotype Gassabi produced the highest value (12.1% ), followed by genotype Geshaish, whereas the minimum value of (3.4%) recorded in genotype Taqqat.9A during 2$^{nd}$ winter season. Relatively the performance of winter season was higher than rainy season with respect to ash % (Appendix 5).

#### 4.4.2. 3 Crude protein (CP %).

Taqqat.9A produced significantly higher crude protein contents (13.18 %) than all other genotypes (Table 17) and it was followed by cultivar Pioneer which had crude protein contents of (10.02%).While the lowest protein percentage (6.90 %) was recorded by genotype Geshaish during the rainy season. Also crude protein was significantly different during the 2nd winter season; the highest percentage (11.4%) in crude protein was recorded by cultivar Pioneer which was statistically par with genotype Abu70 followed by genotype Aish-Baladi.

**Table** 12. Effect of genotypes and watering intervals on yield of forage sorghum (*Sorghum bicolor* L. Moench) grown during winter season (2014/ 2015).

| Parameters | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | dry forage yield (ton/ha). | | | (%) of dry matter | | | fresh forage yield ( g /plant) | | |
| (Treatments) Genotypes. | $W_1$ | $W_2$ | Mean | $W_1$ | $W_2$ | Mean | $W_1$ | $W_2$ | Mean |
| Tagat.9A | 2.0 e | 2.0 e | 1.8 *c* | 31.1 | 37.7 | 34.4 | 37.0 bcd | 33.0bcd | 35.0 *abc* |
| Pioneer | 5.3 a | 4.0 b | 4.6 *a* | 30.0 | 39.0 | 34.5 | 57.0 a | 33.0bcd | 44.0 *a* |
| Tagat.7B | 3.5 ab | 2.3cde | 2.9 *ab* | 40.3 | 32.0 | 36.1 | 47.0 abc | 40.0abcd | 43.0 *a* |
| Aish –Baladi | 1.6 e | 1.4 e | 1.5 *c* | 36.8 | 31.6 | 34.2 | 27.0 d | 27.0 d | 26.0 *c* |
| Abu70 (Aliab) | 3.2 bc | 2.3cde | 2.7 *ab* | 34.2 | 32.8 | 33.5 | 33.0 bcd | 33.0 bcd | 33.0 *abc* |
| Tagat.5A | 1.7 e | 2.0 de | 1.9 *c* | 44.2 | 34.6 | 39.4 | 27.0 d | 30.0 cd | 28.0 *bc* |
| Nabig | 3.0 bcd | 2.1 de | 2.5 *ab* | 33.5 | 29.1 | 31.3 | 50.0 ab | 37.0 bcd | 43.0 *a* |
| Grawia | 2.1 de | 1.8 e | 1.9 *bc* | 31.3 | 36.5 | 34.1 | 40.0 abcd | 30.0 cd | 35.0 *abc* |
| Geshaish | 2.2 cde | 1.7 e | 2.0 *bc* | 36.2 | 33.3 | 34.8 | 33.0 bcd | 33.0 bcd | 33.0 *abc* |
| Gasabi | 1.7 e | 1.6 e | 1.7 *c* | 39.3 | 38.0 | 38.7 | 23.0 d | 23.0 d | 23.0 *c* |
| Mean | 2.6 **a** | 2.1 **b** | | 35.7 | 34.5 | | 35.1**b** | 31.9 **b** | |
| C.V% | 23.06 % | | G.M **:**2.20 | 17.30 % | | G.M**:**35.07 | 17.52% | | G.M**:** 34.3 |
| SE± | SE (w) = 0.14, SE (g) = 0.11, SE (w×g) = 0.30 | | | SE (w) = 1.73, SE (g) = 1.41, SE (w×g) = 1.82 | | | SE (w) = 1.04, SE (g) = 0. 85, SE (w×g) = 4.5 | | |

*****$W_1$ and $W_2$ denote watering interval every 7 and 10 days, respectively.***** G.M denote for grand mean *****SE (w), SE (g) and SE (w×g) denote for standard error of water intervals, genotype and their interaction respectively.*****Values having the same letter are not significant differently at5% (using Duncan multiple range test) italic letter denote genotypes, bold letter denote watering intervals and normal for their interaction.

**Table** 13.Effect of genotypes and watering intervals on yield of forage sorghum (*Sorghum bicolor* L. Moench) grown during winter season (2015/ 2016).

| | Parameters | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | dry forage Yield (ton/ha). | | | (%) of dry matter | | | fresh forage yield (g/plant) | | |
| (Treatments) Genotypes. | $W_1$ | $W_2$ | Mean | $W_1$ | $W_2$ | Mean | $W_1$ | $W_2$ | Mean |
| Taqqat.9A | 2.9 | 1.9 | 2.4 *h* | 33.9 | 31.6 | 32.8 | 43.3 | 40.4 | 41.8 *i* |
| Pioneer | 3.6 | 3.1 | 3.3 *b* | 32.2 | 37.5 | 34.9 | 89.2 | 87.5 | 88.3 *a* |
| Taqqat.7B | 3.3 | 2.6 | 2.9 *e* | 33.3 | 33.2 | 33.3 | 79.7 | 58.1 | 68.9 *d* |
| Aish –Baladi | 1.4 | 1.7 | 1.6 *j* | 33.6 | 38.9 | 36.3 | 26.3 | 27.3 | 26.8 *j* |
| Abu70 (Aliab) | 3.6 | 3.0 | 3.3 *d* | 33.1 | 37.1 | 35.1 | 84.1 | 43.6 | 63.9 *e* |
| Taqqat.5A | 3.8 | 3.8 | 3.8 *a* | 33.8 | 32.9 | 33.3 | 83.0 | 57.2 | 70.1 *c* |
| Nabig | 3.7 | 3.0 | 3.3 *c* | 32.3 | 30.3 | 31.3 | 82.6 | 64.0 | 73.3 *b* |
| Grawia | 3.2 | 3.1 | 3.1 *e* | 32.8 | 35.5 | 34.2 | 66.1 | 56.0 | 61.0 *f* |
| Geshaish | 2.5 | 1.8 | 2.2 *i* | 33.9 | 33.8 | 33.9 | 51.5 | 47.2 | 49.3 *g* |
| Gasabi | 2.6 | 2.7 | 2.8 *g* | 31.9 | 31.9 | 31.9 | 53.2 | 45.2 | 49.2 *h* |
| Mean | 3.1 **a** | 2.3 **b** | | 33.1 | 34.3 | | 65.9 **a** | 52.6 **b** | |
| C.V% | 25.48 % | | G.M :2.9 | 8.54 % | | G.M:33.9 | 19.09% | | G.M: 59.25 |
| SE± | SE (w) = 0.07, SE (g) = 0.06, SE (w×g) = 0.29 | | | SE (w) = 0.56, SE (g) = 0. 45, SE (w×g) = 1.46 | | | SE (w) = 2.75, SE (g) = 2.24, SE (w×g) = 4.39 | | |

* $W_1$ and $W_2$ denote watering interval every 7 and 10 days, respectively.* G.M denote for grand mean *SE (w), SE (g) and SE (w×g) denote for standard error of water interval, genotype and their interaction respectively.*Values having the same letter are not significant differently at5% (using Duncan multiple range test) italic letter denote genotypes, bold letter denote watering intervals and normal for their interaction.

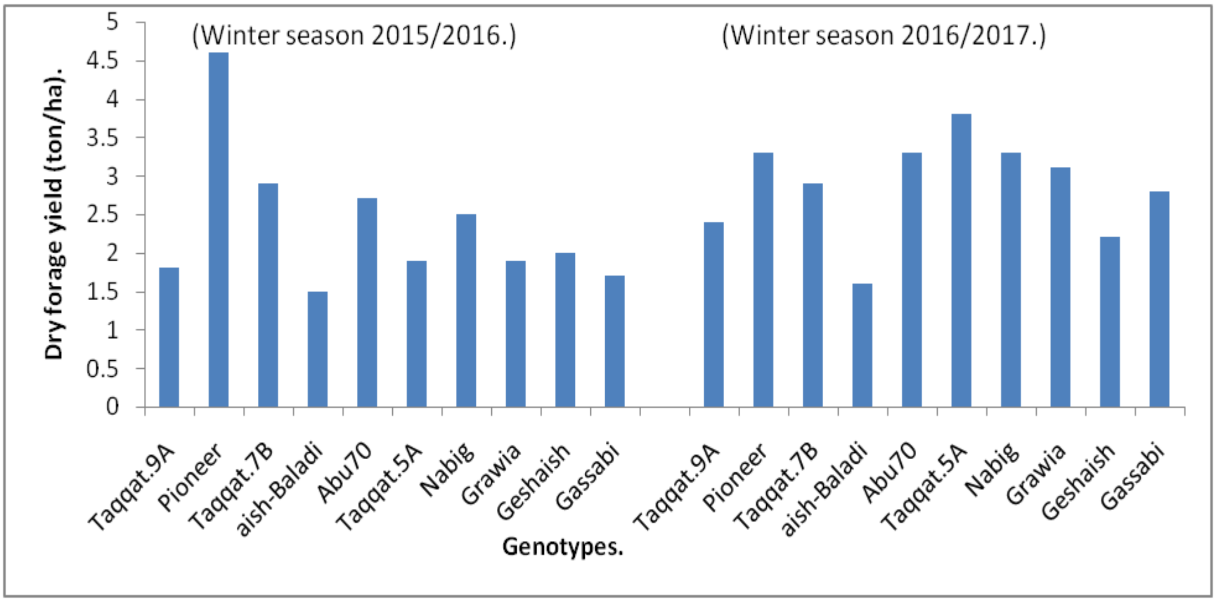


**Figure .13** Dry forage (ton/ha) of 10 forage sorghum genotypes, grown during winter season.

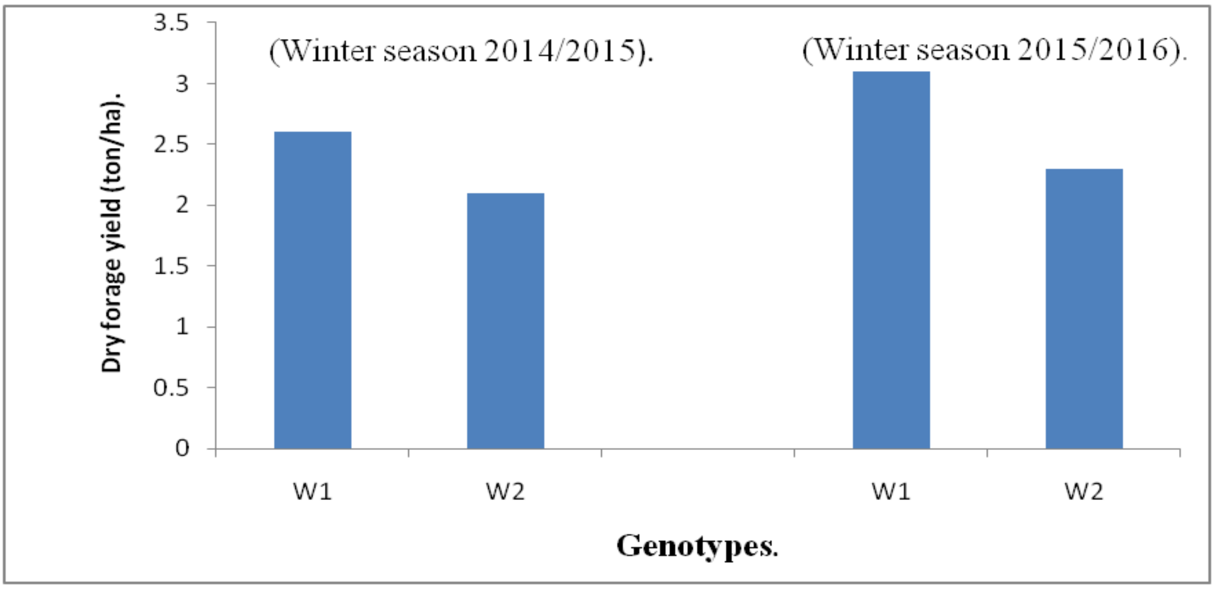


**Figure. 14** Effect of two watering intervals on dry forage yield (ton/ha) during winter season.

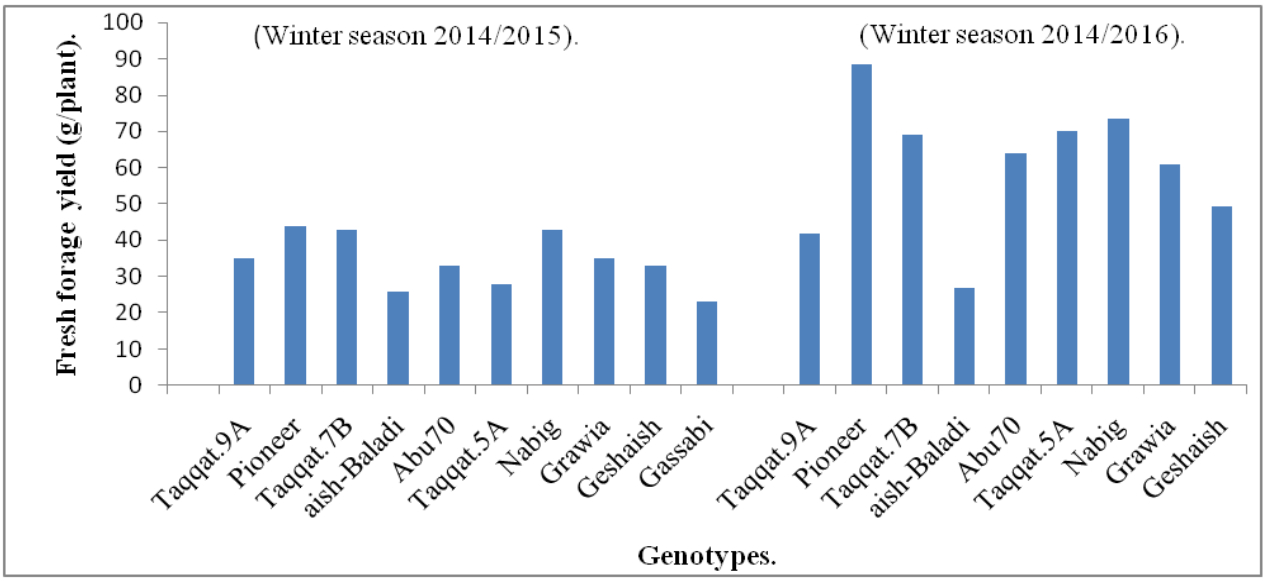


**Figure .15** Fresh forage yields (g/plant) of 10 forage sorghum genotypes, grown during winter season.

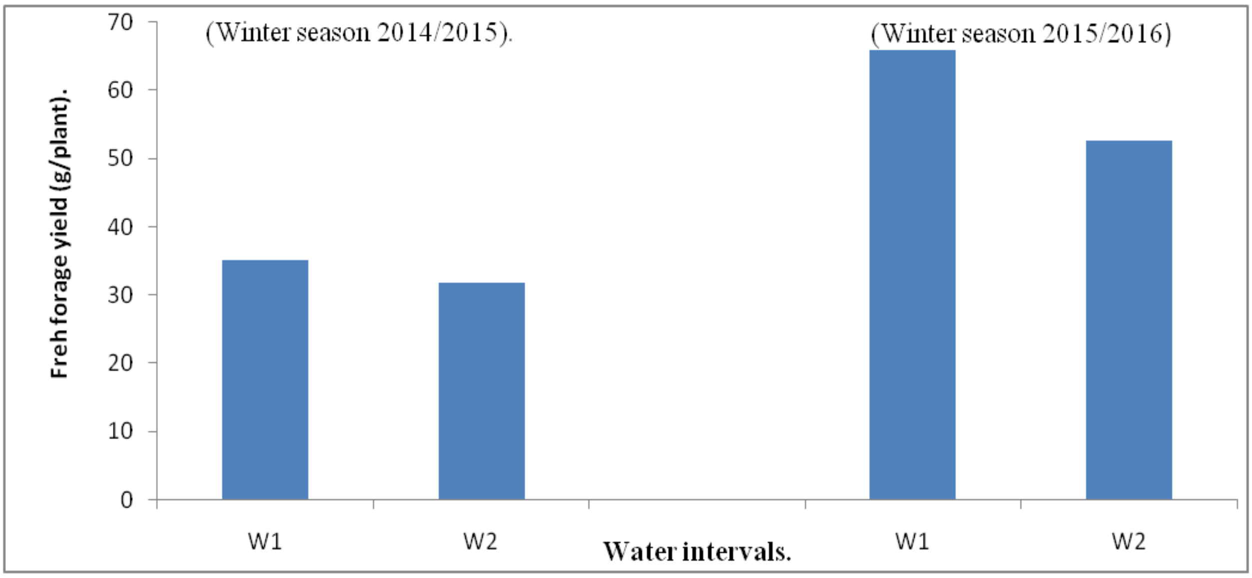


**Figure .16** Effect of two watering intervals on fresh forage yield (g/plant) during winter season.

**Table** 14. Effect of genotypes and watering intervals on yield attributes of forage sorghum (*Sorghum bicolor* L. Moench) grown during winter season (2014/ 2015).

| | Parameters | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | dry forage yield (g /Plant ) | | | fresh forage yield (g /plant ) during 2nd cut | | | dry forage yield (g/plant) during 2nd cut | | |
| (Treatments) Genotypes. | $W_1$ | $W_2$ | Mean | $W_1$ | $W_2$ | Mean | $W_1$ | $W_2$ | Mean |
| Tagat.9A | 12.3 e | 10.7 i | 11.5 c | 30.0 | 27.0 | 28.5 | 13.0 | 8.0 | 10.0 |
| Pioneer | 16.7 a | 11.0 h | 13.8 a | 33.0 | 23.0 | 28.0 | 12.0 | 9.0 | 11.0 |
| Tagat.7B | 11.7 f | 14.3 c | 13.0 b | 20.0 | 20.0 | 20.0 | 12.0 | 6.0 | 9.0 |
| Aish –Baladi | 9.0 m | 8.3 o | 8.7 g | 40.0 | 27.0 | 33.5 | 16.0 | 9.0 | 12.0 |
| Abu70 (Aliab) | 9.3 l | 9.7 k | 9.5 f | 20.0 | 13.0 | 16.5 | 8.0 | 8.0 | 8.0 |
| Tagat.5A | 15.0 b | 11.0 h | 13.0 b | 30.0 | 23.0 | 26.5 | 13.0 | 8.0 | 11.0 |
| Nabig | 13.3 d | 12.33 e | 12.8 b | 40.0 | 27.0 | 33.5 | 17.0 | 13.0 | 15.0 |
| Grawia | 10.3 j | 9.7 k | 10.0 e | 27.0 | 27.0 | 27.0 | 13.0 | 7.0 | 10.0 |
| Geshaish | 9.0 m | 11.3 g | 10.2 d | 30.0 | 23.0 | 26.5 | 13.0 | 8.0 | 11.0 |
| Gasabi | 7.7 o | 7.7 o | 7.7 h | 23.0 | 20.0 | 21.5 | 8.0 | 7.0 | 7.0 |
| Mean | 11.4 **b** | 10.6 **b** | | 30.0 **a** | 23.0 **b** | | 13.0 | 8.0 | |
| C.V% | 16.50 % | | G.M : 11.02 | 22.35% | | G.M : 26.2 | 28.00 % | | G.M**:** 10.5 |
| SE± | SE (w) =0.38, SE (g) =0.31 , SE (w×g) = 1.02 | | | SE (w) =1.87, SE (g) = 0.85, SE (w×g) = 3.43 | | | SE (w) = 0.9, SE (g) = 1.01, SE (w×g) = 1.71 | | |

*****$W_1$ and $W_2$ denote watering interval every 7 and 10 days, respectively.***** G.M denote for grand mean *****SE (w), SE (g) and SE (w×g) denote for of watering interval, genotype and their interaction respectively.*****Values having the same letter are not significant differently at5% (using Duncan multiple range test) italic letter denote genotypes, bold letter denote watering intervals and normal for their interaction.

**Table** 15. Effect of genotypes and watering intervals on yield attributes of forage sorghum (*Sorghum bicolor* L. Moench) grown during winter season (2015/ 2016).

| (Treatments) Genotypes. | dry forage yield (g /Plant ) $W_1$ | $W_2$ | Genotype mean | fresh forage yield (g /plant ) during 2nd cut $W_1$ | $W_2$ | Genotype mean | dry forage yield (g/plant) during 2nd cut $W_1$ | $W_2$ | Genotype mean |
|---|---|---|---|---|---|---|---|---|---|
| Taqqat.9A | 18.5 | 13.9 | 16.2 *i* | 44.2 d | 42.8 e | 43.5 *b* | 18.6 | 15.6 | 17.1 |
| Pioneer | 23.0 | 20.3 | 21.6 *d* | 41.5 h | 39.3 j | 40.4 *e* | 14.6 | 14.8 | 14.6 |
| Taqqat.7B | 27.0 | 21.8 | 24.4 *b* | 38.7 l | 38.0 m | 38.3 *g* | 12.8 | 13.9 | 13.3 |
| Aish –Baladi | 11.0 | 12.6 | 11.8 *j* | 29.2 t | 30.6 s | 29.9 *j* | 14.7 | 14.1 | 14.4 |
| Abu70 (Aliab) | 22.3 | 17.4 | 19.8 *f* | 31.5 q | 30.8 r | 31.2 *i* | 11.1 | 11.3 | 11.2 |
| Taqqat.5A | 25.9 | 26.1 | 26.0 *a* | 34.4 o | 33.2 p | 33.8 *h* | 14.7 | 15.0 | 14.9 |
| Nabig | 23.0 | 22.5 | 22.8 *c* | 59.0 a | 45.5 b | 52.3 *a* | 22.7 | 20.8 | 21.7 |
| Grawia | 21.5 | 21.6 | 21.5 *e* | 42.7 f | 38.9 k | 40.8 *d* | 15.5 | 16.1 | 15.8 |
| Geshaish | 20.5 | 18.6 | 19.5 *g* | 42.4 g | 36.4 n | 39.4 *f* | 13.5 | 14.6 | 14.0 |
| Gasabi | 20.8 | 16.4 | 18.6 *h* | 40.8 i | 45.0 c | 42.9 *c* | 16.1 | 15.4 | 15.7 |
| Mean | 21.3 **a** | 19.1 **b** | | 40.4 **a** | 38.1 **b** | | 15.4 | 15.2 | |
| C.V% | 13.12 % | | G.M : 20.2 | 2.09 % | | G.M : 39.2 | 9.68 % | | G.M**:** 15.3 |
| SE± | SE (w) =0.50, SE (g) =0.41 , SE (w×g) = 1.52 | | | SE (w) =0.10, SE (g) = 0.08, SE (w×g) = 0.25 | | | SE (w) = 0.46, SE (g) = 0.38, SE (w×g) = 0.58 | | |

***$W_1$ and $W_2$ denote watering interval every 7 and 10 days, respectively.*** G.M denote for grand mean ***SE (w), SE (g) and SE (w×g) denote for of water interval genotype and their interaction respectively.*Values having the same letter are not significant differently at5% (using Duncan multiple range test) italic letter denote genotypes, bold letter denote watering interval and normal for their interaction.

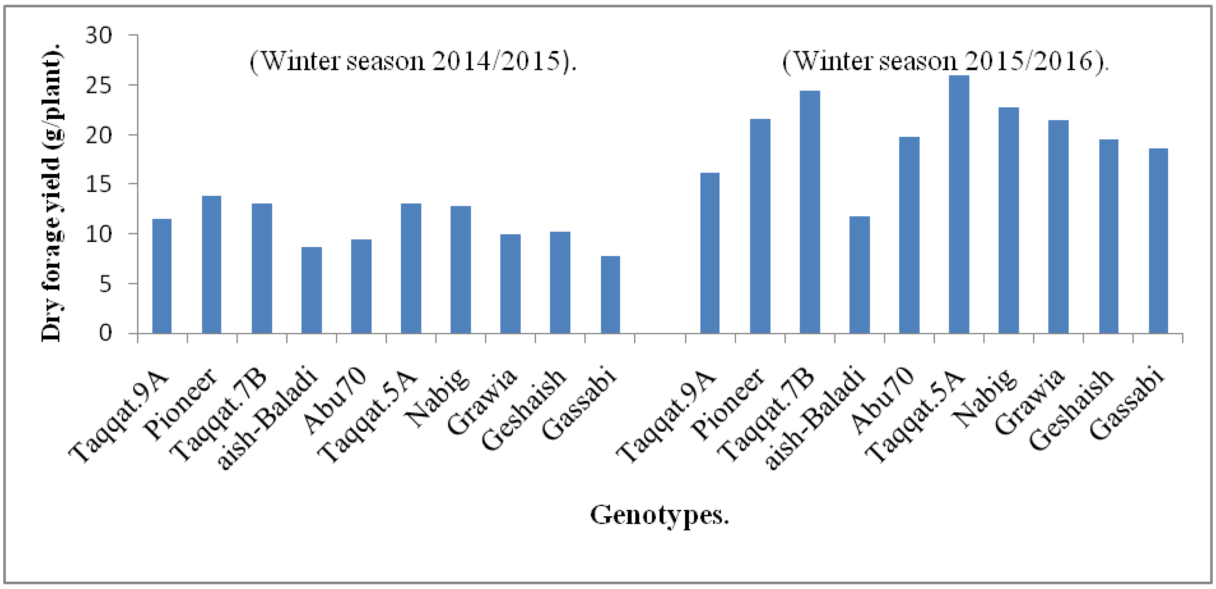


**Figure .17** dry forage yields (g/plant) of 10 sorghum forage genotypes, grown during winter season.

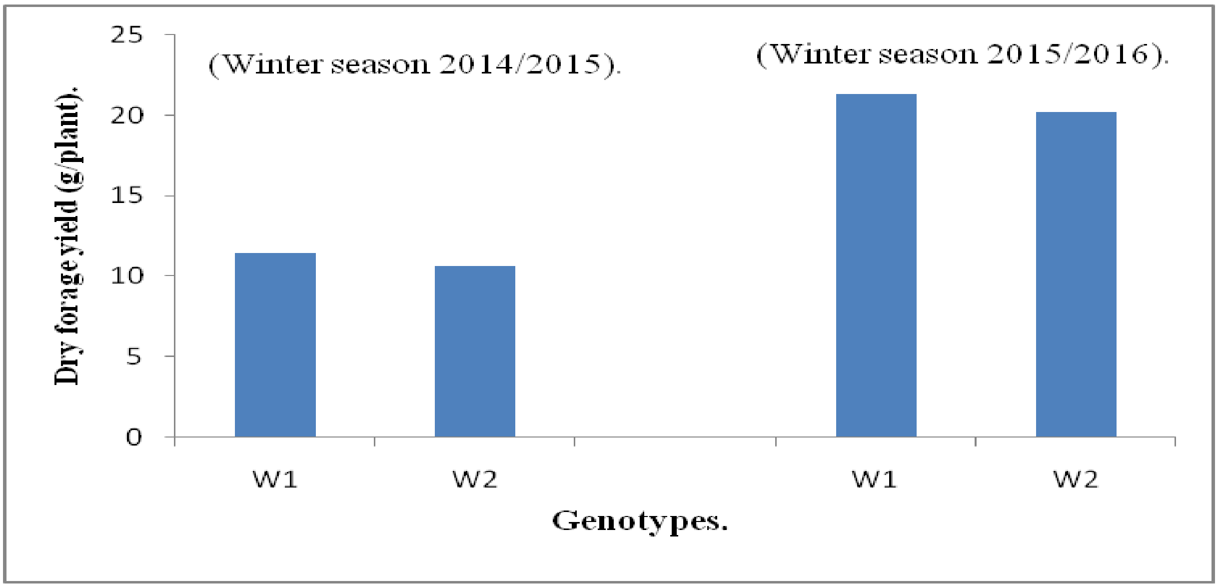


**Figure .18** Effect of two watering interval on dry sorghum forage yield (g/plant) during winter season.

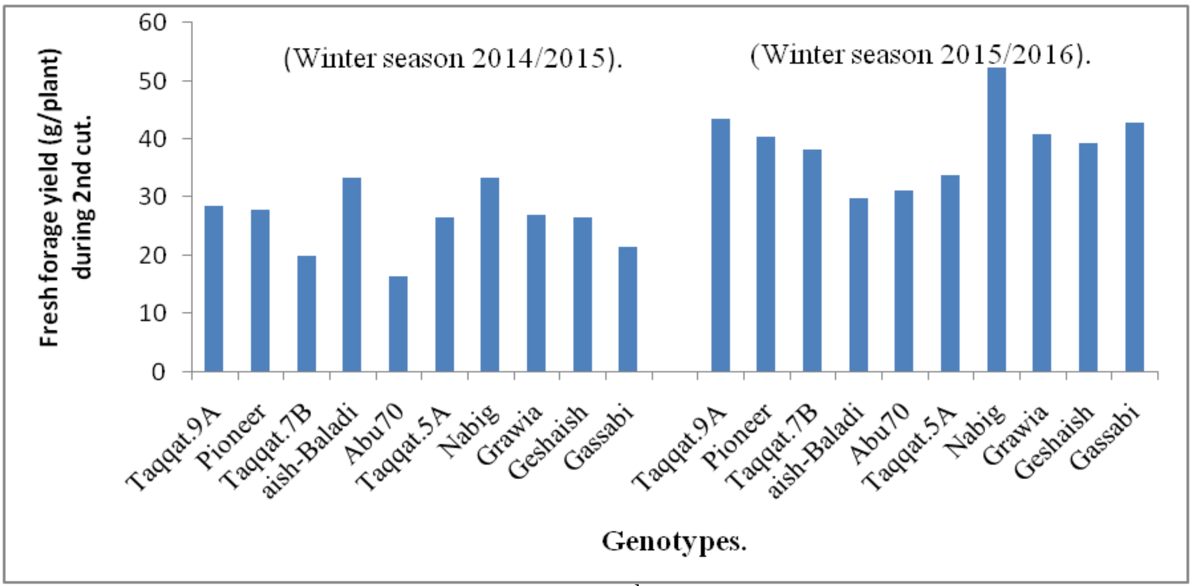


**Figure .19** Fresh forage yield (g/plant)/ 2nd cut of 10 sorghum forage genotypes grown during winter season.

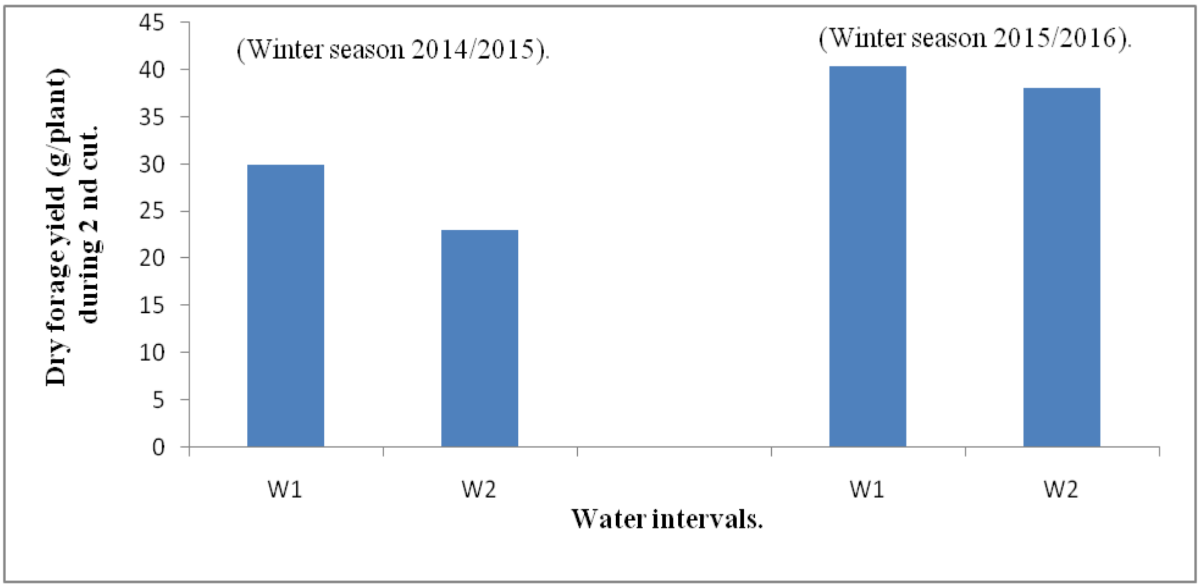


**Figure .20** Effect of two watering interval on fresh forage yield (g/plant) during 2nd cut /winter, season.

The minimum (6.20 %) crude protein was obtained by genotype Gassabi in the same season (Appendix 5).

**4.4.2.4 Ether extractable fats (E.E %).**

The highest ether extractable fat percentage during 2$^{nd}$ rainy season was 4.0 % and was recorded in case of genotype Aish-Baladi followed by genotype Taqqat.5A, while the genotype Nabig gave significantly the lowest ether extractable fat percentage of (1.42 %) than all other genotypes, whereas at the 2$^{nd}$ winter season, cultivar Abu70 had the highest (3.6) ether extractable fat followed by genotype Taqqat.5A. The minimum percentage (1.7) was recorded by genotype Taqqat.7B (Appendix 5).

**4.4.2. 5 Crude fiber (CF %).**

The data pertaining to crude fiber % revealed that the genotype Abu70 gave significantly higher crude fiber percentage (37.67 %) than all other genotypes followed by genotype Nabig. The minimum crude fiber content (33.0 %) was noted for genotypes Taqqat.5A and Gassabi during the 2$^{nd}$ rainy season, while crude fiber ranged between (29.6 – 46.3 %) during 2$^{nd}$ winter season. Maximum CF % was obtained by local genotype Nabig (46.3%) followed by Abu70 (36.3%). The lowest percentage during the 2$^{nd}$ winter season (29.6%) was given by cultivar Grawia (Appendix 5).

**Table** 16. Effect of genotypes on dry matter, ash, crude protein, ether extract (crude fat) and crude fiber percentages of fodder sorghum (*Sorghum bicolor* L. Moench) grown during rainy and winter seasons (2014/2015).

| Treatments (genotypes) | Rainy season 2014/2015 | | | | | Winter season 2014/2015 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | D.M% | Ash% | C.P% | E.E% | C.F% | D.M% | Ash% | C.P% | E.E% | C.F% |
| Taqqat.9A | 94.2 b | 5.9 fg | 12.0 a | 0.1 d | 35.0 bc | 94.9 a | 3.5 c | 10.2 b | 2.6 ab | 31.5 d |
| Pioneer | 93.6 cd | 6.1 ef | 9.4 cd | 2.5 bc | 33.0 bc | 95.1 a | 6.7 bc | 11.6 a | 2.8 a | 33.3 c |
| Taqqat.7B | 93.4 cd | 5.7 g | 9.3 cd | 2.0 c | 35.5 bc | 94.8 a | 9.1 ab | 10.3 b | 1.4 d | 31.0 d |
| Aish –Baladi | 94.7 a | 6.4 de | 6.5 f | 4.5 a | 35.5 bc | 94.9 a | 9.4 ab | 11.1 a | 1.8 cd | 35.2 b |
| Abu70(Aliab) | 94.1 b | 6.2 ef | 7.2 f | 3.5 ab | 45.0 a | 94.1 a | 9.9 ab | 11.4 a | 3.2 a | 36.0 b |
| Taqqat.5A | 93.4 d | 6.6 cd | 8.3 e | 4.0 a | 33.5 bc | 94.4 a | 9.9 ab | 9.9 b | 3.0 a | 31.3 d |
| Nabig | 93.7 c | 7.0 b | 8.9 de | 1.5 c | 38.5 b | 94.5 a | 9.9 ab | 10.1 b | 1.8 cd | 49.0 a |
| Grawia | 93.0 e | 6.4 de | 10.0 bc | 2.0 c | 34.0 bc | 94.7 a | 10.7 a | 8.8 c | 2.8 a | 29.0 e |
| Geshaish | 93.4 cd | 6.9 bc | 10.1 bc | 2.0 c | 34.0 bc | 95.3 a | 11.3 a | 9.7 b | 1.8 cd | 31.3 d |
| Gassabi | 93.6 cd | 7.9 a | 10.4 b | 1.5 c | 32.0 c | 95.4 a | 12.4 a | 5.5 d | 2.2 bc | 30.5 e |
| Grand mean | **93.7** | **6.5** | **9.2** | **2.4** | **35.6** | **94.8** | **9.3** | **9.95** | **2.3** | **33.8** |
| SE± | 0.016 | 0.27 | 0.02 | 0.02 | 0.44 | 0.10 | 0.61 | 0.14 | 0.10 | 0.32 |
| C.V% | 0.13% | 2.53 | 4.39 | 7.00 | 7.13 | 0.66 | 20.78 | 4.37 | 13.75 | 3.03 |

* Values having the same letter are not significantly differ 5% levels according to Duncan's multiple range test (DMRT).

**Table** 17. Effect of genotypes on dry matter, ash, crude protein, ether extract (crude fat), and crude fiber percentages of fodder sorghum (*Sorghum bicolor* L. Moench) grown during rainy and winter seasons (2015/2016 ).

| Treatments (genotypes) | Rainy season 2015/2016 | | | | | Winter season 2015/2016 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | D.M% | Ash% | C.P% | E.E% | C.F% | D.M% | Ash% | C.P% | E.E% | C.F% |
| Taqqat.9A | 92.70 c | 7.33 c | 13.18 a | 3.08 d | 31.67 g | 94.4 a | 3.4 j | 10.1 e | 2.5 f | 31.0 h |
| Pioneer | 91.50 h | 7.42 b | 10.02 b | 2.60 e | 30.33 h | 94.5 a | 6.06 i | 11.4 a | 2.6 e | 33.6 d |
| Taqqat.7B | 90.90 i | 7.44 a | 6.94 g | 2.13 h | 30.33 h | 94.7 a | 9.4 h | 10.5 c | 1.7 i | 31.1 g |
| Aish –Baladi | 92.4 f | 6.45 e | 8.91 d | 4.00 a | 33.67 e | 94.8 a | 9.7 f | 11.1 b | 1.9 g | 35.0 c |
| Abu70(Aliab) | 93.40 a | 5.82 i | 8.23 e | 3.37 c | 37.67 a | 94.0 a | 10.0 e | 11.4 a | 3.6 a | 36.3 b |
| Taqqat.5A | 91.60 g | 6.32 f | 6.94 g | 3.92 b | 33.00 f | 94.3 a | 10.2 d | 10.2 d | 3.1 b | 31.4 f |
| Nabig | 92.63 d | 5.81 j | 6.94 g | 1.42 j | 36.37 b | 94.4 a | 9.5 g | 10.0 f | 1.8 h | 46.2 a |
| Grawia | 92.60 e | 6.70 d | 8.0 f | 2.17 g | 36.33 c | 94.7 a | 10.4 c | 8.87 h | 2.7 d | 29.6 j |
| Geshaish | 93.20 b | 6.30 g | 6.90 h | 2.53 f | 35.33 d | 95.2 a | 11.3 b | 10.0 f | 1.8 h | 32.0 e |
| Gassabi | 92.40 f | 6.09 h | 9.53 c | 1.60 i | 33.00 f | 95.5 a | 12.1 a | 6.20 g | 2.8 c | 31.0 h |
| Grand mean | **92.33** | **6.57** | **8.56** | **2.48** | **33.8** | **94.7** | **9.19** | **10.01** | **2.5** | **33.6** |
| SE± | 0.092 | 0.022 | 0.113 | 0.075 | 0.872 | 0.205 | 0.427 | 0.193 | 0.075 | 0.517 |
| C.V% | 0.31 | 1.07 | 4.18 | 9.53 | 8.15 | 1.09 | 9.19 | 6.10 | 9.53 | 4.84 |

* Values having the same letter are not significantly differ 5% levels according to Duncan's multiple range test (DMRT).

# CHAPTER FIVE
# DISCUSSION

## 5.1 Rainy Experiments.

### 5.1.1 Growth attributes.

Highly significant (P >0.05) differences between the genotypes were detected for most of the characters studied in this experiment. In both seasons, plant height (cm) was significantly different among the different genotypes. The highest plant height was obtained by hybrid Pioneer and Nabig genotype. Variations in plant height among genotypes might be due to their genetic variability. Younas (2002) reported a maximum plant height of (190.85 cm) for Pioneer hybrid. Also significant differences in plant height among the sorghum cultivars have been reported by Yousef *et al*. (2009) and Ayub *et.al.* (2010). However, the greater mean of plant height during the 1$^{st}$ season might be attributed to the seasonal variation like moisture, temperature during growing period of the crop.

The thinner plant (smaller stem diameter) was produced by local genotype Aish-Baladi during both seasons compared to other studied genotypes. This variation in stem diameter may be due to difference in heritability of the genotypes. Ayub, *et.al,* (1999) found that there were significant variations in stem diameter of different sorghum cultivars grown for forage purposes.

Data regarding the number of leaves per plant during rainy season 2014 and 2015 showed a significant difference between the genotypes in which Taqqat.7B and hybrid Pioneer produced the highest values, in contrast the lowest values were recorded by genotype Aish-Baladi. This variation is probably due to genetic make-up of the genotype under investigation. Differences in number of leaves among sorghum cultivars have been reported by Ahmed *et al.* (2007) and Ayub *et al.* (2010).The relatively increased in number of leaves during the 1$^{st}$ season might be due to better availability of soil moisture during the growing period. Most of forage sorghum genotypes are characterized by ability to produce tillers.

Significant differences among all genotypes with respect to number of tillers per plant might be due to climatic conditions that prevailed during the crop season. This is in line with Saifullah *et al.* (2011) who reported a considerable variation in number of tillers per plant among sorghum varieties due to different moisture levels. Abu 70 scored a lesser number of tillers during both seasons. Similar results were obtained by Ibrahim and Rashid (1996) who found that, Abu Sab'in gave lesser number of tillers per plant.

In number of leaves per tiller differences between the genotypes might be attributed to genetic make-up of different genotypes and adaptability of the tested genotypes to the different environmental conditions. This result was confirmed by the findings of Shakoor *et al.* (1983) and Bhatti *et al.* (1991).

Leaf area index (L.A.I) is the main contributing factor for photosynthesis. Significant differences were found among all genotypes for leaf area index during both years. Genotype Taqqat.7B, Pioneer and Nabig had the highest leaf area index. These variations in leaf area index among genotypes might be due to increase in number of leaves per plant and single leaf area of tested sorghum forage genotypes. These results were in accordance with the results of Wiedenfeld and Matocha (2010) in sorghum fodder crop .In days to 50% flowering, genotype Geshaish reached this period in (53days) during the 1$^{st}$ season while the local genotype Aish-Baladi reached it in (50 days) during the 2$^{nd}$. This variation in number of days to 50% flowering might be attributed to genetic make-up of these genotypes. These results are in line with the findings previously reported by Idris and Mohammed (2012).Genotypes Geshaish and Aish-Baladi had the great value of selection for early flowering from local forage genotypes in breeding programs.

### 5.1.2 Yield attributes.

In fresh yield (g) per plant the results revealed that, the range was (37.5 – 120.5 g) during 1$^{st}$ rainy season scored by local genotypes Aish-Baladi and Nabig respectively and the range of (30 – 120.5 g) was recorded by genotypes Gassabi and hybrid Pioneer respectively during 2$^{nd}$ season. Also the overall mean of the 1$^{st}$

rainy season was greater. This variation could be attributed to large effect of environmental factors during the growing season, such that better amount of rain-fall and even distribution. The high yield of hybrid Pioneer and genotype Nabig can be attributed to taller plants with more leaves per plant. The significant differences in green forage yield among sorghum cultivars have also been undertaken by Chughtai *et al*. (2007).

In this study the variation between genotypes in dry forage yield (g) / plant could be attributed to the fact that, genotypes had highest green forage yield (g) per plant gave a higher dry weight. Similar results were obtained by Yagoub and Abdulsalam (2010); Ayub, *et.al,* (2010).In fresh weight (ton/ha) the results indicated that, the range was (10.4– 26.5 ton/ha), scored by the genotypes Gassabi and hybrid Pioneer during both seasons. This result be due the fact that high yielding genotypes had taller plant and denser stands. The over mean of this character (16.8) was similar to the findings obtained by Idris (2006). Differences in dry forage yield (ton/ha) might be a result of significant variations in their respective morphological attributes. The significant variations among sorghum genotypes for dry matter production have already been reported in studies conducted by Yousef *et al*. (2009), and Palta and Karadavut, (2011).

In percentage of the dry matter, the variations between the genotypes and their overall mean might be attributed to variation in the genetic make-up and adaptability of these varieties to different environmental conditions. These results are in accordance with those of Amnullah, (2007). Leaf to stem ratio is one of the most significant parameters determining forage quality. The significant differences between the genotypes during both seasons with respect to leaf to stem ratio might be attributed to better growth which caused increased number of leaves than stems under specific conditions. Similar results were reported by Mohammed and Moataz (2009) that, significant difference of LSR was observed by different genotypes. In this study, the green weight (g) / plant of the second cut revealed a significant difference. Genotype Nabig followed by Taqqat.7B and Pioneer during both years scored the highest values. The difference among genotypes may be due to relative contribution of their high number of leaves /tiller, and relative increase in number of tillers per plant, while the variation between over mean could be due to the favorable environmental conditions for crop growth during this season. Mohammad )1989)reported variations in fodder yield of sorghum genotypes under diverse environments .In dry weight (g) / plant of the second cut the differences might be due to the decrease occurred in fresh yield per plant during the second cut in addition to the effect of environment. This result was in line with Ahmed (1999) who investigated that, the dry matter yield decreased from the first cut to the second cut.

## 5.2 Winter Experiment.

### 5.2.1 Growth attributes.

Data recorded about plant height (cm) showed significant differences in main effects of genotypes as well as water interval treatments. The differences among genotypes may be due to their intermodal distance and genetic factors of the investigated genotypes. The variations between watering intervals might be due to the fact that irrigation every seven days enhanced the growth due to availability of soil moisture. These results were consistent with those of Sher, (2013) and Abdel-Motagally (2010) who stated that, plant height differed significantly due to genotypes and irrigation regimes.

Irrigation every seven days ($W_1$) with hybrid Pioneer and genotype Nabig scored the highest value during both seasons. This increase in plant height might be due genetic make-up of these cultivars and availability of moisture. These results were also in agreement with Saifullah *et al*. (2011); Saeed and El-Nadi (1998) who found that plant height of forage sorghum decreased with increasing irrigation intervals. Okiyo *et al.* (2011) reported the same findings.

The significant differences of genotypes on stem diameter might be due to genetic make-up of the studied genotypes. Similar results were reported by Ayub, *et.al*, (1999). Watering interval every seven days gave the highest stem diameter. These results could be attributed to higher growth rate under more frequent irrigation. Similarly, Asgharipour and Mahmood (2011) reported maximum stem diameter at different irrigation regimes. The non significant differences in number leave per plant between genotypes and watering intervals during both years were probably due to the relatively unfavorable conditions at the experimental site and adaptation of these genotypes to different environments (Feb winter). Zahid and Bahatti, (1994), found that, no difference in number of the leaves due to variety under specific environment. However, in the present study differences in number of leaves during the 2nd season might be due to genetic factors and potential of the genotypes. Ahmed *et al.* (2007) and Ayub *et al.* (2010) reported that, different sorghum genotypes have large variations among number of leaves per plant. In number of tillers per plant, the differences among genotypes could be attributed to genetic factors .This result was in accordance with those of Sher (2013) who stated that, number of tillers differed significantly due to genotypes and contradicted with Saifullah, *et .al,* (2011) who stated that no variation was observed in number of tillers per plant among the varieties but only irrigation level significantly affected this parameter. However, Abdalla, *et.al*, (2004) found that, the narrow irrigation recorded insignificant increases in growth and forage yield except number of tillers/unit area in both cuts. The maximum and minimum number of leaves per tiller among genotypes may be attributed to variations in genetic make-up and adaptability of these varieties to different environment. These findings were in confirmation to those of Shakoor *et al.* (1983) and Faridullah, (2010) who also indicated that varieties differ significantly in number of leaves per tiller.

In leaf area index, hybrid cultivar Pioneer gave the highest L.A.I during both seasons, whereas local genotype Aish-Baladi scored the lowest values during both years. High leaf area index may be due to relative high number of leaves per plant while minimum leaf area index may be due to less number of leaves per plant in these forage sorghum genotypes. Mahmud, *et.al*, (2003) and Ghohan, *et.al*, (2006) also perceived differences in leaf area index of various pearl millet forage cultivars. Genotype Taqqat.7B reached the period of days to 50% flowering in 64.2 and 65.7 days during both winter seasons, while local genotype Aish-Baladi accelerated this period in 54.3 and 53.2 days during the respective seasons. This variation between genotypes may be due to genetic factors of the genotypes rather than environmental factor such as water status. These results are in line with the findings previously reported by Idris and Mohammed (2012). Mohamed (2011) confirmed that, there were highly significant differences among Sudanese sorghum accessions in days to flowering.

**5.2.2 Yield attributes.**

The differences among genotypes regarding fresh yield (ton/ha), could be attributed to higher plant height, high leaf to stem ratio and presence of extra leaves of this genotype which reflected in high fresh weight under different environments. Similar results were reported by Ping *et.al* (2005) and Raki *et al.* (2013). They found that, forge yield was influenced by plant height, stem diameter, number of leaves and leaf area. Improving these agronomic traits led to an increase in forage yield. Sarafaz, *et.al* (2012) found considerable variations in the performance of varieties with respect to years in green forage yield. In case of irrigation interval the highest yield was scored by water intervals of seven days ($W_1$). Interval every 10 days caused a rapid drying in surface layer in root zones in sandy soil by deep percolation and decreased the growth rate. Aishah, *et.al*, (2011) reported that irrigation frequency was found to affect growth and yield of forage sorghum. Interaction between varieties and irrigation intervals indicated that, highest fresh yield was obtained from hybrid Pioneer with watering interval $W_1$ while the lowest fresh forage yield (ton/ha) was recorded by Taqqat.5A and Aish-Baladi at watering interval $W_2$ .These results might be due to the fact that, cultivars had more active root system and thrive well under well watered conditions. Likewise, these findings were confirmed by the results reported by Naeem, *et.al.* (2003).

The genotypes, significantly affected the dry forage yield (ton/ha), the differences in the main effect of the genotypes might be due to the relative increase in fresh weight. The significant variations among sorghum genotypes for dry matter production had been reported by Palta and Karadavut, (2011) .They observed differences among irrigation intervals and their interaction on dry forage yield (ton/ha). These increases in dry forage yield may be due to availability of good moisture conditions in water interval every seven days compared to every 10 days. These results matched with the findings of Nagi, *et.al*, (1985) who reported that, dry fodder yield increased with increase in irrigation frequencies. In dry percentage, the non-significant difference of individual effect of the genotypes, watering interval and their interaction, could be attributed to the fact that, the relative contribution of optimal dry weight to fresh weight was equal in all studied genotypes during specific condition (Feb, winter), visually in this study may be the fresh forage sorghum of the genotypes when planted during off season (winter) by irrigation contained less moisture compared to fresh forage which produced during rainy seasons. Amnullah *et al.,* (2007) reported that, variations in percent dry matter may be attributed to variation in the genetic make-up and adaptability of these varieties to different environmental conditions and moisture levels. The differences between studied genotypes in LSR could be attributed to their high growth of single leaf area, with highest number of leaves. Abd-Elbakheit (2007) found that, leaf to stem ratio for Abu Sabin was slightly higher than that of Sudan grass. In this study, water intervals and their interactive effect were not significant in leaf to stem ratio. This result disagreed with the findings of Moosavi*et.al,* (2011) who reported that, the irrigation intervals had a significant effect on the leaf to stem ratio. The maximum green and dry yield (g) per plant was observed in hybrid Pioneer and minimum fresh weight (g) was scored by local genotype Aish-Baladi during both seasons.

The high fresh and dry yield (g) /plant of hybrid Pioneer can be attributed to the highest plants with highest leaf area and more leaves per plants, which were reflected in high dry weight. These findings are in line with Zahid and Bhatti (1994) who reported that, sorghum hybrids having high number of leaves/plant and higher leaf area produced maximum fresh and dry fodder yields. The result was also supported by results of Chughtai *et al*. (2007). The highest fresh and dry forage yield (g) /plant were noticed at watering intervals of seven days, during both seasons. The differences could be attributed to increased soil-moisture content, which improved internal water status and growth of plant. Similar findings were reported by Atem, (2007) who investigated that, treatments irrigated every seven days showed higher forage fresh and dry weights than treatments irrigated every ten days. Interaction of hybrid Pioneer with water interval $W_1$ attained the highest green and dry yield (g) /plant during both season. This may be due to the more active root system of this cultivar to thrive well under well moisture ($W_1$treatment) conditions than other genotypes. This result was in accordance with Sifullah, *et.al*, (2011) who reported a significant interaction between millet genotypes with regard to water regime.

The differences in fresh forage, weight (g) among the genotypes during second cut, might be due to variations in their morphological traits and yield components like number of tillers, and number of leaves per tiller/plant. Ayub *et al.* (2010) noticed major contrasts among different sorghum cultivars regarding their yield and yield components. Although the variations were detected between genotypes, the fresh weight (g) / plant of the second cut was lower than that of the first cut. Atis, *et al.* (2012) reported that, there were obvious forage fresh and dry yields reduction in the second growth compared to the first growth. The non-significant differences in green and dry weight (g) of the second cut among watering interval treatments and their interaction might be due to slightly unfavorable conditions required for the crop. These results were confirmed by the findings of Ahmed, (1999) who stated that, the second cut coincided with the unfavorable conditions for forage sorghum production.

## 5.3 Quality Attributes.

### 5.3.1 Performance of quality traits during rainy seasons (2014-2015) and winter seasons (2015-2016).

Mean values of dry matter yield had significant differences among the genotypes during both rainy seasons which might be attributed to high potential and good vegetative growth of these genotypes. The greater values of DM % during winter season were attributed to variation in environmental conditions between summer and winter seasons. Similar findings of Miron *et al.* (2006) reported that significant differences in dry matter content were recorded in different varieties. Geta, *et.al* (2014) investigated the same results and stated that, higher fodder dry matter percentage during specific environment indicated better quality of maize fodder.

In ash percentages, genotypes revealed significant differences during both rainy and winter seasons. The same trait was higher during both winter seasons than rainy seasons. These variations could be attributed to differences in genotypes to absorb nutrients due to variable rooting pattern in the same soil. These results agreed with the results of Ayub, *et al.* (2010) who, found significant differences for total ash content among different sorghum forage genotypes. Crude protein is a significant determinant of forage quality. Forage containing high crude protein content was considered as a good quality. Genotype Taqqat.9A achieved the highest values (12.0 and 13.18 %) of crude protein, respectively, during the two rainy seasons while hybrid Pioneer had the highest crude protein (11.4%) during both winter seasons. This variation in crude protein might be attributed to the relative contribution of leaves to total biomass and high concentration of protein in dry matter content. These results were consistent with those of Ayub *et.al*. (2012); Sarfraz, *et. al.,* (2012) and Silungwe, (2011). They found that, there were significant differences among sorghum forage cultivars in crude protein percentage. Also Mohammad (1989), reported variation in fodder yield and quality traits of sorghum under diverse environments. The maximum crude protein was observed under rain-fed conditions.

Data regarding ether extract revealed significant differences among genotypes during both rainy seasons. Local genotype Aish-Baladi scored the highest values while cultivar Abu 70 (Aliab) registered the maximum values in the same trait during both winter seasons. These differences among genotypes may be attributed to differences in genetic traits of crop plants. These results agreed with those of Shobha *et al.* (2008), Mahammed and Moataz (2009) and Ayub *et al.* (2010). They found significant differences in ether extractable fats of different cultivars.

The forage containing low crude fibre content is better in quality (Sher, 2013).In this study, highest crude fiber was obtained during rainy seasons. Genotype Abu70 (Aliab) produced the highest crude fiber during the two rainy seasons. While local genotype Nabig produced maximum crude fiber during both winter seasons, Sudan grass (Grawia) had the lowest values during winter seasons .Relatively, the rainy season was greater in the mean value for this trait. This variation in crude fiber might be due to genetic- make up of theses genotypes and adaptability to different environmental conditions. Abd-Elbakheit (2007), reported that, crude fibre was slightly higher in Abu Sabein compared to Sudan grass, also differences in crude fibre between genotypes have already been reported by Ayub *et al.* (2010) and Abusuwar and Hala (2010). They reported that, there was a significant difference among sorghum varieties regarding crude fibre. While Mohammad, (1989) reported, maximum fiber content at the optimum environment (irrigated) condition.

# CONCLUSIONS AND RECOMMENDATIONS

From the present study, the following conclusions were drawn:

- Mostly, hybrid cultivar Pioneer and genotype Nabig had the highest vegetative growth characteristic compared to other genotypes under rain-fed and irrigated conditions.
- Local genotype Aish-Baladi characterized by thinner stems compared to other studied genotypes in terms of a good forage characteristics.
- Hybrid Pioneer produced the highest fresh and dry weight (ton/ha) under rain-fed condition of North Kordofan state.
- Hybrid Pioneer performed better in percentage of dry weight during both rainy seasons, and is recommended to be cultivated for fresh and dry forage purposes in marginal area in North Kordofan State.
- Local genotypes Aish-Baladi and Gassabi were the earlier genotypes to flower (50 -54 days) of 50 % flowering stage , which could be helpful in the development of new sorghum cultivars if used in a sorghum forage breeding program.
- In the second cut, the genotype Nabig had the highest fresh and dry weight (g /plant) under rain-fed.
- Irrigation every seven days produced better growth and yield of forage sorghum compared to irrigation every ten days.
- Hybrid Pioneer was characterized by the highest plant height (cm), Leaf area index (*L.A.I)*, and high leaf to stem ratio (*LSR*), during winter season (Feb).
- The high fresh (11.3) and dry (9.7) weight ton/ha was shown by cultivar Pioneer during both winter seasons, therefore it is recommended to be cultivated under irrigation condition (winter) of North Kordofan State.

- Local genotype Nabig produced high, green and dry weight (g/plant) in $2^{nd}$ cut due to high tillering capacity with high leaves per tiller compared to other genotypes in Feb (winter).
- The mean of ash and crude protein % was higher during winter seasons, while the mean of crude fiber was relatively higher during both rainy seasons.
- Genotype Taqqat.9A produced the highest crude protein during both rainy seasons; contrarily hybrid Pioneer gave the highest values of crude protein during winter seasons.
- Genotypes Gassabi and Grawia recorded the lowest crude fiber while Abu70 and Nabig produced the highest values of crude fiber during both conditions (winter and rainy season).
- Genotypes Aish-Baladi and Taqqat.5A produced the highest ether extractable fats percentage during rainy years, whereas Abu70 and Taqqat.5A obtained the highest values during winter season.
- An expanded study with different irrigation quantities and intervals are suggested to determine whether there are greater benefits or yield increases at other levels than those observed in this study.

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**Appendix.** 1 Mean squares of some morphological and yield component characters of **10** genotypes of sorghum forage **grown** during rainy season (2014/2015).

| | | Parameters | | | | |
|---|---|---|---|---|---|---|
| Source of variation | d.f | Plant height(cm) | Stem diameter(cm) | No. of leaves/ plant | No. of tillers/plant | No. of leaves /tiller |
| Replication | 2 | 197.900 | 0.019 | 0.433 | 0.025 | 3.201 |
| Genotypes | 9 | 1556.76 $^{**}$ | 0.124$^{**}$ | 4.815$^{**}$ | 0.445$^{**}$ | 7.557$^{**}$ |
| Error | 18 | 41.028 $^{n.s}$ | 0.014$^{n.s}$ | 0.137$^{n.s}$ | 0.111$^{n.s}$ | 1.579 $^{n.s}$ |
| C.V % | - | 5.48 | 7.26 | 3.58 | 22.04 | 18.35 |

*and ** denotes levels of significance at 5% and 1% levels.
ns = non significant.

**Cont.**1

| Source of variation | d.f | Days to 50% flowering | Leaf to stem ratio | L.A.I | Fresh forage yield (ton/ha) | % of the dry matter |
|---|---|---|---|---|---|---|
| | | Parameters | | | | |
| Replication | 2 | 1.233 | 0.023 | 0.183 | 21.491 | 1.726 |
| Genotypes | 9 | $256.21^{**}$ | $0.206^{*}$ | $0.726^{**}$ | $86.20^{**}$ | $92.137^{**}$ |
| Error | 18 | $8.752^{n.s}$ | $0.086^{n.s}$ | $0.055^{n.s}$ | $5.714^{n.s}$ | $14.141^{n.s}$ |
| C.V % | - | 4.41 | 29.31 | 11.28 | 14.19 | 12.66 |

*and ** denotes levels of significance at 5% and 1% levels.
ns = non significant.

**Cont.**1

| Source of variation | d.f | Parameters | | | | |
|---|---|---|---|---|---|---|
| | | Dry forage yield (ton / ha) | Fresh forage Yield (g /plant ) | Dry forage Yield (g/plant) | Fresh forage yield(g/plant) /2nd cut. | Dry forage Yield(g/plant) /2nd cut. |
| Replications | 2 | 1.820 | 622.88 | 0.416 | 2.100 | 0.917 |
| Genotypes | 9 | 11.440** | 2395.58*** | 245.27*** | 18.30*** | 8.61*** |
| Error | 18 | 0.715 ns | 63.12ns | 0.213 ns | 1.656 | 0.401ns |
| C.V % | - | 16.65 | 10.07 | 1.50 | 7.99 | 11.39 |

*and ** denotes levels of significance at 5% and 1% levels.
ns = non significant.

**Appendix.** 2 Mean square of some morphological and yield component characters of **10** genotypes of sorghum forage grown in, 2015/2016 rainy season.

| | | Parameters | | | | |
|---|---|---|---|---|---|---|
| Source of variation | d.f | Plant height/cm | Stem diameter/cm | No. of leaves/ plant | No. of tillers/plant | No. of leaves /tiller |
| Replication | 2 | 86.43 | 0.033 | 1.733 | 0.100 | 2.500 |
| Genotypes | 9 | 1618.36 $^{***}$ | 0.049 $^{*}$ | 3.781 $^{***}$ | 0.744 $^{ns}$ | 37.559 $^{***}$ |
| Error | 18 | 222.55 $^{n.s}$ | 0.015 $^{n.s}$ | 0.881$^{n.s}$ | 0.322 $^{n.s}$ | 4.537 $^{n.s}$ |
| C.V % | - | 11.43 | 7.74 | 10.17 | 19.57 | 14.11 |

*and ** denotes levels of significance at 5% and 1% levels.
ns = non significant.

**Cont.**2

| | | Parameters | | | | |
|---|---|---|---|---|---|---|
| Source of variation | d.f | Days to 50% flowering | Leaf to stem ratio | L.A.I | Fresh forage yield (ton/ha) | % of the dry matter |
| Replication | 2 | 6.10 | 0.003 | 0.114 | 5.392 | 73.90 |
| Genotypes | 9 | 256.389 *** | 0.28 * | 0.202 *** | 85.134 *** | 82.681* |
| Error | 18 | 7.100 ns | 0.008 ns | 0.112 ns | 7.259 ns | 25.715 ns |
| C.V % | - | 4.20 | 12.09 | 20.66 | 21.00 | 14.01 |

*and ** denotes levels of significance at 5% and 1% levels.
ns = non significant.

**Cont.**2

| | | Parameters | | | | |
|---|---|---|---|---|---|---|
| Source of variation | d.f | Dry forage yield (ton / ha) | Fresh forage Yield (ton/ha) | Dry forage Yield (g/plant) | Fresh forage yield(g/plant) /2nd cut. | Dry forage Yield(g/plant) /2nd cut. |
| Replications | 2 | 3.380 | 63.33 | 63.33 | 11.70 | 0.400 |
| Genotypes | 9 | 18.497 *** | 2820.74 *** | 218.15*** | 344.13*** | 55.47*** |
| Error | 18 | 1.779 ns | 237.41ns | 33.70 ns | 2.59 ns | 1.18 ns |
| C.V % | - | 27.84 | 26.87 | 29.52 | 5.09 | 7.98 |

*and ** denotes levels of significance at 5% and 1% levels.
ns = non significant.

**Appendix.** 3 Mean squares of some morphological and yield component characters of **10** genotypes of sorghum forage grown during winter season (2014/2015).

| | | Parameters | | | | |
|---|---|---|---|---|---|---|
| Source of variation | d.f | Plant height/cm | Stem diameter/cm | No. of leaves/ plant | No. of tillers/plant | No. of leaves /tiller |
| Replication | 2 | 19.65 | 0.018 | 4.03 | 0.650 | 1.517 |
| Water Interval | 1 | 1099.62 *** | 0.020 n.s | 0.417 n.s | 0.600 n.s | 0.817 n.s |
| Error (a) | 2 | 4.98 | 0.013 | 0.433 | 0.650 | 0.817 |
| Genotypes | 9 | 934.15*** | 0.078 *** | 21.75 * | 0.993 n.s | 15.491 *** |
| Error (b) | 18 | 89.53 | 0.013 | 14.30 | 0.465 | 0.702 |
| A×B | 9 | 191.82 * | 0.008 n.s | 5.75 n.s | 0.415 n.s | 0.261 n.s |
| Error (c ) | 18 | 54.37 n.s | 0.011n.s | 7.90 n.s | 0.576 n.s | 0.817 n.s |
| C.V % | - | 7.68 | 8.05 | 8.37 | 23.00 | 8.68 |

a, b and (a×b) denotes error of water interval, genotypes and their interaction respectively.
*and ** denotes levels of significance at 5% and 1% levels.
ns = non significant.

**Cont.**3

| | | Parameters | | | | |
|---|---|---|---|---|---|---|
| Source of variation | d.f | Days to 50% flowering | Leaf to stem ratio | L.A.I | Fresh forage yield (ton/ha) | % of the dry matter |
| Replication | 2 | 0.817 | 0.002 | 0.003 | 2.819 | 29.436 |
| Water interval | 1 | 0.0001 n.s | 0.022 n.s | 0.002 n.s | 45.782 * | 21.648 n.s |
| Error (a) | 2 | 0.650 | 0.040 | 0.017 | 1.725 | 59.962 |
| Genotypes | 9 | 49.844 *** | 0.101 * | 0.146 *** | 18.935 *** | 34.981 n.s |
| Error (b) | 18 | 7.650 | 0.034 | 0.021 | 3.703 | 19.917 |
| A×B | 9 | 8.000 n.s | 0.034 n.s | 0.004 n.s | 12.954 *** | 59.514 n.s |
| Error (C) | 18 | 6.594 n.s | 0.019 n.s | 0.012 n.s | 2.525 n.s | 30.803 n.s |
| C.V % | - | 4.24 | 16.99 | 6.71 | 24.84 | 17.30 |

a, b and (a×b) denotes error of water interval, genotypes and their interaction respectively.
*and ** denotes levels of significance at 5% and 1% levels.
ns = non significant.

**Cont.**3

| | | Parameters | | | | |
|---|---|---|---|---|---|---|
| Source of variation | d.f | Dry forage yield (ton / ha) | Fresh forage Yield (g/plant) | Dry forage Yield (g/plant) | Fresh forage yield (g/plant) /2nd cut. | Dry forage Yield(g/plant) /2nd cut. |
| Replication | 2 | 0.118 | 41.66 | 0.242 | 131.67 | 95.71 |
| Water interval | 1 | 5.667 * | 666.67 ns | 10.42ns | 666.67 * | 220.42ns |
| Error (a) | 2 | 0.378 | 21.67 | 2.92 | 21.67 | 30.82 |
| Genotypes | 9 | 1.896 *** | 317.78** | 0.0042** | 162.22ns | 39.61 ns |
| Error (b) | 18 | 0.523 | 125.0 | 6.246 | 70.56 | 0.067 |
| A×B | 9 | 0.790 * | 144.4** | 0.0243* | 29.63ns | 5.78 ns |
| Error (C) | 18 | 0.258 ns | 38.33 ns | 3.31ns | 34.63ns | 18.96 ns |
| C.V % | - | 23.06 | 17.52 | 16.50 | 22.35 | 28.00 |

a, b and (a×b) denotes error of water interval, genotypes and their interaction respectively.
*and ** denotes levels of significance at 5% and 1% levels.
ns = non significant.

**Appendix.** 4 Mean square of some morphological characters, yield and yield component of **10** genotypes of sorghum forage during winter season (2015/2016).

| | | Parameters | | | | |
|---|---|---|---|---|---|---|
| Source of variation | d.f | Plant height(cm) | Stem diameter(cm) | No. of leaves/ plant | No. of tillers/plant | No. of leaves /tiller |
| Replication | 2 | 28.50 | 0.002 | 0.69 | 0.743 | 0.558 |
| Water Interval | 1 | 50.12 * | 0.001 n.s | 3.95 n.s | 0.536 n.s | 0.118 n.s |
| Error (a) | 2 | 88.09 | 0.013 | 0.53 | 0.112 | 0.201 |
| Genotypes | 9 | 36.94 *** | 0.010 *** | 12.17 *** | 0.810 n.s | 5.933 *** |
| Error (b) | 18 | 56.22 | 0.010 | 0.91 | 0.192 | 0.158 |
| A×B | 9 | 105.89 n.s | 1.92 n.s | 1.38 n.s | 0.111 n.s | 0.422 n.s |
| Error (c ) | 18 | 118.82 n.s | 0.005 n.s | 0.75 n.s | 0.109 n.s | 0.123 n.s |
| C.V % | - | 8.58 | 4.71 | 9.30 | 14.65 | 3.24 |

(a×b) denotes error of water interval, genotypes and their interaction respectively.
*and ** denotes levels of significance at 5% and 1% levels.
ns = non significant.

**Cont.**4

| Source of variation | d.f | Days to 50% flowering | Leaf to stem ratio | L.A.I | Fresh forage yield (ton/ha) | % of the dry matter |
|---|---|---|---|---|---|---|
| Replication | 2 | 9.017 | 0.013 | 0.437 | 0.669 | 58.77 |
| Water interval | 1 | 17.067 n.s | 0.48 * | 6.61 n.s | 59.60 * | 21.60 n.s |
| Error (a) | 2 | 7.317 | 0.040 | 0.061 | 0.998 | 6.24 |
| Genotypes | 9 | 65.65 *** | 0.25 *** | 4.16 *** | 23.10 *** | 13.52n.s |
| Error (b) | 18 | 10.28 | 0.025 | 0.844 | 5.19 | 12.89 |
| A×B | 9 | 8.993 n.s | 0.174** | 1.18 n.s | 3.20 * | 12.43 n.s |
| Error (C) | 18 | 8.909 n.s | 0.028 n.s | 0.768 n.s | 1.55 n.s | 8.29 n.s |
| C.V % | - | 4.93 | 17.07 | 24.51 | 15.31 | 8.54 |

a, b and (a×b) denotes error of water interval, genotypes and their interaction respectively.
*and ** denotes levels of significance at 5% and 1% levels.
ns = non significant.

**Cont.**4

| | | Parameters | | | | |
|---|---|---|---|---|---|---|
| Source of variation | d.f | Dry forage yield (ton / ha) | Fresh forage Yield (g/plant) | Dry forage Yield (g/plant) | Fresh forage yield (g/plant) /2nd cut. | Dry forage Yield(g/plant) /2nd cut. |
| Replication | 2 | 0.351 | 123.02 | 16.72 | 0.256 | 1.669 |
| Water interval | 1 | 2.37 * | 2650.16 * | 73.46ns | 84.704 * | 0.840 ns |
| Error (a) | 2 | 0.106 | 150.74 | 4.92 | 0.216 | 4.219 |
| Genotypes | 9 | 2.701 *** | 1891.53*** | 100.98** | 258.785*** | 45.54 *** |
| Error (b) | 18 | 0.502 | 115.37 | 13.78 | 0.387 | 2.016 |
| A×B | 9 | 0.301 n.s | 259.026 ns | 9.16 ns | 34.18*** | 2.691 ns |
| Error (C) | 18 | 0.53 ns | 38.33 ns | 7.05 ns | 0.674ns | 2.184 ns |
| C.V % | - | 25.48 | 19.09 | 13.12 | 2.09 | 9.68 |

a , b and (a×b) denotes error of water interval, genotypes and their interaction respectively.
*and ** denotes levels of significance at 5% and 1% levels.
n.s = non significant.

**Appendix.**5 Mean square of some quality characters of **10** genotypes of sorghum forage during rainy (2014/2015) and winter season (2015/2016).

| | | Quality parameters | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Rainy season2014/2015 | | | | | Winter season 2015/2016 | | | | |
| Source of variation | d.f | D.M% | ASH% | C.P% | E.E% | C.F% | D.M% | ASH% | C.P% | E.E% | C.F% |
| Replication | 2 | 0.288 | 0.009 | 0.107 | 1.976 | 0.0001 | 8.024 | 58.345 | 0.156 | 0.456 | 0.158 |
| Genotypes | 9 | 31.633 ** | 0.570** | 1.486** | 15.18 * | 4.359n.s | 4.310*** | 19.15*** | 9.06 *** | 1.15 *** | 99.06 ** |
| Error | 18 | 0.016 n.s | 0.027 n.s | 0.163 n.s | 0.228n.s | 6.444n.s | 0.387 n.s | 3.728 n.s | 0.19 n.s | 0.104n.s | 1.05n.s |
| C.V% | - | 0.13 | 2.53 | 4.39 | 7.00 | 7.13 | 0.66 | 20.78 | 4.37 | 13.75 | 3.03 |

*,**and *** denotes levels of significance at 5% and 1% levels ,
ns = non significant.

**Appendix.**6 Mean square of some quality characters of **10** genotypes of sorghum forage during rainy season (2014/2015) and winter season (2015/2016).

| | | Quality parameters | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Rainy season2015/2016 | | | | | Winter season 2016/2017 | | | | |
| Source of variation | d.f | D.M% | ASH% | C.P% | E.E% | C.F% | D.M% | ASH% | C.P% | E.E% | C.F% |
| Replication | 2 | 0.120 | 0.004 | 0.012 | 0.045 | 1.30 | 7.15 | 33.36 | 0.027 | 0.456 | 2.23 |
| Genotypes | 9 | 1.83 *** | 1.19*** | 11.86* | 2.42 *** | 20.6n.s | 0.569*** | 19.79*** | 7.17 *** | 1.14 *** | 70.89*** |
| Error | 18 | 0.084 n.s | 0.005n.s | 0.128 n.s | 0.043n.s | 7.59n.s | 0.387 n.s | 1.82 n.s | 0.37 n.s | 0.056n.s | 2.67n.s |
| C.V% | - | 0.13 | 1.07 | 4.18 | 7.72 | 8.15 | 0.69 | 14.68 | 6.10 | 9.53 | 4.84 |

*, **and *** denotes levels of significance at 5% and 1% levels,
ns = non significant.

**Appendix .**7 Mean monthly weather data for Elobeid during cropping seasons (2014-2015/ 2015-2016).

| Months | Season 2014/ 2015 | | | | Season 2015/ 2016 | | | |
|---|---|---|---|---|---|---|---|---|
| | Rainfall (mm) | Temperature ($C^o$) | | Relative Humidity % | Rainfall (mm) | Temperature ($C^o$) | | Relative Humidity % |
| | | **Max** | **Min** | | | **Max** | **Min** | |
| Jan. | — | 30.9 | 15.1 | 25 | — | 29.2 | 13.4 | 24 |
| Feb. | — | 34.0 | 19.0 | 22 | — | 35.5 | 18.8 | 22 |
| March | 2.4 | 36.9 | 22.5 | 25 | — | 37.5 | 22.6 | 26s |
| April | 8.9 | 39.3 | 25.5 | 20 | *Light* | 36.8 | 21.5 | 30 |
| May | *Light* | 39.3 | 25.8 | 35 | 46.0 | 39.9 | 25.6 | 55 |
| June | 68.3 | 38.4 | 25.2 | 56 | 30.8 | 38.2 | 25.1 | 60 |
| July | 119.0 | 33.0 | 22.7 | 80 | 111.9 | 36.3 | 24.2 | 75 |
| Aug. | 63.7 | 31.5 | 22.1 | 75 | 89.8 | 33.2 | 22.6 | 76 |
| Sept. | 41.6 | 34.2 | 21.8 | 70 | 109.1 | 34.9 | 23.6 | 70 |
| Oct. | 35.2 | 36.2 | 22.6 | 55 | 29.5 | 36.6 | 24.4 | 50 |
| Nov. | — | 33.9 | 19.4 | 33 | — | 33.4 | 19.1 | 29 |
| Dec. | — | 32.1 | 16.9 | 30 | — | 27.2 | 13.5 | 26 |
| Total | **339.10** | | | | **418.10** | | | |
| Average | 28.26 | 34.98 | 21.55 | 43.83 | 34.76 | 34.89 | 21.2 | 45.25 |

**Source**: Metrological Station, Faculty of Natural Resources & Environmental Studies, University of Kordofan.

**Appendix**.8 Metrological data (air temperature, relative humidity (R.H %) and wind speed) recorded at experiential site during off season (Feb winter).

| | Year (2015/2016) | | | | Year (2016/2017) | | | |
|---|---|---|---|---|---|---|---|---|
| | **Temperature** (C°) | | | | **Temperature** (C°) | | | |
| **Months** | **Max** | **Min** | **R.H%** | **Wind speed** | **Max** | **Min** | **RH%** | **Wind speed** |
| February | 29.2 | 13.4 | 24 | 14 | 28.0 | 17.3 | 26 | 14 |
| March | 35.5 | 18.8 | 22 | 14 | 34.7 | 22.3 | 23 | 13 |
| April | 37.5 | 22.6 | 26 | 12 | 37.7 | 23.5 | 20 | 12 |
| May | 36.8 | 21.5 | 30 | 11 | 35.0 | 24.5 | 40 | 11 |
| June | 39.9 | 25.6 | 55 | 14 | 37.2 | 25.2 | 56 | 11 |
| **Mean** | **35.8** | **20.4** | **31.4** | **13 N/sec** | **34.5** | **22.6** | **33** | **12.2 N/sec** |

**Source**: Metrological Station, Faculty of Natural Resources & Environmental Studies, University of Kordofan.

**Plate .1** General view of the field (rainy season).

**Plate.2** 50 % flowering stage, hybrid cultivar Pioneer (Harvesting time).

**Plate.**3 Data collection (Experimental units)

Genotype (Nabig). Genotype (Aish-Baladi) Hybrid (Pioneer).

**Plate.**4 Plant regrowth 25 days after harvesting (Winter season -February).