CHAPTER ONE

INTRODUCTION

Sorghum (*Sorghum bicolour* L. Monech) belongs to family Poaceae, It is a self pollinated crop cultivated for its edible grains, commonly called sorghum and also known as durra in Sudan. Sorghum genetically is considered as a drought tolerant crop and has evolved various eco types that withstand an array of biotic factor. It is considered more tolerant to many stresses, including heat, drought, salinity and flooding as compared to other cereal crops (Ejeta and Knoll, 2007; Ali *et al*. 2011). However, the crop grown in rain-fed areas is highly effected by drought stress (Kebede *et al*. 2001). Sorghum grain is the stable food of poor and the most food-insecure people, living mainly in the semiarid tropics (Ali *et al*., 2011). Sorghum is originated in eastern Africa, (Sudan along with Ethiopia-Eretria areas) and now is cultivated widely in tropical and subtropical regions. It is the most important staple cereal crop for more than 500 million people in more than 30 countries worldwide (ICRISAT, 2011). Major world's producers include Sudan, Nigeria, India, Americas, Mexico, China and Argentina (FAO, 2011). Sorghum is influenced by water stress at terminal growth stage like anthesis and post-anthesis which renders the most adverse effect on yield in sorghum (Tuinstra *et al*., 1997). Sorghum is used for food, forage, building material and in industry for biosynthesis of starch and alcohol (ICRISAT, 2011). In Africa and Asia small-scale subsistence farmers who have minimal access to production inputs such as fertilizer(s), pesticides, improved seeds (hybrids or varieties), good soil and water and improved credit facilities for their purchase are the main sorghum producers (Ceske, 2010). Sorghum grains, typically, have protein levels of around 9 percent, enabling needy human populations to survive on it in times of famine (FAO, 2011). The crop is crucially important to food security in Africa as it is exclusively drought resistant and can withstand periods of high temperature (Taylor, 2006). landraces from Sudan has been extensively used in sorghum breeding programs worldwide (Bantilan *et al . ,* 2004). However, average yield per unit area in the Sudan is very low (540 kg/ha) compared to the world average (1300 kg/ha) **(**Elagib *et al*., 2004). In Sudan the amount and rainfall patterns of and length of rainy seasons as in Sub-Sahara Africa is fluctuating. These climatic changes adversely affect traditionally sorghum growing areas of North Gdaref, Gezira, Sennar, White Nile State and North Kordofan. These fragile drought prone areas now constitute more than 50% of the total sorghum production area. This area is going to increase with climatic changes. In these fragile drought areas (200 – 450mm) farmers are still using landraces that are low yield and suffer severe drought at all stages of growth, resulting in low yield and occasional complete crop failures. In the last few years several improved sorghum cultivars imergance, including varieties such as Ingaz, Feterita, Wad Ahmed, Tabat and hybrids, Hageen Dura-1 (HD-1) and Sheican (ICRISAT, 1983) have been released by the Agricultural Research Corporation (ARC) of the Soudan for commercial use in irrigated and high rain fall (>500mm) areas. These improved varieties and hybrids wouldn’t suit these drought prone areas.

Water stress affects almost every developmental stage of the plant. However, damaging effects of this stress was more noted when it coincided with various growth stages such as germination, seedling, shoot length, root length, and flowering (Rauf, 2008; Khayatanezhad, *et al.*2010). Therefore, the main objectives of this study were:

1. To assess the genetic variability among grain sorghum genotypes under drought stress conditions.
2. To estimates the phenotypic correlation between different characters.
3. To identify the most drought tolerance genotypes under drought stress conditions.

CHATER TWO

LITERATURE REVIEW

2 -1 General background

Sorghum ($2n = 2x = 20$) is a C_4 crop that displays excellent tolerance to high moisture stress (Doggett, 1998). It has the highest water use efficiency among major crop plants and is unusually tolerant to low soil fertility. It also has traits essential for survival and productivity in arid and semi-arid areas with limited irrigation capability (Zhanguo *et. al.*2008). Global cultivation of sorghum covers an area of 43.73ha with annual production of 64mt (Sasaki and Antonio, 2009). It is the fifth most important cereal crop grown globally after wheat, maize, rice and barley production (Sato *et al.*, 2004 and Khalil, 2008), providing food and fodder for the inhabitants of drought-prone regions. Recently, sorghum has been demonstrated as a viable bio-energy feedstock (Wang,*et.al.*2008). Its remarkable ability to reliably produce grains under adverse conditions makes sorghum important "fail-safe" sources of food, feed and fuel (Addissu, 2011).

2-1-1 Uses of sorghum in Sudan

In Sudan, grain sorghum is the most important cereal crop and is considered the main food for more than 70% of the population. The stalks are used as building material and the straw is used as animal feed or as a source of fuel. Sorghum is undoubtedly the nutritional backbone of the country. The areas under crop is estimated to be (6-7 million ha), constitutes 74% of the area under cereal and 45% of the total cultivated area in Sudan (Hamdoun and Babiker, 1989). Sorghum grain has limited use for livestock. Its use is limited, however, because the starch and protein in sorghum is more difficult for animals to digest than the starches and protein in corn.

2-2 Drought as production limiting factors:

Drought response in sorghum has been classified into two distinct stages pre-flowering and post-flowering. Resistance to water deficit stress at both of these stages has been reported to occur in the existing germplasm. However, many genotypes with a high level of resistance at one stage are susceptible at the other stage. The effect of drought on crop production and over economy is well known (Singh, 1990). In sorghum, water stress occurring decreases seed filling duration, seed size and number, thus leading to strong yield reduction or even total crop loss (Tuinstra *et al*., 1997). Sorghum avoids dehydration by enhanced water uptake through its deep and extensive root system, and tolerates dehydration by osmotic regulation (Singh, 1990). Soil moisture deficiency 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). Previous studies in sorghum have shown that total leaf area and specific leaf area decrease under water stress (Munamava *et al*., 2001).

2-3 Mechanisms of drought resistance:

The crop grown under unfavorable environments withstands the stress through different modifications. Drought stress is a serious agronomic problem contributing to severe yield losses worldwide. This agricultural constraint may nevertheless be addressed by developing crops that are well adapted to drought prone environments. Drought tolerance depends on the plant developmental stage at the onset of the stress syndrome, which in sorghum may happen during the early vegetative seedling stage, during panicle development and in post-flowering, in the period between grain filling and physiological maturity (Rosenow and Clark 1995; Rosenow *et al*. 1996).

2-3-1 Drought escape:

Drought escape is particularly an important strategy phenological developmental with the period of soil moisture availability to minimize the impact of drought stress on crop production in environments where the growing season is short and terminal drought stress predominates (Truner, 1986). Also later flowering can be beneficial in escaping early season drought that is followed by rains (Ludlow and Muchow, 1990).

2-3-2 Drought avoidance:

Drought avoidance is defined as the ability of plants to retain a relatively high level of hydration under conditions of soil and atmospheric water stress. Plant can exhibited dehydration avoidance through increasing water uptake and reducing water loss of means of morphological or physiological modifications (Blum, 1998).

2.3.3. Drought tolerance:

Drought is the major important constraint on crop production in the world today. Drought tolerance is one of sorghum’s most important traits, allowing it to be grown in harsh environments. Complexity of inheritance pattern of drought resistance encouraged breeders to adopt alternative strategies to improve stress resistance (Borrell*, et al* 2006). Plant tolerates drought by ability of their tissue to withstand water stress. The mechanism of drought tolerance is maintenance of turgor through osmotic adjustment (a process which induces solute and decreased accumulation in cell), increase in elasticity in cell and decreased in cell size and desiccation tolerance by protoplasmic resistance (Ugherughe, *et al* 1996).

2.4: Effect of drought on yield and yield components:

The effect of water deficit on yield and yield components have been the subject of many investigations. Moisture deficit was found to account for 65% of variation in grain yield of sorghum and pearl millet (Mahalkshmi and Rao, 1990). Timing of water supply generally has a larger effect on grain yield than total water for many crops (Show, 1998). Both pearl millet and grain sorghum productivity are most sensitive to water stress during flowering and grain filling (Garrity *et al.*, 1993 and Hattendorf *et al.*, 1998). Unger (1991) indicated that, in sorghum grain mass was the most affected grain yield component by water stress, followed by seed per unit area. Harvest index of sorghum was also reported to be significantly affected by water stress. Field trials with sorghum, irrigated and rainfed showed significant differences between those two moisture regimes in grain yield, time to 50% flowering, time to maturity, number of heads per unit's area, (Osmanzai, 1992).

2-5 Methods of determining of drought tolerance:

Identification and understanding the mechanisms of drought tolerance in sorghum have been major goals of plant physiologists and breeders including prolific root system, ability to mention stomata opening at low levels of water potential and high osmotic adjustment and various seedling parameters (Rajendran *et al.* 2011). Only a few of the many techniques reported for measuring drought stress have been motioned, but it is believed that selection and use of combinations of method will give necessary information and three types of measurements are suggested .

1- Desiccations tolerance tests or related heat tolerance tests give information on how much tissue drying can be tolerated before severe injury occurs.

2- Field measurements of water potential (or relative water content) show how far the internal water status is kept above the critical point during the drought period.

3- Diffusive observation indicated if the internal water potential is kept up by related transpiration or water an efficient root and conducting systems is keeping the plant shoot supplied with water.

Accordingly, many yield – based parameters were suggested to evaluate drought tolerance. Many of them were contracted informs of indices, e.g., stress susceptibility index (SSI) suggested by Fisher and Maurer (1978). The stress susceptibility index is ratio of relative reduction in yield of genotypes due to drought compared to the mean relative reduction in yield of all tested genotypes. This (SSI) is found to be equivalent to the ratio of yield under stress to yield under non – stress yd/yw (Heringa *et al*., 1984). Considered the ratio of absolute reduction in yield due to stress (AR) to yield under non - stress (yw), AR/Yw what is again equivalent to a ranking of genotypes according to their ratios Yd / Yw. A further yield – based parameter of drought tolerance is geometric mean (GMP). (Fernandez, 1993) which is the square root of the product of yield under stress times under non stress. The geometric mean is often used by breeders, who are interested in performance under favorable and stress condition, since drought stress can vary in severity in field environments over years.

2-6 Variability in Grain Sorghum

2-6-1 Genetic Variability

Genetic variability is essential to secure the success of any breeding program. Selection is not effective unless considerable genetic variation is present in the population. Evidence for the existence of considerable amount of variability in sorghum has been reported by many investigators, and the germplasm resources are still largely unexploited. Abuelgasim, (1989) reported that variation between sorghum genotypes were found in all studied characters (Tag El-Din and Hessen 2012). Berwal and khairwal (1997) in their study of genetic divergence in sorghum, where forty two accessions were evaluated, found highly significant differences in plant height, number of tillers, stem diameter and leaf area. They predicated successful crosses between these accessions to improve each of these traits. Eight indigenous grain sorghum genotypes representing the types widely grown in Kordofan and West White Nile districts of Sudan were studied by (Ahmed, 2010). The result indicated a wide genetic diversity for all characters, some genotypes from different clusters were superior in grain yield and some yield components. These genotypes could be recommended for further breeding programs. Highly significant ($P<0.01$) genotypic differences among the varieties for all the root and shoot morphological traits reported. Traits such as plant height, total root number, root volume, root dry weight, shoot dry weight and root to shoot weight ratio showed significant reduction. Shoot dry weight, root dry weight, root number and root volume are biomass-related traits and indicated that plant produces lesser biomass to conserve water and to increase water use efficiency (Blum, 1988).

2-6-2 Phenotypic and Genotypic Variability

The variations occurring in segregating populations of cereal crops are attributable to three main sources: namely additive genetic effects, non additive effects due to dominance and interaction of non allelic genes, and environmental effects. The term genotypic variation is used throughout the study with reference only to the additive genetic or heritable variation responsible for progress resulting from selection. Phenotypic fluctuations may results from combinations of all types of variations, since the breeder is concerned with selecting superior genotypes.

2-6-3 Phenotypic (PCV) and Genotypic (GCV) coefficient of Variation

Genetic coefficient of variation (GCV), heritability and genetic advance expected from selection. Highly significant differences were obtained among the RILs for all traits studied. Grain yield, stay green traits, panicle exertion and number of spikelets per head showed a relatively high GCV and PCV (21–34%). The GCV was near to PCV for most of the characters, indicating a highly significant effect of genotype on phenotypic expression with very little effect of environment heritability estimates observed for most of the characters ranged from 47(stem thickness) to 95 percent (head length). Similar findings were also reported in sorghum by (Haussmann *et al.* 2002) for stay-green and yield per plant and (Rao and Patil, 1996) for head length panicle exertion and plant height characters.

2-7 Heritability and Genetic Advance

. In sorghum heritability (h^2) and Genetic Advance (GA) were high for all the traits under well watering condition. Hence, for these characters, scope for selection is amenable, as the influence of environment on these traits was at very low extent; more uniform condition is expected to show higher heritability for the traits (Falconer, 1996).

Heritability of all traits decreased from well watering to drought stress conditions as a result of increased environmental variance. (Blum, 1988) has revealed similar pattern of heritability decrease. Johnson *et al*, (1955) indicated that estimates of heritability along with genetic coefficient of variation are useful in predicing the resulting effects of sample size, environment, the character and population on heritability estimates. Moreover, heritability value indicates the confidence with which selection of genotypes can be based on phenotypic performance. However, estimation of heritability in broad sense has limitation because it includes both additive and epistasis gene effects (Abraham *et al*, 1998). Comparatively high heritability(63-99%) were obtained from all traits except for green leaf area at 15 days after flowering(GLA15),days to 50% flowering and yield, which showed moderate heritability value (52-57%) (Wilolud Journals, 2011). Therefore, estimates of heritability in broad sense would be more meaning if accompanied by estimates of genetic coefficient of variation. High GCV along with high heritability and genetic advance provide better information than other parameters alone. On the basis of the present study, stay-green parameters (%GLA15, %GLA30, and % GLA45), yield per plant, panicle exertion, head length and 1000 seed weight are the most important quantitative characters to be taken into consideration for effective selection in sorghum. Opportunities to improve these traits appear to be likely though the degree varies depending on h^2 and GCV values (Addissu, 2011).

2-8. Phenotypic correlation

The variations occurring in segregating populations of cereal crops are attributable to three main sources: namely additive genetic effects, non additive effects due to dominance and interaction of non allelic genes, and environmental effects. The term genotypic variation is used throughout with reference only to the additive genetic or heritable variation responsible for progress resulting from selection. Phenotypic fluctuations may results from combinations of all types of variations. Since the breeder is concerned with selecting superior genotypes. Furthermore, variation in the morphological characters of pearl millet was reported by many workers (Yadav *et al*., 1997) and others.

Abraham *et al* (1998) found that genotypes correlation coefficient were slightly higher than the association with days to 50% flowering, productive tillers / plant, days to maturity and 1000 – grain weight. The positive genetic association of grain yield with flowering and maturity dates indicates limitation in development of early maturity types and high grain yield.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Genetic materials used in the study

The genetic material used in this study was consisted of twenty two lines Sorghum (*Sorghum bicolour* L. Moench) genotypes, Seventeen genotypes were obtained from Agricultural Research Corporation (ARC),Wad Madni , Sudan and the other five were obtained from Agronomy Laboratory, College of Agricultural Studies Sudan University of Science and Technology.

3.2 Field experiments

3.2.1 Field experiments Location and years:

The experiments were carried out at Sudan University of Science and Technology the Demonstration Farm, College of Agricultural Studies, Shambat (15^0 40N, 32^0 32E and altitude 386m above sea level) over two consecutive summer seasons of 2012 and 2013 under irrigation system.

3.2.2 Design and Description of the experiments.

The experiments were laid out in a randomized complete block design (RCBD) with three replications at both years. The treatments were arranged in a split plot arrangement. The water intervals (7days and 21days) were considered as main plots and the twenty two sorghum genotypes as sub plots. The experiment field was disc ploughed, disc harrowed leveled and ridged up north - south, 70cm apart. The land was divided into 2 x $3.5m^2$ plots, each composed of 4 ridges two meters long, seeds were sown on the 7th of July 2012 and 7th of July 2013. Seeds rate applied were (2.5 kg /fed). The seeds were sown in low than the top of the ridge. Nitrogen fertilizer (urea 46% N) 40Kg/F was applied in one dose two weeks after planting, 2.5cm spacing between holes. Hand weeding was done when needed, irrigation was conducted every one week intervals for wet and three week intervals for drought stress.

3.3 Data collection

At each of the two seasons, when the plants reached physiological maturity, five plants from the two inner ridges at each plot separately were randomly selected and tagged and from them data for the following growth and yield characters except days to 50%flowering and days to maturity were collected as following:

3.3.1 Growth characters

3.3.1.1 Plant height (cm)

The plant height was measured from the base of the main stem to the tip of panicle using meter tape.

3.3.1.2 Stem diameter (cm)

It was determined at maturity on the stalk at 10cm above the ground level.

3.3.1.3 Number of leaves/plant

It was counted for the five tagged plants and the average was determined.

3.3.1.4 Leaf area (cm^2)

It was calculated according to the following formula as described by sticker method

Leaf area (LA) =Maximum Length ×Maximum Width × 0.75

Table (1) List of sorghum genotypes used in the study:

Entry No.	Varity	Origin
1	HSD 7507	Plant Genetic Resource Unit (ARC).
2	HSD 7567	Plant Genetic Resource Unit (ARC).
3	HSD 7584	Plant Genetic Resource Unit (ARC).
4	HSD 7591	Plant Genetic Resource Unit (ARC).
5	HSD 7601	Plant Genetic Resource Unit (ARC).
6	HSD 7602	Plant Genetic Resource Unit (ARC).
7	HSD 7606	Plant Genetic Resource Unit (ARC).
8	HSD 7610	Plant Genetic Resource Unit (ARC).
9	HSD 7616	Plant Genetic Resource Unit (ARC).
10	HSD 8150	Plant Genetic Resource Unit (ARC).
11	HSD 8176	Plant Genetic Resource Unit (ARC).
12	HSD 8228	Plant Genetic Resource Unit (ARC).
13	HSD 8234	Plant Genetic Resource Unit (ARC).
14	HSD 7511	Plant Genetic Resource Unit (ARC).
15	HSD 8653	Plant Genetic Resource Unit (ARC).
16	HSD 8849	Plant Genetic Resource Unit (ARC).
17	HSD 9566	Plant Genetic Resource Unit (ARC).
18	Wed Ahmed	CAS. SUSTECH, Released by (ARC).
19	Tetron	CAS. SUSTECH, Released by (ARC).
20	Hagega	CAS. SUSTECH, Released by (ARC).
21	Arfa gadamk	CAS.SUSTECH, Released by (ARC).
22	Botana	CAS.SUSTECH, Released by (ARC).

ARC: Agricultural Research Corporation, Sudan.

CAS. SUSTECH College of Agriculture Study Sudan University of Science and Technology.

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3.3.1.5 Plant dry weight (g)

It was calculated as average for the dry weight to the five tagged plans.

3.3.1.6 Days to 50% flowering:-

The days of 50% flowering were recorded from sowing date up to the day when 50%of the plants at each plot had fully exerted heads.

3.3.1.7 Days to maturity

They were taken as the number of days from sowing date to the day when all the heads at each plot had reached physiological maturity.

3.3.2 Yield Characters

3.3.2.1 Panicle length (cm)

It was measured from the base of the panicle to its tip using the meter tape.

3.3.2.2 Grain yield/plant (g)

After harvesting the panicles of the five selected tagged plants stored at room temperature for four weeks to minimize change in weight due to moisture content, then they were threshed manually and the grain yield/plant was determined using sensitive balance.

3.3.2.3 1000 grain weight (g)

The weight of 1000 grains was determined by weighting 1000 grain obtained randomly from the five selected panicles using sensitive balance.

3.3.2.4 Grain yield (Ton /ha)

After harvesting all the covered heads from an area of 0.7 m^2 in the middle ridges of each plot were cut and stored for four weeks to minimize change in weight due to moisture content manually threshed ,cleaned weighted by using the sensitive balance and the grain yield Ton/ /ha was determined as the following formula :

$$\text{Grain yield Ton/ha.} = \frac{(\text{grain weight/plot}) \times 10000}{\text{Plot area}}$$

3.4 Data Statistical Analysis

The collected data for growth and yield characters was subjected to analysis of variance used for a randomized complete block design (RCBD) arranged in split plot arrangement by using M.STAT computer packages.

3.4.1Coefficient of variation (C. V)

Coefficient of variation (C. V) for each character was determined according to the following formula.

$$C.V = \frac{\sqrt{(\mathrm{MSE})}}{(G)} \times 100$$ Where

MSE = mean square of Error,   G= Grand mean

3.4.2 Comparison between seasons:

The means were separated using the least significant difference (LSD) at 5% level of significance according to the formula:

$$L.S.D = \sqrt{\frac{2 \times \text{Error Mean square}}{\mathrm{r}}} \times t$$

Where:

r= number of replications

t =level of significance for t-value at 0.05

Table (2) the form of analysis of randomized complete block design used in the study

Source of variation	d.f	MS	EMS
Replications	(r-1)=2	M_6	
Stress (a)	(s-1) = 1	M_5	
Error a	(r-1)(a-1)=2	M_4	
Genotype (g)	(g-1)=21	M_3	$\partial^2 e\ ^{+}\partial^2 g$
a x g	(a-1)(g-1)=21	M_2	$^{+}\partial^2 g$
Error g	(r-1)(g- 1)=84	M_1	
Total	rag-1=131		

Where:

r= replication

g= genotypes

MS= Mean square

EMS= Expected mean square

M_1 , $M_{2,}$ and M_6 = Mean square for error, (A x B), Varieties, error (A), stress, and replication, respectively.

$\partial^2 e$ = error variance

$\partial^2 g$ =genotypic variance

Table (3). Combined analysis of variance for characters of 22 varieties of sorghum evaluated under two water treatments with three replications During season (2012-2013).

Source of variation	Degree freedom	Mean squares	Expected mean squares
Season(S)	(S-1)=1	MQ1	
Reps within seasons	R(S-1)=3	MQ2	
Stress (D)	(D-1)=1	MQ3	
Stress x Season	D(S-1)=2	MQ4	
Pooled Error (a)	R(D-1)(S-1)=3	MQ5	
Genotypes(G)	(G-1)=21	MQ6	**$\sigma^2e-r\sigma^2gtl-rt\sigma^2gl-rl\,\sigma^2gt-rtl\sigma^2g$**
genotypes x Season	(G-1)(S-1) =21	MQ7	**$\sigma^2e-r\sigma^2gtl-rl\sigma^2gt$**
Genotype x Stress	(D-1)(S-1)=21	MQ8	**$\sigma^2e-r\sigma^2gtl-rl\sigma^2gl$**
Season x Genotype x Stress	(S-1)(D-1)(G-1)=21	MQ9	**$\sigma^2e-r\sigma^2gtl$**
Pooled Error (b)	169	MQ10	**σ^2e**
Total	263		

S= season R=replication D = stress G= genotypes,

∂^2e=pooled error variance

∂^2g= genotypic variance,

∂^2Gl=variance due to genotypes, season interaction.

MQ1, MQ2, MQ3,… = mean squares for pooled error. Genotypes, Season, interaction, Genotypes x replication with in season interaction and season respectively.

3.5 Phenotypic (σ^2ph) and genotypic (σ^2g) variances.

a) For the separate analysis of variance. They were estimated as follows:

$\sigma^2 g = (M_2 - M_1)/r$

$\sigma^2 ph = \sigma^2 g + \sigma^2 e$

Where:

r= number of replications

σ^2e= error or environments

M_1, M2= error and genotype mean squares

b) For combined analysis of variance, they were estimated as follows

Genotypic variance (σ^2g) = $(M_2-M_1)/rL$

Phenotypic variance (σ^2ph) = $\sigma^2 g + \sigma^2 gL + \sigma^2 e$

Where:

G=number of genotypes

L and R number of seasons and replications, respectively.

σ^2g = error or environmental variance .

M_1=expected mean squares of pooled error

M_2=expected mean squares of genotypes x seasons interaction.

Phenotypic variance (σ^2 ph) = $\sigma^2 g + \sigma^2 e$

Genotypic variance (σ^2g) = (MQ4-MQ6)/r

3.6 Heritability (h^2):

Broad sense heritability was estimated in each season separately, using the formula suggested by Johnson *et al*, (1955) as the follows:

a/ From the separated ANOVA:

$h^2 = \sigma^2 g / \sigma^2 ph$

σ^2g = genotype variance , σ^2ph = phenotypic variance b/ Form the combined ANOVA: It was calculated as a ratio of the genotypic variance to the phenotypic variance according to the formula :

$$h^2 = \sigma^2 g / \left[\sigma^2 g + \frac{\sigma^2 gL}{r} + \frac{\sigma^2 e}{rL}\right]$$

Where:

$\sigma^2 g$ = the estimated genetic variance

$\sigma^2 gL$ =the variance due to genotypes x seasons interaction .

$\sigma^2 e$ = the pooled error variance

L and r=are a number of seasons and replication respectively.

3.7 Phenotypic and genotypic coefficient of variation:

They were according to formula suggested by Burton and Dewane (1952) as the following

$$\text{Phenotypic coefficient of variation (PCV)} = \frac{\sqrt{\sigma^2 Ph}}{\text{Grand mean}} \times 100$$

$$\text{Genotypic coefficient of variation (GCV)} = \frac{\sqrt{\sigma^2 g}}{\text{Grand mean}} \times 100\%$$

3.8 Genetic advance (GA):

It was estimated by the formula of Robinson *et al*, (1949) as follows

$$GA = K\, \sigma^2 g / \sqrt{\sigma^2 Ph}$$

Where: K=selection differential and it was 2.06 at selection of 5%

3.9 Phenotypic correlation:

It was used to estimate phenotypic covariance between two seasons .They were used further for computation of phenotypic correlation between different characters, using the formula suggested by Miller *et al.* (1958).

Phenotypic corrélation coefficient (r ph) = $\sigma^2 phxy / \sqrt{(\sigma^2 ph\ x)(\sigma^2 phy)}$

Where:

σ^2 ph x y = phenotypic covariance between two traits (x ,y)

σ^2phx = phenotypic variance for trait x, σ^2phy = phenotypic variance for trait y.

3.10 Drought tolerance measurements

Yield (ton/ha) was used as parameter to evaluate drought tolerance. This parameter was based on collected data of grain yield (ton /ha).

The parameters which developed in this study were:

y w = grain yield (Ton /ha) under non – drought condition (W_0)

yd= grain yield (Ton /ha) under dry condition for (W_1) treatments

yd/y

W % = ratio grain yield (Ton /ha) (dry) to grain yield (Ton /ha) (non –drought) as percent

SSI = stress susceptibility index of Fisher and Maurer (1978). It was determined using the formula:

$$\mathbf{SSI = (yw - yd) / (yw \{1 - yd / yw\})}$$

yd and yw = mean yields of genotype that evaluated under dry and well watered conditions, respectively.

(yw- yd) = drought intensity index (relative yield reduction over all variety in the environment). Values of SSI > 1 denote. Below average reaction is defined by SSI = 1. And values of SSI >1 describe above drought susceptibility (= below average drought tolerance).

GMP = Geometric mean of productivity in g, it is measured as (Yd ×Yw) 0.5 as described by Fernandez (1993).

CHAPTER FOUR

RESULTS

4.1 Growth characters

4.1.1 Plant height (cm)

The analysis of variance revealed that there were significant differences among the genotypes as well as water treatments ($P \leq 0.05$) at both seasons (appendices 1, 2). The variation due to the interaction between water treatments x genotypes was significant deferent in the second season only (appendix 2). The combined analysis (appendix 3). revealed highly significant ($P \leq 0.01$) among genotypes, under the two level of water stress (7days 21days) for this treatments, genotypes, seasons, and interactions (season x water; season x genotypes; water x genotypes and season x genotype x water), (appendix 3). The highest values of plant height (179.00cm) and (142.72cm) were recorded by genotype HSD7506 in (7days and 21days) respectively and the lowest values (76.06cm) and (61.49cm) were regarded by the genotype HSD6702 under drought stress condition 7days and 21days, respectively (Table, 1).

4.1.2 Stem diameter (cm)

The analysis of variance indicated that the mean of stem diameter was highly significant ($P \leq 0.01$) affected by genotypes in the two seasons whereas only significant ($P \leq 0.01$) by stress in the second season (appendix 1, 2). The combined analysis revealed that there were highly significant difference ($P \leq 0.01$) between genotypes, seasons, and the interaction between all treatments except stress x seasons which was significant ($P \leq 0.05$), (appendix 3). The mean for stem diameter showed that highest values of the stem diameter (21.03cm) and (20.39cm) were obtained by the genotype HSD7511for (7days and 21days) consecutively whereas lowest value (15.81cm) and (14.90cm) were recorded by the genotype Arfagadamek for (7days), and the genotype HSD7507 for (21days), (Table, 2).

4.1.3 Number of leaves /plant

Highly significant differences ($P \leq 0.01$) were shown for the 22 sorghum genotypes for number of leaves at both seasons 2012 and 2013 (appendices 1 and 2). This character was significant ($P \leq 0.05$) for stress in season (2013), (appendix 2). The results of combined analysis showed highly significant differences ($P \leq 0.01$), (appendix 3).The means of number of leaves due to combined results showed that the highest values (16.21) and (14.60) for the genotype HSD8653and HSD7584 in (7days and 21 days) respectively and the lowest values (10.38) and (10.67) were obtained by the genotypes HSD7616 and Arfa gdamek in (7 days and 21days), respectively (Table,3).

4.1.4 Leaf area (cm^2)

The result showed that, highly significant differences ($P \leq 0.01$) were detected among genotypes and between water stress for this character in the two seasons (2012) and (2013) (appendices 1 and 2). The combined analysis also showed highly significant difference ($P \leq 0.01$) among season and interaction (genotype x season and genotypes x season x stress) due to combined analysis (appendix 3).For the means of leaf area , the highest values due to combined analysis were (525.31 cm^2) and (503.32cm^2) obtained by the genotypes Botana and Wed Ahmed under water regimes (7days and 21days) successively and the lowest values were reveled by the genotypes HSD7610 and HSD7601was (364.08 cm^2) and (290.22 cm^2), respectively (Table,4).

Table (1): Means of plant height (cm) for (22) sorghum genotypes evaluated under two water treatments during two season 2012and 2013as well as the means of combined analyses.

Season	2012			2013			Combined(2012-2013)	
Treatments	7 days	21 days	Mean	7 days	21 days	Mean	(7 days)	(21 days)
HSD7507	187.16	158.65	172.90	125.22	114.89	120.06	156.19	136.77
HSD7506	170.79	156.78	163.78	187.22	128.67	157.94	179.00	142.72
HSD7584	137.53	133.00	135.27	167.67	122.11	144.89	152.60	127.56
HSD7591	152.77	134.51	143.64	132.22	132.67	132.45	142.50	133.59
HSD7601	126.00	115.66	120.83	105.78	92.89	99.34	115.89	104.27
HSD7602	84.45	61.98	73.21	67.67	61.00	64.33	76.06	61.49
HSD7606	109.13	111.14	110.14	117.44	93.33	105.39	113.29	102.24
HSD7610	89.54	69.96	79.75	68.22	54.11	61.17	78.88	62.03
HSD7616	138.60	117.47	128.03	114.44	93.67	104.06	126.52	105.57
HSD8150	137.88	104.88	121.38	99.33	74.00	86.67	118.61	89.44
HSD8176	160.60	137.61	149.11	127.33	110.00	118.67	143.97	123.81
HSD8228	177.83	159.80	168.82	135.78	109.33	122.56	156.81	134.57
HSD8231	142.20	117.46	129.83	106.22	91.67	98.95	124.21	104.56
HSD7511	128.70	114.89	121.80	117.78	91.11	104.45	123.24	103.00
HSD8653	119.88	97.00	108.44	101.44	75.67	88.56	110.66	86.33
HSD8849	143.25	111.22	127.24	142.56	99.56	121.06	142.90	105.39
HSD9566	89.78	95.36	92.57	99.00	82.33	90.67	94.39	88.85
Wad Ahmed	136.79	120.99	128.89	98.89	91.00	94.95	117.84	106.00
Tetron	152.13	128.78	140.46	155.00	123.56	139.28	153.57	126.17
Hagega	116.33	105.93	111.13	94.78	81.11	87.95	105.56	93.52
Arfa gadamek	106.39	93.98	100.19	98.56	82.11	90.34	102.47	88.05
Botana	169.16	111.77	140.46	92.78	77.11	84.94	130.97	94.44
Mean	135.31	116.31	125.81	116.15	94.63	105.39	125.73	105.47
LSD S			27.08			5.95		
LSD G			16.62			12.75		
LSD S x G			-			18.04		

Table (2): Means of stem diameter (cm) for (22) sorghum genotypes evaluated under two water treatments during two season 2012and 2013as well as the means of combined analyses.

Season	2012			2013			Combined(2012-2013)	
Treatments	7 days	21 days	Mean	7 days	21 days	Mean	(7 days)	(21 days)
HSD7507	16.44	15.86	16.15	15.63	13.93	14.78	16.03	14.90
HSD7506	18.26	16.42	17.34	17.08	15.82	16.45	17.67	16.12
HSD7584	16.73	23.43	20.08	16.11	15.17	15.64	16.42	19.30
HSD7591	17.14	19.50	18.32	17.21	15.46	16.33	17.17	17.48
HSD7601	18.38	21.49	19.94	17.37	15.29	16.33	17.88	18.39
HSD7602	20.51	23.65	22.08	17.83	17.04	17.43	19.17	20.35
HSD7606	18.77	24.44	21.61	18.29	15.49	16.89	18.53	19.97
HSD7610	18.69	26.77	22.73	15.28	11.92	13.60	16.98	19.35
HSD7616	18.60	20.14	19.37	17.53	15.29	16.41	18.06	17.71
HSD8150	20.57	18.52	19.55	16.85	15.12	15.98	18.71	16.82
HSD8176	20.62	17.28	18.95	15.88	13.59	14.73	18.25	15.43
HSD8228	22.00	19.76	20.88	18.78	16.48	17.63	20.39	18.12
HSD8231	18.98	21.84	20.41	16.16	15.00	15.58	17.57	18.42
HSD7511	23.51	24.05	23.78	18.54	16.74	17.64	21.03	20.39
HSD8653	17.44	20.00	18.72	20.53	18.91	19.72	18.99	19.45
HSD8849	20.75	21.28	21.01	16.71	16.95	16.83	18.73	19.11
HSD9566	15.30	22.39	18.85	19.91	17.43	18.67	17.61	19.91
Wad Ahmed	17.04	21.41	19.22	18.94	17.37	18.16	17.99	19.39
Tetron	16.54	17.16	16.85	16.35	13.75	15.05	16.45	15.45
Hagega	17.66	16.34	17.00	18.62	16.73	17.68	18.14	16.54
Arfa gadamek	13.97	21.09	17.53	17.64	16.20	16.92	15.81	18.65
Botana	16.77	21.84	19.30	17.64	17.56	17.60	17.20	19.70
Mean	18.39	20.67	19.53	17.49	15.78	16.64	17.94	18.23
LSD S			4.16			0.17		
LSD G			2.58			1.92		
LSD S x G			5.02			-		

Table (3): Means of number of leaves for (22) sorghum genotypes evaluated under two water treatments during two season 2012and 2013as well as the means of combined analyses.

Season	2012			2013			Combined(2012-2013)	
Treatments	7 days	21 days	Mean	7 days	21 days	Mean	(7 days)	(21 days)
HSD7507	11.23	10.66	10.95	10.89	12.17	11.53	11.06	11.47
HSD7506	11.13	11.00	11.07	12.44	13.17	12.81	11.78	12.08
HSD7584	13.53	15.00	14.27	12.00	14.00	13.00	12.76	14.60
HSD7591	15.77	12.67	14.22	11.66	12.94	12.13	13.71	12.80
HSD7601	12.67	13.33	13.00	13.33	13.17	13.25	13.00	13.20
HSD7602	9.57	8.90	9.23	12.33	12.83	12.58	10.95	10.87
HSD7606	12.80	14.00	13.40	12.44	13.67	13.06	12.62	13.88
HSD7610	10.10	9.67	9.88	11.33	12.89	12.11	10.72	11.32
HSD7616	9.43	9.87	9.60	11.33	13.00	12.17	10.38	11.62
HSD8150	10.10	10.33	10.22	12.44	12.33	12.39	11.27	11.33
HSD8176	11.57	10.33	10.95	11.56	13.44	12.50	11.56	11.88
HSD8228	11.23	12.66	11.95	12.78	12.78	12.78	12.01	12.72
HSD8231	16.00	12.90	14.45	12.67	12.56	12.61	14.33	12.78
HSD7511	12.80	13.66	13.23	12.33	13.22	12.78	12.57	13.44
HSD8653	17.20	14.00	15.60	15.22	13.00	14.11	16.21	13.50
HSD8849	13.43	12.33	12.88	13.56	12.11	12.83	13.49	12.22
HSD9566	11.53	14.67	13.10	14.33	12.44	13.39	12.93	13.55
Wad Ahmed	14.53	16.67	15.60	15.44	10.67	13.06	14.99	13.67
Tetron	14.80	14.67	14.73	13.44	11.67	12.56	14.12	13.17
Hagega	14.37	14.67	14.51	12.22	12.33	12.28	13.29	13.50
Arfa gadamek	10.80	9.57	10.18	13.00	11.78	12.39	11.90	10.67
Botana	14.10	11.33	12.72	11.00	11.00	11.00	12.55	11.16
Mean	12.67	12.40	12.53	12.62	12.58	12.60	12.64	12.89
LSD S			2.58			0.71		
LSD G			1.89			1.31		
LSD S x G			-			-		

Table (4): Means of leaf area (cm^2) for (22) sorghum genotypes evaluated under two water treatments during two season 2012and 2013as well as the means of combined analyses.

Season	2012			2013			Combined(2012-2013)	
Treatments	7 days	21 days	Mean	7 days	21 days	Mean	(7 days)	(21 days)
HSD7507	415.33	435.33	425.33	338.27	310.32	324.30	376.80	372.83
HSD7506	459.00	483.33	471.17	363.48	264.45	313.97	411.24	373.89
HSD7584	483.57	440.33	461.95	340.12	328.44	334.28	428.85	384.39
HSD7591	581.27	508.67	544.97	300.97	258.67	279.82	441.12	383.67
HSD7601	435.67	348.33	392.00	330.14	232.11	281.13	382.91	290.22
HSD7602	383.33	337.00	360.17	410.23	365.46	387.84	396.78	351.23
HSD7606	467.10	360.67	413.88	411.21	328.88	370.04	439.16	344.77
HSD7610	388.67	350.33	369.50	339.49	273.45	306.47	364.08	311.89
HSD7616	422.60	334.67	378.63	368.25	291.04	329.65	395.42	312.86
HSD8150	467.17	391.67	429.42	348.41	316.67	332.54	407.79	354.17
HSD8176	437.17	346.33	391.75	373.69	335.74	354.72	405.43	341.04
HSD8228	394.43	382.33	388.38	401.48	306.21	353.85	397.96	344.27
HSD8231	519.33	445.33	482.33	447.87	341.38	404.63	483.60	393.36
HSD7511	548.90	505.67	527.28	390.11	351.37	370.74	469.51	428.52
HSD8653	429.33	449.00	439.17	374.89	272.81	323.85	402.11	360.91
HSD8849	473.73	455.00	464.37	362.68	332.94	347.81	418.20	393.97
HSD9566	466.40	476.33	471.37	376.49	274.27	325.38	421.45	375.30
Wad Ahmed	603.33	550.00	576.67	415.20	456.64	485.92	509.27	503.32
Tetron	466.33	518.33	492.33	318.05	278.37	298.21	392.19	398.35
Hagega	679.23	577.67	628.45	371.27	348.08	359.68	525.25	482.88
Arfa gadamek	405.77	340.67	373.22	353.27	250.80	302.04	379.52	295.74
Botana	638.43	562.67	600.55	412.18	328.74	370.46	525.31	445.71
Mean	480.28	436.35	458.31	371.26	306.68	338.97	425.31	373.78
LSD S			58.65			65.94		
LSD G			108.29			66.02		
LSD S x G			-			-		

4.1.5 Plant dry weight (g)

The analysis of variance (appendices 1 and 2) reveled highly significant differences ($P \leq 0.01$) among sorghum genotype, water stress for both seasons (2012 and 2013) as well as interaction (genotypes x stress) in both season (2012 and 2013) (appendices 1 and 2). The stress only showed significant ($P \leq 0.05$) in season (2012, 2013). Whereas, the combined reveled highly significant differences ($P \leq 0.01$) only for genotypes, and the interactions genotypes x season, genotype x stress and genotypes x season x stress (appendix 3). Due to combined means showed highest values (104.09g) and (73.89g) were regarded by the genotypes HSD7616 and HSD7606 under watering 7days, 21days respectively, and lowest values (50.14g) and (37.48g) were reveled by the genotype Botana for the tow water regime in succession (Table5).

4.1.6 Days to 50% flowering (days)

The means for days to 50% flowering was highly significant ($p \leq 0.01$) affected by genotypes, in seasons (2012) (appendix 1). Whereas significant differences among genotype and water stress in the second season (appendix 2), the combined showed significant ($p \leq 0.05$) in stress, and highly significant ($P \leq 0.01$) in season, and the interaction between all treatments (appendix 3). The means separation due to combined analysis reveled that the highest values (100.00days) and (108.50days) were shown by the genotype Tetron in 7day, 21days water regime respectively, (Table, 6) whereas, lowest value (58.67days) and (60.83days) in two water regime (7days 21days), consecutively, were obtained by the genotype HSD7616 (Table, 6).

4.1.7 Days to maturity (days)

The individual analysis showed that this character was highly significant ($P \leq 0.01$) affected by genotypes in the two seasons 2012 and 2013 (appendices 1 and 2), and also by stress in season (2013) (appendix 2).

Table (5): Means of plant dry weight (g) for (22) sorghum genotypes evaluated under two water treatments during two season 2012and 2013as well as the means of combined analyses

Season	2012			2013			Combined(2012-2013)	
Treatments	7 days	21 days	Mean	7 days	21 days	Mean	(7 days)	(21 days)
HSD7507	80.47	60.00	70.23	44.69	48.99	46.84	62.58	54.49
HSD7506	55.70	60.20	57.95	122.16	69.16	95.66	88.93	64.68
HSD7584	74.77	66.37	70.57	116.17	45.18	80.67	95.47	55.77
HSD7591	79.87	78.20	79.03	88.03	63.67	75.85	83.95	70.93
HSD7601	57.57	70.47	64.02	79.13	49.17	64.15	68.35	59.82
HSD7602	105.43	58.43	81.93	51.19	54.04	52.62	78.31	56.24
HSD7606	113.80	99.97	106.88	70.21	47.81	59.01	92.01	73.89
HSD7610	80.17	55.67	67.92	26.17	26.96	26.56	53.17	41.31
HSD7616	150.83	59.67	105.25	57.36	40.58	48.97	104.09	50.12
HSD8150	69.47	72.43	70.95	54.19	47.06	50.62	61.83	59.74
HSD8176	56.67	50.43	53.55	65.78	58.83	62.31	61.22	54.63
HSD8228	50.90	61.33	56.12	134.08	82.79	108.43	92.49	72.06
HSD8231	79.13	81.77	80.45	66.51	57.32	61.92	72.82	69.54
HSD7511	58.43	69.67	64.05	82.03	77.14	79.59	70.23	73.41
HSD8653	56.33	76.57	66.45	115.49	68.39	91.94	85.91	72.48
HSD8849	41.67	29.63	35.65	95.12	72.12	83.62	68.39	50.88
HSD9566	55.90	44.00	49.95	89.46	60.38	74.92	72.68	52.19
Wad Ahmed	50.10	42.87	46.48	125.82	62.03	93.93	87.96	52.45
Tetron	76.50	67.77	72.13	74.59	63.11	68.85	75.54	65.44
Hagega	48.63	46.00	47.32	57.71	42.97	50.34	53.17	44.48
Arfa gadamek	50.23	50.57	50.40	85.26	61.59	73.42	67.74	56.08
Botana	41.33	32.00	36.67	58.94	42.97	50.96	50.14	37.48
Mean	69.72	60.64	65.18	80.00	56.47	68.23	74.86	58.55
LSD S			11.87			14.36		
LSD G			20.07			16.41		
LSD S x G			28.88			23.22		

Table (6) : Means of days to 50% flowering for (22) sorghum genotypes evaluated under two water treatments during two season 2012and 2013as well as the means of combined analyses

Season	2012			2013			Combined(2012-2013)	
Treatments	7 days	21 days	Mean	7 days	21 days	Mean	(7 days)	(21 days)
HSD7507	68.33	70.33	69.33	57.00	64.67	60.83	62.67	67.50
HSD7506	73.00	73.67	73.33	65.67	72.33	69.00	69.33	73.00
HSD7584	88.33	92.00	90.17	72.00	82.67	77.33	80.17	87.33
HSD7591	87.67	87.67	87.67	75.00	70.33	72.67	81.33	79.00
HSD7601	73.67	77.00	75.33	59.67	66.00	62.83	66.67	71.50
HSD7602	65.00	68.33	66.67	58.67	62.00	60.33	61.83	65.17
HSD7606	84.00	85.00	84.50	67.33	70.67	69.00	75.67	77.83
HSD7610	67.33	70.67	69.00	53.00	53.33	53.17	60.17	62.00
HSD7616	63.33	67.33	65.33	54.00	54.33	54.17	58.67	60.83
HSD8150	65.67	67.00	66.33	76.00	80.00	78.00	70.83	73.50
HSD8176	69.67	70.67	70.17	58.67	62.00	60.33	64.17	66.33
HSD8228	72.67	77.67	75.17	82.67	91.67	87.17	77.67	84.67
HSD8231	94.67	79.67	87.17	64.33	69.67	67.00	79.50	74.67
HSD7511	79.00	84.00	81.50	66.67	69.33	68.00	72.83	76.67
HSD8653	93.00	93.00	93.00	79.67	85.00	82.33	86.33	89.00
HSD8849	87.00	92.67	89.83	61.33	68.67	65.00	74.17	80.67
HSD9566	92.00	93.67	92.83	68.33	79.00	73.67	80.17	86.33
Wad Ahmed	87.67	95.00	91.33	98.00	94.33	96.17	92.83	94.67
Tetron	103.33	111.67	107.50	96.67	105.33	101.00	100.00	108.50
Hagega	86.00	88.00	87.00	85.00	90.67	87.83	85.50	89.33
Arfa gadamek	65.67	66.00	65.83	67.33	86.67	77.00	66.50	76.33
Botana	83.00	77.00	80.00	82.33	87.00	84.67	82.67	82.00
Mean	79.55	81.27	80.41	70.42	75.71	73.07	74.98	78.49
LSD S			6.58			3.03		
LSD G			6.32			6.10		
LSD S x G			-			-		

Table (7): Means of days to maturity for (22) sorghum genotypes evaluated under two water treatments during two season 2012and 2013as well as the means of combined analyses

Season	2012			2013			Combined(2012-2013)	
Treatments	7 days	21 days	Mean	7 days	21 days	Mean	(7 days)	(21 days)
HSD7507	89.33	90.33	89.83	83.67	89.33	86.50	86.50	89.83
HSD7506	127.33	123.67	125.50	100.00	107.00	103.50	113.67	115.33
HSD7584	130.67	124.67	127.67	100.33	111.33	105.83	115.50	118.00
HSD7591	121.33	117.67	119.50	96.00	98.00	97.00	108.67	107.83
HSD7601	121.00	124.00	122.50	82.67	92.33	87.50	101.83	108.17
HSD7602	92.33	92.67	92.50	81.67	85.67	83.67	87.00	89.17
HSD7606	107.33	117.00	112.17	85.67	91.67	88.67	96.50	104.33
HSD7610	100.33	108.00	104.17	80.67	84.67	82.67	90.50	96.33
HSD7616	102.67	106.00	104.33	83.33	88.33	85.83	93.00	97.17
HSD8150	114.00	106.33	110.17	85.00	98.00	91.50	99.50	102.17
HSD8176	99.67	108.67	104.17	83.67	87.67	85.67	91.67	98.17
HSD8228	110.00	106.33	108.17	112.00	119.00	115.50	111.00	112.67
HSD8231	121.33	126.33	123.83	86.67	100.67	93.67	104.00	113.50
HSD7511	114.00	121.33	117.67	97.67	105.00	101.33	105.83	113.17
HSD8653	126.00	124.67	125.33	103.33	113.33	108.33	114.67	119.00
HSD8849	121.67	100.33	111.00	94.00	102.00	98.00	107.83	101.17
HSD9566	125.33	120.00	122.67	95.67	103.33	99.50	110.50	111.67
Wad Ahmed	118.33	111.33	114.83	102.33	106.33	104.33	110.33	108.83
Tetron	133.67	134.00	133.83	95.67	104.67	100.17	114.67	119.33
Hagega	121.33	115.33	118.33	86.33	88.33	87.33	103.83	101.83
Arfa gadamek	100.00	102.67	101.33	92.67	88.33	90.50	96.33	95.50
Botana	107.67	108.67	108.17	80.67	86.00	83.33	94.17	97.33
Mean	113.88	113.18	113.53	91.35	97.77	94.56	102.61	105.48
LSD S			10.48			1.75		
LSD G			10.90			4.79		
LSD S x G			-			-		

Combined analysis showed highly significant (P ≤0.01) with season, and the interaction (genotypes x season); (genotypes x stress) and (genotypes x season x stress), (appendix 3). Mean separation due to combined showed highest values (115.50) and (119.33) reveled by the genotypes HSD7584 and Tetron for the two watering (7days and 21days) successively and lowest values (86.50) and (89.17) registered by the genotypes HSD7507 and HSD7602 for (7days and 21days) respectively (Table, 7).

4.2 Grain yield characters

4.2 .1 Panicle length (cm)

Analysis of variance showed highly significant differences (P ≤0.01) due to genotypes and significant due to stress in the two seasons 2012 and 2013 respectively, (appendices 1 and 2). Whereas, the combined analyses revealed highly significant differences (P ≤0.01) due to stress, genotypes, and interactions between (genotype x stress) and (season x genotype x stress), (appendix 3). The mean separation due to combined analyses regarded highest values (27.83cm and 25.19cm) were shown by the genotypes HSD8849 and Hagega in the two water regimes (7days, 21days) in succession (table,8), whereas, lowest values (16.19cm) and (15.78cm) showed by the genotypes HSD9566 and HSD7602 for watering (7days and 21days) respectively, (Table,8).

4.2 .2 Grain yield / plant (g)

The study showed that grain yield/plant was highly significant differences (P ≤0.01) in stress, genotype, and interaction (stress x genotype), in first season (appendix 1). Whereas, the individual analyses in season (2013), revealed that grain yield/ plant significant in stress and interaction between (stress x genotype) and highly significant due to genotype (appendix 2). On the other hand combined analysis showed, highly significant (P ≤0.01) only in interaction between (season x stress), and highly significant in interaction between (season x stress x genotype), (appendix 3). For this character the highest values (56.08g) (25.32g) were shown by the genotype Botana for two watering (7days and 21days) consecutively, and lowest values (17.54g) and (11.30g) were showed by the genotypes HSD7602 and HSD7506 for the two watering (7days and 21days) respectively (Table, 9).

4.2 .3 Thousand seed weight (g)

Analysis of variance indicated that thousand seed weight was highly significant (P ≤0.01) affected by stress, genotype in season (2012) (appendix 1). Whereas in season (2013) significant by stress, and highly significant differences (P ≤0.01) were shown by genotype (appendix 2), but the interaction not significant in the two seasons. Combined analysis was only significant (P ≤0.05) due to interaction between (stress x season), but highly significant (P ≤0.01) by interaction between (season x stress x genotype), (appendix 3).The mean separation due to combined analysis, the highest values (31.09g) and (29.18g) showed by the genotypes HSD8849 and HSD8231 in the two water regimes (7days and 21days) in succession and the lowest values (19.82g) and (16.46g) were reveled by the genotype HSD8150 in the two watering (7days and 21days), respectively (Table, 10).

4.2 .4 Grain yield (Ton/ha)

The means yield ton/ha was significantly affected by all treatments in both seasons, in season (2012) the analysis of variance showed, highly significant differences (P ≤0.01) were shown by the stress, genotype, and interaction (stress x genotype), (appendix 1). Whereas, in season (2013) significant differences (P ≤0.05) showed by stress, interaction (stress x genotype), and high significant differences (P ≤0.01) only showed by the genotypes (appendix 2). The results showed that no significant due to combined (appendix 3). Separation of means due to combined analysis revealed highest values (3.84ton/ha) and (2.14ton/ha) revealed by the

Table (8): Means of panicle length for (22) sorghum genotypes evaluated under two water treatments during two season 2012and 2013as well as the means of combined analyses.

Season	2012			2013			Combined(2012-2013)	
Treatments	7 days	21 days	Mean	7 days	21 days	Mean	(7 days)	(21 days)
HSD7507	27.59	23.11	25.35	28.02	22.56	25.29	27.81	22.83
HSD7506	21.22	17.11	19.17	23.00	17.67	20.33	22.11	17.39
HSD7584	17.10	10.00	13.55	15.77	10.39	13.08	16.43	10.19
HSD7591	26.23	22.94	24.59	23.83	17.72	20.78	25.03	20.33
HSD7601	19.00	18.99	18.99	18.48	18.10	18.29	18.74	18.54
HSD7602	18.78	15.44	17.11	19.58	16.11	17.84	19.18	15.78
HSD7606	19.37	15.81	17.59	20.16	18.14	19.15	19.76	16.98
HSD7610	18.31	16.06	17.18	18.24	17.39	17.82	18.28	16.72
HSD7616	18.50	19.33	18.92	20.11	18.11	19.11	19.31	18.72
HSD8150	21.11	19.88	20.49	22.73	20.04	21.39	21.92	19.96
HSD8176	27.83	27.28	27.56	26.48	27.72	27.10	27.16	27.50
HSD8228	17.17	13.80	15.48	17.78	13.47	15.62	17.47	13.63
HSD8231	19.10	18.22	18.66	18.56	17.67	18.11	18.83	17.94
HSD7511	25.17	22.46	23.81	26.24	22.46	24.35	25.71	22.46
HSD8653	23.11	19.00	21.06	22.89	17.67	20.28	23.00	18.33
HSD8849	29.36	19.22	24.29	26.30	20.89	23.59	27.83	20.06
HSD9566	16.11	13.92	15.02	16.28	13.56	14.92	16.19	13.74
Wad Ahmed	22.89	18.22	20.56	20.53	15.00	17.77	21.71	16.61
Tetron	22.00	19.78	20.89	22.67	18.83	20.75	22.33	19.31
Hagega	26.33	25.13	25.73	27.69	25.24	26.47	27.01	25.19
Arfa gadamek	17.69	19.54	18.62	18.20	21.26	19.73	17.94	20.40
Botana	28.59	22.67	25.63	26.52	24.33	25.43	27.56	23.50
Mean	21.93	19.00	20.47	21.82	18.83	20.33	21.88	18.91
LSD S			2.27			3.61		
LSD G			3.12			2.89		
LSD S x G			-			-		

Table (9): Means of grain yield/ plant (g) for (22) sorghum genotypes evaluated under two water treatments during two season 2012and 2013as well as the means of combined analyses.

Season	2012			2013			Combined(2012-2013)	
Treatments	7 days	21 days	Mean	7 days	21 days	Mean	(7 days)	(21 days)
HSD7507	26.32	27.37	26.84	28.28	11.25	19.77	27.30	19.31
HSD7506	18.79	8.11	13.45	18.57	14.49	16.53	18.68	11.30
HSD7584	25.44	16.69	21.07	14.93	8.60	11.77	20.19	12.65
HSD7591	15.90	12.65	14.28	30.94	20.12	25.53	23.42	16.39
HSD7601	28.47	18.27	23.37	34.73	25.54	30.14	31.60	21.91
HSD7602	13.99	15.06	14.53	21.08	17.05	19.07	17.54	16.06
HSD7606	23.46	9.62	16.54	26.98	16.47	21.73	25.22	13.05
HSD7610	22.94	17.28	20.11	34.10	28.96	31.53	28.52	23.12
HSD7616	23.91	9.33	16.62	28.69	21.02	24.85	26.30	15.18
HSD8150	17.82	9.36	13.59	19.57	13.49	16.53	18.69	11.43
HSD8176	23.17	14.22	18.70	39.26	28.97	34.12	31.22	21.60
HSD8228	19.70	12.97	16.33	19.88	9.89	14.88	19.79	11.43
HSD8231	26.54	15.65	21.09	22.16	11.93	17.05	24.35	13.79
HSD7511	35.57	18.77	27.17	47.80	29.46	38.63	41.68	24.12
HSD8653	34.70	21.87	28.29	26.15	13.35	19.75	30.43	17.61
HSD8849	46.67	14.72	30.70	61.94	40.30	51.12	54.31	27.51
HSD9566	28.54	11.68	20.11	24.50	15.59	20.04	26.52	13.63
Wad Ahmed	28.45	15.65	22.05	37.13	24.72	30.93	32.79	20.19
Tetron	32.77	19.93	26.35	33.79	17.37	25.58	33.28	18.65
Hagega	17.85	11.72	14.79	39.74	31.49	35.61	28.79	21.61
Arfa gadamek	15.99	13.88	14.94	37.25	26.71	31.98	26.62	20.30
Botana	50.54	21.83	36.18	61.63	28.80	45.21	56.08	25.32
Mean	26.25	15.30	20.78	32.23	20.71	26.47	28.56	17.82
LSD S			2.34			17.01		
LSD G			6.40			22.68		
LSD S x G			9.06			9.86		

Table (10): Means of thousand seed weight (g) for (22) sorghum genotypes evaluated under two water treatments during two season 2012and 2013as well as the means of combined analyses.

Season	2012			2013			Combined(2012-2013)	
Treatments	7 days	21 days	Mean	7 days	21 days	Mean	(7 days)	(21 days)
HSD7507	21.70	19.45	20.57	26.82	20.60	23.71	24.26	20.03
HSD7506	26.13	24.20	25.17	21.73	20.02	20.87	23.93	22.11
HSD7584	25.78	25.35	25.57	25.32	20.97	23.15	25.55	23.16
HSD7591	25.43	22.72	24.07	31.60	25.69	28.64	28.51	24.20
HSD7601	22.50	19.35	20.93	24.03	21.59	22.81	23.27	20.47
HSD7602	24.63	22.92	23.78	21.84	22.22	22.03	23.24	22.57
HSD7606	19.82	16.99	18.40	24.19	22.09	23.14	22.00	19.54
HSD7610	26.27	23.02	24.64	23.53	23.56	23.54	24.90	23.29
HSD7616	21.80	23.71	22.75	23.86	21.97	22.91	22.83	22.84
HSD8150	18.90	17.13	18.02	20.73	15.79	18.26	19.82	16.46
HSD8176	24.97	22.47	23.72	26.45	23.75	25.10	25.71	23.11
HSD8228	22.81	22.04	22.42	20.03	16.92	18.47	21.42	19.48
HSD8231	34.68	39.82	37.25	19.15	18.54	18.85	26.92	29.18
HSD7511	25.05	24.53	24.79	25.33	20.97	23.15	25.19	22.75
HSD8653	32.71	32.32	32.52	25.29	22.76	24.03	29.00	27.54
HSD8849	32.82	23.93	28.37	29.37	26.03	27.70	31.09	24.98
HSD9566	20.65	16.62	18.64	23.74	22.46	23.10	22.19	19.54
Wad Ahmed	23.41	24.16	23.79	27.55	22.11	24.83	25.48	23.14
Tetron	25.01	22.66	23.84	30.11	25.31	27.71	27.56	23.99
Hagega	25.92	23.09	24.51	23.01	23.17	23.09	24.46	23.13
Arfa gadamek	26.99	21.95	24.47	23.16	28.38	25.77	25.07	25.16
Botana	26.83	21.57	24.20	22.73	20.70	21.72	24.78	21.14
Mean	25.22	23.18	24.20	24.53	22.07	23.30	24.87	22.63
LSD S			0.04			1.73		
LSD G			5.02			3.36		
LSD S x G			-			-		

Table (11): Means of grain yield (Ton/ha) for (22) sorghum genotypes evaluated under two water treatments during two season 2012and 2013as well as the means of combined analyses.

Season	2012			2013			Combined(2012-2013)	
Treatments	7 days	21 days	Mean	7 days	21 days	Mean	(7 days)	(21 days)
HSD7507	1.88	1.95	1.92	2.02	0.87	1.45	1.95	1.41
HSD7506	1.34	0.58	0.96	1.33	1.03	1.18	1.33	0.80
HSD7584	1.82	1.19	1.51	0.80	0.71	0.76	1.31	0.95
HSD7591	1.14	0.90	1.02	2.21	1.44	1.82	1.67	1.17
HSD7601	2.03	1.31	1.67	2.48	1.82	2.15	2.25	1.56
HSD7602	1.00	1.08	1.04	1.51	1.22	1.36	1.25	1.15
HSD7606	1.68	0.69	1.18	1.93	1.18	1.55	1.80	0.93
HSD7610	1.64	1.23	1.44	2.44	2.07	2.25	2.04	1.65
HSD7616	1.71	0.69	1.20	2.05	1.50	1.78	1.88	1.09
HSD8150	1.27	0.67	0.97	1.40	0.96	1.18	1.33	0.82
HSD8176	1.66	1.02	1.34	2.80	2.07	2.44	2.23	1.54
HSD8228	1.41	0.93	1.17	1.42	0.71	1.06	1.41	0.82
HSD8231	1.90	1.12	1.51	1.58	0.85	1.22	1.74	0.98
HSD7511	2.54	1.34	1.94	3.08	2.10	2.59	2.81	1.72
HSD8653	2.48	1.56	2.02	1.87	0.95	1.41	2.17	1.25
HSD8849	3.33	1.05	2.19	3.65	2.88	3.22	3.49	1.96
HSD9566	2.04	0.83	1.44	1.52	1.11	1.32	1.78	0.97
Wad Ahmed	2.03	1.12	1.58	2.65	1.77	2.21	2.34	1.44
Tetron	2.34	1.42	1.88	2.41	1.24	1.83	2.37	1.33
Hagega	1.28	0.84	1.06	2.84	2.58	2.71	2.06	1.71
Arfa gadamek	1.14	0.99	1.07	2.66	1.91	2.28	1.90	1.45
Botana	3.61	1.56	2.58	4.07	2.72	3.40	3.84	2.14
Mean	1.88	1.09	1.49	2.21	1.53	1.87	2.04	1.31
LSD S			0.16			5.49		
LSD G			0.45			6.97		
LSD S x G			-			0.65		

genotype Botana in the two watering (7days and 21days) consecutively and the lowest values (1.31ton/ha) and (0.80ton/ha) showed by the genotypes HSD7584 and HSD7506 respectively, (Table, 11).

4.3 Genotypic ($\partial^2 g$) Phenotypic (∂^2 ph), variances and heritability (h^2).

The results of this study for the two seasons (2012 and 2013) estimates of the genotypic variances (∂^2g) 1298.76 and 1174.60 were scored by leaf area. Whereas, the lowest estimates of genotypic for the two seasons 0.09 and 0.18 were attended by grain yield (Ton/ha) (Table, 12). On the other hand, highest estimates of phenotypic variance (∂^2 ph) (8846.17, 5555.30), (1888.07, 1298.10) regarded by leaf area and plant height for the two seasons (2012 and 2013), respectively whereas, the lowest values 0.22 and 0.32 obtained by yield (Ton/ha) for the two seasons. Regarding heritability estimates, the values characters were greater at second season than first season for all characters except number of leaves. The high value of heritability (h^2) were revealed for plant dry weight for the two seasons, in both second season, the highest heritability estimated ($h^2 = 0.92$) were recorded for plant dry weight (Table, 12).

4.4 Genotypic (GCV) Phenotypic (PCV), coefficients of variation and genetic advance (GA) in the two seasons (2012 - 2013).

Estimates of genotypic coefficient of variation (GCV) in season 2012 regarded highest value 2149.74 was by leaf area, and also in season 2013 leaf area showed highest1599.89. On the other hand the lowest value 24.31 in season (2012), regarded by yield (Ton/ha), whereas, 32.34 in season (2013), 29.32 showed with number of leaves (Table, 13). On the other hand, (PCV) regarding high values 1051.97, 1114.53 by plant height in the two seasons, respectively. Whereas, low value 9.30, 18.39 revealed by yield (ton/ha), for the two seasons consecutively (table 13). Genetic advance (GA) was recorded high value for all characters in the first season (2012), compared with second season(2013).The highest value of genetic advance (GA) was 6157, 67.16 recorded by plant height in the two seasons, respectively and the lowest value was 0.3, 0.67 showed by yield ton/ha in two season (table, 13).

4.5 Phenotypic correlation:

Phenotypic correlation coefficient between pair wise combination for the different characters in each seasons is presented in (Table, 17, 18,) .The results showed that grain yield t /ha exhibited highly significant ($p \leq 0.01$) positive correlation with all yield component in both season (table 14, 15) on the other hand significant ($p \leq 0.01$) and positive phenotypic correlation with all other vegetative characters except maturity and number of leaves per plant are negative in season (2013), table (15). In this study the estimated similar results grain yield is a complex character and is the final product of actions and interactions of various characters; hence understanding relationship between yield and its components. They suggest that selection for these characters components would be effective in the improvement of grain yield and agree in this study grain yield showed height significant phenotypic correlation with 1000seed weight based on result obtained. Yield selection for late flowering and genotypes and should be given to the characters which exhibited negative association between them.

4.6 Drought tolerance parameters:

A wide range for values of drought tolerance parameters were exhibited by genotype (table 17). The analysis for drought tolerance recorded that the ratio grain yield ton/ha under dry condition (21days) to non – drought (7days) (W_1/W_0) estimated highest value 0.92 by HSD7602, and low value 0.52 showed by HSD7606 (table 17).

Table (12): Phenotypic (∂^2 ph) and Genotypic (∂ ^{2}g) variances and Heritability h^2 for different characters in season (2012-2013)

	(∂^2g		(∂^2ph		h^2	
Season	(2012)	(2013)	(2012)	(2013)	(2012)	(2013)
Plant height (cm)	1298.76	1174.60	1888.07	1298.10	0.69	0.90
Stem diameter (cm)	10.88	3.10	19.80	5.92	0.55	0.52
Number of leaves	7.08	2.38	9.80	3.63	0.72	0.66
Leaf Area (cm^2)	4015.07	1688.20	8846.17	5555.30	0.45	0.30
Plant dry weight (g)	251.73	324.11	282.09	352.40	0.89	0.92
Daysto50%flowering	230.11	167.53	320.31	184.96	0.72	0.91
Days to maturity	27.761	26.24	35.19	32.62	0.79	0.80
Panicle length (cm)	31.04	12.32	50.21	20.91	0.62	0.59
1000seed weight (g)	491.37	652.43	1494.47	1042.93	0.33	0.63
Grain yield / plant (g)	44.72	57.61	113.74	112.47	0.39	0.51
Grain yield (ton/ha)	0.085	0.18	0.22	0.32	0.38	0.56

The stress susceptibility index (SSI) were recorded highest value 1.88 showed by Botana, and lowest value o.65 obtained by HSD7506 and HSD8150 (table 17). Whereas, geometric mean of productivity (GMP) estimated the highest value 2.87 of (GMP) by obtained Botana and lowest value 1.03 recorded by HSD7506 table (17).

Table (13) Phenotypic (PCV), Genetic (GCV), coefficient of variation and genetic advance (GA) for season (2012 – 2013).

Characters	GCV		PCV		AG%	
Season	(2012)	(2013)	(2012)	(2013)	(2012)	(2013)
Plant height (cm)	1529.29	1231.71	1051.97	1114.53	61.57	67.16
Stem diameter (cm)	101.37	35.58	55.70	18.65	5.04	2.63
Number of leaves	78.10	29.32	56.42	19.24	4.66	2.58
Leaf Area (cm^2)	2149.74	1599.89	975.71	486.19	87.94	46.66
Plant dry weight (g)	350.46	482.30	312.74	443.58	30.87	35.57
Daysto50%flowering	282.13	195.60	202.69	177.16	26.49	25.38
Days to maturity	171.93	160.46	135.64	129.08	9.64	9.46
Panicle length (cm)	207.47	89.77	128.25	52.87	9.02	5.55
1000seed weight (g)	1892.52	1477.60	622.24	924.35	26.18	41.62
Grain yield / plant (g)	567.95	566.75	223.32	290.30	8.64	11.19
Grain yield (ton/ha)	24.31	32.34	9.30	18.39	0.37	0.67

Table (14) Phenotypic Correlation Season 2012

	Plant H	Stem D	Number of L	Leaf Aria	Plant D. W	Flowering	Maturity	panicle L	1000 S W	Yield / plant
Stem D (cm)	-0.18^{*}									
Number of leaves	0.23	-0.60^{**}								
Leaf Area (cm^2)	0.26^{**}	0.34	0.50^{*}							
Plant dry W (g)	0.004	-0.09	-0.14	-0.21^{*}						
Daysto50%flower	-0.05	0.39^{**}	0.67^{**}	0.37^{**}	-0.09					
Days to maturity	0.10	0.20^{*}	0.45^{**}	0.26^{**}	-0.01	0.57^{**}				
Panicle L (cm)	0.39^{**}	-0.04	0.09	$0.2\ 7^{**}$	-0.14^{*}	-0.02	-.07			
1000seed W (g)	0.08	0.13	0.20^{*}	0.11	0.05	0.14	0.31^{**}	0.07		
Grain yield /plant(g)	0.30^{**}	0.15^{*}	0.21^{*}	0.29^{**}	0.12	0.17^{*}	0.05	0.40^{**}	0.23^{**}	
Grain yield Ton/ha	0.30^{*}	0.15^{*}	0.21^{*}	0.29^{**}	0.12	0.17^{*}	0.05	0.40^{**}	0.23^{**}	1.00^{**}

**correlation is significant at the 0.01 level

* Correlation is significant at the 0.05 level

Table (15) Phenotypic Correlation Season 201٣

	Plant H	Stem D	Number of L	Leaf Aria	Plant D. W	Flowering	Maturity	panicle L	1000 S W	Yield / plant
Stem D (cm)	-0.04									
Number of leaves	0.23^{**}	0.43^{**}								
Leaf Area (cm^2)	0.05	0.39^{**}	0.08							
Plant dry W (g)	0.52^{**}	0.43^{**}	0.50^{**}	0.23^{**}						
Daysto50%flower	0.03	0.16^{*}	0.38^{**}	-0.06	0.22^{*}					
Days to maturity	0.22^{*}	0.07	0.40^{**}	-0.12	0.38^{**}	0.48^{**}				
Panicle L (cm)	0.14	0.11	-0.09	0.16^{*}	0.01	-0.08	-0.42^{**}			
1000seed W (g)	0.26^{**}	0.04	-0.01	-0.07	0.19^{*}	-0.01	-0.19^{*}	0.36^{**}		
Grain yield /plant(g)	0.44^{**}	0.45^{**}	0.53^{**}	0.25^{**}	0.89^{**}	0.24^{**}	0.32^{**}	0.02	0.17^{*}	
Grain yield Ton/ha	0.01	0.25^{**}	-0.05	0.24^{**}	0.11	-0.12	-0.36^{**}	0.55^{**}	0.43^{**}	0.09

**correlation is significant at the 0.01 level

* Correlation is significant at the 0.05 level

Table (16) Phenotypic Correlation combining analysis for Season (2012 and 201٣)

	Plant height	Stem diameter	Number of leaves	Leaf Aria	Plant dry weight	Flowering	Maturity	panicle L	1000 S W	Yield / plant
Stem D (cm)	-0.47*									
Number of leaves	0.15	0.20								
Leaf Area (cm^2)	0.15	0.12	0.60**							
Plant dry W (g)	0.14	0.15	0.62**	1.00**						
Daysto50%flower	0.21	-0.02	0.79**	0.65**	0.66**					
Days to maturity	0.40	0.12	0.79**	0.41*	0.42*	0.71**				
Panicle L (cm)	0.18	-0.28	-0.09	0.34	0.33	-0.03	-0.33			
1000seed W (g)	0.05	-0.05	0.44*	0.17	0.18	0.27	0.27	0.21		
Grain yield /plant(g)	-0.09	0.12	0.10	0.39*	0.89*	0.18	-0.16	0.57**	0.35	
Grain yield Ton/ha	-0.08	0.15	0.11	0.37*	0.37*	0.15	-0.13	0.57**	0.38*	1.00**

**correlation is significant at the 0.01 level

* Correlation is significant at the 0.05 level

Table (17): **Means of drought tolerance parameters of 22 sorghum genotypes evaluated at two water treatments across two seasons.**

	Yield ton/ha				
Varities	7 Days(W0)	21 Days(W1)	W1/W0	SSI	GMP
HSD7507	1.95	1.41	0.72	0.95	1.66
HSD7506	1.33	0.8	0.60	0.65	1.03
HSD7584	1.31	0.95	0.73	0.64	1.12
HSD7591	1.67	1.17	0.70	0.82	1.40
HSD7601	2.25	1.56	0.69	1.10	1.87
HSD7602	1.25	1.15	0.92	1.00	1.20
HSD7606	1.8	0.93	0.52	0.88	1.29
HSD7610	2.04	1.65	0.81	1.00	1.83
HSD7616	1.88	1.09	0.58	0.92	1.43
HSD8150	1.33	0.82	0.62	0.65	1.04
HSD8176	2.23	1.54	0.69	1.09	1.85
HSD8228	1.41	0.82	0.58	0.69	1.08
HSD8231	1.74	0.98	0.56	0.85	1.31
HSD7511	2.81	1.72	0.61	1.38	2.20
HSD8653	2.17	1.25	0.58	1.06	1.65
HSD8849	3.49	1.96	0.56	1.71	2.62
HSD9566	1.78	0.97	0.54	0.87	1.31
Wad Ahmed	2.34	1.44	0.62	1.15	1.84
Tetron	2.37	1.33	0.56	1.16	1.78
Hagega	2.06	1.71	0.83	1.01	1.88
Arfa gadamek	1.9	1.45	0.76	0.93	1.66
Botana	3.84	2.14	0.56	1.88	2.87
Mean	2.04	1.31	1.56	1.018	1.632

CHAPTER FIVE

DISCUSSION

5.1 Drought effect on growth characters

Most of the growth characters were sensitive to water stress, plant height, leaf area, stem diameter, number of leaves, 50% days to flowering, 50% to maturity. Moreover, water stress was highly significant reduced plant height in the two seasons among all genotypes. Similar finding were shown by (Rauf, 2008; Khayatnezhad*, et al.* 2010) who found that effect of stress coincided with various growth stages such as germination; seedling; shoot length; and flowering. On the other hand stem diameter, leaf area and number of leaves also were highly significant and decrease due to stress, generally all of this characters were highest in (7days) watering and lowest in (21days) watering.

5.2 Drought effect on yield and yield components

Drought had highly significant effect on yield and yield component of all the twenty two genotypes of sorghum used in this study. Yield/plant showed high value in (7days) 56.08g in both season among all genotypes. Whereas, (21days) regime reveled small value 25.32g among all genotypes. Similar results showed by (Al-karaki, and Clark, 1998), who found that sorghum differed in their responses to deficit irrigation. Under full irrigation sorghum yields was good. However, irrigation deficit reduced growth character and yield in sorghum, giving higher yields for sorghum under moderate or severe water deficit treatments. Under water limited conditions; soil water extraction was more important component in sorghum yield. Panicle length had significant affect due to water stress the means value reveled high value 27.83cm in (7days) watering and 25.19cm (21days) watering this result are agreement with (Yadav, *et, al.* 1997 and Berwal and

Khairwal 1997 findings. Thousand seed weight as one of the yield component was affected by drought stress (7days) watering register 31.09g which was high than (21days) value 29.18g. The reduction of thousand seed weight due to drought stress was reported by ELDikhary, 1992 and Osmanzai, 1992. Grain yield ton/ha was highly significantly affected by drought stress and high values were reported by Botana in (7days) was 3.84 ton/ha compered with (21days) reported by Botana 2.14 ton/ha. This result matched the one reported by (Vanderlip 1991). In this study Botana, HSD8849 and Hgega scored high yield under stress condition and could be used in stress breeding program.

5.3 Phenotypic and genotypic Variability

Phenotypic variability estimated for twenty two sorghum genotypes under normal and water stress condition variation can be attributed to phenotypic as well as genotypic variability. Similar conclusion were detected by others in different cereal crops under different environments (Khalafalla, 1993 and Abuelgusim, 1989). Most of the characters, estimates for phenotypic variance were greater than their respective genotypic ones. This result indicates that large proportion of phenotypic variance was due to environmental effects. In general, the morphological characters had low genotypic variance than their respective phenotypic ones indicating that most differences among genotypes were mainly environmental factors.

5.4 Phenotypic coefficients of variation (PCV), genotypic coefficients of variation (GCV), Genetic advance (GA) and Heritability (H^2)

All characters showed wide range for individual character. Genotypic coefficient of variation (GCV) was maximum in leaf area (2149.74, 1599.89) for the two seasons and plant height (1529.29, 1231.71) and it was not different with phenotypic coefficient of variation (PCV). It was also showed maximum value in leaf area (975.71, 486.19) for the two seasons and plant height (1051.97, 1114.53).

This result indicates that these traits were affected by environmental fluctuations. The high value of (GCV) and (PCV) suggested that there is possibility to use environmental effects in direct selection for these traits.

High heritability in this study was showed among vegetative characters, plant height, plant dry weight, 50% flowering and maturity whereas it was less in thousand seed weight, yield/plant and yield (ton/ha). High heritability indicates that these characters are controlled by additive gene action and selection for these characters will be effective. High heritability and high genetic advance for plant height have been shown by Rao and Patil (1996) and similar results were observed by Bello *et al*. (2001). Bello *et al*. (2007) reveled that the low heritability estimates of grain yield is due to the direct and indirect multiplicative effects of yield components on grain yield.

5.5. Drought tolerance and yield relationship

From the stress susceptibility index (SSI) value the lowest values were recorded for genotypes HSD7506, HSD7584 (SSI = 0.65, 0.64 respectively) table (16). This index only pointed out the genotypes with the lowest yield in normal conditions. Based on high value for (SSI) recorded by Botana, HSD8849, HSD7511 (SSI = 1.88, 1.71, 1.38 respectively) table (16) these genotypes could be considered as sensitive to drought. Geometric mean productivity (GMP) recorded lowest values with genotypes HSD7506, HSD7584 (GMP = 1.03, 1.12 respectively) and highest values with Botana, HSD8849, HSD7511 (GMP = 2.87, 2.62, 2.20 respectively). A larger value of (SSI) and (GMP) show relatively more sensitivity to stress (Gobaladi et al. 2006). Most sorghum cultivars used for grain production have pre-flowering drought resistance but do not have any significant post-flowering drought resistance (Subudhi *et al*. 1999).

5.6. Phenotypic correlation

Phenotypic correlations were presented in table (16). However, the results showed significant ($p \leq 0.05$) and negative association of stem diameter with plant height (-0.47). Whereas highly significant ($p \leq 0.01$) and positive was detected between leaf area with number of leaves (0.60). Plant dry weight was highly significant ($p \leq 0.01$) correlation with number of leaves and leaf area (060), (1.00). Yield ton/ha significant ($p \leq 0.05$) affected positively with leaf area, plant dry weight and thousand seed weight (0.37), (0.37), (38) respectively. Whereas, highly significant ($p \leq 0.01$) positive effect panicle length (57), with yield/plant (1.00). These results is a good indicator for high yield. This result was agreed with Amal and Eatemad (2012) who find highly significant and positive correlation between panicle length and grain yield.

CHAPTER SIX

SUMMARY AND CONCLUSIONS

The results obtained in this study, can be summaries as follows:

1. A wide range of genetic variability was detected by genotypes for drought tolerance. This variability can be exploited in the improvement for drought tolerance in this crop.
2. All genotypes under the study were significantly different in growth characters and yield components.
3. Plant height, leaf area, plant dry weight and thousand seed weight, these characters recorded highest GCV and GA, Therefore it can be used as selection program.
4. Plant dry weight, days to 50% flowering, days to maturity, and plant height, these characters attained high (h^2) and can be used in selection programs.
5. Grain yield ton/h and its components were more sensitive to water stress than other morphological characters.
6. Reduction yield ton/ha was mainly due to the reduction in yield/plant and thousand seed weight.
7. . Botana, HSD8849 and HSD7511 showed high geometric mean productivity (GMP). This result can be used in the improvement for drought tolerance in this crop.
8. Grain yield ton/ha had strong positive phenotypic and correlation with some of its components and some of morphological characters.

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Appendices

Appendix (1): Mean squares from the analysis of variance for different characters in (22) Sorghum genotypes evaluated in season 2012

Sources	Stress(S)	Error	genotype(g)	S x g	C.V s	C.V g
D.F	1	2	21	21		
Plant .H (cm)	11917.8^{*}	1308.0	4112.5^{**}	252.9^{ns}	28.75	11.51
Stem D (cm)	170.57^{ns}	4.89	23.22^{**}	17.40^{ns}	28.44	15.29
Number of Leaves	2.37^{ns}	11.29	23.98^{**}	4.45^{ns}	27.45	13.07
Leaf A (cm^{2})	63721.1^{*}	6122.15	36195.05^{**}	3147.58	17.09	20.58
Plant dry weight (g)	2724.55^{*}	264.55	2077.78^{**}	813.05^{**}	24.46	27.8
Days to50% flowering	118.37^{ns}	77.37	785.55^{**}	34.90^{ns}	10.93	6.85
Days to maturity	16.03^{ns}	195.78	780.53^{**}	74.01^{ns}	12.32	8.37
Panicle Length (cm)	284.68^{*}	9.19	90.71^{**}	10.73^{ns}	14.81	23.32
Grain yield/plant (g)	3945.62^{**}	9.78	235.70^{**}	97.57^{**}	15.05	26.84
1000 Seed weight (g)	136.74^{**}	0.00	112.28^{**}	11.38^{ns}	0.27	18.09
Grain yield (Ton/ha)	20.18^{**}	0.05	1.2^{**}	0.50^{**}	15.12	26.81

**: significant at the 0.01 level of probability

* : significant at the 0.05 level of probability

ns : none significant at the 0.05 level of probability

Appendix (2): Mean squares from the analysis of variance for different characters in (22) Sorghum genotypes evaluated in season 2013

Sources	Stress	Error	genotype(g)	S x g	C.V s	C.V g
D.F	1	2	21	21		
Plant .H (cm)	15283.3^{**}	63.1	3647.3^{**}	282.5^{**}	7.54	10.54
Stem D (cm)	96.43^{**}	0.05	12.12^{**}	1.07^{ns}	1.4	10.09
Number of Leaves	8.4^{*}	0.89	11.15^{**}	0.62^{ns}	7.62	9.23
Leaf A (cm^2)	143526^{*}	7752	7240^{**}	1505^{ns}	25.92	16.93
Plant dry weigh (g)t	18284.5^{*}	367.7	2330.2^{**}	687^{**}	28.10	20.95
Days to50% flowering	922.73^{*}	16.37	1000.63^{**}	38.72^{ns}	5.54	7.28
Days to maturity	1361.94^{**}	5.46	520.01^{**}	24.24^{ns}	2.47	4.42
Panicle Length (cm)	294.78^{*}	23.26	85.09^{**}	8.65^{ns}	23.73	12.42
Gain yield/plant (g)	16673.9^{*}	516.1	2347.7^{**}	1078.2^{**}	32.18	28.00
1000 Seed weight (g)	199.78^{*}	5.37	45.55^{**}	10.09^{ns}	9.94	12.59
Grain yield (Ton/ha)	15.17^{*}	0.27	63.25^{**}	0.16^{*}	27.72	19.39

**: significant at the 0.01 level of probability

* : significant at the 0.05 level of probability

ns : none significant at the 0.05 level of probability

Appendix (3): Mean squares from the analysis of variance for different characters in 22 Sorghum genotypes (*Sorghum bicolour*) evaluated in season 2012/2013 Combined

	Season	Stress	stress x season	genotype	genotype x season	genotype x stress	season x genotype x stress	Total
D.F	1	1	2	21	21	21	21	263
Plant height (cm)	21552.93**	13959.27**	1606.40^{ns}	5371.19**	2651.93**	798.23**	4759.29**	1183.83
Stem diameter (cm)	551.89**	5.24^{ns}	130.92*	18.19**	17.16**	9.01**	48.10**	12.36
Number of leaves	0.26^{ns}	1.15^{ns}	0.36^{ns}	16.42**	9.97**	3.67**	18.13**	4.89
Leaf area (cm^2)	195502.99**	11256.97*	24801.08^{ns}	15052.77**	7447.85**	6681.39**	24234.97**	8072.45
Plant dry weight (g)	4639.62^{ns}	2092.22^{ns}	9366.07^{ns}	2185.41**	2982.41**	799.14**	6923.23**	1247.86
Days to50Flowering	3556.67**	812.00*	104.59^{ns}	1459.50**	340.50**	34.84**	423.37**	186.63
Days to 50%maturity	23750.06**	541.23^{ns}	418.37^{ns}	1003.99**	296.55**	42.50**	434.65**	243.31
Panicle Length (cm)	1.27^{ns}	579.39**	0.02^{ns}	171.23**	4.56**	16.61**	23.93**	23.06
1000 Seed weight (g)	53.53*	332.51**	1.44^{ns}	79.87**	77.81**	9.18**	99.41**	24.77
Grain yield/plant	0.96^{ns}	6354.92**	32.95^{ns}	429.53**	44.26**	104.29**	174.75**	114.37
Grain yield (Ton/ha)	0.53*	11.89**	0.16^{ns}	1.04**	0.11**	0.30**	0.48**	0.26

**: significant at the 0.01 level of probability

* : significant at the 0.05 level of probability

ns : none significant at the 0.05 level of probability