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Genotypic Variability and Phenotypic Correlation between Growth and Yield characters of some Sweet Sorghum (*Sorghum bicolor* [L.] Moench) Genotypes

التباين الوراثي و الارتباط المظهري بين الصفات الخضرية و الانتاجية لبعض الطرز الوراثية من الذره الرفيعة السكرية

By

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DEDICATION

To My:

Family,

Teachers

And All Friends.

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ABSTRACT

A field experiment was conducted at the demonstration farm, College of Agricultural Studies, Sudan University of Science and Technology Shambat, in the period from July to November 2014, to invest variability and correlation between yield and yield components in twenty genotypes of sweet sorghum. The experiment was laid out in a randomized complete block design (RCBD) with three replications. Parameters were studied for some growth and yield characters included plant height (cm), stem diameter (mm), number of leaves, leaf area (cm^2), biomass (t\ha), weight of leaves (t\ha), weight of stem (t\ha), weight of heads (t\ha), baggas (t\ha), volume of juice (t\ha) and brix. The phenotypic and genotypic variances, phenotypic and genotypic coefficients of variation and phenotypic correlation for yield and yield components were determined. The analysis of variance revealed significant differences between genotypes for all characters under study. For phenotypic variance the results showed that the highest value (52000) was scored for weight of heads and the lowest value (0.00497) was scored for fresh weight plant, On the other hand, for the genotypic variance the highest value (5045.3) was scored for weight of heads and lowest value (0.00471) was scored for fresh weight. For the phenotypic coefficients of variation, the highest value (75.8) was scored for weight of heads and lowest value (0.20) was scored for biomass, moreover, for the genotypic coefficient of variation the highest value (74.6) was scored for weight of heads and lowest value (0.49) was scored for weight of leaves. The highest value of heritability was obsereved for biomass and the lowest value for weight of leaves. The results showed positive and significant phenotypic correlation between weight of leaves, biomass, baggas and volume of juice, moreover, negative and significant correlation between brix, biomass, weight of

stem and fresh weight. It could be that a variability was detected among the different sweet sorghum genotypes used in this study. Which has strong impact for breeding programs.

المستخلص

اجريت الدراسة بالحقل التجريبي لكلية الدراسات الزراعية جامعة السودان للعلوم و التكنولوجيا خلال موسم 2014في الفتره من يوليو حتى نوفمبر بهدف دراسة التباين والارتباط المظهري و الوراثي بين عشرين صنف من الذره السكرية لبعض الصفات. استخدم في هذه التجربة تصميم القطاعات العشوائية الكاملة بثلاث مكررات. تم تجميع البيانات لعدد من الصفات وهي: طول النبات (سم)، سمك الساق (مم)، عدد الاوراق في النبات، مساحة سطح الورقه (سم^2)، الوزن الرطب للنبات (جم)، الوزن الجاف للنبات (جم)، الوزن الحيوي (طن\هكتار)، وزن الاوراق (طن\هكتار)، وزن الساق (طن\هكتار)، وزن القناديل (طن\هكتار)، البقاس (طن\هكتار)، حجم العصير (طن\هكتار) وتركيز المواد الصلبة في العصير. تم تقدير كل من التباينين المظهري و الوراثي ومعامل التباينين المظهري والوراثي والارتباطات المظهريه لصفات الانتاجية. اظهر تحليل التباين فروقات معنوية عاليه بين الاصناف لكل الصفات تحت الدراسة، كذلك وجد ان اعلى قيمة للتباين المظهري كانت لوزن القناديل(52000) واقل قيمة كانت للوزن الرطب (0.00497) بينما وجد ان اعلى قيمة للتباين الوراثي كانت لوزن القناديل (5045.3) واقل قيمة للوزن الرطب (0.00471). اما بالنسبة لمعامل الاختلاف المظهري وجد ان اعلى قيمة كانت لوزن القناديل (75.8) واقل قيمة كانت للوزن الحيوي (0.20) بينما اعلى قيمة لمعامل الاختلاف الوراثي كانت لوزن القناديل (74.6) واقل قيمة كانت لوزن الاوراق (0.49). دلت النتائج على ان الارتباط المظهري لوزن الاوراق كان موجب وبمعنوية عاليه مع الوزن الحيوي، البقاس وحجم العصير، كذلك الارتباط المظهري لتركيز المواد الصلبة في العصير سالب مع الوزن الحيوي، وزن الساق والوزن الرطب. خلصت الدراسة الى وجود مدى واسع من التباين الوراثي بين السلالات التي استخدمت في هذه الدراسة و التي يمكن استخدامها في برامج التربية

CHAPTER ONE

INTRODUCTION

Sorghum (*Sorghum bicolor* [L.] Moench) is a warm season tropical cereal crop belong to family poaceae, it is self pollinated crop and has a chromosome number of 2n=20 (Poehlman 1987). East of Sudan, Ethiopia and Eretria is considered the reigion of origin of sorghum, land races of sudan has been extensrrely used in sorghum breeding programs worldwide (Ejeta, *et al* 2004) Sorghum is an important food crop in Africa, Central America and South Asia, it is the "fifth-most important cereal crop grown in the world after wheat, maize, rice and barley (Sato *et al*, 2004 and ICRISAT 2009) Sorghum is the staple dietary for more than 500 million people in more than 30 countries (ICRISAT 2009). Global cultivation of sorghum covers an area of 43.73 m ha with annual production of 64 m t (Sasaki and Antonio, 2009). Sorghum 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 (sorghum maintains its physiological activity close to that of plants with sufficient moisture by increasing root length, density, and water use efficiency (Lizarazu,2012). Makes sorghum important sources of food, feed and fuel (Addissu, 2011).

Sweet sorghum belongs to the same species of grain sorghum and forage sorghum, sweet sorghum produces less grain but it contains a large amount of readily fermentable sugars in the stem (Bennett and Anex 2008). The juice extracted from sweet sorghum cane contains high levels of sucrose and inverted sugar that are easily fermented to produce ethanol (Prasad *et al*., 2007). The bagasse produced from sorghum is also used as forage or as raw material for the paper industry (FAO,2009). The juice of sorghum has been used to produce syrup in the USA and alcohol in Brazil and India. It is estimated that, under favorable conditions, sweet sorghum can produce around 43 Mg ha^{-1} per year of juice, which contains 11.8% of fermentable sugars (Kim & Day, 2011). Some varieties have been reported to produce sugar yields similar to those of sugar cane (Ratnavathi *et al*, 2010 and Almodares *et al*, 2008). Additionally, Sweet sorghum is highly efficient in water use, even in areas where there are frequent periods of drought and high temperature . The cultivation costs of sweet Sorghum are also three times lower than those of sugarcane (Reddy et a, 2005), Sweet sorghum is a promising crop for use in the bio-energy industry. Several characteristics of sweet sorghum makes it suitable for bio-energy (e.g A short growth cycle (about four months) that may allow for double cropping, Easy propagation from seed, Potential for fully mechanized production, Dual purpose cropping for both stem sugar and grain starch, High water and nutrient use efficiency, By product (bagase and forage) utilization for energy production and wide adaptability to different environments (Reddy, *et al* 2005). Because it matures and is harvested in a single season , it has better return on a unit land area basis as compared to sugarcane (Grassi, 2001). 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 un doubtedly 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). Sudan as a center origin of sorghum witch of different sorghum genotypes, more than 3000 land race were collected by gene bank in ARC from all region of Sudan in ARC (Ejeta, *et al* 2004). Recently, sweet sorghum witch its essential components`, has become an important research subject in the tropics and sub tropics. Existing of variability among different sorghum genotypes could be of a great value in sweet sorghum breeding programs, therefore the main objectives of this study are:

1. To estimates variability for growth and yield characters of some sweet sorghum genotypes
2. To estimate heritability, genetic coefficient of variation and genetic advance for the different character of sweet sorghum .
3. To determine the correlation between yield and yield components.

CHAPTER TWO

LITERATURE REVIEW

2-1. Historical Background

The origin and early domestication of sorghum in north eastern Africa north of the Eguator and east of 10^{o}E latitude, approximately 5000 years ago (Mann et al, 1983). There are five basic races of sorghum: *bicolor, guinea, caudatum, durra,* and *kafir* (Harlan and de Wet. 1972). A major step in the process of domestication is the loss of the seed shattering characteristic (Mann *et al.,* 1983). Harlan (1975) asserted that domestication of sorghum occurred over time and in several areas where it was probably enabled many times over several years. Early domestication occurred in an area extending from near the Ethiopian border, west through Sudan and up to Lake Chad. There is great diversity in this area as well as the presence of the primitive race *bicolor* (Harlan and de Wet, 1972). Sorghum is plausibly domesticated in north easten sudan (Kasala and its environs) since the 2nd 1st Millennium BC (Beldado and Costantini, 2011).

2-2. Adaptation to Environment

Sweet sorghum has many characteristic such as, wide adaptability, tolerance to a biotic stresses like drought (Tesso et al, 2005), water lodgging, salinity, alkalinity (Almodares et al, 2007 and Almodares et al, 2008), and capacity to grow quickly and also to accumulate sugar in stalks. All these desirable agronomic and biochemical characteristics of sweet sorghum make it an attractive feedstock for fuel-grade ethanol production. With growing concerns for environmental pollution, energy security, and future oil supplies, the global community is seeking non-petroleum-based alternative fuels, along with more advanced energy technologies, and ethanol has the potential to contribute in creating a clean environment (Prasad et al, 2007).

2-3. Sweet Sorghum Uses

Sweet sorghum (Sorgos) is a multi-purpose crop yielding food in the form of grain, fuel in the form of ethanol from its stem juice, and fodder from its leaves and baggass (Nimbkar and Rajvanhi, 2003). Sweet sorghum is an important cereal grown in semiarid and other regions for food and animal feed. Sweet sorghums are also used for biogas and alcohol production because of the accumulation of sucrose in the stems (Rao et al, 1995). Sweet sorghum is a versatile crop that can be used for silage making, alcohol production and a grain crop. It also possesses high photosynthetic efficiency and high biomass yield (FAO, 1994). ``we consider sweet sorghum an ideal (smart crop) because it produces food as well as fuel``, Said William Dar, Director General of the International Crops Research Institute for the Semi-Arid Tropic (ICRISAT, 2009) (Reddy, et al 2006). Among different crops, sweet sorghum (*Sorghum bicolor* L. Moench) is of particular interest because its biomass is used for the production of energy, fiber or paper, as well as for syrup and animal feed. Sweet sorghums are typically characterized by low grain yields, but high biomass production. The stalks contain 10-25% sugars (mainly sucrose, glucose, and fructose) at maturity (Byrt*et al.,* 2011). Sweet sorghum can give a high alcohol output and it is suitable for bioethanol production. The best genotypes are able to produce 6,000 L/ha of bioethanol. This is also supported by the studies of Zhao et al. (2009) where bioethanol output derived from sugars found in the stem of sweet sorghum was as high as 5,414 L/ha. Gnansounou et al. (2005) concluded that sweet sorghum is one of the most favourable plants for bio-ethanol production amongst those currently being investigated and researched for suitability for use at an industrial level. Sweet sorghum is not only suitable for bio ethanol production, but can also be a feedstock for hydrogen. During the fermentation of 1 ton of sweet sorghum stem with n-butyl acetate, 30 m^3 hydrogen, 114 kg butanol and 40 kg acetone are produced (Pantskhava and Pozharnov, 2006). Similar to maize, sweet sorghum is an excellent material to produce biogas. There is a significant potential to use it in biogas plants (Karellas et al, 2010). One ton of sweet sorghum has a biogas output of 600 – 1,000 m^3 (Weiland, 2000). Sweet sorghum can be a suitable crop for bioethanol and biogas production and it offers an alternative in regions where maize production is uneconomic. However, further studies are needed on the subjects of harvesting, storage, cultivation methods and biology to utilize all the potential of this plant. Sugar in a crop of sweet sorghum has the potential to produce up to 8000 litres of ethanol ha-1 or about twice that of maize. Sweet sorghum as a source of ethanol has not been fully developed because it is bulky and heavy and also spoils unless processed immediately after harvest. But, recently increasing amounts of sweet sorghum are being used for ethanol production (Hunter and Anderson, 1997).

2-4. Sweet Sorghum in the Sudan

In the Sudan sweet Sorghum are called `ankolib` Sorghum Ankolib which was recognized by snowden, belongs to the intermediate race, durra-bicolor (Harlan and de wet, 1972). Sweet sorghum grows in areas south of Gadarif, in the Blue Nile area and to less extent in Gezira. It is mainly used for chewing. The crop is adapted to a wide range of soil and soil pH (5-8.5). The suitable temperature for growth is about 28C. 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 a durra-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 sorghums are highly recognized for forage and syrup production in other parts of the world (Dwayne *et al.* 1999). According to Zhu Cuiyun (1998) sweet sorghum is a type of grain sorghum belonging to Graminaceae and its stem is full of sweet juice. In some villages, sweet sorghum is sun-dried after peeling and is used later to sweeten tea or coffee when sugar is not available. The use of sweet sorghum in the Sudan could be extended to producing more usefull products, the raw sugar `jaggary` which is used instead of crystalline sugar in some areas could be produced from sweet sorghum. This will spare time and money taking into consideration the shorter growing period of sweet sorghum compared to that of sugar cane and the simplicity of making jaggary to even at home. Ankolib was less productive than abu Sabin but, being highly mixed land race variety, selection within Ankolib population for high forage yield while retaining its desirable quality attributes (leafiness, juiciness, and sweet stems) would result in identification of lines with better yield and quality than abu Sabin and \or the original stock (Mohammed and Moataz, 2009). The program has also succeeded in developing improved forage types by selection within Ankolib population (Mohammed and Mohamed, 2009). The improved Ankolib type outperformed the parent population and Abu Sab'in with respective yield advantage amounting to 86.7 %, and 25.8%. Its forage yield was comparable to the recommended cultivar Kambal, however, quality wise, it was better than Kambal in protein percentage and leafiness and excelled the check Ankolib in sugar content and digestibility

2-5. Chemical Composition of Sweet Sorghum Juice

There is high sugar content in juice of sweet sorghum stalk. Sucrose, fructose and glucose are the main components of sugar (FAO, 1994). Sucrose is the major disaccharide in the stem of sweet sorghum. sweet sorghum juice contains 2.2-3.57 %phosphorus, 1-1.56 %nitrogen, 6.12-9.86% protein, .05-.06% magnesium, .11-.15 %calcium, .4-.6%potassium and .08-.11 %sodium. That means sweet sorghum juice contains in addition to the carbon source also other nutrients which can support microbial growth (Sirelkhatim, 2003). The stem juice of sweet sorghum is rich of fermentative sugars addition to other kinds of sugar (xylose, ribose, arabinose, sorbose, galactose, mannose and polyglcose) of course the total sugar content is much more than sucrose, glucose and fructose. There are also some ammonia acids and minerals in the juice that make the use of sweet sorghum better with multi-purpose (FAO, 1994).

2-6.Variability in Sorghum

2-6-1. Genotypic Variability

Assessment of the genetic variability within cultivated crops and varieties has a strong impact on plant breeding strategies and conservation of genetic resources (Dean et al 1999 and. Simioniuc et al 2002) is particularly useful in the characterization of individuals, accessions and cultivars in germplasm collections and for the choice of parental genotypes in breeding programs (Davila et al 1998 and Ribaut and Hoisington, 1998). In the past, indirect estimates of similarity based on morphological information have been widely used in many species including sorghum (Ayana and Bekele, 1999). However, morphological variation does not reliably reflect the real genetic variation because of genotype environment interactions and the largely unknown genetic control of poly-genetically inherited morphological and agronomic traits

(Smith and Smith, 1992). The tremendous source of genetic variability in sorghum available in the world collection has made a significant contribution to sorghum improvement in many countries (House, 1995). (Palanisamy *et al.* 1990) reported that, dry matter production of 12 sorghum cultivars, increased from boot stage to the dough ripe and mature stages. (Mummigatti *et al.* 1998) at Dharwad revealed that among the genotypes studied SSV-74 and SSV-96T, which were superior over other genotypes in brix and sugars were better suited for commercial purposes over other genotypes. (Ratnavati *et al.* 2004) evaluated five sweet sorghum genotypes (Keller, SSV 84, BJ 248, Wrey and NSSH 104) for juice quality and ethanol production. Among the genotypes, Keller recorded higher brix value and high ethanol production.

2-6-2. Phenotypic Variability

Phenotypic variability is a great importance for any successful sorghum breeding program. This is because selection of desirable genotype for hybrid industry will not effective unless a considerable amount of variation is exists in the genotypes under study. Phenotypic variability in sorghum is a wide range of number of leaves, emergence and panicle length (Swarup and Chagall, 1962). The phenotypic variability can be measured easily, but it reflects non genetic effects as well as genetic facts are inferred from phenotypic observation (bello et al, 2007). (Palanisamy and Prasad 1984) in Tamil Nadu, observed forty genotypes of sweet sorghum for their plant height. They reported that, the plant height of three genotypes ranged from 108 to 244 cm. (Bapat *et al.* 1988) at Rahuri screened twelve sweet sorghum cultivars and effected crosses among promising genotypes to get good quality syrup. The pH of juice observed was in the range of 4.9 to 5.3 in all the cultivars. Better extraction percentage (37.5) was recorded in SSV-1333 with minimum reducing sugar. They were of the view that a high yielding genotype with desirable attributes could be developed for jaggery making. In sweet sorghum Brandes genotype, the fastest growth was observed between 56 and 70 days of crop growth (Nascimento *et al.*, 1988). (Terauchi *et al.* 1999) reported that, the sweet sorghum . Brandes recorded more leaf area compared to sugarcane cultivars NIF-3 and RK-65-37 at 47 days after germination. An experiment was conducted in Russia with ten improved sweet sorghum varieties by Smilovenko and Poida (1999). They found that, the sweet sorghum var. Sakharnoe-40 recorded higher cane yield of 56.2 t ha-1. The genotype Pudukalakatti-1 produced more dry matter production, higher cane yield (16 t ha-1) and higher leaf area of 22.19 dm^2 plant-1 at 120 days after sowing as compared to Shiggaon genotype in Dharwad under black soil condition (Naganagouda, 2001).

2-7. Penotypic Correlation

Correlation among traits could be utilized to enhance the rate of selection response in the primary traits (Moll and Stuber, 1974). The plant height was positively correlation with number of leaves per plants and leaves to stem ratio (Pooran and Chard, 2000). (Kishan and Seesharam *et al.* 1987) revealed that brix readings were highly correlated with total sugars in the juice (r=0.94, P=0.001). While the sugar percentage in stalk juice and grain yield were not significant. (Patil et al, 1995) reported that significant positive correlation among brix and leaf area at physiological maturity, and green stalk yield. In spite of the sugar in literature on drought tolerance in sweet sorghum during the past decades, clear picture on association between shoot morphological characters and sugar-related traits is yet to be determined. This is mainly because. Most of the studies relied on simple correlation coefficients to analyze relationships. Simple correlations are inadequate to address this complex issue as shoot and sugar yield component traits are neither independent from each other nor among themselves. Therefore one has to consider the correlation between these two sets of variables, simultaneously. Canonical correlation, a well-known multivariate technique, has been established for similar situations, where one would like to measure the relationship between two sets of interrelated variables (Kanbar *et al*., 2009, 2011). The results of redundancy showed that about 67% of the variability in the first linear function of the sugar-related characters is accounted for by the shoot morphological traits under control condition. And this value was reduced up to 52% under drought condition. The correlation studies indicated that brix was positively correlated with sucrose and reducing sugars, while juice purity was positively correlated with sucrose content. Among the sweet sorghum varieties studied cv. SSV-108, SSV-74, SSV-53, SSV-1333, SSV-96 and SSV-7073 were found to have superior juice quality (Jadhav *et al*., 1994).

CHAPTER THREE

MATERIALS AND METHODS

3.1. Field experiment Location, Design and layout

The experiment was 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) in the period from july to December 2014. The experiment was laid out in a randomized complete block design (RCBD) with three replications. The experiment land was disc ploughed, disc harrowed, leveled and ridged up north-south, 70cm apart. The land was divided into 2 x $3.5m^2$ plot, each composed of 4 ridges two meters long, seeds were sown on 27 July 2014. Hand weeding was done when needed, irrigation schedules was7-15 days, nitrogen fertilizer added after two week from germination.

3.2. Plant materials used in the study

The genetic material used in this study was consisted of twenty genotypes of sweet sorghum, which were collected from different part of Sudan as show in table 3.1.

3.3. Data collection

The following characters were taken from five randomly selected plants in the plot.

3.3.1 Growth characters

3.3.1.1 Plant height P.H (cm)

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

Table 3.1 List of sweet sorghum genotypes used in the study:

Entry No.	Genotypes	Origin
1	W. N-M-1	White Nile. Sudan
2	W. N-M-3	White Nile. Sudan
3	Genotype-3	White Nile. Sudan
4	Genotype-4	White Nile. Sudan
5	Genotype-5	White Nile. Sudan
6	W. N-M-2	White Nile. Sudan
7	Genotype-7	South Al Gadarif
8	Genotype-8	Elhawata
9	Elhawata-1	Elhawata
10	Genotype-10	Kosti
11	Genotype-11	Elhosh
12	Elsouky-1	Elsouky
13	Elsouky-2	Elsouky
14	Elobied-1	Elobied
15	Elobied-2	Elobied
16	Genotype-16	El Fao
17	Genotype-17	Sennar
18	Elshouk-1	Elshouk
19	Elshouk-2	Elahouk
20	Genotype-20	El Gadarif.

3.3.1.2 Stem diameter (mm)

Measured by taking the average thikness of the stem at the fourth counting node from the base of the plant using vernier apparatus.

3.3.1.3 Number of leaves/plant

They were counted after maturity.

3.3.1.4 Leaf area (cm^2)

It was calculated according to the following formula as described by (sticker et al 1961).

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

3.3.1.5 Fresh weight per plant (g)

Five plant cut in each plot was weighed using spring balance immediately in the field.

3.3.1.6. dry weight per plant (g)

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

3.3.2 Yield Characters

3.3.2.1. Weight of Biomass (t\ha)

Harvest one meter long in each plot was weighed using spring balance immediately in the field, the plants harvested cut above the soil surface 20 cm.

3.3.2.2. Weight of stem or Stover (t\ha)

Determined by weighed stems in each plot after remove the leaves and the heads.

3.3.2.3 Weight of leaves (t\ha)

Weighted the leaves without stem and heads.

3.3.2.4 Weight of heads (t\ha)

Weighted the head without stem and leave.

3.3.2.5. Weight of baggas(t\ha)

Weighted the stem after extracted the juice.

3.3.2.6. Volume of Juice (t\ha)

Calculated by the volume of juice produced by one kg of cane.

3.3.2.7. Brix (%)

The brix value was recorded from the entire volume of juice using a hand refractometer.

3.4 Data Statistical Analysis

The collected data for growth and yield character were subjected to analysis of variances were for a randomized complete block design (RCBD) by using statistic-8 computer package.

3.4.1Coefficient of Variation (C. V)

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

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

Where:

MSE = mean square of Error, G= Grand mean

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

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

$\sigma^2 e$= error or environments

M_1, $M2_=$ error and genotype mean squares

3.4.3. Heritability estimate (h^2):

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

From the separated ANOVA:

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

$\sigma^2 g$ = genotype variance , $\sigma^2 ph$ = phenotypic variance

3.4.4. Phenotypic and genotypic coefficient of variation:

They were according to formula suggested by Burton and Dewane (1952).

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

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

3.4.5. Phenotypic Correlation:

It was used to estimate phenotypic covariance .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) = $\sigma^2 phxy \backslash \sqrt{(\sigma^2 ph\ x)(\sigma^2 phy)}$

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.

Table 3.2. The analysis of variance of randomized complete block design with three replication used in this study

Source of variation	Degree of fredom	Mean square
Replication	(r-1)=2	M3
Treatment	(t-1)=19	M2
Error	(r-1) (t-1)=38	M1
Total	(rt-1)=59	

CHAPTER FOUR

RESULTS

4.1 Growth characters

4.1.1 Plant height PH (cm)

The analysis of variance showed that there was significant differences at (P≤ 0.01) among genotypes for plant height (Table, 4.1). The highest value (164.87cm) was given by the genotype-3 and lowest value (109.27 cm) was obtained by the genotype-5. The overall mean for this character was 144.13 and the coefficient of variation (CV) was 9.68 (Table, 4.2).

4.1.2 Stem diameter SD (mm)

The analysis of variance indicated that the mean of stem diameter was significant differences at (P≤0.01) among genotypes (Table, 4.1). The highest value (17.60 mm) was obtained by Elshouk-2 and lowest value (9.44 mm) was given by the genotype-5. The overall mean for this character was 14.04 and the coefficient of variation (CV) was 11.89 (table, 4.2).

4.1.3 Number of leaves /plant NL

The results showed that significant differences at (P≤0.05) among genotypes for number of leaves (Table, 4.1). The highest value of number of leaves per plant (12.00) was given by the genotype-10 and the lowest value (9.00) was obtained by the genotype-5 and Elshouk-1. The overall mean for this character was 10.50 and the coefficient of variation (CV) was 10.97 (table, 4.2).

Table 4. 1: Mean squares for different characters of twenty sweet sorghum genotypes evaluated during this study

Sourse of variation	Replication df=2	Genotype df=19	Error df=38
Plant height	2319.5	475**	194.78
Stem diameter	7.78	9.67**	3.16
Number of leaves	5.1167	2.347*	1.292
Leaf area	826.83	3719.27**	427.38
Fresh weight	0.00026	0.01422**	0.0008
Dry weight	0.0531	58.850**	0.0324
Biomass	23042	497568**	24094
Stover	2375	150743**	3822
Weight of Leaves	26167	1630**	23447
Weight of Heads	1541.7	15217.1**	796.1
Baggas weight	2651.7	40611.5**	602.5
Volume of juice	393.1	15166**	692
Brix %	0.7041	9.4737**	0.235

**= highly significant at $P \leq 0.01$ level

*=significant

Table 4. 2: Means of different characters of twenty genotypes of sweet sorghum evaluated during this study

Geno	PH	SD	NL	L. area	f.wieght	d.wieght	Biomass	w.leaves	w.stem	wheads	baggas	brix	Juice
1	147.33	15.20	10.00	173.73	186.7	89.00	27.5	14.00	8.8	3.3	4.20	17.0	2.26
2	149.67	16.07	10.00	196.00	246.7	137.0	27.8	14.00	11.0	3.3	5.66	16.3	3.96
3	164.87	15.70	10.00	154.00	206.7	143.0	24.5	17.66	13.5	3.1	6.33	15.0	2.36
4	151.60	15.15	11.00	187.00	250.0	127.0	29.6	13.66	6.5	2.1	3.26	16.3	2.18
5	109.27	09.44	09.00	211.67	88.70	55.00	25.3	12.66	4.3	4.3	2.00	17.0	1.96
6	147.00	14.32	11.00	281.27	173.3	110.0	26.3	17.66	6.3	3.6	3.33	13.6	1.66
7	157.53	13.90	09.67	215.10	140.0	73.00	22.3	12.66	6.8	2.5	3.66	14.6	2.60
8	141.87	16.57	10.33	201.30	256.7	140.0	16.6	10.33	4.6	1.1	2.93	19.6	1.61
9	133.07	16.13	11.00	137.87	193.3	110.0	26.8	16.66	7.3	3.2	2.90	16.3	2.45
10	148.23	16.00	12.33	204.67	196.7	113.0	33.5	17.00	9.6	3.5	5.66	17.1	3.56
11	136.87	14.63	11.00	197.03	203.3	133.0	24.0	14.33	6.3	3.3	3.66	15.3	3.58
12	129.33	14.60	09.67	193.27	126.7	96.00	26.6	13.50	7.3	3.0	3.66	12.1	1.84
13	152.27	12.77	09.67	133.10	240.0	100.0	24.1	12.33	9.0	2.1	4.50	16.6	2.59
14	147.67	12.30	10.33	145.67	256.7	133.0	24.8	13.33	7.5	3.6	3.66	16.3	2.99
15	135.63	15.10	10.33	151.30	133.3	44.00	19.6	11.33	7.1	2.6	2.03	15.5	1.21
16	138.00	15.73	12.00	190.90	240.0	133.0	18.6	11.33	5.3	2.1	2.93	17.0	2.35
17	142.53	15.90	09.33	146.03	196.7	110.0	24.8	13.83	7.1	3.8	3.60	18.6	2.06
18	157.20	15.86	09.00	160.17	230.0	130.0	18.3	17.00	6.6	2.6	4.03	18.3	2.48
19	158.20	17.60	11.33	212.80	423.3	223.0	23.1	13.83	9.3	3.1	4.83	16.5	2.21
20	134.00	15.93	10.33	192.87	203.3	110.0	21.3	10.00	8.6	2.1	2.66	13.6	1.58
C.V %	9.68	11.89	10.97	11.22	4.22	11.99	6.39	11.09	7.90	9.38	6.50	3.00	11.07
Mean	144.13	14.94	10.50	184.05	204.6	115.4	24.3	13.80	7.8	2.9	3.75	16.1	2.27
L.S.D	23.07	2.93	1.87	34.17	14.6	29.76	2.56	2.5	1.01	0.46	0.40	0.80	43.47

4.1.4 Leaf area (cm^2)

The results indicate significant differences at (P≤o.o1) among genotypes (table, 4.1). The highest value (281.3) was obtained by W.N.M-2 genotype and the lowest value (133.10) was obtained by Elsouky-2. The overall mean for this character was 184.05 and the coefficient of variation (CV) was 11.22 (Table, 4.2).

4.1.5. Plant fresh weight(g)

The analysis of variance indicated that the mean of fresh weight was significant differences at (P≤0.01) among genotypes (Table, 4.1).The highest value (423.3) was obtained by El shouk-2 genotype, lowest value (88.7) was given by the genotype-5. The overall mean for this character was 204.6 and the coefficient of variation (CV) was 4.22 (Table, 4.2).

4.1.6. Plant dry weight (g)

The result showed that significant differences among genotypes at (P≤0.01). The highest value was (223) given by Elshouk-2, lowest value was (44) obtained by Elobied-2. The overall mean of this character was 115.4 and the coefficient of variation (CV) was 11.99 (Table, 4.2).

4.2 Yield characters

4.2.1. Weight of biomass (t\ha)

The results showed that significant differences at (P≤0.01) among genotypes (Table, 4.1). The highest value (33.5 t\ha) was given by the genotype-10, lowest value (16.6 t\ha) was obtained by the genotype-8.The overall mean for this character was 24.3and the coefficient of variation (CV) was 6.39 (Table, 4.2).

4.2.2. Weight of stem (t\ha)

The result showed that significant differences at (P≤0.01) among genotypes (Table, 4.1). The highest value (13.5 t\ha) was given by the genotype-3, lowest value (4.3 t\ha) was obtained by the genotype-5 .The overall mean for this character was 7.8 and the coefficient of variation (CV) was 7.90 (Table, 4.2).

4.2.3. Weight of leaves (t\ha)

The result showed significant differences at (P≤0.01) among genotypes (Table, 4.1).The highest value (17.66 t\ha) was obtained by the genotype-3, lowest value (10.00 t\ha) was given by Elshouk-2. The overall mean for this character 13.80 and the coefficient of variation (CV) was 11.09 (Table, 4.2).

4.2.4 .Weight of heads (t\ha)

The analysis of variance revealed significant differences at (P≤0.01) among genotypes (Table, 4.1). The highest value (4.3t\ha) was obtained by the genotype-5 and lowest value (1.1 t\ha) was obtained by the genotype-8. The overall mean for this character was 2.9, and the coefficient of variation (CV) was 9.38 (Table, 4.2).

4.2.5. Weight of baggase (t\ha)

The analysis of variance indicated that significant differences at (P≤0.01) among genotypes (Table, 4.1). The highest value (6.3 t\ha) was obtained by the genotype-3 and lowest value (2.0 t\ha) was given by the genotype-5.The overall mean for this character was 3.75 and the coefficient of variation (CV) was 6.50 (Table, 4.2).

4.2.6. Volume of Juice (t\ha)

The analysis of variance indicated that the mean of juice was significant differences at ($P \leq 0.01$) among genotypes (Table, 4.1). The highest value (3.96 t\ha) was obtained by W.N. M-3 genotype and lowest value (1.21 t\ha) was given by Elobied-2 genotype. The overall mean for this character was2.27and the coefficient of variation (CV) was 11.07 (Table, 4.2).

4.2.7. Brix %

The results showed that significant differences at ($P \leq 0.01$) among genotypes (Table, 4.1). The highest value (19.6) was given by the genotype-8 and lowest value (12.1) was obtained by Elsouky-2. The overall mean for this character was 9.47 and the coefficient of variation (CV) was 3.00 (Table, 4.2).16.1

4.3 Genotypic (∂^2g) Phenotypic (∂^2 ph), variances and Heritability (h^2)

The results of this study revealed the highest genotypic variance (50458.30) was regarded by weight of heads and the lowest estimatesof genotypic variance (0.00471) was given by fresh weight. On the other hand, the highest estimate of phenotypic variance (51348.66) was regarded by weight of stem and the lowest one (0.00497) was obtained by weight of heads. The highest estimate of heritability (6.80) was obtained by biomass and lowest value was (0.002) obtained by weight of leaves (Table, 4.3).

4.4 Genotypic (GCV) Phenotypic (PCV), coefficients of variation

Estimates of genotypic coefficient of variation (GCV) of dry weight regarded highest value was (284), weight of leaves showed lowest value was (0.49). The (PCV) estimate highest value by dry weight it was (285), lowest value obtained by biomass it was 0.20.(Table 4.4).

Table 4. 3: Phenotypic (σ^2g) and genotypic (σ^2ph) variances and Heritability (h^2)

Character	**(σ^2g)**	**(σ^2ph)**	**(h^2 b)**
Plant height (cm)	93.4	288.19	0.324
Stem dimeter (mm)	2.16	5.320	0.406
Number of leaves	0.35	1.640	0.213
Leaf area (cm^2)	15.91	442.91	0.036
Fresh weight (g)	0.00471	0.0050	0.948
Dry weight (g)	18.272	18.325	0.997
Biomass (t\ha)	157.8	23.199	6.800
Weight of leaves (t\ha)	46.52	26214	0.002
Weight of stover (t\ha)	48973.66	51349	0.950
Weight of heads (t\ha)	50458.3	52000	0.970
Baggas (t\ha)	13336.3	15988	0.834
Volume of juice (t/ha)	4824.7	5218	0.924
Brix	3.07	3.774	0.813

Table 4. 4: Phenotypic (PCV) and genotypic (GCV) coefficients of variation

Source of variation	**GCV %**	**PCV %**
Plant height	6.5	12
Stem diameter	9.8	15
Number of leaves	5.7	12
Leaf area	21.6	11.4
Fresh weight	32.7	33.6
Dry weight	284	285
Biomass	0.52	0.20
Weight of stem	28.2	28.9
Weight of leaves	0.49	11.7
Weight of heads	74.6	75.8
Baggas	30.5	33.4
Volume of juice	29.2	30.4
Brix	12	12

GCV=Genotypic coefficient of variation.

PCV=Phenotypic coefficient of variation.

4.5 Phenotypic correlation for yield characters

The results of phenotypic correlation among different character in this study were presented in table 4.5. Fresh weight per plant was positive and non significant correlation with dry weight, weight of stem, and volume of juice. where as it was positive highly significant correlation with baggas and brix . On other hand, negative and non significant correlation with biomass, weight of heads and weight of leaves. Dry weight was positive highly significant correlation with weight of stem, baggas, weight of heads and volume of juice. On other hand positive non significant correlation with biomass and weight of leaves. Where as it was negative non significant correlation with brix. Biomass was positive highly significant correlation with weight of leaves, stover, weight of heads, volume of juice and baggas, But it was negative significant correlation with brix. Weight of leaves was positive highly significant correlation with stover, weight of heads, baggas and volume of juice, stover positive non significant with weight of heads, and fresh weight, moreover negative highly significant correlation with brix. Weight of heads was positive significant with volume of juice, moreover negative non significant correlation with brix. Baggas was positive highly significant correlation with volume of juice, where as, it was positive non significant with brix.

Table 4. 5: Phenotypic Correlation for Yield Characters

	fresh.w	Dry.w	biomass	w.leaves	w. stem	w.heads	baggas	brix
Dry.w	0.090							
Biomass	-0.111	0.144						
w.leaves	-0.004	0.203	0.477**					
W.stem	0.168	0.661**	0.390**	0.315*				
w.heads	-0.206	0.217*	0.502**	0.386**	0.166			
Baggas	0.385**	0.647**	0.393**	0.429**	0.766**	0.200		
Juice	0.197	0.355**	0.414**	0.252*	0.286*	0.322*	0.322**	0.121**
Brix	0.317*	-0.093	-0.217*	-0.069	-0.352**	-0.058	0.015	

**= highly significant at P≤ 0.01 level

*=significant

Ns= non significant

CHAPTER FIVE

DISCUSSION

5.1.Phenotypic variability

In this study, the analysis of variance revealed significant differences among the twenty genotypes of sweet sorghum for all studies character. This variation could be attributed to genetic factor, these result are in accordance with (Idris and Mohammed, 2012 and idris 2006).

5.1.1.Plant height (cm)

The result showed that plant height varied from 164.9 cm to 109.3 cm. Palanisamy and Prasad (1984) in Tamil Nadu, observed forty genotypes of sweet sorghum for their plant height. They reported that the plant height of three genotypes ranged from 108 to 244 cm. Putnam *et al.* (1991) recorded the tallest plant with a height of 302 cm recorded in X-405 sweet sorghum genotype at University of Minesota Southern Experiment station in Waseca. These differences could be due genetic factor or the different environment condition .

5.1.2.Stem diameter (mm)

The result indicated that, the stem diameter varied from (9.44 to 17.60mm). These result are agree with Ganesh *et al.* (1995) registered higher stem diameter (17.3 mm) in AKSS-5 genotype. Sudewad (1976) reported that wide range of variability was observed in stem diameter (1.2 to 3.7 cm) of different sweet sorghum genotypes.

5.1.3.Number of leaves\plant

The result showed that number of leave varied from 9 to 12 leaves plant. Mehra *et al*. (1970) opined that average number of leaves plant varied from 5 to 25 among 526 genetic stocks, while Sudewad (1976) found that it varied from 6 to 12, in a few genotypes, these differences could be to genatic factor, environment or the enter action between environment and genotype.

5.1.4.Leaf area (cm^2)

The result showed that leaves area varied from ($281cm^2$ to 133 cm^2),these result dis agree with obtained by Meli (1989) The experiment conducted at Dharwad in medium black soil among ten sweet sorghum genotypes and Those recorded leaf area varied from (38.48 dm^2 to27.58 dm^2). these differences could be to genetic factor, environment condition or type of soil.

5.1.6.Biomass (t/ha)

The green biomass yield differed among the genotypes, high value was (33.5 t\ha) and lowest value was (16.6 t\ha) . The differences in biomass in vary genotypes were also reported by Agnal *et al.* (1997).

5.1.7.Weight of stem (t/ha)

The result showed that, weight of stem varied from 13.5 to 4.3 t\ha. Rutto et al (2013) evaluate five sweet sorghum cultivars. They found the fresh stem weight ranged from 21 to 54 t\ha. This variation could be to genetic factor or the environment.

5.1.8.Weight of leaves (t/ha)

The result showed that weight of leaves varied from 10 to 17.6.

Sweet sorghum genotype Keller produced 43 tonnes of stem and leaves per acre and yielded 633 gallons of ethanol per acre (Hills *et al.*, 1981).

5.1.9.Weight of heads (t/ha)

The result showed that weight of heads varied from 1.6 to 4.3 t\ha. Rauppu *et al*. (1980) at Pelotas (Brazil) revealed that, sweet sorghum plants produced the panicle yield of 8.8 ton per ha. This differences could be to genetic factor, environmental condition, interaction between genotype and environment or type of soil.

5.1.10.Baggas (t/ha)

The baggas yield was significant differences among genotypes, the highest value was(6.3 t\ha) and lowest value was (2.00 t\ha), Such differences in baggas yield with varying genotypes were also reported by Agnal *et al.* (1997) and Raju (2003).

5.1.11.Volume of juice (t/ha)

The results showed that, the volume of juice varied from (3.96 l\ha to1.20 l\ha), while batoul (2009) in the study to evaluate eight introduce sweet sorghum genotypes obtained the stalk yield varied from 22.7 t\ha to 15.7 t\ha. This differences could be to genetic factor .

5.1.12.Brix

The result showed that highly value of brix was 19.6 and the lowest value was 12. The varying value of brix were also reported in different genotypes by Channa Naik and Jayakumar (1994) and Ratnavathi *et al.* (2004), (FAO1994) indicate value of brix varied from 15 to 20. These differences could be to genetic factor.

5.2.Genetic Coefficient of Variation and Hertability

A wide range of genetic variability among the evaluated genotypes was detected for the studied characters. The highest estimate of GCV was shown by weight of heads and the lowest one was shown by weight of leaves (74.6-.49%). Similar results , under different environments were reported by Yadav *et al* .(1997) and Harer and Karad (1999) in pearl millet .

Regarding heritability estimates , wide range variability in the values was detected for most of the characters. Fadlalla (1994) , in bread wheat. The highest estimates of heritability ($0.60 \leq p$) was shown by fresh weight, dry weight, biomass, baggas, brix, volume of juice and sugar content. Whereas, most of the morphological characters had low moderate estimates ($P \leq 0.60$). These results agree with those obtained by some investigators in some crops, e.g Falconer (1980) and Fadlalla (1994) .

5.3.Phenotypic correlation for yield components

The juice volume positive significant correlation with biomass, weight of leave, weight of stem and bagass. This result was agree with Rutto *et al* (2013) and Makanda *et al*, (2009). The brix was positive non significant correlation with the juice. This result dis agree with (Patil *et al*, 1993) reported that significant positive correlation among brix and leaf area at physiological maturity, and green stalk yield. This differences could be to genetic factor or the environment.

CHAPTER SIX

CONCLUSION

Based on the results observed from this study, it could be concluded as the followings

1-High phenotypic and genotypic variability was observed between the twenty sweet sorghum genotypes, this variability could be of a great value in any sweet sorghum breeding programs.

2-the highest value of heritability was observed from dry weight. This character could be of a great benefit in selection of sweet sorghum genotypes characterized high dry weight.

3-the positive and significant phenotypic correlation between weight of leaves, biomass, bagass and volume of juice observed in this study revealed that any of these characters can be used as indicator from the other character in any sorghum breeding program.

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