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Performance of Some Sunflower (*Helianthus annuus* L.) Hybrids Under Rain Fed and Irrigated Systems in Sudan

أداء بعض هجن زهرة الشمس تحت النظم المطرية والمروية في السودان

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DEDICATION

To my family and friends

With respect

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ABSTRACT

Two experiments were carried out at two locations (Ellkandi and Essuki area) for two consecutive seasons 2013 and 2014, to estimate the genetic variability among 15 sunflower hybrids, characters correlations with seed yield (t/ha) and to determine the genotype x environment interaction as well as to evaluate the stability of performance for the hybrids at the four environments. A randomized complete block design with four replications was used at each environment and data on 11 characters including yield and its components in addition to oil yield was collected in all investigated environments. At both locations and in both seasons significant differences were detected for days to 50% flowering, days to physiological maturity, plant height (cm), stem diameter (cm) and head diameter (cm), while highly significant differences were detected for number of seeds per head, empty seeds percentage, 1000-seed weight (g), seed yield per plant (g), seed yield (t/ha) and oil yield (t/ha) suggesting a wide range of genetic variability. The combined analysis of variance was carried out only for those characters with homogeneous error variance viz: head diameter (cm), number of seeds per head, empty seeds percentage, 1000-seed weight (g), seed yield per plant (g) seed yield (t/ha) and oil yield (t/ha). The genotype x season and genotype x location interactions were only significant for seed yield (t/ha) and oil yield (t/ha). The overall ranking of the 15 sunflower hybrids for seed and oil yields (t/ha) according to the stability parameters (average mean (μ), regression coefficient (bi) and deviation from regression (S^2di) showed that Pan-7057 was the most top hybrid followed by Ausigold61, Ausigold7, SFH301, Hysun-33, Pan7033, Aguara-4 and SFH304,whereasPan-7351was the last ranked hybrid. Five hybrids viz: Pan-7057, Ausigold61, Ausigold7, SFH301 andHysun-33 were stable for seed and oil yields (t/ha) under favorable environments. However Pan-7033, Aguara-4 and SFH304 were stable hybrids under unfavorable environments.

خلاصة الأطروحة

نفذت هذه التجربة في موقعين, اللكندي والسوكي بولاية سنار ولمدة موسمين (2013 و 2014م) وذلك بغرض تقدير التباين الوراثي وارتباط الصفات لعدد 15 هجين من زهرة الشمس وكذلك لتقدير اثر التداخل الوراثي البيئي لهذه الهجن و لتقييم درجة ثبات الإنتاجية للهجين ومكوناتها وأقلمتها في الأربعة بيئات. تم استخدام التصميم العشوائي كامل القطاعات بعدد أربعة مكررات لكل بيئة, وقد جمعت البيانات لعدد 11 صفة من بينها الإنتاجية (طن/ه) ومكوناتها وإنتاجية الزيت (طن/ه). في كل البيئات أظهرت نتائج التحليل الفردي وجود فروقات معنوية بين الهجن لعدد الأيام حتى 50% أزهار, عدد الأيام حتى النضج الفسيولوجي ,طول النبات (سم),قطر الساق (سم) وقطر القرص (سم) .,بينما كانت الفروقات عالية المعنوية لعدد البذور في القرص, نسبة البذور الفارغة (%), وزن ال 1000- حبة (جم), إنتاجية النبات الواحد (جم), إنتاجية الهكتار (طن/ه) وإنتاجية الزيت (طن/ه). التحليل التجمعي لعدد 7 صفات هي قطر القرص (سم), عدد البذور للقرص, نسبة البذور الفارغة (%), وزن ال 1000- حبة (جم), إنتاجية البذور للنبات (جم), إنتاجية البذور (طن/ه) وإنتاجية الزيت (طن/ه) اظهر فروقات معنوية بين الهجن ولكنه اظهر فروقات معنوية فقط لإنتاجية البذور (طن/ه) وإنتاجية الزية الزيت (طن/ه) للتفاعل بين الهجن والمواسم وبين الهجن و المواقع. كما اظهر التحليل أن معظم التباين يعزي للتباين التي لا يمكن التنبؤ به عنه للتباين الذي يمكن التنبؤ به. الترتيب العام للإنتاجية ومكوناتها للخمسة عشر هجين وفقاً لمعاملات درجة الثبات :متوسط الإنتاجية (µ), معامل الانحدار(bi) و الانحراف عن خط الانحدار(S^2di) أوضحت أن الهجين Pan-7057 قد احتل المرتبة الأولى بين الهجن يليهAusigold61 ثم Ausigold7 ثم SFH301 ثم Hysun-33 بينما الهجين Pan-7351 احتل المرتبة الأخيرة. اظهر الهجن Pan-7057, Ausigold61, Ausigold7_, SFH301 وHysun-33 درجة ثبات للإنتاجية ومكوناتها تحت الظروف البيئية الملائمة , بينما أظهرت الهجن Pan-7033, Aguara-4 والهجين SFH 304 درجة ثبات للإنتاجية ومكوناتها تحت الظروف الغير ملائمة.

CHAPTER ONE

INTRODUCTION

Sunflower *(Helianthus annuus L.)* belongs to family compositeae which comprises of diploid (2n= 2x=34), tetraploid (2n=3x=68) and hexaploid species (2n=2x=120). Sunflower has a high potential for grain yield and oil accumulation in the seed. Grain yield of about 1500 Kg/ha has been reported in the literature for both open-pollinated and hybrid cultivars (Arshard *et al*, 2007). Sunflower is one of the four most important oil crops globally(FAO, 2010). Sunflower producing countries are Argentina, Russia, France, Ukraine, Spain, India, USA, China, Turkey, Romania and Hungarian (FAO, 2010). The total sowing area, production and yield in 2012/ 2013 and 2013/ 2014 were 23,839,000 and 24,626,000 ha producing 36,062,000 Tons and 42,867,000 tons respectively (FAS, 2014). Although sunflower is a temperate zone crop, it can perform well under a wide spectrum of climatic and soil conditions (FAO, 2010). In the Sudan the crop is grown both as summer and winter crop under irrigated systems and as summer crop under rain-fed system. The area under sunflower cultivation had shown an increasing manner in the last ten years. The rabidly increased areas is a consequence of farmers and private sector's interest, genetic improvement, wide adaptability and suitability to mechanization, low labor needs, short growth duration, higher yield potential as well as its good quality (Mohamed,2009). In the Sudan, the climatic conditions and soil requirements of sunflower, generally, indicate that the central clay plain is potentially suitable for sunflower growing. This includes Blue Nile, White Nile, Gadarif, South Kordofan, and South Darfour States which are suitable areas for rain fed cultivation, whereas Gezira, Sinnar, Rahad and Suki are regions potentially favorable for sunflower cultivation with supplementary irrigation Skoric, (1982). Sunflower was first introduced in to the Sudan in1932 by Gezera Research Station; it tried as summer crop in1951 but failed due its low fertilization (Khidir, 1997). The extensive commercial production was initiated in the Sudan in the late 1980'S and the early 1990's with the introduction of hybrids such as Hysun-33 from Australia and Pan-7351 from South Africa (El Ahmadi, 2003and Nour *et al*, 2005). A variety testing program was initiated by Agricultural Research Corporation (ARC) in 1989 and resulted in the release of two open-pollinated cultivars, Rodeo and Bolareo that were renamed Damzin-1 and Damazi-2. In addition three hybrids; Hysun-33, Jwamakhi and Pan-7392 have been released by Arab Sudanese Seed Company (ASSCO) and (ARC) (El Ahmedi, 2003 and Nour, 2003), and two hybrids (Salih and Shambat from university of Khartoum (H, 2004). However in the last three years there was a release of local and introduced hybrids such as; Bohooth-1, Bohooth-2 and Bohooth-3 (2009), Pan-7049, Pan-7033 and Aguara-4 (2011), Opera and Sirena (2012), Nugold Dowana and Nugold Darya (2013). Problems facing sunflower production in Sudan could be summarized as follows:

1. Lack of high yielding hybrids or improved varieties for different agro-ecological zones.
2. Inadequate adoption of improved agronomic practices.
3. Fluctuation in cultivated areas and production constraints as a result of poor organization setup for production and absence of clear plans.
4. Poor financing and credit availability.
5. High cost of introduced hybrids and problems of importations.
6. Frequent dry spells and mal-distribution and fluctuations of rains.
7. Unstable policies concerning importing facilities, funding processing and marketing.
8. The local hybrid seed production needs some times to be adopted and utilized.

9. Most of the international seed companies stopped their business in Sudan due to instability or lack of sustainability in production of sunflower and absence of incentives and attractiveness to investors.
10. Poor linkages between stakeholders and seed producing sectors.

According to Becker and Leon (1988), successful new hybrids must show good performance for yield and other essential agronomic traits, and then superiority should be reliable over a wide range of environmental conditions. Therefore the objectives of this study were to:

1. Estimate genetic variability among fifteen hybrids.
2. Determine genotype x environment interaction, as well as to evaluate the stability of performance for the hybrids at the four environments.
3. Study the correlations between different characters of fifteen hybrids, as well as to estimate the best selection criteria of most adapted hybrid (s) for both sites (rain fed and irrigated) under Sinnar ecological conditions.

CHAPTER TWO

LITERATURE REVIEW

2.1 General:

Sunflower (*Helianthus annuus L.*) is native to North America and grows nearly, in all parts of the United State of America (Miller, 1987). Fifty species have been identified in North America and fifteen identified in South America (Heiser, 1951). The cultivated species (*Helianthus annuus* L.) has a diploid chromosome number. The sunflower ability of its flower to turn towards where the sun is, accounts for both its common name and botanical name, Greek Helios = sun and anthos = flower (Miller, 1987). In the thirties of the 20^{th} century, sunflower ranked the tenth among the world sources of vegetable oil, then the fourth in the fifties of the century. However today it ranks the third after soybean and rapeseed (Khidir, 1997). Abdalla and Abdelnour, (2001) reported that, sunflower ranked fourth in the world oil crops after palm oil, rapeseed and soybean. The possible variation in cultivated sunflowers, independent of oil content is not well known, but this topic may become of paramount importance (Dauget, 2016).

The first commercial production of sunflower as an oil crop was started in Canada in 1934 and U.S.A. in 1947 and the former U.S.S.R was the world leading producer in the 1960's (Metakalfe and Elkin, 1980). The first hybrid produced and made available for the commercial production in the United States of America in 1972 and by 1976, hybrids were grown on over 80% of the sunflower production area (Miller and Guya, 1984).

2.2 Economic importance:

Sunflower , which is a rich source of good quality edible oil and has a nice fit in our cropping pattern, is visualized as the most potential crop to narrow the gap between the total requirement and the domestic production of edible oil in the country. This could help in saving the huge amount of foreign exchange that is being incurred on importing edible oil annually (FAO, 2010). Sunflower oil has excellent nutritional properties, and sunflower seeds contains high oil content ranging from 35-48% with some types yielding up to 50% and 20-27% protein and high percentage of polyunsaturated fatty acids (60%) including oleic acid (16.0%) and linoleic acid (72.5%), which control cholesterol in blood Amirian *et al*, (2013).Commercially available sunflower varieties contain from 39 to 49% oil in the seed. The oil accounts to80% of the value of sunflower crop. Sunflower oil is generally a premium oil because of its light color, high level of unsaturated fatty acids and lack of linolenic acid, bland flavor and high smoke points. The primary fatty acids in the oil are oleic and linolenic (typically 90% unsaturated fatty acids), with reminder consisting of palmatic and stearic saturated fatty acids. The primary use is as salad and cooking oil or in margarine. In many sunflowers producing countries sunflower oil is the preferred and the most used oil Miller, (1987). Non-dehulled or partly dehulled sunflower meal has substituted successfully for soybean meal in iso-nitrogenous (equal protein) diets for ruminant animals, as well as for swine and poultry feeding. Sunflower meal is higher in fiber, has a lower energy value and is lower in lysine but, higher in methionine than soybean meal. Protein percentage of sunflower meal ranges from 28% for non-dehulled seeds to 42% for completely dehulled seeds. The color of the meal ranges from grey to black, depending upon extraction processes and degree of dehulling Skoric (1982). Hulled sunflower would be good alternative protein source to replace imported soybean in Europe and hulls are now an economic fuel (Dauget *et al*., 2015). However the question of hull ability as necessary breeding objective has not yet been answered (Dauget *et al*., 2015). Sunflower can also be used as silage crop. Sunflower silage contains considerably more fat than many other types of forage. The nutritional quality of sunflower silage is often higher than corn, but lower than alfalfa (Ishag, 1988).

Sunflower oil contains a high proportion of unsaturated fatty acids than other vegetable oils and is therefore useful as a row material for biodiesel production, The technology for processing sunflower oil in to biodiesel has recently been developed; consequently, the importance of sunflower is increased (Amirian, 2013). Sunflower oil is also used in certain paints, varnishes and plastics because of the good semi drying properties without color modification associated with oils high in linolenic acid (Ishag, 1988).

2.3 Types of sunflower:

According to Arnon (1972) there are two types of sunflower recognized all over the world namely, the oil seed type and non-oil seed type. The oil seed type is used for oil extraction. It is usually small seeded type and the kernel accounts for about 60% of the weight of the seed. The non-oil seed type is used for direct human consumption. The seeds are usually large with higher protein contents than the oil type, and the kernels do not fill the husk, constituting about 50% of the weight of the seed.

2.4 Growth habit:

Sunflower is an annual erect, broad leaf plant with strong taproot and prolific lateral surface roots. Stems are usually round early in the season, and normally, unbranched. Sunflower leaves are phototropic and will follow the sun's rays with a lag of 12^o behind the sun's azimuth. This property has been shown to increase light interception and possibly photosynthesis. The sunflower is not a single flower (as the name implies), but is made up of 1000 to 2000 individual flowers joined at common receptacle. The flowers around the circumference are ligulate ray flowers without stamens or pistils; the remaining flowers are perfect flowers (with stamens and pistils). Anthesis (pollen shedding) begins at prefer and proceeds to the center of the head. Since many sunflower varieties have a degree of self-incompatibility, pollen movement between plants by insects is important and bee colonies generally increased yields. In temperate regions, sunflower requires approximately 11 days from planting to emergence, 33 days from emergence to head visible, 27 days from head visible to first anther, 8 days from first to last anther and 30 days from last anther to maturity. Cultivars difference in maturity are usually associated with changes in vegetative period before the head visible (Khidir, 1997).

Over the years the research of sunflower breeders, has resulted in the development of sunflower cultivars which are agronomicaly improved over those sunflower commonly found growing in nature, For instance some cultivars are commonly capable of undergoing a greater degree of self-pollination assuming advantageous growing conditions are encountered. At least some of the physiological self-compatibility is overcomed in such cultivars and it is possible for the stigma to curve around and eventually contact its own pollen and accomplish fertilization assuming it has not already been killed due to adverse environmental conditions. However, even under the most advantageous environmental conditions, such self-fertilization is limited and falls far short of accomplishing pollination of all the most individual florets encountered in commercial growing areas where such plants are grown Nour, (2005).

2.5 Adaptation:

Sunflower is adapted to a wide range of environments in the World. Temperature, rainfall, light and photoperiod, water requirements and soil type are the major components of the natural environmental factors which influence crop growth and production. Agronomic models can now take account of environmental conditions and architecture in the field to define the best environments for field trails and predict yields of hybrid combinations according to environmental conditions (Casadelabaig *et al*., 2015).

2.5.1 Temperature:

Sunflower can be grown from Equator to 55^0 N. It is generally considered as a worm season crop. High yield occurs between latititudes from 20^0 to 50^0 N and 20^0 to 40^0 S. Sunflower is tolerant to both lowand high temperatures, this contributed to its wide adaptability (Robinson, 1978). Temperature of 8-10^0c seems to be minimum for satisfactory establishment, while the optimum is much higher, about 24^0-27^0C (Fadl Elmulla, 2003). A reduction in oil percentage of the seeds occurs at high temperature (Canvin, 1965), as temperature increased the seed protein content was increased too, but low temperature during seed development favored the production of high linoleic acid and decrease in the oleic acid content. It is well known that oil seeds grown at low temperature are comparatively rich in saturated fatty acids (Canvin, 1965).

2.5.2 Rainfall:

Sunflower is commonly grown as a dry land crop. It is not suitable to the wet tropics and very heavy rain during the early stages of growth**.** Cool wet weather during ripening stage is not good for the crop. Sunflower will produce moderate yield under rainfall as low as 300 mm, but the field relationship between rainfall and seed yield is often linear from 200 to 500 mm. The peak water demand by the crop is in the immediate post-anthesis period and that sunflower is capable restricting its water use when about 70% of the maximum available water remains in the root zone (Anderson, 1979). Sunflower ability to extract more water from deep soil layers plays an important role in its productivity under low rainfall Nielsen, (1998) reported that, water requirement of the crop as low as 128 mm and moisture stress during productive stage can lead to reduction in seed size, number of seeds per head and seed weight.

2.5.3 Light and photoperiod:

Sunflower is classified as insensitive because it flowers under a wide range of day length (short-day, neutral and long-day). Therefore photoperiod is not important in choosing its planting date or production area 1978). Sunflower leaves are phototropic. It was found to be an efficient user of light, so it does not become light saturated at relatively high levels of light (Hesketh and Moss, 1963).

2.5.4 Soil type:

Sunflower can grow on a wide range of soils, but it should be deep and well drained. It grows well in soils ranging from sand to clay and ranging PH from 6.5-8. Sunflower roots play an important role in the plant tolerance to salinity. They act as accumulators of sodium rather than as assimilators. It cannot tolerate very acidic or water logged soils(Robinson, 1978). In Sudan, Skoric, (1982) reported that central clay land is suitable for sowing sunflower as Khidir (1997) reported, which soils have up to 70% clay and PH is ranging from 8.5-9 with free calcium carbonate in the profile. In dry land conditions the depth of the soil profile and its moisture storage capacity will be important factors in determining the distribution and productivity of the crop.

2.6 Sowing dates of sunflower in Sudan:

There is an increasing interest in sunflower over the world, due to its wide adaptability and high percentage of excellent oil. The savannah areas of the Sudan mainly the central clay plains, where rains occur during the period of May-October, with a total of annual rainfall varying from 400 to 900 mm, are suitable for sunflower production. The main production problem is the inadequate soil moisture during flowering which causes poor seed setting (Skoric, 1982). In central Sudan and during the rainy season day temperature is around $34C^o$ and night temperature $22C^o$ Khidir (1997). Skoric (1982) considered Gedarif and Damazine as the potential region I ; Kadugli and Rank as the potential region II; for rain fed production ; however , Blue Nile, White Nile, Suki and Rahad schemes are potentially favorable for sunflower growing with supplementary irrigation. Water requirements of crops vary substantially during the growing period mainly due to variation in crop canopy and climatic conditions. Anderson (1979) suggested three growing stages, heading, flowering and milking in sunflower as sensitive to water stress. Flowering stage is most sensitive stage to water stress causing considerable decrease in both yield and oil contents. Schnieter and Miller, (1984) stated that, Sunflower growth stages can be divided in to four physiological phases; vegetative, floral, seed filling and dry down phase. Therefore, several reports in literature indicate that better yields were achieved with irrigation applied at the most critical stage, i.e. flowering than irrigation at other growth stages (Connor, 1985 and Unger, 1982).

Sunflower can be planted at a wide range of dates, as most cultivars are earlier in maturity than the length of growing season in most areas of the world with no winter (frost), sunflower has been planted at all months of the year to obtain satisfactory yields Khidir (1997). Khalifa (1981) tested three sowing dates, namely 15 July, 30 July and 15 August. He found that delayed sowing resulted in significantly lower grain yields. Overall earlier sowing was associated with higher grain yields, whereas sowing as late as 15 August, gave extremely low grain yields under rain fed conditions. This was attributed to decreasing moisture availability with delayed sowing. On the other hand, under supplementary irrigation, the effect of sowing date on grain yield was less marked. There was no significant difference between sowing on 15 July and 30 July. Sowing as late as 15 August could give good grain yields depending on environmental conditions (mild temperature during flowering period late in October enhanced by long rainy season). On the evidence available, 15^{th} July is recommended as optimum sowing date for sunflower under rain fed conditions. However under supplementary irrigation sowing up to 30 July is recommended (Ishag, 1988 and Khidir, 1997). According to Ishag (1988), in irrigated Rahad scheme high grain yield was obtained from winter sowing particularly with non-hybrids. Sowing dates affected the oil composition in summer by increasing the percentage of oleic acid and decreasing the percentage of linoleic acid and vice versa in winter sowing. In Gezira Research Station for winter season, six sowing dates at two weeks intervals from first October to 15 December were tested with two cultivars Rodeo (open-pollinated) and Pioneer 634 (hybrid). The result showed that higher seed yield, head yields and other better agronomic characteristics were obtained from the crop during the period, from first October to 15 November (Khidir, 1997).

2.7 Variability in sunflower:

Phenotypic variability in a population is of paramount importance for any successful breeding program. This is because of selection of desirable genotypes for a certain trait will not be effective unless considerable variation is existed in the genetic material under study. Variability analysis has been found useful for getting information about the characters that are expected to response for selection (Arshard *et al*, 2013). Many workers have reported evidence for the existence of considerable amount of variability in sunflower for all characters such as: Highly significant difference was observed for days to fifty percent flowering (Casadelabaig *et al*, 2015).Sunflower breeders have emphasized development of early maturing hybrids. Sunflower head has many disc flowers, in circles or rings on sunflower head. However these disc flowers do not open at the time. After ray flowers appearance, the outer of disc flowers start to open, thereafter, the flower rings of disc flowers open towards the head center. Kandil and El Mohandis (1986) stated that, flowering duration of sunflower head is about 7-10 days according genotype and prevailing environmental conditions. AAID, (1986) found no significant differences in the number of days to flowering when comparison was made between hybrids and non-hybrid genotypes. In a field trial, conducted at Sumsum, Gedaref State of Sudan to compare 31 sunflower varieties from different origins under rain fed conditions; the result showed that, there were significant differences in days to flowering (Arnon, 1972). Also significant differences were reported by other workers (Seiler, 1984 and Asifkhan *et al*., 2003). Patil *et al*, (1996) stated that, days to 50% flowering were less affected by environmental conditions. A wide range of variability in days to 50% flowering was also reported by (El. Ahmer *et al*, 1989). Significant difference was registered for days to physiological maturity by (Arshard, 2013). The achievements by first breeding efforts were; earlier maturing genotypes, with high oil percentage of the seeds (Fick, 1978). Asifkhan *et al,* (2003) stated that, there were significant differences in days to physiological maturity in the breeding materials he studied. Plans have been outlined by plant breeders to develop shorter season hybrids (70 to90 days) to maturity with minimal reduction in yield ” Massa” A zimbabwian sunflower hybrids maturing in 83 days and yield between 1.5 to 3 t/ha, depending in weather conditions. Conversely in climates with very long growing season, breeding objectives have to develop hybrids with 120 to 140 days to mature (Miller, 1987). AAID, (1986) found non-significant differences among compared sunflower hybrids. Cruz (1986) reported that, significant variations were detected among sunflower hybrids for days to physiological maturity. In a field trial to study variability in sunflower a wide range of variability in plant height was reported by El- Ahmer *et al*. (1989). Cruz, (1986) recorded significant variation among hybrids for plant height and other agronomic characters. Considerable variation was reported among genotypes for plant height (Chervet and Vear, 1990). But non- significant difference was observed by (Arshard *et al*, 2013).Sheriff and Appandurai, (1985) reported that, a wide range of variation was observed and the genotypes differed significantly in plant height. Patil *et al*, (1996) stated that, the plant height was less affected by environmental conditions. Their study showed significant differences for all the traits. Chervet and Vear (1990) recorded highly significant differences among sunflower hybrids and open pollinated cultivars for stem diameter, While non- significant difference was noticed by (Arshard, 2013). A wide range of variability in stem diameter was reported by El-Ahmer, (1989). Genetic variability was observed among 77 recombinant inbred lines for flowering, plant height, stem diameter, head diameter, grain weight/plant and 1000 seed weight and found to be significant for all above mentioned traits (Rashid *et al,* 2004). Suzer and Atakisi, (1993) reported marked difference in the stem diameter of the sunflower genotypes and attributed these variations to the gene effects. Patil *et al*, (1996) reported that significant differences were found among genotypes for stem diameter. Hakan *et al*. (2003), in evaluation of twenty sunflower genotypes, the result showed that, the genotypes differed significantly in the entire characters investigated including head diameter except for kernel percentage. In study of 36 genotypes of sunflower Singh *et al,* (1986) reported significant variations for agronomic characters including head diameter. However (Asifkhan *et al*, 2003)stated non- significant difference for eight characters of sunflower hybrids among them was head diameter. Bernardo, 2002) stated that number of seeds per plant was non- significantly differed among the studied sunflower hybrids. Kshisagar *et al.* (1995) reported that, the variation among the genotypes was greatest for seed yield / plant followed plant height and 1000-seed weight. Chervet and Vear (1990) stated that, for the components directly determining yield, seed number per head appeared to be more important than 100-sed weight. Patil *et al*,(1996) reported significant genotypic differences for all the characters studied in sunflower genotypes. The variation was high for number of seeds / head, followed by the weight of the head and seed yield. Significant difference was stated by (Arshard, 2013) for empty seeds percentage among studied sunflower hybrids. Hedge and Havangi, (1989) stated that, the moisture stress during the flowering stage decreased the number of filled seeds and stress during seed filling decreased seed weight. Human *et al*. (1990) found that water stress during an thesis and seed filling stages resulted in more empty seeds. Nour, (1978)was the first investigator to tackle the problem of empty seeds in sunflower. Khidir (1997) reported that, one of the major problems facing sunflower production in the Sudan the high percentage of empty seeds in non-hybrid varieties and to a lesser extend in the hybrid genotypes. Poperlan, (1987) in study of 42 genotypes of 20 helianthus species indicated that the percentage of empty seeds was ranged from 20.8% to53% and the 1000-seed weight (g) ranged from 2.18 g to 57.7 g. Karami, (1980) and Steer *et al*.,(1986)found that,1000-seed weight decreased, with increasing plant population, Kanna (1972) indicated that, the problem is further complicated by the fact that, the 1000-seed weight varies considerably even within the same variety. Anonymous, (1978) and Mirza *et al*, (1997) reported significant genetic and phenotypic variations for 1000-seed weight in sunflower genotypes, while(Human *et al*, 1990) registered non- significant difference for 1000- seed weight among studied sunflower hybrids. Kshirsagar *et al.* (1995) stated that, the variation among sunflower genotypes was greatest for seed yield / plant, followed by plant height and 1000-seed weight. In study of 20 sunflower varieties, Kefene, (1994) revealed that there were highly significant differences among the cultivars for yield attributes namely; number of seeds per head, 1000- seed weight, oil content and harvest index, as well as different growth and agronomic traits. Kshirsagar *et al*, (1995) reported that high genetic variance for seed yield per plant were found in 14 studied sunflower cultivars. Fereres *et al*, (1983) studied 53 genotypes of sunflower, and revealed that substantial variability exists among genotypes in yield. Areas under sunflower production declined dramatically in recent years, production is low and the productivity was as low as 0.2 ton per feddan in 1998 / 1999 according to Faisal *et al*, (2005). Gorashi and Elzaein, (2005) reported that average yield in the Blue Nile state as about 0.2 tons / fedan. Oil content in sunflower seed ranges between 25-48%, and it can reach 65%

depending in genotype and environmental factors. The kernel contains the highest percentage of oil (87%) followed by the embryo (7.4%). The oil percentage of whole sunflower achenes depends on both percentage of oil in the kernel and the proportion of the hull. The hull contains a low percentage of oil and is reported to be between0.4-5.2% by several authors. Sunflower is a promising oilseed in Sudan. The seeds of sunflower have a high oil content (40- 50%) and are 30% digestible protein and can thus be used as source for human or as poultry feed (El Ahmadi. 2003; Nour, 2005). The oil content of sunflower ranges between 36 and 52%, whereas protein content is at 28-32% (Rosa *et al*, 2009). Sunflower is the most important oil plant, being the third as importance among grass oilseeds (13% of the world oil production). The sunflower fruits (achenes) contain approximately 50% oil with exceptional food quality and high preservability, being used for human food (refined) and (margarine, soap, Lecithin phosphatide, etc…) (3W, 7) W325 pdf. Sunflower seed contains 40-48% oil and 20-27 protein (Rosa *et al*, 2009).

2.7.1 Phenotypic and genotypic variability:

Genetic variability is essential for successful crop improvement through breeding programs. The main objectives in sunflower breeding vary with specific programs generally emphases on high seed yield and high oil contents. Any progress in a breeding program depends on the magnitude of genetic variability in the genotypes (Casadelabaig, 2015). According to Fick,(1978) sunflower possesses much genetic variability for seed yield. However, Sheriff and Appandurai (1985) studied the genetic variability in 23 sunflower genotypes. They found a wide range of variation, and the phenotypic variance was greater than genotypic variance for the traits. Tariq *et al*, (1992) studied the genetic variability and correlation in fourteen sunflowers hybrids. They found that the genotypic and the phenotypic variance was high for plant height, seed yield and oil content. Gill *et al*. (1997) studied 45 genotypes of sunflower grown under four environments and fertilizer level. Their results showed significant phenotypic variability for head diameter, 100-seed weight, seed yield per plant and number of seeds per head. Patil *et al.* (1996) stated that, the analysis of variance revealed significant genotypic differences for all the characters studied in sunflower genotypes, the range of variation was high for number of seeds per head followed by weight of the head and seed yield. Mahmmood and Mehdi, (2003) indicated that, the genotypic variances were smaller than their corresponding phenotypic ones for all characters.

2.7.2 Phenotypic (PCV %) and genotypic (GCV% coefficient of Variation:

The goal of the plant breeders is to develop genotypes, which are adapted over a wide range of environmental conditions. The breeders, therefore, select those genotypes, which to some extent, show some extend of variability. Chikkadevaiah, *et al*, (1998) reported high genotypic and phenotypic coefficient of variability for seed yield/plant, percentage of husk, head diameter and filled seeds/plant. Saravanan *et al*, (1996) reported moderate genotypic and phenotypic coefficient of variability for head diameter, plant height and 100-seedweight.

2.8 Heritability in broad sense (h^2) and genetic advance (GA) and genetic advance as percentage of mean (GA %):

.Any progress in a successful breeding program depends on the extent of the heritability of the desirable characters (Arshard *et al*, 2013).The heritability coefficients in a broad sense were high in all characters and ranged from 69.74% to 96.96% (Casadelabiag *et al*, 2015). Heritability represents the ratio between genetic and all factors (including non-genetic ones) that influences variability Bernardo, (2002). Heritability as defined by Johnson *et al.* (1955) is the portion of the phenotypic variability, which is due to genetic causes. Since genetic progress increases with increase in genetic variance, the utility of the heritability estimates increases when it is used in conjunction with genetic coefficient of variation. Estimation of heritability together with the genetic coefficient of variation is usually useful in predicting the resulting effect of selection than heritability value alone. This is mainly because, heritability estimates as a ratio of genotypic to phenotypic variance, varies greatly depending on sample size, environment, character and population. The higher ratio of the genetic components in phenotypic expression of a certain trait, the higher is the heritability and selection for these traits can be performed in earlier generation, in field trials set up at a smaller number of locations, years and replications. Heritability accompanied with an estimation of genetic gain is more useful than heritability alone in accurate prediction of the selection effects (Johnson *et al.,* 1955). Muhammad *et al,* (1992) reported that, the dominant and epistatic nature of inheritance was reflected by high heritability and low genetic advance estimates. Kloczowski, (1975) and Shabana, (1974) reported broad sense heritability estimates 40% and 80% for plant height. Kshisagar *et al,* (1995) stated that, heritability estimates for plant height and 100-seed weight were high, while that for yield was moderate. Dash *et al*, (1996) reported that, heritability and genetic advance were high for all physiological characters. Patil *et al.* (1996) reported high heritability estimates with low genetic advance for days to 50% flowering, plant height and stem diameter Pellet, (1993) indicated that, heritability and genetic advance were high for all studied characters in sunflower, except the physiological characters, which showed very low amount of genetic advance. Gill *et al.* (1997) reported high estimates of heritability and genetic advance of head diameter and 100-seed weight, while for seed yield/plant and number of seeds/ head moderate values were shown.

2.9 Phenotypic correlation:

Correlation analysis measures the mutual relationship between various plant characters and determines the component characters on which selection can be based for improvement of seed yield (Habiballh *et al*, 2006).The inherent association between two characters is called genetic correlation (Anonymous, 1978).Analysis of genetic correlation measures the mutual relationship among various plant characters and help in determining the yield components on which direct selection can be based for achieving genetic improvement in yield (Habiballah *et al*, 2006). Phenotypic correlation refers to observed association between two characters; it includes both genotypic and environmental effects and therefore, differs under different environmental conditions (Habiballah *et al*, 2006). Seed yield per plant correlated positively and significantly with all quantitative characters, while oil content was correlated negatively and non-significantly with head diameter, 1000- seed weight, plant height, stem diameter and days to 50% flowering (Casadelabaig *et al*, 2015). Seed yield per plant could be increased by selection of plant height, stem diameter, head diameter and number of seeds per plant, because they had high positive correlation with seed yield per plant and high heritability estimates (Yankov and Tashin, 2015). Teclewold *et al*, (2000) studied the correlations in sunflower and reported positive and significant correlation between seed yield/plant and plant height, number of filled seeds, head diameter, stem diameter. 100-seed weight and the harvest index on one side and oil yield/plant on the other. The simple linear correlation coefficient analysis showed that seed yield was positively and significantly associated with days to 50% flowering, head diameter, harvest index, seeds number/ head, number of filled seeds/head, percentage of seeds set, 100-seed weight, self-compatibility and oil content, while negatively correlated with empty seed percentage. On the other hand empty seeds percentage was positively and significantly correlated with plant height, number of seeds/plant, but negatively and significantly correlated with days to 50% flowering, harvest index, seeds number/plant, number of filled seeds/head, percentage of seed set,1000- seed weight and oil content (Muhammad *et al*, 2003). Mahender *et al*,(1998) reported that, 1000-seed weight had significant and positive association with the final seed yield. Anderson, (1979) stated that, the 1000-seed weight had positive correlation with head diameter. Abdel Aal, (1992) reported that, positive seed yield was strongly and positively correlated with head diameter. Nour, (1978) found a positive and a very highly significant ($p \leq 0.01$) correlation between the percentages of unfilled seed / head and each of the plant height, days to physiological maturity, head diameter and hull percentage. Chervet and Vear (1990) stated that yield was positively and significantly correlated with morphological characters which varied with plant vigor. Kandil and El- Mohandes (1986) stated that the head diameter was positively and significantly correlated with seed yield per head.

2.10 Stability of performance:

The goal of the plant breeders is to develop genotypes, which are adapted over a wide range of environmental conditions. The breeders, therefore, select those genotypes, which to some extent, show stability across environments. These stable genotypes provide a stock which superior genotypes may be selected (Gafoor *et al*, 2005). In study of 20 sunflower genotypes, the results showed that, the year had a significant influence on the agronomic parameters of the genotypes, with the exception of 1000-seedweight (Hakan *et al,* 2003). Also Schoeman, (2003) reported significant genotype x environment interaction for characters studied in 20 South African sunflower hybrids. On the other hand Alvarez *et al,* (1992) found wide genetic variability and significant genotype x environment interaction for 37 open-pollinated population evaluated in three environments. Bange *et al*, (1997) stated that, the potential yield of sunflower is highly dependent on environmental condition during the life of the crop. The basic of the differences between genotypes in their yield stability, is the wide occurrences of genotype x environment interaction, that is, the ranking of the genotypes depends on the particular environmental condition, where it is grown. Very few breeders use statistical measures of yield stability in their breeding programs. A deeper insight into the relation among the numerous stability parameters, and their similarity, may be obtained by comparing the resulting stability rank orders of different genotypes, which are derived by applying different concepts of phenotypic stability (Huehn, 1990). The aim of a breeding program is to identify genotype which is widely adapted. According to Frey, (1964) a variety of wide or good adaptability is the one which gives consistently superior performance over several environments. The process of identification of stable genotypes is difficult because of the genotype x environment interaction. Although the breeders have observed genetic differences for adaptability, they have been unable to fully exploit these differences in breeding stable genotypes; this has been largely due to the problem of defining and measuring the phenotypic stability. Various attempts were made to characterize the behavior of genotypes in response to varying environments (Lewise, 1954 and Finlay and Wilkinson, 1963). Finlay and Wilkinson (1963) pointed out that, the slope (bi) of the linear regression of the yield (Yij) of i^{th} genotype and j^{th} environment, on the mean yield (y.j) of all the genotypes in j^{th} environment was helpful to test the genotypic stability. They pointed that, a genotype which has a slope of bi=1 is the most stable , but genotypes which have slope greater than 1 and less than 1 are specifically adapted to high yielding environment and better adapted to low yielding environment, respectively. In addition to the coefficient of regression (bi) and mean, the deviation (S^2-di) from regression which describes the contribution of genotype to the G x E interaction, is used (Eberhart and Russell, 1966). Both statistics are used in different ways to assess the reaction of genotypes to the varying environments, while (S^2-di) is strongly related to the remaining unpredictable part of variability of any genotype and is therefore considered as a stability parameter, the coefficient of regression (bi) characterizes the specific response of genotypes to environmental effects, and may be regarded as a response parameter. Several statistical techniques have been developed to analyze the interaction of genotypes with environments (GxE) and regression analysis has extensively used. The first proposal of a regression analysis to study GxE interaction was modified and used by Finlay and Wilkinson, (1963). They carried out a study on 277 varieties of oats grown on at three locations for three years. The varietal mean and the regression coefficient were used to measure the adaptation response of varieties, and the varietal mean was regressed on the environmental mean. Since the population mean had a regression coefficient of one (b=1), the varieties with a regression coefficient of one (b=1) had an average stability overall testing environments. When the regression coefficients of one (b=1) were associated with above or below average mean yield, they indicated general or poor adaptability to the testing environments, respectively. Regression coefficient less than one (b=1) indicated below average stability and thus adaptability to high yielding environments. Regression coefficient less than one (b=1) indicated above average stability and thus adaptability to low yielding environments i.e. greater resistance to environmental changes. Eberhart and Rusell (1966) defined stable varieties as those having a regression coefficient of b=1 and deviation from regression as small as possible (S^2d=0). This technique is used to select stable genotypes that interact less with the environment in which they are to be grown. Allard and Bradshow, (1964) defined stability as adaptation to withstand unpredictable transient environmental conditions. They pointed out that heterozygous population offers the best opportunity to produce varieties, which show small GxE interactions. In addition, they used the term ” individual buffering” for individuals where the individual members of a population are well buffered such that each member of the population is well adapted to a range of environments, and ”population buffers buffer buffering” a variety consists of a number of genotypes each adapted to somewhat different range of environment. Thus heterozygous or homozygous genotype may possess individual buffering and a heterozygous population will posses population buffering. Lin and Binns,(1986) studied the statistical relationship among nine environmental stability parameters and classified them into three types. A genotype is considered to be stable of type one (1), if its variance overall environment is small; of type 2 if it's environmental response is parallel to the mean response of all cultivars in the test; and of type 3 if its deviation mean square (MS) from the regression model is small. Lin and Binns,(1986) concluded that among these types of stability, type three is the most problematical, because the residual MS from regression model is merely an indicator of goodness of fit, and cannot be considered as stability parameter. In addition, Lin and Bins (1988) proposed stability parameter type 4, based on MS (as part of genotype x location x year experiment); a genotype is considered to be stable if this MS is small. On the other hand, Lin and Bins (1990) tested the genetic properties of the four types of stability parameters, and it appeared that stability parameters of type 1 and 4 are heritable, and thus useful for selection, while those of type 2 and 3 are non-heritable and thus they are not useful.

CHAPTR THREE

MATERIALS AND METHODS

3.1 Experimental site:

Two experiments were carried out at two locations in Sinnar State, Ellkandi area under rain fed condition (latitude 12^0 $32^/$ 30 N, longitude $34^0 29^\backslash$ 53 E and Altiude 469 meters above the sea level), and irrigated Essuki area (latitude $13^0 40^\backslash$ N , longitude $34^0 60^\backslash$ E and Altitude 445 meters above the sea level) for two consecutive seasons; 2013 and 2014. The soil is deep cracking clays, very grayish brown and moderately well- drained. The pH was 7.7 at Ellkandi and 7.9 at Essuki. The total porosity was 28.5% at Ellkandi and 29% at Essuki. The available water capacity was 9.0 and 18.1 cm in the 0-30 and 30-120 cm soil depth respectively (SSMAD, 2016). At each location the trial was carried out in the summer, thus four environments (E1= Ellkandi 2013, E2= Ellkandi 2014, E3= Essui 2013 and E4= Essuki 2014) were possible. Metrological data in terms of rain fall, relative humidity and temperature obtained from (NMC, 2017) are depicted in appendices (1, 2, 3, 4and 5).

3.2 Genetic material:

Fifteen sunflower hybrids derived from Agricultural Research Corporation (ARC) were used in this study (Table.1).

3.3 Experimental procedure:

A randomized complete block design (RCBD) with four replications was used for laying out the field experiments. Each block (replicate) was divided

Table 1: List of the sunflower hybrids used in the study

No	Hybrid	Origin
1	SFH301	ARC-Sudan
2	SFH302	ARC-Sudan
3	SFH303	ARC-Sudan
4	SFH304	ARC-Sudan
5	SFH310	ARC-Sudan
6	Ausigold7	Nuseed-Australia
7	Ausigold4	Nuseed-Australia
8	Asigold61	Nuseed-Australia
9	Pan-7033	Pannar-South Africa
10	Pan-7049	Pannar-South Africa
11	Pan-7057	Pannar-South Africa
12	Pan-7351	Pannar-South Africa
13	Opera	Syngenta-France
14	Aguara-4	Advanta-Argentina
15	Hysun-33	Advanta-India

(ARC, 2013)

Into 15 plots, to which sunflower hybrids were assigned randomly. The plot size was 6x3 meters. Each hybrid was presented by four ridges each 6 meters long and 70 cm apart. Three seeds were sown in the holes of 5 cm depth and 25 cm distance along the ridge, and then thinned to one plant per hole after three weeks after sowing. In season 2013 the sowing date was on 10^{th} of July for Ellkandi and Essuki locations, while in season 2014 it was on 15^{th} of July for both locations. Standard agronomic practices were followed from time to time during the growing season of the crop. Ellkandi location was fully under rain fed, while Essuki location was irrigated at intervals of fifteen days, although some sporadic rains were recorded and considered during summer. Five plants from inner two rows were taken from each plot randomly and their heads were bagged using paper bags before flowering to ensure self-pollination and to avoid later bird's damage. No infestation of pests or diseases was registered.

3.3.1 Data collection: Data were collected from the selected inner five plants on the following parameters:

3.3.1.1 Days to 50% flowering: Was taken as a number of days from sowing to the date on which 50% of the heads in the plot had reached 50% bloom.

3.3.1.2 Days to physiological maturity: The number of days from planting to the date of physiological maturity of the heads was calculated.

3.3.1.3 Plant height (cm): Was measured at height from the soil surface to the point where the head attached to the stem.

3.3.1.4 Stem diameter (cm): Stem diameter was measured as the thickness of the stalk at ten centimeter above the soil surface using the vernier.

3.3.1.5 Head diameter (cm): Head diameter was measured in terms of (cm).

3.3.1.6 Number of seeds per head: Number of seeds per head was determined by calculating the seeds in each head in the sample.

3.3.1.7 Empty seeds (%): Determined by counting the number of empty seeds per plant and expressed as percentage of the total number of seeds in the plant.

3.3.1.8 1000-seed weight (g): It was estimated by taking 4 random samples each made of 1000 seeds, taken from the bulk of seeds of the 5 plants in the random sample and then the average.

3.3.1.9 Seed yield per plant (g): It was calculated as mean of weight of the bulk of the seeds of the 5 plants.

3.3.1.10 Seed yield (t/ha): Seed yield per hectare was calculated according to the following formula:

$$\text{Seed yield (t / ha)} = \frac{\text{Seed weight"kg"/plot x10000(m}^2\text{)}}{\text{Plot area (m}^2\text{) x1000}}$$

3.3.1.11 Oil yield(t/ha): The oil yield (t/ha) was obtained by using Soxhelt method.

3.3.2 Statistical analysis:

The collected data were then analyzed according to the standard statistical procedures:

3.3.2.1 Individual analysis of variance:

Individual analysis of variance was carried out for the data from each of the four environments to determine the extent of variation according to procedure described by Gomez and Gomez (1984) (Table. 2).The means of the different characters for the fifteen hybrids were separated using Duncan Multiple Range Test (DMRT)at ($P<0.05$) level of significance. The estimates obtained from the individual analysis of variance were then used to compute the following variances for each character in each season as follows:

3.3.2.1.1 Coefficient of variation:

It was determined according to the formula:

C.V % = $\sqrt{EMS / G}$ X 100

3.3.2.1.2 Phenotypic variance (δ^2ph):

It is calculated according to the following formula:

$$\delta^2 ph = M_2 / r$$

Where:

M_2 and r refer to the mean square for hybrid and number of replications, respectively.

3.3.2.1.3 Genotypic variance (δ^2ph):

It is estimated as follows:

$$\delta^2 g = (M_2 - M_3) / r$$

3.3.2.1.4 Environmental variance (δ^2e):

This variance was calculated by dividing the mean squares of the error by the number of the replications: $\delta^2 e$ = M3/ r

3.3.2.1.5 The phenotypic (PCV %)and genotypic (GCV %) coefficient of variation:

These were calculated according to the following formula of Burton and De Vane (1953) as follows:

$$PCV\ \% = (\delta^2 ph / G) \times 100$$

$$GCV\ \% = (\delta^2 g / G) \times 100$$

Where:

G = is the grand mean.

3.3.2.1.6 Heritability estimates (h^2):

The heritability in broad sense was estimated for each character according to the procedure of Johnson *et al* (1955) by dividing the genotypic variance by the phenotypic one in percentage form:

$h^2 = (\delta^2 g / \delta^2 ph) \times 100$

3.3.2.1.7 The genetic advance (GA) and genetic advance as percentage of mean (GA %):

These were estimated by the formula of Robinson *et al* (1949):

$$GA = \delta^2 gk / \sqrt{\delta^2 ph}$$

$$GA\ \% = (GA / G) \times 100$$

Where:

G = the grand mean.

K = the selection differential. It equals 2.06 at 5% selection intensity as defined by Lush (1943). $\delta^2 g$ and $\delta^2 ph$ were the genotypic and phenotypic variances, respectively.

3.3.2.2 Combined analysis of variance:

Data from the four environments were analyzed together to examine the average effect of the genotypes across the environments (Table.3). Bartletts test (Gomez and Gomez, 1984) for homogeneity of variance was carried out to verify homogeneity of error variance in combined data from the four environments. Chi- square test for homogeneity of variance was applied to the individual analysis of variance.

3.3.2.3 Genotype x environment interaction:

The data from the four environments were further subjected to combined analysis to estimate the variance of genotype x environment interaction, the form of analysis of variance when(g) genotypes are grown in (e) environments is shown in (Table.3). When the G x E interaction variance was found to be significant, the analysis was further proceeded to estimate the stability parameters.

3.3.2.4 Stability of genotype performance:

Eberhart and Russell (1966) model for the estimation of stability was adopted, because it is the most popular regression technique used in G x E interaction and stability studies, being relatively simple and combines the useof both the regression coefficient and deviation from regression and the model

Table 2: The form of analysis of variance and the expected means squares in a randomized complete block design for one season and one location

Source of	df.		SS	MS	EMS	variation
Replications	(r-1)	= 3	S_1	M1		
Genotypes	(t-1)	= 14	S_2	M2	$\delta^2e + r\,\delta^2gsl + rs\delta^2gl + rl\delta^2gs$	
Error	(r-1) (t-1)	= 42	S3	M3	δ^2e	
Total	(rt-1)	= 69				

Where:

∂^2e = Error variance

∂^2g= Genotypic variance

r = Number of replications

t = Number of genotypes

Table 3: The form of combined analysis of variance and the expected mean squares for the pooled data of two seasons and two locations

Source of variation	*df.*		*MS*	*EMS*
Season (S)	(s-1)	= 1	*M*	
Location (L)	(L-1)	= 1	*M*	
Season x Location	(S-1) (L-1)	= 1	M_3	
Rep x season x Location	(r-1) SL	=12	M_4	
Hybrid (G)	(H-1)	= 14	M_5	$\delta^2 e + r\,\delta^2 gsl + rs\delta^2 gl + rl\,\delta^2 gs + rls\delta^2 g$
Season x Hybrid	(S-1) (g-1)	= 14	M_6	$\delta^2 e + r\,\delta^2\, gsl + rl\,\delta^2 gs$
Location x Hybrid	(L-1) (g-1)	= 14	M_7	$\delta^2 e + r\,\delta^2 gsl + rs\,\delta^2 g\,l$
Season x Location x Hybrid	(S-1) (L-1) (g-1)	= 14	M_8	δ^2e + r δ^2 gsl
Pooled error	SL (r-1) (g-1)	= 168	M_9	δ^2e
Total	(SLrg -1)	= 239		

Where: $\delta^2 e$ = Pooled error variance, $\delta^2 g$ = Genotypic variance, $\delta^2 gs$ = Genotype X season variance, $\delta^2 gsl$ = Genotype X season X location variance and r = Number of replication is:

$Y_{ij} = \mu + b_i I_j + \delta^2_{ij}$

Where:

Y_{ij}= mean performance of i^{th} genotype in j^{th} environment ($i = 1, 2…,t$ and $j = 1, 2,…, s$)

μ = Means of all the genotypes over environments

b_i = The regression coefficient of the i^{th} genotype on the environmental index which measures the response of this genotype to varying environment.

I_j = The environmental index which is defined as the deviation of the mean of all the genotypes at a given location from the overall mean.

δ^2_{ij} = The deviation from regression of the i^{th} genotype at j^{th} environment.

According to the model, the computational procedures of stability parameters are as follows:

$$I_j = \frac{\sum_j Y_{ij}}{} - \frac{\sum_i \sum_j Y_{ij}}{}$$

Where:

I_j = Environmental index.

$\sum_j Y_{ij}$ = Total of all the genotypes at j^{th} location.

$\sum_i \sum_j Y_{ij}$ = Grand total.

t = Number of genotypes.

S = Total number of the observations.

Two parameters of stability were calculated:

(i) The regression coefficient (b_i) was calculated as follows:

$b_i = \sum_j Y_{ij} I_j / \sum_j I^2_j$

Where:

$\sum_j Y_{ij} I_j$ = The sum of products.

$\sum_j I^2_j$ = the sum of squares.

The summation of squared deviations from regression ($\sum_j \delta^2_{ij}$) for a genotype was calculated as follows:

$\sum_j \delta^2_{ij} = [\sum_j Y^2_{ij} - Y^2_i / t] - (\sum_j Y_{ij} I_j)^2 / (\sum_j I^2_j)$

Where:

$\sum_j Y^2_{ij} - Y^2_i / t$ = The variance due to dependent variable.

$(\sum_j Y_{ij} I_j)^2 / (\sum_j I^2_j)$ = The variance due to regression.

(ii) The mean square deviation ($\delta^2 d$) from linear regression for a genotype was calculated as follows:

$\delta^2 d = \sum j\ \delta^2_{ij} / (S-2) - (\delta^2_e / r)$

Where:

$\sum_j \delta^2_{ij} / (S-2)$ = Variance due to deviation from regression.

δ^2_e = Estimate of mean square for pooled error.

r = Number of reps.

(J = 1.2…n) environment.

μ_i = Mean of i^{th} genotype over all environments.

bi = Regression coefficient which measures the response of i^{th} genotype to varying environments.

δ^2_{ij} = Deviation from regression i^{th} genotype at the j^{th} environment.

I_i = Environmental index.

The environmental index I_j, for I^{th} environment which is defined as the deviation of the mean of all the genotypes at a given location from the overall mean was calculated as:

I_j= [{$\sum IY_{ij}$} / g - {$\sum_i \sum_j Y_{ij}$}/ gn] with $\sum_i I_j$ = zero and

δ^2_{ij} = the deviation from regression of i^{th} genotype in the j^{th} environment.

According to Eberhart and Russell (1966), a genotype can be considered as stable if it meets the following requirements:

1. High mean value with respect to character (μ).
2. Regression coefficient not significantly different from one (b = 1).
3. A deviation (δ^2di) not significantly different from zero.

   The format of analysis of variance for stability was in (Table.4).

   .

Table 4: Format for analysis of variance for stability analysis of variance (Eberhart and Russell, 1966)

Source of Variation	df		MS
Genotypes	(g-1)	=1	M_1
Environment + (GxE)	g(n- 1)= (n-1) +(g-1) (n-1)	=45	
Environment (linear)	1		
(G x E)(Linear)	(g-1)	= 14	M_2
Pooled deviations	g(n- 2)	= 30	M_3
Genotype one	(g- 2)	= 2	
Genotype two	(g- 2)	= 2	
” ”	(g- 2)	= 2	
” ”	(g- 2)	= 2	
Genotype I	(g- 2)	= 2	
Pooled error	n(r- 1) (g- 1)	= 168	M_4
Total	(ng- 1)	= 59	

Where: r = number of replications, g = number of genotypes, n = numberof environments, M_1, M_2, M_3 and M_4 = mean of squares of genotypes, G x E (linear), pooled deviation and pooled error respectively.

CHAPTER FOUR

RESULTS

4.1 Variability in sunflower hybrids:

4.1.1 Phenotypic variability:

Fifteen sunflower hybrids were evaluated at two locations, Ellkandi under rain fed conditions and Essuki under irrigation for two consecutive summer seasons of 2013 and 2014. At both locations the individual analysis of variance showed significant differences ($p \leq 0.05$) for five characters viz: days to 50% flowering, day to physiological maturity, plant height (cm), stem diameter (cm), head diameter (cm) and empty seeds(%) and highly significant differences ($p \leq 0.01$)for the rest of studied characters in both seasons and at both locations (Table 5). The combined analysis of variance was carried out only for those characters with homogeneous error variance, i.e. head diameter (cm), number of seeds/head, empty seeds(%), 1000-seed weight (g), seed yield/plant (g), seed yield (t/ha) and oil yield (t/ha) (Table 7). These characters revealed highly significant differences ($p \leq 0.01$) among the hybrids, but non-significant differences for the genotype x season interaction, genotype x location interaction and genotype x season x location interaction.

4.1.1.1 Days to 50% flowering: At Ellkandi the earliest hybrids for days to 50% flowering (58 days) were SFH 303and Ausigold4 in season 2013, while the earliest hybrids in season 2014 (57 days) wereAusigold4, SFH 304 and SFH 301 (Table 7). The latest one in season 2013 was Pan-7049 (60 days),

Table 5: Mean squares from the analysis of variance for 11 characters of 15 sunflower hybrids evaluated at two locations for two seasons.

Trait	Ellkandi				Essuki			
	2013		2014		2013		2014	
	Hybrids df =14	Error df =42	Hybrids df =14	Error df =42	Hybrids df = 14	Error df =42	Hybrids df =14	Error df =42
DF	2.043*	0.330	3.921*	0.056	2.931*	0.0541	0.456*	0.07037
DM	13.52*	0.7705	14.79*	0.186	9.052*	0.5087	6.738*	0.5557
PH	10.676*	8.0630	11.862*	5.967	10.862*	3.867	11.000*	4.129
SD	0.154*	0.0163	0.0292*	0.055	0.147*	0.0186	0.0275*	0.0111
HD	3.43*	0.3015	9.052*	0.508	8.111*	1.087	6.738*	1.321
NSP	0.581**	0.0431	0.801**	0.0256	0.3333**	0.0862	0.1953**	0.045
ES	2.11*	1.018	2.035*	1.470	1.730*	1.046	2.486*	1.816
SW	17.178**	3.282	10.795**	1.459	9.011**	0.980	19.432**	1.313
SYP	2.923**	1.550	3.023**	1.647	2.445**	1.864	0.341**	0.166
SYH	0.0213**	0.0087	0.06317**	0.01197	0.0457**	0.0318	0.06723**	0.0453
OY	0.0131**	0.0016	0.0129**	0.0013	0.0142**	0.0031	0.0141**	0.0045

*DF= days to 50% flowering, DM= days to physiological maturity, PH = plant height (cm), SD = stem diameter (cm), HD = head diameter (cm), NSP = number of seeds per Plant, ES = percentage of empty seeds (%), SW = 1000- seed weight (g),SYP= seed yield per plant (g) ,SY = seed yield (t/ha).& OILY = oil yield

Table 6: Mean square from the combined analysis of variance for 11 characters of 15 sunflower hybrids evaluated at four environments:

Character	Hybrids df =14	Hybrids x seas df =14	Hybrid x loca df =14	Hyb x season x loca df =14	Pooled error df =168
Days to50% flow	-	-		-	-
Days to maturity	-	-		-	-
Plant height (cm)	-	-		-	-
Stem diameter (cm)	-	-		-	-
Head diameter (cm)	7.194**	3.618^{ns}	7.494 ^{ns}	8.110 ^{ns}	4.453
Number of seeds/p	58173**	8816^{ns}	152824 ^{ns}	11188 ^{ns}	18808
Empty seeds%	2.395**	2.500^{ns}	6.507^{ns}	3.129^{ns}	2.081
1000-seeds weight (cm)	707.93**	18.84^{ns}	57.00 ^{ns}	8.62 ^{ns}	25.84
Seed yield/p (g)	295.16**	178.80^{ns}	93.80 ^{ns}	123.21 ^{ns}	20.31
Seed yield (t/ha)	0.125**	0.037**	0.009**	0.0136**	0.008
Oil yield (t/ha)	0.053**	0.850**	0.550**	2.778**	5.654

-Not calculated for their heterogeneity of error variance
Ns = not significant

*Significant at (P≤ 0.05) level

** Significant at P<0.01 Level

while, Ausigold61 was the latest hybrid in season 2014 which flowered in (61 day).Mean days to 50% flowering was (59 days) in season 2013 and (58 days) inseason 2014. The coefficients of variation (CV %) was 3.2 and 4.1 in season 2013 and 2014 respectively (Table 7). At Essuki the earliest hybrid in season 2013 (55 days) was SFH 304, but the earliest one in season 2014 (55 days) was Ausigold4. The latest hybrid in season 2013 and 2014 was Pan 7057 which flowered in (66 days) and(65days) respectively (Table 8). Mean days to 50% flowering in season 2013 was (59 days), while it was (60 days) in season 2014. The coefficient of variation (CV %) for this trait in season 2013 was 4.1, while it was 4.4 in season 2014 (Table 8).

4.1.1.2 Days to physiological maturity: The earliest hybrids at Ellkandi in season 2013 (99 days) were Aguara-4, Opera, Pan-7351, Ausigold61, Ausigold7 and SFH 303, while the earliest ones in season 2014 (82 days) were Ausigold4 and Pan 7351. The latest one in season 2013 and 2014 was Pan-7057 which reached the physiological maturity in (102 days) and (89 days) respectively (Table 8). Mean days to physiological maturity were (100 days) and (85 days) for season 2013 and 2014 respectively. The coefficient of variation for this trait was 2.8% for season 2013and 5.1% for season 2014(Table 8). At Essuki the earliest hybrids in season 2013 (82 days) were Pan 7351 and Ausigold4, while the earliest hybrids in season 2014 (84 days) were OperaandPan-7351 (Table 9).On the other hand the latest hybrid (89 days) in season 2013was Pan-7057, while the latest one (92 days) in season 2014 was SFH-304. Mean days to physiological maturity in season 2013and 2014 were (85days) and (88 days) respectively. The coefficient of variation was 5.1% in season 2013, while it was 6.7% for season 2014 (Table 9).

4.1.1.3 Plant height (cm): The tallest hybrid at Ellkandi in season 2013 (159.0cm) was Ausigold7, while the tallest one in season 2014(230.5 cm) was SFH-303 (Table 7). On the other hand the shortest hybrid in season 2013 (140

.8 cm) was SFH-310, while the shortest hybrid in season 2014 (208.5 cm) was Pan-7033. Means plant height were (148.2 cm) and (219.02) in season 2013 and 2014,respectively.The coefficient of variation (CV) was 6.1 in season 2013 and 3.5 in season 2014(Table 7). At Essuki the tallest hybrid in season 2013 (225.5 cm) was SFH 303, while the tallest one in season 2104 (186.8 cm) was Ausigold4. However the shortest hybrid in season 2013 (203.5 cm) was Pan-7033, but the shortest one (168.5 cm) in season 2014 wasAusigold7 (Table 8). Mean plant height was (214.01 cm) in season 2013, while it was (175.2 cm) in season 2014. The coefficients of variation were 3.5% and 6.1% for season 2013 and 2014, respectively (Table 8).

4.1.1.4 Stem diameter (cm): In season 2013 at Ellkandi the thickest stem diameter (2.28 cm) was registered for SFH 301, while the thinnest stems diameter (1.75 cm) were showed by SFH302, Pan-7033 and Opera (Table 7). In season 2014 the thickest stems diameter (3.05 cm) were registered for Ausigold7 and Ausigold4, while the thinnest one (2.15 cm) was showed by Hysun-33. Mean stem diameter in season 2013 was (1.9 cm) and it was (2.8 cm) in season 2014 (Table 7).The coefficients of variation were (2.1%) and (11.4%) for season 2013 and 2014 respectively. At Essuki the thickest stem diameter in season 2013 (2.85 cm) wasAusigold7, while the thinnest one (2.05 cm) was Ausigold4 (Table 8).However, in season 2014 the thickest stem diameter (2.35 cm) was Pan-7351 and the thinnest one (1.70 cm) was SFH310. Mean stem diameter in season 2013 was (2.46 cm),while it was (2.00 cm) in season 2014. The coefficients of variation were (11.4%) and (16.6%) for season 2013 and 2014, respectively (Table 8).

4.1.1.5 Head diameter (cm): At Ellkandi and in season 2013 the largest head diameter (16.6 cm) was registered for Hysun-33, while the smallest one (13.2 cm) was shown by Pan-7033. On the other hand the largest heads diameter in season 2014 (23.50 cm) were scored by Pan-7351 and Aguara-4, while the smallest ones 18.5 were obtained by Ausigold4 and SFH310 (Table 7). Means head diameter were (15.00 cm) and (21.00 cm) for season 2013 and 2014, respectively. The coefficients of variation were (11.6%)and (10.7%) for season 2013 and 2014 respectively (Table 8). At Essuki and in season 2013, the largest heads diameter (23.50 cm) were obtained by Aguara-4 and Pan-7351, while the smallest ones (18.50 cm) were registered for Hysun-33 and Ausigold4 (Table 9). In season 2014 the largest heads diameter (21.25 cm) were scored by SFH 302 and SFH310, while the smallest head diameter (17.00 cm) was obtained by SFH 301. Mean head diameter in season 2013 was (21.01 cm) and it was (18.8 cm) in season 2014. The coefficients of variation were 10.7% and 12.5% for season 2013 and 2014, respectively (Table 9).

4.1.1.6 Number of seeds per head: At Ellkandi and in season 2013 SFH 301(1221seeds) scored the highest number of seeds per head and Pan-7033 (781 seeds) recorded the lowest number of seeds per head (Table 7). In season 2014 at Ellkandi also SFH-301 (1302 seeds) scored the highest number of seeds per head, while Pan-7033(822 seeds) scored the lowest number of seeds per head. Mean number of seeds per head in season 2013 was (988 seeds) and (1073 seeds) in season 2014. The coefficients of variation were, 2.1% and 4.7% for season 2013 and 2014 respectively (Table 7). At Essuki SFH-301(1290 seeds) scored the highest number of seeds per head in season 2013 and Pan-7033 (810 seeds) the lowest number of seeds per head (Table 8). However in season 2014Pan-7033 (1257 seeds) showed the highest seeds number per head, while Hysun-33 (855 seeds) registered the lowest number of seeds/head. Mean number of seeds per head in season 2013 was (1072 seeds) and (1034 seeds) in season 2014. The coefficients of variation were, 4.7% and 6.5% for season 2013 and 2014, respectively (Table 8).

4.1.1.7 Empty seeds (%): In season 2013 the highest empty seeds percentage at Ellkandi (8.6%)were scored byAusigold61 and Pan-7049, while SFH302 (6.2%) was the lowest empty seeds percentage (Table 7). However, in season 2014 the highest empty seeds% (7.9%) was scored by Pan-7049, but the lowest empty seeds percentage (5.9%) was SFH-304.Mean empty seeds percentage in season 2013 was 7.5% and it was 7.0% in season 2014. The coefficients of variation were 16.5% and 17.4% in season 2013 and 2014, respectively (Table 7). At Essuki the highest empty seeds percentage in season 2013 (14.5%) was scored by Opera, but the lowest one (9.0%) was SFH-304. In season 2014 the highest empty seeds percentage (15.8%) was also Opera, while the lowest empty seeds percentage (8.4%) was SFH-302 (Table 8). Mean empty seeds percentage in season 2013 at Essuki was 11.7% and it was 11.8 in season 2014. The coefficients of variation were 17.4% and 11.4% for season 2013 and 2014, respectively (Table 8).

4.1.1.8 1000-seed weight (g): In season 2013 at Ellkandi, the highest 1000-seed weight (45.25g) was Pan-7033 and the lowest one (20.25g) was Hysun-33,while in season 2014 the highest 1000-seed weight (37.10g) was also Pan-7033 but the lowest one (22.00g) was Pan-7351 (Table 7). Mean 1000-seed weight (g) was (31.85g) in season 2013 and it was (28.54g) in season 2014.The coefficients of variation were 18.0% and 13.4% for season 2013 and 2014, respectively (Table 7). At Essuki, in season 2013, the highest 1000-seed weight (37.10g) was Pan-7033 and the lowest one (22.00g) was Hysun-33,while in season 2014 the highest 1000-seed weight (41.00g) was Pan-7033 and the lowest one (18.00 g) was Pan-7351(Table 8).Mean1000-seed weight were (29.30g) and (32.43g) for season 2013 and 2014 respectively.The coefficients of variation were 13.4% and 11.6% for seasons2013 and 2014, respectively (Table 8).

4.1.1.9Seed yield per plant (g): At Ellkandi and in season 2013the highest seed yield/head (44.1g) was Pan-7057and the lowest one (22.3g) was Hysun-33, while in season 2014, the highest one (43.47g) was Aguara-4 and the lowest one (20.2 g) was Oepra (Table 7). Mean seed yield per plant (g)was (31.68g) for season 2013 and it was (30.26g) in season 2014. The coefficients of variation were 17.9% and 8.5% for season 2013 and 2014 respectively (Table 7). At Essuki and in season2013 the highest seed yield/head (40.52 g) was Ausigold61 and the lowest one (20.00 g) was Ausigold4. In season 2014 the highest seed yield (44.38 g) was Pan-7057and the lowest one (18.12g) was Pan-7351(Table 8). Mean seed yield/head in season 2013 was (26.52 g), but it was (29.38 g) in season 2014.The coefficients of variation were 8.5% and 12.5% for seasons 2013 and 2014, respectively (Table 8).

4.1.1.10 Seed yield (t/ha): At Ellkandi and in season 2013, the highest seed yield/ha (2.35t/ha) was Pan-7057 and the lowest one (1.18t/ha) was Aguara-4, but in season 2014 the highest One (2.31t/ha) was Aguara-4 and the lowest one (1.07t/ha) was Opera (Table 7). Mean seed yield/ha was (1.68t/ha) in season 2013 and it was (1.61t/ha) in season 2014. The coefficients of variation for this character in season 2013 was 15.1% and it was 6.7% in seasons 2014 (Table 7). At Essuki and in season 2013, the highest seed yield/ha (2.16 t/ha) was Ausigold61, while the lowest ones (1.07t/ha) were Aguara-4 and Pan-7351. In season 2014 the highest seed yield t/ha (2.36 t/ha) was Pan-7057, but the lowest one (0.97t/ha) was Pan-7351(Table 8). Mean seed yield (t/ha) in season 2013 was (1.41 t/ha) and it was (1.44 t/ha) in season 2014. The coefficients of variation were 6.7% and 12.8% for season 2013 and 2014, respectively (Table 8).

4.1.1.11 Oil yield (t/ha): At Ellkandi and in season 2013, the highest oil yield (t/ha) (1.104 t/ha) was Pan-7057, while the lowest one (0.306 t/ha) was SFH310 (Table 7). In season 2014, the highest oil yield (t/ha) (0.937 t/ha) was

Ausigold7 and the lowest one (0.300 t/ha) wasPan-7351(Table 7). Mean oil yield was (0.622 t/ha) in season 2013 and it was (0.598 t/ha) in season 2014. The coefficients of variation were (10.5%) and (4.0%) for season 2013 and 2014,respectively (Table 7). At Essuki and in season 2013, the highest oil yield (t/ha) (0.987 t/ha) was Pan-7057 and the lowest one (0.267 t/ha) was Pan-7351 .In season 2014, the highestoil yield (t/ha) (1.109 t/ha) was Pan-7057 and the lowest one (0.242 t/ha) was Pan-7351 (Table 8). Mean oil yield (t/ha) in season 2013 was (0.530 t/ha) and it was (0.590 t/ha) in season 2014. The coefficients of variation were (4.0%) and (1.9%) for season 2013 and 2014, respectively (Table 8).

4.1.2 Phenotypic (ph δ^2), genotypic (δ^2g) and environmental (δ^2e) variances:

The estimated values of the phenotypic, genotypic and environmental variances, for eleven characters, at both locations, are presented in (Table 9).At Ellkandi the phenotypic variances for most of the characters were greater in season 2014 than in season 2013except for empty seeds percentage and 1000-seeds weight (g),the phenotypic variances for which were smaller in season 2014 than in season 2013 (Table 9). In both seasons the genotypic variances for most of the characters were greater than the environmental variances, except or plant height (cm) in both seasons, stem diameter (cm) in season 2014, head diameter (cm) in season 2014, empty seeds percentage in season 2014, seed yield/p (g) in both seasons and oil content (t/ha) in season 2014 their environmental variances were greater than the genotypic ones (Table 9). In season 2013,the highest phenotypic variance (4.290) and genotypic variance (3.474) were scored by 1000- seeds weight (g), while the lowest ones (0.003) and (0.002) were registered for oil yield (t/ha) (Table 9). On the other hand the highest phenotypic variance (3.679) and genotypic variance (3.651) in season 2014 were scored by days to physiological maturity (Table 9). Whereas, the lowest phenotypic (0.003) and genotypic (0.002) variances in season 2014 were scored by oil yield (t/ha) (Table 9).At Essuki the genotypic variances for most of the investigated characters in both seasons were greater than the environmental ones except for empty seeds percentage in both seasons, seed yield/p (g) in season 2013 and seed yield (t/ha) in both seasons (Table 9).The highest phenotypic (2.263) and genotypic (2.136) variances in season 2013 were scored by days to physiological maturity (Table 9). On the other hand the lowest phenotypic (0.003) and genotypic (0.002) variances in season 2013 at Essuki were scored by oil yield (t/ha) (Table 4.7). In season 2014 at Essuki the highest phenotypic (4.85) and genotypic (4.52) variances were scored by 1000-seeds weight (g), while the lowest phenotypic (0.003) and genotypic (0.002) variances were scored by oil yield (t/ha) (Table 9).

4.1.3 Phenotypic (PCV%) and genotypic (GCV %) coefficient of variation:

Estimates for phenotypic (PCV %) and genotypic (GCV %) coefficient

Table 7: Means of growth characters of 15 sunflower hybrids evaluated at Ellkandi in summer 2013 and 2014.

Hybrid	Days to 50% flowering		Days to Maturity)		Plant Height (cm)		Stem Diameter (cm)		Head diameter (cm)	
	2013	**2014**	**2013**	**2014**	**2013**	**2014**	**2013**	**2014**	**2013**	**2014**
SFH301	59^{a}	57^{a}	100^{a}	85^{a}	147.2^{ab}	225.3^{bc}	2.275^{b}	2.50^{a}	16.1^{b}	21.5^{b}
SFH302	59^{a}	59^{a}	101^{b}	84^{a}	147.0^{ab}	219.0b	1.75^{a}	2.70^{b}	14.0^{a}	20.3^{a}
SFH303	58^{a}	58^{a}	99^{a}	84^{a}	153.5^{b}	230.5^{bc}	2.20^{b}	2.70^{b}	14.8^{a}	19.5^{a}
SFH304	59^{a}	57^{a}	101^{b}	87^{b}	152.2^{b}	222.7^{bc}	2.00^{ab}	2.30^{a}	14.9^{a}	21. 0^{b}
SFH310	59^{a}	58^{a}	100^{a}	85^{a}	140.8^{a}	218.0^{b}	2.00^{ab}	2.60^{ab}	15.4^{a}	18.5^{a}
Ausigold7	59^{a}	59^{a}	99^{a}	84^{a}	159.0^{bc}	222.8^{bc}	2.00^{ab}	3.05^{c}	14.6^{a}	21.0^{b}
Ausigold4	58^{a}	57^{a}	100^{a}	82^{a}	150.2^{b}	217.3^{b}	2.20^{b}	3.05^{c}	15.2^{ab}	18.5^{a}
Ausigold61	59^{a}	61^{b}	99^{a}	83^{a}	155.8^{bc}	214.0^{ab}	1.90^{a}	2.50^{a}	14.5^{a}	21.8^{b}
Pan-7033	59^{a}	59^{a}	100^{a}	87^{b}	148.0^{ab}	208.5^{a}	1.75 ^{a}	2.90^{b}	13.2^{a}	21.5^{b}
Pan-7049	60^{b}	58^{a}	100^{a}	86^{b}	142.8^{a}	220.0^{b}	1.90^{a}	2.30^{a}	14.5^{a}	21. 0^{b}
Pan-7057	59^{a}	59^{a}	102^{b}	89^{b}	144.5^{ab}	212.8^{ab}	2.20^{b}	2.50^{a}	16.3^{b}	22.3^{b}
Pan-7351	59^{a}	58^{a}	99^{a}	82^{a}	153.5^{b}	215.0^{b}	1.90^{a}	2.30^{a}	15.3^{ab}	23.5^{b}
Opera	59^{a}	58^{a}	99^{a}	85^{a}	143.0^{ab}	223.3^{bc}	1.75^{a}	2.80^{b}	13.8^{a}	20.0^{a}
Aguara-4	59^{a}	59^{a}	99^{a}	84^{a}	147.2^{ab}	217.5^{bc}	2.10^{b}	2.40^{a}	15.4^{ab}	23.5^{b}
Hysun-33	59^{a}	58^{a}	101^{b}	83^{a}	143.5^{ab}	218.8^{b}	2.00^{ab}	2.15^{a}	16.6^{b}	21.5^{b}
Mean	**59**	**58**	**100**	**85**	**148.5**	**219.0**	**1.9**	**2.8**	**15.0**	**21.0**
SE$\pm$	0.95	1.2	1.39	2.16	4.49	3.86	0.20	0.15	0.87	1.13
CV%	3.2	4.1	2.8	5.1	6.1	3.5	2.09	11.4	11.6	10.70

Any means have the same letter(s) are not significantly different according to Duncan Multiple

Table.7: (Cont) Ellkandi.

Hybrid	Number of seeds per head		Percentage of empty seeds (%)		1000- seed weight (gm)		Seed yield per plant (gm)		Seed yield (t/ha)		Oil yield (t/ha)	
	2013	**2014**	**2013**	**2014**	**2013**	**2014**	**2013**	**2014**	**2013**	**2014**	**2013**	**2014**
SFH 301	1221^{cde}	1303^{i}	7.9^{ab}	7.3^{ab}	34.50^{bc}	28.00^{b}	32.88^{ab}	36.50^{bc}	1.75^{c}	1.94^{cd}	0.735^{cd}	0.814^{de}
SFH 302	870^{ab}	965^{bc}	6.2^{a}	6.3^{a}	32.00^{b}	28.90^{b}	28.28^{a}	27.80a	1.50^{b}	1.48^{b}	0.495^{b}	0.488^{b}
SFH 303	990^{b}	1006^{bc}	7.6^{ab}	7.1^{ab}	26.25^{ab}	23.70^{a}	25.80^{a}	23.80^{a}	1.37^{ab}	1.26^{ab}	0.411^{ab}	0.378^{ab}
SFH 304	1031^{bc}	1156^{fg}	6.7^{a}	5.9^{a}	27.50^{ab}	23.83^{a}	34.45^{ab}	27.50^{a}	1.83^{cd}	1.46^{b}	0.677^{c}	0.540^{b}
SFH 310	1024^{bc}	1171^{fg}	8.1^{b}	7.6^{ab}	35.50^{bcd}	32.00^{c}	31.35^{ab}	38.40^{cd}	1.67^{b}	2.04^{de}	0.684^{c}	0.836^{de}
Ausigold7	1017^{bc}	1104^{ef}	7.7^{ab}	7.0^{ab}	29.00^{b}	27.20^{ab}	32.40^{ab}	30.00^{b}	1.72^{bc}	1.60^{bc}	0.584^{bc}	0.544^{b}
Ausigold4	1097^{cd}	1215^{ghi}	7.9^{ab}	7.5^{ab}	34.50^{bc}	33.00^{c}	36.63^{bc}	40.10^{cd}	1.95^{de}	2.13^{e}	0.858^{d}	0.937^{ef}
Ausigold61	1002^{b}	1077de	8.6^{b}	7.8^{ab}	38.75^{cd}	34.60^{cde}	32.18^{ab}	38.52^{cd}	1.71^{bc}	2.05^{de}	0.769^{cd}	0.922^{ef}
Pan- 7033	781^{a}	822^{a}	6.8^{a}	6.1^{a}	45.25^{cde}	37.10^{cde}	33.33^{ab}	30.5^{b}	1.77^{c}	1.62^{bc}	0.690^{c}	0.631^{c}
Pan- 7049	862^{ab}	905^{b}	8.6^{b}	7.9^{ab}	26.25^{ab}	24.55^{a}	30.18^{a}	22.30^{a}	1.60^{b}	1.18^{a}	0.448^{ab}	0.330^{a}
Pan-7057	1064^{bc}	1194^{fgh}	6.3^{a}	6.1^{a}	37.8^{c}	33.1^{cd}	44.1^{cd}	29.5^{cd}	2.35^{ef}	1.57^{bc}	1.10^{de}	0.74^{cd}
Pan- 7351	1002^{b}	1027^{cd}	6.4^{a}	6.0^{a}	23.75^{ab}	22.00^{a}	25.25^{a}	22.60^{a}	1.34^{a}	1.20^{a}	0.335^{a}	0.300^{a}
Opera	795^{a}	901^{b}	8.5^{b}	7.0^{ab}	30.25^{b}	22.50^{a}	30.4^{a}	20.2^{a}	1.62^{b}	1.07^{a}	0.550^{b}	0.36^{ab}
Aguara-4	1114^{cd}	1249^{hi}	8.2^{b}	7.7^{ab}	36.25^{c}	34.80^{cde}	35.73^{bc}	43.47^{de}	1.90^{de}	2.31^{ef}	0.700^{c}	0.854^{de}
Hysun-33	949^{b}	1000^{cd}	7.7^{ab}	7.4^{ab}	20.25^{a}	22.80^{a}	22.30 ^{a}	22.82^{a}	1.18^{a}	1.21^{a}	0.306^{a}	0.314^{a}
Mean	***988***	***1073***	***7.5***	***7.0***	***31.85***	***28.54***	***31.68***	***30.26***	***1.68***	***1.61***	***0.623***	***0.599***
SE+	103.8	25.3	0.62	0.61	2.87	1.91	3.03	1.31	0.05	0.02	2.04	0.82
CV%	2.1	4.7	16.5	17.4	18.0	13.4	17.9	8.5	15.1	6.7	10.5	4.00

Any means have the same letter(s) are not significantly different at 0.05 level according to Duncan Multiple Range Test

Table 8: Means of growth characters of 15 sunflower hybrids evaluated at Essuki in summer 2013 and 2014.

Hybrid	**Days to 50% flowering**		**Days to maturity**		**Plant height (cm)**		**Stem diameter(cm)**		**Head diameter (cm)**	
	2013	**2014**	**2013**	**2014**	**2013**	**2014**	**2013**	**2014**	**2013**	**2014**
SFH301	57^{a}	59^{a}	85^{b}	87^{b}	220.25^{bc}	177.8^{a}	2.525^{cd}	1.800^{ab}	21.50^{a}	17.00^{a}
SFH302	57^{a}	61^{b}	84^{a}	88^{b}	214.00^{b}	176.2^{a}	2.675^{de}	1.825^{ab}	20.25^{a}	21.25^{b}
SFH303	58^{a}	62^{b}	84^{a}	86^{a}	225.50^{c}	176.5^{a}	2.650^{de}	2.250^{b}	19.50^{a}	18.00^{a}
SFH304	55^{a}	56^{a}	87^{b}	92^{c}	217.75^{b}	169.0^{a}	2.200^{b}	1.925^{ab}	21.00^{a}	18.50^{a}
SFH310	58^{a}	57^{a}	83^{a}	91^{c}	213.75^{ab}	178.2^{a}	2.150^{a}	1.700^{a}	21.50^{a}	21.25^{b}
Ausigold7	59^{b}	62^{b}	84^{a}	86^{a}	217.75^{b}	168.5^{a}	2.850^{ef}	1.925^{ab}	21.00^{a}	18.75^{a}
Ausigold4	57^{a}	55^{a}	82^{a}	91^{c}	212.25^{ab}	186.8^{a}	2.050^{ef}	1.750^{a}	18.50^{a}	17.75^{a}
Ausigold61	65^{c}	61^{b}	83^{a}	88^{b}	209.00^{ab}	170.5^{a}	2.525^{cd}	1.875^{ab}	21.75^{a}	18.75^{a}
Pan-7033	62^{b}	59^{a}	87^{b}	86^{a}	203.50^{a}	181.2^{a}	2.725^{ef}	2.150^{b}	21.50^{a}	17.75^{a}
Pan-7049	58^{a}	60^{b}	86^{b}	85^{a}	215.00^{b}	173.8^{a}	2.300^{b}	2.000^{ab}	21.00^{a}	19.75^{ab}
Pan-7057	66^{c}	65c	89^{b}	89^{b}	207.75^{ab}	171.0^{a}	2.475^{bc}	1.750^{a}	22.25^{a}	17.25^{a}
Pan-7351	62^{b}	58^{a}	82^{a}	84^{a}	210.00^{ab}	169.2^{a}	2.275^{b}	2.350^{bc}	23.50^{a}	19.75^{ab}
Opera	63^{b}	61^{b}	85^{a}	84^{a}	218.25^{b}	180.0^{a}	2.500^{cd}	2.000^{ab}	20.00^{a}	18.25^{a}
Aguara-4	57^{a}	60^{b}	84^{a}	91^{c}	212.50^{ab}	172.0^{a}	2.425^{bc}	2.400^{bc}	23.50^{a}	18.75^{a}
Hysun-33	58^{a}	59^{a}	85^{a}	90^{c}	213.00^{ab}	176.8^{a}	2.625^{d}	1.875^{ab}	18.50^{a}	19.75^{ab}
Mean	***59***	***60***	***85***	***88***	***214.01***	***175.16***	***2.46***	***2.00***	***21.01***	***18.8***
SE±	1.190	1.326	2.160	2.941	3.862	5.31	0.146	0.163	1.128	1.179
CV%	4.1	4.4	5.1	6.7	3.5	6.1	11.4	16.6	10.7	12.5

Any means have the same letter(s) are not significantly different according to Duncan Multiple

Table.8: (Cont) Essuki.

Hybrid	Number of seeds per head		Percentage of empty seeds (%)		1000- seed weight (gm)		Seed yield per plant (g)		Seed yield (t/ha)		Oil yield (t/ha)	
	2013	**2014**	**2013**	**2014**	**2013**	**2014**	**2013**	**2014**	**2013**	**2014**	**2013**	**2014**
SFH 301	1290^{hi}	968^{b}	10.5^{a}	13.7^{b}	28.00^{b}	37.00^{efg}	37.30^{cde}	35.78^{de}	1.98^{c}	1.90^{c}	0.831^{c}	0.798^{bc}
SFH 302	953^{bc}	1226^{def}	9.4^{a}	8.4^{a}	28.90^{b}	34.00^{ef}	20.90^{ab}	22.6^{ef}	1.11^{b}	1.20^{b}	0.363^{a}	0.396^{a}
SFH 303	1065de	999^{b}	13.9^{ab}	11.0^{b}	34.60^{cd}	40.00^{gh}	20.80^{a}	24.93^{b}	1.10^{b}	1.32^{b}	0.330^{a}	0.396^{a}
SFH 304	1144^{gh}	1147^{cd}	9.0^{a}	9.5^{a}	23.83^{a}	32.00^{de}	21.50^{ab}	36.67^{de}	1.14^{b}	1.95^{c}	0.416^{b}	0.711^{bc}
SFH 310	1169^{gh}	940^{ab}	12.7^{ab}	11.2^{b}	32.00^{bc}	35.00^{efg}	23.80^{cde}	18.6^{cd}	1.26^{b}	0.99^{a}	0.327^{a}	0.257^{a}
Ausigold7	1192^{ef}	1112^{cd}	11.1^{ab}	9.6^{a}	27.20^{b}	28.00^{cd}	36.00^{def}	31.30^{bcd}	1.92^{c}	1.67^{bc}	0.844^{c}	0.734^{bc}
Ausigold4	1203^{ghi}	868^{a}	10.6^{ab}	14.0^{bc}	33.00^{c}	36.00^{efg}	20.00^{def}	21.00^{bcd}	1.06^{a}	1.12^{b}	0.360^{a}	0.380^{a}
Ausigold61	1064de	999^{b}	12.3^{ab}	11.0^{b}	34.60^{cd}	40.00^{gh}	40.52^{cde}	39.82^{ef}	2.16^{c}	2.12^{c}	0.972^{c}	0.954^{c}
Pan-7033	810^{a}	1257^{def}	11.8^{a}	12.5^{b}	37.10^{de}	41.00^{h}	20.50^{bc}	40.55^{g}	1.09^{a}	2.16^{c}	0.425^{b}	0.842^{c}
Pan-7049	893^{b}	1054^{bc}	12.0^{ab}	14.9^{bc}	24.55^{a}	25.25^{bc}	21.00^{a}	20.20^{bc}	1.12^{b}	1.07^{a}	0.313^{a}	0.299^{a}
Pan-7057	1182^{gh}	1127^{cd}	10.7^{a}	8.7^{a}	33.10^{c}	39.00^{fgh}	39.47^{c}	44.38^{f}	2.10^{c}	2.36^{d}	0.987^{c}	1.109^{d}
Pan-7351	1015^{cd}	981^{b}	10.6^{a}	9.1^{a}	22.00^{a}	18.00^{a}	20.10^{a}	18.12^{a}	1.07^{a}	0.97^{a}	0.267^{a}	0.242^{a}
Opera	889^{b}	1118^{cd}	14.5^{ab}	15.8^{c}	22.50^{a}	28.00^{cd}	30.22^{a}	31.27^{bcd}	1.61^{bc}	1.66^{bc}	0.547^{b}	0.564^{b}
Aguara-4	1237^{ghi}	866^{ab}	13.8^{ab}	15.1^{c}	34.80^{cd}	31.25^{de}	20.10.^{de}	22.5^{bc}	1.07^{a}	1.21^{b}	0.395^{a}	0.447^{b}
Hysun-33	988^{cd}	855^{a}	11.6^{ab}	12.8^{b}	22.80^{a}	22.00^{ab}	25.7	33.00^{a}	1.42^{b}	1.76^{bc}	0.582^{b}	0.721^{bc}
Mean	**1072**	**1034**	**11.7**	**11.8**	**29.26**	**32.43**	**26.52**	**29.38**	**1.41**	**1.56**	**0.530**	**0.590**
SE+	**25.31**	**33.87**	**0.**	**0.674**	**1.910**	**1.812**	**1.310**	**2.041**	**0.02**	**0.034**	**0.822**	**0.37**
CV%	**4.7**	**6.5**	**17.4**	**11.4**	**13.4**	**11.6**	**8.5**	**12.5**	**6.7**	**12.8**	**4.0**	**1.9**

Any means have the same letter(s) are not significantly different at 0.05 level according to Duncan Multiple Range Test of variation for eleven characters in season 2013 and 2014 at both locations are depicted in (Table.10).The highest phenotypic (PCV%)(13.46) and genotypic(GCV%) (10.90) coefficients of variation were registered for 1000-seeds weight (g) in season 2013 at Ellkandi, while the lowest ones (0.014) and (0.013) were registered for number of seeds per head. In season 2014 the highest phenotypic coefficients of variation(PCV%)(10.77) and genotypic coefficient of variation (GCV%) (10.17) were scored by head diameter (cm), while the lowest phenotypic coefficients of variation(PCV %) (0.018) and genotypic coefficient of variation (GCV%) (0.017) were obtained by number of seeds per head (Table 10).At Essuki the heist phenotypic coefficient of variation(PCV%) (9.64) was scored by head diameter (g) in season 2013, while the lowest one (0.007) was obtained by number of seeds per head (Table 10). Whereas, the highest and lowest genetic coefficients of variation(GCV%) (8.35) and (0.005) were scored by head diameter (g) and number of seeds per head respectively(Table 10). In season 2014 the highest phenotypic coefficient of variation(PCV%) (14.95) was scored by 1000-seeds weight (g), while the lowest one (0.004) was registered by number of seeds per head. On the other hand the highest genotypic coefficient of variation (GCV%) (13.93) was also scored by 1000-seeds weight (g) in season 2014 (Table 10), while the lowest one (0.003) was scored by number of seeds per head.

4.1.4 Heritability (h^2_B estimates Genetic advance (GA) and genetic advance as percentage of mean (GA %):

The broad sense heritability (h^2_B) estimates, genetic advance (GA)and genetic advance as percentage of mean (GA %) for both seasons and at both locations aredisplayed in (Table11). The heritability estimates in broad sense (h^2_B) was generally high for most of the characters. At Ellkandi andin season 2013the heritability estimates ranged from 24.5% to 94.2%, while in season 2014 it was ranged from 27.7%to 98.7%. The characters showed relatively high (>50%) heritability estimates in season 2013, were days to 50% flowering, days to physiological maturity, stem diameter (cm), head diameter, number of seeds per plant, empty seeds (%), 1000-seeds weight (g), seed yield (t/ha) and oil yield (t/ha). However characters registered low heritability estimates ($\leq$50%) in season 2013, were plant height, empty seeds (%) and seed yield per plant (g).On the other hand characters showed relatively high heritability estimates (>50%) in season 2014, were days to 50% flowering, days to physiological maturity, stem diameter (cm), number of seeds per plant,1000-seeds weight (g), seed yield (t/ha) and oil yield (t/ha).Whereas, characters revealed low heritability (< 50%) estimates in season 2014were plant height (cm), head diameter (cm), empty seeds (%) and seed yield per plant (g)(Table 11).At Essuki and in season 2013 the heritability estimates (h^2_B) ranged from (22.6%)to (98.2%).Characters showed relatively high heritability estimates (>50%) in season 2013 were, days to 50% flowering, days to physiological maturity, plant height (cm), stem diameter (cm), head diameter (cm), number of seeds per head,1000-seeds weight (g) and oil yield (t/ha). Whereas, characters revealed low heritability estimates (<50%) were empty seeds (%), seed yield per plant (g) and seed yield (t/ha) (Table 11). Whoever, in season 2014 at Essuki the heritability estimates ranged from (26.8%) to (97.0%). Characters relatively showed high heritability estimates values (> 50%) were days to 50% flowering, days to physiological maturity, plant height (cm), stem diameter (cm), head diameter (cm), number of seeds per plant, 1000-seeds-weight (g) seed yield per plant (g) and oil yield (t/ha), while characters showed relatively low heritability (< 50%) estimates in season 2014 at Essuki were empty seeds (%) and seed yield (t/ha) (Table 11).

At Ellkandi days to physiological maturity scored the highest genetic advance (3.57) and (3.91) in season 2013 and 2014 respectively, while oil yield (t/ha) scored the lowest genetic advance (0.07) and (0.08)in season 2013 and 2014 respectively(Table 11). The highest genetic advance as percentage of mean (GA %) (18.4) in season 2013 was scored by stem diameter (cm), while the lowest one (0.07) was scored by number of seeds per head. However in season 2014 the highest genetic advance as percentage of mean (GA %) (12.25) was scored by oil yield (t/ha), while the lowest one (0.08) was scored by number of seeds per plant. At Essuki the highest genetic advance(GA) (2.9) in season 2013 was scored by days to physiological maturity, while in season 2014 the highest one (4.22) was scored by 1000-seeds weight (g). On the other hand the lowest genetic advance (GA) (0.07) was scored by oil yield (t/ha) in both seasons. The highest genetic advance as percentage of mean (GA %) (14.1) and (26.5) were scored by stem diameter (cm) in season 2013 and 2014 respectively(Table 11).

4.2 The phenotypic correlations:

The results of correlation among the fifteen characters are presented in (Table 12). Days to 50% flowering correlated positively and non-significantly with physiological maturity, stem diameter (cm), head diameter(cm), number of seeds per head, empty seed% and oil yield (t/ha), while it haspositively and significantly ($P>0.05$) correlated with plant height (cm),1000-seed weight (g) and seed yield per plant (g). On the other hand, days to 50% flowering correlated positively and highly significantly ($p<0.001$) with seed yield (t/ha) (Table 12). Days to physiological maturity correlated negatively and highly significantly ($P<0.001$) with empty seed percentage, but it has correlated positively and non-significantly with the other traits. Plant height (cm) correlated positively and non-significantly with stem diameter (cm),head diameter (cm), number of seeds per head, empty seeds percentage and oil yield (t/ha), while it has correlated positively and significantly ($P< 0.05$) with1000- seed weight (g) and seed yield per plant (g).Whereas, it has correlated positively and highly significantly ($P<0.001$) with seed yield (t/ha).Stem diameter correlated positively and significantly($P<0.05$)with head diameter (cm) and number of seeds per head, while positively and non-significantly with the rest of the characters. Head diameter correlated positively and non-significantly with number of seeds per head, seed yield per plant (g), seed yield (t/ha) and oil yield (t/ha) and negatively and highly significantly($P<0.001$) with empty seeds percentage, while positively and significantly ($P<0.05$) with1000-seed weight(g). Number of seeds per head correlated positively and non-significantly with empty seed percentage and oil yield (t/ha), while positively and significantly with 1000- seed weight (g), seed yield per plant (g) and seed yield (t/ha).Empty seeds percentage correlated positively and non-significantly with 1000-seeds weight (g), while negatively and non-significantly correlated with seed yield per plant (g), seed yield (t/ha) and oil yield (t/ha). 1000-seeds weight correlated positively and highly significantly ($P<0.001$) with seed yield/p (g) and seed yield (t/ha), while positively and non-significantly with oil yield (t/ha). Seed yield per plant (g) correlated positively and highly significantly ($P<0.001$) with seed yield (t/ha) and positively and non-significantly with oil yield (t/ha). Seed yield (t/ha) correlated positively and non-significantly with oil yield (t/ha) (Table 12).

Table 9: The phenotypic (δ^2ph), genotypic (δ^2g)) and environmental (δ^2e) variances for 11 characters of 15 sunflower hybrids evaluated at two locations for two seasons.

at Ellkandi						
Character	**Summer 2013**			**Summer 2014**		
	δ^2ph	**δ^2g**	**δ^2e**	**δ^2ph**	**δ^2g**	**δ^2e**
Days to50% flow	0.510	0.428	0.082	0.980	0.839	0.0141
Days to maturity	3.38	3.187	0.192	3.697	3.651	0.046
Plant height (cm)	2.66	0.653	2.16	2.965	1.474	1.492
Stem diameter (cm)	0.038	0.034	0.005	0.0730	0.006	0.0130
Head diameter (cm)	0.857	0.782	0.0752	2.263	0.991	1.272
Number of seeds / p	0.145	0.134	0.0107	0.2000	0.193	0.006
Empty seeds %	0.547	0.273	0.0.254	0.508	0.141	0.367
1000- seeds weight	4.290	3.474	0.820	2.698	2.334	0.354
Seed yield / p	0.730	0.341	0.387	0.755	0.344	0.411
Seed yield (t /ha)	0.005	0.003	0.002	0.004	0.003	0.001
Oil yield (t/ ha)	0.003	0.002	0.0004	0.003	0.002	0.003
at Essuki						
Character	**Summer 2013**			**Summer 3014**		
	δ^2ph	**δ^2g**	**δ^2e**	**δ^2ph**	**δ^2g**	**δ^2e**
Days to50% flow	0.732	0.719	0.0135	0.114	0.096	0.017
Days to maturity	2.263	2.136	0.127	1.684	1.545	0.138
Plant height (cm)	2.715	1.748	0.966	2.750	1.717	1.032
Stem diameter (cm)	0.036	0.0321	0.004	0.068	0.066	0.003
Head diameter (cm)	2.027	1.756	0.271	1.684	1.351	0.330
Number of seeds / p	0.0832	0.0617	0.0215	0.048	0.037	0.0112
Empty seeds %	0.432	0.171	0.261	0.621	0.167	0.454
1000- seeds weight	2.252	2.007	0.245	4.85	4.52	0.328
Seed yield / p	0.611	0.145	0.466	0.0852	0.0 81	0.004
Seed yield (t /ha)	0.015	0.0034	0.007	0.016	0.005	0.0132
Oil yield (t/ ha)	0.003	0.002	0.0007	0.003	0.002	0.001

Table 10: The phenotypic (PCV %) and genotypic (GCV %) coefficient of variation in11 characters of 15 sunflower hybrids evaluated at two locations for two seasons

at Ellkandi				
Character	**Summer 2013**		**Summer 2014**	
	PCV%	**GCV%**	**PCV%**	**GCV%**
Days to50% flow	0.864	0.725	1.689	1.539
Days to maturity	3.380	3.187	4.349	4.295
Plant height (cm)	1.791	0.439	1.210	0.673
Stem diameter (cm)	2.000	1.789	2.607	0.214
Head diameter (cm)	5.710	5.213	10.77	10.17
Number of seeds / p	0.014	0.013	0.018	0.017
Empty seeds %	7.293	3.640	7.257	2.014
1000- seeds weight	13.46	10.90	9.453	8.177
Seed yield / p	2.304	1.076	2.495	1.136
Seed yield (t /ha)	0.297	0.178	0.975	0.795
Oil yield (t/ ha)	0.481	0.321	0.500	0.333
at Essuki				
Character	**Summer 2013**		**Summer 2014**	
	PCV%	**GCV%**	**PCV%**	**GCV%**
Days to50% flow	1.240	1.218	0.193	0.160
Days to maturity	2.662	2.544	1.913	0.903
Plant height (cm)	1.268	0.816	1.569	0.980
Stem diameter (cm)	1.463	1.304	3.400	3.300
Head diameter (cm)	9.647	8.357	8.957	7.186
Number of seeds / p	0.007	0.005	0.004	0.003
Empty seeds %	3.693	1.461	5.262	1.415
1000- seeds weight	7.696	6.859	14.95	13.93
Seed yield / p	2.303	0.546	2.893	2.760
Seed yield (t /ha)	1.063	0.241	1.025	0.320
Oil yield (t/ ha)	0.566	0.377	0.500	0.333

Table 11: Heritability (h^2), estimates, genetic advance (GA) and genetic advance as percentage of mean (GA %) of 11 characters in 15 sunflower hybrids evaluated at two locations for two seasons

At Ellkandi						
Character	Summer 2013			Summer 2014		
	h^2	GA	GA%	h^2	GA	GA%
Days to50% flow	84.0	1.23	2.08	85.6	1.74	3.00
Days to maturity	94.2	3.57	3.57	98.7	3.91	4.6
Plant height (cm)	24.5	0.82	0.55	49.7	1.76	0.80
Stem diameter (cm)	89.5	0.35	18.4	85.7	0.147	5.25
Head diameter (cm)	91.2	1.74	11.6	43.7	1.35	6.42
Number of seeds per head	92.4	0.72	0.07	96.5	0.88	0.08
Empty seeds (%)	50.0	0.76	10.1	27.7	0.407	5.81
1000- seeds weight (g)	81.0	3.45	10.8	86.5	2.92	10.23
Seed yield per plant (g)	46.7	0.82	2.58	45.6	0.81	2.67
Seed yield (t /ha)	60.0	0.08	5.17	81.5	0.097	6.02
Oil yield (t/ ha)	66.6	0.07	12.0	66.6	0.075	12.25
at Essuki						
Character	Summer 2013			Summer 2014		
	h^2	GA	GA%	h^2	GA	GA%
Days to50% flow	98.2	1.73	2.32	84.2	0.58	0.97
Days to maturity	94.3	2.90	3.41	91.7	2.45	2.78
Plant height (cm)	64.4	2.18	1.02	62.4	2.13	1.21
Stem diameter (cm)	89.1	0.34	14.1	97.0	0.52	26.5
Head diameter (cm)	86.6	2.45	11.6	80.2	2.14	11.4
Number of seeds per head	74.2	0.44	0.41	77.1	0.34	0.03
Empty seeds (%)	39.6	0.53	4.57	26.8	0.43	3.69
1000- seeds weight (g)	89.1	2.75	9.42	93.1	4.22	13.0
Seed yield per plant (g)	23.7	0.38	1.44	50.5	0.57	1.94
Seed yield (t /ha)	22.6	0.05	3.54	31.3	0.08	5.19
Oil yield (t/ ha)	66.6	0.07	14.1	66.6	0.07	12.5

Table 12: Show the phenotypic correlations among 11 sunflower characters of 15 sunflower hybrids evaluated at two locations for two seasons

Trait	DM	PH	SD	HD	NSP	ES	SW	SYP	SY	OY
DF	0.05	0.23*	0.15	0.16	0.03	0.12	0.19*	0.14*	0.09**	.203*
DM		0.02	0.05	0.02	0.10	-0.36**	0.01	0.07	0.09	.093
PH			0.03	0.02	0.03	0.13	0.23*	0.23*	0.16**	.076
SD				0.30**	0.23*	0.03	0.08	0.03	0.07	.277
HD					0.12	-0.26**	0.21*	0.16	0.04	.099
NSP						0.11	0.21*	0.73**	0.57**	.069
ES							0.15	-0.22	-0.09	-.165
SW								0.72**	0.60**	.128
SYP									0.82**	.107
SYH										.139

*DF= days to 50% flowering, DM= days to physiological maturity, PH = plant height (cm), SD = stem diameter (cm), HD = head diameter (cm), NSP = number of seeds per Plant, ES = percentage of emptyseeds (%), SW = 1000- seed weight (g),SYP= seed yield per plant (g) ,SY = seed yield (t/ha).& OY = oil yield

4.3 Assessment of genotype x environment interaction for yield (t/ha) and yield components in sunflower hybrids:

The combined analysis of variance and genotype by environment interaction were only carried out for those characters in which homogeneous error variance were obtained viz: head diameter (cm), number of seeds per plant, empty seeds percentage, 1000-seeds weight, seed yield per plant (g), seed yield (t/ha) and oil yield (t/ha). Table 14 shows analysis of variance for genotype x environment interaction for seed yield (t/ha) and oil yield (t/ha) over the four environments. The results of both characters were as follows:

4.3.1 Seed yield (t/ha):

Analysis of variance for G x E interaction in 15 sunflower hybrids showed highly significant (P>0.001) differences among the hybrids (G) and hybrids x environment (G x E) for this character (Table 14).

4.3.2 Oil yield (t/ha):

Analysis of variance for G x E interaction in 15 sunflower hybrids showed highly significant (P>0.001) differences among the hybrids (G) and hybrids x environment (G x E) for oil yield (t/ha) (Table 14).

4.4 Stability performance:

From the results of combined analysis, only characters that showed significant hybrid x environment (G x E) interaction were further analyzed for estimating stability of performance. Pooled analysis of variance of sunflower hybrids for seed and oil yields data across the four environments (rain fed and irrigation)was performed (Table 14). The results showed highly significant differences among the hybrids (G) and environments (E). The results also revealed that difference among hybrids and environments were also highly significant indicating the presence of genetic variability among the hybrids as well as the environments under study .The sums of squares due to environments and hybrid x environment are partitioned into environments (linear), hybrid x environment (linear) and deviations from the regression model. The significance of both these components showed that both predictable and unpredictable components shared G x E interaction.Therefore there was a need for assessing stability of performance for each of the fifteen hybrids in order to identify hybrids with superior seed and oil yield (t/ha) using Eberhart and Russell; (1966) stability model.

4.4.1 Stability of performance for seed yield (t/ha):

The mean performance of the individual hybrid along with their stability parameters (bi and S2di) for seed yield (t/ha) are presented in (Table 1). From the environmental means it was observed that E1 (Ellkandi, 2013) had the highest mean of seed yield (1.68 t/ha), while E3 (Essuki, 2013) had the lowest seed values of seed yield (1.41 t/ha) (Table 4.14).The overall mean of seed yield (t/ha) was 1.56 t/ha. Analysis of the stability parameters of individual hybrids indicated that five hybrids had higher mean than the overall mean. These were; Pan-7057, Ausigold61, Ausigold7, SFH-301, and Hysun-33 with seed yield (t/ha) means of 2.09, 2.01, 1.91, 1.88, and 1.72 (t/ha), respectively. Also, the above five hybrids had a regression coefficients(bi) close to unity of 1.02, 1.04,1.07, 1.08, and 1.09, respectively and deviation from regression (S2d) not significantly different from zero of (0.00) (Table 4.14).On the other hand, Pan-7033, Aguara-4 and SFH304 had also mean yield over grand mean of1.66, 1.62 and 1.59 (t/ha),regression coefficients (bi) below unity of 0.01, 0.00 and 0.01 and deviation from regression(S2di) of 0.01, 0.00 and 0.01 respectively. The rest of the hybrids had mean seed yield (t/ha) below grand mean, regression coefficients not close to unity and deviation from regression not close to zero. The last ranked hybrid in terms of mean seed yield was Pan-7351(1.14 t/ha) (Table 4.14).

4.4.2 Stability of performance for oil yield (t/ha):

Table 4.15 displayed the mean (µ), regression coefficients (bi), deviation from regression line ((S2di) with their ranking on oil yield (t/ha). From the environmental means it was observed that E1 (Ellkandi, 2013) had the highest means of oil yield (0.623 t/ha), while E3 (Elsuki, 2013) had the lowest values of oil yield (0.530 t/ha) (Table 4.15). The overall mean for oil yield was 0.585 (t/ha). Eight hybrids showed means above the average of oil yield per hectare. These hybrids were; Pan-7057, Ausigold61, Ausigold7, SFH 301,Hysun-33, Pan-7033, Aguara-4 and SFH 304 , with respective mean oil yield of 0.982, 0.904, 0.843, 0.794, 0.705, 0.647, 0.599 and 0.589 (t/ha). The first five out of theabove eight hybrids (Pan-7057, Ausigold61, Ausigold7, SFH 301 and Hysun-33) had respective regression coefficients (bi) above unity of 1.00, 1.01, 1.01, 1.03 and 1.06 and respective deviation from regression around zero of (0.00). While,the three hybrids; Pan-7033, Aguara-4 and SFH-304 had respective regression coefficients (bi) below unity of 0.77, 0.82 and0.78 and deviation from regression not significantly different from zero of 0.01, 0.00 and 0.01. The rest of the hybrids had means of oil yield below the overall mean, regression coefficients not close to unity and deviation from regression not around zero.The last ranked hybrid in terms of mean oil yield (t/ha) 0.285 (t/ha) was pan-7351 (Table 4.15).

Table 13: Analysis of variance for stability of seed and oil yield in 15 sunflower hybrids across four environments

Source of Variation	**d.f**	**Mean squares for seed yield t/ha**	**Mean squares for oil yield %**
Hybrid (G)	14	0.031**	133.196**
Environment + (E xG	45	0.010**	1.070**
Environment (linear)	1	0.001	0.001
Hybrid ×Env.(linear)	14	0.009**	0.826**
Pooled deviation	30	0.003	0.104
Pooled error	180	0.002	1.379

** Significant at (0.01) probability level

Table 14: Estimates of stability and adaptability parameters of seed and oil yields (t/ha) of 15 sunflower hybrids evaluated in four environments

Hybrid	Seed yield (t/ha)							
	E1	**E2**	**E3**	**E4**	**μ**		**b_i**	**S^2_{di}**
SFH 301	1.75	1.94	1.98	1.90	1.88	(4)	0.79	0.00
SFH 302	1.50	1.48	1.10	1.20	1.32	(11)	0.20	0.13
SFH 303	1.37	1.26	1.10	1.32	1.26	(12)	0.29	0.20
SFH 304	1.83	1.46	1.14	1.95	1.59	(8)	0.71	0.01
SFH 310	1.18	1.21	1.26	0.99	1.16	(14)	0.39	0.16
Ausigold7	1.95	2.13	1.97	1.67	1.91	(3)	1.07	0.00
Ausigold4	1.72	1.60	1.06	1.12	1.37	(10)	0.50	0.25*
Ausigold61	1.71	2.05	2.16	2.12	2.01	(2)	1.04	0.00
Pan-7033	1.77	1.62	1.09	2.16	1.66	(6)	1.09	0.01
Pan-7049	1.60	1.18	1.12	1.07	1.24	(13)	0.58	0.05
Pan-7057	2.35	1.57	2.10	2.36	2.09	(1)	1.02	0.00
Pan-7351	1.34	1.20	1.07	0.97	1.14	(15)	0.56	0.33*
Opera	1.62	1.07	1.61	1.66	1.49	(9)	0.29	0.04
Aguara-4	1.90	2.31	1.07	1.21	1.62	(7)	0.88	0.00
Hysun-33	1.67	2.04	1.42	1.76	1.72	(5)	1.08	0.00
G M	1.68	1.61	1.41	1.56	1.56			
Hybrid	**Oil yield (t/ha)**							
	E1	**E2**	**E3**	**E4**	**μ**		**b_i**	**S^2_{di}**
SFH 301	0.735	0.814	0.831	0.798	0.794	(4)	1.03	0.02
SFH 302	0.495	0.488	0.363	0.396	0.435	(10)	0.27	0.42*
SFH 303	0.411	0.378	0.330	0.396	0.378	(11)	0.41	0.32*
SFH 304	0.667	0.532	0.416	0.711	0.581	(8)	0.78	0.01
SFH 310	0.306	0.314	0.327	0.257	0.301	(13)	0.55	0.24*
Ausigold7	0.858	0.937	0.844	0.734	0.843	(3)	1.01	0.01
Ausigold4	0.584	0.544	0.360	0.380	0.465	(14)	0.22	0.29*
Ausigold61	0.769	0.922	0.972	0.954	0.904	(2)	1.01	0.00
Pan-7033	0.690	0.631	0.425	0.842	0.647	(6)	0.77	0.00
Pan-7049	0.448	0.330	0.313	0.299	0.347	(12)	0.51	0.21
Pan-7057	1.104	0.737	0.987	1.109	0.982	(1)	1.00	0.00
Pan-7351	0.335	0.300	0.267	0.242	0.285	(15)	0.32	0.49*
Opera	0.550	0.363	0.547	0.564	0.506	(9)	0.27	0.56*
Aguara-4	0.703	0.854	0.395	0.447	0.599	(7)	0.82	0.00
Hysun-33	0.684	0.836	0.582	0.721	0.705	(5)	1.06	0.02
G. M	0.622	0.598	0.530	0.590	0.584			

Between brackets refer to rank, *Significant at $p < 0.05$ level, b_i =Regression coefficient, S^2_{di} =Deviation from regression, μ = Mean

CHAPTER FIVE

DISSCUSION

5.1 Variability in sunflower:

Variability in a population is of paramount importance for any successful breeding program. This is because selection of desirable genotype for a certain trait will not be effective unless considerable variation exists in the genetic material under study. At both location and in both seasons significant differences were observed for days to 50% flowering and days to physiological maturity. Hence, these hybrids can be planted in areas with short to medium rainfall and/or under irrigation to make use of available water and to reduce irrigation cost. On the other hand, days to maturity are often closely correlated to days to flowering and therefore, these hybrids seem to belong to the early and medium maturity group. Similar findings have been stated by (Chervet and Vear, 1990 and El-Ahmer *et al*;1989).Plant height (cm) and stem diameter (cm) showed significant differences among the investigated sunflower hybrids in both seasons and at both locations. The significance of these characters could be attributed to the interaction of the studied hybrids with seasons. These results were in general agreement with what have been registered by (Dash *et al*, 1996).However, short-stature sunflower hybrids are preferred because tall plants are likely to lodge during wind storm or heavy rains. These hybrids are of reasonable heights, suitable for mechanical harvest and had good resistance to lodging. In addition to that, the tall and thick plants of sunflower hybrids can be used in the buildings, fencing, and fuel and for manufacturing papers. Head diameter and empty seeds percentage as important yield related parameter showed significant differences at both location and both seasons. The significance of the head diameter could be attributed to the genetic material under study as well as the interaction with the environments. The lower percentage of empty seeds is an indicator of higher seed setting per head and consequently increased seed yield. The hybrids under study showed very low percentage of empty seeds, suggesting the good seed set of these hybrids and could be used for commercial production under both rain fed and irrigated areas. Also, this means that these hybrids have a high level of self-compatibility under a wide range of environments. Similar results were found by Chervet and Vear, (1990).

The importance of any character is determined by its contribution to the final yield. In this study number of seeds per head and 1000-seed-weight (g) showed highly significant differences in both seasons and at both locations(Kshisagar *et al*; 1995).The ultimate aim of any breeding program is to increase the yield. However, seed yield per plant (g), seed yield (t/ha) and oil yield (t/ha) at both locations and inboth seasons revealed highly significant differences and were of high seed yield (t/ha) and oil yield (t/ha). Similar results were obtained by (Anonymous 1978, Kefene; 1994, Faisal *et al*; 2005).

5.2 Phenotypic (δ^2ph), genotypic (δ^2g) and environmental variance (δ^2e):

The phenotypic variance includes the genotypic variance as well as the environmental one. The estimation of phenotypic, genotypic and environmental variances is of paramount importance. This because their relative values would indicate to whether selection would be effective or not. Furthermore, the relative values of these variances will help researchers in using the most efficient method of selection to improve and study the genotypic properties of the population. For all investigated sunflower traits, in both seasons andat both locations the phenotypic variances were greater than the genotypic ones. These results were in agreement with what have been reached by Arshard*et al*, (2013) and Tarig *et al*, (1992). It is worthy to mention that, the differences between the phenotypic**(**δ^2ph**)** and genotypic(δ^2g) variances were small for all investigated characters. This indicates that the contribution of the environmental conditions was small in the expression of these characters and the selection of these characters based on the phenotype among the evaluated hybrids would be effective. Similar results were reached by Mahmood and Mehadi, (2003). However, the difference between these two variances was high for plant height. This indicates that, most of the variation for this character was attributed to the environmental conditions. Thus direct selection for this character would not be effective. In addition plant height is a quantitative character, which was complex trait and much more affected by the environmental conditions. These finding were in agreement with what have been reached by (Scheoman, 2003; Sheriff and Appandurai, 1985). On the other hand, the difference between these two variances for stem diameter (cm) and head diameter (cm) did not follow a certain pattern but fluctuated between seasons and locations. This indicates that these characters were much more affected by both adverse and favorable environmental conditions. These findings were similar to what have been reported by Rashid *et al*, (2004) and Mirza *et al*, (1997).

5.3 Heritability (h^2), genetic coefficient of variation (GCV %) and genetic advance (GA):

The utility of the heritability estimates increases when it is used in conjunction with the genetic coefficient of variation. Estimation of heritability together with genetic coefficient of variations is useful in predicting the resulting effect than the heritability value alone. This is mainly because heritability estimates as a ratio of genotypic to phenotypic variance varies greatly depending on sample size, environment, character and population. Furthermore heritability estimates in broad sense would enable plant breeders to base their selection on the phenotypic performance. In this study a wide range of variation in the magnitude of heritability, genetic coefficient of variation and genetic advance in both seasons and at both location were observed. High heritability estimates, genetic coefficient of variations and genetic advance were shown by days to physiological maturity, head diameter (cm) and 1000-seeds weight (g). Since heritability, genetic coefficient of variations and genetic advance are genetically determined, these characters could be possible to be improved through selection and can be used as selection index. Similar findings have reported by (Saravana *et al*, 1996; Kefene, 1994; Lewis, 1954 and Gill *et al*, 1997). High heritability estimates coupled with low genetic coefficient of variation (GCV %) and genetic advance (GA) values were expressed by days to 50% flowering, stem diameter (cm) and number of seeds/p. This indicates that the dominant and epistatic nature of inheritance for these two characters (Suzer *et al*, 1993; Skoric, 1982 and Seiler, 1984).

The values of heritability estimates and genetic advance for plant height, empty seeds percentage, seed yield per plant (g) and seed yield (t/ha) at both locations and in both seasons did not follow a certain pattern. Their heritability estimates and genetic advance values fluctuated between seasons and locations. These differences could be attributed to the deferential response of hybrids to the environment. These findings in agreement with those have been reported by (Mirza *et al*, 1997).Oil yield (t/ha) stable heritability (h^2) estimates, genotypic coefficient of variation (GCV %) and genetic advance (GA),could be attributed to the adaptability of this character to a wide range of environmental conditions. Similar findings were registered by (Yankov and Tashin, 2015).

5.4 Phenotypic correlations:

Knowledge of the degree of associations of different traits with seed yield could be useful in better understanding of the inheritance of these characters and sunflower seed yield, as they give information on directions and magnitude of association between different traits.In this study, highly significant positive and negative correlations were obtained. The highest positively and highly significantly ($P< 0.01$) phenotypic correlation was found between days to 50 % flowering, plant height, number of seeds per head, seed yield per plant (g) and oil yield with seed yield (t/ha).Emphasis should be placed on these characters for formulating reliable selection indices for development and/or releasing of high yielding sunflower hybrids for climatic conditions. Similar results were obtained by Yankov and Tashin (2015). On the other hand, the highest negatively and highly significantly ($P< 0.01$) phenotypic correlation was found between days to maturity and head diameter with percentage of empty seeds. Also, the seed yield per plant and the seed yield per hectare were negatively correlated with percentage of empty seeds per head. Therefore, selection of high yielding sunflower hybrids based on seed yield per plant ($r = 0.82^{**}$), 1000-seed weights ($r = 0.60^{**}$) and number of seeds per head ($r = 0.57^{**}$) could be used to improve seed yield in sunflower breeding programs. These findings agree with what have been reached by (El-Ahmer *et al*., 1989; Muhammad *et al*, 2003; Abdel Aal, 1992 and Chrvet and Vear, 1990).

5.5 Genotype x environment interactions:

In the combined analysis of variance, significant differences were detected among the 15 sunflower hybrids for head diameter (cm), number of seeds per plant, empty seeds percentage, 1000-seeds weight (g), seed yield per plant (g), seed yield (t/ha) and oil yield (t/ha). However the genotype x season interaction was not significant for head diameter (cm), number of seeds per head, empty seeds percentage, 1000- seeds weight (g) and seed yield per plant (g), indicating that the relative ranking of the genotypes (Hybrids), averaged over location, did not differ from one season to another. Similarly, they also did not show significant differences regarding genotype x location interaction, indicating that the relative ranking of the genotypes (Hybrids), averaged over seasons did not differ from location to another. On the other hand seed yield (t/ha) and oil yield (t/ha) showed significant differences at the genotype x season interaction and genotype x location interaction, confirmig what have been registered by Kambal and Mahamoud, (1978).Who worked in sorghum and found the same results. The highly significance of genotype x environment interaction (non-linear) for seed yield (t/ha) and oil yield (t/ha) indicated that the unpredictable factors were predominant and the breeder would search for a cultivar that has general adaptability and good performance over a range of environments. These significant levels of interaction suggest that, the breeding programs should encourage the development of number hybrids each adapted to specific kind of environment with respect to these characters; for example, Aguara-4yielded above average level at Ellkandi in season 2013 but below average at Essuki in season 2014. Moreover, Hybrid SFH304 yielded above average level at Ellkandi in season 2013 but below average at Ellkandi and Essuki in season 2014 and 2013 respectively. These results confirm what have been reported by Bange *et al*, 1997. Who stated that, the potential yield of sunflower is highly dependent on the environmental conditions throughout the life of the crop. It is relatively easier to evolve hybrids specifically adapted to predictable environment than to breed for unpredictable environmental condition. This is because the unpredictable fluctuations vary from year to another and cannot be predicted in advance and hardly the breeders can aim their programs to develop varieties suited to those fluctuations. A variety which can adjust its genotypic or phenotypic state in response to transient fluctuations in environment in such way that it gives high and stable economic return for location and season, is termed as well buffered (Allard and Bradshow, 1964).The second order interaction, genotype x season x location was non-significant among the 15 sunflower hybrids for the five characters viz: head diameter (cm), number of seeds/head, empty seeds percentage,1000-seeds weight (g) and seed yield plant (g). The non-significance of the second order interaction of these characters would be due to the masking effects of the first order interaction for the season and location with genotypes. These findings contradict what have been reported by Bakheit and Mahdi, (1988) and Kambal and Mahmoud, (1978) who worked in sorghum and sesame and found significant differences at varietyx season x location level of interaction.

5.6 Phenotypic stability:

The stability parameters were only assessed for those characters that

Showed significant (G xE) interaction viz: seed yield (t/ha) and oil yield (t/ha). For the two characters, environment one (E1) (Ellkandi 2013), was considered the most favorable one, as indicated by higher grand mean followed by environment four (E4) (Essuki 2014), then environment two (E2) (Ellkandi 2014) and environment three (E3) (Essuki 2013) was the poorest environment which scored the lowest seed yield (t/ha) and oil yield (t/ha). In this study there were highly significant differences at the genotype level, genotype x environment (G xE) interaction and pooled deviation from regression on the overall mean. The significant G x E interaction for the two characters indicates that, these characters were sensitive to the environmental changes. The significant pooled deviation from regression for the two characters suggests that, hybrids differ considerably with respect to their stability. Thiscould be attributed to the amount of rains during growth period and temperature at flowering stage. Similar results have been registered by (Gafoor *et al*, 2005 and Hakan *et al*, 2003). Who worked in sunflower and found the same results. According to the stability parameters with respect to seed yield (t/ha), three groups of hybrids could be identified. The first one, which had a mean value (μ), higher than the average mean, regression coefficients(bi) above unity and deviation (S^2di) from regression not-significantly different from zero. This group was considered to be below average in stability, so it was sensitive to the environmental changes and hence it could be recommended for favorable environments. This group includes the following hybrids Pan-7057, Ausigold61, Ausigold7, SFH 301, and Hysun-33. The second group comprises Pan-7033, Aguara-4 and SFH304were said to be specifically adapted for unfavorable environments, because it was above in average stability, in that it had mean(µ) seed yield (t/ha) above the average mean, regression coefficients (bi) below unity and deviation(S^2di) from regression line not significantly different from zero. However the third group includes Opera,Ausigold4, SFH302, SFH303, Pan-7049, SFH310 and Pan-7351. This group did not follow a particular pattern concerning the mean(µ), regression coefficients (bi) and deviation (S^2di) from regression. They either had a mean value below average, regression coefficients not close to unity or deviation (S^2di) from regression line significantly different from zero and therefore they were not adapted to either kind of environments. These statements agree with that recorded by (Lin and Binn*s*, 1986; Becker and leon, 1988 and frey, 1964).Concerning oil yield (t/ha), also three groups of hybrids were considered. The first one, which had a mean value (µ), higher than the average mean, regression coefficients(bi) above unity and deviation (S^2di) from regression not-significantly different from zero. This group was considered to be below average in stability, so it was sensitive to the environmental changes and hence it could be recommended for favorable environments. This group comprises Pan-7057;Ausigold61, Ausigold7, SFH301 and Hysun-33.The second group comprises Pan-7033, Aguara-4 and SFH304which were adapted for unfavorable environments, because it was above in average stability, in that it had mean (µ) oil yield (t/ha) above the average mean, regression coefficients (bi) below unity and deviation(S2di) from regression line not significantly different from zero. However the third group includes Opera, Ausigold4, SFH302, SFH303, Pan-7049, SFH310 and Pan-7351 were neither adapted for favorable nor unfavorable environments. In that it did not follow a particular pattern concerning the mean (μ), regression coefficients (bi) and deviation (S^2di) from regression. They either had a mean value below average, regression coefficients not close to unity or deviation (S^2di) from regression line significantly different from zero and therefore they were not adapted to either kind of environments and showed fluctuation in oil yield (t/ha) through the different environments. Similar findings have been reported by (Huhen, 1990; Hakan *et al* 2003 and Alvarez *et al*1992).

CHAPTER SIX

SUMMAR AND CONCLUSIONS

Two experiments were carried out, at two locations and over two seasons in each location, to evaluate fifteen sunflower hybrids. At each location a randomized complete block design with four replications was used. Data on 11 growth and yield characters in addition to oil yield were collected in four environments. Individual and combined analyses of variance were carried out for the collected data. Phenotypic, genotypic and environmental variance were carried out as well as heritability, genetic advance, phenotypic coefficient of variation, genotypic coefficient of variation and correlation for the collected data. In addition characters that showed significant genotype x environment interactions were further analyzed to estimate stability parameters (mean performance (μ), regression coefficient (bi) and the deviation (S^2di) from regression) according to Eberhart and Russell, (1966) model. Significant differences among hybrids were detected for most of the studied characters at the four environments, which indicated the presence of sufficient genetic variability in the evaluated materials. Some characters showed significant ($P<0.05$) differences, while other characters showed highly significant($p \leq 0.01$) differences at the same environment, which revealed the importance of the environmental components of variance in evaluating these traits. Moreover, the first order interaction, genotype x season and genotype x location showed significant differences among the evaluated hybrids for seed yield (t/ha) and oil yield (t/ha). On the other hand head diameter (cm), number of seeds/p, empty seeds%, 1000-seeds weight (g) and seed yield/p (g) did not show significant differences for genotype x season and genotype x location interaction (first order). However, genotype x season x location interaction (the second order) showed non-significant differences among the evaluated hybrids for all characters. Based on individual genotype stability, on the basis of the three parameters viz mean performance of the hybrid(μ), regression coefficient (bi) and deviation from regression (S^2di), three groups could be identified. The first group comprises Pan-7057, Ausigold61, Ausigold7, SFH 301 and Hysu-33 which was stable hybrids and adapted for favorable environments. The second group includes Pan-7033, Aguara-4 and SFH 304which were stable hybrids and adapted for unfavorable environments. However the third group comprises Ausigold4, Pan-7351, Pan-7049, SFH 302, SFH310 and Opera which were neither adapted for favorable nor unfavorable environments and showed fluctuations in seed and oil yields (t/ha). Concerning the classification of the four environments according to their adaptability, environment one (E1= Ellkandi 2013) was the most favorable one, followed by environment four (E4= Essuki 2014) and environment two (E2= Ellkandi 2014) whereas, environment three (E3= Essuki 2013) the least favorable one for the evaluated fifteen sunflower hybrids.

Based on the findings obtained in this study, the following conclusions could be drawn:

1. A wide range of variability was noticed for most of the tested sunflower hybrids. This offers a good opportunity for further breeding programs.
2. The high heritability values for most of the investigated traits suggest the possible efficiency of phenotypic selection for these traits.
3. The high genetic advance as percentage of mean and genetic coefficient of variation (GCV %) for most of the traits suggested greater response for selection.
4. The simple linear correlation assured the presence of positive and significant correlations of the quantitative traits with seed yield (t/ha)

5. The significant first order interactions of genotype x season and genotype x location for seed (t/ha) and oil yield (t/ha) necessitate evaluation of the hybrids under different locations and through many seasons.
6. The significant genotype x environment interactions for seed yield (t/ha)and oil yield (t/ha) are attributed to non-linear components (unpredictable factors) rather than the genetic effect of the genotypes. Therefore good husbandry of the hybrids is essential to minimize the variation in seed and oil yields of sunflower.
7. Grouping of the different hybrids according to their adaptability through the four environments assured that, Pan-7057, Ausigold61, Ausigold4, SFH 301 and Hysun-33 were most likely stable andadapted hybrids for favorable environments. Whereas, Pan-7033, Aguara-4 and SFH 304were the most stable and adapted hybrids for adverse environmental conditions.
8. Emphasis should be made on locally produced hybrids like SFH301 and SFH304 since they were stable and adapted for favorable and unfavorable environments respectively.
9. Stakeholders should encourage local seeds production by allocating considerable budgets tothesun flower breeding programs.

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APPENDICES

Appendix 1: Show the daily minimum and maximum temperature in C^0 during July, August and September at Ellkandi in season 2013 and 2014

Day	2013						2014					
	July		August		September		July		August		September	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
1	23.8	33.6	23.2	33.0	23.0	23.4	22.4	35.5	22.0	32.5	23.0	30.5
2	25.8	40.8	22.0	32.6	20.2	35.0	23.5	39.6	22.5	35.0	21.8	31.2
3	24.2	36.4	23.6	34.2	20.5	32. 0	27.2	39.8	19.0	27.5	20.5	31.0
4	25.5	36.2	23.0	32.4	23.5	27.8	19.5	39.5	21.0	27.5	22.0	32.5
5	22.0	33.5	21.5	32.6	22.5	32.0	23.5	33.2	22.7	33.0	21.5	33.2
6	22.7	37.4	21.8	32.0	21.5	30.0	20.0	34.6	22.5	33.0	23.0	32.5
7	23.5	38.0	21.0	31.8	22.5	33.6	20.0	31.0	22.0	31.4	20.5	32.5
8	26.0	38.4	22.3	36.0	24.0	35.2	20.0	32.2	21.6	33.8	21.0	31.5
9	25.5	36.0	24.5	32.6	20.0	29.2	22.5	36.5	20.8	29.0	20.0	33.2
10	27.5	38.2	21.3	33.2	20.0	29.3	21.2	35.0	21.4	34.0	22.0	30.5
Mean	**24.7**	**27.0**	**22.4**	**33.0**	**21.8**	**21.7**	**22.0**	**35.7**	**21.6**	**31.7**	**21.5**	**32.0**
11	22.3	33.2	23.0	33.2	20.0	34.3	22.0	35.0	21.7	34.8	21.5	32.5
12	23.5	37.0	20.5	32.5	24.0	36.0	23.5	35.2	21.2	31.7	22.0	34.0
13	23.0	32.0	21.5	33.2	23.2	32.8	23.5	38.0	22.0	35.4	21.5	32.4
14	24.5	36.0	23.0	29.2	21.5	31.5	21.7	37.0	19.6	33.5	21.6	31.8
15	21.0	34.4	24.0	29.5	22.5	35.0	22.0	30.0	22.2	35.0	21.6	34.5
16	23.5	31.7	20.0	29.4	22.5	32.5	23.5	35.4	21.5	34.5	21.4	29.3
17	23.7	34.0	22.5	30.7	22.0	36.7	22.9	34.7	19.0	28.0	22.3	32.5
18	25.0	30.8	24.5	36.0	22.2	35.0	23.0	36.2	23.0	33.5	22.2	34.5
19	23.7	37.4	23.0	35.8	23.5	35.8	21.5	25.2	20.0	28.3	19.5	34.0
20	25.8	37.0	23.5	31.0	22.5	33.5	21.0	27.5	19.7	28.0	22.0	35.5
Mean	**23.6**	**34.4**	**22.6**	**32.1**	**22.4**	**34.3**	**22.5**	**33.4**	**21.1**	**32.3**	**21.6**	**33.1**
21	25.0	36. 0	22.5	33.8	22.0	34.5	22.5	34.0	21.6	33.5	22.5	35.3
22	25.0	36.4	23.0	35.4	22.5	35.7	22.0	36.0	24.0	35.0	21.3	33.7
23	22.0	32.6	21.5	28.3	23.5	37.0	21.0	30.5	18.0	29.7	21.9	33.0
24	24.5	39.3	23.5	32.4	23.0	35.7	21.5	32.8	20.5	34.2	21.0	33.0
25	23.5	34.3	23.5	34.8	22.0	35.4	21.5	31.5	18.5	31.0	22.0	35.3
26	21.5	31.5	22.0	29.0	24.2	36.0	21.8	32.4	18.2	25.6	24.5	36.5
27	22.0	36.7	23.5	32.4	22.7	34.8	22.5	36.0	20.5	33.0	22.0	31.0
28	21.5	30.5	20.5	31.7	23.8	37.0	21.5	33.7	22.4	35.0	22.7	32.7
29	23.0	34.2	20.5	30.5	24.0	39.8	23.2	36.0	19.5	28.0	22.2	35.5
30	23.8	36.5	24.5	31.6	23.0	36.0	20.0	30.0	21.0	31.0	22.0	36.0
31	24.0	35.5	21.8	32.4	---	---	22.0	29.5	23.5	30.5	-----	----
Mean	**23.3**	**31.6**	**22.4**	**32.0**	**23.1**	**36.2**	**21.8**	**33.0**	**20.7**	**31.5**	**22.2**	**34.2**
GM	**24.0**	**31.0**	**22.5**	**32.4**	**22.4**	**30.7**	**22.1**	**34.0**	**21.1**	**31.8**	**21.8**	**33.1**

Source: Sudan National Metrological Center (SNMC) - Khartoum,(2017)

Appendix 2: **show the daily minimum and maximum temperature in C^0 during July, August and September at Essuki in season 2013 and 2014**

Day	2013						2014					
	July		August		September		July		August		September	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
1	24.2	35.0	23.6	32.0	24.0	36.0	24.5	37.0	23.0	33.0	21.5	32.0
2	24.2	40.0	23.0	32.5	21.6	29.5	24.0	39.0	23.5	35.0	23.0	34.0
3	25.5	37.3	23.5	34.0	21.0	32.5	27.5	39.7	22.2	27.6	19.8	30.2
4	26.0	35.8	23.2	31.5	22.6	28.0	20.0	29.0	22.5	28.5	22.0	31.8
5	22.5	35.0	20.5	31.2	23.0	33.6	20.2	32.2	23.5	31.6	22.3	32.6
6	22.2	37.0	22.0	30.5	21.6	30.6	22.4	39.2	22.4	30.2	23.0	28.0
7	24.5	38.5	21.5	31.0	22.8	34.5	21.5	30.2	22.6	31.5	22.2	29.5
8	26.4	40.0	22.0	34.6	23.2	36.2	21.0	31.5	21.8	33.5	22.4	32.5
9	25.0	36.6	25.2	33.0	24.2	31.4	23.0	35.0	22.5	27.7	22.0	30.7
10	27.0	38.0	21.6	31.5	20.6	31.0	21.2	31.5	22.0	33.5	22.0	30.0
Mean	**24.8**	**37.3**	**22.6**	**32.2**	**22.5**	**32.3**	**22.5**	**34.4**	**22.6**	**31.2**	**22.0**	**31.1**
11	24.6	35.7	23.0	32.5	21.0	35.5	22.0	33.5	22.0	33.5	21.5	32.8
12	24.2	36.5	20.5	31.5	25.0	37.6	23.6	34.2	22.0	32.5	22.5	35.0
13	26.0	35.0	22.4	31.4	22.6	33.3	23.6	37.2	23.5	34.6	22.8	34.0
14	23.8	36.3	23.5	28.5	22.3	34.0	22.5	36.2	21.0	33.0	21.5	32.5
15	21.5	34.5	24.0	31.0	23.2	35.5	22.8	30.2	23.4	34.3	22.0	35.5
16	24.0	30.5	20.4	28.0	23.0	31.0	23.0	34.2	23.0	34.0	22.2	29.5
17	24.0	33.8	21.0	30.0	22.7	37.0	23.5	33.5	22.5	29.5	22.0	31.7
18	25.3	32.0	23.5	35.2	21.0	31.5	23.7	35.0	23.6	33.8	22.5	35.0
19	22.6	37.0	23.2	35.0	23.5	35.0	22.5	36.0	20.6	28.6	21.0	32.8
20	25.4	37.0	24.0	29.8	22.4	34.0	22.0	37.0	21.5	26.0	23.5	35.0
Mean	**24.1**	**34.8**	**22.6**	**31.3**	**22.7**	**34.4**	**22.9**	**34.7**	**22.3**	**32.0**	**22.2**	**33.4**
21	26.0	36.5	23.0	34.0	23.1	35.6	23.4	32.5	21.5	33.5	24.3	35.2
22	25.0	37.0	23.6	34.0	23.3	35.6	23.2	33.7	24.2	34.0	23.0	34.0
23	22.0	31.0	21.0	28.5	24.5	36.5	22.0	31.0	20.5	29.5	24.6	33.0
24	23.0	39.2	23.0	31.0	23.8	35.5	22.5	33.0	22.0	32.8	22.2	32.2
25	23.0	35.5	24.0	34.5	23.0	35.5	23.3	32.0	20.5	30.7	23.0	34.8
26	22.0	34.0	22.0	29.0	24.5	35.0	22.7	33.0	20.0	24.5	23.5	35.6
27	23.5	36.0	23.0	32.2	22.3	35.5	23.0	34.6	21.5	31.0	22.8	31.0
28	21.8	30.8	21.5	32.2	24.0	36.5	22.4	33.7	23.6	33.5	23.5	33.2
29	22.6	33.8	22.0	30.0	23.0	38.5	24.0	35.2	19.2	27.5	23.0	34.6
30	23.0	36.5	22.0	32.0	23.2	35.5	22.0	30.2	21.5	29.5	22.5	36.5
31	24.2	35.0	22.8	33.0	---	---	23.2	38.6	23.6	31.0	---	---
Mean	**23.3**	**35.0**	**22.5**	**32.0**	**21.3**	**36.1**	**23.0**	**33.4**	**21.6**	**30.7**	**23.2**	**34.0**
GM	**24.1**	**35.7**	**22.7**	**31.8**	**22.2**	**34.3**	**22.8**	**34.2**	**22.2**	**31.3**	**22.5**	**32.8**

Source: Sudan National Metrological Center (SNMC) - Khartoum,(2017)

Appendix 3: Show the daily relative humidity (%) during July, Augustand September at Ellkandi in seasons 2013 and 2014

Day	Elkandi					
	2013			2014		
	July	August	September	July	August	September
1	28	66	67	57	77	82
2	42	64	83	43	67	79
3	56	67	79	45	84	80
4	51	77	85	79	80	76
5	65	79	76	73	71	75
6	58	81	82	67	75	82
7	53	80	73	73	75	85
8	48	73	67	68	76	79
9	50	77	75	59	82	83
10	45	72	78	76	74	79
Mean	**49.6**	**73.6**	**76.5**	**64.0**	**76.1**	**80.0**
11	64	70	71	65	77	76
12	53	75	72	62	79	70
13	65	71	71	61	74	73
14	60	83	74	61	69	73
15	68	79	68	72	73	68
16	76	88	71	62	71	78
17	64	79	67	63	84	73
18	69	69	72	56	74	75
19	58	65	78	81	82	73
20	53	78	74	81	83	69
Mean	**63.0**	**75.7**	**71.8**	**66.4**	**76.6**	**72.8**
21	53	68	73	71	72	71
22	55	68	69	70	75	77
23	69	85	66	84	81	77
24	55	77	66	77	75	77
25	68	73	61	76	81	70
26	69	84	65	76	90	66
27	66	78	68	67	75	72
28	80	79	64	75	76	75
29	73	82	54	69	84	66
30	59	83	63	83	82	69
31	63	78	64	84	---	--
Mean	**71.0**	**85.5**	**71.3**	**83.2**	**79.1**	**72.0**
GM	**61.2**	**78.3**	**73.2**	**71.2**	**77.3**	**74.9**

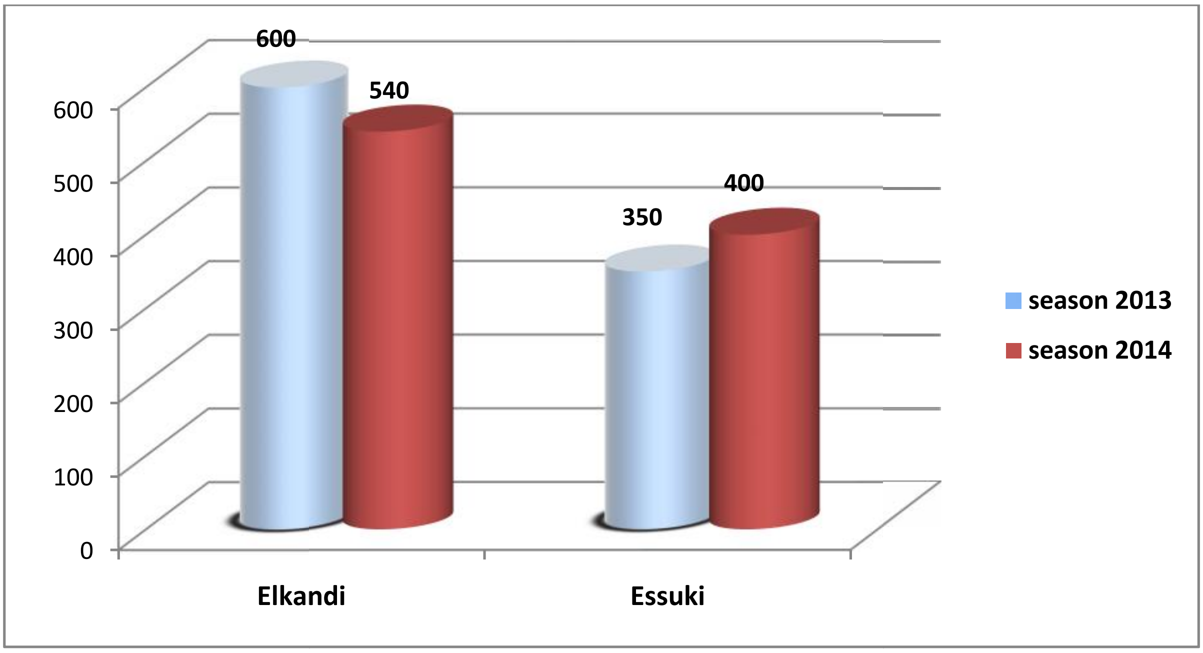
Source: Sudan National Metrological Center (SNMC) - Khartoum,(2017)

Appendix 4: Show the daily relative humidity (%) during July, August and September at Essuki in seasons 2013 and 2014

Day	Essuki					
	2013			2014		
	July	August	September	July	August	September
1	58	60	52	43	64	75
2	57	75	62	37	62	68
3	54	72	58	37	80	75
4	74	79	56	81	79	70
5	73	61	52	68	70	68
6	81	71	58	59	71	80
7	72	61	63	71	72	76
8	63	58	56	62	67	69
9	80	64	68	54	83	76
10	75	77	61	73	73	79
Mean	**68.7**	**67.8**	**58.6**	**58.5**	**72.1**	**73.6**
11	74	63	60	60	68	66
12	75	65	62	58	76	61
13	78	63	59	53	71	57
14	82	71	55	55	69	64
15	71	62	35	70	57	57
16	82	69	40	64	58	77
17	76	62	34	61	72	69
18	63	72	34	54	60	64
19	62	73	34	92	83	68
20	75	65	44	84	87	61
Mean	**73.8**	**66.5**	**45.7**	**65.1**	**70.1**	**64.4**
21	65	67	40	70	69	62
22	60	60	46	60	65	60
23	81	56	51	81	76	75
24	75	57	50	65	70	71
25	69	56	54	59	72	65
26	81	62	51	71	94	60
27	72	63	49	72	78	65
28	65	54	35	70	70	67
29	81	35	33	66	83	58
30	77	52	29	80	80	58
31	70	54	31	78		
Mean	**72.4**	**56.0**	**42.6**	**77.2**	**75.7**	**64.1**
GM	**71.6**	**63.4**	**49.2**	**67.1**	**72.6**	**67.4**

Source: Sudan National Metrological Center (SNMC) - Khartoum,(2017)

Appendix 5: Show the amount of rains (mm) in the period from July to Octoberat Ellandi and Essuki in seasons 2013 and 2014



Source: SSMAD, (2017).