ESTIMATION OF HETEROSIS AND GENERAL AND SPECIFIC COMBINING ABILITIES IN SOME SUNFLOWER (*Helianthus annuus L.*) HYBRIDS

By

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DEDICATION

For my parents, wife and my two kids,Nasir and Mowada with love.

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خلاصة الأطروحة

اجريت هذه الدراسة على ثمانية و عشرون هجيناً من محصول زهرة الشمس انتجـت عـن طريق تلقيح اثنين من الأمهات عقيمة الذكر مع أربعة عشر أباً معيدا للخصوبة. قيمـت هـذه الهجـن بالأضافة للصنف التجارى Hysun-33 كشاهد في موقعين ، هما المزرعة التجريبية لجامعة الخرطوم بشمبات و محطة ابحاث الرهد ، لموسمين متتاليين 2000/ 2001 و 2002/2001 تحت ظروف الري المستديم. و قد استخدم تصميم القطاعات العشوائية الكاملة بثلاثة مكررات لتنفيذ التجربة.

أوضحت النتائج وجود فروقات معنوية بين الهجن في غالبية الصفات المدروسة في البيئـات المختلفة، ووجود مدي واسع من التباين بين الآباء و بين الأمهات. كما اتـضح أيـضا أن التفـاعلات معنوية بين الطراز الوراثي مع الموقع لصفات عدد البذور في القرص، ووزن الألف بذرة و انتاجية البذور في القرص بالإضافة للتفاعلات بين الموقع و الموسم، وبين الطراز الوراثي و الموسم و بـين الطراز الوراثي والموقع و الموسم لكل الصفات موضوع الدراسة.

أعطت بعض الهجن من كلا الأمين Kr و Ka قيم سالبة لقوة الهجين بالنسبة لأفـضل الآبـاء لصفات طول النبات وعدد الأيام حتي 50% إزهار وعدد الأيام حتي النضج والنسبة المئويـة للبـذور الفارغة في البيئات الأربع . وسجلت قيم موجبة لقوة الهجين بالنسبة لافضل الآباء لصفات قطر الساق و قطر القرص وعدد البذور في القرص و وزن الألف بذرة و انتاجية القرص الواحـد مـن البـذور وانتاجية الهكتار في كل البيئات الأربع. في شمبات وجد أن 14.3% و 78.6% من هجـن الأم Kr أعطت إنتاجية أعلي من الصنف التجاري في الموسم الأول والموسم الثاني علي التتالي، بينمـا كـل الهجن من الأم Ka أعطت إنتاجية أعلى من الصنف التجاري في الموسم الثاني. أما في الرهد، فـإن 21.4% من هجن الأم Ka أعطت إنتاجية أعلي من الصنف التجاري في الموسم الأول.

كذلك أوضحت النتائج أن كل الصفات التي تمت دراستها يتحكم فيها الأثر الجينـي التجميعـي (الإضافي) عدا الإنتاجية للقرص الواحد و الإنتاجية في وحده المساحة في الموسم الأول بموقع شمبات و قطر القرص ووزن الألف بذرة في الموسم الأول بموقع الرهد حيث يتحكم فيها الأثر الجيني غيـر التجميعي .

أظهرت النتائج كذلك، في موقع شمبات، أن أفضل الآباء في القدرة العامة للتوافـق لـصفات الإنتاجية و مكوناتها هي SH-24 و SH-10 لعدد البذور في القرص و SH-5 و SH-24 للنسبة المئوية للبذور الفارغة و SH-6 و SH-2 لوزن الألف بذرة و SH-23 وSH-12 لإنتاجية القرص الواحد و -SH

SH-2و23 للإنتاجية في وحدة المساحة في الموسم الأول و الموسم الثاني على التتالي. أما في الرهد، فكانت افضل الآباء في القدرة العامة للتوافق SH-12 وSH-8 لعدد البذور في القرص و SH-3 وSH-21 لوزن الألف بذرة و SH-6 وSH-7 لإنتاجية القرص الواحد و الإنتاجية في وحدة المساحة في الموسم الأول والموسم الثاني على التتالي. كما بينت الدراسة أن الأم Ka هي الأفضل في القدرة العامة للتوافق لكل الصفات المدروسة عدا وزن الألف بذرة لكلا الموسمين بموقع الرهد، حيث كانت الأم Kr هي الأفضل في القدرة العامة للتوافق لهذه الصفة.

أعلي قيمة للقدرة الخاصة للتوافق في موقع شمبات أعطتها الهجن SHR-2 وSHR-13 لعدد البذور في القرص و SHR-5 وSHR-13 للنسبة المئوية لعدد البذور الفارغة و SHA-18 وSHA-24 لوزن الألف بذرة و SHA-6 وSHR-2 للإنتاجية في القرص الواحد و الإنتاجية في وحدة المساحة في الموسم الأول والموسم الثاني علي التتالي. أما في موقع الرهد فإن أعلى قيمة للقدرة الخاصة للتوافق فقد عبرت عنها الهجن SHR-2 وSHR-9 لعدد البذور في القرص و SHA-18 وSHA-24 لوزن الألف بذرة و SHR-9 وSHA-6 للإنتاجية في القرص الواحد و الإنتاجية في وحدة المساحة في الموسم الأول والموسم الثاني علي التتالي.

أظهرت تحاليل ثبات الأداء إن كل الهجن من الأم Ka بالإضافة للصنف التجاري عالية الإنتاجية، إلا انها حساسه لتباين البيئات لذا فإنها أكثر ملاءمة للظروف البيئية المناسبة. بينما تميزت كل الهجن من الأم Kr بأنها مقاومة للتغيرات البيئية، إلا إنها متوسطة الإنتاجية مما يدل على ملاءمتها لظروف البيئات الفقيرة.

ABSTRACT

Twenty-eight sunflower hybrids were produced, using two cytoplasmically male sterile lines as female parents and fourteen fertility restorer lines (testers). The hybrids and a commercial check (Hysun-33) were evaluated for two seasons (2000/01and 2001/02) at two locations; namely, the University of Khartoum Farm at Shambat and Rahad Research Station . The experiment was carried out under irrigation, using a randomized complete block design with three replications.

Significant differences were detected among the tested hybrids for most of the studied characters, at the two locations and for the two seasons. Moreover, a wide range of variability among the fourteen testers and between the two lines was obtained for most of the characters. The genotype x location interaction was significant for number of seeds per head, 1000-seed weight and seed yield per head. In addition, significant location x season, genotype x season and genotype x location x season interactions were detected for all characters.

Negative heterotic values, under the better- parent, were expressed by some of the hybrids produced from the female parents Kr and Ka for plant height, days to 50% flowering, days to maturity and percentage of empty seeds per head over the four environments. Positive heterosis over the better-parent was expressed by all the hybrids for stem diameter, head diameter, number of seeds per head, 1000-seed weight, seed yield per head and seed yield per hectare over the four environments.

At Shambat, 14.3% and 78.6% of the hybrids obtained from the female parent Kr were high yielders than the commercial check in the first and the second

seasons, respectively, wheras all the hybrids from the female Ka were high yielders than the check in the second season. At Rahad, 21.4% of Ka hybrids were high yielders than the check in the first season.

All the characters studied were controlled by additive gene action over the four environments, except seed yield per head and seed yield per hectare at Shambat in the first season and head diameter and 1000-seed weight at Rahad in the first season, which were controlled by non-additive gene action.

At Shambat, the best general combiner males for seed yield and seed components were SH-24 and SH-10 for number of seeds per head, SH-5 and SH-24 for percentage of empty seeds, SH-6 and SH-2 for 1000-seed weight, SH-23 and SH-12 for seed yield per head and SH-23 and SH-2 for seed yield per hectare respectively, in the first and the second seasons. At Rahad, the best general combiner males were SH-12 and SH-8 for number of seeds per head , SH-3 and SH-21 for 1000-seed weight, SH-6 and SH-7 for seed yield per head and seed yield per hectare respectively, in the first and the second seasons. With regard to the females, Ka was the better general combiner for all the characters studied over the environments, except 1000-seed weight at Rahad in both seasons, where the female Kr was the better general combiner.

The highest specific combining ability (SCA) estimates at Shambat were scored by the hybrids SHR-2 and SHR-13 for number of seeds per head, SHR-5 and SHR-13, for percentage of empty seeds, SHA-18 and SHA-24 for 1000-seed weight, SHA-6 and SHR-2 for seed yield per head and seed yield per hectare, respectively, in the first and the second seasons. At Rahad, the highest SCA estimates were obtained for SHR-2 and SHR-9 for number of seeds per head, SHA-18 and SHA-24 for 1000-seed weight and SHR-9 and SHA-6 for seed yield per head and seed yield per hectare in the first and the second seasons, respectively.

The analysis of stability parameters indicated that the hybrids produced from the female parent Ka as well as the check were the highest yielders but sensitive to changing environments, hence they were adapted to favourable environments, on the other hand, those produced from the female parent Kr were resistant to changing environments, but they were average yielders, and thus they were adapted to poor environments.

CHAPTER ONE

INTRODUCTION

Sunflower (*Helianthus annuus* L.) is a member of the Asteraceae or Compositae family. The genus *Helianthus* comprises 67 herbaceous annual and perennial species, of which 17 are cultivated and only two, *Helianthus annuus* and *Helianthus tuberosus* are used for food. Most of the species (a bout 50) are found in south America
(Weiss, 1983). *Helianthus annuus* is diploid (2n = 2x = 34), while some other species are tetraploids (2n = 4x = 68) and hexploids (2n = 6x = 102) (Pustovoit, 1966). The sunflower characteristic of turning towards the sun during the day accounts for both its common name and its botanical name, in Greek Helio means the sun and anthos means flower.

Heiser *et al.* (1969) suggested that sunflower is native to North America and grows wild in nearly all parts of the United States. Archaeological explorations in the United States found evidence that sunflower was used by the American Indians as early as 3000 B.C. It was introduced into Spain as an ornamental plant early in the 16^{th} century, then spread to France Hungarya , Russia, and other parts of Europe, where it became very popular as an ornamental plant (Heiser as cited by Miller,1988). It reached the former U.S.S.R. at the end of the 18^{th} century where it used to be grown as an ornamental plant for more than 200 years (Khidir ,1997).

In the thirties of the 20^{th} century, sunflower ranked tenth among the world sources of vegetable oils then fourth in 1950 and today it ranks the third, after soybean and rapeseed (Khidir,1997). The first commercial production of sunflower as an oil crop was started in Canada in 1943 and U.S.A . in 1947, and the former U.S.S.R. was the world's leading producer in the 1960's (Metcalfe and Elkin, 1980).

The economic importance of sunflower can be summarized as follows:

1- Seeds are used as poultry feed.

2- The seeds contain 25% - 50% edible oil and 30% digestible protein, and the cake is a good feed for livestock and poultry.

3- The highly polyunsaturated sunflower oil, which is high in linoleic acid, is used in salad, margarine, soap, dyes and varnish and paints industry.

4- The unsaturated high oleic sunflower oil is used as cooking or frying oil.

5- The achenes of the non-oil seed type are consumed whole, dehulled, roasted or raw, alone or added to other food.

6- The non-oil seed sunflower is used in the confectionery industry.

7- The green shoots are used for silage and forage.

8- The dry stems are used as energy source and as fencing materials.

9- The plant is grown as an ornamental, a windbreak in vegetable farms and for honey bee husbandary.

10-The inner part of the stem is used in the paper industry.

The first breeding efforts to improve sunflower for cultivation seem to have been by the early Ozark Bluff dwellers in North America. Deliberate selection for genetic improvement was initiated in Russia in the 1920s. The major achievements by these first breeding efforts were earlier maturity and higher oil percentage of the achene (Fick as cited by Miller,1988). The most successful early breeding programme was that of V. S. Pustovoit in the former U.S.S.R who by

1965 had increased the oil percentage of commercial cultivars to 40%-45%. In addition, breeding efforts improved resistance to sunflower head moth (*Homoeosoma nebullela* Hb) and to the broomrape (Miller,1988).

Leclercq (1969), in France, reported finding cytoplasmic male sterility in the progeny of a cross between *Helianthus petiolaris* Nutt. and cultivated sunflower.The resultant crosses with fertile cultivated plants produced a progeny that was also sterile. Kinman (1970) discovered genetic fertility restoring genes in lines that were also derived from wild species crosses.Vranceanu and Stoenescu (1979) also reported fertility restoring genes. Thus, the two factors necessary for the cytoplasmic-genetic system of hybrid seed production were found and distributed among the breeding programmes of the world. The first hybrid produced by this system was made available for commercial production in the United States in 1972 and by 1976, hybrids were grown on over 80% of the sunflower production area (Miller and Guya,1984).

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, Upper Nile, South Kordofan and South Darfour States which are suitable areas for rainfed cultivation, whereas Gezira, Sennar, Rahad and Suki are regions potentially favourable for sunflower cultivation with supplementary irrigation (Skoric, 1982).

The commercial production of sunflower in the Sudan was started in the mid-eighties by the private sector in Damazine, Gadarif and Renk. A variety testing programme, was initiated by Agricultural Reseach Corporation (ARC) in 1989 have resulted in the release of two open-pollinated cultivars, Rodeo and Bolero that were renamed Damazin-1 and Damazin-2. In addition, three hybrids Hysun-33, Jwalmukhi and PAN 7392, have recently been released by Arab Sudanese Seed Company (Assco) and ARC (ElAhmadi,2003; Nour,2003). According to the statistics of the FAO (2001), sunflower was grown in the world on 23400, 21081 and 18398 thousand hectares in the years 1999, 2000, 2001, respectively. The total production in these three seasons was 29129, 26169 and 20903 thousand m.t., respectively. In the Sudan MAF (2004) , report stated that sunflower was grown on 21, 5 and 11 thousand hectares in the years 1999, 2000 and 2001, repectively. The corresponding total production was 8, 4 and 4 thousand m.t.

The low productivity is due to many constraints which could be summarized as follows: -

1- Lack of high yielding hybrids or improved open-pollinated varieties for different agro-ecological zones.

2- Inadequate adoption of improved agronomic practices.

3- Lack of suitable machinery for planting, harvesting and threshing.

4- Damage by birds, insects and diseases.

5- Exposture of late sown areas to water stress by the end of the season.

6- High cost of introduced hybrid seeds and high percentage of empty seeds especially in non-hybrids varieties.

7- Mal-distribution and fluctuation of rains.

The objectives of this study were

i. to estimate the magnitude of heterosis in different characters of some sunflower hybrids, and to study the relative importance of general and specific combining ability of these hybrids,

ii. to identify lines with superior combining ability to be used for synthetic populations,

iii. to identify good pollinators for direct use in synthesis of new hybrids or improved lines for future breeding programmes,

iv. to determine the components of genotype x environment interaction in order to find the relative contribution of each component, and

v. to determine the stability of performance of the hybrids in various environments.

CHAPTER TWO

LITERATURE REVIEW

2.1 Phenotypic variability

Sunflower breeders use diverse inbred lines, grown across a wide range of latitude and ecological areas, in the development of hybrids. It has been established that most controllable and uncontrollable environmental conditions can increase or decrease the rate of development of sunflower (Goyne and Hammer, 1982).

Kluza and Musnicki (1998) stated that the variability in plant height at different development stages and some features characterizing stems of maturing plants, their leaves and heads, were different for hybrids and open-pollinated varieties. Hybrids were more phenologically uniform than open-pollinated varieties, with respect to number of leaves per plant and morphological features of capita. A wide range of variability in plant height, 50% flowering, number of seeds per head, seed yield, stem diameter, 100-seed weight and yield per plant was reported by El-Ahmer *et al*. (1989).

Wang *et al*. (1997) found a wide range of variability in husk percentage, number of seeds per head seed yield per plant and seed weight . Garcia Ruiz (1994) reported that the ease of hull removal was generally highest in cultivars which matured early, and cultivars of high 100-seed weight, following application of nitrogen, and in drier seeds and in seeds of low oil content. Cruz (1986) recorded significant variation among hybrids for plant height, head diameter, 1000-seed weight and seed yield per plant, while highly significant differences among parents were detected for 1000-seed weight and plant height. A considerable variation was reported among genotypes for 50% flowering, plant height, days to maturity, number of seeds per capitulum, 1000-seed weight, seed yield per plant, head and stem diameter and seed yield per hectare (Chervet and Vear, 1990).

2.2 Heterosis

The biological phenomenon in which an F_1 hybrid of two genetically dissimilar parents shows increased vigour at least over the mid-parent (P1+P2/2), is known as heterosis. The term was coined by Shull (1908) to describe the stimulation resulting from increased heterozygosity and is used synonymousely with the term hybrid vigour which describes the beneficial effects of hybridization. The German botanist, J.G. Koelreuter, who carried out the first systematic studies on plant hybridization, observed increased vigour in some of his hybrids, and in 1761 and 1766 he published the first record on hybrid vigour (Burton, 1983).

The economic significance of heterosis in crop breeding was widely appreciated after the success of hybrid maize. By 1910, Shull and others provided the essential framework for commercial exploitation of this phenomenon in maize; however, its use was delayed 20 years, because of lack of suitable inbred lines as well as skepticism about the feasibility of commercial production of hybrid seed (Burton, 1983). Genetically, heterosis refers to the significant increase or decrease in F_1 value over mid-parent value. However, from the plant breeders view points, increase over better-parent and/or the popular commercial cultivar is more relevant. The former is designated as heterobeltiosis and the latter as standard heterosis (Fonesca and Patterson, 1968). Gallas (1987) indicated that the phenomenon of heterosis is more frequent and more intense in the cross-pollinated plants than in self-pollinating ones (approximately 10% in wheat and more than 200% in corn). Heterosis for plant height is usually positive, although some studies showed negative one for this trait e.g (Singh and Singh, 1979) in rice. Heterosis for days to flowering has been reported to be generally negative by (Virmani *et al*., 1982) in rice.

Channakrishnaiah *et al.* (1996), in a study of 120 three-way crosses (TWC) in sunflower and their 24 single crosses, reported that except for days to 50% flowering and oil content, the relative performance of TWC hybrids was significantly higher than related single cross hybrids for yield and yield related characters. Kumar *et al*. (1999) found that the extent of heterosis in 24 sunflower hybrids over the better- parent (BP) ranged from –24.75% to 40.36% for seed yield and from -15.56% to 29.41% for oil contents. The superiority of the hybrids over the standard variety (check) ranged from -33.06% to 34.35% and from -23.11% to 16.13% for seed yield and oil content, respectively.

Lande *et al*. (1998) reported positive heterosis for plant height and negative heterosis for days to 50% flowering and maturity. In addition, a high degree of heterosis for number of seeds per head (166.45%) and seed yield per plant (146.4%) and the highest negative and significant heterotic values for number of seeds (-75.50%) and seed yield per plant (-53.03%) were reported by Limbore *et al*. (1998). Goksoy *et al.* (1999b) indicated that heterosis of F_1 combinations varied between 3.5% and 43.1% for plant height, 10% and 64.5% for head diameter, 12.3% and 93.0% for 1000-seed weight, 7.8% and 98.4% for seed yield per plant and 15.9% and 178.0% for seed yield. Giriraj *et al*. (1986) found that the average heterosis ranged from 7.7%
for days to flowering to 192.4% for achene yield per plant. The percentage contribution of number of filled achenes, leaf area, head diameter and 100-achene weight towards heterosis for achene yield was 37.7%, 20.7%, 15.3% and 8.7%, respectively.

Cheres *et al*. (2000) detected significant heterosis for seed yield and plant height, but not for oil concentration and days to flowering. A heterotic effect of 47 g/kg over the mid-parent value was obtained for achene oil content (Dedio, 1993). On the other hand, Sheriff *et al.* (1985) reported that most of the hybrids studied exceeded their respective better- parents in achene yield per capitulum, Singh *et al*. (1984) concluded that heterosis in F_1 is correlated with performance of the better-parent for days to maturity, head diameter, and shelling percentage and generally high in low x low or average x low combinations. The range of heterosis was 47% to 206% for yield and 5% to 55% for other traits. Chaudhary and Anand (1984) stated that the values of heterosis over the better- parent were 66.23% for 1000-seed weight, 69.89% for seed yield, 64.65% for head diameter, 23.17% for oil content, 18.47% for number of leaves and –7.69% for days to flowering. Cruz (1986) reported positive heterosis for 1000-seed weight, yield per plant, and head diameter while negative heterosis effect for plant height was observed.

Sun (1986) indicated that heterosis for yield per plant, 100-seed weight and seed oil content showed a close positive correlation with general combining ability of parents. Sudhakar (1979) reported that heterosis relative to mid-parent value accounted for up to 41% for yield and 31% for oil content. On the other hand, Ge-CF (1981) obtained an average increase of 75.9% in yield, 47% in number of achenes per head, 15.9% in head diameter and 22.4% in stem diameter. Zazharskii (1978) claimed that among F_1 hybrids between varieties differing in length of growth period, early predominated (46.2%) and 14% showed overdominance of earliness. Intermediate inheritance was found in 33.3%, while 18.3% showed dominance of the late parent. Gorbachenko (1984), in a study of top-cross hybrids between tall and short with a somewhat lower 1000-seed weight than that of normal sunflowers, reported that 88.6% of the hybrids showed heterosis for achene yield relative to the short standard variety, and most of the hybrids outyielded the standard variety.

Bounnit *et al*. (1978), in a study of heterosis for oil content and quality, stated that heterosis for oil content was 5-10 times less than that for seed yield. Linoleic acid mostly showed in-complete positive dominance in single and three-way hybrids, and oleic acid showed incomplete negative dominance. Filipescu *et al*. (1977) found that, in the hybrids, the better-parent positively influenced oil quality. In 58.3% of the cases, the male parent had the main influence and in 16.7% of the cases it was the female parent and heterosis ocrurred in 16.7% cases. In addition, significant heterosis was obtained for plant height, stem girth, head diameter and yield per plant. Heterosis for oil content was significant only over the mid-parental value and was negative for 100-achene weight (Shrinivasa, 1982). Also, high levels of heterosis for filled seed, harvest index, seed yield and oil content was reported by Madrap and Makne (1993).

In crops other than sunflower, many researhers have detected heterosis for different traits. In maize, khalafalla and Abdalla (1997) reported heterosis over mid-parent for number of cobs per plant, number of rows per cob, number of seeds per cob, 100-grain weight and grain yield per plant. Krishnaswami and Appadurai (1984), in a study of heterosis in sesame, found that, it was high for number of capsules and seed yield. In oil seed rape, Grant and Beversdorf (1985) reported heterosis for 50% days to flowering over the better- parent.

2.3 Combining ability

Knowledge of gene action and combining ability helps in proper understanding of inheritance of characters, in selection of suitable parents for hybridization and in isolation of promising F_1 hybrids for further exploitation in breeding programmes. Combining ability in the general sense is defined as the average performance of a line in a series of crosses. In specific sense, it is a deviation from performance predicted on the basis of general combining ability.

Sprague and Tatum (1942) reported that general combining ability (GCA) provides an estimate of additive gene action, while specific combining ability (SCA) provides an estimate of non- additive gene actions. Shekar *et al*. (1999) indicated non-additive gene action for days to flowering, plant height, head diameter, stem girth, seed yield per plant, oil content and oleic acid, and additive gene action for 100-seed weight. On the other hand, Lande *et al.* (1997) reported high SCA for plant height, 50% flowering, days to maturity, stem and head diameters, 1000-seed weight, seed yield per plant, percentage of empty seeds, seed yield and oil content, indicating that all these traits are controlled by non-additive gene action. Kumar *et al*. (1998) recorded a predominance effect of additive gene action for stem diameter, days to 50% flowering and number of leaves per plant, whereas non-additive gene action was predominant for plant height, head diameter, number of filled seeds per head, 100-seed weight, oil percentage and oil yield. In addition, Ashok *et al.* (2000) stated that additive gene action was predominant for days to 50% flowering, days to maturity, plant height, stem and capitulum diameter, yield per plant and harvest index, while 100-seed weight and oil content were controlled by non-additive gene action.

In a genetic analysis of quantitative traits, Singh and Singh (2000) reported the predominance of non-additive gene action for seed yield, plant height, number of leaves and harvest index. Meanwhile, days to flowering, head diameter and 100-seed weight were governed by additive gene action. However, both additive and non-additive gene action were reported to be equally important for days to maturity and oil content. Rudranaik *et al.* (1990) claimed that only leaf area index and 100-seed weight were controlled by additive gene effect. Sheriff and Appadurai (1985) found that additive gene effects were important for seed yield, plant height, number of leaves, number of seeds per capitulum and dry matter content. Cruz (1986) found that the variance due to the interaction of lines and testers was significant only for head diameter indicating that non-additive gene action effects predominated for this trait, whereas additive gene action predominated for plant height. Ortegonn-Morales and Escobedo-Mendoza (1993) recorded that additive gene effects were predominant in the control of achene yield, and non-additive effects in the control of oil content. On the other hand, Kadal *et al*. (1984) reported that all the characters studied except the days to flowering were controlled predominantly by non-additive gene action.

Goksoy *et al*. (2000) stated that variances due general and specific combining ability were highly significant for number of seeds per head and seed yield. Specific combining ability variance was significant for head diameter, seed weight and 1000-seed weight only, while general combining ability variance was significant for plant height. Shrinivasa (1982) found that non-additive gene effects predominated for yield, whereas additive and epistatic effects were found for oil content. On the other hand, Sudhakar (1979) reported that additive gene variance was more important for number of leaves, seed yield, hull content and oil content, while non-additive variance was important for plant height, stem diameter, 1000-seed weight, number of seeds per head, number of days to 50% flowering and days to maturity. Higher dominant actions than additive effects were reported for plant height, 1000-seed weight, seed yield per head and seed yield (Goksoy *et al*., 1999a). In addition, Pathak *et al*. (1989) stated that non-additive gene action was important for plant height, head diameter, 1000-achene weight, yield per plant, achene filling, achenes per plant, husk content and oil content. A greater additive genetic variance, than non-additive one, was reported for achene yield and oil percentage (Rincon- Carreon and Palafox- Barreda, 1983).

Analysis of 8 x 8 half-diallel cross indicated that dominance gene effects were predominant for plant height, number of leaves, oil content and number of days to flowering, but both additive and non-additive gene effects affected seed yield, 100-seed weight, plant height, stem diameter, husk content and number of leaves (Rao and Ananda-Rao,1980). However, in 8 x 8 diallel analysis, they reported that GCA variances were higher than the SCA variances. Pratial dominance occurred for seed yield, 1000-seed weight and oil content. Complementary expistasis occurred for plant height, stem diameter, yield, husk content and oil content. Dominant genes predominated in the control of number of days to flowering, plant height, number of leaves and oil content. On the other hand, Tuberosa *et al*. (1982) reported that GCA effects of the female parents were significant for plant height, 50% flowering, stem girth, head diameter, 100-seed weight and number of seeds per head, but not significant for oil yield and achene yield, and GCA effects in the male parents were significant for every character studied except oil content and plant height. SCA for achene yield and oil yield were greater than GCA effects.

Under saline conditions, SCA variances were higher than GCA for days to 50% flowering, days to maturity, stem and head diameter, 1000-seed weight, seed yield per plant and seed yield which were generally controlled by additive gene actions (Hussain *et al*. 1998) On the other hand, Sassikumar *et al*. (1999)

reported predominance of non-additive gene action for plant height, days to flowering, days to maturity, stem and head diameters, seed yield per plant, 100-seed weight, seed yield/ha and seed oil content. Ali *et al.* (1992), in a half-diallel analysis, indicated additive gene action for oil percentage with partial dominance, while protein percentage and seed yield per plant showed over-dominance type of gene action. Alba *et al*. (1980) indicated that non-additive effects were more important than additive ones for achene yield, plant height, flowering date and percentage central fertility of the head, whilst additive effect predominated for percentage oil content and head diameter.

In crops other than sunflower, many researchers have emphasized the importance of combining ability in breeding programmes. Ranvir-Singh *et al*. (1983) reported, in durum wheat, that both the GCA and SCA variances were significant for plant height, grain yield, spike number, grain number, 100-grain weight and days to heading, but the SCA components of variance were higher than those of GCA for grain yield per plant, spike per plant, grains per spikes and 100-grain weight. However, for spike length, plant height and days to heading GCA was of higher magnitude. The higher magnitudes of SCA components of variance for grain yield indicated the predominance of non-additive genetic effects for those characters. On the other hand, Pava (1978), working on grain sorghum, stated that SCA was important for grain yield, grain number and percentage protein, whereas GCA was only important for grain weight. In addition, Khalafalla and Abdalla (1997), in maize, indicated that the contributions of GCA and SCA among the hybrids for number of cobs/plant, number of rows/cop, cob weight and grain yield per plant were of equal magnitudes. However, for 100-grain weight and grain yield/ha, GCA effect was more important than SCA effect, and the contribution of SCA among the hybrids was higher than GCA for number of seeds/cob.

Yadav *et al*. (1988) studied spring wheat and reported that days to heading, plant height, grain per head and 1000-seed weight appeared to be controlled by additive gene effect, whereas tiller number and grain yield were influenced by both non-additive and additive gene effects. On the other hand, Gowda and Bahl (1978) found that variances due to GCA in chickpea were of higher magnitude than the corresponding SCA variances for plant height, 100-seed weight, flowering time and seed yield, indicating that these traits were controlled by additive gene action. However, Mathotra *et al* (1983) claimed that both additive and non-additive gene actions were important for yield, 100-seed weight, plant height, flowering time, seed per pod and pods per plant in chickpea. Labana *et al*. (1981) reported greater SCA variance for pods per plant and pod yield in groundnut, while GCA variance was greater for 100-seed weight.

In rice, many workers claimed that heterotic crosses showing high SCA for yield are usually derived from parents possessing high x high or high x poor GCA (Peng and Virmani, 1990). Occasionally average x poor combiners also showed heterosis (Kumar and Saini, 1983). On the other hand, Singh and Nanda (1976) and Rahman *et al.* (1981) reported that high SCA values of certain crosses were derived from poor combining parents. Singh *et al*. (1977) indicated that high x high general combiners had resulted in crosses showing high SCA effects. However, Shrivastava and Seshu (1982) stated that crosses between high general combiners did not always result in good F_1 combinations.

2.4 Stability of performance

Increased concern with the importance of homeostasis in living organisms has stimulated plant breeders' awareness for the need to develop well-buffered cultivars. This has led to a greater emphasis on phenotypic stability in breeding programmes. stability is defined in many ways depending on how the scientist wishes to look at the problem, and the statistics that parameterize the various concepts are also numerous. Lin *et al*. (1986) reported several stability models proposed by, Plaisted and Peterson (1959),Wrickle (1962),Finlay and Wilkinson (1963), Eberhart and Russell (1966), Perkins and Jinks (1968) and Francis and Kannenberg (1978). Witcombe (1988), stated that several statistical techniques have been developed to analyse the interaction of genotypes with environments

(G x E) and regression analysis has been extensively used. He added that the first proposal of a regression analysis to study GxE interactions was by Yates and Cochran, (1938) and a modification of this method has been used by Finlay and Wilkinson (1963), They carried out a study on 277 varieties of oats grown 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 above 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 deviations 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 Bradshaw (1964) defined stability as adaptation to withstand unpredictable transient environmental conditions. They pointed out that heterozygous and heterogeneous populations offer the best opportunity to produce varieties, which show small G x E 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 buffering” 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 heterogeneous population will possess population buffering.

Lin *et al*. (1986) studied the statistical relationship among nine conventional 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 its 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 *et al*. (1986) concluded that among these types of stability, type 3 is the most problematical, because the residual MS from regression model is merely an indicator of goodness of fit, and can not be considered as stability parameter. In addition, Lin and Binns (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 Binns (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 types 2 and 3 are non-heritable, and thus not useful.

The use of genetic mixtures rather than homogeneous, or pure line, varieties has been suggested as a mean to reduce GxE interactions. Jensen-Neal (1952) suggested that a multi-line variety of oats as compared to pure line varieties would possess greater stability of production, broader adaptation to environment and greater protection against disease. Sprague and Federer (1951), in their analysis of maize data, obtained over many environments, presented evidence that doubl-crosses interacted with environment less than single crosses. The data suggested that double-crosses were superior to single crosses for stability of performance. Eberbart *et al*. (1964) claimed that hybrid x year interactions are significantly greater for single-crosses than for three-way crosses. Rasmusson and Lambert (1961) reported that variety x year component was more than 4 times as large as the variety x location component in barley trials, over 4 years at 8 locations in Minnesota, with the variety x year x location component still larger. Such findings have an important bearing on methods of testing varietal differences.

Genotype x environment interactions in sunflower have been long recognized as an important factor influencing the performance of sunflower. When changes deviate widely from the normal patterns either towards high or low temperatures, rainfall, humidity, latitudes and/or light, the crop will react differently.

Prusti *et al*. (1999), studying stability analysis for oil yield and its components, reported highly significant differences among genotypes (G), environments (E) and G x E interactions for oil yield, oil content, plant height, 100-seed weight and percentage of hull content. Stability of five out of twenty-one sunflower hybrids for plant height, head diameter, days to 50% flowering and single plant yield, across the testing environment was reported by Pillai *et al*.(1995). Laishram and Singh (1997) reported significant genotype x environment interaction for plant height, days to 50% flowering and maturity, head diameter, 100-seed weight, percentage of filled seeds per head, seed yield per plant and oil content. Shinde *et al*. (1992) found significant environmental effects and genotype x environment interactions for plant height, days to 50% flowering, head diameter, 100-seed weight, percentage of empty seeds, seed yield per plant, head diameter and seed yield/ha. On the other hand, Chaudhary and

Anand (1988) noted that variety x season interactions were only significant for days to heading and flowering, plant height, days to maturity and seed oil and protein content. They concluded that, in evaluating yield and its components, results from one site in several seasons might be as reliable as those from several sites and seasons.

In a study aimed at synchronizing anthesis for crossing purposes, Goyne and Schneiter (1988) subjected 16 sunflower genotypes to day/night temperature regimes and different light hours. The light x temperature x genotype interaction was not significant. Light x genotype and temperature x genotype interactions were highly significant for number of days from emergence to visible bud stage (R_1) and for number of leaves at R_1. Other significant interactions were temperature x genotype for number of leaves and plant height at R_1 and light x genotype interaction for plant height. Differences in light energy levels had little influence on genotype photoperiodic behaviour . On the other hand, Seetharam and Satyanarayana (1980) studied the effect of seasonal fluctuations in temperature and humidity of cytoplasmic male-sterility (CMS) in terms of percentage stained fertile pollen, during three different seasons. They claimed that all lines tested produced stainable pollen when sown in summer, indicating the breakdown of CMS due to high temperature.

Moro *et al*. (1994), found that days to flowering x latitude and days to flowering x mean temperature did show significant influence on genotype x environment interaction. Halaswamy *et al*.(2000) studied the stability of sixteen genotypes, and reported genotypic differences in four locations for head diameter, 1000-seed weight, seed yield per plant and seed yield/ha, while stem diameter, number of filled seeds and oil yield per plant were not. On the other hand, Velazquez-Cagal *et al*. (1990) reported that genotype x environment interaction was important for achene yield, oil content, oil yield, kernel and hull percentage and 1000-seed weight. Rangaswamy *et al*. (1986) found non-significant genotype x environment interaction for seed yield, oil yield per plant and oil content for five varieties grown at five sites under rainfed and irrigation. Tuberosa *et al*. (1982) reported significant genotype x locality interaction for plant height, 1000-seed weight, number of seeds per capitulum and seed yield/ha.

Dua and Ram-Parkash-Dua (1979), examined 12 x 12 diallel crosses together with F_2, BC_1 and BC_2 of ten yield components. They found that plant height, stem diameter and head diameter had the greatest effect on yield. Additive genetic variance was relatively more stable with respect to number of days to flowering, number of days to maturity and oil content, in contrast to dominance component in the cases of yield per plant, plant height and 100-seed weight. On the other hand, Luduena and Marta (1979) reported that the eight varieties investigated yielded well when grown under favourabe environmental conditions. Two varieties were relatively insensitive to environmental influences even on poor sites, which could be used as source material for breeding. Five displayed moderate sensitivity, giving unacceptable yield on poor sites, while only one variety was most sensitive and was suited only to the best testing sites. Alvarez *et al*. (1992) found a wide range of variability and significant genotype x environment interaction for plant height, days to 50% flowering, days to maturity, seed length, 1000-seed weight, seed yield per plant, seed size, stem and head diameter, seed yield/ha and oil content.

CHAPTER THREE
MATERIALS AND METHODS
3.1 Experimental material, location and design

Two exotic male-sterile lines (Kr and Ka) and fourteen fertility restoring lines (testers), designated SH-2 to SH-24, were locally improved at the Department of Agronomy, Faculty of Agriculture, University of Khartoum (Table 1).They were planted in the winter seasons of 2000/01 and 2001/02 at the University Farm. Crossing was made by hand pollination and nicking was ensured by differential planting of the males and females. Parents were immediately bagged after the appearance of the ray florets and before the appearance of the disc flowers using paper bags. The pollen was collected from the bagged male, either by rubbing the male disc by toilet tissue or tapping the male disc into the paper bag. Then, the pollen was rubbed onto the female disc which was, thereafter, covered by a paper bag. Hence, 28 single cross hybrids were produced.

The 28 hybrids designated SHR produced by the female Kr and SHA produced by the female Ka and the commercial hybrid Hysun-33 (check) were evaluated for two summer seasons (2000/01 and 2001/02) at two locations, namely, University of Khartoum Farm at Shambat (15˚40´N, 32˚32´E) and Rahad Research Station (13˚14´ N, 33˚34´ E), Agriculture Research Corporation. Meteorological data of the two locations are shown in appendices 1 and 2.

The trial was sown on 17 July at Shambat and 18 of August at Rahad in the first season and 21and 29 July at Shambat and Rahad in the second season respectively . A randomized complete block design, with three replications at each location and season, was used.

The plot for each entry consisted of four rows, each two meters long. The plants were spaced at 70 and 20 cm apart between rows and within row, respectively. Two seeds were sown per hill. Three weeks after sowing, the plants were thinned to one plant per hill. The first irrigation at both locations was given immediately after planting, and the subsequent irrigation intervals were scheduled at 10 days unless there was precipitation. Fertilizer was applied as urea (46% N) in two split doses at a rate of 190 kg/ha, with half the amount applied at the four leaves stage and the other half at the bud stage. Weeding was done, whenever necessary, by hand to maintain a clean field. No diseases or insects' damage were recorded during the experimentation period.

3.2 Data collection

Data on the following parameters were recorded using 10 plants randomly selected from the two inner rows in each plot, which were immediately covered after flower fertilization by paper bags for protection against bird damage

A. Morphological characters

1. **Plant height (cm):** The average distance from the soil to the point where the capitulum is attached to the stem, immediately after fertilization
2. **Stem diameter (cm):** The average thickness of the stem at the fourth internode,using a vernier
3. **Days to 50% flowering:** The number of days from planting to the date when 50% of the heads in a plot have initiated anthesis
4. **Days to physiological maturity:** The stage when the back of The head turned from green to yellow and its peripheries turned brown.
5. **Head diameter (cm) :** The average diameter of heads using scale tape

B. Yield and yield components:-

The following parameters were determined at harvst:

1. **Number of seeds per head:** Calculated by dividing the seed yield by the corresponding 1000-seed weight, and multipling by 1000
2. **Percentage of empty seeds:** Due to some difficulties, this parameter was studied only for the Shambat location, and it was determined by dividing the number of empty seeds per head by the total number of seeds per head multiplied by 100.

3. 1000-seed weight (g): Average weight of triplicate random sample of 1000-seeds, from the bulked dried seeds of each plot

4. Seed yield per head (g): Calculated by dividing the seed yield per plot by the corresponding number of heads per that plot.

5. Seed yield/ha(t): The heads from each plot were air dried, separately threshed, cleaned, bulked and weighed. The seed yield was then calculated according to the following formula:

$$\text{Seed yield/ha (t)} = \frac{\text{Seed weight plot(kg) x 10000}}{\text{Plot area x 1000}}$$

3.3 Statistical analysis

The recorded data were subjected to individual and combined analyses of variance (ANOVA).

3.3.1 Individual analysis of variance: To determine the extent of variation in the experimental material, individual analysIs of variance was carried out separately, for each location and season, using the form of ANOVA (Table 2) of a randomized complete block design, described by Gomez and Gomez (1984), and the form of ANOVA (Table 3) for a randomized complete block design for line x tester analysis, described by Kempthorne (1957). Coefficient of variation (C.V.) for each character was calculated according to the following formula:

$$C.V.\% = \frac{\sqrt{\text{Error mean square}}}{\text{Grand mean}} \times 100$$

The mean separation for all possible pairs of treatment means was carried out by using Duncan Multiple Range Test, as described by Gomez and Gomez (1984).

3.3.2 Combined analysis of variance: Combined analysis of variance was carried out using the form of ANOVA (Table 4), described by Gomez and Gomez (1984), for the data collected at Shambat and Rahad over the two seasons (2000/01 and 2001/02).

3.4 Magnitude of heterosis

Estimation of mid-parent and better-parent heterosis percentage was carried out according to the following formulae (Davis, 1978).

$$\text{Mid-parent heterosis (MPH)} = \frac{F_1 - (P_1 + P_2)/2}{(P_1 + P_2)/2} \times 100$$

$$\text{Better-parent heterosis (BPH)} = \frac{F_1 - BP}{BP} \times 100$$

where, F_1, P_1 and P_2 and BP are the means of F_1 hybrid, the first, the second and the better- parent, respectively.

3.5 Combining ability

General and specific combining ability (GCA and SCA) effects were computed following the procedure developed by Kempthorne (1957) for line x tester analysis procedure.

General combining ability (GCA) effects:

(a) Lines

$$\text{GCA (line)} = \frac{\sum (L_1 \times t_1 + .. + L_1 \times t_n)}{tr} - \frac{\sum (L_1 \times t_1 + \ldots + L_1 \times t_n) + (\ldots) + (L_n \times t_1 + \ldots + L_n \times t_n)}{Ltr}$$

(b) Testers

$$\sum(t_1 \times L_1 + \ldots + t_1 \times L_n) - \sum (t_1 \times L_1 + \ldots + t_1 \times L_n) + (\ldots) + (t_n \times L_1 + \ldots + t_n \times L_n)$$

$$\text{GCA (testers)} = \frac{}{Lr} - \frac{}{Ltr}$$

Specific combining ability (SCA) effects:

(c) $$SCA_{Lxt} = \frac{L_1 x\, t_1}{r} - \frac{\sum (L_1 x\, t_1 + \ldots + L_1 x\, t_n)}{tr} - \frac{\sum (t_1 x\, L_1 + \ldots + t_1 x\, L_n)}{Lr} +$$

$$\frac{\sum (t_1 \text{ x } L_1 + \ldots + t_1 \text{ x } L_n) + (\ldots) + (t_n \text{ x } L_1 + \ldots + t_n \text{ x } L_n)}{Ltr}$$

where, L, t and r are the number of lines, testers and replications, respectively.

(d) Standard errors of combining ability effects were calculated as follows:

S.E. (GCA for lines) = $(M.S.e/rt)^{1/2}$

S.E. (GCA for testers) = $(M.S.e/rL)^{1/2}$

S.E. (SCA effects) = $(M.S.e/r)^{1/2}$

(e) Percentage contribution of variation in GCA for lines and testers and SCA to the total variation among hybrids were estimated as:

$$\text{The contribution due to lines} = \frac{\text{SS due to lines}}{\text{SS due to crosses}} \times 100$$

$$\text{The contribution due to testers} = \frac{\text{SS due to testers}}{\text{SS due to crosses}} \times 100$$

The contribution due to line x tester =

$$\frac{\text{SS due to lines x testers interactions}}{\text{SS due to, crosses}} \times 100$$

3.6 Stability of 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 use of both the regression coefficient and deviation from regression.

$Y_{ij} = \mu_i + b_i I_j + \sigma_{ij}$

where,

Y_{ij} is the mean of i^{th} genotype in j^{th} environment (i = 1, 2…, t and j = 1, 2,…, S)

μ_i = Mean of all the genotypes over the 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.

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

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

$$I_i = \frac{\sum_j Y_{ij}}{t} - \frac{\sum_i \sum_j Y_{ij}}{ts}$$

where:

I_i = 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 observations

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 ($\sum_j \sigma^2_{ij}$)

for a genotype was calculated as follows:

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

where:

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

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

The mean square deviation ($S^{-2}d$) from linear regression for a genotype was calculated as follows:

$$S^{-2}d = \sum_j \sigma^2_{ij} /(S-2) - (S_e^2/r)$$

where:

S_e^{-2}/r = the estimate of mean square for pooled error.

CHAPTER FOUR

RESULTS

4.1 Phenotypic variability

4.1.1 Plant height

Highly significant differences, among the evaluated sunflower hybrids, in plant height were detected in the first season at Shambat (2000/01) and in both seasons at Rahad (Table 5). Likewise, the line x tester analysis of variance (Table 6) showed highly significant differences for crosses at shambat in the first season and at Rahad in both seasons. Highly significant differences for lines and non-significant differences for lines x testers, at both locations and seasons, were also detected. Testers, on the other hand, exhibited highly significant differences at shambat in the first season and at Rahad in the second one. The combined analysis of variance showed highly significant interaction for locations, genotypes, genotype x location and location x season (Table 7).

At Shambat, the tallest hybrid was SHR-2 (166.6 cm) in the first season, and the shortest one was SHR-24 (123 cm) (Table 8). In the second season, SHA-6 was the tallest (161.3 cm) and SHR-7 was the shortest (107.6 cm). The overall mean plant height was 145.1 and 134.7 cm in the first and the second season, respectively. The coefficient of variation was 8.3% in the first season and 11.1% in the second one. At Rahad , on the other hand, the tallest hybrid was SHA-6 (177.3 cm) in the first season and SHA-9 (180.0 cm) and SHA-10 (179.7 cm) in the second season (Table 9).

The shortest hybrid was SHR-8, in the first and the second seasons. The overall mean plant height was 148.4 and 158.9 cm in the

first and the second season, respectively, and the coefficient of variation was 8.6% in the first season and 4.6% in the second one.

The across location and season means (Table 10) showed that the shortest hybrid was SHR-8 (128.3 cm), and the tallest one was SHA-6 (164.2 cm). The overall mean plant height was 146.3 cm, and the coefficient of variation was 8.6 %.

4.1.2 Stem diameter : -

The individual analysis of variance for stem diameter indicated highly significant differences among the evaluated hybrids at Shambat in the first season and at Rahad in both seasons. The mean squares for line x tester analysis (Table 6) showed highly significant differences for crosses at Shambat in the first season and at Rahad in the second one, and a highly significant mean squares for lines at Shambat in both seasons and at Rahad in the second season. Non-significant differences among testers at Shambat in both seasons and at Rahad in the second season were detected. Line x tester interactions exhibited significant differences at Shambat in the first season and non-significant differences in the second season and at Rahad in both seasons. The combined analysis of variance (Table 7) for locations, seasons, genotypes, genotype x location and location x season indicated highly significant differences for this trait.

At Shambat, stem diameter ranged from 2.5 cm for SHR-24 to 3.3 cm for SHR-2 in the first season (Table 8). In the second season, it ranged from 2.6 cm recorded for SHR-10 to 3.7 cm scored by SHA-6. The overall mean stem diameter was 2.9 and 2.8 cm for the first and the second seasons, respectively. The coefficient of variation was 7. 7% for the first season and 6.6% for the second one.

At Rahad, stem diameter ranged from 2.8 cm recorded for SHR-24 to 3.4 cm scored by the hybrid SHR-2, in the first season (Table 9). In the second season, it ranged fron 2.0 cm scored by SHR-8 to 3.0 cm recorded for SHA-2. The overall mean was 2.9 cm for the first season and 2.6 cm for the second one. The coefficient of variation was 6.3% and 10.2% for the first and the second seasons, respectively.

The across location and season means (Table 10) revealed that stem diameter ranged from 2.6 cm recorded for SHR-24 to 3.1 cm scored by SHA-24. The overall stem diameter was 2.8 and the coefficient of variation was 8.9 %.

4.1.3 Days to 50% flowering: -

Highly significant differences among the evaluated sunflower hybrids were obtained for days to 50% floweing at Shambat in both seasons and at Rahad in the second season (Table 5). Line x tester analysis of variance (Table 6) revealed highly significant differences for crosses and lines at both locations and seasons, while highly significant differences among testers were obtained at Shambat in the first season and at Rahad in the second one. Line x tester interactions were highly significant at Rahad in the second season only. The combined analysis of variance showed highly significant differences for locations, seasons, genotypes, genotype x location, location x season and genotype x location x season (Table 7).

At Shambat, the latest hybrid was SHA-2 (60.0 days), while the earliest was SHR-8 (45.7 days) in the first season. In the second season, the latest hybrid was again SHA-2 (59.7 days) (Table 8). The overall mean days to 50% flowering was 52.1 and 53.3 days for the first and the second seasons, respectively. The coefficient of variation was 1.8% for the first season and 4.3% for the second season.

At Rahad, the latest hybrid was Hysun 33 and SHA-9, while SHR-8 was the earliest in the first season (Table 9). However, in the second season SHA-9 and SHA-24 were the latest, whereas SHR-18 was the earliest. The overall mean days to 50% flowering was 56.9 and 59 days in the first and the second seasons, respectively. The coefficient of variation was 3.5% in the first season and 1.9% in the second one.

The across location and season means (Table 10) indicated that the earliest hybrid was SHR-8 (48.9 days) and the latest one was SHA-9 (60.8

days). The overall mean days to 50% flowering was 55.3, and the coefficient of variation was 3.3%.

4.1.4 Days to physiological maturity:-

Individual analysis of variance revealed highly significant differences among the evaluated hybrids in the number of days to physiological maturity at both locations and seasons (Table 5). Crosses and lines were showed highly significant differences at both locations and seasons. Highly significant differences for line x tester interactions were obtained at Shambat in the first season and at Rahad in both seasons (Table 6). The combined analysis of variance recorded highly significant differences for locations, seasons and genotypes and highly significant differences for genotype x location, location x season, genotype x season and genotype x location x season interactions (Table 7).

At Shambat, the latest maturing hybrids were SHA-9 (93 days) and SHA-2 (92.7 days), and the earliest maturing one was SHA-8 (76 days) in the first season. The latest maturing hybrids were SHA-9 (96 days) and SHA-24 (95.7 days) in the second season, while SHR-8 was the earliest (Table 8). The overall mean days to physiological maturity was 84.5 in the first season and 91.1 in the second season. The coefficient of variation was 1.9% and 3.3% in the first and the second seasons, respectively.

At Rahad, the latest maturing hybrids in the first season were SHA-10 (92.7 days) and Hysun 33 (92.3 days), whereas the earliest one was SHR-8 (81.7 days) (Table 9). Nevertheless, in the second season, the latest hybrids were SHA-10 (92.3 days) and SHA-9 (92 days), whereas SHR-8 (86.7 days) and SHR-7 (86.7 days) were the earliest. The overall mean was the same in both seasons, and the coefficient of variation was the same in both seasons.

Means across locations and seasons (Table 10) showed that the earliest hybrid was SHR-8 (82.7 days) and the latest one was SHA-9 (93.2 days). The overall mean was 88.4 days, and the coefficient of variation was 2.5%.

4.1.5 Head diameter : -

The mean squares of head diameter (Table 5) showed highly significant differences among the evaluated hybrids at Shambat and at Rahad in the first season. The line x tester analysis of variance exhibited highly significant differences of crosses and line x tester interactions at Shambat and at Rahad, in the first season. Highly significant differences between lines and significant differences among testers were shown at Rahad, in the first season only (Table 6). In the combined analysis of variance (Table 7), highly significant differences were detected for locations, seasons and genotypes and location x season, genotype x location and genotype x location x season interactions.

Table 8 shows that the largest head diameter at Shambat was attained by SHR-23 and Hysun 33, whereas the smallest head diameter was possessed by SHR-8 in the first season. On the other hand, SHA-3 and SHR-2 had the largest head diameter in the second season. The overall mean was the same in the first and the second seasons. The coefficient of variation was 8.7% in the first season and 12.2% in the second season.

At Rahad, SHR-2 and SHA-12 possessed the largest head diameter, whereas SHR-8 had the smallest head diameter in the first season (Table 9). In the second season, SHR-2 and SHA-23 had the largest head diameter, while SHR-8 possessed the smallest. The overall mean in the first and the second seasons was 16.8 and 19 cm, respectively. The coefficient of variation was 5.4% in the first season and 6.9% in the second season.

The across location and season means (Table 10) showed that the largest head diameter was possessed by SHR-2 and SHA-3, whereas SHR-8 had the smallest one. The overall mean was 17.2 cm, and the coefficient of variation was 8.5%

4.1.6 Number of seeds per head: -

The individual analysis of variance (Table 5) showed highly significant differences among the evaluated hybrids for number of seeds per head mean squares, at both locations and seasons. Crosses, lines and line x tester interactions were showed highly significant differences at Shambat in the first season and at Rahad in both seasons (Table 6). Differences among crosses,between lines and among testers were significant at Shambat in the second season. Highly significant differences for locations, seasons and genotypes, and genotype x location x season interactions and significant differences for genotype x location interaction were detected for this trait (Table 7).

Hybrid SHA-24 had the largest number of seeds per head in the first season at Shambat, whereas the smallest number was possessed by SHR-6. In the second season, SHA-13 had the largest number of seeds per head, while SHR-8 possessed the smallest number (Table 8). The overall mean number of seeds per head was 1164 and 1083 in the first and the second seasons, respectively, and the coefficient of variation was 16.3% in the first season and 19.8% in the second one.

At Rahad, (Table 9) SHA-3 and SHA-7 had the largest number of seeds per head, while SHR-8 possessed the smallest number in the first season. On the other hand, in the second season, SHA-8 exhibited the largest number of seeds per head, whereas SHR-6 had the smallest number.The overall mean was 1238 in the first season and 1220 in the second one. The coefficient of variation was 9.7% and 14.4% in the first and the second seasons, respectively.

The across location and season means (Table 10) revealed that the largest number of seeds per head was produced by SHA-8, whereas the smallest number was produced by SHR-6. The overall mean was 1176, and the coefficient of variation was 15.5%.

4.1.7 Percentage of empty seeds:-

This trait was not properly measured at Rahad and thus was not included in the analysis of variance. At Shambat, significant differnces were detected among the hybrids in the second season (Table 5), while, higly significant differences for crosses and line x tester interactions were revealed in the first season (Table 6).

At Shambat, SHR-5 had the highest percentage (41%) of empty seeds in the first season, whereas SHA-8 produced the lowest percentage. In the second season, SHR-24 possessed the highest percentage of empty seeds, while SHA-13 had the lowest percentage (Table 8). The overall mean was 10.6 and 19.8 in the first and the second season, respectively. The coefficient of variation was 53.2% in the first season and 41.4% in the second season.

4.1.8 1000-seed weight : -

The individual analysis of variance revealed highly significant differences in this trait at Shambat in the first season and at Rahad in both seasons (Table 5). Differences among crosses and between lines were highly significant at Shambat in the first season. Crosses, lines and line x tester interactions showed highly significant differences at Rahad in the first and the second seasons (Table 6). In the combined analysis of variance (Table 7), highly significant differences for this trait were obtained for locations, genotypes and location x season, genotype x season and genotype x location x season interactions. Significant difference for genotype x location interaction was also detected for this character.

At Shambat, the heaviest 1000-seed weight was scored by SHR-5 and SHR-23, whereas the lightest 1000-seed weight was recorded for SHA-10 in the first season (Table 8). In the second season, on the other hand, the heaviest 1000-seed weight was produced by SHR-2, while the lightest one was produced by SHR-9. The overall mean was 60.7 g in the first season and 47.9 g in the second one. The coefficient of variation was 9.6% in the first season and 20.7% in the second one.

The data in Table 9 show that SHR-3 and SHR-9 scored the heaviest 1000-seed weight at Rahad in the first season, whereasg SHR-8 had the lightest seeds. In the second season, SHR-18 exhibited the heaviest 1000-seed weight. The lightest ones were scored by SHA-8. The overall mean was 55.2 g in the first season and 66.2 g in the second season. The coefficient of variation was 11.1% and 5.4% in the first and the second seasons, respectively.

Means across locations and seasons (Table 10) showed that the heaviest 1000-seed weight was scored by SHR-3 and SHR-7 and the lightest was recorded for SHA-8. The overall mean was 51.5 g, and the coefficient of variation was 12.1%.

4.1.9 Seed yield per head: -

Highly significant differences were detected among the evaluated hybrids for this trait at Shambat in the first season and at Rahad in both seasons (Table

5), whereas significant differences were detected at Shambat in the second season. Line x tester analysis of variance (Table 6) showed highly significant differences for crosses and lines at Shambat in the first season, while highly significant differences for testers were obtained at Shambat in the second season. Also, highly significant differences were obtained for crosses, lines and line x tester interactions for this character at Rahad in both seasons. In the combined analysis of variance (Table 7), highly significant differences were detected for locations, genotypes and location x genotype, genotype x season and genotype x location x season interactions for seed yield per head, and significant differences among seasons and genotype x location interaction were also obtained.

At Shambat, SHA-23 and SHR-2 scored the highest yield per head, whereas the lowest one was produced by SHR-6 in the first season (Table 8). However, in the second season, SHR-2 produced the highest seed yield per head, while the lowest one was scored by SHR-9.The overall mean was 69.4 and 53.7g in the first and the second season, respectively. The coefficient of variation was 18.8% in the first season and 27% in the second one.

At Rahad, (Table 9), the highest seed yield per head was produced by SHA-12 in the first season, while the lowest one was produced by SHR-8. In the second season, Hysun-33 scored the highest seed yield per head, whereas SHR-6 produced the lowest. The overall mean was 68.3 g in the first season and 78.5 g in the second season. The coefficient of variation was 14.5% and 13.8% in the first and the second seasons, respectively.

The across location and season means (Table 10) revealed that the highest seed yield per head was produced by SHA-12 and SHA-6, whereas the lowest one was scored by SHR-6. The overall mean was 67.5 g, and the coefficient of variation was 18.1%.

4.1.10 Seed yield per ha (t) : -

The individual analysis of variance showed highly significant differences among the evaluated hybrids for this trait at both locations and seasons (Table

5). Line x tester analysis of variance (Table 6), revealed highly significant differences for crosses and line x tester interactions at Shambat in the first season as well as highly significant and significant differences among testers and crosses at Shambat in the second season, respectively. Highly significant differences were obtained for crosses, lines and line x tester interactions at Rahad in both seasons. The combined analysis of variance (Table 7) revealed highly significant differences for locations, seasons and genotypes and genotype x location, location x season, genotype x season and genotype x location x season interactions.

At Shambat, the highest seed yield /ha was produced by SHA-12 and SHA-6 in the first season, whereas the lowest one was produced by SHR-8 (Table 8). In the second season, SHR-2 produced the highest seed yield/ha, and SHR-9 produced the lowest one. The overall mean was 4.9 t in the first season and 3.3 t in the second season. The coefficient of variation was 14.1% and 23.3% in the first and the second seasons, respectively.

At Rahad, SHR-23 scored the highest seed yield /ha in the first season, whereas the lowest one was scored by SHR-6 (Table 9). In the second season, the highest seed yield /ha was produceed by Hysun-33, and SHR-6 produced the lowest one. The overall mean was 4.4 and 5.6 t in the first and the second seasons, respectively. The coefficient of variation was 18.9% in the first season and 13.8% in the second one.

Means across locations and seasons (Table 10) showed that the highest seed yield /ha was produced by SHA-6 and Hysun-33, while the lowest seed yield /ha was scored by SHR-8. The overall mean was 4.5 t and the coefficient of variation was 16.9%.

4.2 Heterosis

The difference between each hybrid and its parents is an indication of the magnitude of heterosis over or under mid- parent heterosis (MPH) or better-parent heterosis (BPH) value. The observed effects of heterosis on the different traits can be described as follows:

4.2.1 Plant height : -

The highest MPH (9.7%) at Shambat (Table 11) was scored by SHR-2 in the first season and SHA-6 in the second season, whereas the lowest one was exhibited by SHR-24 (-9.9%) in the first season and SHR-7 (-14.3%) in the second one. On the other hand, the highest BPH was expressed by SHA-10 (5.5%) in the first season and SHA-6 (7.9%) in the second one. In addition, the lowest BPH was obtained for SHA-24 (-11.4%) and SHR-7 (-17.4%) in the first and the second
seasons, respectively. The overall mean MPH was –0.1% and 0.1% in the first and the second seasons, respectively, whereas the overall mean BPH was -2.6% in the first season and -2.3% in the second one.

At Rahad , the highest percentage of MPH was scored by SHA-10 in both seasons (11.3% and 7.1%) (Table 12). The lowest ones were obtained for SHR-8 (-12.8%) in the first season and SHR-18 (-8.2%) in the second one. On the other hand, The highest BPH was expressed by SHA-6 (8.2%) and SHA-9 (5.4%) in the first and the second seasons, respectively, whereas the lowest ones were obtained for SHR-13 (-15.4%) in the first season and SHA-8 (-11.2%) in the second one. The overall mean MPH was -0.3% in the first season and -0.2% in the second one, and the overall mean BPH was -5.0% and -3.9% in the first and the second seasons, respectively.

4.2.2 Stem diameter : -

The highest MPH percentage at Shambat was scored by SHR-2 (13.8%) in the first season and SHA-6 (7.1%) in the second one (Table 11). The lowest ones were recorded for SHR-24 and SHR-6 in the first and the second seasons, respectively. Similarly, the highest BPH percentages were scored by SHA-9 and SHA-24 (6.7%) in the first season and by SHA-6 (6.6%) in the second one. The lowest BPH percentages were exhibited by SHR-24 and SHR-6 in the first and the second seasons, respectively. The overall mean MPH was 0.3% in the first season and 0.02% in the second one, while the overall mean BPH was -1.9% and -1.7% in the first and the second seasons, respectively.

At Rahad, the highest MPH percentages (Table12) were expressed by SHA-6 and SHA-24 in the first and the second seasons, respectively, whereas the lowest ones were recorded for SHR-24 in the first season and SHR-8 in the second one. On the other hand, SHA-6 had the highest BPH (6.6%) in the first season, while SHA-2 and SHA-24 scored the highest (9.7%) in the second season. The lowest BPH perecntages were scored by SHR-6 and SHR-8 in the first and the second seasons, respectively. The overall mean MPH was 0.1% in the first season and -0.4% in second season. The overall mean BPH was -1.5% in the first season and -3.6% in the second one.

4.2.3 Days to 50% flowering : -

SHA-2 had the highest MPH (7.3%) and SHR-8 had the lowest, at Shambat, in the first season, whereas the highest BPH was scored by SHA-2 and the lowest by SHR-9 (Table 11). In the second season, the highest MPH (8.0%) was obtained for SHA-10 and the lowest one was scored by SHR-8. In addition, the highest BPH (6.7%) and the lowest one were recorded for SHA-10 and SHR-10, repectively. The overall mean MPH was -0.3% in the first and -0.1% in the second season , while th,e overall mean BPH was -4.2 in the first season and -2.5% in the second one.

At Rahad, the highest MPH percentages were recorded for SHA-7 (5.0%) in the first season and for SHA-24 (4.7%) in the second one (Table 12). The lowest MPH were scored by SHR-8 in the first season and SHR-5 in the second season. On the other hand, the highest BPH percentages were expressed by SHA-9 (2.8%) in the first season and SHR-9 (2.4%) in the second one, whereas the lowest BPH was scored by SHR-8 and SHR-18 in the first and the second seasons, rspectively. The overall mean BPH was -2.8% and -3.0% in the first and the second seasons, respectively.

4.2.4 Days to physiological maturity : -

At Shambat, the highest MPH (4.5%) was expressed by SHA-9, SHA-12 and SHA-13 in the first season and by SHA-10 (3.4%) in the second season (Table 11). On the other hand, the lowest MPH was obtained for SHR-24 in the first season and SHR-8 in the second one. The highest BPH was given by SHA-2 (2.2%) and SHA-24 (2.8%) in the first and the second seasons, respectively. The lowest one was obtained for SHR-10 in the first season, whereas SHR-10 scored the lowest BPH in the second season. The overall mean was -0.6% in the first season and -0.03% in the second season. The overall mean BPH was -3.9% in the first season and -1.2% in the second one.

The highest MPH percentages at Rahad (Table 12) were given by SHA-2 (2.3%) in the first season and SHA-10 (3.1%) in the second season. The lowest one was given by SHR-8 and SHR-10 in the first and the second season, repectively. On the other hand, the highest BPH was scored by SHA-10 in both seasons. The lowest one was obtained for SHR-8 in the first season and SHR-10 in the second season. The overall mean MPH for this character was -0.03% in the first season and zero in the second season, whereas the overall mean BPH was -0.9% and -0.5% in the first and the second season, respectively.

4.2.5 Head diameter : -

SHR-2 and SHA-3 scored the highest MPH at Shambat in the first and the second seasons, respectively (Table 11), whereas the lowest values were given by SHR-8 at both seasons. The highest BPH for this trait was given by SHR-2 (11.9%) in the first season and SHR-3 (11.6%) in the second. On the other hand, the lowest values were obtained for SHA-2 and SHR-8 in the first and the second seasons, respectively. The overall mean was -0.1% in the first season and -0.04% in the second one, whereas the overall mean BPH was -2.5% and -2.3% in the first and the second seasons, respectively.

At Rahad, the highest MPH value was obtained for SHR-2 (13.2%) in the first season and SHA-23 (7.6%) in the second one (Table 12). The lowest values were given by SHR-6 and SHR-10 in the first season and SHR-8 in the second one. The highest BPH values were obtained for SHA-24 (10.4%) in the first season and SHA-23 (6.8%) in the second one, while the lowest values were expressed by SHR-8 and SHA-18 in the first and the second seasons, respectively. The overall mean MPH was -0.1% in the first season and -0.2% in the second season, whereas the overall mean BPH was -1.5% and -1.9%in the first and the second seasons, respectively.

4.2.6 Number of seeds per head: -

The highest MPH values at Shambat (Table 13) were obtained for SHR-2 (22.7%) in the first season and SHA-13(31.3%) in the second one. The lowest values were scored by SHR-6 and SHR-13 in the first and the second season, respectively. On the other hand, the highest BPH values were given by SHA-24 (17.4%) and SHA-18 (16.9%) in the first season and SHA-13 (24.9%) in the second one. In addition, the lowest values were scored by SHR-6 and SHR-13 in the first and the second season, respectively. The overall mean MPH was -0.7% in the first season and -0.5% in the second one, and the overall mean BPH was -6.4% and -5.8% in the first and the second season, respectively.

At Rahad, the highest MPH values were obtained for SHA-3 (15.1%) in the first season, and SHR-9 (27.9%) and SHA-8 (27.1%) in the second season (Table 14). However, the lowest values were expressed by SHR-3 in the first season and SHR-6 in the second one. On the other hand, the highest BPH was obtained for SHA-3 in the first season and SHA-8 (25.7%) in the second one. The lowest values were given by SHR-3 and SHR-6 in the first and the second season, respectively. The overall mean MPH was -0.3% in the first season and -0.9% in the second one, while the overall mean BPH was -5.0% and -8.7% in the first and the second seasons, respectively.

4.2.7 Percentage of empty seeds: -

SHR-5 scored the highest MPH (115.9%) in the first season at Shambat (Table 13), and the lowest value was given by SHR-24 However, the highest BPH values were obtained for SHR-5 (64.0%) and the lowest one was expressed by SHA-8. In the second season, on the other hand, the highest MPH value was obtained for SHR-24 (36.0%). The highest BPH value was scored by SHA-13 (54.6%), whereas the lowest value was given by SHR-10. The overall mean MPH was -5.1% in the first season and 2.4% in the second one. The overall mean BPH value was -21.1% and -6.6% in the first and the second season, respectively.

4.2.8 1000-seed weight : -

At Shambat, the highest MPH values were expressed by SHR-5 (16.4%) in the first season. and SHR-2 (17.7%) in the second one (Table 13). The lowest values were scored by SHA-10 and SHR-9 in the first and the second seasons, repectively. On the other hand, the highest BPH values were expressed by SHR-5 (14.7%) and SHR-23 (13.9%) in the first season and SHR-7 (10.7%) in the second one. The lowest BPH values were given by SHR-18 in the first season and SHR-9 in the second one. The overall mean MPH was -0.5% and -0.3% in the first and the second seasons, respectively. Meanwhile, the overall mean BPH value was -5.5% in the first season and -3.7% in the second one.

At Rahad, the highest MPH values were exhibited by SHR-3 (17.6%) in the first season, whereas SHR-18 (17.6%) had the highest values in the second season (Table 14). The lowest MPH values were scored by SHR-8 in the first season and SHA-8 in the second one. In addition, the highest BPH values were given by SHR-3 (13.6%) in the first season and SHR-18 (11.6%) in the second one. The lowest values were expressed by SHR-8 and SHA-8 in the first and the second seasons, respectively. The overall mean MPH was -0.1% in the first season and -1.5% in the second season, and the overall mean BPH was -2.8% in the first season and -7.3% in the second season.

4.2.9 Seed yield per head : -

The highest MPH values at Shambat (Table 13) were expressed by SHA-6 (29.5%) and SHR-2 (28.1%) in the first season, whereas the lowest one was recorded for SHR-6. The highest BHP value was obtained for SHA-6 (28.2%), while the lowest one was given by SHR-6. In the second season, SHR-2 exhibited the highest MPH value (27%) and the lowest one was obtained for

SHR-9. The highest BPH value was given by SHA-13 (18.5%), whereas the lowest one was scored by SHR-24. The overall mean MPH was-0.3% and -0.9% in the first and the second seasons, respectively, and the overall mean BPH value was -3.7% in the first season and -7.8% in the second one.

Similarly at Rahad, SHA-12 scored the highest MPH value (18.3%) in the first seeason, whereas the lowest one was given by SHR-8 (Table 14). The highest BPH was shown by SHA-12 (15.2%), while the lowest one was obtained for SHR-8. In the second season,
on the other hand, the highest MPH value was expressed by SHA-6 (19.9%), whereas the lowest one was obtained for SHR-6. The highest BPH value was exhibited by SHA-6 (14.1%) and the lowest one was scored by SHR-6. The overall mean MPH value was -0.2% and -0.3% in the first and the second seasons, repectively, and the overall mean BPH value was -4.9% in the first season and -4.2% in the second one.

4.2.10 Seed yield per hectare (t) : -

SHR-23 scored the highest MPH value (31.9%) at Shambat in the first season (Table 13), and SHR-2 scored the highest value (28.9%) in the second season. The lowest MPH values were scored for SHR-6 and SHR-9 in the first and the second seasons, respectively. On the other hand, the highest BPH value (29.2%) was expressed by SHR-23 in the first season and SHA-13 (16.2%) in the second one. However, the lowest values were obtained for SHR-6 and SHR-9 in the first and the second seasons, respectively. The overall mean MPH value was -9.4% in the first season and -1.3% in the second one, whereas, the overall mean BPH value was -15.1% in the first season and -7.8% in the second season.

At Rahad, the highest MPH value was exhibited by SHA-13 (47.5%) in the first season and SHA-6 (20.1%) in the second one (Table 14). The lowest value was obtained for SHR-8 in the first season and SHR-6 in the second one. On the other hand, the highest BPH values were scored by SHR-12 (38.6%) in the first season and SHA-6 (14.1%) in the second one. The lowest value was obtained for SHR-8 in the first season and SHR-6 in the second season. The overall mean MPH value for this character was 9.5% and -0.2% in the first and the second seasons, respectively, while the overall mean BPH value was 7% in the first season and -4.3% in the second season.

4.3 Combining ability

4.3.1 Plant height: -

Estimates of general combining ability (GCA) effect at Shambat (Table 15) showed that the highest value among males was obtained for tester SH-2 (20.9), whereas between females it was given by line Ka (5.6) in the first season. The lowest GCA value among males was given by tester SH-24 (-10.3). In the second season, the highest value for this trait was expressed by tester SH-2 (13.2) and line Ka (4.9), and the lowest value was obtained for tester SH-7. On the other hand, among hybrids, the highest specific combining ability (SCA) effect (Table 16) was expressed by SHA-9 (8.9) in the first season, and SHR-5 (11.5) in the second season. The lowest SCA value was scored by SHR-9 and SHA-5 in the first and the second season, repectively. The percentage contribution of GCA among males and females and their interaction (Table 17) was 52.8 and 36.4 for males, 27.9 and 29.4 for females and 19.3 and 34.2 for males x females interaction in the first and the second seasons, respectively.

At Rhahad, the highest GCA effect for plant height was given by tester SH-2 (17.3) and line Ka (14.6) in the first season and SH-9 (10.5) and line Ka (12.2) in the second one (Table 18). The lowest effect was recorded for tester SH-8 in both seasons. The highest SCA effect (Table 19) was expressed by SHR-2 in both seasons (9.6 and 9.7). The lowest SCA values were given by SHA-2 in both seasons. The percentage contribution due to males, females and males x females interaction to the total variation among hybrids was 21.6 and 21.3 for males, 68.3 and 72.1 for females, 10.1 and 6.6 for males x females interaction in the first and the second seasons, respectively

4.3.2 Stem diameter : -

The highest values of GCA effect at Shambat were scored by testers SH-3 and SH-2, in the first season, whereas SH-2 scored the highest value in the second season. In both seasons, female Ka showed the highest GCA effect. The lowest GCA value was expressed by tester SH-5 in the first season and SH-10 in the second one (Table 15). The highest SCA effect was scored by SHR-2 in the first season and SHA-6 in the second season, whereas the lowest effect was recorded for SHA-2 in the first season and SHR-6 in the second one (Table 16). The percentage contribution due to males, females and males x females interaction to the total variation among hybrids (Table 17) was 28.2 and 42 for males, 31.5 and 32.2 for females and 40.3 and 25.6 for males x females interaction in the first and the second seasons, respectively.

On the other hand, at Rahad, the highest GCA effect (Table 18) was expressed by tester SH-2 (0.4 and 0.2) in both seasons. Female Ka scored the highest GCA in both seasons, and the lowest GCA effect was exhibited by SH-8 in the first season and SH-10 in the second one. Meanwhile, the highest SCA effect (Table 19) was obtained for SHA-6 in the first season and SHA-24 in the second one. The lowest SCA effect was given by SHR-6 and SHR-24 in the first and the second seasons, respectively. The percentage contribution due to males, females and males x females interaction to the total variation among hybrids was 62.9 and 31.8 for males, 4.5 and 44.7 for females and 32.8 and 23.5 for males x females interaction in the first and the second seasons, respectively.

4.3.3 Days to 50% flowering: -

At Shambat, the highest GCA effect (Table 15) was shown by testers SH-2 and SH-9 in both seasons, and the lowest effect was expressed by tester SH-8 in both seasons. Ka had higher GCA value than Kr in both seasons. On the other hand, the highest SCA effect (Table 16) was scored by SHA-9 in the first season and SHA-10 in the second one, and the lowest values were obtained for SHR-9 and SHR-10 in the first and the second season, respectively. The percentage contribution due to males, females and males x females interaction to the total variation among hybrids (Table 17) was 6.7 and 31.5 for males, 96.5 and 55.4 for females, 0.8 and 13.1 for males x females interaction in the first and the second seasons, respectively.

At Rahad, estimates of GCA effect (Table 18) revealed that the highest effect was given by tester SH-9 in both seasons, and the lowest GCA effect was recorded for tester SH-8 in both seasons. The female Ka scored higher value than Kr in both seasons. Meanwhile, the highest SCA effect (Table 19) was obtained for SHA-8 and the lowest one was scored by SHR-8 in the first season. In the second season, the highest effect was given by SHR-9, while the lowest one was obtained for SHA-9. The percentage contribution due to males and females and their interaction to the total variation among hybrids (Table 17) was 14.3, 77.1 and 8.6, respectively in the first season, and 7.7 for males, 86.9 for females and 5.4 for males x females interaction in the second season.

4.3.4 Days to physiological maturity : -

Estimates of GCA effect at Shambat (Table 15) showed that the highest value was scored by tester SH-2 in the first season, whereas the lowest value was scored by SH-8. In the second season, the highest GCA effect was given by tester SH-9, while the lowest one was scored by SH-8. Female Ka had higher GCA effect than Kr in both seasons. On the other hand, the highest SCA effect (Table 16) was given by SHR-2, and the lowest effect was scored by SHA-2 in both seasons. The percentage contribution due to males, females and males x females interaction to the total variation among hybrids (Table 17) was 6.8 and 26.1 for males, 90.1 and 51.7 for females and 3.1 and 22.2 for males x females interaction in the first and the second seasons, respectively.

At Rahad, on the other hand, the highest GCA effect was expressed by testers SH-10 and SH.5 in the first and the second season, respectively, whereas the lowest one was obtained for tester SH-8 in the first season and SH-7 in the second one. The female Ka scored higher GCA effect than Kr in both seasons. The estimates of SCA effect (Table 19) showed that SHA-8 had the highest value in the first season and SHA-10 in the second one, whereas the lowest effect was scored by SHR-8 and SHR-10 in the first and the second seasons, respectively. The percentage contribution due to males, females and males x females interaction to the total variation among hybrids (Table 17) was 28.5 and

32.6 for males, 55.3 and 25.6 for females and 16.2 and 41.8 for males x females interaction, in the first and the second seasons, respectively.

4.3.5 Head diameter : -

Table 15 shows that the highest values of GCA at Shambat were scored by testers SH-23 and SH-9, in the first season, whereas the lowest value was scored by tester SH-8. In the second season, on the other hand, the highest GCA effect was given by testers SH-3 and

SH-2, whereas the lowest value was recorded for tester SH-24. Meanwhile, the female Ka had higher GCA effect than Kr in both seasons. The estimates of SCA effect (Table 16) showed that the highest effect was expressed by SHR-2 and the lowest was expressed by SHA-2, in both seasons. The percentage contribution due to males, females and males x females interaction, to the total variation among hybrids (Table 17) was 40.8, 13.8 and 45.4 for males, females and their interaction, repectively, in the first season. In the second season, it was 27.2 for males, 14.1 for females and 58.7 for males x females interaction.

At Rahad, the highest GCA effect (Table 18) was scored by tester SH-5 and, the lowest values were scored by tester SH-8, in both seasons. In addition, higher GCA effect was given by Ka than Kr in both seasons. On the other hand, the estimates of SCA effect (Table 19) showed that SHR-2 scored the highest effect in the first season, while SHR-18 had the highest effect in the second one. The lowest SCA value was expressed by SHA-2 and SHA-18 in the first and the second seasons, respectively. The percentage contribution due to males, females and males x females interaction to the total variation among hybrids (Table 17) was 43.7, 2.0 and 54.4 for males, females and their interaction, respectively, in the first season, while in the second season it was 45.2 for males, 35.0 for females and 19.8 for males x females interaction.

4.3.6 Number of seeds per head: -

The data in Table 15 indicate that, the highest value of GCA was expressed by tester SH-24 in the first season, and the lowest value was obtained for SH-7. Meanwhile, in the second season, the highest GCA effect was shown by tester SH-10, whereas the lowest one was given by SH-24. Between females, Ka scored higher GCA effect Kr, in both seasons. On the other hand, the highest value of SCA was scored by SHR-2, whereas the lowest one was given by SHA-2 in the first season. In the second season, the highest SCA effect was scored by SHA-13, and the lowest one was expressed by SHR-13. The percentage contribution due to males, females and males x females interaction to the total variation among hybrids (Table 17) was 21.8, 42.8 and 35.4 for males, females and males x females interaction, respectively, in the first season. In the second season, the contribution was 62.0 for males, 9.3 for females and 28.7 for males x females interaction.

At Rahad, the highest values of GCA was expressed by tester SH-12, whereas the lowest one was obtained for SH-9 in the first season (Table 18). On the other hand, in the second season, the highest GCA effect was scored by tester SH-8 and the lowest one was given by SH-21. Higher GCA effect was scored by Ka than Kr in both seasons. The highest SCA effect (Table 19) was given by SHR-2 while the lowest one was obtained for SHA-2, in the first season. In the second season, the highest value was expressed by SHR-9 and the lowest one was scored by SHA-9. The percentage contribution due to males, females and males x females interaction to the total variation among hybrids (Table 17) was 12.4, 64.0 and 23.6 for males females and males x females interaction in the first season, respectively, whereas, in the second season it was 18.1 for males, 53.7 for females and 28.2 for males x females interaction.

4.3.7 Percentage of empty seeds: -

Tester SH-5 had the highest value of GCA and the lowest one was given by tester SH-8 at Shambat in the first season (Table 15). Meanwhile, the highest GCA effect, in the second season, was scored by tester SH-24 and the lowest one by SH-10. The female Kr had higher GCA than Ka in both seasons. The highest SCA effect for this trait (Table 16) was obtained for SHR-5 in the first season and SHR-13 in the second one. The lowest value was scored by SHA-5 and SHA-13 in the first and the second season, respectively. The percentage contribution due to males, females and males x females interaction to the variation among hybrids was 51.0 for males, 8.7 for females and 40.3 for males x females interaction in the first season, whereas, in the second season, it was 58.7, 7.3 and 34.0 for males, females and males x females interaction, respectively.

4.3.8 1000-seed weight : -

At Shambat, the highest estimates of GCA effect (Table 15) was expressed by tester SH-6 and tester SH-2 in the first and the second seasons, respectively. The lowest effect was obtained for tester SH-18 in the first season and SH-9 in the second one. With regard to females, Kr scored higher GCA value than Ka in the first season but the reverse was obtained in the second season. The highest SCA effect, on the other hand, was obtained for SHA-18 in the first season and SHA-24 in the second one, while the lowest SCA value was given by SHR-18 in the first season and SHR-24 in the second one (Table 16). The percentage contribution due to males, females and males x females interaction to the total variation among hybrids (Table 17) in the first season was 26.7, 57.6 and 15.7 for males, females and males x females interaction, respectively, whereas in the second season it was 66.1 for males, 0.3 for females and 33.6 for males x females interaction.

At Rahad, the highest estimales of GCA effect (Table 18) was expressed by tester SH-3 in the first season and tester SH-21 in the second one. The lowest effect was given by tester SH-8 in both seasons. With respect to females, line Kr scored higher GCA than Ka in the first season, but Ka was higher in the second one. The highest estimates of SCA effect, on the other hand, was shown by SHR-3 in the first season, and the lowest one was scored by SHA-3. In the second season, the highest SCA effect was obtained for SHR-18, and the lowest value was obtained for SHA-18 (Table 19). The percentage contribution due to males, females and males x females interaction to the total variation among hybrids (Table 17) was 37.0, 0.5 and 65.5 for males, females and males x females interaction in the first season, respectively. In the second season, it was 29.7 for males, 44.2 for females and 26.1 for males x females interaction.

4.3.9 Seed yield per head : -

At Shambat, the highest estimate of GCA was obtained for tester SH-23 and the lowest one was obtained for tester SH-8 in the first season (Table 15). In the second season, the highest GCA effect was expressed by tester SH-12 and the lowest was given by SH-9. Female Ka showed higher GCA value than Kr in both seasons. Estimates of SCA effect, on the other hand, showed that the highest value was obtained for SHA-6 and SHR-2 in the first and the second season, respectively. The lowest effect was scored by SHR-6 in the first season and SHA-2 in the second one (Table 16). The percentage contribution due to males, females and males x females interaction to the total variation among hybrids (Table 17) was 32.4, 0.3 and 67.3 for males, females and males x females interaction in the first season, respectively. Meanwhile, in the second season the contribution was 73.6 for males, 5.1 for females and 21.3 for males x females interaction.

At Rahad, the highest GCA for this trait was shown by testers SH-3 and SH-24 in the first season and tester SH-7 in the second one. The lowest effect was obtained for testers SH-8 and SH-13 in the first and the second seasons, respectively. Line Ka had higher GCA effect than line Kr in both seasons. The highest value of SCA was expressed by SHR-9 and the lowest one was scored by SHA-9 in the first season. In the second season, SHA-6 scored the highest SCA value, while, the lowest one was given by SHR-6 (Table 19). The percentage contribution due to males, females and males x females interaction to the total variation among hybrids (Table 17) was 23.0, 39.7 and 37.1 for males, females and males x females interaction in the first season, respectively, whereas, in the second season, it was 31.7 for males, 26.1 for females and 42.2 for males x females interaction.

4.3.10 Seed yield per ha : -

The highest estimates of GCA effect at Shambat was obtained for tester SH-23 in the first season and SH-2 in the second one. The lowest value was scored by SH-8 and SH-9 in the first and the second season, respectively. In addition, the highest GCA value between females was given by line Ka in both seasons (Table 15). Estimates of SCA effect, on the other hand, indicated that the highest values (Table 16) were obtained for SHA-6 in the first season and SHR-2 in the second one. The lowest SCA value was expressed by SHR-6 and SHA-2 in the first and the second seasons, respectively. The percentage contribution due to males, females and males x females interaction (Table 17) to the total variation among hybrids was 33.1 for males, 0.2 for females and 66.7 for males x females interaction in the first season. In the second season, it was 71.3, 4.6 and 24.2 for males, females and males x females interaction, respectively.

At Rahad, the highest effect of GCA among males was shown by testers SH-3 and SH-6 in the first season and SH-7 in the second one. The lowest one was scored by testers SH-8 and SH-13 in the first and the second seasons, respectively. The higher GCA effect between females was obtained for line Ka in both seasons. Estimates of SCA effect, on the other hand, revealed that the highest value was shown by SHR-9 and SHA-6 in the first and the second season, respectively, whereas, the lowest value was obtained for SHA-9 in the first season and SHR-6 in the second one. The percentage contribution due to males, females and males x females interaction to the total variation among hybrids (Table 17) was 23.0 for males, 39.5 for females and 37.5 for males x females interaction in the first season. In the second season, it was 32.5, 26.2 and 41.3 for males, females and males x females interaction, respectively.

4.4 Stability of performance

4.4.1 Plant height: -

The results of the regression analysis for stability parameters of the 29 F_1 sunflower hybrids are shown in Table 20. The tallest hybrid was SHA-6, the shortest one was SHR-8 and the overall mean was 147.8 cm. Thirteen hybrids produced by the female Ka and the commercial check had above average plant height.All hybrids of the line Ka and the check had non-significant deviations, nine of them had regression coefficient greater than unity, only two and the check had slopes equal to unity and three had slopes closer to unity. On the other hand, all the hybrids produced by the female parent Kr scored below the average except SHR-2. Only SHR-9 had significant deviation, and ten hybrids had regression coefficients smaller than unity, two had slopes above unity and two had slopes closer to unity.

4.4.2 Days to 50% flowering : -

Table 20 shows the results of the regression analysis of hybrids, tested over the four environments. It indicates that SHA-9 and SHA-2 were the latest, whereas SHR-8 was the earliest. The overall mean was 55.3. All the hybrids produced by the female Ka and the commercial check scored above average mean. Eight hybrids and the check had non-significant deviations. Five hybrids and the check had slopes greater than one, five around one, two equal to one and two had slopes smaller than one. However, all the hybrids produced by the female Kr performed below average mean, and ten had non-significant deviations. Five hybrids had regression coefficients greater than unity, five closer to unity and three smaller than unity, while only one had slope equal to unity.

4.4.3 Days to physiological maturity: -

The range of number of days to maturity was between 82.7 for SHR-8 and 93.2 for SHA-9; the overall mean was 88.4 days. All the hybrids produced by the female Ka and the commercial check scored above average mean. Nine hybrids and the check had non-significant deviations, tweleve had slopes smaller than unity and only two had slopes around unity. On the other hand, all the hybrids produced by the female Kr performed below the average, with only five hybrids had non-significant deviations. Thirteen hybrids had regression coefficients greater than unity, and only one had slope closer to unity.

4.4.4 Number of seeds per head: -

Stability parameters for number of seeds per head are shown in Table 20. The largest number of seeds per head were scored by SHA-8 and SHA-24, whereas the smallest number was scored by SHR-6. The overall mean was 1176.4. All the hybrids produced by the female parent Ka and the commercial check performed above average mean, ten hybrids and the check had non-significant deviations. Eleven hybrids and the check had slopes greater than unity and three had slopes smaller than unity. On the other hand, all the hybrids produced by female Kr had scored below the average mean, except hybrid SHR-2. Eleven hybrids had non-significant deviations. Nine hybrids had regression coefficients smaller than unity and only five with slopes greater than unity.

4.4.5 1000-seed weight : -

Table 20 shows the results of stability parameters for 1000-seed weight. The heaviest 1000-seed weight was scored by SHR-3 and SHR-and the lightest one was given by SHA-8. The overall mean 1000-seed weight was 57.5 g. Twelve cross combinations produced by the female Kr and the commercial check performed above average mean. All the hybrids of line Kr had regression coefficients greater than unity except SHR-2 and SHR-13,while six hybrids had significant deviations. Only two hybrids produced by the female Ka scored above the average mean. All the hybrids had non-significant deviations except SHA-10. Eight hybrids had slopes smaller than unity, four greater than unity, one equal to unity and one closer to unity.

4.4.6 Seed yield per head: -

The results of the regression analysis for seed yield per head are shown in Table 20. The highest seed yield per head was given by SHA-12 and SHA-6; the overall mean was 67.5 g. All the hybrid combinations produced by the female Ka as well as the commercial check had non-significant deviations. Eleven hybrids along with the check scored above the mean, while only four performed below the mean. Seven hybrids and the check had slopes greater than one, five hybrids smaller than one and only two closer to one. Thirteen hybrids produced by female Kr had non-significant deviations and nine performed below the mean. Seven hybrids had regression coefficients below unity, three above unity, one equal to unity and one closer to unity.

4.4.7 Seed yield per ha : -

Table 20 shows the results of stability for seed yield /ha The highest seed yield/ha was expressed by SHA-6 (5.5/ha) and the commercial check (5.4/ha) whereas the lowest one was given by SHR-6 (3.7/ha). The overall mean was 4.5/ha. Eleven hybrid combinations produced by female Ka in addition to the commercial check performed above the mean, while only three hybrids scored below the average. All the hybrids had non-significant deviations, except SHA-2 and SHA-13. Seven hybrids and the check had slopes above unity and two had slopes below unity, while four hybrids had slopes around unity and only one had slope equal to unity. All the hybrid combinations produced by the female parent Kr had non-significant deviations, except SHR-23. Nine hybrids performed below the mean, and only five scored above the average. Seven hybrids had regression coefficients smaller than unity, four greater than unity and only three closer to unity.

CHAPTER FIVE

DISCUSSION

5.1 Variability

The individual analysis of variance showed that differences among the tested sunflower hybrids were highly significant across the four environments for all characters except plant height, stem diameter, head diameter and 1000-seed weight at Shambat in the second season, and head diameter at Rahad in the second season. The highly significant variations for the different characters, among the evaluated sunflower hybrids, could be attributed to genetic and environmental factors as well as their interactons. Similar results were reported by El-Ahmer *et al*. (1989), Chervet and Vear (1990) and Kluza and Musnicki (1998).

Furthermore, line x tester analysis showed highly significant mean squares among the crosses for most of the characters studied, across the four environments. Non-significant differences were detected for plant height, stem diameter, head diameter and percentage of empty seeds at Shambat. These highly significant variations indicate the presence of variability among the cross combinations. The partitioning of the crosses sum of squares into variations due to lines and testers (GCA) and line x tester (SCA) showed that mean squares due to lines and testers (GCA) were highly significant, whereas line x tester interactions (SCA) were non-significant for most of the characters at a particular environment. This indicated that the performance of single cross hybrids can be adequately predicted on the basis of general combining ability. However, for some characters highly significant line x tester interaction mean squares were accompanied by both non-significant lines and testers mean squares, indicating that performance of single cross hybrids can be predicted on the basis of specific combining ability. Moreover, the presence of significant lines and testers mean squares, accompanied by significant line x tester interaction, indicate the importance of the role of both GCA and SCA in the expression of heterotic effect in the character. Similar results were reached by Brandle and McVetty (1989).

The combined analysis of variance revealed highly significant location mean squares for all characters studied, indicating sufficient diversity among the four environments. Moreover, the highly significant differences among the tested hybrids over the four environments for most of the traits suggest differences in pedigrees and parentages of the hybrids used. However, the significant genotype x location interaction for number of seeds per head, 1000-seed weight and seed yield per head indicates the differential response of genotypes to change in season and location. On the other hand, the non-significant genotype x location for stem diameter and days to 50% flowering indicates relatively consistent ranking of performance of these genotypes over locations and seasons for these traits. The highly significant mean squares for location x season, genotype x season and genotype x location x season suggest that the different genotypes were not consistent in their performance over varying environments, indicating that selection of desired characters could be done through multi-location testing. Similar results were reported by Shinde *et al.* (1992). Moro *et al*. (1994) and Prusti *et al.* (1999).

The variability in environment has been recognized as an important factor influencing the performance of genotypes. Since the studied characters were greatly influenced by the environment, selection for high yielding genotypes and hybrids, with relatively stable performance, should be done through multi-locations and/or seasons testing. The magnitude of genotypic component, relative to that of genotype x environment interaction component, is a fundemental factor in determining the most likely area for the successful cultivar. If the interaction component is larger than the genotypic component, the plant breeder would have to select for cultivars to meet the specific requirement of that environment, but if not the plant breeder would have to select for a cultivar that has a general adaptability and stable performance over a range of environments.

5.2 Heterosis

5.2.1 Plant height:-

About 64.3% and 86% of the hybrids of the female parent Kr scored negative values for the mid-parent and the better-parent heterosis, respectively, in plant height at Shambat in the first season. In the second season, 71.4% of them exhibited negative mid-parent values and 85.7% better-parent values. At Rahad, 85.7% of the hybrids of the female parent Kr expressed negative heterosis values for mid-parent and all of them showed negative better-parent values in the first season. In the second season, 78.6% and 92.9% of the hybrids of Kr showed negative heterotic values for the mid- and better-parent values, respectively. These results indicate the possibility of obtaining shorter hybrid combinations as compared to the parents. Cruz (1986), reported the occurrence of negative mid-and better-parent heterosis in his study of sunflower hybrids. Short stem is a desirable characteristic for resistance to lodging and easy combine harvesting . It was found that 92.9% of the hybrids of the female parent Kr were shorter than the commercial check at Shambat in both seasons. At Rahad, all hybrids were shorter than the check in both seasons.

With respect to the female parent Ka, 21.4% and 57.3% of its hybrids exhibited negative values, respectively, under the mid- and better-parent heterosis for plant height at Shambat in the first season. In the second season, 28.6% of its hybrids scored negative mid-parent value and 42.9% better- parent ones. At Rahad, 21.4% and 57,1% of the crosses of Ka showed, respectively, negative mid- and better- parent values in the first season, and 7.2% and 50% in the second one.

It was found that 92.9% and 85.7% of the hybrids of the female parent Ka were shorter than the commercial check at Shambat in the first and the second season, respectively. At Rahad, 71.4% of the hybrids were shorter in the first season and 50% were shorter in the second season than the commercial check.

5.2.2 Stem diameter:

Among the hybrids of the female Kr, 27.6% showed positive mid-parent values; 14.3% of them showed positive better-parent heterosis at Shambat in the first season. In the second season, 27.6% and 7.2% of the hybrids expressed positive mid-and better-parent values. At Rahad, 42.9% of the hybrids of the female Kr showed positive both mid- and better-parent heterosis in the first season and 50% and 7.1% in the second season. These findings indicate heterosis for stem diameter in the positive direction. It was found that 14.3% and 50% of the hybrids of the female Kr had thicker stems than the commercial check in the first and the second season, respectively. At Rahad, only 7.1% of the hybrids were charaterized by thicker stems than the commercial check in the first season.

With respect to the female Ka at Shambat, 71.4% and 50% of the hybrids expressed, respectively, positive mid-and better-parent heterosis for stem diameter in the first season, and 78.6% and 50% of them exhibited mid-and better- parent heterosis in the second season. At Rahad, 42.8% and 28.6% of the hybrids of Ka had, respectively, positive mid- and better-parent heterosis in the first season. Also, 71.4% of the hybrids expressed positive mid-parent values, and 57.1% of them had positive better heterosis in the second season. Ge-CF (1981) and Shrinivasa (1982) reported positive mid-and better-parent heterosis in their studies. Thick stem diameter is a desirable feature, particularily in resistance to lodging. The results obtained indicate that the possibility of utilizing the heterotic effect in developing loddging resistant hybrids. It was found that 57.1% and 92.9% of the hybrids of the female parent Ka were thicker than the commercial check at Shambat in the first and the second season, respectively. At Rahad, 64.3% only of the hybrids were thicker than the commercial check.

5.2.3 Days to 50% flowering: -

At Shambat, all the hybrids of the female Kr had negative both mid- and better-parent heterosis in the first season. In the second season, 78.6% and 100% of the hybrids had, respectively, negative mid- and better-parent values. At

Rahad, 92.8% and all of the hybrids from the female parent Kr expressed negative mid-and better-parent heterosis in the first and the second season. It was found that all the hybrids involving the female parent Kr were earlier than the commercial check over the four environments.

On the other hand, only 64.3% of the hybrids of the female Ka had scored negative mid- and better- parent heterosis at Shambat in the first season. In the second season, 21.4% and 50% of these hybrids had, respectively, negative mid- and better- parent heterosis. At Rahad, only 57.1% of the hybrids had negative mid- and better-parent heterosis in the first season, and 35.7% in the second one, indicating that these hybrids were earlier in flowering than the mean days to flowering of the two parents as well as the late parent. Furthermore, 21.4% and 71.4% of the crosses of the female Kr were earlier than the commercial check at Shambat in the first and the second season, respectively. At Rahad, 100% and 42.8% of the hybrids were earlier than the commercial check in the first and the second season, respectively.

These results indicate that the hybrids were earlier than the mid-parental mean days to flowering as well as the late flowering parent. Mallick *et al*.(1978) and Virmani *et al*. (1982) reported that heterosis of days to 50% flowering has been generally negative. These hybrids can be planted in areas with short to medium rainfall. Also, they can be planted under irrigation in order to save water and consequently to reduce the production cost.

5.2.4 Days to physiological maturity: -

At Shambat, 92.8% and 100% of the hybrids of the female Kr expressed, respectively, negative mid-and better- parent heterosis in the first season. In the second season, 71.4% showed negative mid- parent heterosis and 78.6% expressed better- parent one. At Rahad, 64.3% and 85.7% of the hybrids exhibited, respectively, negative mid- and better-parent heterosis in the first season. In the second season, 71.4% showed negative mid-parent and 85.7% expressed better-parent heterosis. At Shambat, all hybrids of the female Kr were earlier than the commercial check in the first season and 71.4% in the second season. At Rahad, all the hybrids were earlier than the commercial check in both seasons.

Furthermore, at Shambat none of the hybrids involving the female Ka exhibited negative mid-parent and 57.1% showed better-parent heterosis in the first season. In the second season, 14.3% of the hybrids scored negative mid-parent heterosis and 57.1 % expressed negative better-parent heterosis. At Rahad, 14.3% and 57.1% of the hybrids showed, respectively, negative mid- and better-parent heterosis in the first season. In the second season, 42.9% of the hybrids indicated negative both mid-and better- parent heterosis. Lande *et al*. (1998) indicated the presence of negative mid- and better-parent heterosis for days to physiological maturity. These result indicate the possibility of obtaining early maturing hybrids compared to the parents. Such early maturing hybrids could be grown in areas with short to medium rainfall.

Among hybrids involving Ka, 28.6% and 14.3% were earlier than the commercial check in the first and the second season, respectively. At Rahad , 92.9% of the hybrids were earlier than the check in both seasons. The differences in mid-and better-parent heterosis between seasons and locations could be attributed to the influence of the environment on expression of heterosis, therefore evaluation of hybrids over many seasons and locations is needed. **5.2.5 Head diameter: -**

Among the hybrids obtained from the female Kr, 28.6% showed positive mid-parent value, and 21.4% exhibited positive better-parent heterosis at Shambat in the first season. In the second season, 42.9% and 35.7% of the hybrids showed, respectively, positive mid- and better-parent values. At Rahad, on the other hand, 35.7% of the crosses of the female parent Kr expressed positive mid-parent value and 28.6% scored positive better-parent heterosis in the first season. In the second season, 21.4% and 14.3% scored, respectively, positive mid- and better-parent heterosis. At Shambat, 7.1% and 50% of the hybrids involving the female parent Kr had larger head diameter than the commercial check in the first and the second season, respectively. At Rahad, 28.6% of the hybrids had larger head diameter than the check in the first season and 21.4% in the second season.

With respect to the female Ka, 57.1% and 42.9% of its hybrids showed positive values, respectively, over the mid-and better-parent at Shambat in both seasons. At Rahad, 50% of the crosses scored positive mid-parent value and 42.9% expressed better-parent heterosis in the first season. In the second season, 64.3% and 42.9% showed, respectively, positive mid-and better-parent values. At Shambat, only 85.7% of the hybrids of the female Ka had larger head diameter than the commercial check in the second season. At Rahad, 42.9% of the hybrids had larger head diameter than the check in the first season and 78.6% in the second season. These results indicate the possibility of obtaining larger head diameter as compared to the parents. The larger head can contribute positively to the final yield. Chaudhary and Anand (1984), Goksoy *et al*. (1999b) and Goksoy *et al*. (2000) reported positive mid- and better-parent heterosis among some of the hybrids they studied.

5.2.6 Number of seeds per head: -

At Shambat, 21.4% and 14.3% of the crosses having Kr as female parent showed positive values for, respectively, the mid- and better-parent heterosis in number of seeds per head in the first season. In the second season, on the other hand, 42.9% of the hybrids scored positive mid-parent values and 35.7% expressed better-parent heterosis. At Rahad, 7.1% of the hybrids showed positive both mid- and better-parent heterosis in the first season. In the second season, 21.4% of the crosses expressed positive mid-parent values and 7.1% gave better-parent ones. At Shambat, 14.3% and 35.7% of the hybrids of female Kr had greater number of seeds per head than the commercial check in the first and the second season, respectively. At Rahad, 7.1% of the hybrids had greater number of seeds per head than the check in the second season.

With respect to the female Ka, 57.1% and 50% of its hybrids had scored, respectively, positive mid- and better-parent heterosis at Shambat in the first season. In the second season, 57.1% of the hybrids showed positive mid-parent heterosis and 21.4% exhibited better-parent values. At Rahad, 78.6% and 42.9% of the hybrids had, respectively, positive mid- and better-parent values in the first season. In the second season, 71.4% of the crosses showed positive mid-parent values and 50% had positive better-parent ones. At Shambat, 50% and all the hybrids involving the female parent Ka had greater number of seeds per head than the commercial check in the first and the second season, respectively. At Rahad, on the other hand, 85.7% of the hybrids had greater number of seeds per head in the first season and 42.9% in the second season than the commercial check. Limbore *et al*.(1998) and Goksoy *et al.* (2000) reported positive mid- and better- parent heterosis in some hybrids. Such positive heterotic effects could be used in breeding programmes for the improvement of number of seeds per head. This consequently improves seed yield, as number of seeds per head is considered one of the important yield components.

5.2.7 Percentage of empty seeds:-

Among the hybrids of the female Kr, 64.3% and 78.6% showed negative mid- and better-parent values, respectively, at Shambat in the first season. In the second season, 50% of the hybrids scored negative mid-and better-parent heterosis. With regard to the female Ka, 64.3% and 71.4% of its hybrids expressed negative mid- and better-parent heterosis for the percentage of empty seeds at Shambat in the first season. In the second season, 64.3% scored negative mid- and better-parent heterosis. These results indicate the possibility of obtaining more filled seeds in hybrids as compared to the parents. The combinations which showed maximum negative heterosis could be used to improve this trait. Madrap and Makne (1993) reported negative heterotic values for empty seeds.

At Shambat, 21.4% and 14.3% of the hybrids of the female Kr had lower percentage of empty seeds than the commercial check. With regard to the female Ka, 35.7% and 42.9% of its hybrids showed lower percentage of empty seeds than the commercial check in the first and the second seasons, respectively.

5.2.8 1000-seed weight :-

About, 79% and 43% of the crosses of the female Kr, expressed positive heterotic values for, respectively, mid- and better- parent heterosis in 1000-seed weight at Shambat in the first season. In the second season, 42.9% of the hybrids scored positive mid-parent values and 35.7% had better-parent values. At Rahad, 42.9% of the hybrids of the female parent Kr exhibited positive heterotic values for both mid- and better-parent heterosis in the first season. In the second season, 71.4% and 50% of the hybrids showed positive heterotic effects for, respectively, the mid-and better-parent heterosis. At Shambat, 35.7% and 64.3% of the hybrids had heavier seeds than the commercial check in the first and the second seasons, respectively. At Rahad, 14.3% of the crosses carried heavier seeds than the check in the first season and 50% in the second one.

With regard to the female Ka, 14.3% of the hybrids had positive heterotic values for the mid-parent heterosis at Shambat in the first season. In the second season, 50% of the crosses exhibited positive mid- parent values and 28.6% scored positive better-parent heterosis. At Rahad, 42.9% and 35.7% of the hybrids showed positive values, respectively, over the mid- and better-parent heterosis in the first season. In the second season, 28.6% of the crosses expressed positive heterotic effects and 14.3% scored positive better- parent ones. None of the hybrids had heavier seeds than the commercial check at Shambat in the first and 78.6% in the second season. At Rahad, none of the hybrids produced heavier seeds than the check in the first season and only 7.1% produced heavier seeds in the second one.

Cruz (1986) and Lande *et al.* (1999) reported mid-and better- parent heterosis in some hybrids.The cross combinations which showed maximum positive heterotic values for 1000-seed weight could be exploited to improve the seed size in sunflower breeding programmes. The 1000-seed weight is one of the most important yield components. The positive heterotic values obtained indicate the possibility of improving this character and consequently seed yield.

5.2.9 Seed yield per head :-

At Shambat, 42.9% and 28.6% of the crosses of the female Kr exhibited, respectively, positive mid- and better-parent values in the first season. In the second season, 50% of the crosses showed positive mid-parent heterosis and 28.7% showed positive better- parent heterosis. At Rahad, on the other hand, 35.7% and 14.3% of the hybrids expressed, respectively, positive mid- and better-parent values in the first season. In the second season, 35.7% of the hybrids scored positive mid- parent values and 21.4% showed better- parent heterosis. At Shambat, 7.1% and 85.7% had higher seed yield per head than the commercial check in the first season and the second season, respectively. At Rahad, none of the hybrids were high yielders than the check in both seasons.

With respect to the female Ka, 42.9% of the hybrids expressed positive heterotic effects for both mid- and better-parent values for seed yield per head at Shambat in the first season. In the second season, 64.3% of the hybrids showed positive mid-parent heterosis and 35.7% expressed better- parent heterosis. At Rahad, 85.7% and 64.3% of the hybrids had positive heterotic effects, respectively, over mid- and better-parent values in the first season. In the second season, 64.3% of the crosses exhibited positive mid-parent values and 35.7% had scored positive better-parent heterosis. Cruz (1986), Limbore *et al* (1998) and Goksoy *et al*. (2000) reported positive heterosis in some of the materials they studied. Such positive values indicate the possibility of improving yield per head through utilization of hybrid vigour in suitable cross combinations. At Shambat, none of the hybrids of the female Ka yielded higher than the commercial check in the first season. In the second season, all the hybrids were high yielder than the check. At Rahad, the commercial check was the higher yielder in both seasons.

5.2.10 Seed yield/ha: -

At Shambat, 35.7% and 21.4% of the hybrids of Kr scored positive heterotic values for, respectively the mid-and better-parent heterosis for seed yield per hectare in the first season. In the second season, 42.9% of the hybrids showed positive mid-parent heterosis and 28.6% had better-parent values. At

Rahad, on the other hand, 57.1% and 50% of the hybrids of the female Kr expressed positive values for, respectively, the mid-and better-parent heterosis in the first season. In the second season, 35.7% of the hybrids exhibited positive heterosis and 21.4% showed better- parent one. At Shambat, 14.8% and 78.6% of the hybrids from the female parent Kr were high yielders than the check in the first and the second season, respectively. At Rahad, none of the hybrids yielded higher than the commercial check .

With respect to the female Ka, 14.3% and 7.1% of its hybrids showed positive heterosis values for, respectively, mid-and better- parent heterosis for seed yield per hectare, at Shambat in the first season. In the second season, 64.3% of the hybrids scored positive mid-parent heterosis and 57.1% showed better -parent heterosis. At Rahad, 85.7% and 78.6% of the hybrids exhibited positive heterosis for, respectively, the mid-and better-parent values in the first season. In the second season, 64.3% of the hybrids expressed positive mid-parent values and 28.6% expressed better- parent heterosis. Madrap and Makne (1993), Chaudhary and Anand (1984), Giriraj *et al*. (1986), and Gosksoy *et al.* (2000) reported positive heterosis for seed yield and other characters. At Shambat, none of the hybrids of the female Ka yielded higher than the commercial check in the first season and all of them exceeded the check in the second season. At Rahad, on the other hand, 21.4% of the hybrids were high yielding than the check in the first season, whereas in the second season none of the hybrids exceeded the commercial check in yield.

Yield is a complex character which is determined by many components, hence the relative importance of each of these components is determined by its contribution to the final yield. At Shambat, the hybrid SHR-23 and SHR-2 expressed the highest heterosis for seed yield per hectare in the first season. These high yielding hybrids had high heterosis for head diameter, number of seeds per head and 1000-seed weight. In the second season, SHR-2 , SHA-13 and SHR-10 expressed the highest heterosis for seed yield per hectare; they had high heterosis for number of seeds per head. It seems that the contribution of increased number of seeds per head to heterosis in seed yield was more impotant than that of head diameter and 1000-seed weight.

At Rahad, the maximum heterosis for seed yield was shown by SHA-13, SHA-12 and SHA-6 in the first season. These hybrids had high heterosis for number of seeds per head and 1000-seed weight. The contribution of increased in 1000-seed weight to the heterosis found in seed yield was more important than that of the number of seeds per head. Parh *et al*. (1986) reported the importance of 100-grain weight in contributing to grain yield in maize. In the second season, SHA-6 and SHR-9 had high heterosis for seed yield per hectare, and number of seeds per head. The relative importance of yield components seems to differ with location and season. Moll *et al*.(1962) stated that heterosis appears to increase with increase in genetic divergence of the parental populations. Salih and Khidir (1975) in castor and Abdelmula *et al*. (1993) in faba bean indicated that the inherent associations between the different characters are reduced and modified under the influence of the environment.

5.3 Combining ability

Information on combining ability effects helps the breeders to choose the parents with high combining ability (GCA) and hybrids with high specific combining ability (SCA) effects. High GCA effects mostly contribute to additive gene effects or additive x additive interaction effect (Griffing, 1956a and 1956b) and represent fixable portion of genetic variation. However, high magnitude of SCA effects represents dominance and epistatic components of variation which are non-fixable. The contribution of the GCA to the variation among the hybrids was greater than that of SCA for plant height, stem diameter, days to 50% flowering, days to maturity and number of seeds per head at both sites and in the two seasons. Also, the contribution of GCA was greater than that of SCA for seed yield per head and seed yield per hectare at Shambat in the first season, and head diameter and 1000-seed weight at Rahad in the second season. The higher magnitude of GCA components of these characters are indicative of preponderance of additive gene effects in the inheritance of these traits. Tuberosa *et al.* (1982), Sheriff and Appadurai (1985), Kumar *et al.*(1998) and Ashok *et al*. (2000) reported the importance of additive gene action in determining these traits. However, Lande *et al.* (1997) and Shekar *et al*. (1999) reported that non-additive gene action was more prominent for most of these characters in their material. In view of this, it becomes evident that breeding for higher yield in sunflower may become more effective by appropriate exploitation of additive gene effects along with the non-additive gene effects. This points to the desirability of obtaining combining ability estimates over diverse environments. As such, to derive valid estimates, the material needs to be tested over varying situations.

The predominance of additive genetic variability in the present study for plant height, stem diameter, days to 50% flowering, days to maturity, number of seeds per head, 1000-seed weight and seed yield per hectare, indicates that genetic advance in these traits can be made by simple breeding procedures. However, to exploit the non-additive portion of variability, the recurrent selection scheme (diallel mating system) as proposed by Joshi (1979) may be used.This will help building the population from which desirable pure lines could be developed simultaneously. The higher magnitudes of SCA, on the other hand, was expressed in seed yield per head and seed yield per hectare at Shambat and head diameter and 1000-seed weight at Rahad in the first season. This indicates that non-additive gene effects were more important than the additive ones for the expression of these traits. Recurrent selection can effectively be used for making improvement in these traits.

Among the male parents, SH-2 had the highest GCA effects for plant height, days to 50% flowering and days to maturity at Shambat, in both seasons hence it was the best general combiner for these characters. The male parents SH-24, SH-5, SH-6 and SH-23 were the best general combiners for the number of seeds per head, percentage of empty seeds, 1000-seed weight and seed yield per hectare, respectively, at Shambat in the first season. On the other hand, the male parents SH-10, SH-24 and SH-12 were the best general combiners for number of seeds per head, percentage of empty seeds, seed yield per head, respectively. However, SH-2 was the best general combiner for both 1000-seed weight and seed yield per hectare at Shambat in the second season.

The differences in the GCA effects among inbred lines, indicate the presence of variability, in breeding values among inbred lines and that hybrid sunflower breeding programmes should be based on crosses of inbredlines . The best general combiner males can be used extensively in hybridization programmes to exploit their maximum genetic variability and to isolate transgressive segregents for the desired characters such as seed yield. Between the female parents, Ka was the better general combiner for all morphological characters studied at Shambat in both seasons, and it was the better general combiner for yield and yield components, except percentage of empty seeds, in both seasons. Hence, Ka could be exploited for improving yield and yield components in sunflower breeding programmes.

At Rahad, SH-2, SH-5 and SH-6 were the best general combiner males for plant height, SH-2 and SH-3 for stem diameter, SH-9, SH-12 and SH-13 for days to 50% flowering, SH-10, SH-9 and SH-24 for days to maturity and SH-5 and SH-2 for head diameter in the first season.In the second season, SH-9, SH-2, SH-10 and SH-12 were the best general combiner males for plant height, SH-2, SH-6 and SH-18 for stem diameter, SH-9, SH-24 and SH-10 for days to 50% flowering, SH-5, SH-24, SH-9 and SH-10 for days to maturity, SH-5, SH-23 and SH-10 for head diameter. The female parent Ka was better general combiner than Kr for all morphological characters in both seasons. The best general combiner males for yield and yield components in the first season were SH-12, SH-7, SH-10, SH-24 and SH-6 for number of seeds per head, SH-3, SH-9, SH-24 and SH-6 for 1000-seed weight, SH-6, SH-3 and SH-24 for seed yield per head and seed yield per hectare, respectively. However, in the second season, the best general combiner males were SH-8, SH-9 and SH-12 for number of seeds per head, SH-21, SH-3 and SH-7 for 1000-seed weight and SH-7, SH-12 and SH-9 for seed yield per head and seed yield per hectare. The female parent Ka was better than Kr as a general combiner for all the characters except 1000-seed weight in both seasons.

This study showed that it was difficult to have good combiners for all characters, because the combining ability effects were not consistent for all morphological characters and yield components. This might be due to the differential influence of the environmental factors on the different characters as well as the negative association among some of the characters.

With regards to SCA, generally, the five hybrids with the highest SCA for yield components were the result of crosses in which both or at least one of the parents was a high general combiner. This is in accord with the findings of Ranvir- Singh *et al*. (1983) who stated that crosses showing high SCA effects for a certain character, while involving either both or one general combiner parent for that character, could be successfully exploited for varietal improvement and is expected to show stable transgressive segregants carrying fixable gene effects. Lefort-Buson *et al*.(1987) reported that the presence of high SCA was a general feature of hybrids involving divergent parents, and was in some way responsible for the higher levels of heterosis found in the hybrids. The relatively few cases encountered in this study in which hybrids with high SCA resulting from crosses between low combiners indicate that poor combiners were not always inferior. Singh and Nanda (1976) and Rahman *et al*. (1981) obtained hybrids with high SCA from crosses between low combiners.

5.4 Stability of performance

Existence of significant genotype x environment interaction creates difficulty in genetic analysis in several ways, such as by confounding estimate of genetic parameters and statistics and by complicating selection and testing strategies. Such interactions reflect differences in adaptation, which may be exploited by selection and by adjustments to the test strategy. In this context, conflict inevitably exists between breeding for broad adaptation (minimizing interaction) and specific adaptation (emphasizing favourable interaction).

However, any objective decision requires a full understanding of the nature of genotype x environment interaction. Further complications arise because, commonly, breeders are interested in more than one attribute at a time. Information on a cultivar's stability performance across environments would enable breeders to select more consistent-performing cultivars for economically important traits. According to Eherhart and Russell (1966), a stable genotype is the one with above average mean, slope of one (b=1) and deviation from regression approaching zero.

In the present study, based on the mean plant height, regression coefficient and deviation from regression, nine of the hybrids had high regression values (1.38 to 1.93) and almost zero deviations, indicating the sensitivity of these hybrids to the changing environments. However, hybrids SHA-6 and SHA-3 had regression values (0.89 and 0.98) closer to unity and deviations approaching zero, indicating that they had better stability for plant height. This could be considered in the breeding programme to stabilize this character for mechanical harvesting. In addition, hybrid Hysun -33 (Check), SHA-3 and SHA-23 had regression values of one and almost zero deviations, indicating that these hybrids are stable for this character. On the other hand, many hybrids were shorter and had low regression values, indicating that these hybrids have greater resistance to changing environment and have better adaptability in poor environments only.

The stability analysis for days to 50% flowering revealed that among the top late flowering fifteen hybrids, SHA-3, SHA-7 and SHA-21 had high regression values (1.13, 1.44 and 1.17) that were associated with higher deviations, demonstrating that these hybrids were not stable (less than average). Hysun - 33, SHA-18, SHA-6 and SHA-5 had slope values greater than one and deviations from regression approaching zero showing the sensitivity of these hybrids to the changing environments. However, SHA-13, SHA-12, SHA-24 and SHA-23 (with regression values of 0.99, 0.94, 0.86 and 0.80, respectively) had better stability for days to 50% flowering. This indicates that the flowering time for these hybrids could be predicted due to positive response to different environments. Hybrid SHA-18 was the only stable one for days to to 50% flowering according to the three stability parameters. All the hybrids resulting from the female parent Kr, on the other hand , were not stable for days to 50% flowering. Similar pattern was found in days to maturity; all the hybrids obtained from the female parent Ka had higher mean than overall mean. Eight hybrids had slope values of less than one, with almost zero deviations, whereas four hybrids had low regression values that were associated with high deviations, which indicate high sensitivity to poor environments. However, the hybrids SHA-24 and SHR-5 had regression values (0.91 and 0.80) closer to unity and were relatively stable for days to maturity. On the other hand, all hybrids obtained from the female parent Kr were unstable.

Based on the mean number of seeds per head, almost all the hybrids from the female Ka, and hysun-33 (Check) and hybrid SHR-2 from the female Kr had greater mean number of seeds per head than the average. The three top hybrids SHA-8, SHA-24 and SHA-13 had higher slope values than unity accompanied by significant deviations from regression indicating instability and unpredictable response to environmental changes. However, eight hybrids including the check had high regression values (greater than one) and almost zero deviations, indicating below average stability and thus adaptability to favourable environments. Hybrids SHA-10, SHA-3 and SHA-2 with regression values of 0.67, 0.60 and 0.55 respectively, had above average stability and thus adaptability to less favourable environmental conditions. On the other hand, all the hybrids from the female parent Kr had lower mean number of seeds per head than the average associated with above or below unity regression values, reflecting their resistance to changes in the environment and better adaptability to poor environments for this trait.

Fifteen hybrids, and the check had mean 1000-seed weight above the average. However, among these SHR-5, SHR-10, SHR-12, SHR-23 and SHR-18 had regression values greater than one and significant deviations, indicating high sensitivity of these hybrids to changing environments, and that they are suited only to the highly favourable testing sites. Seven hybrids had high regression values ranging from 1.17 to 1.75 and deviations approaching zero, expressed below average stability and hence adaptability to relatively favourable environments. However, only hybrid SHA-7 with reression of 0.99 had better stability for 1000-seed weight. On the other hand, fourteen hybrids scored below average 1000-seed weight, accompanied with regression coefficients above or below unity, indicating that they had above average stability and better adaptability to poor environments.

With respect to the mean seed yield per head, seven high yielding hybrids and the check had higher regression values between 1.21 and 2.72 and almost zero deviations, while five others had slopes lower than one, indicating sensitivity of these hybrids to environmental influences and thus adaptability to relatively favourable environments. However, hybrids SHA-12 and SHA-18 had regression values of 0.89 and 0.87 suggesting that they had relatively better adaptability to varying environments. Hybrids with low seed yield per head and have regression values above or below unity had greater resistance to changes in the environment and better yielding ability in poor conditions.

In the stability analysis for seed yield per hectare, seventeen hybrids had a mean seed yield above the average. Among them, ten had slopes higher than one and three with slopes less than one and deviations from regression approaching zero, indicating that they had below average stability and adaptability to high yielding environments. Hybrids SHA-3, SHA-10 and SHA-18 with regression values of 0.90, 0.81 and 0.87, respectively, had better stability for seed yield. On the other hand, SHA-13 and SHA-2 had regression values less than one and significant deviations indicating instability and unpredictable response to changing environments. Most of the hybrids obtained from the female Kr were low yielders and accompanied by low regression values, demonstrating that these hybrids had greater resistance to changes in environemnt and better yielding ability in poor environemnts.

These results are in accord with the findings reported by Singh and Yadav (1983) and Singh and Geletu-Bejiga (1990) who concluded that lines with above average mean and high regression values (greater than one), that were associated with high deviations are sensitive to changing environments. Lines with above average mean and a regression values of one and almost zero deviations are stable in changing environments. Lines with low regression values have greater resistance to changing environments.

CHAPTER SIX
SUMMARY AND CONCLUSIONS

This study was conducted to realize several objectives; these were (i) to estimate the magnitude of heterosis for different characters in sunflower hybrids, (ii) to study the relative importance of general and specific combining ability, (iii) to identify the good general combiner male and female lines for future sunflower breeding, and (iv) to determine the stability of performance of the evaluated genotypes in varying testing environments.

A total of 28 F_1 hybrids along with a commercial check (Hysun - 33) were evaluated at two locations; namely, Shambat and Rahad for two consecutive rainy seasons (2000/01 and 2001/02). The crosses were made using two cytoplasmic male sterile lines and fourteen promising fertility restoring lines. The tested hybrids were arranged in a randomized complete block design with three replications.

At Shambat, the hybrids of the female parent Kr scored negative better-parent heterosis for plant height, days to 50% flowering, days to maturity and percentage of empty seeds in the first and the second seasons. Positive better-parent heterosis was expressed for stem diameter, head diameter, number of seeds per head, 1000-seed weight, seed yield per head and seed yield per hectare in both seasons.

At Rahad, the hybrids of the female Kr showed negative better-parent heterosis for plant height , days to 50% flowering and days to maturity in the first and the second season. However, positive better-parent heterosis was exhibited for stem diameter,head diameter, number of seeds per head , 1000-seed weight , seed yield per head and seed yield per hectare in both seasons.

With regard to the female, Ka negative better-parent heterosis was expressed at Shambat for plant height , days to 50% flowering , days to maturity and percentage of empty seeds in both seasons. On the other hand, positive heterotic values were exhibited for stem diameter, head diameter, number of seeds per head, seed yield per head and seed yield per hectare in the two seasons, and 1000-seed weight in the second season.

At Rahad, the hybrids of the female Ka had negative better- parent heterosis for plant height , days to 50% flowering and days to maturity in both seasons. Positive better-parent values were scored for stem diameter , head diameter , number of seeds per head , 1000-seed weight, seed yield per head and seed yield per hectare in the two seasons.

The additive gene action was more important than the non-additive one in the control of most of the studied characters, over the four environments. On the other hand, the non-additive gene action was of greater importance than the additive one for seed yield per head and seed yield per hectare at Shambat in the first season and for head diameter and 1000-seed weight at Rahad in the first season.

Among the male parents, SH-2 was the best general combiner for plant height, days to 50% flowering and days to maturity, whereas SH-24, SH-5, SH-6 and SH-23 were the best general combiners for number of seeds per head, percentage of empty seeds, 1000-seed weight and seed yield per hectare, respectively, at Shambat in the first season. In the second season, SH-2 was the best general combiner for 1000-seed weight and seed yield per hectare, and SH-10, SH-24 and SH-12 were the best general combiners for number of seeds per head, percentage of empty seeds and seed yield per head, repectively.

At Rahad, the best general combiner males were SH-2 and SH-9 for plant height, SH-12 and SH-8 for number of seeds per head, SH-3 and SH-21 for 1000-seed weight, SH-6 and SH-7 for seed yield per head and seed yield per hectare in the first and the second seasons, respectively. Ka was better general combiner than Kr for all the characters studied over the four environments. The only exception was percentage of empty seeds at Shambat and 1000-seed weight at Rahad in both seasons. With regards to SCA for yield components, the highest values were obtained from crosses in which both or at least one of the parents was a high general combiner. However, high SCA values resulting from low combiners were also obtained.

Regarding the stability parameters, some hybrids along with the commercial check showed below average stability for number of seeds per head, 1000-seed weight and seed yield per head indicating adaptability to favourable environments. However, some hybrids expressed above average stability suggesting adaptability to poor environments, and some performed better only in highly favourable environments.

Based on the findings of this study, the following conclusions could be drawn:-

1- There is a wide range of genetic variability for almost all the studied characters. Such variability could be exploited in sunflower breeding.
2- The combinations of lines that result in undesirable mid-parent heterosis could be discarded without great threat of losing potentially useful material. Therefore, mid-parent may be a useful and cost-effective guide for the selection of parents for evaluation in hybrid combinations.
3- Since characters studied were controlled by additive or non-additive gene action, the improvement of these characters could be made through selection procedures, such as pedigree, bulk method or recurrent selection.
4- Sunflower is sensitive to environmental changes as was shown by the highly significant first and second order interactions. Hence, evaluation of sunflower genotypes should be made in multilocations over years or seasons prior to their release.
5- Almost all hybrids of the female Ka as well as the commercial check performed better under favourable environments, whereas hybrids of the female Kr were suitable in poor environments.
6- Although Eberhart and Russell method of stability analysis is simple, it does not provide enough information that satisfies all breeder's objectives. In certain circumstances, the stable genotype which has above average mean many not have some desirable parameters in sunflower

breeding such as shortness and earliness.

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Table 1. List of the sunflower genotypes used in the study

serial No.	Genotype name	Origin	Entry No.	Genotype name	Genotype name
	Parents			**Crosses**	**Hybrid name**
	(A) females				Hybrid name
			1	SH-2 x Kr	SHR-2
1	Ka	Selection from	2	SH-3 x Kr	
		German material	3	SH-5 x Kr	SHR-3
			4	SH-6 x Kr	SHR-5
2	Kr	Germany	5	SH-7 x Kr	SHR-6
			6	SH-8 x Kr	SHR-7
			7	SH-9 x Kr	SHR-8
	(B) Males	Improved by	8	SH-10 x Kr	
1	SH-2	The department of	9	SH-12 x Kr	SHR-9
2	SH-3	Agronomy,	10	SH-13 x Kr	SHR-10
3	SH-5	Faculty of	11	SH-18 x Kr	SHR-12
4	SH-6	Agriculture,	12	SH-21 x Kr	SHR-2
5	SH-7	University of	13	SH-23 x Kr	SHR-3
6	SH-8	Khartoum	14	SH-24 x Kr	SHR-5
7	SH-9		15	SH-2 x Ka	SHR-6
8	SH-10		16	SH-3 x Ka	SHR-7
9	SH-12		17	SH-5 x Ka	SHR-8
10	SH-13		18	SH-6 x Ka	SHR-9
11	SH-18		19	SH-7 x Ka	SHR-10
12	SH-21		20	SH-8 x Ka	SHR-12
13	SH-23		21	SH-9 x Ka	SHR-12
14	SH-24		22	SH-10 x Ka	SHR-18
			23	SH-12 x Ka	SHR-21
	(C) Hysun-33		24	SH-13 x Ka	SHR-23
	(Control)		25	SH-18 x Ka	SHR-24
			26	SH-21 x Ka	SHA-2
			27	SH-23 x Ka	SHA-3
			28	SH-24 x Ka	SHA-5
					SHA-6
					SHA-7
					SHA-8
					SHA-9
					SHA-10
					SHA-12
					SHA-12
					SHA-18
					SHA-21
					SHA-23
					SHA-24
					SHR-24SHR-13 SHR-13
					SHR-13SHR-18
					SHR-21

SHR-23
SHR-24
SHA-2
SHA-3
SHA-5
SHA-6
SHA-7
SHA-8
SHA-10
SHA-12
SHA-13
SHA-18
SHA-21
SHA-23
SHA-24

Table 2. The form of individual analysis of variance for a randomized complete block design

Source of variation	Degree of freedom	Mean squares	F- ratio
Block	(r-1)	M_1	M_1/M_3
Treatments	(t-1)	M_2	M_2/m_3
Error	(r-1) (t-1)	M_3	
Total	(rt-1)		

M_1, M_2 and M_3 = Mean squares for blocks, treatments and error , respectively

Table 3. The form of individual analysis of variance for a randomized complete block design for Line x Tester analysis

Source of variation	Degree of freedom	Means square	F- ratio
Replication	(r – 1)	$M. S._r$	$M.S._r/M.S._e$
Crosses	(c – 1)	$M.S._c$	$M.S._c/M.S._e$
Lines	(L – 1)	$M.S._L$	$M.S._L/M.S._{(Lxt)}$
Testers	(t – 1)	$M. S._t$	$M.S._t/M.S._{(Lxt)}$
Line x tester	(t – 1)(L – 1)	$M.S._{(Lxt)}$	$M.S._{(Lxt)}/M.S._e$
Error	(r – 1) (c – 1)	$M.S._e$	
Total	rc – 1		

r = number of replications
c = Number of crosses
L= Number of lines
t = Number of testers

Table 4. The form of the combined analysis of variance for the pooled data of two seasons and two locations.

Source of variation	Degree of freedom	Means square	F- ratio
Location (L)	(L – 1)	M_1	M_1/M_9
Season (S)	(S – 1)	M_2	M_2/M_9
Reps.within L	L (r – 1)	M_3	M_3/M_9
Genotypes (G)	g – 1	M_4	M_4/M_9
G x L	(L – 1) (g – 1)	M_5	M_5/M_9
L x S	(L – 1) (S – 1)	M_6	M_6/M_9
G x S	(g – 1) (S – 1)	M_7	M_7/M_9
G x L x S	(G – 1) (L – 1) (S – 1)	M_8	M_8/M_9
Pooled error	LS (r – 1) (t – 1)	M_9	
Total	(LSrt-1)		

L = Number of locations; S = Number of seasons; r = Number of replications; G = Number of genotypes M_1, M_2, M_3, M_4, M_5, M_6, M_7, M_8, M_9 = Mean squares for locations, seasons, replications within locations, genotypes, location x genotype, location x season, genotype x season, genotype x location x season and pooled error, respectively.

Table 8. **Means of some morphological characters, seed yield and seed yield components in 29 F_1 sunflower hybrids, evaluated at Shambat for two seasons**

Hybrid	Plant height (cm)	Stem diameter (cm)	Days to 50% flowering	Days to physiological maturity	Head diameter (cm)
			2000/01		
SHR-2	**166.66 a**	**3.30 a**	**50.66 c**	**87.00 e**	**18.86 abc**
SHR-3	**145.53 a,.,g**	**3.26 abc**	**48.33 d**	**78.33 f**	**16.23 b,.,f**
SHR-5	**138.66 c,.,g**	**2.56 fgh**	**47.66 d**	**78.00 f**	**15.83 c,.,g**
SHR-6	**139.66 c,.,g**	**2.66 e,.,h**	**47.33 de**	**77.66 f**	**15.50 d,.,g**
SHR-7	**139.33 c,.,g**	**2.96 a,.,g**	**47.00 de**	**76.66 f**	**15.63 c,.,g**
SHR-8	**136.33 d,.,g**	**2.70 d,.,h**	**45.66 e**	**76.00 f**	**13.30 g**
SHR-9	**129.00 fg**	**2.80 b,.,h**	**48.66 d**	**78.00 f**	**18.30 a,.,d**
SHR-10	**138.66 c,.,g**	**2.83 b,.,h**	**47.33 de**	**77.33 f**	**16.33 b,.,f**
SHR-12	**129.66 fg**	**2.53 gh**	**47.00 de**	**76.66 f**	**14.76 f g**
SHR-13	**132.66 fg**	**2.66 e,.,h**	**47.00 de**	**77.33 f**	**15.56 d,.,g**
SHR-18	**140.33 b,.,h**	**2.76 c,.,h**	**47.33 de**	**77.33 f**	**14.76 f g**
SHR-21	**139.66 c,.,g**	**2.80 b,.,h**	**47.66 d**	**77.00 f**	**15.30 fg**
SHR-23	**146.33 a,.,g**	**2.96 a,.,g**	**48.33 d**	**77.66 f**	**19.33 a**
SHR-24	**123.00 g**	**2.50 h**	**47.33 de**	**76.33 f**	**16.30 b,.,f**
SHA-2	**163.66 ab**	**2.90 a,.,h**	**60.00 a**	**92.66 a**	**14.83 fg**
SHA-3	**156.33 a,.,e**	**3.06 a,.,e**	**56.66 b**	**91.00 a,.,d**	**18.06 a,.,e**
SHA-5	**152.33 a,.,f**	**2.93 a,.,h**	**55.33 b**	**88.66 cde**	**18.36 abc**
SHA-6	**157.33 a,.,d**	**3.13 a,.,d**	**55.00 b**	**91.00 a,.,d**	**18.30 a,.,d**
SHA-7	**152.33 a,.,f**	**3.06 a,.,e**	**55.00 b**	**88.33 de**	**17.80 a,.,e**
SHA-8	**135.00 fg**	**3.00 a,.,f**	**55.00 b**	**88.66 cde**	**15.33 efg**
SHA-9	**158.00 a,.,d**	**3.20 abc**	**58.66 a**	**93.00 a**	**16.96 a,.,f**
SHA-10	**158.33 a,.,d**	**3.10 a,.,d**	**56.66 b**	**90.66 a,.,d**	**16.63 a,.,f**
SHA-12	**143.66 a,.,g**	**3.13 a,.,d**	**56.33 b**	**92.33 ab**	**17.13 a,.,f**
SHA-13	**144.66 a,.,g**	**2.93 a,.,g**	**56.33 b**	**92.33 ab**	**16.60 a,.,f**
SHA-18	**137.66 c,.,h**	**2.86 a,.,h**	**55.66 b**	**91.66 abc**	**18.06 a,.,e**
SHA-21	**146.00a,.,g**	**2.90 a,.,h**	**56.00 b**	**90.66 a,.,d**	**16.96 a,.,f**
SHA-23	**150.00 a,.,f**	**3.16 abc**	**56.00 b**	**90.66 a,.,d**	**17.63 a,.,f**
SHA-24	**145.33 a,.,g**	**3.23 ab**	**56.66 b**	**89.00 cde**	**17.83 a,.,e**
Hysun-33	**161.33 abc**	**3.03 a,.,e**	**55.33 b**	**89.66 b,.,e**	**18.86 ab**
Overall mean	**145.05**	**2.92**	**52.13**	**84.54**	**16.72**
C.V%	**8.28**	**7.66**	**1.88**	**1.86**	**8.70**

SHR = hybrids produced by female Kr
SHA= hybrids produced by female Ka

Table 8 **(Cont.)**

Hybrid	Number of seeds/head	Percentage of empty seeds	1000 -seed weight (g)	Seed yield / head (g)	Seed yield / ha (t)
			2000/01		

SHR-2	1397.80 a,.,d	8.03 cd	64.67 c,.,f	90.20 ab	5.83 ab
SHR-3	951.40 fgh	13.20 cd	71.06 a,.,d	66.53 b,.,g	4.30 b,.,e
SHR-5	744.01 h	41.00 a	76.63 a	57.07 efg	3.63 de
SHR-6	697.40 h	30.36 b	72.70 abc	50.70 g	3.23 e
SHR-7	935.00 gh	5.83 cd	68.30 a,.,e	64.20 efg	4.10 de
SHR-8	941.30 gh	8.40 cd	60.93d,.,i	54.73 efg	3.66 de
SHR-9	1200.20 b,.,g	9.60 cd	65.20 b,.,f	78.20 a,.,f	5.00 a,.,d
SHR-10	1019.40 e,.,h	11.23 cd	71.00 a,.,d	73.03 a,.,g	4.63 a,.,e
SHR-12	934.20 gh	8.76 cd	64.63 c,.,f	60.83 efg	3.86 de
SHR-13	997.80 e,.,h	12.43 cd	60.83 d,.,i	60.97 efg	3.86 de
SHR-18	1044.01 d,.,h	8.00 cd	52.10 hij	53.57 fg	3.43 de
SHR-21	994.50 e,.,h	12.36 cd	66.50 a,.,e	68.71 b,.,g	4.36 b,.,e
SHR-23	1288.10 a,.,g	7.03 cd	76.10 ab	97.63 a	6.23 a
SHR-24	1127.00 c,.,g	6.06 cd	64.33 c,.,g	72.60 a,.,g	4.66 a,.,e
SHA-2	1119.00 c,.,h	14.16 c	48.53 j	54.40 efg	3.50 de
SHA-3	1176.40 b,.,g	7.80 cd	52.26 hij	61.33 efg	3.90 de
SHA-5	1361.40 a,.,e	10.00 cd	52.96 g,.,j	71.63 b,.,g	4.56 b,.,e
SHA-6	1427.00 abc	9.26 cd	63.43 c,.,h	90.53 abc	5.76 abc
SHA-7	1119.00 c,.,g	6.50 cd	57.70 e,.,j	65.33 a,.,g	4.16 cde
SHA-8	1335.40 a,.,e	2.93 d	51.63 ij	57.73 efg	3.63 de
SHA-9	1221.70 b,.,g	9.06 cd	50.86 ij	62.97 efg	4.03 de
SHA-10	1337.90 a,.,e	6.70 cd	47.56 j	64.87 d,.,g	4.16 cde
SHA-12	1252.00 a,.,g	12.03 cd	58.50 e,.,j	73.73 a,.,g	4.70 a,.,e
SHA-13	1158.70 b,.,g	17.96 c	54.90 f,.,j	60.67 efg	3.86 de
SHA-18	1520.10 ab	5.73 cd	52.63 hij	80.27 a,.,e	5.10 a,.,d
SHA-21	1323.90 a,.,g	6.06 cd	57.33 e,.,j	75.90 a,.,g	4.86 a,.,e
SHA-23	1252.90 a,.,g	4.40 cd	58.90 e,.,j	73.53 a,.,g	4.66 a,.,e
SHA-24	1597.60 a	9.90 cd	47.66 j	76.57 a,.,g	4.86 a,.,e
Hysun-33	1282.30 a,.,f	7.16 cd	70.83 a,.,d	90.73 abc	5.80 abc
Overall	1164.05	10.65	60.72	69.42	4.42
mean	16.28	53.17	9.64	18.93	18.90
C.V%					

Table 8 **(Cont.)**

Hybrid	Plant height (cm)	Stem diameter (cm)	Days to 50% flowering	Days to physiological maturity	Head diameter (cm)
			2001/02		
SHR-2	146.33 ab	2.93 a,.,d	53.00 c,.,g	98.66 a,.,d	18.46 ab
SHR-3	125.00 abc	2.83 a,.,d	51.66 d,.,g	90.33 a,.,g	15.33 bcd
SHR-5	144.00 ab	2.76 a,.,e	49.33 ghi	89.33 c,.,g	16.33 a,.,d
SHR-6	129.00 abc	2.63 cd	47.00 hi	87.00 fg	16.40a,.,d
SHR-7	107.67 c	2.63 cd	51.00 e,.,h	89.66 c,.,g	15.60 a,.,d
SHR-8	127.00 abc	2.76 a,.,d	46.00 i	85.33 g	13.53d
SHR-9	136.00 abc	2.76 a,.,d	52.00 d,.,g	91.66 a,.,f	14.20cd
SHR-10	126.67 abc	2.56 d	49.00 ghi	87.33 e,.,h	4.80 a,.,d
SHR-12	128.00 abc	2.66 bcd	52.00 d,.,g	89.00 d,.,g	17.33 abc
SHR-13	130.00 abc	2.66 bcd	49.66 ghi	89.66 c,.,g	14.36 cd
SHR-18	125.67 abc	2.86 a,.,d	52.66 c,.,g	87.33 efg	13.66 d
SHR-21	120.00 bc	2.73 a,.,d	50.33 f,.,i	89.00 d,.,g	15.63 a,.,d
SHR-23	131.67 abc	2.70 a,.,d	53.33 c,.,g	89.33 d,.,g	15.33 bcd
SHR-24	134.00 abc	2.73 a,.,d	51.66 d,.,g	88.33 d,.,g	14.90 bcd
SHA-2	148.67 ab	3.03 ab	59.66 a	93.33 a,.,e	16.00a,.,d
SHA-3	141.33 ab	2.86 a,.,d	52.66 c,.,g	90.00 b,.,g	19.33 a
SHA-5	131.00 abc	2.86 a,.,d	54.66 b,.,f	94.33 a,.,d	15.60 a,.,d
SHA-6	151.33 a	3.66 a	53.66 c,.,g	91.33 a,.,f	16.03 a,.,d
SHA-7	136.00 abc	2.83 a,.,d	52.66 c,.,g	89.33 c,.,g	16.33 a,.,d
SHA-8	130.00 abc	2.63 cd	53.00 c,.,g	92.00 a,.,f	17.23 a,.,d
SHA-9	133.33 abc	2.90 a,.,d	58.33 ab	96.00 a	18.43 ab
SHA-10	140.00 ab	2.80 a,.,d	59.33 a	95.33 abc	16.83 a,.,d
SHA-12	139.66 ab	2.90 a,.,d	55.33 a,.,e	93.00 a,.,f	15.50 a,.,d
SHA-13	143.00 ab	2.93 a,.,d	55.66 a,.,d	94.33 a,.,d	16.36 a,.,d
SHA-18	137.66 ab	3.00 abc	56.00 a,.,d	93.66 a,.,d	16.93 a,.,d
SHA-21	143.66 ab	2.76 a,.,d	53.66 c,.,g	93.00 a,.,f	16.53 a,.,d
SHA-23	140.00 ab	2.76 a,.,d	56.00 a,.,d	92.33 a,.,f	17.33 a,.,d
SHA-24	135.00 abc	2.90 a,.,d	58.33 ab	95.66 ab	14.43 cd
Hysun-33	145.33 ab	2.73 a,.,d	57.00 abc	91.00 a,.,g	15.53 a,.,d
Overall mean	134.72	2.80	53.29	91.09	16.09
C.V%	11.14	6.57	4.31	3.30	12.15

Table 8 **(Cont.)**

Hybrid	Number of seed/head	Percentage of empty seeds	1000-seed weight (g)	Seed yield / head (g)	Seed yield /ha (t)
			2001/02		
SHR-2	1224.30 a,.,e	29.86 ab	67.60 a	76.07 a	4.86 a
SHR-3	1143.70 b,.,e	22.23 a,.,d	51.43 abc	62.53 abc	3.70 a,.,e
SHR-5	1174.60 a,.,e	14.16 bcd	44.26 abc	54.10 a,.,e	3.33 b,.,f
SHR-6	1081.00 b,.,e	22.95 a,.,d	46.76 abc	47.90 a,.,e	3.03 b,.,g
SHR-7	941.70 cde	22.06 a,.,d	55.66 ab	56.60 a,.,e	3.30 b,.,g
SHR-8	831.10 e	21.96 a,.,d	44.63 abc	42.77 b,.,e	2.33 efg
SHR-9	902.10 de	22.90 a,.,d	33.90 c	30.43 e	1.80 g
SHR-10	1336.10 ab	13.33bcd	46.10 abc	63.50 abc	4.06 abc
SHR-12	1208.60 a,.,e	15.66 bcd	52.46 abc	67.07 abc	3.96 a,.,d
SHR-13	948.80 cde	25.96 abc	52.46 abc	49.50 a,.,e	3.16 b,.,g
SHR-18	945.30 cde	12.50 cd	50.70 abc	51.53 a,.,e	3.13 b,.,g
SHR-21	940.30 cde	17.90 a,.,d	45.93 abc	40.73 cde	2.60 c,.,g
SHR-23	942.40 cde	27.20 a,.,d	43.56 abc	49.97 a,.,e	2.83 b,.,g
SHR-24	838.10 de	33.60 a	37.90 bc	31.33 de	1.96 fg
SHA-2	1184.30 a,.,e	20.66 a,.,d	54.90 ab	60.20 a,.,e	3.86 a,.,e
SHA-3	1335.20 abc	21.76 a,.,d	44.56 abc	63.50 abc	3.96 a,.,e
SHA-5	1137.60 b,.,e	17.76 a,.,d	48.23 abc	54.17 a,.,e	3.40 a,.,f
SHA-6	1014.80 b,.,e	18.33 a,.,d	53.00 abc	53.77 a,.,e	3.40 a,.,f
SHA-7	1002.50 b,.,e	27.86 abc	45.00 abc	52.47 a,.,e	2.83 b,.,g
SHA-8	1210.80 a,.,e	14.46 bcd	45.93 abc	57.87 a,.,e	3.56 a,.,e
SHA-9	929.30 cde	26.90 abc	43.73 abc	40.93 cde	2.50 d,.,g
SHA-10	1312.00 a,.,d	11.63 cd	46.80 abc	62.83 abc	3.86 a,.,e
SHA-12	1196.40 a,.,e	14.30 bcd	49.70 abc	70.67 ab	3.53 a,.,e
SHA-13	1581.00 a	8.26 d	47.63 abc	71.93 a	4.26 ab
SHA-18	1078.10 b,.,e	13.40 bcd	55.70 ab	62.67 abc	3.93 a,.,e
SHA-21	1088.60 b,.,e	23.63 a,.,d	49.26 abc	53.70 a,.,e	3.46 a,.,f
SHA-23	974.30 b,.,e	15.53 bcd	41.93 bc	41.93 cde	2.63 c,.,g
SHA-24	960.50 cde	21.86 a,.,d	50.86 abc	49.57 a,.,e	3.16 b,.,g
Hysun-33	882.10 de	16.66 bcd	44.83 abc	39.40 cde	2.40 efg
Overall mean	1082.72	19.84	47.92	53.74	3.26
C.V%	19.81	41.39	20.72	27.01	23.34

Means with the same letter(s) within a column are not significantly different, according to Duncan Multiple Range Test.

Table 9. **Means of some morphological characters, seed yield and seed yield components in 29 F_1 sunflower hybrids, evaluated at Rahad for two seasons**

Hybrid	Plant height (cm)	Stem diameter (cm)	Days to 50% flowering	Days to physiological maturity	Head diameter (cm)
			2000/01		
SHR-2	160.00 a,.,f	3.43 a	55.00 cd	86.66 gh	19.60 a
SHR-3	131.66 g,.,k	3.16 a,.,d	53.33 d	83.33 i	18.60 abc
SHR-5	140.66 e,.,k	2.96 b,.,e	51.66 de	87.66 fgh	18.73 abc
SHR-6	136.33 f,.,k	2.83 de	54.66 d	82.66 i	15.33 ghi
SHR-7	131.33 g,.,k	3.00 b,.,e	52.65 de	86.33 h	16.33 e,.,i
SHR-8	117.33 k	2.83 de	48.66 e	81.66 i	14.86 i
SHR-9	126.66 h,.,k	3.03 b,.,e	58.66 abc	89.33 b,.,f	15.96 ghi
SHR-10	131.00 g,.,k	2.80 de	54.66 d	88.66 d,.,h	15.10 i
SHR-12	143.33 d,.,j	2.80 de	54.33 d	88.33 e,.,h	16.63 d,.,i
SHR-13	122.66 ijk	2.90 cde	55.00 cd	88.00 e,.,h	15.70 ghi
SHR-18	122.00 jk	2.83 de	53.66 d	89.33 b,.,f	15.70 ghi
SHR-21	128.33 h,.,k	2.96 b,.,e	51.33 de	86.66 gh	16.03 ghi
SHR-23	141.333 e,.,k	2.96 b,.,e	54.00 d	88.33 e,.,h	17.86 a,.,e
SHR-24	131.00 g,.,k	2.76 e	52.66 d	8.66 d,.,h	16.26 e,.,i
SHA-2	170.00 abc	3.26 abc	59.66 ab	92.33 a	16.43 e,.,i
SHA-3	162.33 a,.,e	2.96 b,.,e	58.66 abc	90.66 a,.,e	17.00 c,.,h
SHA-5	175.66 ab	2.96 b,.,e	60.00 ab	91.66 abc	17.93 a,.,e
SHA-6	177.33 a	3.23 abc	59.66 ab	90.66 a,.,e	18.56 abc
SHA-7	147.33 c,.,i	3.00 cde	61.33 ab	89.00 c,.,g	18.00 a,.,e
SHA-8	154.66 a,.,g	2.83 de	59.66 ab	90.00 a,.,f	16.10 f,.,i
SHA-9	163.66 a,.,e	2.90 cde	62.00 ab	91.66 abc	15.46 ghi
SHA-10	175.66 ab	2.90 cde	58.66 abc	92.66 a	17.83 b,.,f
SHA-12	161.00 a,.,f	3.00 b,.,e	61.00 ab	90.33 a,.,f	18.80 ab
SHA-13	167.33 a,.,d	2.93 b,.,e	60.00 ab	90.66 a,.,e	18.26 a,.,d
SHA-18	158.00 a,.,f	3.06 b,.,e	59.66 ab	90.33 a,.,f	17.00 b,.,g
SHA-21	150.00 c,.,h	2.93 b,.,e	59.33 ab	90.00 a,.,f	15.96 ghi
SHA-23	159.00 a,.,f	3.10 a,.,e	58.33 c	91.33 a,.,d	15.36 ghi
SHA-24	151.00 b,.,h	3.10 a,.,e	60.00 ab	92.00 ab	15.23 hi
Hysun-33	166.66 a,.,d	3.30 ab	62.33 a	92.33 a	17.13 b,.,g
Overall mean	148.37	2.99	56.91	89.01	16.82
C.V%	8.60	6.28	3.53	1.53	5.76

Table 9 **(Cont.)**

Hybrid	Number of Seeds / head	1000- seed weight (g)	Seed yield / head (g)	Seed yield /ha (t)
		2000/01		

SHR-2	1265.10 b,.,f	53.33 b,.,g	67.50 a,.,g	4.83 a,.,g
SHR-3	1018.37 g	67.46 a	68.80 a,.,g	4.93 a,.,g
SHR-5	1089.07 fg	51.16 d,.,g	55.73 fgh	4.00 hg
SHR-6	1178.80 c,.,g	53.80 b,.,g	63.66 b,.,h	4.53 c,.,g
SHR-7	1108.13 efg	60.66 a,.,d	67.26 a,.,g	4.80 a,.,f
SHR-8	1008.53 g	43.73 g	45.00 h	3.20 h
SHR-9	1084.13 fg	65.26 ab	71.20 a,.,g	5.10 a,.,g
SHR-10	1129.17 c,.,g	47.13 fg	53.36 gh	4.03 fgh
SHR-12	1182.90 c,.,g	47.16 efg	55.46 fgh	3.96 gh
SHR-13	1073.03 fg	55.43 b,.,g	59.66 c,.,h	4.23 d,.,h
SHR-18	1060.50 fg	53.00 c,.,g	56.23 fgh	4.03 fgh
SHR-21	1082.40 fg	59.50 a,.,e	64.03 b,.,h	4.60 b,.,g
SHR-23	1174.63 c,.,g	55.26 b,.,g	65.30 b,.,g	4.66 b,.,g
SHR-24	1122.63 d,.,g	61.03 a,.,d	68.40 a,.,g	4.90 a,.,g
SHA-2	1124.50 d,.,g	52.10 c,.,g	56.73 e,.,h	4.06 e,.,h
SHA-3	154.53 a	51.36 d,.,g	77.56 a,.,d	5.53a,.,d
SHA-5	1282.93 a,.,f	57.50a,.,f	74.36 a,.,f	5.40 a,.,f
SHA-6	1363.27 abc	60.76 a,.,d	82.86 ab	5.93 ab
SHA-7	1488.23 ab	51.36 d,.,g	76.20 a,.,e	5.43 a,.,e
SHA-8	1351.70 abc	48.93 d,.,g	66.20 a,.,f	4.73 a,.,g
SHA-9	1128.87 c,.,g	51.46 d,.,g	57.96 d,.,h	4.13 e,.,h
SHA-10	1436.87 ab	54.36 b,.,g	78.03 abc	5.56 a,.,d
SHA-12	1448.70 ab	59.13 a,.,g	85.50 a	6.10 a
SHA-13	1414.07 ab	57.86 a,.,f	81.83 ab	5.86 abc
SHA-18	1334.30 a,.,e	58.56 a,.,f	78.40 abc	5.56 a,.,d
SHA-21	1437.67 ab	49.90 d,.,g	71.70 a,.,g	5.13 a,.,g
SHA-23	1330.43 a,.,e	54.36 b,.,g	73.30 a,.,f	5.26 a,.,g
SHA-24	1422.47 ab	54.36 b,.,g	77.43 a,.,d	5.53 a,.,d
Hysun-33	1261.60 b,.,f	64.00 abc	81.10 ab	5.76 abc
Overall mean	1238.43	55.20	68.30	4.89
C.V%	9.72	11.14	14.47	14.14

Table 9 **(Cont.)**

Hybrid	Plant height (cm)	Stem diameter (cm)	Days to 50% flowering	Days to physiological maturity	Head diameter (cm)
			2001/02		
SHR-2	165.33 b,.,e	2.50 b,.,f	56.00 e	88.00 d,.,g	18.30 cde
SHR-3	142.00 hi	2.57 a,.,e	55.33 ef	89.33 b,.,g	18.27 cde
SHR-5	145.00 f,.,i	2.43 c,.,f	53.67 f	90.00 a,.,e	19.13 a,.,e
SHR-6	148.00 fgh	2.67 a,.,d	54.67 ef	88.00 d,.,g	18.57 b,.,e
SHR-7	141.33 hi	2.57 a,.,e	54.67 ef	86.66 g	17.70 de
SHR-8	137.67 i	2.03 f	55.00 ef	87.67 efg	17.13 e
SHR-9	158.00 def	2.23 def	60.69 cd	89.00 fg	19.37 a,.,e
SHR-10	149.66 fgh	2.07 ef	55.33 ef	86.67 g	19.27 a,.,e
SHR-12	156.67 efg	2.57 a,.,e	55.33 ef	87.66 efg	18.67 b,.,e
SHR-13	145.33 f,.,i	2.50 b,.,f	54.67 ef	90.00 a,.,e	18.66 cde
SHR-18	138.67 hi	2.60 a,.,d	53.66 f	87.00 fg	18.63 b,.,e
SHR-21	139.00 hi	2.53 a,.,f	54.33 ef	88.33 d,.,g	17.43 de
SHR-23	143.33 ghi	2.50 b,.,f	55.33 ef	88.67 c,.,g	18.50 cde
SHR-24	143.33 ghi	2.28 def	55.67 ef	88.66 c,.,g	18.73 a,.,e
SHA-2	170.33 a,.,e	3.03 a	60.33 d	90.00 a,.,e	19.07 a,.,e
SHA-3	167.33 a,.,e	2.83 abc	63.00 ab	87.67 efg	19.40 a,.,e
SHA-5	175.33 abc	2.73 a,.,d	63.00 ab	90.66 a,.,d	21.33 a
SHA-6	170.66 a,.,e	2.80 abc	63.00 ab	89.00 c,.,g	19.00 a,.,e
SHA-7	169.00 a,.,e	2.53 a,.,f	63.00 ab	87.67 efg	19.40 a,.,e
SHA-8	151.66 fgh	2.60 a,.,d	60.333 d	90.00 a,.,e	19.46cde
SHA-9	180.00 a	3.00 ab	64.00 a	92.00 ab	19.23 a,.,e
SHA-10	179.67 ab	2.47 c,.,f	63.33 ab	92.33 a	19.80 a,.,e
SHA-12	178.66abc	2.83 abc	61.66 bcd	88.66 c,.,g	19.83 a,.,d
SHA-13	175.33 abc	2.80 abc	62.67 abc	88.66 c,.,g	20.43 abc
SHA-18	172.67 abc	2.83 abc	62.66 abc	87.67 efg	17.96cde
SHA-21	172.00 a,.,d	2.60 a,.,d	63.00 ab	90.00 a,.,e	18.70 b,.,e
SHA-23	165.00 cde	2.60 a,.,d	61.66 bcd	89.67 a,.,f	21.20 ab
SHA-24	168.33 a,.,e	3.03 a	63.33 abc	90.66 a,.,d	19.53 a,.,e
Hysun-33	17.67 a,.,d	2.70 a,.,d	63.00 ab	91.33 abc	18.73 a,.,e
Overall mean	158.95	2.60	59.03	88.95	18.91
C.V%	4.99	10.21	1.92	1.63	6.97

Table 9 **(Cont.)**

Hybrid	Number of seeds/head	1000- seed weight (g)	Seed yield / head (g)	Seed yield /ha(t)
		2001/02		
SHR-2	1167.50 d,.,j	68.00 efg	79.00 b,.,f	5.67 b,.,g
SHR-3	828.10 jkl	77.66 bc	64.33 e,.,h	4.60 fgh
SHR-5	901.60 kl	72.67 cde	60.67 fg	4.37 gh
SHR-6	717.10 l	76.33 bcd	55.00 g	3.90 h
SHR-7	1154.60 d,.,j	80.00 ab	92.33 abc	6.60 abc
SHR-8	1074.30 f,.,k	70.00 def	75.33 b,.,g	5.37 b,.,h
SHR-9	1488.10 bcd	59.67 hij	88.67 a,.,d	6.30 a,.,e
SHR-10	1054.20 g,.,k	77.33 bc	81.33 b,.,f	5.80 b,.,g
SHR-12	1023.60 h,.,l	76.66 bc	78.33 b,.,f	5.60 b,.,g
SHR-13	1007.50 h,.,l	63.00 ghi	63.33 efg	4.50 fgh
SHR-18	882.60 jkl	84.33 a	74.33 b,.,g	5.30 b,.,h
SHR-21	841.4 0jkl	77.67 bc	64.67 d,.,g	4.60 fgh
SHR-23	1086.00 e,.,k	63.00 ghi	69.00 d,.,g	4.93 d,.,h
SHR-24	978.00 I,.,l	70.00 def	68.33 d,.,g	4.87 e,.,h
SHA-2	1436.30 b,.,e	57.00 ijk	81.33 b,.,f	5.80 b,.,g
SHA-3	1244.80 c,.,i	67.33 efg	83.33 b,.,e	5.93 b,.,f
SHA-5	1427.01 b,.,e	61.33 ghi	87.67 a,.,d	6.23 a,.,e
SHA-6	1604.40 ab	58.67 kij	94.33 ab	6.73 ab
SHA-7	1409.20 b,.,f	63.66 f,.,i	89.67 a,.,d	6.43 a,.,d
SHA-8	1819.4 0a	42.67 l	77.33 b,.,f	5.53 b,.,g
SHA-9	1148.09 d,.,j	65.00 fgh	75.00 b,.,g	5.37 b,.,h
SHA-10	1367.60 b,.,h	57.33 ijk	78.33 b,.,f	5.57 b,.,g
SHA-12	1567.60 abc	59.33 hij	93.00 abc	6.63 abc
SHA-13	1330.80 b,.,h	54.33 jk	71.33 c,.,g	5.10 c,.,h
SHA-18	1573.00 abc	51.33 k	81.00 b,.,f	5.80 b,.,g
SHA-21	1091.60 e,.,k	76.33 bcd	83.00 b,.,e	5.90 b,.,g
SHA-23	1246.30 c,.,i	64.67 fgh	80.67 b,.,f	5.77 b,.,g
SHA-24	1571.80 abc	52.00 k	81.66 b,.,f	5.83 b,.,g
Hysun-33	1434.80 b,.,e	73.33 b,.,e	105.00 a	7.47 a
Overall mean	1220.28	66.29	78.58	5.63
C.V%	14.49	5.37	13.80	13.75

Means with the same letter(s) within a column are not significantly different , according to

Duncan Multiple Range Test.

Table 5. **Mean squares from the analysis of variance for some morphological characters, seed yield and seed yield components in 29 F_1 sunflower hybrids evaluated at Shambat and Rahad for two seasons**

Character	Source of variation			
	2000/01			
	Replication	Treatment	Error	Replication
	Shambat			
Plant height (cm)				

Stem diameter (cm)	6550.25**	365.76**	144.44	2852.82**
Days to 50% flowering	1.06**	0.14**	0.05	0.01^{ns}
Days to physiological maturity	4.58 **	62.67**	0.96	92.56**
Head diameter (cm)	17.04**	139.50**	2.48	110.49**
Number of seeds/head	13.85**	6.61**	2.11	13.17*
Percentage of empty seeds	45145.46^{ns}	139683.43**	35943.26	410508.71**
1000-seed weight (g)	77.78^{ns}	175.84**	32.10	71.66^{ns}
Seed yield/head (g)	656.80**	227.55**	34.31	227.37^{ns}
Seed yield / ha (t)	559.02*	47.55**	170.90	346.55^{ns}
	0.09^{ns}	1.58**	0.47	1.26^{ns}

Table 5. **(Cont.)**

Character	Source of variation			
	2000/01			
	Replication	Treatment	Error	Replication
			Rahad	
Plant height (cm)	1069.37**	976.94**	162.84	9.55^{ns}
Stem diameter (cm)	0.03^{ns}	0.07**	0.03	2.81**
Days to 50% flowering	11.90^{ns}	41.37*	4.03	0.31^{ns}
Days to physiological maturity	0.49^{ns}	24.24**	1.87	2.7^{ns}
Head diameter (cm)	2.05^{ns}	5.33**	0.83	8.44*

Number of seeds/head	**10896.66^{ns}**	**73185.54****	**14501.38**	**189889.14****
1000-seed weight (g)	**6.21^{ns}**	**95.48****	**37.87**	**1.14^{ns}**
Seed yield/head (g)	**28.84^{ns}**	**318.11****	**97.77**	**797.83****
Seed yield /ha (t)	**2.13***	**1.83****	**0.70**	**4.09**

*** Significant at $p \leq 0.05$**
**** Significant at $p \leq 0.01$**
ns Non-significant

Table 6. **Mean squares from the analysis of variance for some morphological characters, seed yield and seed yield components in 28 F_1 sunflower hybrids evaluated at Shambat and Rahad for two seasons**

Character	Source of variation			
	Crosses d.f = 27	Lines d.f = 1	Testers d.f = 13	Linesx d.f = 13
	Shambat 2000/01			
Plant height (cm)	348.82**	2629.76**	382.58**	139.60
Stem diameter (cm)	0.14**	1.23**	0.08^{ns}	0.12*
Days to 50% flowering	63.82**	1594.71**	8.94**	0.95^{ns}
Days to physiological maturity	141.65**	3445.76**	20.09*	9.02**
Head diameter (cm)	6.33**	23.57^{ns}	5.36^{ns}	5.98**
Number of seeds/head	143247.07**	1655400.00**	64738.80^{ns}	105435
Percentage of empty seeds	180.95**	422.55^{ns}	191.60^{ns}	151.71
1000-seed weight (g)	224.22**	3486.87**	124.21^{ns}	73.25*
Seed yield/head (g)	411.85**	28.85^{ns}	277.50^{ns}	575.70
Seed yield /ha (t)	1.68**	0.10^{ns}	1.15^{ns}	2.33**

Table 6. **(Cont.)**

Character	Source of variation			
	Crosses d.f = 27	Lines d.f = 1	Testers d.f = 13	Lin d.f =
			Shambat 2001/02	
Plant height (cm)	263.29^{ns}	2090.01**	198.80^{ns}	187.
Stem diameter (cm)	0.04^{ns}	0.42**	0.04^{ns}	0.02
Days to 50% flowering	34.43**	515.04**	22.53*	9.35
Days to physiological maturity	24.66**	344.04**	13.37^{ns}	11.3
Head diameter (cm)	6.10^{ns}	23.15^{ns}	3.44^{ns}	7.45
Number of seeds/head	95709.70*	239082.70*	123309.80*	570
Percentage of empty seeds	114.41^{ns}	226.05^{ns}	139.47^{ns}	80.7
1000-seed weight (g)	102.75^{ns}	9.60^{ns}	141.01*	71.6
Seed yield/head (g)	391.92*	542.12^{ns}	599.17**	173.
Seed yield /ha (t)	1.45**	1.80**	2.15**	0.73

Table 6. **(Cont.)**

Character	Source of variation			
	Crosses	Lines	Testers	Li
	d.f = 27	d.f = 1	d.f = 13	d.
		Rahad 2000/01		
Plant height (cm)	974.64**	17981.44**	436.91*	20
Stem diameter (cm)	0.071*	0.08*	0.09*	0.
Days to 50% flowering	39.53**	823.44**	11.73^{ns}	7.
Days to physiological maturity	23.97**	356.27**	14.14^{ns}	8.
Head diameter (cm)	5.52**	2.93^{ns}	5.01^{ns}	6.
Number of seeds/head	75834.37**	13111.00**	19522.72^{ns}	37
1000-seed weight (g)	90.12**	13.04^{ns}	69.20^{ns}	11
Seed yield/head (g)	311.10**	3336.48**	148.77^{ns}	24
Seed yield /ha (t)	1.55**	16.56**	0.74^{ns}	1.

Table 6. (Cont.)

Character	Source of variation			
	Crosses d.f = 27	Lines d.f = 1	Testers d.f = 13	Li d.
			Rahad 2001/02	
Plant height (cm)	642.75**	12507.44**	284.19**	88
Stem diameter (cm)	0.19**	2.36**	0.12^{ns}	0.
Days to 50% flowering	45.97**	1078.58**	7.40**	5.
Days to physiological maturity	6.82**	47.25**	4.69^{ns}	5.
Head diameter (cm)	2.93*	27.77**	2.75*	1.
Number of seeds/head	242345.**	3510856.00**	91113.08^{ns}	14
1000-seed weight (g)	308.49**	3680.19**	190.27^{ns}	16
Seed yield/head (g)	311.12**	2190.96**	205.07^{ns}	27
Seed yield /ha (t)	1.58**	11.20**	1.07^{ns}	1.

* Significant at p≤ 0.05
** Significant at p≤ 0.01
^{ns} non-significant

Table 7. Mean squares from the combined analysis of variance for some morphological characters, seed yield and seed yield components in 29 F_1 sunflower hybrids evaluated at Shambat and Rahad for two seasons

Source of variation	Character					
	Plant height (cm)	Stem diameter (cm)	Days to 50% flowering	Days to physiological maturity	Head diameter (cm)	Number of seeds/head
Location (L) d.f =1	16524.14**	0.40**	2405.81**	118.41**	195.15**	977097.44**
Season (S) d.f =1	1.39^{ns}	5.84**	233.40**	917.31**	51.13**	215131.48**
Reps within L d.f =4	4555.20**	1.01**	22.24**	12.18*	16.35**	215752.86**
Genotypes (G) d.f =28	1674.50**	0.27**	161.97**	116.40**	9.77**	306989.22**
G x L d.f =28	317.01**	0.03^{ns}	9.81**	33.37**	3.00^{ns}	50279.69*
L x S d.f =1	9518.39**	1.56**	19.79**	950.07**	171.36**	87149.85^{ns}
G x S d.f =28	159.16^{ns}	0.07^{ns}	5.07^{ns}	31.23**	4.10**	48836.49^{ns}
G x L x S d.f =28	96.10^{ns}	0.06^{ns}	2.34**	13.73**	3.83**	142332.59**
Pooled error d.f =228	156.23	0.06	3.41	4.74	2.13	33285.36

* Significant at $p \leq 0.05$
** Significant at $p \leq 0.01$
ns Non-significant

Table 10. **Performance of sunflower hybrids, in eight characters, evaluated at two locations for two seasons**

Hybrid	Plant height (cm)			Days to 50% flowering			D
	Shambat S_1+S2	Rahad S_1+S2	Hybrid mean	Shambat S_1+S2	Rahad S_1+S2	Hybrid mean	
SHR-2	156.49	162.66	158.58 a,.,d	51.83	55.50	53.66 fg	
SHR-3	135.16	136.83	136.00 ijk	50.00	54.33	52.16 ghi	
SHR-5	141.33	142.83	142.08 f,.,i	48.50	52.66	50.58 i	
SHR-6	134.33	142.16	138.25 ijk	47.16	54.66	50.91 i	
SHR-7	123.00	136.33	129.66 jk	49.00	53.66	51.33 hi	
SHR-8	131..66	124.99	128.33 k	45.83	51.83	48.83 j	
SHR-9	122.50	142.33	137.41 ijk	50.33	59.66	55.00 f	
SHR-10	132.66	140.33	136.50 ijk	48.16	55.00	51.58 hi	
SHR-12	128.83	150.00	139.41 h,.,k	49.50	54.83	52.16 ghi	
SHR-13	131.33	134.00	132.66 ijk	48.33	54.83	51.58 hi	
SHR-18	133.00	130.33	131.66 ijk	50.00	53.66	51.83 hi	
SHR-21	129.83	133.66	131.75 ijk	49.00	52.83	50.91 i	
SHR-23	139.00	142.33	140.66 g,.,j	50.83	54.66	52.75 gh	
SHR-24	128.50	137.16	132.83 ijk	49.50	54.16	51.83 hi	
SHA-2	156.16	170.16	163.16 abc	59.83	60.00	59.91 ab	
SHA-3	148.83	164.83	156.83 a,.,d	54.66	60.83	57.75 de	
SHA-5	141.66	175.50	158.58 a,.,d	55.00	61.50	58.25 b,.,e	
SHA-6	154.33	174.00	164.16 a	54.33	61.33	57.83 cde	
SHA-7	144.16	158.16	151.16 c,.,g	53.83	62.16	58.00 cde	
SHA-8	132.50	153.16	142.83 e,,i	54.00	60.00	57.00 e	
SHA-9	145.66	172.33	159.00 a,.,d	58.50	63.00	60.75 a	
SHA-10	149.16	177.66	163.41 ab	58.00	61.00	59.50 a,.,d	
SHA-12	141.66	166.83	154.25 a,.,e	55.83	61.33	58.58 b,.,e	
SHA-13	143.83	171.33	157.58 a,.,d	56.00	61.33	58.66 bcd	
SHA-18	137.66	165.33	151.50 b,.,g	55.83	61.16	58.50 b,.,e	
SHA-21	144.83	161.00	152.91 a,.,f	54.83	61.16	58.00 cde	
SHA-23	145.00	162.00	153.50 a,.,f	56.00	60.00	58.00 cde	
SHA-24	140.16	159.66	149.91 d,.,h	57.50	61.66	59.58 abc	
Hysun-33	153.33	169.16	161.12 a,.,d	56.16	62.66	59.41 a,.,d	
verall mean	139.89	153.67	146.78	52.71	57.97	55.34	
C.V%			8.51			3.33	

Table 10. **(Cont.)**

Hybrid	Head diameter (cm)			Number of seeds / head			1
	Shambat S1+S2	Rahad S1+S2	Hybrid mean	Shambat S1+S2	Rahad S1+S2	Hybrid mean	

SHR-2	18.66	18.95	18.80 a	1311.1	1216.30	1263.70 a,.,e
SHR-3	15.78	18.43	17.10 a,.,e	1047.6	923.24	985.42 ijk
SHR-5	16.08	18.93	17.50 a,.,h	959.4	945.34	952.37 jk
SHR-6	15.95	16.95	16.45 f,.,i	889.2	947.95	918.57 k
SHR-7	15.61	17.01	16.31 ghi	938.4	1131.36	1034.88 g,.,k
SHR-8	13.41	16.00	14.70 j	886.2	1041.42	963.81 jk
SHR-9	16.25	17.66	16.95c,.,i	1051.2	1286.12	1168.65 d,.,h
SHR-10	16.26	17.18	16.72 c,.,i	1204.3	1091.69	1147.99 d,.,i
SHR-12	16.25	17.65	16.95 c,.,i	1071.4	1103.25	1087.32 f,.,k
SHR-13	14.96	16.98	15.97 i	973.3	1040.27	1006.78 h,.,k
SHR-18	14.21	17.16	15.69 ij	994.7	971.55	983.12 ijk
SHR-21	15.46	16.73	16.10 hi	967.4	961.90	964.65 jk
SHR-23	17.28	18.18	17.73 a,.,g	1115.3	1135.32	1125.30 e,.,j
SHR-24	15.60	17.50	16.55 f,.,i	982.6	1050.32	1016.45 h,.,k
SHA-2	15.41	17.75	16.58 e,.,i	1151.70	1280.40	1216.05 b,.,f
SHA-3	18.70	18.20	18.45 ab	1255.80	1378.16	1316.98 a,.,d
SHA-5	16.98	19.63	18.30 abc	1249.50	1355.01	1302.25 a,.,d
SHA-6	17.16	19.13	18.15 a,.,d	1220.90	1483.83	1352.36 abc
SHA-7	17.06	18.70	17.88 a,.,f	1060.80	1448.71	1254.75 a,.,f
SHA-8	16.28	17.28	16.78 d,.,i	1273.10	1585.55	1429.32 a
SHA-9	17.70	17.35	17.52 a,.,h	1075.50	1138.88	1107.19 e,.,j
SHA-10	16.73	18.81	17.77 a,.,f	1324.95	1402.23	1363.59 abc
SHA-12	16.31	19.31	17.81 a,.,f	1224.20	1508.15	1366.17 abc
SHA-13	16.48	19.35	17.91 a,.,e	1369.85	1372.43	1371.14 abc
SHA-18	17.50	17.48	17.49 b,.,h	1299.10	1453.65	1376.37 abc
SHA-21	16.75	17.33	17.04 b,.,i	1206.25	1264.63	1235.44 b,.,f
SHA-23	17.48	18.28	17.88 a,.,f	1113.60	1288.36	1200.98 c,.,g
SHA-24	16.13	17.38	16.75 d,.,i	1279.05	1497.13	1388.09 ab
Hysun-33	17.20	17.93	17.56 a,.,g	1082.20	1348.20	1215.20 b,.,f
Overall mean	16.40	17.90	17.15	1123.39	1229.36	1176.37
C.V%			8.521			15.50

Table 10. (Cont.)

Hybrid	Seed yield / head (g)			
	Shambat S1+S2	Rahad S1+S2	Hybrid mean	Shambat S1+S2

SHR-2	83.13	73.25	78.19 ab	5.35
SHR-3	64.53	66.56	65.54 c,.,j	4.00
SHR-5	55.58	58.20	56.89 ij	3.48
SHR-6	49.30	59.33	54.31 j	3.13
SHR-7	60.40	79.80	70.10 a,.,h	3.70
SHR-8	50.25	60.16	55.20 j	3.00
SHR-9	54.31	79.93	67.12 b,.,i	3.40
SHR-10	68.26	67.35	67.80 b,.,i	4.35
SHR-12	63.95	66.90	65.42 c,.,j	3.91
SHR-13	55.23	61.50	58.36 hij	3.51
SHR-18	52.55	65.28	58.91 g,.,j	3.28
SHR-21	54.75	64.35	59.55 e,.,j	3.48
SHR-23	73.80	67.15	70.47 a,.,g	4.53
SHR-24	51.96	68.36	60.16 d,.,j	3.31
SHA-2	57.30	69.03	63.16 d,.,j	3.68
SHA-3	62.41	80.45	71.433 a,.,e	3.93
SHA-5	62.90	81.01	71.95 a,.,d	3.98
SHA-6	72.15	88.60	80.37 a	4.58
SHA-7	58.90	82.93	70.91 a,.,f	3.50
SHA-8	57.80	71.76	64.78 c,.,j	3.60
SHA-9	51.95	66.48	59.21 f,.,j	3.26
SHA-10	63.85	78.18	70.01 a,.,f	4.01
SHA-12	72.20	89.25	80.72 a	4.11
SHA-13	66.30	76.58	71.44 a,.,e	4.06
SHA-18	71.47	79.70	75.58 abc	4.46
SHA-21	64.80	77.35	76.07 a,.,f	4.16
SHA-23	57.73	76.98	67.35 b,.,i	3.65
SHA-24	63.07	79.55	71.31 a,.,e	4.01
Hysun-33	65.06	93.05	79.05 ab	4.10
Overall mean	61.58	73.41	67.499	3.84
C.V%			18.11	

Table 11. Magnitude of heterosis for some morphological characters in 28 F_1 sunflower hybrids expressed as percentage increase over or decrease under mid-parent heterosis (MPH) or better-parent heterosis (BPH),evaluated at Shambat (Seasons 2000/01 and 2001/02).

Hybrid	Plant height (cm)		Stem diameter (cm)		Days to 50% flowering		Days to p maturity
	MPH(%)	BPH(%)	MPH(%)	BPH(%)	MPH(%)	BPH(%)	MPH(%)
					2000/01		

SHR-2	**9.7**	**0.9**	**13.8**	**6.5**	**-1.6**	**-8.3**	**3.6**
SHR-3	**0.3**	**-3.6**	**10.3**	**3.2**	**-3.6**	**-8.0**	**-4.9**
SHR-5	**-2.5**	**-4.8**	**-3.6**	**-3.6**	**-3.8**	**-7.4**	**-3.7**
SHR-6	**-2.9**	**-5.9**	**-6.9**	**-6.9**	**-4.4**	**-7.6**	**-3.7**
SHR-7	**-2.8**	**-4.8**	**1.9**	**-1.6**	**-4.9**	**-7.8**	**-4.9**
SHR-8	**-0.7**	**-1.9**	**-6.9**	**-10.0**	**-6.7**	**-9.1**	**-5.0**
SHR-9	**-8.6**	**-10.1**	**-3.4**	**-3.4**	**-3.9**	**-9.3**	**-4.9**
SHR-10	**-3.5**	**-6.6**	**-10.7**	**-10.7**	**-5.2**	**-9.0**	**-6.1**
SHR-12	**-5.9**	**-6.6**	**-3.6**	**-3.6**	**-5.4**	**-9.1**	**-6.1**
SHR-13	**-4.4**	**-4.5**	**-4.8**	**-4.8**	**-5.4**	**-9.1**	**-4.9**
SHR-18	**1.0**	**0.9**	**-3.4**	**-3.4**	**-4.6**	**-8.2**	**-6.1**
SHR-21	**-0.9**	**-2.2**	**-0.9**	**-1.8**	**-4.2**	**-7.9**	**-4.9**
SHR-23	**1.9**	**-1.3**	**3.4**	**-3.2**	**-3.2**	**-7.5**	**-3.7**
SHR-24	**-9.9**	**-11.4**	**-13.8**	**-13.8**	**-5.2**	**-9.0**	**-6.2**

Table 11.(Cont.)

Hybrid	**Plant height (cm)**		**Stem diameter (cm)**		**Days to 50% flowering**		**Days t matur**
	MPH(%)	**BPH(%)**	**MPH(%)**	**BPH(%)**	**MPH(%)**	BPH(%)	**MPH(**
					2000/01		

SHA-2	3.9	-0.9	-6.5	-6.5	7.3	6.4	2.2
SHA-3	3.9	3.6	-0.5	-1.6	4.0	0.5	3.4
SHA-5	3.0	1.5	3.6	-6.5	2.4	-2.0	1.9
SHA-6	5.4	4.9	5.4	2.3	1.3	-2.5	4.9
SHA-7	3.1	1.5	3.3	3.3	2.4	-2.5	1.1
SHA-8	-5.5	-10.0	1.8	-1.5	2.9	-2.5	2.3
	7.6	5.3	6.7	6.7	6.5	4.1	4.5
SHA-9	6.0	5.5	3.3	3.3	4.6	0.5	3.2
SHA-10	0.2	-4.2	6.9	3.3	4.1	-0.2	4.5
SHA-12	0.2	-3.5	0.3	-3.7	4.1	-0.2	4.5
SHA-13	-4.7	-8.2	-2.2	-5.8	3.4	-1.2	3.4
SHA-18	-0.3	-2.7	-3.3	-3.3	3.5	-0.7	3.9
SHA-21	0.6	-0.1	6.7	6.7	3.1	-0.7	3.7
SHA-23	2.3	-3.1	10.3	6.7	4.6	0.5	2.3
SHA-24	-0.1	-2.6	0.3	-1.9	-0.3	- 4.2	- 0.6
Overall mean							

Table 11.(Cont.)

Hybrid	Plant height (cm)		Stem diameter (cm)		Days to 50% flowering		Days to p maturity
	MPH(%)	BPH(%)	MPH(%)	BPH(%)	MPH(%)	BPH(%)	MPH(%)
					2001/02		

SHR-2	**5.7**	**-0.8**	**2.6**	**-1.7**	**-0.9**	**-5.9**	**2.6**
SHR-3	**4.5**	**-6.2**	**1.5**	**-0.6**	**0.6**	**-1.0**	**0.8**
SHR-5	**4.8**	**4.7**	**-0.3**	**-1.7**	**-3.9**	**-5.2**	**-1.3**
SHR-6	**-4.3**	**-8.0**	**-5.7**	**-7.6**	**-6.9**	**-7.3**	**-2.4**
SHR-7	**-14.3**	**-17.3**	**-3.7**	**-3.7**	**-0.6**	**-1.5**	**0.4**
SHR-8	**-1.5**	**-1.9**	**2.0**	**1.2**	**-8.4**	**-9.3**	**-4.0**
SHR-9	**3.0**	**1.0**	**-0.6**	**-2.3**	**-1.7**	**-5.8**	**0.2**
SHR-10	**-3.5**	**-4.9**	**-5.2**	**-6.1**	**-6.7**	**-9.8**	**-3.2**
SHR-12	**-2.7**	**-4.3**	**-3.3**	**-4.2**	**-0.6**	**-3.3**	**-1.1**
SHR-13	**-2.2**	**-4.8**	**-3.6**	**-4.8**	**-3.9**	**-5.7**	**-0.9**
SHR-18	**-3.7**	**-4.6**	**1.2**	**-2.3**	**0.4**	**-2.9**	**-2.8**
SHR-21	**-8.1**	**-8.9**	**-0.3**	**-0.6**	**-1.9**	**-3.3**	**-1.1**
SHR-23	**-0.7**	**-3.0**	**-1.2**	**1.2**	**1.1**	**-2.6**	**-0.7**
SHR-24	**1.6**	**-0.4**	**-1.5**	**-2.9**	**-2.1**	**-6.0**	**-2.4**

Table 11.(Cont.)

Hybrid	**Plant height (cm)**		**Stem diameter (cm)**		**Days to 50% flowering**		**Days t matur**
	MPH(%)	**BPH(%)**	**MPH(%)**	**BPH(%)**	**MPH(%)**	BPH(%)	**MPH(**
				2001/02			
SHA-2	**3.7**	**0.8**	**3.5**	**1.7**	**6.8**	**6.0**	**0.1**
SHA-3	**3.7**	**1.4**	**0.1**	**-0.3**	**-2.2**	**-5.2**	**-1.7**
SHA-5	**5.3**	**-6.0**	**0.7**	**-0.3**	**1.7**	**-1.6**	**1.9**
SHA-6	**8.2**	**7.9**	**7.1**	**6.6**	**1.3**	**-3.4**	**0.2**
SHA-7	**4.1**	**-2.4**	**0.9**	**-1.5**	**-1.8**	**-5.2**	**-2.2**
SHA-8	**-2.9**	**-6.7**	**-5.6**	**-8.4**	**0.6**	**-4.7**	**1.2**
SHA-9	**-2.6**	**-4.3**	**1.6**	**0.8**	**5.3**	**4.9**	**2.7**
	2.7	**0.5**	**0.7**	**-2.6**	**8.0**	**6.7**	**3.4**
SHA-10	**2.3**	**0.3**	**2.5**	**0.8**	**1.1**	**-0.5**	**1.0**

SHA-12	**3.7**	**2.7**	**3.3**	**1.9**	**2.9**	**0.2**	**1.8**
SHA-13	**1.6**	**-1.1**	**3.3**	**0.1**	**2.0**	**0.7**	**2.1**
SHA-18	**6.0**	**3.2**	**-1.6**	**-3.8**	**-0.2**	**-3.4**	**1.0**
SHA-21	**1.7**	**0.5**	**-1.4**	**-3.8**	**1.4**	**0.7**	**0.3**
SHA-23	**-1.4**	**-3.1**	**1.9**	**-0.8**	**5.4**	**4.9**	**3.3**
SHA-24	**-0.1**	**-2.3**	**0.02**	**-1.7**	**-0.1**	**-2.5**	**-0.03**
Overall mean							

Table 12. Magnitude of heterosis for some morphological characters in 28 F_1 sunflower hybrids expressed as percentage increase over or decrease under mid-parent heterosis (MPH) or better-parent heterosis (BPH), evaluated at Rahad (Seasons 2000/01 and 2001/02)

Hybrid	**Plant height (cm)**		**Stem diameter (cm)**		**Days to 50% flowering**		**Days to p maturity**
	MPH%	**BPH%**	**MPH%**	**BPH%**	**MPH%**	BPH%	**MPH%**
						2000/01	
SHR-2	**7.4**	**-3.0**	**6.3**	**0.1**	**-0.8**	**-4.1**	**-1.7**
SHR-3	**-5.9**	**-10.4**	**6.7**	**3.2**	**-2.7**	**-4.7**	**-4.1**
SHR-5	**-3.4**	**-11.1**	**0.3**	**0.1**	**-5.6**	**-7.5**	**-0.7**
SHR-6	**-6.3**	**-13.1**	**-3.4**	**-6.7**	**-1.3**	**-4.4**	**-4.7**
SHR-7	**-3.6**	**-5.7**	**3.4**	**0.2**	**-4.8**	**-7.6**	**-1.1**
SHR-8	**-12.8**	**-13.8**	**-2.0**	**-3.9**	**-9.7**	**-10.2**	**-5.4**
SHR-9	**-8.9**	**-12.7**	**2.5**	**2.3**	**3.0**	**-2.7**	**0.8**
SHR-10	**-8.5**	**-14.5**	**-3.4**	**-5.1**	**-0.8**	**-3.5**	**-0.1**
SHR-12	**0.6**	**-5.7**	**-4.3**	**-5.1**	**-2.3**	**-5.8**	**0.3**
SHR-13	**-4.7**	**-15.4**	**-1.1**	**-1.7**	**-0.9**	**-4.3**	**-0.1**
SHR-18	**-10.6**	**-12.9**	**-4.0**	**-4.0**	**-2.6**	**-5.3**	**1.1**
SHR-21	**-5.7**	**-7.8**	**0.6**	**0.6**	**-5.7**	**-7.2**	**-1.0**
SHR-23	**-0.2**	**-5.9**	**-0.8**	**-2.2**	**-1.6**	**-3.9**	**0.1**
SHR-24	**-4.4**	**-7.1**	**-5.9**	**-6.2**	**-4.2**	**-6.5**	**0.1**

Table 12.(Cont.)

Hybrid	Plant height (cm)		Stem diameter (cm)		Days to 50% flowering		Days to p maturity
	MPH%	BPH%	MPH%	BPH%	MPH%	BPH%	MPH%
						2000/01	
SHA-2	**3.8**	**3.0**	**2.7**	**-2.5**	**1.8**	**-0.3**	**2.3**
SHA-3	**4.9**	**-0.1**	**-2.4**	**-1.3**	**1.3**	**-2.0**	**1.9**
SHA-5	**9.6**	**8.2**	**-0.8**	**-1.6**	**3.7**	**0.2**	**1.5**
SHA-6	**11.1**	**9.2**	**6.9**	**6.6**	**2.0**	**-0.3**	**2.1**
SHA-7	**-2.3**	**-9.3**	**-0.2**	**-0.5**	**5.0**	**2.5**	**-0.3**
SHA-8	**3.7**	**-4.7**	**-3.1**	**-6.0**	**4.7**	**0.3**	**1.8**
SHA-9	**6.4**	**0.8**	**-3.0**	**-3.8**	**3.2**	**2.8**	**1.0**
	11.3	**8.2**	**-1.1**	**-3.8**	**0.7**	**-2.0**	**2.0**
SHA-10	**2.4**	**-0.9**	**1.5**	**-0.5**	**3.8**	**1.9**	**0.6**
SHA-12	**8.8**	**3.1**	**-1.1**	**-2.7**	**2.3**	**0.2**	**-0.1**
SHA-13	**4.5**	**-2.7**	**2.9**	**1.8**	**2.4**	**-0.3**	**0.1**
SHA-18	**-0.5**	**-7.6**	**-1.6**	**-2.7**	**3.0**	**-0.9**	**0.4**
SHA-21	**1.7**	**-2.1**	**2.5**	**2.2**	**0.6**	**-2.5**	**1.0**
SHA-23	**-0.5**	**-7.0**	**4.2**	**2.9**	**3.3**	**0.2**	**1.5**
SHA-24	**-0.3**	**-5.0**	**0.1**	**-1.5**	**-0.1**	**-2.8**	**-.03**
Overall mean							

Table 12. (Cont.)

Hybrid	Plant height (cm)		Stem diameter (cm)		Days to 50% flowering		Days to p maturity
	MPH%	BPH%	MPH%	BPH%	MPH%	BPH%	MPH%

					2001/02		
SHR-2	**5.3**	**-1.5**	**-3.7**	**-9.6**	**-1.2**	**-3.4**	**-0.6**
SHR-3	**-5.6**	**-8.2**	**0.1**	**-4.9**	**-3.3**	**-6.5**	**1.2**
SHR-5	**-5.4**	**-9.5**	**-2.9**	**-5.8**	**-5.6**	**-8.0**	**0.9**
SHR-6	**-3.2**	**-7.1**	**3.3**	**-2.4**	**-4.7**	**-7.1**	**-0.3**
SHR-7	**-6.2**	**-9.2**	**3.1**	**0.7**	**-4.2**	**-7.1**	**-1.1**
SHR-8	**-8.0**	**-9.3**	**-14.3**	**-16.3**	**-2.6**	**-4.6**	**-0.9**
SHR-9	**0.2**	**-6.5**	**-11.5**	**-14.6**	**3.1**	**-2.7**	**-2.0**
SHR-10	**-3.7**	**-9.1**	**-11.9**	**-14.9**	**-3.5**	**-6.7**	**-2.4**
SHR-12	**0.1**	**-5.9**	**0.1**	**-4.9**	**-2.8**	**-5.4**	**-0.5**
SHR-13	**-5.2**	**-9.4**	**-1.5**	**-5.7**	**-4.1**	**-6.8**	**1.4**
SHR-18	**-8.2**	**-10.9**	**1.1**	**-4.3**	**-5.4**	**-8.0**	**-0.8**
SHR-21	**-7.9**	**-10.6**	**1.4**	**-1.3**	**-4.7**	**-7.4**	**-0.3**
SHR-23	**-4.6**	**-7.0**	**0.4**	**-1.9**	**-2.8**	**-5.4**	**0.1**
SHR-24	**-5.1**	**-8.0**	**-11.7**	**-15.2**	**-2.2**	**-4.8**	**-0.3**

Table 12.(Cont.)

Hybrid	Plant height (cm)		Stem diameter (cm)		Days to 50% flowering		Days to p maturity
	MPH%	BPH%	MPH%	BPH%	MPH%	BPH%	MPH%
					2001/02		

SHA-2	**0.6**	**-0.2**	**9.7**	**9.7**	**0.2**	**-3.4**	**0.7**
SHA-3	**2.9**	**-0.2**	**3.7**	**2.5**	**3.6**	**0.8**	**-1.6**
SHA-5	**6.0**	**2.7**	**2.2**	**-1.1**	**4.3**	**0.8**	**0.8**
SHA-6	**3.4**	**-0.2**	**1.9**	**1.3**	**3.9**	**0.8**	**-0.1**
SHA-7	**3.7**	**-1.0**	**-4.7**	**-8.4**	**3.9**	**0.8**	**-0.8**
SHA-8	**-3.1**	**-11.2**	**2.4**	**-5.9**	**0.4**	**-3.4**	**0.9**
	5.9	**5.4**	**11.5**	**8.5**	**2.6**	**2.4**	**2.7**
SHA-9	**7.1**	**5.2**	**-9.0**	**-10.7**	**4.0**	**1.4**	**3.1**
SHA-10	**2.4**	**1.1**	**3.7**	**2.5**	**1.9**	**-1.3**	**-0.3**
SHA-12	**5.9**	**2.7**	**3.4**	**1.3**	**3.5**	**0.3**	**-0.9**
SHA-13	**5.9**	**1.1**	**3.4**	**2.5**	**3.9**	**0.3**	**-0.9**
SHA-18	**5.5**	**0.8**	**-2.4**	**-5.9**	**4.0**	**0.8**	**0.7**
SHA-21	**1.6**	**-3.3**	**-2.1**	**-5.9**	**1.9**	**-1.3**	**0.3**
SHA-23	**3.1**	**-1.4**	**12.4**	**9.7**	**4.7**	**1.4**	**1.1**
SHA-24	**-0.2**	**-3.9**	**-0.4**	**-3.6**	**0.0**	**-3.0**	**0.0**
Overall mean							

Table 13. Magnitude of heterosis for seed yield and seed yield components in 28 F_1 sunflower hybrids expressed as percentage increase over or decrease under mid-parent heterosis (MPH) or better-parent heterosis (BPH) evaluated at Shambat (Seasons 2000/01 and 2001/02)

Hybrid	**Number of seeds/head**		**Percentage of empty seeds**		**1000-seed weight (g)**		**Seed yiel**
	MPH%	**BPH%**	**MPH%**	**BPH%**	**MPH%**	BPH%	**MPH%**
					2000/01		

SHR-2	**22.7**	**11.1**	**-33.3**	**-38.5**	**4.9**	**-3.1**	**28.1**
SHR-3	**-8.7**	**-10.6**	**13.8**	**7.8**	**10.6**	**6.4**	**0.9**
SHR-5	**-28.2**	**-29.3**	**115.9**	**64.0**	**16.4**	**14.4**	**-13.9**
SHR-6	**-32.9**	**-34.3**	**86.5**	**52.8**	**7.7**	**6.8**	**-26.8**
SHR-7	**-8.6**	**-8.9**	**-39.6**	**-55.4**	**5.2**	**2.2**	**-3.3**
SHR-8	**-12.8**	**-17.1**	**-10.6**	**-35.4**	**-1.1**	**-8.8**	**-8.3**
SHR-9	**4.8**	**-0.9**	**-14.3**	**-26.2**	**4.5**	**-2.4**	**12.8**
SHR-10	**-7.2**	**-13.5**	**2.8**	**-13.8**	**12.3**	**6.3**	**6.6**
SHR-12	**-11.6**	**-14.4**	**-24.8**	**-32.3**	**0.6**	**-3.3**	**-10.1**
SHR-13	**-4.9**	**-7.5**	**-7.5**	**-9.5**	**-2.4**	**-8.9**	**-5.4**
SHR-18	**-9.3**	**-18.6**	**-19.2**	**-38.5**	**-12.6**	**-22.0**	**-20.5**
SHR-21	**-8.7**	**-14.2**	**11.7**	**-4.2**	**3.3**	**-0.4**	**-1.9**
SHR-23	**12.5**	**1.4**	**-25.5**	**-46.2**	**13.2**	**13.9**	**27.1**
SHR-24	**-5.4**	**-17.3**	**-41.9**	**-53.1**	**4.6**	**-3.9**	**1.8**

Table 13 .(Cont.)

Hybrid	**Number of seeds/head**		**Percentage of empty seeds**		**1000-seed weight (g)**		**Seed y**
	MPH%	**BPH%**	**MPH%**	**BPH%**	**MPH%**	BPH%	**MPH%**
					2000/01		
SHA-2	**-12.5**	**-13.9**	**44.9**	**27.9**	**-12.3**	**-14.3**	**-23.9**
SHA-3	**-0.4**	**-9.5**	**-17.9**	**-25.7**	**-9.5**	**-15.2**	**-7.9**
SHA-5	**15.7**	**4.7**	**-41.2**	**-60.8**	**-10.9**	**-18.4**	**7.2**
SHA-6	**20.8**	**9.8**	**-34.5**	**-53.3**	**3.9**	**-6.9**	**29.5**
SHA-7	**-3.8**	**-13.9**	**-12.2**	**-23.5**	**-1.4**	**-8.4**	**-2.9**
SHA-8	**9.5**	**2.7**	**-59.2**	**-65.9**	**-6.4**	**-8.2**	**-9.1**
SHA-9	**-2.7**	**-6.1**	**2.3**	**-2.2**	**-8.9**	**-12.2**	**-10.1**
	7.9	**2.8**	**-22.9**	**-24.7**	**-16.0**	**-19.7**	**-6.5**
SHA-10	**4.7**	**-3.7**	**26.3**	**15.4**	**1.2**	**-5.0**	**7.9**
SHA-12	**-2.6**	**-10.9**	**34.2**	**8.8**	**-1.8**	**-5.2**	**-6.6**
SHA-13	**17.7**	**16.9**	**-28.9**	**-36.5**	**-1.1**	**-2.4**	**18.1**

SHA-18	**7.6**	**1.8**	**-31.5**	**-33.7**	**-1.0**	**-7.4**	**7.2**
SHA-21	**-2.6**	**-3.7**	**-38.0**	**-48.2**	**-3.0**	**-12.7**	**-5.0**
SHA-23	**19.9**	**17.3**	**20.7**	**16.5**	**-12.9**	**-14.7**	**6.5**
SHA-24	**-0.7**	**-6.4**	**-5.1**	**-21.1**	**-0.5**	**-5.5**	**-0.3**
Overall mean							

Table 13.(Cont.)

Hybrid	**Number of seeds / head**		**Percentage of empty seeds**		**1000-seed weight (g)**		**Seed yiel**
	MPH%	**BPH%**	**MPH%**	**BPH%**	**MPH%**	BPH%	**MPH%**
					2001/02		
SHR-2	**9.3**	**1.7**	**27.9**	**18.2**	**17.7**	**6.5**	**27.0**
SHR-3	**0.5**	**-7.7**	**1.8**	**0.9**	**7.3**	**7.1**	**9.1**
SHR-5	**7.1**	**1.6**	**-14.5**	**-34.3**	**-5.5**	**-7.1**	**2.3**
SHR-6	**3.7**	**3.2**	**8.5**	**6.1**	**-4.1**	**-6.2**	**-6.6**
SHR-7	**-6.2**	**-9.1**	**-5.2**	**-11.2**	**13.7**	**10.7**	**6.6**
SHR-8	**-19.2**	**-19.8**	**10.1**	**1.4**	**-4.1**	**-6.5**	**-16.1**
SHR-9	**-7.6**	**-12.9**	**-1.3**	**-8.0**	**-21.7**	**-28.9**	**-29.6**
SHR-10	**16.4**	**2.9**	**-21.8**	**-38.4**	**-2.1**	**-3.4**	**10.6**
SHR-12	**7.9**	**0.5**	**-14.2**	**-27.3**	**6.3**	**3.7**	**11.3**
SHR-13	**-17.5**	**-24.9**	**33.5**	**19.9**	**7.4**	**4.8**	**-11.9**
SHR-18	**-7.7**	**-8.8**	**-27.7**	**-42.1**	**0.4**	**-4.7**	**-5.3**
SHR-21	**-8.3**	**-9.3**	**-15.6**	**-17.1**	**-3.8**	**-3.8**	**-17.8**
SHR-23	**-5.5**	**-9.1**	**26.5**	**25.9**	**-3.5**	**-8.6**	**2.9**
SHR-24	**-13.4**	**-19.1**	**36.0**	**21.3**	**-18.7**	**-21.8**	**-32.1**

Table 13. (Cont.)

Hybrid	Number of seeds / head		Percentage of empty seeds		1000-seed weight (g)		Seed
	MPH%	BPH%	MPH%	BPH%	MPH%	BPH%	MPH
					2001/02		
SHA-2	0.9	-1.7	-5.0	-18.2	2.4	-6.6	-3.7
SHA-3	12.1	7.7	7.9	-0.9	-7.5	-7.9	0.6
SHA-5	-1.1	-1.6	4.1	2.7	1.9	-0.4	-2.3
SHA-6	-7.4	-11.2	-6.2	-11.6	7.3	6.2	0.3
SHA-7	-5.2	-12.3	29.2	12.0	-8.9	-10.5	-5.7
SHA-8	11.9	5.9	-20.8	-20.8	-1.9	-5.2	8.0
	-9.7	-18.7	24.5	8.0	-0.2	-9.7	-11.5
SHA-9	5.2	-2.9	-24.7	-36.6	-1.3	-3.3	4.8
SHA-10	2.0	-0.5	-18.9	-21.9	0.2	-2.7	12.6
SHA-12	31.3	24.9	-53.1	-54.6	-3.3	-5.0	22.5
SHA-13	0.1	-5.7	-14.1	-26.8	9.4	4.7	10.2
SHA-18	0.9	-4.8	11.3	9.0	2.9	1.9	3.3
SHA-21	-7.3	-14.8	-27.9	-28.2	-8.1	-13.4	-18.2
SHA-23	-6.0	-15.9	-11.3	-20.9	10.2	5.2	2.1
SHA-24	-0.5	-5.8	-2.4	-6.6	-0.3	-3.7	-0.9
Overall mean							

Table 14. Magnitude of heterosis for seed yield and yield components in 28 F_1 sunflower hybrids expressed as percentage increase over or decrease under mid-parent heterosis (MPH) or better-parent heterosis (BPH) evaluated at Rahad (Seasons 2000/01 and 2001/02)

Hybrid	Number of seeds/head		1000 - seed weight (g)		Seed yield / head (g)		Seed yield
	MPH%	BPH%	MPH%	BPH%	MPH%	BPH%	MPH%
				2000/01			

SHR-2	9.7	5.9	-1.3	-3.6	9.2	8.7	6.7
SHR-3	-14.3	-19.5	17.6	13.6	2.1	-6.0	16.7
SHR-5	-5.2	-8.2	-6.6	-7.4	-11.3	-13.0	-4.8
SHR-6	-1.1	-7.3	-4.4	-6.1	-5.5	-13.1	2.3
SHR-7	-8.1	-14.6	8.9	8.4	1.1	-6.1	14.3
SHR-8	-12.0	-14.5	-13.9	-20.9	-23.2	-26.8	-17.9
SHR-9	-2.3	-2.6	14.9	11.8	12.7	9.9	15.9
SHR-10	-5.7	-11.9	-10.9	-14.8	-15.4	-17.5	-9.1
SHR-12	-2.6	-10.1	-12.9	-14.6	-15.9	-21.2	-9.3
SHR-13	-8.9	-13.7	-0.9	-2.3	-9.7	-15.7	2.4
SHR-18	-8.2	-11.4	-4.5	-5.0	-12.7	-16.5	-7.0
SHR-21	-8.8	-14.1	8.4	7.6	-1.1	-5.7	2.2
SHR-23	-0.7	-6.2	0.5	0.1	-0.2	-5.8	-4.1
SHR-24	-5.9	-11.8	7.5	5.6	1.8	-6.2	6.5

Table 14.(Cont.)

Hybrid	Number of seeds/head		1000-seed weight (g)		Seed yield / head (g)		Seed yi
	MPH%	BPH%	MPH%	BPH%	MPH%	BPH%	MPH%
				2000/01			

SHA-2	**-12.1**	**-17.5**	**-2.8**	**-4.4**	**-16.7**	**-23.6**	**-8.9**
SHA-3	**15.1**	**10.9**	**-9.7**	**-13.5**	**5.3**	**4.6**	**27.9**
SHA-5	**0.7**	**-5.8**	**5.7**	**5.5**	**7.7**	**0.3**	**25.6**
SHA-6	**3.5**	**0.1**	**8.8**	**6.1**	**12.5**	**11.7**	**31.1**
SHA-7	**11.9**	**9.2**	**-7.1**	**-8.2**	**4.5**	**2.7**	**25.6**
SHA-8	**6.3**	**-0.8**	**-3.0**	**-10.3**	**2.0**	**-10.8**	**17.5**
	-8.6	**-17.1**	**-8.7**	**-11.8**	**-16.7**	**-21.9**	**-8.9**
SHA-9	**8.6**	**5.5**	**3.4**	**-0.2**	**12.4**	**5.1**	**27.3**
SHA-10	**8.2**	**6.3**	**9.8**	**8.4**	**18.3**	**15.2**	**41.9**
SHA-12	**8.5**	**3.8**	**4.1**	**2.1**	**12.8**	**10.2**	**47.5**
SHA-13	**4.3**	**-7.1**	**6.4**	**5.0**	**10.9**	**5.7**	**30.2**
SHA-18	**9.6**	**5.5**	**-8.6**	**-8.8**	**1.0**	**-3.4**	**13.3**
SHA-21	**1.8**	**-2.4**	**-0.9**	**-1.6**	**2.2**	**-1.2**	**8.2**
SHA-23	**8.3**	**4.4**	**-3.0**	**-5.7**	**5.3**	**4.3**	**19.6**
SHA-24	**-0.3**	**-5.0**	**-1.0**	**-2.8**	**-0.2**	**-4.9**	**9.5**
Overall mean							

Table 14.(Cont.)

Hybrid	**Number of seeds /head**		**1000- seed weight (g)**		**Seed yield / head (g)**		**Seed yiel**
	MPH%	**BPH%**	**MPH%**	**BPH%**	**MPH%**	BPH%	**MPH%**
				2001/02			

SHR-2	**1.1**	**-10.3**	**-1.4**	**-10.1**	**3.5**	**-1.5**	**3.9**
SHR-3	**-18.9**	**-20.1**	**4.9**	**2.7**	**-12.1**	**-12.9**	**-11.9**
SHR-5	**-24.5**	**-28.1**	**1.9**	**-3.9**	**-17.3**	**-18.2**	**-16.6**
SHR-6	**-33.9**	**-38.2**	**6.7**	**0.9**	**-25.2**	**-26.3**	**-26.6**
SHR-7	**0.8**	**-9.9**	**8.5**	**5.8**	**12.9**	**1.5**	**12.9**
SHR-8	**-12.5**	**-25.8**	**6.1**	**-7.4**	**1.2**	**-1.3**	**1.1**
SHR-9	**27.9**	**12.9**	**-13.5**	**-21.1**	**14.9**	**8.4**	**14.5**
SHR-10	**-4.9**	**-12.9**	**8.2**	**2.3**	**6.8**	**1.9**	**6.9**
SHR-12	**-11.1**	**-20.9**	**6.8**	**1.4**	**-0.8**	**-8.9**	**-0.8**
SHR-13	**-7.5**	**-13.8**	**-6.2**	**-16.7**	**-9.4**	**-12.2**	**-9.7**
SHR-18	**-21.1**	**-28.1**	**17.6**	**11.6**	**-1.0**	**-4.3**	**-1.1**
SHR-21	**-14.8**	**-16.5**	**1.8**	**0.9**	**-11.6**	**-12.4**	**-11.7**
SHR-23	**0.6**	**-6.4**	**-8.7**	**-16.7**	**-6.3**	**-7.8**	**-6.2**
SHR-24	**-14.3**	**-23.3**	**2.5**	**-7.4**	**-7.8**	**-9.3**	**-7.5**

Table 14. (Cont.)

Hybrid	**Number of seeds/head**		**1000-seed weight (g)**		**Seed yield / head (g)**		**Seed**
	MPH%	**BPH%**	**MPH%**	**BPH%**	**MPH%**	BPH%	**MPH**
				2001/02			

SHA-2	**5.6**	**1.4**	**-6.4**	**-8.8**	**-0.1**	**-1.6**	**-0.3**
SHA-3	**1.5**	**-11.7**	**2.1**	**-7.2**	**6.5**	**0.8**	**6.3**
SHA-5	**12.8**	**0.7**	**-2.9**	**-8.5**	**11.8**	**6.0**	**11.3**
SHA-6	**24.5**	**13.2**	**-7.5**	**-12.4**	**19.9**	**14.1**	**20.1**
SHA-7	**4.4**	**-0.6**	**-2.9**	**-11.4**	**3.2**	**-1.5**	**3.6**
SHA-8	**27.1**	**25.7**	**-26.2**	**-28.1**	**-2.7**	**-6.5**	**-0.8**
	-16.0	**-18.9**	**6.8**	**4.3**	**-8.8**	**-9.3**	**-8.5**
SHA-9	**4.1**	**-3.5**	**-9.5**	**-14.4**	**-3.6**	**-5.3**	**-3.9**
SHA-10	**15.6**	**10.6**	**-6.8**	**-12.7**	**10.5**	**8.6**	**10.4**
SHA-12	**2.9**	**-6.1**	**-7.9**	**-8.5**	**-4.9**	**-13.7**	**-4.7**
SHA-13	**18.9**	**11.0**	**-19.3**	**-24.3**	**1.0**	**-2.0**	**1.3**
SHA-18	**-8.4**	**-22.9**	**11.9**	**-0.9**	**6.1**	**0.4**	**5.8**
SHA-21	**-3.7**	**-12.1**	**4.9**	**1.3**	**2.4**	**-2.4**	**2.5**
SHA-23	**19.8**	**10.9**	**-13.6**	**-14.8**	**3.6**	**-1.2**	**3.7**
SHA-24	**-0.9**	**-8.7**	**-1.5**	**-7.3**	**-0.3**	**-4.2**	**-0.2**
Overall mean							

Table 15. **Estimates of general combining ability (GCA) effects of 16 parents for some morphological characters, seed yield and seed yield components evaluated at Shambat (Seasons 2000/01 and 2001/02)**

Parent	**Character**					
	Plant height (cm)	**Stem diameter (cm)**	**Days to 50% flowering**	**Days to physiological maturity**	**Head diameter (cm)**	**Number of seeds/head**	**Percent of empty seeds**
Tester					**2000/01**		

	20.69	0.17	3.30	5.47	0.03	98.56	0.31
	6.35	0.19	0.47	0.30	0.49	-95.90	-0.28
	1.19	-0.17	-0.52	-1.02	0.44	-107.08	14.71
	4.02	-0.02	-0.85	-0.02	0.24	-97.65	9.18
	0.85	0.09	-1.02	-1.85	0.06	-132.76	-4.61
	-8.80	-0.07	-1.69	-2.02	-2.33	-21.50	-5.11
	-0.97	0.07	1.64	1.14	0.98	51.09	-1.44
	4.02	0.04	-0.02	-0.35	-0.16	18.79	-1.81
	-7.80	-0.09	-0.35	0.14	-0.70	-66.73	-0.38
	-5.80	-0.12	-0.35	0.47	-0.56	-81.58	2.91
	-5.47	-0.10	-0.52	0.14	-0.23	122.28	-4.06
	-1.64	-0.07	-0.19	-0.52	-0.51	-0.634	-1.56
	3.69	0.14	0.14	-0.19	1.83	110.64	-5.06
	-10.30	-0.05	-0.02	-1.69	0.41	220.46	-2.79
	4.91	0.09	0.40	0.64	0.59	78.76	2.34
	-5.59	-0.12	-4.35	-6.40	-0.52	-140.38	2.24
	5.59	0.12	4.35	6.40	0.52	140.38	-2.24
	1.80	0.03	0.15	0.21	0.21	29.77	0.88

Table 15 . (Cont.)

Parent	Character						
	Plant height (cm)	Stem diameter (cm)	Days to 50% flowering	Days to physiological maturity	Head diameter (cm)	Number of seeds/head	Per of e see
Tester					2001/02		
SH-2	13.15	0.17	3.16	2.40	1.12	114.37	5.3
SH-3	-1.17	0.04	-1.0	-0.92	1.22	149.54	2.0
SH-5	3.15	0.01	-1.16	0.73	-0.14	66.20	-3.9
SH-6	5.82	0.04	-2.83	-1.92	0.10	-41.97	0.6
SH-7	-12.51	-0.07	-1.33	-1.59	-0.14	-117.80	5.0
SH-8	-5.84	-0.10	-3.50	-2.42	-0.72	-68.90	-1.7
SH-9	0.32	0.02	2.00	2.73	0.20	-174.00	4.9
SH-10	-1.01	-0.12	1.16	0.23	0.70	260.64	-7.4
SH-12	-0.51	-0.02	0.66	-0.09	0.50	112.64	-4.9
SH-13	2.15	-0.00	-0.50	0.90	-0.74	175.00	-2.8

SH-18	**-2.67**	**0.12**	**1.16**	**-0.59**	**-0.81**	**-78.20**	**-7.0**
SH-21	**-2.51**	**-0.05**	**-1.16**	**-0.09**	**-0.02**	**-75.42**	**0.8**
SH-23	**1.48**	**-0.07**	**1.50**	**-0.26**	**0.17**	**-131.50**	**1.4**
SH-24	**0.15**	**0.01**	**1.83**	**0.90**	**-1.44**	**-190.59**	**7.7**
SE±	**6.12**	**0.07**	**0.94**	**1.21**	**0.81**	**89.18**	**3.4**
Line							
Kr	**-4.98**	**-0.07**	**-2.47**	**-2.02**	**-0.52**	**-53.35**	**1.6**
Ka	**4.98**	**0.07**	**2.47**	**2.02**	**0.52**	**53.35**	**-1.6**
SE±	**2.31**	**0.02**	**0.35**	**0.45**	**0.30**	**33.70**	**1.2**

Table 16. **Estimates of specific combining ability (SCA) effects of 28 F_1 sunflower hybrids for some morphlogical characters , seed yield and seed yield components evaluated at Shambat (Seasons 2000/01 and 2001/02)**

Hybrid	Character						
	Plant height (cm)	Stem diameter (cm)	Days to 50% flowering	Days to physiological maturity	Head diameter (cm)	Number of seeds /head	Percent of empty seeds
						2000/01	
SHR-2	7.09	0.32	-0.30	3.57	2.37	279.74	-5.30
SHR-3	0.09	0.17	0.19	0.07	-0.38	27.88	0.45
SHR-5	-1.40	-0.06	0.52	1.07	-0.73	-168.23	13.25
SHR-6	-3.23	-0.11	0.52	-0.26	-0.87	-224.43	8.15
SHR-7	-1.40	0.07	0.35	0.57	-0.55	48.31	-2.57
SHR-8	6.26	-0.02	-0.30	0.07	-0.48	-56.68	0.49
SHR-9	-8.90	-0.07	-0.64	-1.09	1.19	129.64	-1.97
SHR-10	-4.23	-0.01	-0.30	-0.26	0.37	-18.85	0.02
SHR-12	-1.40	-0.17	-0.30	-1.42	-0.65	-18.48	-3.87
SHR-13	-0.40	-0.01	-0.30	-1.09	0.01	59.96	-3.50
SHR-18	6.92	0.07	0.19	-0.76	-1.12	-97.60	-0.95
SHR-21	2.42	0.07	0.19	-0.42	-0.30	-24.28	0.90
SHR-23	3.76	0.02	0.52	-0.09	1.37	157.96	-0.92
SHR-24	-5.57	-0.24	-0.30	0.07	-0.23	-94.95	-4.15

Table 16. **(Cont.)**

Hybrid	Character						
	Plant height (cm)	Stem diameter (cm)	Days to 50% flowering	Days to physiological maturity	Head diameter (cm)	Number of seeds/head	Percer of emp seeds
						2000/01	

SHA-2	**-7.09**	**-0.32**	**0.30**	**-3.57**	**-2.37**	**-279.74**	**5.30**
SHA-3	**-0.09**	**-0.17**	**- 0.19**	**-0.07**	**0.38**	**-27.88**	**-0.45**
SHA-5	**1.40**	**0.06**	**-0.52**	**-1.07**	**0.73**	**168.23**	**-13.25**
SHA-6	**3.23**	**0.11**	**-0.52**	**0.26**	**0.87**	**224.43**	**-8.15**
SHA-7	**1.40**	**-0.07**	**-0.35**	**-0.57**	**0.55**	**-48.31**	**2.57**
SHA-8	**-6.26**	**0.02**	**0.30**	**-0.07**	**0.48**	**56.68**	**- 0.49**
SHA-9	**8.90**	**0.07**	**0.64**	**1.09**	**-1.19**	**-129.64**	**1.97**
	4.23	**0.01**	**0.30**	**0.26**	**-0.37**	**18.85**	**-0.02**
SHA-10	**1.40**	**0.17**	**0.30**	**1.42**	**0.65**	**18.48**	**3.87**
SHA-12	**0.40**	**0.01**	**0.30**	**1.09**	**-0.01**	**-59.96**	**3.50**
SHA-13	**-6.92**	**-0.07**	**-0.19**	**0.76**	**1.12**	**97.60**	**0.95**
SHA-18	**-2.42**	**-0.07**	**-0.19**	**0.42**	**0.30**	**24.28**	**-0.90**
SHA-21	**-3.76**	**-0.02**	**-0.52**	**0.09**	**-1.37**	**-157.96**	**0.92**
SHA-23	**5.57**	**0.24**	**0.30**	**-0.07**	**0.23**	**94.95**	**4.15**
SHA-24	**6.73**	**0.13**	**0.56**	**0.82**	**0.81**	**111.39**	**3.31**
SE ±							

Table 16. (Cont.)

Hybrid	Character Plant height (cm)	Stem diameter (cm)	Days to 50% flowering	Days to physiological maturity	Head diameter (cm)	Number of seeds/head	Percent: of empt: seeds
					2001/02		
SHR-2	3.82	0.02	-0.85	2.19	1.75	73.35	2.95
SHR-3	-3.17	0.05	1.97	2.19	-1.47	-42.38	-1.40
SHR-5	11.48	0.02	-0.19	-0.47	0.89	71.88	-3.44
SHR-6	-6.17	-0.14	-0.85	-0.14	0.70	86.46	0.67
SHR-7	-9.17	-0.02	1.64	2.19	0.15	22.96	-4.54
SHR-8	3.48	0.13	-0.85	-1.30	-1.32	-136.50	2.10
SHR-9	6.32	0.00	-0.69	-0.14	-1.59	39.93	-3.64
SHR-10	-1.67	-0.04	-2.52	-1.97	0.50	91.91	-0.79
SHR-12	-0.84	-0.04	0.97	0.02	1.64	59.45	-0.95
SHR-13	-1.51	-0.06	-0.52	-0.30	-0.47	-262.78	7.20
SHR-18	-1.01	0.00	0.80	-1.14	-1.10	-13.03	-2.09
SHR-21	-6.84	0.05	0.80	0.02	0.07	-20.78	-4.50
SHR-23	0.82	0.03	1.14	0.52	-0.52	37.40	4.19
SHR-24	4.48	-0.01	-0.85	-1.64	0.75	-7.88	4.22

Table 16. (Cont.)

Hybrid	Character Plant height (cm)	Stem diameter (cm)	Days to 50% flowering	Days to physiological maturity	Head diameter (cm)	Number of seeds/head	Percent: of empt: seeds
					2001/02		

SHA-2	**-3.82**	**-0.02**	**0.85**	**- 2.19**	**- 1.75**	**-73.35**	**-2.95**
SHA-3	**3.17**	**-0.05**	**-1.97**	**-2.19**	**1.47**	**42.38**	**1.40**
SHA-5	**-11.48**	**-0.02**	**0.19**	**0.47**	**-0.89**	**-71.88**	**3.44**
SHA-6	**6.17**	**0.14**	**0.85**	**0.14**	**-0.70**	**-86.46**	**0.67**
SHA-7	**9.17**	**0.02**	**-1.64**	**-2.19**	**-0.15**	**-27.96**	**4.50**
SHA-8	**-3.48**	**-0.13**	**0.85**	**1.30**	**1.32**	**136.50**	**-2.10**
SHA-9	**-6.32**	**-0.00**	**0.69**	**0.14**	**1.59**	**-39.93**	**3.64**
	1.67	**0.04**	**2.52**	**1.97**	**-0.50**	**- 91.91**	**0.79**
SHA-10	**0.84**	**0.04**	**-0.92**	**-0.02**	**-1.64**	**-59.45**	**0.95**
SHA-12	**1.51**	**0.06**	**0.52**	**0.30**	**0.47**	**262.78**	**-7.20**
SHA-13	**1.01**	**-0.00**	**-0.80**	**1.14**	**1.10**	**13.03**	**2.09**
SHA-18	**6.84**	**-0.54**	**-0.80**	**-0.02**	**-0.07**	**20.78**	**4.50**
SHA-21	**-0.82**	**-0.03**	**-1.14**	**-0.52**	**0.52**	**37.40**	**-4.50**
SHA-23	**-4.48**	**0.01**	**0.85**	**1.64**	**-0.75**	**7.88**	**-4.22**
SHA-24	**8.66**	**0.10**	**1.33**	**1.71**	**1.14**	**126.12**	**4.81**
SE ±							

Table 17. Percentage contribution for GCA, among males and females, and SCA to the total variation among hybrids, for different characters estimated at Shambat and Rahad in the first season (S_1) and the second season (S_2)

Character	**Contribution % due to males**		**Contribution % due to females**		**Contribution % due to males x females**		**Contribution ' due to males**	
	S_1	**S_2**	**S_1**	**S_2**	**S_1**	**S_2**	**S_1**	**S**
Plant height (cm)	**52.8**	**36.4**	**27.9**	**29.4**	**19.3**	**34.2**	**21.6**	**21.**
Stem diameter (cm)	**28.2**	**42.0**	**31.5**	**32.2**	**40.3**	**25.8**	**62.9**	**31.**

Days to 50% flowering	**6.7**	**31.5**	**92.5**	**55.4**	**0.8**	**13.1**	**14.3**	**7.**
Days to physiological maturity	**6.8**	**26.1**	**90.1**	**51.7**	**3.1**	**22.2**	**28.5**	**32.**
Head diameter (cm)	**40.8**	**27.2**	**13.8**	**14.1**	**45.4**	**58.7**	**43.7**	**45.**
Number of seeds /head	**21.8**	**62.1**	**42.8**	**9.3**	**35.4**	**28.7**	**12.4**	**18.**
Percentage of empty seeds	**51.0**	**58.7**	**8.7**	**7.3**	**40.3**	**34.0**	**-**	**-**
1000-seed weight (g)	**26.7**	**66.1**	**57.6**	**0.3**	**15.7**	**33.6**	**37.0**	**29.**
Seed yield/head (g)	**32.4**	**73.6**	**0.3**	**5.1**	**67.3**	**21.3**	**23.0**	**31.**
Seed yield /ha(t)	**33.1**	**71.2**	**0.2**	**4.6**	**66.7**	**24.2**	**23.0**	**32.**

Table 18. **Estimates of general combining ability (GCA) effects of 16 parents for some morphological characters, seed yield and seed yield components , evaluated at Rahad (Season 2000/01 and 2001/02)**

Parent	Character					
	Plant height (cm)	Stem diameter (cm)	Days to 50% flowering	Days to physiological maturity	Head diameter (cm)	Number (seeds/hea
Tester					**2000/01**	
SH-2	17.27	0.36	0.60	0.60	1.20	-42.80
SH-3	-0.72	0.08	-0.72	-1.89	0.98	27.34
SH-5	10.44	-0.01	-0.89	0.77	1.52	-51.60
SH-6	9.10	0.05	0.44	-2.22	0.13	33.42
SH-7	-8.39	0.01	0.27	-1.22	0.35	60.57
SH-8	-11.72	-014	-2.55	-3.05	-1.32	-57.48
SH-9	-2.55	-0.01	3.60	1.60	-1.09	-131.10
SH-10	5.60	-0.13	-0.05	1.77	-0.34	45.41
SH-12	4.27	-0.08	0.94	0.44	0.90	78.19
SH-13	-2.72	-0.06	0.77	0.44	0.17	5.94
SH-18	-7.72	-0.03	-0.05	0.94	-0.46	-40.20
SH-21	-8.55	-0.03	-1.37	-0.55	-0.81	22.42
SH-23	2.44	0.05	-0.55	0.94	-0.19	14.92
SH-24	-6.72	-0.04	-0.39	1.44	-1.06	34.94
SE±	5.24	0.07	0.83	0.56	0.37	49.50
Line						
Kr	-14.63	-0.03	-3.13	-2.05	-0.18	-124.93
Ka	14.63	0.03	3.13	2.05	0.18	124.93
SE±	1.98	0.02	0.31	0.21	0.14	18.71

Table 18. **(Cont.)**

Parent	Character					
	Plant height (cm)	Stem diameter (cm)	Days to 50% flowering	Days to physiological maturity	Head diameter (cm)	Number (seeds/hea
Tester					**2001/02**	

	9.32	0.17	-0.89	0.13	-0.31	89.28
	-3.84	0.10	0.27	-0.36	-0.16	-176.14
	1.65	1.01	-0.55	1.46	1.23	-98.27
	0.82	0.13	-0.05	-0.36	0.13	-51.87
	-3.34	-0.04	-0.05	-1.70	-0.45	69.28
	-16.34	-0.27	-1.22	-0.03	-1.20	234.25
	10.48	0.02	3.44	0.63	0.29	105.87
	6.15	-0.32	0.44	0.63	0.53	-1.72
	6.15	0.10	-0.39	-0.70	0.24	82.98
	1.82	0.05	-0.22	0.46	0.34	-43.47
	-2.84	0.12	-0.72	-1.53	-0.70	15.15
	-3.01	-0.02	-0.22	0.29	-0.93	-246.11
	-4.34	-0.04	-0.39	0.29	0.84	-41.47
	-2.67	0.03	0.60	0.29	0.13	62.25
	3.02	0.10	0.47	0.60	0.50	68.70
	-12.20	-0.16	-3.58	-0.75	-0.57	-204.44
	12.20	0.16	3.58	0.75	0.57	204.44
	1.14	0.04	0.17	0.22	0.19	25.96

Table 19. **Estimates of specific combining ability (SCA) effects of 28 F_1 sunflower hybrids for some morphological characters, seed yield and seed yield components evaluated at Rahad (Seasons 2000/01 and 2001/02)**

Hybrid	Character					
	Plant height (cm)	Stem diameter (cm)	Days to 50% flowering	Days to physiological maturity	Head diameter (cm)	Number of seeds/hea
					2000/01	

SHR-2	-9.63	0.11	0.79	-0.77	1.77	195.23
SHR-3	0.70	0.13	0.46	-1.60	0.98	-121.65
SHR-5	2.86	0.03	-1.03	0.05	0.58	28.00
SHR-6	-5.86	-0.16	0.63	-1.94	-1.42	32.70
SHR-7	6.63	0.03	-1.20	0.72	-0.64	65.11
SHR-8	-4.03	0.03	-2.36	-2.10	-0.42	46.65
SHR-9	-3.86	0.09	1.46	0.89	0.43	102.56
SHR-10	-7.70	-0.01	1.13	0.05	-1.17	28.91
SHR-12	5.63	-0.06	-0.20	1.05	-0.89	-7.96
SHR-13	-7.70	0.01	0.63	0.72	-1.09	45.58
SHR-18	-3.36	-0.08	0.13	1.55	-0.46	-11.96
SHR-21	3.79	0.04	-0.86	0.39	0.22	52.70
SHR-23	5.79	-0.03	0.96	0.55	1.43	47.03
SHR-24	4.63	-0.13	-0.53	0.39	0.70	-24.98

Table 19. **(Cont.)**

Hybrid	Character						
	Plant height (cm)	Stem diameter (cm)	Days to 50% flowering	Days to physiological maturity	Head diameter (cm)	Number of seeds/head	100 wei
					2000/01		

SHR-2	-9.63	- 0.11	-0.79	0.77	-1.7	-195.23	-0.2
SHR-3	0.70	-0.13	-0.46	1.60	-0.9	121.65	-7.6
SHR-5	2.86	-0.03	1.03	-0.05	-0.5	-28.00	3.5
SHR-6	5.86	0.16	-0.63	1.94	1.42	-32.70	3.8
SHR-7	-6.63	-0.03	1.20	-0.72	0.64	65.11	-4.2
SHR-8	4.03	-0.03	2.36	2.10	0.42	46.65	2.9
SHR-9	3.86	-0.09	-1.46	-0.89	-0.43	-102.56	-6.5
	7.70	0.01	-1.13	-0.05	1.17	-28.91	4.0
SHR-10	-5.63	0.06	0.20	-1.05	0.89	7.96	6.3
SHR-12	7.70	-0.01	-0.63	-0.72	1.09	-45.58	1.6
SHR-13	3.36	0.08	-0.13	-1.55	0.46	11.96	3.1
SHR-18	-3.79	-0.04	0.86	-0.39	-0.22	-52.70	-4.4
SHR-21	-5.79	0.03	-0.96	-0.55	-1.43	-47.03	0.3
SHR-23	-4.63	0.13	0.53	-0.39	-0.70	24.98	-2.9
SHR-24	7.41	0.10	1.17	0.80	0.53	70.00	3.3
SE ±							

Table 19 (Cont.)

Hybrid	Character					
	Plant heigh (cm)	Stem diameter (cm)	Days to 50% flowering	Days to physiologica l maturity	Head diameter (cm)	Number of seeds/head
					2001/02	
SHR-2	9.70	-0.09	1.58	-0.25	0.19	70.02
SHR-3	-0.46	0.03	-0.25	1.58	0.00	-3.90
SHR-5	-2.96	0.01	-1.08	0.41	-0.52	-108.31
SHR-6	0.86	0.10	-0.58	0.25	0.00	-239.21
SHR-7	-1.63	0.18	-0.58	0.25	-0.27	77.12
SHR-8	2.70	-0.11	0.91	-0.41	-0.09	-168.11
SHR-9	1.20	-0.21	1.91	-1.75	0.64	374.00
SHR-10	-2.79	-0.03	-0.41	-2.08	0.30	47..74

SHR-12	4.20	0.03	0.41	0.25	-0.00	-67.54
SHR-13	-2.79	0.01	-0.41	1.41	-0.50	42.79
SHR-18	-4.79	0.05	-0.91	0.41	0.90	-140.77
SHR-21	-4.29	0.13	-0.75	-0.08	-0.05	79.35
SHR-23	1.36	0.11	0.41	0.25	-0.77	129.25
SHR-24	-0.29	-0.23	-0.25	-0.25	0.17	-92.44

Table 19. **(Cont.)**

Hybrid	Character					
	Plant height (cm)	Stem diameter (cm)	Days to 50% flowering	Days to physiological maturity	Head diameter (cm)	Number of seeds/head
					2001/02	
SHA-2	9.70	-0.09	1.58	-0.25	0.19	70.02
SHA-3	-0.46	0.03	.25	1.58	0.00	-3.90
SHA-5	-2.96	0.01	.08	0.41	-0.52	-108.31
SHA-6	0.86	0.10	.58	0.25	0.00	-239.21
SHA-7	-1.63	0.18	.58	0.25	-0.27	77.12
SHA-8	2.70	0.11	0.91	-0.41	-0.09	-168.11
SHA-9	1.20	-0.21	1.91	-1.75	0.64	374.00
SHA-10	-2.79	-0.03	-0.41	-2.08	0.30	47.74
SHA-12	4.20	0.03	0.41	0.25	-0.00	-67.54
SHA-13	-2.79	0.01	-0.41	1.41	-0.50	42.79
SHA-18	-4.79	0.05	-0.91	0.41	0.90	-140.77
SHA-21	-4.29	0.13	-0.75	-0.08	-0.05	79.35
SHA-23	1.36	0.11	0.41	0.25	-0.77	129.25
SHA-24	.29	-0.23	-0.25	-0.25	0.17	-92.44

Table 20. **Stability parameters for some morphological characters, seed yield and seed yield components in 29 F_1 sunflower Hybrids evaluated over four different environments**

Hybrid	Plant height (cm)					
	Mean	**Slope**	Probability	**Squared deviations**	**Mean**	**Slo**
SHR-2	**159.58**	**0.73**	**1.00**	**-6.26**	**53.66**	**0.7**
SHR-3	**136.00**	**0.61**	**1.00**	**19.45**	**52.16**	**0.8**
SHR-5	**143.08**	**0.05**	**0.04**	**-43.23**	**50.58**	**0.8**
SHR-6	**138.25**	**0.75**	**0.28**	**-47.13**	**50.91**	**1.2**
SHR-7	**129.66**	**1.32**	**1.00**	**31.38**	**51.33**	**0.9**
SHR-8	**128.33**	**0.12**	**0.27**	**44.65**	**48.91**	**1.2**
SHR-9	**137.41**	**0.88**	**1.00**	**133.31***	**55.00**	**1.7**
SHR-10	**136.50**	**0.89**	**1.00**	**-22.04**	**51.66**	**1.2**
SHR-12	**139.33**	**1.23**	**1.00**	**-15.66**	**52.25**	**1.0**
SHR-13	**132.66**	**0.57**	**1.00**	**29.43**	**51.58**	**1.1**
SHR-18	**131.66**	**0.42**	**1.00**	**43.71**	**51.83**	**0.7**
SHR-21	**131.75**	**0.70**	**1.00**	**2.00**	**50.91**	**0.8**
SHR-23	**140.66**	**0.44**	**0.22**	**-24.87**	**52.75**	**0.7**
SHR-24	**132.83**	**0.42**	**0.37**	**23.06**	**51.83**	**0.9**

Table 20. **(Cont.)**

Hybrid	Plant height (cm)					**Day**
	Mean	**Slope**	Probability	**Squared deviations**	**Mean**	**Slo**

SHA-2	**163.16**	**0.91**	**1.00**	**-25.40**	**59.83**	**0.0**
SHA-3	**156.83**	**1.08**	**1.00**	**-41.22**	**57.75**	**1.1**
SHA-5	**158.66**	**1.93**	**0.29**	**76.81**	**58.25**	**1.2**
SHA-6	**164.16**	**0.89**	**1.00**	**39.16**	**57.83**	**1.2**
SHA-7	**151.16**	**1.31**	**0.39**	**-30.87**	**58.00**	**1.4**
SHA-8	**142.83**	**0.98**	**1.00**	**21.61**	**57.00**	**1.0**
SHA-9	**158.75**	**1.92**	**0.03**	**-46.26**	**60.75**	**0.8**
	163.41	**1.70**	**0.26**	**7.24**	**59.50**	**0.7**
SHA-10	**154.25**	**1.43**	**0.39**	**-7.96**	**58.58**	**0.9**
SHA-12	**157.58**	**1.43**	**1.00**	**31.35**	**58.66**	**0.9**
SHA-13	**151.50**	**1.53**	**1.00**	**30.25**	**58.50**	**1.0**
SHA-18	**152.91**	**1.15**	**1.00**	**-19.90**	**58.00**	**1.1**
SHA-21	**153.50**	**1.06**	**1.00**	**-45.73**	**58.00**	**0.8**
SHA-23	**149.91**	**1.38**	**0.15**	**-49.67**	**59.58**	**0.8**
SHA-24	**161.25**	**1.09**	**1.00**	**-39.28**	**59.41**	**1.1**
Hysun 33	**146.78**				**55.34**	
Overall mean						

Table 20. **(Cont.)**

Hybrid	**Days to physiological maturity**				**Days to physiol**	
	Mean	**Slope**	Probability	**Squared deviations**	**Hybrid**	**Mean**
SHR-2	**88.83**	**0.80**	**1.00**	**7.43****	**SHA-2**	**92.08**
SHR-3	**85.33**	**1.82**	**0.32**	**8.03****	**SHA-3**	**89.83**
SHR-5	**86.25**	**1.83**	**0.24**	**4.52***	**SHA-5**	**91.33**
SHR-6	**83.83**	**1.49**	**1.00**	**6.88****	**SHA-6**	**90.50**
SHR-7	**84.83**	**2.04**	**0.02**	**-0.76**	**SHA-7**	**88.58**
SHR-8	**82.66**	**1.54**	**1.00**	**10.53****	**SHA-8**	**90.16**
SHR-9	**86.50**	**2.14**	**0.05**	**0.29**	**SHA-9**	**93.16**
SHR-10	**85.00**	**1.71**	**0.32**	**5.52****	**SHA-10**	**92.75**

SHR-12	85.41	2.04	0.13	2.90	SHA-12	91.08
SHR-13	86.25	2.05	0.18	4.93**	SHA-13	91.50
SHR-18	85.25	1.74	0.35	7.65**	SHA-18	90.83
SHR-21	85.25	1.95	0.13	2.10	SHA-21	90.91
SHR-23	86.00	1.93	0.15	2.75	SHA-23	91.00
SHR-24	85.50	2.05	0.22	6.96**	SHA-24	91.83
Overall mean					Hysun-33	91.08
					Overall mean	88.39

Table 20 **(Cont.)**

Hybrid	Number of seeds / head					
	Mean	Slope	Probability	Squared deviations	Mean	Slo
SHR-2	1263.70	-0.14	0.36	3625.44	62.15	0.4
SHR-3	985.42	-1.31	0.13	2774.59	66.9	1.3
SHR-5	952.38	-1.11	0.39	47334.87**	61.18	1.7
SHR-6	918.63	-0.35	1.00	80267.79**	62.40	1.7
SHR-7	1034.86	1.34	1.00	-4718.83	66.15	1.2
SHR-8	963.88	1.38	0.41	-8517.81	54.32	1.4
SHR-9	1168.74	2.26	1.00	42152.38**	56.00	1.3
SHR-10	1147.98	-1.78	0.13	7790.21	60.49	1.8
SHR-12	1087.32	0.43	0.38	13686.46	60.23	1.4
SHR-13	1006.90	0.65	0.26	-9893.90	57.93	0.5
SHR-18	983.11	0.21	1.00	-344.31	59.03	1.5
SHR-21	964.80	0.25	1.00	4155.67	62.40	1.6
SHR-23	1125.33	1.14	1.00	11287.63	59.48	1.2
SHR-24	1016.51	1.37	1.00	3832.04	58.14	1.6

Table 20. **(Cont.)**

Hybrid	Number of seeds / head					
	Mean	**Slope**	Probability	**Squared deviations**	**Mean**	**Slo**
SHA-2	**1216.03**	**0.55**	**1.00**	**20775.18**	**53.13**	**0.0**
SHA-3	**1317.00**	**0.60**	**1.00**	**18246.66**	**53.88**	**1.1**
SHA-5	**1302.33**	**1.29**	**1.00**	**416.96**	**55.00**	**0.5**
SHA-6	**1352.48**	**2.88**	**0.31**	**19701.26**	**58.96**	**0.3**
SHA-7	**1254.63**	**3.16**	**0.08**	**-4160.89**	**54.43**	**0.9**
SHA-8	**1429.33**	**2.31**	**1.00**	**57600.93****	**47.29**	**-0.1**
SHA-9	**1107.29**	**1.25**	**1.00**	**1312.29**	**52.76**	**1.0**
	1363.47	**0.67**	**0.34**	**-95850.97**	**51.51**	**1.2**
SHA-10	**1366.30**	**2.12**	**0.32**	**743.55**	**56.66**	**0.4**
SHA-12	**1371.28**	**-1.09**	**0.31**	**26830.99***	**53.68**	**0.2**
SHA-13	**1676.32**	**2.18**	**1.00**	**29166.06***	**54.55**	**-0.2**
SHA-18	**1235.45**	**1.28**	**1.00**	**22720.52**	**58.20**	**1.3**
SHA-21	**1201.10**	**2.08**	**0.19**	**-6050.71**	**55.18**	**1.1**
SHA-23	**1388.19**	**3.24**	**036**	**42925.38****	**51.22**	**-0.0**
SHA-24	**1215.27**	**2.91**	**0.24**	**9724.00**	**63.25**	**1.5**
Hysun 33	**1176.41**				**57.52**	
Overall mean						

Table 20. **(Cont.)**

Hybrid	Seed yield / head (g)					
	Mean	**Slope**	Probability	**Squared deviations**	**Mean**	**Slo**
SHR-2	**78.44**	**0.16**	**0.32**	**77.75**	**5.30**	**0.2**
SHR-3	**65.55**	**0.10**	**0.03**	**-40.35**	**4.38**	**0.4**
SHR-5	**56.89**	**0.25**	**0.00**	**-48.07**	**3.83**	**0.4**
SHR-6	**54.31**	**0.30**	**0.24**	**6.61**	**3.67**	**0.4**
SHR-7	**70.10**	**1.33**	**1.00**	**32.85**	**4.70**	**1.3**
SHR-8	**55.20**	**1.24**	**1.00**	**44.01**	**3.64**	**1.1**
SHR-9	**67.12**	**2.43**	**0.06**	**-7.09**	**4.55**	**1.9**
SHR-10	**67.80**	**0.65**	**1.00**	**100.25**	**4.63**	**0.6**
SHR-12	**65.42**	**0.33**	**0.40**	**78.03**	**4.35**	**0.6**
SHR-13	**58.36**	**0.58**	**0.05**	**46.80**	**3.94**	**0.5**
SHR-18	**58.91**	**0.82**	**1.00**	**7.23**	**3.97**	**0.8**
SHR-21	**59.55**	**1.07**	**1.00**	**13.82**	**4.04**	**0.8**
SHR-23	**70.47**	**0.99**	**1.00**	**388.74****	**4.66**	**0.8**
SHR-24	**60.16**	**1.64**	**1.00**	**87.48**	**4.10**	**1.2**

Table 20. **(Cont.)**

Hybrid	**Seed yield / head**					
	Mean	**Slope**	Probability	**Squared deviations**	**Mean**	**Slo**
SHA-2	**63.16**	**0.70**	**1.00**	**101.25**	**4.30**	**0.7**
SHA-3	**71.36**	**0.72**	**1.00**	**41.07**	**4.80**	**0.9**
SHA-5	**71.95**	**1.33**	**0.12**	**-44.19**	**4.90**	**1.2**
SHA-6	**80.37**	**1.72**	**0.18**	**-7.99**	**5.45**	**1.4**
SHA-7	**71.91**	**1.40**	**0.41**	**-0.39**	**4.71**	**1.5**
SHA-8	**64.78**	**0.70**	**1.00**	**0.89**	**4.36**	**0.8**

SHA-9	**59.21**	**1.37**	**0.07**	**-45.99**	**4.00**	**1.1**
	71.01	**0.59**	**0.41**	**-1.64**	**4.79**	**0.8**
SHA-10	**80.76**	**0.89**	**1.00**	**1.05**	**5.24**	**1.3**
SHA-12	**71.44**	**-0.06**	**0.21**	**61.74**	**4.77**	**0.5**
SHA-13	**75.58**	**0.87**	**1.00**	**-34.75**	**5.07**	**0.8**
SHA-18	**71.07**	**1.21**	**0.22**	**-45.12**	**4.84**	**1.0**
SHA-21	**67.15**	**1.63**	**0.18**	**-18.41**	**4.58**	**1.3**
SHA-23	**71.30**	**1.36**	**0.37**	**-17.76**	**4.85**	**1.1**
SHA-24	**79.05**	**2.72**	**0.03**	**-17.17**	**5.35**	**1.1**
Hysun-33	**67.50**				**4.54**	
Overall mean						