Genetic Basis of Variation in Achene Yield and Oil Contents in Sunflower Hybrid

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Abstract

Sunflower is most important cultivated crop and its importance is increasing due to its high nutritional value. It is suitable in the environment of Pakistan and has the potential to meet our demand. Hybrids are important due to their superior characters. Successful hybrids are obtained by crossing the female inbred lines with the restorer lines. Existence of variation and its mode of inheritance is very important for the traits like oil contents and achene yield. For high heterosis good combiners must be there. Obtaining the good general and specific combiners and to cross them for obtaining valuable hybrid is very important. Estimate the GCA and SCA with their mean values is important to know the source material. Sunflower is a crop in which heterosis has been much exploited for the better seed and oil yield. In a systematic breeding programme, it is essential to identify superior parents for hybridization and crossed to expand the genetic variability for selection of superior genotypes. Control of inheritance of oil content by additive genes has been observed by many researchers and they reported that the inheritance of oil content is controlled by non-additive genes. Oil yield is also positively correlated with different seed related traits. Present study is carried out to find out the basis of genetic variation in the sunflower hybrid. So that in future we can use this to develop a good hybrid with better oil contents and achene yield.

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INTRODUCTION

Background of sunflower crop

Sunflower is the most important oilseed crop. The cultivated sunflower (*Helianthus annuus* L.) is the main source of edible oil in many countries of the world. It ranks second to soybean in worldwide vegetable oil production. For the last 30 years, the production of sunflower has been increased many folds due to the expansion of its cultivation in several parts of the world (Quresh *et al.*, 1992). Sunflower oil is also popular, sold at a premium price because it contains a high percentage of polyunsaturated fatty acids, and therefore, possesses non-cholesterol and anti-cholesterol properties (Sindagi & Virupakshappa 1986).

Sunflower being a rich source of good quality edible oil and has a nice fit in Pakistan's cropping pattern, is visualized as the most potential crop to narrow the gap between the total requirements and the domestic production of edible oil in the country. This could help saving the huge amount of foreign exchange that is being incurred on importing edible oil annually. Sunflower as an oil seed crop was introduced in Pakistan during 1960's as a non-conventional oil seed crop. Hybrids are preferred by sunflower growers in many countries in the world due to high yield performance, uniformity and quality. The soil and climatic conditions of the Pakistan are highly favorable for sunflower. Correct selection of parents of sunflower hybrids is important for achieving high yield performance in breeding programs. Superior hybrids have been obtained by crossing inbred female and restorer lines with high GCA and SCA values. Hybrid breeding is successful only if enough variation exists in the gene pool, male sterility mechanism is available, proper restorer and maintainer genes are available, and heterosis is very well manifested.

REVIEW OF LITERATURE

Existence of variation

Before undertaking a breeding programme for any character, it is essential to determine the variability that exists and the mode of inheritance. Variability of the trait is characteristic for a group of genotypes grown in a single location as well as for a single genotype grown in several locations (Marinković *et al*., 1994). Hussain (1989) evaluated F_2 crosses of five inbred lines of sunflower and showed significant differences for emergence percentage, fresh shoot and root lengths, fresh shoot weight, and shoot and root dry weights in sunflower types. Among F_2 cross the highest variation was observed for fresh shoot weight. Seiler (1994) worked on roots of different crops and found that differences in root density and rooting depth exist in many crops. Genotypes differed significantly in primary and lateral root lengths and total root length. Kshirsagar *et al.,* (1995) observed genotypic differences for total dry matter (TDM) and seed yield at harvest and reported the highest variation for seed yield per plant followed by plant height and 100-seed weight. Several breeders recognized the potential of reduced-height germplasm to increase stem strength and Alonso *et al.,* (1988); Fick *et al.,* (1985) and Herring, 1985 has tested the said germplasm on a limited basis.

Genetic diversity of parents is equally important as combining abilities, as pointed by Hayes and Johnson (1939) for corn. More recently, Arunachalam and Bandyopadhyay (1980) in *Brassica campestris*, Arunachalam *et al*., (1984) in groundnut, Joshi *et al.*, (1997) in sunflower and Lalitha *et al*., (2000) in sesame have established that there is a close correspondence between the magnitude of genetic divergence and heterosis. However, Cress (1966) and Dikshit and Swain (2000) reported that heterosis is not found to occur always when divergent parents are crossed. Kovacik & Skaloud (1972) and Setty & Sing (1977) suggested that parents for sunflower crosses should be chosen based on SCA variances whereas Sindagi (1979) argued that GCA variance was a more effective criterion than SCA variance for producing high-yielding sunflower hybrids. Gill and Sheoren (2002) observed that crosses CMS- 234A × HRHA-1 and CMS-234A × MRHA-1 were superior to parents over four environments.

Combining abilities in sunflower breeding

General (GCA) and specific combining ability (SCA) are important traits in plant breeding. Due to high heterosis occurring generally in hybrids between genetically unrelated inbred lines, all crop breeders that use heterosis have the challenge to find good combiners. Developing inbred lines that have high general combining ability (GCA) and specific combining ability (SCA) for important yield components remained a main objective of sunflower hybrid breeding. The second important objective of hybrid breeding programme which captured attention of plant breeders is using and crossing these inbred lines to obtain superior hybrids that have high oil and yield potential and resistance to pests and diseases (Miller and Fick, 1997). Estimates of general combining ability (GCA) and specific combining ability (SCA) together with mean values provide information about the breeding potential of the source material. Regarding sunflower regeneration ability, there is limited information about GCA and SCA of elite inbred lines currently used in conventional breeding programs (Mayor *et al.,* 2006). Breeding programs can take advantage from such information on combining ability to find best selection strategy for developing high yielding lines and hybrids (Škorić, 1992). Evaluating genotypes for combining ability is also important in determining appropriate procedures or genotypes to be utilized efficiently in breeding programs for main yield characters in sunflower (Miller, 1987). Combining ability has been extensively used by plant breeders to select suitable parents for realizing high frequency of heterotic hybrids. The GCA of a line means the average value of its performance in hybrids when crossed with other lines. The performance of individual hybrid is its SCA, which is achieved through crossing of the specific lines in that hybrid (Fick and Miller, 1997). Combining ability tests applied to determine best F_1 hybrids and lines with high yield capabilities (Ortegon-Morales *et al*., 1992; Rao *et al*., 1992) indicated that GCA could act as criterion for selecting parents. The experiments have proved that lines with high GCA produce higher yielding hybrids than lines having low GCA (Marinković, 1993; Joksimović *et al.* 1993). Similarly, genetic divergence between parent lines is a prerequisite for the expression of high SCA (Škorić *et al.*, 2004). SCA variance higher than GCA variance for a specific character means that dominant genes have higher effects than recessive ones in determining that character. Conversely, higher GCA variance indicates that additive gene effects play a more important role in determining the trait. If neither variance is significant, it implies the existence of epistatic gene effects (Marinković *et al*., 2000; Škorić *et al*., 2000). Combining ability of important sunflower yield characteristics was evaluated by many researchers. Many breeders have reported that GCA and SCA variances were significant for all characters in sunflower. However, reports on the ratio of GCA and SCA variances are contradictory suggesting a greater proportion of GCA variance (Sindagi *et al*., 1979) than SCA variance (Setty and Singh, 1977; Kadkol *et al.,* 1984). Some researchers found that additive gene effects had important role in some yield traits such as plant height, 1000-achene weight, flowering time, physiological maturity date. Others observed that non-additive genes affect dominated some yield components such as head diameter (Mihaljčević, 1988; Mruthunjaya *et al*., 1995) and physiological maturity time. Putt (1966) has reported that SCA was more important than GCA for seed yield, capitulum diameter, and weight per 1000 achenes. Whereas, Rao and Singh (1978) found significant additive genetic variance for capitulum diameter, and 1000 achene weight in a diallel cross of seven lines. Sindagi *et al.,* (1979) indicated greater proportion of GCA variance for yield characters. Many breeders indicate that the variance of both GCA and SCA were significant for all characters in sunflower (Kadkol *et al.,* 1984; Pathak *et al.,* 1985).

As heterotic performance of a hybrid combination depends upon combining abilities of its parents (Sprague & Tatum 1942 and Kadkol *et al.,* 1984), thus, combining ability of parental lines is the ultimate factor determining future usefulness of the lines for hybrids and synthetics.

Evaluation of combining abilities

Many researchers (Dua and Yadava, 1983 and Rao *et al*., 1992) or line × tester analysis prefer statistical approach given by Griffing (1956) to evaluate combining abilities. However, neither method evaluates efficiently the combining ability of sunflower inbred lines because branched restorers and CMS female lines are not used in commercial sunflower production. Due to economic importance of F_1 hybrids only, North Carolina Design II or factorial mating design are the best methods for measuring combining ability in cross-pollinated crops (Cukadar-Olmedo *et al*., 1997). Using a broad-based genotype as a tester, the general combining ability of lines is tested by the top cross method. Line×tester analysis is an extension of this method in which several testers are used (Kempthone, 1957). This design thus provides information about the general and specific combining ability of parents and at the same time, it is helpful in estimating various types of gene effects (Sing & Chaudhary 1977).

Heterosis

Sunflower is a crop in which heterosis has been much exploited for the better seed and oil yield. Hybrids genetically are uniform, more vigorous, self-fertile and resistant to important foliar diseases. In a systematic breeding programme, it is essential to identify superior parents for hybridization and crossed to expand the genetic variability for selection of superior genotypes.

Farmers prefer hybrids developed based on heterosis due to their high yield performance, quality, and uniformity. Gundaev (1966) followed by many others later on published the pioneer findings on heterosis and inbreeding in sunflower. Ahire *et al.*, (1994) provided information on heterosis and inbreeding depression in eight yield related traits in selected crosses. Kandhola *et al.* (1995) also found a high degree of heterobeltiosis for days to 50 percent flowering, days to flower completion, days to maturity and seed yield in hybrid IB4 × Morden, oil contents in IB14 × EC68415C and 100-seed weight in IB2 × Morden. Kumar *et al.*, (1999) observed that single crosses CMS82A × HA341 and CMS 852A × RHA-25 performed better for seed yield, oil contents and other yield characters. Landf *et al.*, (1998) observed that cross 336A × MRHA2 exhibited higher heterobeltiosis for seed yield per plant and yield contributing characters like oil contents, 100-seed weight and percentage of filled seed. Limbore *et al.*, (1998) noted 146 and 115 % heterobeltiosis for seed yield per plant in crosses 2A × 132/1 and 2A × IB60, respectively. Radhika *et al.*, (2001) found that heterosis was positive for all the characters except days to 50 percent flowering. All these authors reported varying magnitudes of heterosis for different traits in different cross combinations of parents. High heterosis for seed yield and some yield components of sunflower were also reported by some researchers.

Besides, Laureti and Gatto (2001) observed that restorer lines had higher GCA values than CMS lines for some important yield characters such as plant height, 1000-seed weight, and flowering time, so the selection of restorer lines for these traits would be more efficient than the selection of CMS lines.

A study was carried out by khan *et al*. (2004) to find the effect of heterosis on yield components of sunflower. Ten inbreed lines and their nine crosses were evaluated. Analysis showed high significant difference among the inbreed lines for all the traits such as head weight per plant, seed weight per plant, 1000-seed weight etc except weight of filled seeds per head was non-significant. Difference for head weight per plant was non-significant among the hybrids while significant results were shown for all other traits. TS-17 × TR-20, TS-18 × TR-120 and TS-4 ×TS-11 showed the higher level of heterosis for all the traits. Mean performances were calculated and these were higher for 1000-seed weight, weight of filled seed per head and seed weight per head among these hybrids as compared to other hybrids. Based on the heterotic values and mean values these hybrids and their parents were recommended for further use in breeding programme. After this Ahmad *et al*. (2005) conducted the research in NWFP, Peshawar to study the effect of heterosis on parents and on F_1 hybrids. The design was planted in RCBD. All the characters were statistically significant for the parents and F_1 hybrids. High heterosis was observed for the yield and leaf area in F_1 hybrids while lower heterosis was observed for number of leaves per plant. Habib *et al*. (2006) conducted the research to develop the 84 hybrids with great vigor. Plants with their parents were evaluated for different traits. They showed the significant differences for all the traits. The crosses ORI-3 × RL-77and ORI-3 × RL-83 showed the higher heterosis and Heterobeltosis for stem girth and 100 achene weight. Furthermore ORI-6 ×RL-27, ORI-47 × RL-69, ORI-29 × RL-84 and ORI-20 × RL-77 showed the better heterosis and Heterobeltosis for number of seeds per head, oil yield, head diameter and plant height. So these hybrids can be used for further breeding procedures.

Different lines and their hybrids were evaluated to calculate the heterosis and Heterobeltosis about the seed yield and oil contents. The lines and parents were statistically highly significant ($p<0.01$) for moisture factor, harvest contents, yield/hectare and oil contents. TS-18 × 291RGI, TS-335 × 291RGI, TS-228 × 291RGI showed the higher heterosis and Heterobeltosis for all the traits. On the basis of mean performance, heterosis and Heterobeltosis estimations, these lines were declared as best to further use in the breeding program. (Khan et al., 2008).

Jan *et al.* (2009) conducted the research to find out the heterosis for the traits head size, achene yield, achene number, oil contents etc. 58 crosses were made from 8 parents. These hybrids along with their parents were planted in Randomized complete Block design. Sowing was done by drill method by sowing 3 seeds per hole, which was later thinned out and one seed was kept per hole. Data for different parameters were collected. Data showed the higher heterosis for head size and lower heterosis for the achene yield/hectare. Cross TF-11 × TF-335, TF-7 × TF-11, TF-4 × PESH, TF × ARI, TE-7 × GUL showed the maximum heterosis for head size, achene yield/plant, achene number/plant and 100 seed weight with heterosis value of 80.66 %, 27.44%, 29.88%, 31.14%, 10.81% and 10.32% respectively. Researcher suggested that these crosses can be further used in the breeding program.

Machikowa *et al*. (2011) crossed the seven inbred lines to form the F_1 hybrid. These lines were used to calculate the GCA and SCA effects of the parents to find out the best parents so that suitable hybrids can be made. The data was recorded for yield, head diameter, plant height, oil contents etc. Parents along with their crosses were sown in randomized complete block design in Thailand to estimate the General and specific combining ability. Mean squares for GCA and SCA were highly significant for yield, plant height, 1000-seed weight while SCA were non-significant for head diameter and oil contents. 5A showed the highest GCA effects for yield and oil contents and after that best results were shown by 2A. 5A × 2A showed highest SCA effects for 1000-seed weight and oil contents. Thus it was proved that these two lines can be used for the further procedure in the development of hybrid.

The research was conducted in University of Agriculture, Faisalabad to find out the best parents for yield and oil related traits which could be used in the hybrid development. Data for the following traits were taken such as plant emergence, plant height, head diameter, 100-achene weight, oil contents etc. Analysis of variance was done to find out the significant differences among the lines. Significant differences were observed between the interactions of lines which depicted the importance of SCA effects. Results showed that SCA was higher than GCA effects. GCA effects showed that G2 was best to be used in producing the high yielding hybrid. The line G100 showed the negative GCA effect for plant height which can be further used in the development of short stature plants. The line G2 can be used in the breeding program to improve the oil and oleic acid content whereas G65 for linoleic acid and protein contents. G9 × G12 and G65 × G12 was the cross combinations that demonstrate significant SCA effects for most of the traits studied (Qamar *et al.*, 2015).

Six Female lines were crossed with three male lines to develop eighteen F_1 hybrids by Memon *et al.* (2015). These hybrids were evaluated for plant height, days to flower initiation, days to flower maturity, leaves/plant, 1000 seed yield, oil contents etc. The experiment was conducted in Randomized complete block design. Analysis of variance showed the significant differences for the traits in both parents and F_1 hybrids. Three hybrids HO-1 × PAC-0306, PAC-0505 × PAC-0306 and HO-1 × PAC-64-A showed the negative heterosis for days to flower initiation, flower maturity and plant height. While they showed the positive heterosis for number of leaves, head diameter, seed yield, oil yield and for 1000-seed weight. These lines were recommended for further use in the breeding procedure.

Genetic control of important sunflower traits

Oil content varies with location and year of growing (Škorić and Marinković, 1990). Oil content in seed is greatly affected by genotype, soil and climatic conditions and the intensity of cultivation practices. Cultivated sunflower exhibits considerable variability in oil content. In general, however, oil content is much lower in wild species than in cultivated sunflower (Seiler, 1992)**.** Control of inheritance of oil content by additive genes has been observed by many researchers and they reported that the inheritance of oil content is controlled by non-additive genes. In addition to the additive and dominant gene effects involvement of epistatic effects like additive × additive, additive × dominant and dominant × dominant digenous epistasis was determined (Gangappa *et al*., 1997a). Dominant gene effects were found for days to maturity, plant height, head diameter, 100-achene weight, oil content, seed yield and oil yield. The additive component was significant for days to flowering and 100-seed weight only. Overall dominance was highly significant for all characters except 100-seed weight and oil contents. Naik *et al*., (1999) reported dominant gene action for days to 50% flowering, number of leaves per plant, total yield per plant and harvest index and over dominance effects for plant height, leaf area index, head diameter, 100-achene weight, husk content and oil content. Habitability estimates for the later two traits were high, while that for yield was moderate (Kshirsagar *et al*., 1995).

Correlations

Highly significant positive correlations have been observed between oil content in seed on one side and head diameter, number of seeds per head and 1000-seed weight on the other Razi *et al*., (1999) observed positive direct effect of oil content on seed yield. Grain yield and achene yield has positive direct effects on oil yield per plant (Joksimovic *et al*., 1999). Chaudhary and Anand (1993) estimated genotypic correlations between seed yield and its components from data of 77 F_1 and 77 F_2 progenies from a line × tester mating design. Seed yield was significantly and positively correlated with number of leaves per plant, plant height, head diameter and 1000-seed weight in both F_1 and F_2. A positive significant association was observed between oil content and seed yield only in the F_2.

Habib and Mehdi (1993) evaluated sunflower populations to determine the extent of relationship between seed weight and seedling traits. The results indicated that seed weight was significantly and negatively correlated with emergence. Correlation coefficients of seed weight with fresh shoot weight and fresh shoot length were significant and positive. Mogali and Virupakshappa (1994) estimated genotypic and phenotypic correlations and found that seed yield was positively correlated with number of seeds per plant, plant height, stem diameter, head diameter, test weight and seed filling percentage. Plant height was positively correlated with all characters studied except seed filling. Oil content was negatively correlated with seed yield at the genotypic levels. Number of filled seeds per plant had a maximum direct effect on seed yield. All the other character had high, positive indirect effects on seed yield. Seed yield had the highest direct effect on oil yield followed by seed filling percentage, oil content and head diameter. Number of filled seeds per plant had the highest indirect effect via seed yield per plant. Plant height, stem diameter and 1000-seed weight had the greater indirect effect via seed yield.

Punia and Gill (1994) studied correlation involving 63 genotypes (9 single, 18 double and 18 three-way hybrids, their 15 parents and 3 standard controls) showed seed yield per plant to be significantly correlated with number of height and stem diameter. Path coefficient analysis indicated that number of seeds per head. 100-seed weight and head diameter are the most important traits for seed yield per plant. The highest correlation of seed yield was observed with number of filled seeds per plant, followed by seed filling percentage and head diameter (Tahir *et al.*, 2002). They also found maximum direct effects on seed yield exerted by important characters to improve seed yield like number of filled seeds per plant, head diameter and 1000-seed weight.

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