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Genetic behavior and impact of various quantitative traits on oil contents in sunflower under waters stress conditions at productive phase

Mudassar Iqbal[1], *M. Amjad Ali[1], Amjad Abbas[1], M. Zulkiffal[1], M. Zeeshan[1] and Hafeez A. Sadaqat[2]

[1] *Ayub Agricultural Research Institute, Faisalabad, Pakistan.*
[2]*Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad,Pakistan.*

**Corresponding author: Amjad.Ali2001@gmail.com*

Abstract

The research pertaining to the genetic behavior and impact of various quantitative traits on oil contents in sunflower under water stress conditions at reproductive stage in ten accessions (G-5 G-3, G-9, G-33, G-57, G-93, G-128, A-133, A-75 and HBRS-2) of sunflower was conducted following a triplicate randomized complete block design. The genotypes exhibited significant varietal differences among them for all the characters studied. Whorls per head (0.53) and number of leaves (0.66) displayed highest genotypic and phenotypic coefficients of variation respectively. Heritability in broad sense was the maximum for oil contents (0.715±0.346) followed by achene yield per plant (0.499±0.289) with considerable values of genetic advances indicating the involvement of some additive effects in the inheritance of these traits. Total leaf area exhibited the uppermost value of genetic advance (77.088) with moderate heritability (45±2.76). Plant height showed positive and significant genotypic association with leaf area and achene yield. Similarly number of leaves displayed positive and significant correlation (r=0.727*) with total leaf area and oil contents at genotypic level. The parameters stem diameter, head diameter, whorls per head and fertile whorls per head demonstrated positive and significant genotypic and phenotypic relationship between them. The number of whorls per head disclosed positive genetic association (r=0.625*) with oil contents while oil contents were negative associated with hundred achene weight (r= -0.768*). Path analysis based on oil content as dependent variable revealed that number of leaves, total leaf area, stem diameter and achene yield exerted positive direct effects on the oil contents being stem diameter at the top of the list. Stem diameter exposed the highest indirect positive effects on oil contents through head diameter, whorls per head and fertile whorls per head. These studies revealed that the selection of traits positively associated with oil contents and having positive direct and indirect effects on it could be an efficient selection criteria for oil contents in sunflower.

Keywords: Sunflower; water stress; genetic parameters; correlation; path analysis

Introduction

Sunflower as an oilseed crop was introduced in Pakistan in 1960. It ranks third after Soybean and palm oil in worldwide vegetable oil production. The soil and climatic conditions of the country are highly favorable for the production of sunflower. It is being cultivated on 937 thousand acres producing 956 thousand tons of seed and 249 thousand tons of oil (MINFAL 2006-07). Sunflower seed contains 40-48% oil, 20-27% protein (Nazir *et al*., 1994) and high percentage of poly-unsaturated fatty acids (60%) including oleic acid (16.0%) and linoleic acid (72.5%), which control cholesterol in blood (Satyabrata *et al*., 1988). Sunflower oil is considered as premium oil due to its light color, mild flavor and ability to withstand at high cooking temperatures. Furthermore, sunflower oil contains fat-soluble vitamins A, B, E and K, well for heart proteins (Evertt *et al*., 1987; Gossal *et al*., 1988). Sunflower is classified as a low to medium drought sensitive crop. It has been found that both magnitude and supply of water has a significant impact on achene and oil yield in sunflower (Krizmanic *et al*., 2003; Reddy *et al*., 2003; Iqbal *et al*., 2005). Although drought stress affects every developmental stage of sunflower, maximum reduction in yield was experienced when drought occurred during the reproductive stage (Reddy *et al*., 1998; Reddy *et al*., 2003; Vijay 2004). Moreover, water deficiency at a vegetative and reproductive growth phase may cause 40% and 61% yield reduction in sunflower, respectively (Iqbal 2004). Therefore, evaluation of good yielding sunflower varieties with high oil content tolerant to water deficit conditions at reproductive stage for local environment is directly needed.

Estimation of correlated response of different characters is of utmost importance for the selection of desirable plant genotypes (Ali *et al*., 2009) while the path analysis allows the partitioning of correlation coefficient into its direct and indirect components (Dewey & Lu 1959). Positive association of oil contents with other characters along with their direct and indirect effects is vital and must be identified and explored by the sunflower breeders with special reference to water stress conditions. Correlation coefficient and path analysis has been used by many researchers (Nehru & Manjunath 2003; Ozer *et al*., 2003; Sridhar *et al*., 2005; Arshad *et al*., 2007; Habib *et al*., 2007; Behradfar *et al*., 2009) in determining interrelationships between quantitative characters in sunflower under normal conditions. Review of literature showed very limited work on the use of correlation and path analysis under water stress conditions for sunflower, however, it was utilized to assess correlated effects of various traits on yield under water stress conditions for wheat (Subhani & Chowdary 2000; Khan *et al*., 2003) maize (Saleem *et al*., 2007), chickpea (Talebi *et al*., 2007), rice (Yogameenakshi *et al*., 2004), Barley (Campbell *et al*., 1980), safflower (Mozaffari & Asadi 2006).

The main objective of this research was to perform the estimation of genetic variation, genotypic and phenotypic correlation coefficients of various multigenic traits of sunflower with oil contents in order to determine direct and indirect impacts of various traits on oil contents under water stress condition at reproductive stage. This information would have long term application of selecting and developing sunflower types with high oil contents under drought environments.

Materials and methods

Ten sunflower accessions viz., G-5 G-3, G-9, G-33, G-57, G-93, G-128, A-133, A-75 and HBRS-2 were collected from the gene pool of Oilseed Research Group, Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad. These accessions were sown in the experimental area of the Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad (31^o-26^o N and 73^o-06^o E) during crop season 2006-07. Experiment was laid out following Randomized Complete Block Design in a two factorial arrangement with three replications under drought conditions. The water stress was provided by skipping irrigation before the start of button stage to the maturity to achieve low moisture content during whole reproductive phase. The plant to plant distance of 30cm and row to row distance of 75cm was maintained for each accession. Ten plants were tagged at random in each replication and data was recorded at seedling and maturity stages.

Plant height was measured (cm) from ground level to the base of head. Total number of leaves from each selected plant of each accession was counted before harvesting in all replications and average was computed. Middle leaf was selected for taking leaf area of each plant in each accession. Three readings of leaf width were recorded, one from the base, other form the mid and the third from near the tip of the leaf. Average width was calculated and this average was multiplied by leaf length to calculate leaf area.

To obtain total leaf area (cm^2), first a factor was calculated by randomly sampling leaves from field. All of leaf samples were photocopied by using a Photostat machine. These photocopies were cut into square shapes to determine their average area. Thus correction factor and total leaf area were obtained as follows:

Correction factor = Average leaf area of random sample – Average calculated leaf area of all accessions.

Total leaf area = Leaf area of a particular accession - correction factor.

Stem diameter (cm) of plants was measured from the base using measuring tape and average was calculated in all replications. Head diameter (cm), number of whorls on each head and number of fertile whorls on each head were counted at maturity on individual plant basis. Heads of selected plants in each replication were harvested, dried and threshed

Table 1. Means squares from different characters of sunflower genotypes under drought conditions.

Character	MS	GCV (%)	PCV (%)	h^2 (BS)	GA
PH (cm)	328.880*	0.060	0.097	0.388±0.260	7.400
NL	2.346*	0.039	0.66	0.364±0.254	0.594
TLA (cm^2)	28356.45*	0.274	0.408	0.450±0.276	77.088
SD (cm)	0.510*	0.052	0.088	0.355±0.252	0.271
HD(cm)	4.860**	0.077	0.110	0.489±0.286	1.074
W/H	2.804*	0.53	0.085	0.392±0.261	0.688
FW/H	2.687**	0.060	0.087	0.488±0.286	0.796
HAW (g)	4.560**	0.103	0.149	0.478±0.283	1.021
OC (%)	62.040**	0.158	0.187	0.715±0.346	5.061
AY (g)	294.382**	0.254	0.360	0.499±0.289	8.490

Where * significant at P>0.05 and ** significant at P>0.01, MS= Mean squares, GCV= Genotypic coefficient of variation, PCV= Phenotypic coefficient of variation, h^2 (BS)= Heritability in broad sense, GA= Genetic advance, PH = Plant height, NL = Number of leaves, TLA = Total leaf area, SD = Stem diameter, HD = Head diameter, W/H = whorls per head, FW/H = fertile whorls per head, HAW = hundred achene weight, OC = Oil content /head, AY = Achene yield per plant

individually. Achene yield per head (g) and 100 achene weight (g) were determined using an electronic balance. Achenes of each genotype were separately dried and ground into fine powder. The oil contents were determined by using "Soxhlet" apparatus in Oilseed Laboratories, Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad.

The recorded data were analyzed by the analysis of variance technique (Steel *et al.*, 1997) to determine significant varietal differences among the 10 sunflower genotypes using M-STATC (MSTAT-C development Team 1989). Heritability in broad sense was estimated according to Falconer & Mackay (1996) while Genetic Advance was computed at 20% selection intensity using following formula given by Poehlman & Sleper (1995). Genotypic and phenotypic correlations were computed following Kwon & Torrie (1964). Path coefficients were estimated according to Dewey & Lu (1959), where oil content was kept as resultant variable and other contributing characters as causal variables.

Results and discussion

The analysis of variance followed according to Steel *et al.* (1997) revealed highly significant differences (P<0.01) among the sunflower genotypes for head diameter, whorls per head, hundred achene weight, oil content /head and achene yield (Table 1). On the other hand, the genotypes displayed significant differences at P<0.05 for plant height, number of leaves, total leaf area, stem diameter and whorls per head (Table 1). This significant genetic variation among the genotypes advocated that enough scope was present for the selection of good performing lines in relation to the oil contents (Habib *et al.*, 2007). Other studies have also reported highly significant differences among sunflower genotypes for all the traits under normal conditions (Ozer *et al.*, 2003; Al-Chaarani *et al.*, 2004; Sridhar *et al.*, 2005).

Variability is the prerequisite for the initiation of any breeding program for any crop (Ali & Khan, 2007). High magnitude of genetic diversity gives free hand to plant breeder for selection and rejection of any character or the genotype have that specific character. Coefficient of variation also known as 'relative variability' calculated as percentage is a measure to investigate that how much variability exists for the selection. Genotypic (GCV) and phenotypic coefficient of variation (PCV) were the highest for whorls per head and number of leaves per plant respectively which indicated maximum amount of variability to be subjected to selection for these parameters (Table 1). The oil contents revealed lower GCV (0.158) and PCV (0.187) which was an indica-

Table 2. Genotypic correlation and phenotypic correlation coefficients among various characters of sunflower accessions under drought conditions.

Character	Correlation	NL	TLA	SD	HD	W/H	FW/H	HAW	OC	AY
PH (cm)	Genotypic	0.0002	0.799*	-0.188	0.281	-0.021	-0.003	-0.386	-0.037	0.588*
	Phenotypic	0.395	0.400	0.040	0.153	0.068	0.020	-0.131	-0.102	0.386
NL	Genotypic		0.714*	-0.023	0.096	-0.029	-0.208	-0.512	0.727*	0.226
	Phenotypic		0.151	-0.010	0.026	0.052	0.016	-0.239	0.372	0.062
TLA (cm^2)	Genotypic			-0.212	-0.077	-0.314	-0.335	-0.012	-0.362	0.853*
	Phenotypic			-0.019	-0.087	-0.151	-0.147	0.014	-0.011	0.698**
SD (cm)	Genotypic				0.969*	0.989*	0.954*	0.042	0.207	-0.244
	Phenotypic				0.717**	0.518*	0.464*	-0.064	0.198	0.078
HD(cm)	Genotypic					0.978*	0.957*	0.114	0.315	-0.296
	Phenotypic					0.812**	0.736**	-0.078	0.259	-0.043
W/H	Genotypic						0.962*	-0.012	0.625*	-0.308
	Phenotypic						0.941**	-0.004	0.280	-0.170
FW/H	Genotypic							0.005	0.477	-0.181
	Phenotypic							0.121	0.267	-0.199
HAW (g)	Genotypic								-0.768*	-0.042
	Phenotypic								-0.476*	-0.073
OC (%)	Genotypic									0.368
	Phenotypic									0.138

Where * significant at P>0.05 and ** significant at P>0.01, PH = Plant height, NL = Number of leaves, TLA = Total leaf area, SD = Stem diameter, HD = Head diameter, W/H = whorls per head, FW/H = fertile whorls per head, HAW = hundred achene weight, OC = Oil content /head, AY = Achene yield per plant.

tion of limited scope for the selection of this character due to inadequate variability. Heritability is the ratio of variance due to hereditary difference and genotypic variance to the total phenotypic variance. Broad sense heritability includes total genetic variance (Meredith 1984). Oil contents showed maximum magnitude of broad sense heritability and moderate value of genetic advance, which advocated that this character might be improved through selection (Table 1). This was an indication of the involvement of enough genetic and additive effects in the inheritance of oil contents in sunflower. The character, total leaf area exhibited highest genetic advance combined with moderate extent of genetic advance which revealed that selection for the leaves with better area could be helpful for its improvement under water stressed conditions. Other characters possessed moderate heritability coupled with low genetic advance squeezed the chances of early selection for these traits under drought conditions due to the involvement of non-additive genetic effects in the heritage of these characters. Khan *et al*. (2003) also reported that oil content and achene yield had high heritability while Shrinivasa (1982) observed moderate heritability for achene yield but Alam *et al*. (1987) found high heritability for achene yield.

Correlation coefficient is a measure of interdependence between a pair of characters (Ali *et al*., 2009). Knowledge of correlation is required to obtain the expected response of other characters when selection is applied to the character of interest in a breeding program (Falconer 1989). The characters under study showed very few significant correlations with oil contents and among them. The results pertaining to genotypic and phenotypic correlations under drought conditions (Table 2) revealed that at genotypic level only number of leaves per plant and whorls per head exhibited significant ($P<0.05$) association with oil contents at genotypic level. Genetic correlation between two or more characteristics may result from pleiotropic effects of genes or linkage of genes governing inheritance of two or more characteristics (Falconer 1989). It suggested that the choice of number of leaves per plant and whorls per head could be promising selection criteria for oil contents. Conversely, 100-achene weight demonstrated considerable negative relationship with oil contents at both phenotypic and genotypic levels ($P<0.05$). This advocated that while selecting oil contents in sunflower under water stress conditions breeder should be careful about the contradicting nature of these two parameters.

Table 3. Direct (bold diagonal values) and indirect (normal values) effects among all characters on oil contents (drought conditions)

	PH	NL	TLA	SD	HD	W/H	FW/H	HAW	AY	Genotypic Correlation
PH (cm)	-0.339	-4.941	0.791	-0.201	-0.126	0.006	1.131	0.405	-0.574	-0.037
NL	-7.061	0.273	0.707	-0.025	-0.043	0.009	0.0007	0.537	-0.221	0.727
TLA (cm^2)	-0.271	0.169	0.990	-0.226	0.034	0.099	0.001	0.013	-0.833	-0.362
SD (cm)	0.064	0.005	-0.210	1.065	-0.483	-0.424	-0.004	-0.044	0.238	0.207
HD(cm)	-0.095	-0.022	-0.077	1.144	-0.449	-0.349	-0.003	-0.120	0.289	0.315
W/H	0.007	0.007	-0.311	1.424	-0.495	-0.317	-0.003	0.013	0.301	0.625
FW/H	0.001	0.049	-0.332	1.417	-0.497	-0.328	-0.003	-0.005	0.176	0.477
HAW (g)	0.131	0.121	-0.012	0.045	-0.051	0.003	-1.871	-1.047	0.041	-0.768
AY (g)	-0.199	-0.053	0.365	-0.260	0.133	0.098	0.0006	0.044	0.241	0.368

Where PH = Plant height, NL = Number of leaves, TLA = Total leaf area, SD = Stem diameter, HD = Head diameter, W/H = whorls per head, FW/H = fertile whorls per head, HAW = hundred achene weight, OC = Oil content /head, AY = Achene yield per plant

There were some significant associations found among other characters studied under water deficit conditions (Table 2). Total leaf area showed significant positive correlation with plant height and number of leaves per plant ($P<0.05$) at genotypic level. However, head diameter displayed positive, significant genotypic and highly significant phenotypic relationship with stem diameter. Whorls per head revealed considerable positive association with both the stem and head diameters at genotypic as well as phenotypic levels. The character fertile whorls per head demonstrated positive and significant correlations (genotypic and phenotypic) with stem diameter, head diameter and whorls per head. Oil contents had positive and non-significant correlation with achene yield under drought conditions. But Ashoke *et al.* (2000), Teklewold *et al.* (2000) and Ilahi (2006) reported positive and significant correlation of oil contents with achene yield. The positive genetic association among various traits gave a free hand to the sunflower breeders to select these traits simultaneously especially under water stress conditions. In some previous studies carried out under normal conditions, plant height showed positive, genotypic and significant correlation with achene yield (Ashoke *et al.,* 2000; Dagustu, 2002). Similarly, positive genotypic and phenotypic correlation was found between total leaf area and achene yield. Mahender *et al.* (1998) also reported positive correlation of total leaf area with achene yield under water stress conditions. Chikkadevaiah et al. (2002) reported that oil contents was positively associated with plant height, number of leaves per plant, head diameter, 100-seed weight, seed yield and oil yield.

The path coefficient analysis has been utilized efficiently to clarify interrelationships between the dependent and several other independent variable characteristics in plants. The appropriate exploitation of this method requires that, cause and effect exist among the variables and that the researcher assign direction in the causal system, either a priori or based on experimental evidence (Steel *et al*., 1997). Path coefficient analysis (Table 3) revealed that number of leaves, total leaf area, stem diameter, and achene yield per head exerted positive direct effects on oil contents under water stress conditions being the highest for stem diameter (1.065). On the other hand, 100-achene weight exhibited the highest negative direct load on the oil contents which was fully in collaboration with the results of correlation analysis which revealed significant negative association between these two traits at both genotypic and phenotypic levels. In previous studies, positive direct effects on oil contents were exhibited by plant height, 100-achene weight and head diameter (Patil *et al.,* 1996b; Ilahi 2006). In addition to the highest direct load of stem diameter on oil contents, it also contributed indirectly and positively to oil contents through head diameter (1.144), whorls per head (1.424) and fertile whorls per head (1.417) and these were the highest indirect effects (Table 3). Other positive indirect effects on oil contents were exerted by plant height through head diameter, whorls per head and fertile whorls per head. Number of leaves had considerable positive indirect effects on oil contents via total leaf area, fertile whorls per head and 100-achene weight. Besides significant direct influence of total leaf area on oil contents, it also had positive indirect weight in the course of plant height, number of leaves and achene yield. Head diameter had only considerable positive indirect load on oil contents through achene yield. Fertile whorls per head showed substantial positive indirect influence on oil contents on through plant height. Similarly, significant positive indirect effects were exercised by 100-achene weight via plant height, number of leaves. Moreover, achene yield had positive indirect effects on oil contents through stem and head diameters, whorls per head, fertile whorls per head and 100-achene weigh in addition to its positive direct influence on oil contents.

Conclusion

This investigation concluded that significant genotypic variation was present among these genotypes to be subjected to selection for oil contents and its attributes. The higher amount of heritability in broad sense for oil contents and achene yield per plant with considerable genetic advance indicated the additive genetic effects in the heritage of these characters. Positive and significant genotypic relationship of oil contents with number of leaves and number of whorls per head advocated that these traits might be efficient selection criteria for oil contents under water stress environments. Positive direct effects of number of leaves, total leaf area, stem diameter and achene yield on the oil contents revealed that the genotypes with higher oil contents could be selected keeping these parameters under consideration for selection especially in case of water stress at reproductive stage.

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