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HERITABILITY AND CORRELATION STUDIES FOR PHENOLOGICAL, SEED YIELD AND OIL TRAITS IN SUNFLOWER (*HELIANTHUS ANNUUS* L.)

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ABSTRACT

The present studies were carried out during 2009 at Agriculture Research Institute, Tandojam, Pakistan. Six sunflower lines T-4-0319, PAC-0505, HO-I, Hysun-33, Peshawar-93 and CMS-03 and three testers PAC-0306, PAC-64-A and SF-187 were crossed in a line x tester mating design, thus 18 F_1 hybrids were developed for evaluation through genetic analysis. Significant differences were observed among the lines, testers and lines x testers interactions for phenological, seed yield and oil traits in F_1 hybrids. The significance of mean squares of lines and testers determined additive variances while lines x testers interactions estimated the importance of dominant variances, thus the data were worth for estimating heritability for earliness, morphological and yield traits. The major role of dominant genes was very obvious because the degree of dominance ($\sigma^2D/\ \sigma^2A$) being greater than unity. The heritability estimates were generally low to moderate which may be due to greater portion of dominant variances and genes against the additive variances and genes. Results suggested that selection for such traits may be exercised in later generations while giving the opportunity of recombination to occur between desirable genes. Generally, correlations suggested that leaves plant^{-1}, head diameter and 1000-achene weight have shown strong associations with seed and oil yields, and these traits may be used as reliable selection criteria to improve seed yield and oil content of sunflower.

Keywords: Correlations, heritability estimates, seed yield and oil traits, sunflower.

INTRODUCTION

In sunflower, the plants obviously differ in head diameter, plant height, number of leaves, seeds per head and 1000-seed weight. In quantitative traits, these variations are partly attributable to the environmental factors and to a certain

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extent contributed by the genetic influence. For sunflower breeders, it is very important to know the genetic variance which is due to additive genes. The narrow sense heritability determines as how much of the phenotypic appearance of plants is the exact reflection of their genetic value. Alga and Fernandez (1997) reported narrow sense heritability estimates for various sunflower traits as 65% for yield; 80% for seeds head^{-1}; 84% for seed weight; 81% for head diameter; 72% for oil content and 94% for days to bloom. On the contrary, Sayed *et al*. (2013) reported low narrow sense heritability estimates for seed and oil yields which indicated the importance of non-additive gene effects for these traits in sunflower.

Seed yield in sunflower is a complex character because it is expressed with the function of many component traits and their interactions with the environment. It is obvious that the important aspiration of plant breeders is to know the extent of relationship between phenological, seed yield and oil traits which will ultimately enhance their selection efficiency for above traits. Thus, it is necessary to measure the mutual relationship between various plant characters so as to determine the component traits on which selection can be based for genetic improvement in yield and other important traits. Thus, it helps to base selection procedures required to balance two contrary but desirable characters affecting the primary character. Correlation studies also help to improve different characters simultaneously (Sujatha and Nadaf, 2013). Correlation studies determine as how far two variables are associated with each other. The correlation actually reduces the chance of uncertainty to happen, thus the predictions based on correlation analysis are likely to be very closer to reality. Several researchers observed different types of correlations among seed yield, oil content and yield components. Seed yield was significantly and positively correlated with head diameter and 100-seed weight as reported by Lakshminarayana *et al*. (2004) and Sujatha and Nadaf (2013); seed yield was negatively correlated with days to flowering and days to maturity (Manjula, 1997); days to flowering was significantly and positively correlated with plant height (Sathish, 1995; Manjula, 1997); days to flowering showed negative and significant correlations with head diameter and test weight (Patil, 1993; Sujatha and Nadaf, 2013); days to flower initiation and days to flower completion were negatively correlated with oil yield (Habibullah *et al*., 2007); plant height had positive and significant correlation with days to maturity (Anandha *et al*., 2010) and head diameter had positive and significant correlation with seed yield per plant and test weight (Anandhan *et al*., 2010; Sujatha and Nadaf, 2013). Plant height had negative and significant correlation with head diameter (Sujatha and Nadaf, 2013).

From the above discussion, it may be concluded that differential associations were observed among various plant traits. Due to significant and negative association of plant height with head diameter and non-significant association between head diameter and seed yield per plant, it may be inferred that, the early and dwarf genotypes can be developed with high seed yield. The character days to maturity, 100-seed weight and head diameter were considered as important selection indices for seed yield improvement (Sujatha and Nadaf, 2013).

Therefore, the present research was planned to estimate the heritability of multigenic traits and correlation among phenological, seed yield and oil traits in sunflower.

MATERIALS AND METHODS

Present research was carried-out during 2009 at the Agriculture Research Institute, Tandojam, Pakistan. Six female sunflower lines viz.T-4-0319, PAC-0505, HO-I, Hysun-33, Peshawar-93 and CMS-03 and three testers, PAC-0306, PAC-64-A and SF-187 were crossed in line x tester fashion, thus 18 F_1 hybrids were developed to study the narrow sense heritability and correlations. The heads of all the eighteen F_1 hybrids were collected, dried and threshed. The well-filled seeds from each cross were separated for hybrids evaluation. At the time of maturity, the crossed heads were harvested separately and their seeds were stored for sowing of F_1 generation. The F_1 crossed seeds alongwith parental lines and testers were grown in a randomized complete block (RCB) design with four replications. The hybrids and parental lines were sown in six-meter long rows with plant to plant distance of 30 cm and row to distance of 75 cm. A basal fertilizer dose of 120:60 Kg ha^{-1} of nitrogen and phosphorus were applied. Full dose of phosphorus and half dose of nitrogen were applied at the time of sowing, while the remaining half dose of nitrogen was applied before head initiation. For recording the data, ten plants were randomly tagged from each replication for seed germination%, days to initial flowering, days to 75% flowering, days to maturity, number of leaves $plant^{-1}$, plant height, head diameter, number of seeds $plant^{-1}$, 1000-achene weight, seed yield $plant^{-1}$, seed yield Kg ha^{-1}, oil content % and oil yield Kg ha^{-1}. The entire data set was subjected to statistical analysis according to Gomez and Gomez (1984) for determining significance differences among the genotypes and narrow sense heritability and phenotypic correlation of F_1 hybrids for phenological, seed yield and oil traits. Simple correlation coefficient was calculated after Snedecor and Cochran (1980) while heritability (narrow sense) was calculated according to Hallauer and Miranda (1987) as the ratio of additive variance over the phenotypic variance with the following formula:

$$h^2 = \frac{\delta^2 A}{\delta^2 A + \delta^2 D + \delta^2 e / r} \times 100$$

RESULTS AND DISCUSSION

Significant differences in mean squares of genotypes including parental lines and testers and F_1s existed for all the traits indicated that the data is worth for genetic analysis (Table 1). The significant differences between lines x testers interactions indicated the importance of dominant variances (σ^2D) while the significant mean squares due to lines and testers determined the additive variances (σ^2A) which suggested that both variance components could be used to determine narrow sense heritability. Significant genetic variability among the plant traits is particularly useful because variations in these traits would allow further improvement in sunflower yield and quality traits. The major role of dominant gene effects was manifested for all the characters which confirmed the degree of dominance (σ^2D/σ^2A) being greater than unity (Table 2).

Table 1. Mean squares from analysis of variance for phenological, seed yield and oil traits of F_1 hybrids derived from six lines and three testers of sunflower.

Characters	Replications D.F.=3	Genotypes D.F.=26	Lines (L) D.F.=5	Testers (T) D.F.=2	L x T D.F.=10	Error D.F.=78
Days to germination	70.68	441.34**	524.49**	1510.89**	68.22**	0.01
Days to initial flowering	31.47	150.71**	79.29**	6.22**	264.09**	1.44
Days to 75% flowering	18.01	107.22**	136.15**	128.66**	99.27**	0.01
Days to maturity	78.75	85.61**	159.38**	67.53**	99.68**	6.75
Number of leaves plant^{-1}	16.08	48.33**	29.20**	264.67**	9.47**	0.19
Plant height	86.42	3215.52**	4377.07**	8082.63**	2910.02**	1.09
Head diameter	16.08	45.61**	21.61**	329.51**	10.38**	0.08
Seeds plant^{-1}	71505.8	166119.7**	126251.2**	365379.4**	113084.8**	418.4
1000-achene weight	68.08	130.07**	77.04**	716.27**	20.15**	0.08
Seed yield plant^{-1}	16.08	329.19**	181.16**	2322.89**	100.22**	0.08
Seed yield Kg ha^{-1}	1695.73	736249.92**	196767.05**	2900617.55**	95363.91**	2.37
Oil content	15.48	149.43**	6.54**	1086.86**	12.41**	0.15
Oil yield Kg ha^{-1}	8650.40	346174.68**	71400.48**	1950484.55**	43085.85**	53.02

** =Significant at 1% probability level.

Heritability estimates (h^2%) in narrow sense

Heritability estimates provide information about genetic variation and is useful for predicting the response to selection in the succeeding generations. Heritability depends upon the nature of gene action (Chowdhary *et al*., 2007). Character associations and heritability were also determined as they are helpful in making selection of superior genotypes, pointing-out the possibilities and limitations of simultaneous improvement of desirable characters and designing efficient future breeding programmes (Desalegn, 2004). Plant breeders can easily observe and measure phenotypic variation in plant populations, which is caused by the joint action of both genetic and environmental factors. The success of any breeding venture, therefore, depends mainly on the presence of the abundant genetic variability for a trait which is amenable to selection. The degree of genetic variability that is transferable to the offspring referred to as heritability is of great importance in improving any quantitative trait. A lot of work on genetic variability and heritability estimates has already been carried out, yet the differences always existed due to either material and methodology used or environments in which the material is tested (Baloch and Bhutto, 2003; Baloch, 2004). Heritability estimates remained variable depending upon the genetic nature of genotypes and the traits studied. The heritability estimates in narrow sense for various plant traits of sunflower are depicted in Table 2. In crop plants, generally, the heritability estimates in broad sense are higher than narrow sense because narrow sense heritability takes-up only additive genetic variance as a numerator over the total phenotypic variance.

Table 2. Narrow sense heritability estimates of F_1 hybrids for various plant traits of sunflower derived from crosses of six female lines with three testers.

Characters	$(\sigma^2 D/\sigma^2 A)^{½}$	σ^2A	σ^2D	σ^2e	Heritability (h^2 % n.s.)
Days to germination	1.58	27.34	68.21	0.003	28.61
Days to initial flowering	-2.13	-7.62	262.65	0.360	-2.77
Days to 75% flowering	8.78	1.29	99.26	0.003	1.28
Days to maturity	8.66	1.24	92.93	1.690	1.29
Number of leaves plant^{-1}	1.70	3.22	9.28	0.048	25.66
Plant height	5.58	93.55	2908.93	0.273	3.12
Head diameter	1.67	3.67	10.30	0.020	26.23
Number of seeds plant^{-1}	6.11	3018.10	112666.37	104.600	2.61
1000-achene weight	1.50	8.87	20.07	0.020	30.63
Seed yield plant^{-1}	1.98	25.66	100.14	0.020	20.39
Seed yield (Kg ha^{-1})	1.72	32367.85	95361.54	0.593	25.34
Oil content	1.05	11.21	12.26	0.038	47.68
Oil yield (Kg ha^{-1})	1.43	20933.18	43032.83	13.255	32.72

The heritability estimates in F_1s varied from 1.28 to 47.68%. These heritability estimates are generally low which is due to higher portion of dominant variances and dominant genes against the additive variances and additive genes influencing quantitative traits (Table 2). The heritability estimates for various traits were recorded as for seed germination % (h^2 = 28.61%), days to initial flowering (h^2 = 2.77%), days to 75% flowering (h^2 = 1.28%), days to maturity (h^2 = 1.29%), number of leaves plant^{-1} (h^2 = 25.66%), plant height (h^2 = 3.12%), head diameter

(h^2 = 26.23%), number of seeds plant^{-1} (h^2 = 2.61%), 1000-achene weight (h^2 = 30.63%), seed yield plant^{-1} (h^2 = 20.39%) and seed yield Kg ha^{-1} (h^2 = 25.34%). While oil content % and oil yield Kg ha^{-1} estimated relatively higher heritability of h^2 = 47.68% and 32.72%, respectively. The lower heritability estimates for majority of the traits suggested that selection for such traits may be delayed while giving the opportunity for recombination between desirable genes. Attia *et al*. (2012) observed low narrow sense heritability with range of 0.00 to 11.22%. They reported heritability for number of days to first flowering as 5.69%; days to 50% flowering (5.63%); days to maturity (1.22%); plant height (0.00%); head diameter (2.79%); number of seeds head^{-1} (0.19%); seed yield plant-1 (5.63%), 100-seed weight (1.77%); oil 5 (11.22%); oil yield (9.46%). The low narrow sense heritability estimates for all the studied traits were expected due to more importance of non-additive, particularly dominant and over-dominant genes in the inheritance of traits studied. These results are in line with findings of Goksoy *et al*. (2002); Hladni *et al*. (2003); Khan *et al*. (2008b) and Abou-Mowafy (2010) who also observed low heritability due to greater portion of dominant variances over additive. For oil content and oil yield, relatively higher narrow sense heritability estimates were noted and are in consonance with Khan *et al*. (2007) who also found moderate heritability estimates for oil content, seed weight, days to maturity and plant height. Contrary to our findings, Khan *et al*. (2008) estimated high heritability for 1000-seed weight, seeds plant^{-1}, oil content and seed yield in sunflower. Bisne *et al*. (2009) and Nasreen *et al*. (2011) observed higher magnitude of genotypic coefficients of variability for seed yield plant^{-1}, 100-seed weight, seed yield Kg ha^{-1} and oil yield and lower magnitudes for the other traits which could provide higher heritability estimates. Singh *et al*. (2012) recorded higher broad sense heritability coupled with high genetic advances for 1000-seed weight, seed yield plant^{-1} and plant height. The magnitude of high heritability and genetic advance indicated that improvement in such traits could be done through appropriate selection procedure. Sayed *et al*. (2012) observed low narrow sense heritability for plant height, head diameter; life-cycle duration; grain yield, 1000-seed weight, oil content and oil yield indicating the importance of non-additive genetic effects, thus suggesting that these traits would be effective for hybrid crop development.

Correlations

Correlation coefficient (r) determines the closeness of two important variables so that selection criteria could be reliably established. Correlation was calculated from F_1 hybrid data presented in Table 3 and Fig. 1 a-c for yield and oil traits of sunflower. Seed germination (%) exhibited significantly positive correlations with number of leaves plant^{-1}, head diameter, number of seeds plant^{-1}, 1000-achene weight, seed yield plant^{-1}, seed yield Kg ha^{-1}, oil content and oil yield Kg ha^{-1}. The positive associations of seed germination with other traits indicated that vigor in hybrid seeds enhanced seed germination percentage which produced plants with more number of leaves plant^{-1}, bigger head diameters, higher 1000-achene weight, more seeds plant^{-1} and higher seed and oil yields. While negative correlation of seed germination with days to initial flowering and days to maturity suggested that vigorous seeds produced vigorous plants which could be late in opening to initial flower and take more days to maturity. Similar results were also reported by Attia *et al*. (2012). Highly significant positive correlation coefficients were observed between number of days to first flowering and number of days to 50% flowering; days to flowering and plant height However, days to initial flowering was significantly positive associated with days to 75% flowering, days to maturity and plant height. Positive associations between phenological traits revealed that a plant which takes less days to initial flowering will also tend to take less number of days to 75% flowering.

Table 3. Correlation (r) among various traits in eighteen F_1 hybrids of sunflower derived from crosses of six female lines with three testers.

Characters	Days to initial flowering	Days to 75% flowering	Days to maturity	Leaves plant^{-1}	Plant height	Head diameter	Seeds plant^{-1}	1000 achene weight	Seed yield plant^{-1}	Seed yield Kg ha^{-1}	Oil content	Oil yield Kg ha^{-1}
Days to germination	-0.28*	-0.24	-0.36**	0.73**	0.02	0.69**	0.31*	0.65**	0.68**	0.61**	0.61**	0.60**
Days to initial flowering	-	0.62**	0.47**	-0.21	0.50**	-0.19	-0.17	-0.12	-0.10	-0.19	-0.08	-0.12
Days to 75% flowering		-	0.69**	0.13	0.66**	0.19	-0.02	0.10	0.06	-0.01	0.19	0.10
Days to maturity			-	-0. 10	0.59**	-0. 10	-0.00	-0.36**	-0.28*	-0.33*	-0.05	-0.26*
Number of leaves plant^{-1}				-	0.24	0.87**	0.43**	0.68**	0.83**	0.64**	0.80**	0.69**
Plant height					-	0.27*	-0.14	0.13	0.20	0.08	0.26*	0.09
Head diameter						-	0.39**	0.65**	0.75**	0.66**	0.80**	0.70**
Seeds plant^{-1}							-	0.14	0.41**	0.29*	0.40**	0.33**
1000 achene weight								-	0.80**	0.71**	0.69**	0.71**
Seed yield plant^{-1}									-	0.71**	0.80**	0.76**
Seed yield Kg ha^{-1}										-	0.85**	0.94**
Oil content											-	0.88**
Oil yield Kg ha^{-1}												-

* = Significant at 5%, ** = highly significant at 1% probability levels.

Days to 75% flowering expressed significantly positive association with days to maturity and plant height only while rest were non-significantly associated with days to 75% flowering. Positive association of days to 75% flowering with plant height indicated that longer duration plants attained taller plant heights. For earliness traits, Attia *et al.* (2012) observed positive and significant association of days to 75% flowering with days to maturity and plant height. Highly significant positive correlations were also observed between days to first flowering and number of days to 50% flowering. Further more, days to maturity was positively associated with plant height only, yet significant but negatively correlated with 1000-achene weight, seed yield plant^{-1}, seed and oil yields (Fig. 1b). Negative association of days to maturity with yield and oil traits has already been reported in many crop species. Similar to present results, Sujatha and Nadaf (2013) reported negative correlations between days to flowering and seed yield plant^{-1}. The leaves plant^{-1} displayed strong and positive associations with head diameter, seeds plant^{-1}, and 1000-achene weight, seed yield plant^{-1}, seed yield, oil content and oil yield (Fig. 1a). Increase in number of leaves plant^{-1} may increase yield and yield components and oil yields due to greater photosynthetic activity. Present results were in close agreement with those of Hladni *et al*. (2010) who also found close association between number of leaves plant^{-1} and seed yield. While Safavi *et al*. (2011) and Ahmad *et al*. (2012) found that number of leaves was positively correlated with 1000-kernel weight, head diameter, grain yield and other yield related characters from single and double cross hybrids. Their study further suggested that diversity in grain yield characters can be used as effective selection criteria for improving yield in single as well as in double cross hybrids of sunflower.

Plant height showed positive correlation with head diameter and oil content only. A significantly positive relationship between head diameter and plant height was observed by Vidhyavathi *et al*. (2005) and Yalcin and Singh (2010). Plant height, nonetheless did not show significant relationship with seed plant^{-1}, 1000-achene weight, seed and oil yield. Vigorous and taller plants may produce bigger heads as revealed from their positive correlations but again later plants with bigger heads may not necessarily give higher achenes, more yield, and oil contents. Non-significant correlations of plant height with yield and oil traits indicated that plant height showed little association with other traits except head diameter. Present results suggested that plant height can not be used as selection criteria to improve yield and oil traits. Shankar *et al*. (2006) also reported low correlation of plant height with head diameter, oil content %, seeds plant^{-1}, 1000 achene weight, seed yield and oil yield. Contrary to our findings, Zia *et al*. (2013) reported that taller plants produce higher oil content may be due to longer duration of plants. The head diameter manifested strong associations with 1000-achene weight, seed yield plant^{-1}, seed yield Kg ha^{-1}, oil content and oil yield Kg ha^{-1}, yet moderately associated with number of seeds plant^{-1}. Strong and positive association of head diameter with yield and oil related traits suggested that increased head diameter will lead to higher seed yields and greater oil yield. Hence head diameter can serve as a good selection criterion to increase the above traits. Similar to our findings, Cosge and Bayraktar (2004) divulged positive correlations of head diameter with seed yield, thousand seed weight, and seed yield plant^{-1}. It was concluded that number of filled seeds plant^{-1}, head diameter and 1000-seed weight were important characters to improve seed yield in sunflower. Attia *et al.* (2012) and several other researchers also reported a significant and positive correlation of achene yield per plant with head diameter (Tahir *et al.,* 2002; Vidhyavathi *et al.,* 2005; Sowmya *et al.,* 2010; Anandhan *et al.,* 2010).

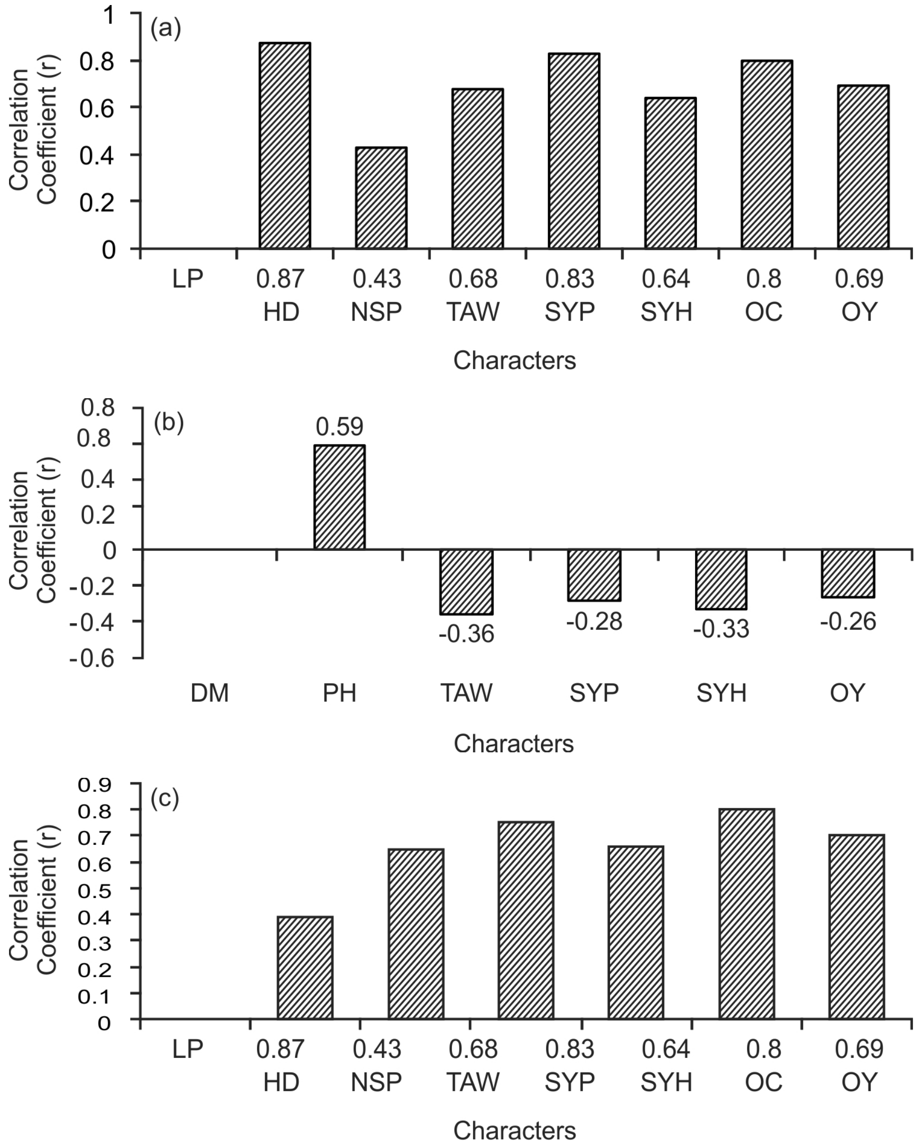

Figure 1. Correlation of (a) Leaves plant^{-1} with seed yield and other traits (b) Days to maturity with seed yield and other traits (c) Head diameter with seed yield and other traits. LP = Leaves (plant^{-1}), HD = Head diameter, NSP = Number of seeds (plant^{-1}), TAW = Thousand achene weight (g), SYP = Seed yield (plant^{-1}), SYH = Seed yield (kg ha^{-1}), OC = Oil content (%), OY = Oil yield (kg ha^{-1}), PH = Plant height (cm) and DM = Days to maturity.

The seed yield and oil traits like number of seeds plant^{-1}, seed yield plant^{-1}, seed yield kg ha^{-1}, oil content % and oil yield revealed positive associations with each other. Habit *et al*. (2007b) observed strong positive associations between seed yield plant^{-1}, seed yield, oil content %, and oil yield. It is very obvious from the correlations that increase in seed yield will simultaneously increase oil yields also. Generally, correlation results suggested that leaves plant^{-1}, head diameter and 1000-achene weight have shown strong associations with seed and oil yields, hence leaves plant^{-1}, head diameter and 1000-achene weight may be used as the most reliable criteria to improve oil content and seed yield in sunflower. Similar to present findings, Farhatullah *et al*. (2006) and Khokhar *et al*. (2006) observed that 1000-achene weight had positive association with seed yield plant^{-1}, seed yield, oil content %, and oil yield. Yalcin and Singh (2010) concluded that for obtaining higher seed and oil yields, the sunflower hybrids should have more number of leaves, larger heads, higher seed weight, lower husk content and shorter physiological maturity period of 107 days.

CONCLUSION

Major role of dominant genes was very obvious because the degree of dominance was greater than unity. The heritability was generally low to moderate which was due to greater portion of dominant variances over the additive ones. Generally, the correlations suggested that leaves plant^{-1}, head diameter and 1000-achene weight have shown strong associations with seed and oil yields, hence leaves plant^{-1}, head diameter and 1000-achene weight may be used as the most reliable selection criteria to improve seed and oil yields in sunflower.

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