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Full Length Research Paper

Correlation and path-cofficient analysis of seed yield and yield related trait in Iranian confectionery sunflower populations

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This study was undertaken in order to determine the association among yield components and their direct and indirect effects on the seed yield of confectionery sunflower. 36 confectionery sunflower populations originated from different regions of Northwest Iran were characterized using 11 agro-morphological traits including: Days to 50% flowering, plant height, stem diameter, head diameter, number of leaves, leaf length, leaf width, petiole length, number of seeds per head, 100-seed weight and seed yield. Phenotypic correlations results show that seed yield per plant was positively and significantly associated with 100-seed weight, head diameter, number of seeds per head, stem diameter and plant height. Path coefficient analysis revealed that number of seed per head, 100-seed weight, and head diameter has positive direct effect on seed yield. Therefore, selection based on these characters would be more effective to improving seed yield in confectionery sunflower in breeding programs.

Key words: *Helianthus annuus* L., direct effect, phenotypic correlation, indirect selection.

INTRODUCTION

Sunflower (*Helianthus annuus* L.) is one of the 67 species in the genus *Helianthus* (Fick, 1989). There are two types of sunflower oily and confectionery ones (Salunkhe et al., 1999). Oilseed sunflower is one of the most important oilseed crops in the world and is the preferred source of oil for domestic consumption and cooking worldwide (Hu et al., 2010). Confectionery sunflower produces large seeds with low oil content and it is used in baking and snack applications (Lu and Hoeft, 2009). Confectionery kernels are roasted and salted, or roasted with no salt added and marketed as edible chips. Confectionery type is one of the most popular and important crop in Iran. It is cultivated in all parts of the country especially in northwest regions.

Seed yield is a complex polygenic trait that is highly affected by environmental factors (Nadarajan and Gunasekaran, 2005). Understanding interrelationships between yield and factors affecting yield is a pre-requisite for designing an effective breeding programme (Velkov, 1980). Plant breeders commonly prefer yield components that indirectly affect seed yield (Marinkovic, 1992; Kaya and Atakisi, 2003; Yasin and Singh, 2010).

The use of simple correlation analysis (Putt, 1943; Ross, 1939) could not fully explain the relationships among yield and yield related traits. Path-coefficient analysis (Varshney et al., 1977; Ivanov et al., 1980; Lakshmanrao et al., 1985; Tyagi, 1985; Marinkovic, 1992; Sujatha and Nandini, 2002; Yasin and Singh, 2010), partition correlation coefficients of one variable to direct and indirect effects, giving a clearer picture of the individual contribution of each variable to seed yield.

This study was conducted to investigate the interrelationships of some characters with seed yield of confectionery sunflower and to determine the direct and indirect effects of studied characters on seed yield. Study on the relationships between yield and yield related traits will improve the efficiency of breeding programs by

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Table 1. Average of 11 morphological traits in the 36 confectionery sunflower populations.

Genotype	SH	SE	SD	SE	HD	SE	NL	SE	LL	SE	LW	SE
01	179.33	±14.88	2.39	0.25	15.40	±1.51	32.50	±1.65	24.29	±2.59	18.44	±1.90
02	180.67	±14.88	2.46	0.25	13.09	±1.51	29.75	±1.65	22.06	±2.59	16.83	±1.90
03	149.16	±14.88	2.23	0.25	15.71	±1.51	30.75	±1.65	25.40	±2.59	14.12	±1.90
04	194.00	±14.88	2.41	0.25	15.48	±1.51	31.75	±1.65	21.64	±2.59	18.22	±1.90
05	167.25	±14.88	2.75	0.25	16.63	±1.51	33.00	±1.65	27.81	±2.59	20.21	±1.90
06	189.63	±14.88	3.08	0.25	16.64	±1.51	33.25	±1.65	29.04	±2.59	20.99	±1.90
07	192.92	±14.88	2.50	0.25	12.49	±1.51	30.50	±1.65	21.66	±2.59	13.34	±1.90
08	210.75	±14.88	2.93	0.25	17.90	±1.51	34.50	±1.65	29.11	±2.59	19.23	±1.90
09	209.21	±14.88	3.39	0.25	19.84	±1.51	35.50	±1.65	27.00	±2.59	20.70	±1.90
10	203.25	±14.88	3.13	0.25	14.39	±1.51	33.25	±1.65	25.19	±2.59	18.48	±1.90
11	189.33	±14.88	2.44	0.25	16.24	±1.51	32.00	±1.65	24.75	±2.59	18.41	±1.90
12	184.92	±14.88	2.61	0.25	16.17	±1.51	30.25	±1.65	23.38	±2.59	15.74	±1.90
13	175.25	±14.88	2.85	0.25	18.59	±1.51	34.00	±1.65	25.59	±2.59	17.55	±1.90
14	209.92	±14.88	2.99	0.25	19.43	±1.51	33.00	±1.65	27.41	±2.59	18.22	±1.90
15	206.87	±14.88	2.82	0.25	20.01	±1.51	36.25	±1.65	28.68	±2.59	18.77	±1.90
16	179.67	±14.88	2.25	0.25	15.15	±1.51	33.50	±1.65	24.93	±2.59	18.28	±1.90
17	193.75	±14.88	2.76	0.25	14.92	±1.51	31.25	±1.65	23.66	±2.59	16.04	±1.90
18	190.83	±14.88	2.56	0.25	17.42	±1.51	33.75	±1.65	24.13	±2.59	17.41	±1.90
19	185.91	±14.88	2.42	0.25	13.22	±1.51	33.75	±1.65	22.13	±2.59	16.09	±1.90
20	173.08	±14.88	2.74	0.25	16.98	±1.51	34.25	±1.65	23.64	±2.59	18.69	±1.90
21	206.41	±14.88	2.78	0.25	17.13	±1.51	32.50	±1.65	25.30	±2.59	17.33	±1.90
22	198.00	±14.88	2.76	0.25	16.05	±1.51	34.00	±1.65	25.82	±2.59	18.10	±1.90
23	204.50	±14.88	3.16	0.25	16.65	±1.51	34.25	±1.65	26.15	±2.59	18.33	±1.90
24	175.29	±14.88	2.38	0.25	16.50	±1.51	31.75	±1.65	25.66	±2.59	18.05	±1.90
25	209.91	±14.88	2.98	0.25	16.80	±1.51	36.00	±1.65	27.29	±2.59	19.07	±1.90
26	205.54	±14.88	2.76	0.25	15.17	±1.51	30.00	±1.65	21.84	±2.59	16.53	±1.90
27	178.66	±14.88	2.42	0.25	13.57	±1.51	31.25	±1.65	23.07	±2.59	16.50	±1.90
28	182.33	±14.88	2.30	0.25	16.42	±1.51	32.25	±1.65	26.44	±2.59	14.11	±1.90
29	187.00	±14.88	2.95	0.25	17.37	±1.51	33.50	±1.65	30.83	±2.59	23.31	±1.90
30	178.67	±14.88	2.64	0.25	15.18	±1.51	32.00	±1.65	23.24	±2.59	17.58	±1.90
31	215.08	±14.88	3.22	0.25	17.67	±1.51	34.00	±1.65	28.55	±2.59	19.11	±1.90
32	174.25	±14.88	2.63	0.25	15.04	±1.51	31.00	±1.65	20.54	±2.59	16.99	±1.90
33	189.41	±14.88	2.85	0.25	17.17	±1.51	33.25	±1.65	26.23	±2.59	16.27	±1.90
34	211.83	±14.88	2.90	0.25	19.91	±1.51	33.50	±1.65	28.15	±2.59	21.79	±1.90
35	167.50	±14.88	2.38	0.25	14.66	±1.51	31.50	±1.65	23.68	±2.59	15.51	±1.90
36	196.67	±14.88	2.81	0.25	17.28	±1.51	33.75	±1.65	27.58	±2.59	18.40	±1.90

determining appropriate selection criteria.

MATERIALS AND METHODS

Plant materials and experimental design

In the study, 36 confectionery sunflower populations, originated from different regions of northwest Iran was investigated during 2009 under field conditions in Urmia University. The experiment was conducted in a randomized complete block design with four replications. Experimental units in each block comprised of one line of 4 m long. Row to row and plant to plant spacing was kept 0.60 and 0.40 m, respectively. The sunflower seeds were sown by putting three seeds to hills by hand. Plants were thinned to one plant per hill 15 days after sowing. Cultural practices, control of insects and weeds and furrow irrigation were given as needed during the growth season according to the local recommendations. Some data were collected during full flower period and some others after seed was harvested. Different agro-morphological traits were measured that included: days to 50% flowering (dayf), plant height (PH), stem diameter (SD), head diameter (HD), number of leaves (NL), leaf length (LL), leaf width (LW), petiole length (PL), number

Table 1 (Continued).

Genotype	PL	SE	dayf	SE	HS	SE	NS	SE	WS	SE
01	12.67	±1.25	88.50	±3.66	6.89	±1.29	423.50	±92.18	417.10	±292.53
02	11.89	±1.25	90.00	±3.66	7.91	±1.29	630.50	±92.18	357.80	±292.53
03	8.38	±1.25	84.75	±3.66	10.10	±1.29	406.00	±92.18	1061.40	±292.53
04	17.03	±1.25	86.50	±3.66	6.89	±1.29	602.50	±92.18	1200.90	±292.53
05	11.62	±1.25	94.00	±3.66	8.68	±1.29	565.25	±92.18	873.90	±292.53
06	13.73	±1.25	83.50	±3.66	10.81	±1.29	570.75	±92.18	648.30	±292.53
07	13.74	±1.25	96.50	±3.66	5.37	±1.29	393.75	±92.18	360.90	±292.53
08	14.42	±1.25	82.50	±3.66	10.91	±1.29	528.50	±92.18	1223.10	±292.53
09	12.33	±1.25	84.25	±3.66	9.87	±1.29	745.50	±92.18	1999.80	±292.53
10	13.79	±1.25	96.25	±3.66	8.60	±1.29	733.50	±92.18	1772.00	±292.53
11	11.99	±1.25	84.00	±3.66	9.89	±1.29	388.33	±92.18	931.73	±292.53
12	11.25	±1.25	84.25	±3.66	10.46	±1.29	580.00	±92.18	858.70	±292.53
13	11.33	±1.25	86.00	±3.66	8.34	±1.29	579.50	±92.18	878.50	±292.53
14	13.48	±1.25	84.00	±3.66	10.11	±1.29	655.75	±92.18	1391.60	±292.53
15	12.53	±1.25	87.50	±3.66	12.77	±1.29	529.25	±92.18	1886.00	±292.53
16	9.88	±1.25	85.75	±3.66	8.03	±1.29	514.50	±92.18	784.30	±292.53
17	11.85	±1.25	89.75	±3.66	8.54	±1.29	495.50	±92.18	1103.70	±292.53
18	10.83	±1.25	94.25	±3.66	10.54	±1.29	655.50	±92.18	1208.00	±292.53
19	12.43	±1.25	94.75	±3.66	8.42	±1.29	796.50	±92.18	1523.60	±292.53
20	11.71	±1.25	85.75	±3.66	8.88	±1.29	511.00	±92.18	1341.80	±292.53
21	11.20	±1.25	91.00	±3.66	10.02	±1.29	644.50	±92.18	1138.00	±292.53
22	11.81	±1.25	91.00	±3.66	10.19	±1.29	545.00	±92.18	1033.90	±292.53
23	12.88	±1.25	89.50	±3.66	9.75	±1.29	984.75	±92.18	1248.00	±292.53
24	10.78	±1.25	86.75	±3.66	8.60	±1.29	440.25	±92.18	571.30	±292.53
25	13.74	±1.25	85.00	±3.66	10.03	±1.29	595.00	±92.18	832.40	±292.53
26	9.57	±1.25	93.25	±3.66	6.48	±1.29	400.00	±92.18	750.20	±292.53
27	11.84	±1.25	96.00	±3.66	6.73	±1.29	643.50	±92.18	993.20	±292.53
28	12.58	±1.25	84.50	±3.66	10.07	±1.29	400.75	±92.18	936.50	±292.53
29	14.56	±1.25	93.25	±3.66	8.51	±1.29	713.00	±92.18	1663.10	±292.53
30	11.94	±1.25	94.50	±3.66	7.25	±1.29	442.25	±92.18	746.00	±292.53
31	13.51	±1.25	94.00	±3.66	7.90	±1.29	563.75	±92.18	837.50	±292.53
32	10.92	±1.25	84.25	±3.66	8.47	±1.29	636.75	±92.18	1519.50	±292.53
33	11.73	±1.25	88.75	±3.66	9.39	±1.29	643.50	±92.18	1041.30	±292.53
34	13.62	±1.25	84.33	±3.66	12.44	±1.29	775.75	±92.18	2299.20	±292.53
35	11.16	±1.25	90.00	±3.66	9.88	±1.29	411.85	±92.18	1086.60	±292.53
36	12.25	±1.25	84.75	±3.66	11.65	±1.29	575.75	±92.18	1378.60	±292.53

PH, plant height; SD, stem diameter; HD, head diameter; NL, number of leaves; LL, leaf length; LW, leaf width; PL, petiole length; Dayf, days to 50% flowering; NS, number of seeds per head; HS, 100-seed weight; SY, seed yield; SE, standard error.

of seeds per head (NSH), 100-seed weight (HSW), seed yield (SY) and harvest index (HI). Morphological traits were measured on five randomly tagged plants from each plot. The sunflower genotypes were hand-harvested at the stage of physiological maturation when the back of the head had turned from green to yellow and the bracts were turning brown.

Data analysis

In the first step, data were exposed to normality test according to Shapiro wilks test, then analysis of variance and comparison of means were done by SAS version 9.1 software (SAS Institute, Cary, NC). Simple phenotypic correlations were calculated among all studied traits and path coefficient analysis was carried out according to Dewey and Lu (1959) by SPSS version 15.0 software (SPSS/PC-15, SPSS Inc.).

RESULTS AND DISCUSSION

Analysis of variance revealed significant differences among genotypes for the studied traits. High degree of variability was observed among confectionery genotypes in most of the studied traits (Table 1). Plant height ranged

Table 2. Phenotypic correlation coefficients among different characters in confectionery sunflower populations.

	SH	SD	HD	NL	LL	LW	DAYF	HS	NS	WS
SH	1	0.71**	0.48**	0.57**	0.13 ns	0.34**	-0.18*	0.33**	0.40**	0.35**
SD		1	0.59**	0.56**	0.43**	0.54**	-0.07 ns	0.33**	0.43**	0.41**
HD			1	0.5**	0.36**	0.44**	-0.40**	0.63**	0.49**	0.61**
NL				1	0.22**	0.44**	-0.16 ns	0.34**	0.40**	0.30**
LL					1	0.54**	0.16 ns	0.18*	0.03 ns	0.07 ns
LW						1	-0.20*	0.32**	0.24**	0.27**
PL							-0.29**	0.29**	0.33**	0.29**
DAYF							1	-0.40**	-0.25**	-0.36**
HS								1	0.36**	0.62**
NS									1	0.60**
WS										1

PH, plant height; SD, stem diameter; HD, head diameter; NL, number of leaves; LL, leaf length; LW, leaf width; PL, petiole length; Dayf, days to 50% flowering; NS, number of seeds per head; HS, 100-seed weight; SY, seed yield.

Table 3. Direct and indirect effects of agronomic traits on seed yield in confectionery sunflower (*H.annuus* L.) populations.

Character	Correlation coefficient	Direct effect	Indirect effect		
			HD	HS	NS
HD	0.61	0.2		0.224	0.186
HS	0.62	0.357	0.126		0.137
NS	0.60	0.38	0.098	0.128	

HD, head diameter; HS, 100-seed weigth; NS, number of seed per head.

from 149.16 to 215.08 cm, stem diameter from 2.23 to 3.39 cm, head diameter from 12.49 to 20.01 cm, number of leaves from 29.75 to 36.25, leaf length from 20.54 to 30.83 cm, leaf width from 13.34 to 23.31 cm, petiole length from 8.38 to 17.03 cm, days to 50% flowering from 82.50 to 96.50 days, number of seeds per head from 5.37 to 12.77, 100-seed weight from 388.33 to 984.75 g and seed yield from 357.0 to 2299.2 g (Table 1). High and low variability were observed for seed yield and stem diameter, respectively (Table 1).

Correlations coefficient between seed yield and most of the studied characters were positive and highly significant (Table 2). Seed yield was positively and significantly associated with 100-seed weight which is in agreement with the findings of Vanisree et al. (1988), Lal et al. (1997) and Teklewold et al. (2000). The correlation coefficient between head diameter and seed yield was significantly positive. This result is in agreement with the findings of Marinkovic (1992), Sujatha and Nandini (2002) and Singh et al. (1988).

The correlation coefficient between seed numbers per head and seed yield were positive and significant. Patil et al. (1996) reported similar results in oily sunflower types. Positive correlation was reported between seed yield and plant height (Sujatha and Nandini, 2002), stem diameter (Punia et al., 1994), number of leaves (Satisha, 1995), leaf width and petiole length. Ahmad et al. (1991) and Marinkovic (1992) reported strong and positive correlation between 100-seed weight and head diameter. The correlation between seed yield and days to 50% flowering was negative and significant (Table 2).

Based on simple correlation coefficient analysis selection for 100-seed weight, number of seeds per head, head diameter, stem diameter and plant height may bring increase in confectionery sunflower seed yield.

The sample correlations between the yields components were not very informative with respect to determining the functional relation between components from diverse hierarchy. A high or low correlation coefficient between two variables may be due to the effect of a third variable or group of variables (Singh and Chaudhary, 1977; Cruz and Regazzi, 1997; Vencovsky and Barriga, 1992). The analytical method of path coefficients analysis permits the decomposition of the correlations between two variables (X and Y) in a sum of the direct effect of X on Y, and the effects of X on Y via other independent variables.

Path coefficients analysis revealed that number of seed per head followed by 100-seed weight had high positive direct effects on seed yield (Table 3). Numerous researchers (Ahmad et al., 1991; Marinkovic et al., 1992; Patil et al., 1996; Lal et al., 1997; Habib et al., 2006) reported positive direct effects of number of seed per head on seed yield. Patil et al. (1996) reported significant positive

direct effects of 100-seed weight on sunflower seed yield. Indirect effect of seed number per head via 100-seed weight and head diameter were positive (Table 3). The direct effect of head diameter on seed yield were positive (Table 3). Many reasearchers also reported the positive direct effect of head diameter on seed yield in sunflower (Ahmad et al., 1991; Hladni et al., 2006; Kaya et al., 2007; Machicowa and Saetang, 2008, Darvishzadeh et al., 2011). However, in some research works (Alba et al., 1979; Marinkovic, 1992; Habib et al., 2006), head diameter had negative direct effect on seed yield. The indirect effects of head diameter on seed yield via 100-seed weight and number of seed per head were positive.

In order to identify a trait as an indirect selection criterion for seed yield through path coefficient, the trait should have positive direct effect on seed yield as well as significant positive correlation with seed yield (Das and Taliaferro, 2009). Considering the aforementioned results, the number of seed per head can be reliable selection criteria as it has positive significant correlation and considrable direct effect on seed yield.

Conclusion

The number of seed per head, 100-seed weight and head diameter showed positive and significant correlation with seed yield. Number of seed per head had positive and important direct effect on seed yield. Therefore, selection for this trait indirectly affects confectionery sunflower seed yield.

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