Genotypic and Phenotypic Path Analysis in Sunflower (*Helianthus annuus* L.)

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Abstract: Two field experiments were conducted at in two locations, Kafr-El-Hamam Agricultural Research Station and Tag-El-Aiz Agricultural Research Station during the summer seasons of 2011 and 2012, to study the effect of three intra-row plant spacing (20, 25 and 30 cm between hills) on seed yield and its components of eight sunflower genotypes. Also, the associations among seed yield and its components were studied using correlation coefficient and path analysis at the genotypic and phenotypic levels. The used experimental design was a split plot design with three replicates. The three plant spacing were assigned to the main plots while the sub plots were devoted to the tested genotypes. Results showed significant differences among sunflower genotypes and among plant spacing treatments, for all studied characters over locations and seasons. It is noted that increasing intra-row plant spacing to 30 cm between hills (low plant density) led to significant increments for all studied characters, except plant height. The elite genotype No 7 (L_{40}) recorded the maximum values of head diameter, weight of 100 seeds, seed yield and oil yield. As a result of interaction, genotype No 7 (L_{40}) produced the maximum values of head diameter, weight of 100 seeds, seed yield and oil yield when it was grown at 30 cm between hills. Highly significant and positive correlation coefficients were obtained between seed yield and each of plant height, head diameter, weight of 100 seeds and seed weight/plant at the genotypic and phenotypic levels. Path analysis (genotypic and phenotypic) showed that the traits *i.e.* seed weight/plant, seed oil percentage gave the maximum influence directly and indirectly upon seed yield indicating their magnitude as selection criteria to obtain a valuable gain of selection for seed yield in sunflower.

Keywords: Genotypic and phenotypic correlation coefficients, Path analysis, Yield components.

INTRODUCTION

Sunflower (*Helianthus annuus* L.) is considered one of the most important edible oilseed crops after soybean and palm oil in the world. Sunflower breeders' focus their entire attention in developing sunflower genotypes with higher seed and oil yields. Abd EL-Gawad *et al.* (1987) mentioned that Giza 1 cultivar significantly surpassed the other studied genotypes for seed yield, oil yield and head diameter while Zaher el haia cultivar had the heaviest 100 seed weight. Plant density is one of the important factors that influencing seed yield and seed oil percentage in sunflower. Bader *et al.* (1988) found that the highest oil yield resulted from a hill spacing of 30 cm while the lowest was from a hill spacing 15 cm. Allam and Galal (1996) indicated that seed and oil yields, and seed oil percentage were positively correlated with plant density while plant height, head diameter, 100 seed weight and seed weight/plant were negatively associated with plant density.

Oil yield as a polygenic trait is influenced by several characters called oil yield contributing traits. These components are related among themselves and with oil yield either positively or negatively. Therefore, the study of correlation and path analysis provides a better understanding of the association between yield and its related traits. The scientists Fick *et al.* (1974), Skoric (1974), Green (1980) and Hlandi *et al.* (2010) used correlation analysis to study the relationships between oil yield and the other sunflower plant characters. Correlation analysis does not depict the clear picture of complex relationships among the plant traits. The path coefficient analysis is a more precise method divides the direct and indirect effects of independent variables on the dependent variable. This method has been extensively used by the sunflower researchers, among them, Marinkovic (1992), Punnia and Gill (1994), El-Hosary *et al.* (1999) and Hassan *et al* (2013) thy reported different characters as selection criteria for oil yield in sunflower.

The present investigation was planned to study the effect of three plant spacing on oil yield and its components in eight sunflower genotypes. Also, the study aimed to investigate the interrelationships among oil yield attributes using genotypic and phenotypic correlation and path analysis.

MATERIALS AND METHODS

Two field experiments were conducted at both of Kafr-El-Hamam and Tag-El-Aiz Agricultural Research Stations during summer season of 2011 and 2012. The current study was carried out to evaluate the oil yield and its components of eight sunflower genotypes grown under three intra-row plant spacing. Also, to find out the relationships between oil yield and its related characters using two statistical procedures i.e. genotypic and phenotypic correlation and path analysis .

The treatments were arranged in a split plot design with three replications. The three plant spacing between hills 20, 25 and 30 cm were assigned to the main plots while the sub-plats contained tested eight genotypes. The name and origin of the sunflower genotypes are given in Table (1).

Cultural practices:

Each sub-plot consisted of 4 ridges, 3 m length and 0.6 m apart (plot area = 7.2 m^2). The agricultural practices were maintained as recommended for sunflower in the two locations. At harvest, 10 guarded plants were chosen from the inner two ridges to collect data on the following characters:

1- Plant height in cm (PH).
2- Stem diameter in cm (SD).
3- Head diameter in cm (HD).
4- 100-seed weight in gm (100- SW).
5- Seed weight /plant in gm (SW/P).
6- Seed yield kg/fed(SY) was primarily calculated from plot(4.8m) area and then converted to the unit of (kg/fed).
7- Seed oil percentage (Oil %).
8- Oil yield (OY): it was calculated by multiplying seed yield (kg/fed) by seed oil percentage (%).

Table (1): The name and origin of tested sunflower genotypes.

Genotypes		Origin	*Genotypes*		Origin
Sakha 53	(g_1)	Egypt	I_{62}	(g_5)	Bulgaria
Giza 102	(g_2)	Egypt	I_{20}	(g_6)	Bulgaria
I_{92}	(g_3)	Bulgaria	I_{40}	(g_7)	Bulgaria
I_{120}	(g_4)	Bulgaria	I_1	(g_8)	Bulgaria

Statistical analysis:

Data were subjected to combined analysis of variance over growing seasons and locations as outlined by Snedecor and Cochran (1989). Significant differences among treatment means were detected using least significant difference test (LSD) at 5% probability level. On the other hand, Levene test (1960) was applied to examine the assumption of homogeneity of variances before running the combined analysis.

The interrelationships among oil yield and its related traits were studied at the genotypic and phenotypic levels using the following methodologies:

1- Correlation coefficients between all pairs of studied traits were computed as suggested by Johnson *et al* (1955).
2- Path coefficient analysis was carried out as suggested by Wright (1921) and rediscovered by Dewey and Lu (1959). The method permits to separate the genotypic and phenotypic correlation coefficient between the oil yield (as a resultant variable) and each of related traits (as explanatory variables) into direct effect (path coefficient) and indirect effects (that exerted through the other variables).

A BASIC program (Atia, 2007) was used to automate the computations of genotypic and phenotypic correlation coefficients and their corresponding path analyses.

RESULTS AND DISCUSSION

The results of Levene test (1960) proved the homogeneity of variances over growing seasons and locations for all studied characters that permits to apply combined analysis. Accordingly, the mean values of oil yield and its related characters for eight sunflower genotypes as affected by three intra-row plant spacing are presented in Table (2).

Intra-row plant spacing effect:

Results in Table (2) revealed that changing the plant spacing (S) between hills significantly affected all estimated sunflower characters. It is obvious from Table (2) that the mean values of all studied characters, except plant height, increased as the plant spacing increased to 30 cm between hills (low density) compared to 20and 25 cm between hills. Wide intra-row plant spacing (30 cm) recorded the highest values of stem diameter (2.59 cm), head diameter (20.79 cm), 100-seed weight (6.20 g) and seed weight plant (57.15 g), highest seed yield (993.13 kg/fed), seed oil percentage (40.64 %) and oil yield (406.05 kg/fed).

Superiority of wide plant spacing may be ascribed to decrease inter plant competition that leads to increase the plant capacity for utilizing the environmental inputs in building great amount of metabolites to be reflected in more dry matter accumulation and in developing new tissues, consequently increasing most yield components. Accordingly, in the current investigation, the highest values of most yield components achieved under wide plant spacing (30 cm) could compensate the depression in plant density.

However, the tallest plants (178.92 cm) were recorded when the distance between hills was as recommend at 20 cm (normal density). This result may be attributed to the competition among plants for collecting the solar radiation.

The current findings are in agreement with those obtained by Bader and Rashid (1988) who found that highest oil yield was resulted from a hill spacing of 30 cm and the lowest from a hill spacing of 20 cm. However, our results contradicts that reported by Allam and Galal (1996) who indicated that seed and oil yields, and seed oil percentage were positively correlated with plant density but plant height, head diameter, 100 seed weight and seed weight/plant were negatively associated with plant density. The contradiction may be returned to the differences in the breeding materials and the environmental conditions. Al-Thabet (2006) found that plant spacing significantly affected all studied characters except seed oil percentage.

Genotype effects:

It is evident from Table (2) that the differences among tested genotypes were clear and significant for all studied characters indicating wide genetic variation among tested genotypes.

Results displayed that genotype No 4 (I_{120}) had the tallest plants recording (203.60 cm) followed by Sakha 53 (186.17 cm). Considering stem diameter, genotypes No 5 (I_{62}) and No 8 (I_1) recorded the highest values being 2.38 and 2.37 cm, respectively, without significant differences between them.

The elite genotype No 7 (I_{40}) surpassed the two check cultivars (Sakha 53 and Giza 102) recording the maximum values of head diameter (23.52 cm), weight of 100 seeds (7.24 gm), seed yield (1499.24 kg/fed) and oil yield (583.86 kg/fed). The previous result indicated the clear magnitude of genotype (I_{40}) as one of the most promising breeding materials to be used in sunflower development breeding program.

Regarding seed weight/plant, it is obvious that cultivar Sakha 53 significantly surpassed all other genotypes recording (80.69 gm) indicating its magnitude as a important source for this trait. On the other hand, the highest values of seed oil percentage were scored by genotype No 8 (I_1) recording (39.41 %)

followed by genotype No 5 (I_{62}) giving (39.23 %) without significant difference between them. Similar results have been reported by Sharief (1998), Vega *et al.* (2002), Allam *et al.* (2003), and Abdou *et al.* (2011) who found significant differences among tested genotypes of sunflower for seed and oil yields and most studied characters.

Plant spacing x genotype interaction effect:

Results of the effect of interaction between plant spacing and tested genotypes on oil yield and its related characters are displayed in Table (2). Results revealed that all studied characters were significantly affected by plant spacing x genotypes interaction overall locations and years, which indicates to the different behavior of tested genotypes when sowing under narrow or wide intra-row plant spacing.

Genotype No 7 (I_{40}) produced the maximum values of head diameter (25.45 cm), weight of 100 seeds (7.58 gm), seed yield (1565.08 kg/fed) and oil yield (634.11 kg/fed) when it was grown at 30 cm between hills. The highest values of stem diameter were obtained by cultivar Sakha 53, genotypes (I_{62}) and (I_1) when they were grown at 30 cm between hills recording 2.73, 2.74 and 2.76 cm, respectively. The heaviest seed weight/plant (87.86 gm) was produced by planting Sakha 53cultivar at wide plant spacing (30 cm).

Also, the highest seed oil percentage values were exerted by each of (I120) (41.89) and (I62) (42.01) with growing them at 30 cm between hills. However, when genotype No 4 (I120) was grown at narrow space between hills (20 cm), it gave the tallest plants recording (225.12 cm). The current results were in harmony with those obtained by **Robinson et al. (1980)** who reported that sunflower genotypes are differently responded under plant density

Correlation matrix:

Genotypic (above diagonal) and phenotypic (below diagonal) correlation coefficients among oil yield and its related characters are given in Table (3). Generally, there was clear convergence between most genotypic and phenotypic correlation coefficients considering the value or sign indicating that the observed associations among most characters may be mostly attributed to genetic effects.

Results showed that the most effective relationships to sunflower breeder, were those between oil yield and each of plant height (0.39** and 0.37**), head diameter (0.48** and 0.40**), 100-seed weight (0.23* and 0.22*), seed weight/plant (0.89** and 0.88**) at the genotypic and phenotypic levels, respectively. The high positive genotypic correlation between each of the aforementioned characters and oil yield reflected the inherent associations; therefore, the breeder can obtain high yielding genotypes through selection program for one or more of these characters, especially if they proved to be more contributors to yield variation as lately shown.

On the other hand, the yield components exhibited various trends of associations among themselves. There was negative and highly significant genotypic or phenotypic association between plant height and each of stem diameter (-0.32** and -0.27**), head diameter (-0.26** and –0.21*) and weight of 100 seed (-0.35** and -0.33**) while on the reverse, plant height had positive and highly significant genotypic and phenotypic associations with each of seed weight/plant (0.25* and 0.27**) and seed oil percentage (0.28** and 0.37**). However, stem diameter was found to be highly significant and positively correlated with head diameter (0.75** and 0.62**) while it significantly and negatively associated with seed oil percentage (-0.24* and -0.22*), at the genotypic and phenotypic, respectively.

The phenotypic correlation between head diameter and weight of 100 seeds was significant and positive with r values being (0.24*). The same result hold true at the genotypic level. Seed weight/plant gave highly significantly and positively correlated with each of head diameter (0.47** and 0.41**) and 100 seed weight (0.29** and 0.28**), at the genotypic and phenotypic levels, respectively.

At the genotypic level, the seed oil percentage exhibited negative association with each of weight of 100 seed and seed weight/plant with(r) values of 0.23* and 0.29**, respectively. Similar result was obtained at the phenotypic level. On the other hand, the remainder correlation coefficients among studied characters were negligible and insignificant.

Generally, the highly significant positive genotypic relationship between any characters indicates that the improvement predicted under selection for one of them, would automatically extended to the other.

These findings are in conflict with those obtained by(Hladni *et al* 2010) who found highly significant and negatively associations between stem diameter, total leaf area, head diameter and 1000 seed weight on one side and seed oil content on the other. This discrepancy in results may be attributed to the used breeding materials and the environmental conditions.

In fact, selection decisions based only on correlation coefficients may not always be effective because it measures the mutual association between a pairs of traits neglecting the complicated interrelationships among all traits (Kang, 1994). Therefore, the correlation procedure may not provide a deep imagine about the importance of each component in the structure of oil yield. The path analysis can efficiently play this vital role.

Path analysis:

Information obtained from correlation coefficients can be augmented by partitioning the correlations into direct and indirect effects for a given set of causal interrelationships. In such situations, the correlation coefficients may be confounded with indirect effects due to common association inherent in trait interrelationships. So, path coefficient analysis has proven useful in providing additional information that describes the casual relationships such as yield and its components.

Table (2): Mean values of oil yield and related characters in sunflower as affected by plant spacing , genotypes and their interaction (combined over years and locations).

Treatment		Characters							
		PH	SD	HD	100-SW	SW/P	SY	Oil %	OY
Plant spacing									
20 cm		178.92	1.55	17.37	5.34	48.06	802.38	33.25	267.07
25 cm		169.18	1.98	19.36	5.84	52.01	890.83	35.30	314.81
30 cm		157.08	2.59	20.79	6.20	57.15	993.13	40.64	406.05
LSD at (5 %)		1.30	0.05	0.26	0.05	0.55	31.78	0.33	10.00
Genotypes									
Sakha 53		186.17	2.00	19.85	4.70	80.69	1210.87	33.30	413.35
Giza 102		161.20	1.49	17.20	6.55	52.29	890.54	31.96	289.88
I_{92}		155.70	1.73	16.27	7.11	47.52	808.37	34.87	287.31
I_{120}		203.60	1.92	18.05	5.57	54.97	1025.17	37.00	386.33
I_{62}		169.86	2.38	20.10	6.47	50.84	772.55	39.23	304.68
I_{20}		163.79	2.25	18.80	4.47	32.35	330.20	36.53	121.39
I_{40}		147.62	1.20	23.52	7.24	62.51	1499.24	38.87	583.86
I_{1}		159.21	2.37	19.61	4.22	38.05	626.65	39.41	247.67
LSD at (5 %)		1.90	0.06	0.53	0.07	1.02	48.26	0.44	13.04
Interaction									
20 cm	**Sakha 53**	201.28	1.33	17.75	4.11	74.92	1057.56	28.74	305.28
	Giza 120	170.18	1.05	15.77	5.91	49.22	775.94	27.65	215.33
	I_{92}	164.75	1.30	15.12	6.42	45.17	700.53	29.54	208.13
	I_{120}	225.12	1.36	16.85	5.44	52.50	839.90	31.97	269.3
	I_{62}	176.59	1.96	18.04	6.06	44.17	718.26	37.43	269.45
	I_{20}	171.9	1.82	17.15	4.05	30.81	297.61	35.22	105.06
	I_{40}	154.97	1.65	20.92	6.93	52.94	1433.03	37.47	537.24
	I_{1}	166.56	1.92	17.34	3.81	34.72	596.2	38.00	226.72
25 cm	**Sakha 53**	190.56	1.95	20.00	4.71	79.29	1171.35	30.18	356.19
	Giza 120	161.80	1.29	16.98	6.67	52.38	885.77	29.21	259.42
	I_{92}	156.54	1.45	16.26	7.23	47.63	785.88	34.12	268.70
	I_{120}	203.51	1.74	18.13	5.56	51.81	1070.28	37.14	399.58
	I_{62}	170.95	2.44	20.63	6.52	53.33	773.13	38.24	296.59
	I_{20}	161.96	2.30	19.01	4.60	32.72	326.25	35.56	116.19
	I_{40}	148.11	2.26	24.19	7.23	63.53	1499.62	38.65	580.22
	I_{1}	160.03	2.43	19.71	4.17	35.36	614.39	39.28	241.59
30 cm	**Sakha 53**	166.67	2.73	21.78	5.27	87.86	1403.71	40.99	578.56
	Giza 120	151.62	2.13	18.86	7.07	55.27	1009.91	39.01	394.90
	I_{92}	145.83	2.43	17.42	7.69	49.77	938.69	40.93	385.11
	I_{120}	182.18	2.66	19.17	5.71	60.61	1165.34	41.89	490.12
	I_{62}	162.03	2.74	21.63	6.82	55.02	826.26	42.01	348.00
	I_{20}	157.50	2.62	20.25	4.76	33.54	366.73	38.82	142.91
	I_{40}	139.77	2.67	25.45	7.58	71.06	1565.08	40.48	634.11
	I_{1}	151.05	2.76	21.77	4.68	44.06	669.35	40.97	274.71
LSD at (5 %)		3.30	0.10	0.92	0.13	1.76	83.58	0.75	22.59

Table (3): Genotypic (above diagonal) and phenotypic (below diagonal) correlation coefficients among oil yield and its related characters in sunflower (combined over the four environments).

Characters	PH	S D	H D	100-SW	SW/P	Oil %	OY
PH		-0.32**	-0.26**	-0.35**	0.25*	0.28**	0.39**
Stem D	-0.27**		0.75**	0.06	0.15	-0.24*	0.02
Head D	-0.21*	0.62**		0.24*	0.47**	-0.03	0. 48**
100-SW	-0.33**	0.06	0.21*		0.29**	-0.23*	0.23*
SW/P	0.24*	0.15	0.41**	0.28**		-0.29**	0.89**
Oil %	0.27**	-0.22*	-0.02	-0.23*	-0.28**		0.17
Oil Y	0.37**	0.02	0.40**	0.22*	0.88**	0.19	

* and **: Significant and highly significant at 0.05 and 0.01 probability levels, respectively.

In the present investigation, the resultant variable was oil yield while the remaining characters represented the casual variables. The matrix of direct and joint effects six predictor characters on oil yield is shown in Table (4).

Positive direct effects were recorded for all oil yield characters except stem diameter which had negative genotypic (-0.08) and phenotypic (-0.04) path coefficients. The maximum direct effects were observed for seed weight/plant (0.95 and 0.98) followed by the seed oil percentage (0.43 and 0.46) considering the genotypic and phenotypic levels, respectively.

In fact, the path analysis gave different picture from what the correlation coefficient did. For example, the simple correlation coefficients (genotypic and phenotypic) between oil yield and each of plant height and head diameter were positive and highly significant (Table 3). When the indirect effects are separated from correlation coefficients, however, the path analysis revealed that both plant height and head diameter had trivial effect on oil yield (Table 4).

Considering the great components of the indirect effects, it is noted that the characters of plant height, stem diameter, head diameter, 100 seed weight had large positively indirect effects on oil yield through only their genotypic and phenotypic associations with seed weight/plant. Meanwhile, a strong negative influence on oil yield was indirectly recorded by seed weight/plant *via* seed oil percentage, whether at the genotypic (-0.130) and phenotypic (-0.127) levels. On the contrary, negative genotypic (-0.30) and phenotypic (-0.273) indirect effects of seed oil percentage were observed through seed weight/plant.

The previous result proves the compensation effect between seed weight/plant and seed oil percentage. Therefore, plant breeder must be cautioned and take these relationships into consideration when conducting the selection program. The remainder indirect effects were very small and low important. An overall view on the results of path analysis, it is revealed that the traits *i.e.* seed weight/plant and seed oil percentage gave the maximum influence directly and indirectly upon oil yield in sunflower, at the genotypic and phenotypic levels. Therefore, the breeder can obtain high yielding genotypes through selection program for these characters, especially if they proved to be more contributors to yield variation as lately shown.

Similar results were reported by Bunnia and Gill (1994), El-Hosary *et al.* (1999), Hladni et al (2010) and Hassan *et al* (2013) who confirmed the importance of path analysis when deciding upon selection criteria using yield components.

The relative importance (RI %) according to genotypic and phenotypic path analysis are presented in Table (5). It is evident that the most oil yield variation (genotypic and phenotypic) was explained by the direct effects for seed weight/plant (56.84 and 62.16) followed by the seed oil percentage (11.64 and 13.40).

Also, the great genotypic and phenotypic components of joint effects were expressed by head diameter on oil yield via its association with seed weight/plant (5.38 and 1.47), weight 100 seeds via seed weight/plant (2.0 and 2.0), and seed weight/plant through seed oil percentage that recorded the highest indirect effect values being (15.13 and 16.17).

Trivial values of relative importance were observed for the other direct and indirect effects. Totally, the studied five characters explained 99.22 and 98.92 % of oil yield variation at the genotypic and phenotypic levels, respectively. In accordance, the residual part may be attributed to unknown variation (random error), committing of errors during measuring the studied characters and/or some other traits that were not incorporated in the present investigation.

In conclusion, among the studied characters, seed weight/plant and seed oil percentage were the most reliable oil yield components as selection criteria in sunflower breeding programs. The two characters had highly significant and positively correlation coefficients with oil yield as well as their influences whether directly or indirectly on oil yield were positive and the highest over the other yield attributes.

Table (4): The direct and indirect effects of six predictor characters on oil yield at genotypic and phenotypic levels in sunflower (combined over the four environments).

Characters	Level	Pathways						
		Direct effect	Indirect effects					
			PH	S D	H D	100-SW	SW/P	Oil %
PH	G	**0.05**		0.03	-0.02	-0.02	0.24	0.12
	Ph	**0.03**		0.01	-0.006	-0.019	0.23	0.124
Stem D	G	**-0.08**	-0.02		0.07	0.003	0.14	-0.10
	Ph	**-0.04**	-0.007		0.018	0.003	0.147	-0.102
Head D	G	**0.09**	-0.01	-0.06		0.01	0.45	-0.01
	Ph	**0.03**	-0.006	-0.023		0.012	0.401	-0.009
100-SW	G	**0.06**	-0.02	-0.004	0.02		0.27	-0.10
	Ph	**0.06**	-0.009	-0.002	0.006		0.272	-0.104
SW/P	G	**0.95**	0.01	-0.01	0.05	0.02		-0.13
	Ph	**0.98**	0.006	-0.006	0.012	0.016		-0.127
Oil %	G	**0.43**	0.01	0.02	-0.003	-0.01	-0.30	
	Ph	**0.46**	0.007	0.008	-0.001	-0.013	-0.273	

Residual effect = 0.126.

Table (5): The coefficient of determination and relative importance (RI %) for six predictor characters on oil yield at genotypic and phenotypic levels in sunflower (combined over the four environments).

Characters		CD Genotypic	CD Phenotypic	RI % Genotypic	RI % Phenotypic
Direct effect:					
Plant height (X_1)		0.003	0.001	0.164	0.047
Stem diameter (X_2)		0.006	0.001	0.378	0.087
head diameter (X_3)		0.009	0.001	0.565	0.052
100-seed weight (X_4)		0.003	0.003	0.216	0.211
Seed weight/plant (X_5)		0.899	0.963	56.84	62.157
Oil % (X_6)		0.184	0.208	11.64	13.409
Total (direct)		1.104	1.177	69.803	75.963
Indirect effects:					
Plant height (X_1) *via*	X_2	0.003	0.001	0.159	0.034
	X_3	-0.002	0.0001	0.156	0.021
	X_4	-0.002	-0.001	0.132	0.066
	X_5	0.024	0.012	1.526	0.806
	X_6	0.012	0.007	0.779	0.435
Stem diameter (X_2) *via*	X_3	-0.011	-0.001	0.695	0.083
	X_4	-0.001	0.0001	0.032	0.015
	X_5	-0.021	-0.011	1.353	0.697
	X_6	0.016	0.007	1.019	0.483
Head diameter (X_3) *via*	X_4	0.003	0.001	0.170	0.043
	X_5	0.085	0.023	5.381	1.468
	X_6	-0.002	-0.001	0.154	0.033
100-seed weight (X_4) *via*	X_5	0.032	0.031	2.002	2.007
	X_6	-0.012	-0.012	0.741	0.767
Seed weight/plant (X5) *via*	X_6	-0.239	-0.249	15.125	16.052
Total (indirect)		-0.115	-0.1928	29.424	23.01
Total (direct+indirect)		0.989	0.9842	99.227	98.97
Residuals		0.011	0.0158	0.773	1.03
TOTAL		100	100	100	100

*The underline cells indicate to the highest values.

REFERENCES

Abd-EL-Gawad, A. A., M. A. Ashoub, S. A. Saleh and M. M. El-Gazzar (1987). Yield response of some sunflower cultivars to irrigation intervals. Annals Agric. Sci., fac. Agric., Ain Shams Univ., 32(2): 1229-1242.

Abdou, S. M. M., K. M. Abd El-Latif, R. M. F. Farrag and K. M. R. Yousef (2011). Response of sunflower yield and water relations to sowing dates and irrigation scheduling under middle Egypt condition. Adv. Appl. Sci.Res., 2(3): 141-150.

Allam A. Y., G. R. El-Nagar and A. H. Galal (2003). Response of two sunflower hybrids to planting dates and densities. Acta Agro. Hung., 51(1): 25-35.

Allam, A.Y. and A. H. Galal (1996). Effect of Nitrogen Fertilization and Plant Density on Yield and Quality of Sunflower. Assiut J. Agric. Sci., 27, No. 2, 169-177.

Al-Thabet, S. S. (2006). Effect of plant spacing and nitrogen levels on growth and yield of sunflower (*Helianthus Annuus* L.). J. king. Saud Univ. Agric, sci., 19: 1-11.

Atia, A. A. M. (2007). Pathca: A basic program for estimating phenotypic, genotypic and environmental path coefficient, an application on maize. The 42nd Annual Conf. of Statistics, Computer Sciences and Operation Research, Institute of Statistical Studies and Research. Cairo Univ., 76-87, Egypt, 2-5 December.

Bader, A. M. and A. H. Rashid (1988). Effect of plant spacing and nitrogen fertilizer levelson growth and yield of sunflower. I. yield and yield components. Iraqi J. Agric. Sci., ZANCO, 6(4): 163-175.

Dewey, D. R. and K. H. Lu (1959). A correlation and path coefficient analysis of components of crested wheat grass seed production. Agron. J. 51: 515-518.

El-Hosary, A., B. El-Ahmar and A. E. El-Kasaby (1999). Association studies in sunflower. Helia, 22 (special issue) : 561-567.

Fick, G. N., D. C. Zimmer and D. C. Zimmerman (1974). Correlation of seed oil content in sunflower with other plant and seed Characteristics. Crop Sci., 14: 755–757.

Green, V. E. (1980). Correlation and path analysis of the components of yield in sunflower cultivars: (*Helianthus annuus* L.). In: Proc. of the 9th Int.

Sunflower Conf., pp: 12–21. June, 8-13, 1980. Terremolinos-Malage, Spain.

Hassan, S. M., M. S. Iqbal, G. Rabbani, N. Alddin, G. Shabbir. M. Riaz and I. R. Noorka (2013). Correlation and path analysis for yield and yield components in sunflower (*Helianthus annuus* L.). African J. Biotech., 12: 1968-1971.

Hlandi, N., S. Jocic, V. Miklic, A. Mijic, D. Saftic, D. pankovic and D. Skoric (2010). Effect of morphological and physiological traits on seed yield and oil content in sunflower. Helia, 33: 101-116.

Johnson, H. W., H. F. Robinson and R. E. Comstock (1955). Estimation of genetic and environmental variability in soybean. Agron. J. 47:314-318.

Kang, M. S. (1994). Applied Quantitative Genetics. Kang publ. Baton Rouge, LA, USA.

Levene, H. (1960). Robust tests for equality of variances. In Ingram Olkin, Harold Hotel ling, Italia, Stanford, Univ. Press, PP. 278- 292.

Marinkovic, R. (1992). Path-coefficient analysis of some yield components of sunflower. Euphytic, 60: 201–205.

Punnia, M. S. and H. S. Gill (1994). Correlations and path-coefficient analysis for seed yield traits in sunflower (Helianthus annuus L.). Helia, 17:7–12.

Robinson, R. G., J. H. Ford, W. E. Lues, D. L. Rabas, I. J. Smith, D. D. Warnes and J. V. Wier Sma (1980). Response of sunflower to plant population. Agron. J., 72:869-871.

Sharief, A. E. (1998). Productivity of some introduced sunflower cultivars as affected by planting date and plant population distance. Zagazig J. Agric. Res., 25:895-909.

Skoric, D. (1974). Correlation among the most important characters of sunflower in F_1 generation. In: Proc. 6th Intl. Sunflower Conf., Bucharest, Romania, 22-24 July. Intl. Sunflower Assoc., paris, Francel:283-289.

Snedecor, G. W. and W. G. Cochran (1989). Statistical Methods. 8th Ed., Iowa State Univ. Press, Ames Iowa, USA.

Vega, A. J., A. J. Hall, A. J. Vega (2002). Effects of planting date, genotype and their interactions on sunflower yield. II. Components of oil yield. Crop Sci., 42: 1202-1210.

Wright, S. (1921). Correlation and causation. J. Agric. Res. 20: 557-585.

تحليل معامل المرور الوراثى و المظهري في محصول زهرة الشمس

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** المعمل المركزى لبحوث التصميم و التحليل الاحصائى– مركز البحوث الزراعية.

يهدف هذا البحث الى دراسة تأثير ثلاثة من المسافات بين النباتات (٢٠ و٢٥ و٣٠ سم) على المحصول ومكوناته لثمانية تراكيب وراثية من محصول زهرة الشمس. ولتحقيق هذا الهدف أجري هذا البحث خلال عامى ٢٠١١ و ٢٠١٢ حيث تم تنفيذ تجربتين حقليتين في الموسم الصيفي بمحطة البحوث الزراعية بكفر الحمام و محطة البحوث الزراعية بتاج العز وذلك باستخدام تصميم القطع المنشقة فى ثلاثة مكررات حيث وزعت معاملات المسافات بين النباتات فى القطع الرئيسية بينما وزعت التراكيب الوراثية فى القطع الشقية. كما تم دراسة العلاقات المتداخلة بين محصول الزيت و باقى الصفات المدروسة باستخدام معامل الارتباط البسيط الوراثى والمظهرى والذى استخدم فى تحليل معامل المرور وذلك لتقدير الاهمية النسبية للصفات المحصولية الاكثر تاثيرا فى محصول الزيت.

وتتلخص اهم النتائج المتحصل عليها فيما يلى:

اظهرت النتائج ان زراعة نباتات زهرة الشمس على مسافة ٣٠ سم قد ادى الى زيادة معنوية فى جميع الصفات تحت الدراسة عدا صفة طول النبات والتى سجلت اعلى اطوال للنباتات عند الزراعة على مسافة ٢٠ سم.

كانت هناك فروقا معنوية بين التراكيب الوراثية المختبرة لجميع الصفات تحت الدراسة حيث اعطى التركيب الوراثي I_{40} أعلى قيمة لكل من قطر القرص و وزن ١٠٠ بذرة و محصول البذرة و محصول الزيت مما يشير الى تفوقه و كونه من التراكيب الوراثية المبشرة التي يوصى بالتوسع في استخدامها في برامج تربية محصول زهرة الشمس.

اشارت النتائج الى تأثر جميع الصفات المدروسة بالتفاعل بين عاملي المسافات بين النباتات و التراكيب الوراثية حيث كانت هناك زيادة معنوية لصفات قطر القرص و وزن ١٠٠ بذرة و محصول البذرة و محصول الزيت عند زراعة نباتات التركيب الوراثي I_{40} على مسافة ٣٠ سم.

اظهرت النتائج وجود علاقة ارتباط موجبة , عالية المعنوية بين محصول الزيت و كل من صفة طول النبات ، قطر القرص و وزن ١٠٠ بذرة وكذا وزن بذور النبات و ذلك على المستوى الوراثى أو المظهرى.

أوضحت نتائج تحليل معامل المرور ان صفتى وزن بذور النبات و نسبة الزيت كانت هما الاكثر إسهاما فى محصول الزيت سواء عن طريق التأثير المباشر او غير المباشر (وراثيا و مظهريا) مما يشير إلى أهمية وضع هاتين الصفتين فى الاعتبار من قبل المربى عند وضع برامج التربية لتحسين محصول الزيت في نبات زهرة الشمس.