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GENE ACTION AND COMPARISON BETWEEN HALF DIALLEL ANALYSES METHODS UNDER SALINE SOIL STRESS CONDITIONS IN SUNFLOWER

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A B S T R A C T

A half diallel cross between five parental sunflower genotypes was evaluated under two contrasting locations of Kafr El-Hamam and Tag Al-Ezz replications. Highly significant genotypes and their components mean squares Agricultural Research Stations using randomized complete block design with three were detected for all studied traits at both and cross locations. Variance of additive, non-additive and experimental error for all studied traits computed by Griffing (1956), Gardner and Eberhart (1966) and (Jones, 1965) was numerically identical; and it was confirmed by F. test. Whereas, Hayman's analysis differed from the other analyses. Selection in early generations would be effective for improving days to 50 % flowering, days to physiological maturity, plant height, head diameter, No. of green leaves plant^{-1} and seed oil content, but the remaining traits showed an opposite trend. The parent L_{125} behaved as the best combiners for seed weight plant^{-1} and one or more of its components. The cross L_{460} χ L_{335} was found to be superior and exhibited highest SCA effects and heterosis for seed weight/plant and one or more of its attributes.

Keywords: sunflower (*Helianthus annuus* L.), half diallel analyses, superior parents and crosses, gene action, salinity.

INTRODUCTION

Sunflower is considered a medium salt tolerant crop and appears to be well adapted for growth under moderately saline soil conditions (Francois, 1996). To be able to improve salt tolerance in sunflower, sunflower breeder should first be able to create genetic variability with a high degree of salt tolerance. For this purpose, improving salt tolerance of sunflower depends on precise estimates of genetic control that have been derived from the plant material developed by crossing the selected parents according to diallel crossing system. Little information however is available about comparing and relative efficiency of half diallel analyses methods. Thus, several methods have been devised for analyzing half diallel data to estimate the genetic components in plant populations. Of these, Griffing method used the half diallel analysis for combining ability (Griffing, 1956), while (Gardner and Eberhart, 1966) using the set-up multiple regression approach, partitioning heterosis in terms of average, general and specific heterosis effects. Jones (1965) extended the analysis of variance of full a diallel table to half a diallel table. The best-known methods for diallellic analysis are those developed by Hayman which include numerical and graphical analyses (Hayman 1954 a &b).

The objectives were (1) to identify relative efficiency of half diallel analyses methods, (2) identify suitable method will be effective for improving studied traits and (3) to find out superior parent with good *per se* performance and combining ability, and superior cross with good *per se* performance, specific combining ability and heterosis.

MATERIALS AND METHODS

A half diallel set of 10 crosses was made from five widely genetic divergent inbred lines of sunflower (*Helianthus annuus* L.) designated as L_{460} (P_1), L_{770} (P_2), L_{125} (P_3), L_{335} (P_4) and $Sakha_{53}$ (P_5) during summer season 2013. In evaluated season 2014, the 10 F_1 crosses and their five parents were sown at two locations that differed in their soil salinity degrees. Since, Kafr El Hamam Agricultural Research station considered as a control and Tag Al Ezz one as a salt affected soil. Prior to the commence of experiments, soil samples from each location were obtained with an auger from soil depths of 0-60 cm to determine soil characteristics across locations (Table 1.)

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Table 1. Soil texture, pH, organic matter, EC, salt concentration in soil, latitude and longitude of field stations

Growing season (summer)	Research station	Soil texture	pH	Organic mature (g/kg)	EC (dsm^{-1})	Salt concentration in soil (ppm)	Latitude	Longitude
2014	Kafr El Hamam	Sand silty loam	7.9	1.85	1.93	1235.2	30^o 58\	31^o 50\
2014	Tag Al Ezz	Clay	7.7	1.32	5.3	3392.0	31^o 36\	30^o 57\

Each experiment was arranged in randomized complete block design with three replicates. Each plot consisted of two ridges of five meters length and 60 cm width. Hills were spaced at 30 cm with three seeds per hill on one side of the ridge. The seedlings were thinned to one plant per hill. The cultural practices were followed as recommended by Oil Crops Research Department, FCRI, ARC, Egypt. Ten competitive plants were randomly taken from each plot to measure plant height (cm), number of green leaves $plant^{-1}$, head diameter (cm), 100-seed weight (g) and seed weight $plant^{-1}$ (g) which was adjusted at 15.5% seed moisture. Seed oil content was determined, after drying at 70 ºC for 48 h (Billsborrow et al. 1993), by Soxhlet extraction technique, using diethyl ether, as reported by AOAC methods (AOAC, 1990). Days to 50% flowering and days to physiological maturity were measured on all plants in plot basis.

Statistical analysis: Analysis of variance was performed for each location as well as for combined data after Bartlett's test for homogeneity of errors across locations as cited by Steel et al. (1997). Heterosis was determined for individual hybrids as the percentage deviation of F_1 means performance from either mid parents or better parents values at both locations. The level of dominance (Potence ratio) calculated using Petr and Frey (1966) formula: $P = (F_1\text{-MP}) / (\text{HP-MP})$. Based on the P value, the degree of dominance is classified as: P = 0 there is no dominance; P = 1 or P = -1 dominant or recessive is full; 0 <P <1 the dominant partial; -1 <P <0 recessive partial; P> 1 or P <-1 over-dominance. The analysis of general and specific combining ability was done according to method 2 model 1 of Griffing (1956). The combining ability ratio was calculated according to Baker (1978) as follow: $2MS_{gca}/(2MS_{gca}+ Ms_{sca})$. Hayman analysis of variance (ANOVA) was computed according to Hayman (1954 a) following Jones (1965) modification. Validity of assumptions in Hayman (1954 a & b) and Jinks (1954) model was tested using two scaling test i.e. uniformity of Wr-Vr (t^2 test) and regression analysis of Wr/Vr. A graphical analysis (Hayman 1954 a, and Jinks 1954) was performed to determine the frequency of dominant and recessive alleles in the parental sunflower genotypes evaluated at the two locations. Genetic components along with related genetic parameters were estimated according to Hayman (1954b). The variance ratio, F, was used to test the statistical equality i.e. homogeneity of variances additive, non additive types of gene action and M.S. error as follows: F = Greater mean square (variance) /smaller mean square (variance). Which, compared with the calculated value with df_1 for greater variance and df_2 for smaller variance.

RESULTS AND DISCUSSION

Genetic variance: The analysis of variance for all studied traits at both locations as shown in Table (2) revealed highly significant differences among populations whether genotypes, parents, crosses or parents *vs.* crosses, indicating existence of adequate magnitude of genetic diversity among these ones which allows to improve these traits, and is essential for diallel cross design to (Hayman 1954). Similar results were reported by Alza and Fernandez-Martinez, 1997 and Abd EL-Satar et al. 2015.

To compare among half diallel analyses methods, the analysis of data were conducted using Griffing method 2 model 1 (1956), Gardner and Eberhart (1966) and Jones (1965) as shown in Table (2) as well as Hayman's numerical analysis (Table 4) and Hayman's graphical analysis (Figure 1a-8b).

General, specific combining ability and error of Griffing (1956)'s analysis were identical with those of varieties, heterosis and error in Gardner and Eberhart (1966)'s analysis and additive effect (a), dominance effect (b) and error in Jones (1965)'s analysis for both and cross locations (Table 2 and 3). While, the Hayman's analysis differed from the previous analyses for additive (D), dominance (H_1) and environmental error (E) in the most traits at both locations (Table 4).

Furthermore, as shown in Table (2 and 3) three heterosis components i.e. average heterosis, variety heterosis and specific heterosis often referred to as Gardner and Eberhart (1966)'s analysis were numerically identical with those of b_1, b_2 and b_3 in Jones analysis for all studied traits at both and cross locations. For average heterosis variance or parents *vs.* crosses was highly significant for all studied traits at both and cross locations, indicating presence of adequate genetic diversity among the parental array which resulted in valuable heterosis in the first generation hybrids. To judge overall contribution of a variety or a parent to its array heterosis or variety heterosis was estimated. Highly significant of variety heterosis variance was detected for all studied traits at both and cross locations, exhibiting the diversities among the parental arrays for the heterosis. With respect to portion of specific heterosis variance as an indicator to importance of total heterosis of the crosses, was highly significant for all traits at both and cross locations, explained that contribution of average, variety and specific heterosis in heterosis of a cross. This result corroborates with the findings of Kaya and Atakisi (2004), Mijic et al. (2008), Machikowa et al. (2011) and Abd EL-Satar et al. 2015.

Table 2. Half diallel's analyses for studied traits at Kafr El-Hamam (K) and Tag Al-Ezz (T) in season 2014

S.O.V	d.f	Days to 50%flowering		Days to physiological maturity		Plant height		No. of green leaves/plant	
		K	T	K	T	K	T	K	T
Genotypes	14	37.28**	40.15**	158.26**	154.91**	481.93**	473.37**	54.10**	53.07**
Parents (P)	4	79.77**	82.23**	290.27**	290.73**	942.69**	844.06**	55.77**	53.67**
GCA V_i a	4	23.64**	25.33**	130.24**	126.30**	363.63**	308.46**	24.03**	25.96**
Cross (C)		18.09**	18.97**	79.37**	71.76**	274.59**	295.45**	16.67**	19.28**
SCA h_{ij} b	10	7.94**	8.61**	21.76**	21.77**	79.45**	97.52**	15.64**	14.38**
P *vs* C h\ b_1	1	13.33**	20.83**	113.43**	120.00**	168.35**	197.29**	128.13**	118.27**
h_j b_2	4	9.03**	10.33**	9.49**	9.97**	37.97**	40.92**	4.14**	3.98**
(Sij\ b_3	5	5.99**	4.78**	13.24**	11.57**	94.86**	122.84**	2.34**	1.92**
Error	28	0.36	0.25	0.36	0.59	3.36	3.90	0.37	0.48
Baker ratio		0.86	0.85	0.92	0.92	0.90	0.86	0.75	0.78

S.O.V	d.f	Head diameter plant^{-1}		Hundred seed weight		Seed weight plant^{-1}		Seed oil content	
		K	T	K	T	K	T	K	T
Genotypes		51.50**	35.42**	2.08**	1.09**	66.457**	59.547**	18.84**	22.50**
Parents (P)		35.42**	29.49**	1.17**	0.73**	28.765**	24.383**	17.97**	21.85**
GCA V_i a	4	21.93**	22.45**	0.51**	0.44**	6.46**	7.59**	11.08**	13.19**
Cross (C)		22.21**	25.49**	1.11**	0.63**	18.567**	17.226**	16.73**	18.51**
SCA h_{ij} b	10	15.26**	7.55**	0.77**	0.33**	28.43**	24.75**	4.36**	5.23**
P *vs* C h\ b1	1	126.49**	49.49**	4.83**	2.24**	216.08**	193.70**	13.78**	20.34**
h_j b2	4	1.78**	1.61**	0.19**	0.12**	5.38**	2.07**	3.00**	2.95**
Sij\ b3	5	3.80**	3.91**	0.42**	0.12**	9.34**	9.11**	3.57**	4.03**
Error	28	0.11	28	0.01	0.01	0.43	0.79	0.15	0.17
Baker ratio		0.74	0.86	0.57	0.73	0.31	0.38	0.84	0.83

[GCA] General and [SCA] Specific combining ability, [Vi] Varieties, [hij] Heterosis, [h\] Average heterosis, [hj] Variety heterosis, [Sij\] Specific heterosis, [a] additive effects, [b] total non-additive (dominance) effects, [b1] mean deviation of F1's from their mid-parents, [b2] test if there is equal or unequal distribution among parents and [b3] detect existence of unique dominance of each F1

Moreover, highly significant mean squares due to location and their interaction with genotypes, parents, hybrids, parents *vs.* crosses were detected for all studied traits (Table 3), indicating that location had sufficient environmental variability resulted in fluctuations in all population components ranking.

Again, the interactions of locations with both types of combining ability for Griffing method-2 were numerically identical and highly significant with those of a (Jones, 1965) and Varieties (Gardner and Eberhart, 1966) for all tested traits (Table 3), reflecting the highly significant environment effect on both types of gene action either additive or non additive ones. Highly significant mean square due to interaction of b_l (Jones, 1965) and Average heterosis (Gardner and Eberhart, 1966) components with location were only detected for head diameter and hundred seed weight, indicating that mean deviation of the F1's from their mid parental values for two traits was probably affected by variations between soil types and climate conditions at each location. However, the other traits showed insignificant interaction mean squares of location with b_l (Jones, 1965) and Average heterosis (Gardner and Eberhart, 1966), indicating that these components were stable cross two locations.

Table 3. Half diallel's analyses of studied traits across Kafr El-Hamam and Tag Al-Ezz in season 2014.

S.O.V.			d.f	Days to 50% flowering	Days to physiological maturity	Plant height	No. of green leaves plant^{-1}
Location (L)			1	1166.40**	528.04**	2791.13**	237.49**
Genotypes (G)			14	19.19**	78.21**	237.00**	26.72**
G χ L			14	58.24**	234.96**	718.30**	80.45**
Parents (P)			4	40.20**	145.14**	445.91**	27.30**
GCA	V_i	a	4	48.89**	256.43**	670.70**	49.95**
P χ L			4	121.80**	435.86**	1340.83**	82.13**
GCA χ L	(V_i) χ L	a χ L	4	0.08	0.11	1.39	0.04
Crosses (C)			9	9.18**	37.71**	140.06**	8.90**
SCA	h_{ij}	b	10	16.27**	43.42**	174.12**	29.90**
	h\	b_1	1	33.75**	233.38**	365.07**	246.31**
	h_j	b_2	4	18.87**	19.36**	76.26**	7.99**
	S_{ij}\	b_3	5	10.69**	24.68**	214.23**	4.14**
C χ L			9	27.88**	113.42**	429.97**	27.04**
SCA χ L	h_{ij} χ L	b χ L	10	0.28	0.11	2.85	0.12
	h\ χ L	b_1 χ L	1	0.42	0.05	0.57	0.10
	h_j χ L	b_2 χ L	4	0.50	0.10	2.63	0.13
	S_{ij}\ χ L	b_3 χ L	5	0.07	0.13	3.48	0.11
P χ C			1	25.31**	175.03**	273.80**	184.73**
P χ C χ L			1	77.19**	525.24**	823.12**	554.49**
Error			56	0.92	1.44	10.89	1.27
S.O.V.			d.f	Head diameter plant^{-1}	Hundred seed weight	Seed weight plant^{-1}	Seed oil content
Location (L)			1	853.16**	143.01**	871.298**	61.64**
Genotypes (G)			14	20.93**	0.74**	31.261**	10.27**
G χ L			14	65.99**	2.44**	94.743**	31.07**
Parents (P)			4	16.06**	0.44**	13.067**	9.88**
GCA	V_i	a	4	43.70**	0.94**	14.01**	24.16**
P χ L			4		1.45**	40.081**	29.94**
GCA χ L	V_i χ L	a χ L		0.68**	0.01.	0.04	0.10
Crosses (C)			9	11.49**	0.38**	8.698**	8.77**
SCA	h_{ij}	b	10	21.58**	1.00**	52.75**	9.51**
	h\	b1	1	167.11**	6.82**	409.47**	33.80**
	h_j	b2	4	2.73**	0.26**	6.82**	5.91**
	S_{ij}\	b3	5	7.55**	0.43**	18.15**	7.53**
C χ L			9	36.21**	1.36**	27.094**	26.48**
SCA χ L	h_{ij} χ L	b χ L	10	1.23**	0.10**	0.43	0.08
	h\ χ L	b1 χ L	1	8.87**	0.25**	0.31	0.32
	h_j χ L	b2 χ L	4	0.65**	0.05**	0.62	0.04
	S_{ij}\ χ L	b3 χ L	5	0.16	0.12**	0.30	0.07
P χ C			1	125.33**	5.12**	307.106**	25.35**
P χ C χ L			1	402.60**	16.08**	922.235**	77.00**
Error			56	0.42	0.03	1.830	0.48

^{GCA} General and ^{SCA} Specific combining ability, ^{Vi} Varieties, ^{hij} Heterosis, $^{h\backslash}$ Average heterosis, ^{hj} Variety heterosis, $^{Sij\backslash}$ Specific heterosis, ^{a} additive effects, ^{b} total non-additive (dominance) effects, ^{b1} mean deviation of F1's from their mid-parents, ^{b2} test if there is equal or unequal distribution among parents and ^{b3} detect existence of unique dominance of each F1

Also, insignificant mean squares of interaction of b_2 (Jones, 1965) and variety heterosis (Gardner and Eberhart, 1966) with location were detected for all traits eχcept, head diameter and hundred seed weight, revealing that b_2 (Jones, 1965) and variety heterosis (Gardner and Eberhart, 1966) components were stable cross two locations. Insignificant mean squares of interaction of b_3 (Jones, 1965) and specific heterosis (Gardner and Eberhart, 1966) with location were detected for all traits except hundred seed weight, indicating that b_3 and specific heterosis components did not affected by differences between two locations.

For a complete genetic analysis, Hayman's numerical analysis (Table 4) is better than the three previous analyses of half diallel.

The data revealed that the component of additive (D) at both locations were positive and significant or highly significant for all studied traits except seed weight plant^{-1} at Tag Al-Ezz. Meantime, significant or highly significant values of dominance (H_1 and H_2) were detected at both locations for all studied traits, indicating that important of both additive and non-additive components in the inheritance of these traits. The magnitude of dominance (H_1& H_2) was significant or highly significant higher than additive components (D) for most traits indicating that the presence of over-dominance for these traits. Value of H_1 was greater than H_2 for all traits indicating that frequency of gene distribution in the parents was unequal, and that was also supported by the ratio of $H_2/4H_1$ (<0.25) which showing asymmetrical gene distribution at the loci in the parents showing dominance for all the traits. The F value was positive for all traits except head diameter at both locations, indicating that the presence of higher number of dominant than recessives genes and it was confirmed by the high value of K_D/K_R for all traits except the above trait, for which negative value indicated presence of higher number of recessive than dominants genes. The overall dominance effects of heterozygous loci (h^2) were found to be positive and significant or highly significant for all studied traits at both locations, indicating that most of the dominant genes had positive effects. All estimates of environmental variance (E) were insignificant for all studied traits, indicating that all traits have not been greatly affected by environmental factors. The h^2/H_2 values were less than unity for all studied traits except days to physiological maturity, No. of green leaves plant^{-1}, head diameter, hundred seed weight and seed weight plant^{-1} at both locations implied to be governed by one gene. The non-significance of t^2 test validated the use of simple additive dominance model for genetic analysis of all studied traits at both locations.

Significant additive and non-additive components of genetic variance illustrated the involvement of both additive and non-additive genetic effects for all studied traits. However, backer ratio, varieties/heterosis ratio and (a/b) ratio of Jones revealed that the inheritance of all studied traits except plant height at Kafr El-Hamam and seed weight/plant cross locations were largely controlled by additive gene effects (fixable), although dominance gene effects (non-fixable) was also involved, so the genetic gain is achievable through selection in early segregating generations for these traits (Table 2). Due to variation of the Hayman's analysis from the previous analyses for additive (D), dominance (H_1) and environmental error (E) in the most traits at both locations (Table 4).

Consequently, the average degree of dominance overall loci, as estimated by $(H_1/D)^{½}$ ratio was found to be more than unity for all traits eχcept days to physiological maturity at both locations and plant height at Kafr El-Hamam, indicating the role of over dominance gene effects in the inheritance of these traits, for which less than unity indicating the presence of partial dominance in the control of the traits. Also, this confirmed by estimating of narrow sense heritability, which recorded high values at both locations for days to physiological maturity (0.68 at Kafr El-Hamam and 0.67 at Tag Al-Ezz), plant height (0.55 at Kafr El-Hamam), head diameter (0.57 at Tag Al-Ezz), and medium for days to 50 % flowering (0.44 at Kafr El-Hamam and 0.47 at Tag Al-Ezz), plant height (0.45 at Tag Al-Ezz), No. of green leaves/plant (0.38 at Kafr El-Hamam and 0.43 at Tag Al-Ezz), head diameter (0.40 at Kafr El-Hamam) and seed oil content (0.50 at Kafr El-Hamam and 0.50 at Tag Al-Ezz). Whereas, narrow sense heritability was low for hundred seed weight (0.21 at Kafr El-Hamam and 0.37 at Tag Al-Ezz) and seed weight/plant (0.06 at Kafr El-Hamam and 0.08 at Tag Al-Ezz).

Table 4. Hayman's analysis for all studied traits at Kafr El-Hamam (K) and Tag Al-Ezz (T) in season 2014

Parameter		Days to 50%flowering	Days to physiological maturity	Plant height	No. of green leaves plant^{-1}
E	K	0.37±1.22	0.38±3.36	3.20±15.43	0.35±1.54
	T	0.25±1.18	0.60±3.17	3.74±16.44	0.48±1.26
D	K	26.22±2.99**	96.38±8.24**	311.03±37.80**	18.24±3.78**
	T	27.16±2.90**	96.31±7.76**	277.61±40.26**	17.41±3.10**
F	K	23.29±7.46**	36.50±20.58	167.95±94.41	8.87±9.45
	T	24.01±7.24**	39.90±19.39*	167.19±100.58	6.09±7.73
H_1	K	31.91±8.07**	71.32±22.25**	296.21±102.07**	42.63±10.21**
	T	34.16±7.82**	69.93±20.96**	363.52±108.74**	38.79±8.36**
H_2	K	24.55±7.32**	63.57±20.18**	266.24±92.58**	39.37±9.26**
	T	25.63±7.10**	61.91±19.01**	331.39±98.63**	35.73±7.58**
h^2	K	10.00±4.94*	86.87±13.62**	127.24±62.51*	98.18±6.25**
	T	15.84±4.79**	91.78±12.83**	149.13±66.59*	90.53±5.12**
$(H1/D)^{0.5}$	K	1.10	0.86	0.98	1.53
	T	1.12	0.85	1.14	1.49
$H_2/4H_1$	K	0.19	0.22	0.22	0.23
	T	0.19	0.22	0.23	0.23
K_D/K_R	K	2.35	1.56	1.77	1.38
	T	2.30	1.64	1.71	1.27
h^2/H_2	K	0.41	1.37	0.48	2.49
	T	0.62	1.48	0.45	2.53
h^2 (n.s)	K	0.44	0.68	0.55	0.38
	T	0.47	0.67	0.45	0.43
t^2	K	0.91	0.06	2.57	1.19
	T	0.36	0.002	0.23	1.34
Parameter		**Head diameter plant^{-1}**	**Hundred seed weight**	**Seed weight plant^{-1}**	**Seed oil content**
E	K	0.11±0.67	0.01±0.08	0.436±1.75	0.15±1.01
	T	0.22±0.81	0.01±0.04	0.806±1.87	0.17±1.03
D	K	11.70±1.65**	0.38±0.19*	9.15±4.30*	5.84±2.48*
	T	9.61±1.98**	0.23±0.11*	7.32±4.58	7.11±2.53**
F	K	-0.08±4.12	0.24±0.48	10.95±10.73	1.15±6.20
	T	-3.49±4.95	0.04±0.27	5.58±11.45	1.21±6.32
H_1	K	41.16±4.46**	2.35±0.52**	79.94±11.60**	15.95±6.70*
	T	22.29±5.35**	0.98±0.29**	66.67±12.38**	18.27±6.83**
H_2	K	39.73±4.04**	2.19±0.47**	75.68±10.52**	13.51±6.08*
	T	21.07±4.85**	0.89±0.27**	65.42±11.23**	15.90±6.19*
h^2	K	97.07±2.73**	3.70±0.32**	165.67±7.11**	10.49±4.10*
	T	37.87±3.28**	1.71±0.18**	148.25±7.58**	15.51±4.18**
$(H1/D)^{0.5}$	K	1.88	2.49	2.96	1.65
	T	1.52	2.06	3.02	1.60
$H_2/4H_1$	K	0.24	0.23	0.24	0.21
	T	0.24	0.23	0.25	0.22
K_D/K_R	K	1.00	1.30	1.51	1.13
	T	0.79	1.08	1.29	1.11
h^2/H_2	K	2.44	1.69	2.19	0.78
	T	1.80	1.93	2.27	0.98
h^2 (n.s)	K	0.40	0.21	0.06	0.50
	T	0.57	0.37	0.08	0.50
t^2	K	0.57	0.75	0.23	0.77
	T	0.03	0.81	1.13	1.02

Hayman's graphical analysis (Figure 1a -9b) highlighted over dominance model as the regression line touched the Wr axis below origin point for days to 50% flowering, plant height, No. of green leaves plant^{-1}, head diameter, hundred seed weight and seed weight plant^{-1} at both locations, as well as seed oil content at Tag Al-Ezz. Whereas, the regression lines at both locations for remaining traits and seed oil content at Kafr El-Hamam intercepts Wr-axis above the point of origin, showing additive type of gene action with partial dominance controlling the genetic mechanism of these traits.

The contradiction between both types of analysis might be a logical result of the presence of allelic and non-allelic interaction genetic types on the expression of these cases which inflated the ratios of baker, $(H_1/D)^{½}$, narrow sense heritability and distorted the (Vr, Wr) graphs (Hayman 1954b and Mather and Jinks 1971).

For abovementioned parameters, selection in early generations would be effective for improving days to 50% flowering, days to physiological maturity, plant height, head diameter, No. of green leaves/plant and seed oil content, but the remaining traits showed an opposite trend.

The array points of parental genotypes were widely scattered for all traits, indicating presence of genetic diversity among the tested parents.

The distribution of parental sunflower genotypes along the regression lines showed that the parental genotypes, P_5 and P_2 for days to 50%flowering, P_5 and P_1 for days to physiological maturity, P_5 for plant height, P_3 and P_2 for number of green leaves plant^{-1}, P_3 and P_5 for head diameter, P_5 for 100- seed weight, P_3 for seed weight plant^{-1}, P_4 and P_1 for seed oil content at Kafr El-Hamam, whereas P_5 and P_2 for days to 50% flowering, P_5 for days to physiological maturity, P_5 for plant height, P_3 for number of green leaves plant^{-1}, P_5 and P_3 for head diameter, P_5 for 100- seed weight, P_3 and P_2 for seed weight plant^{-1}, P_4 and P_1 for seed oil content, at Tag Al-Ezz, seemed to possess the most dominant genes responsible for the expression of these traits which being closer to the origin of regression graph.

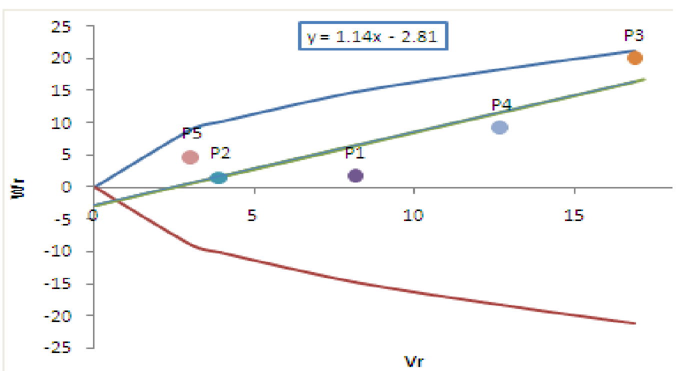

Figure 1a. Wr/Vr graphs for days to 50%flowering at Kafr El-Hamam (2014)

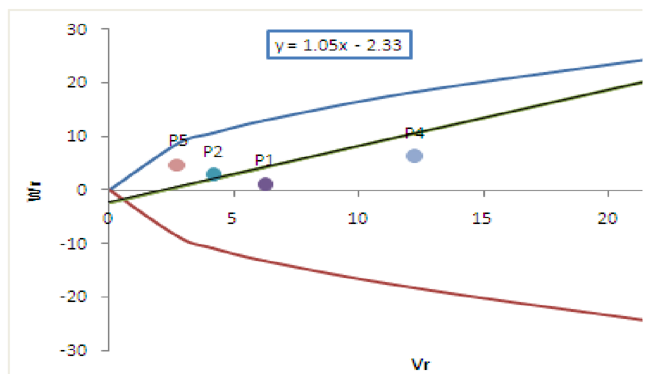

Figure 1b. Wr/Vr graphs for days to 50%flowering at Tag Al-Ezz (2014)

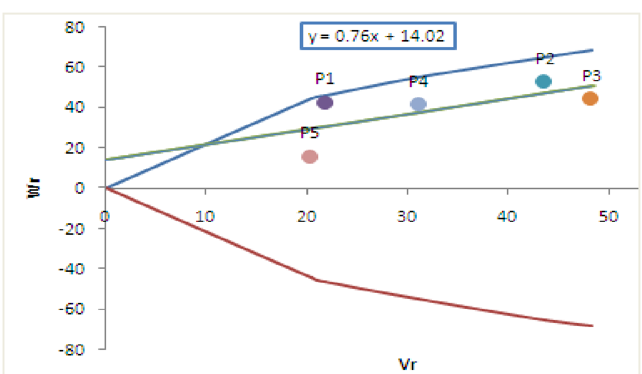

Figure 2a. Wr/Vr graphs for days to maturity at Kafr El-Hamam (2014).

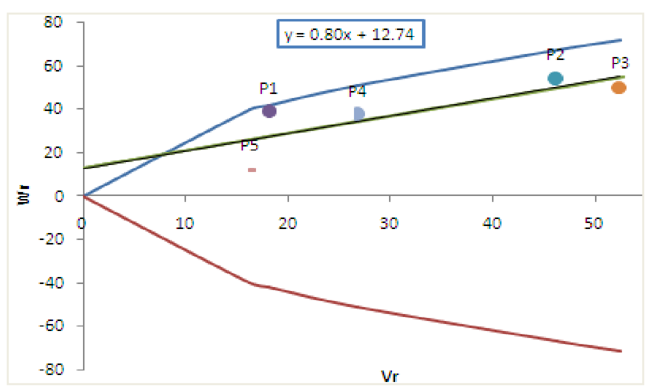

Figure 2b. Wr/Vr graphs for maturity at Tag Al-Ezz (2014).

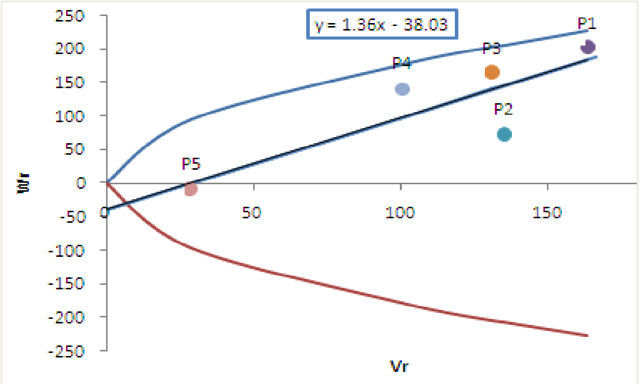

Figure 3a. Wr/Vr graphs for plant height at Kafr El-Hamam (2014).

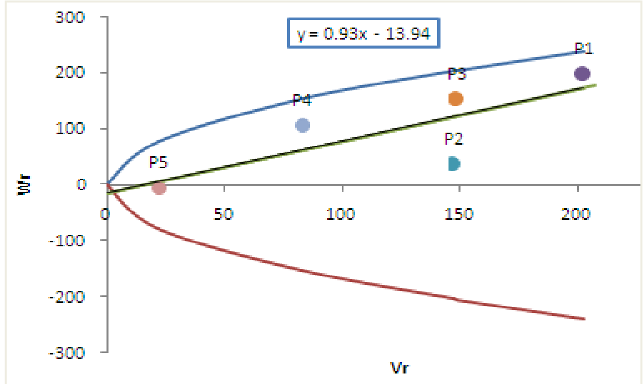

Figure 3b. Wr/Vr graphs for plant height at Tag Al-Ezz (2014).

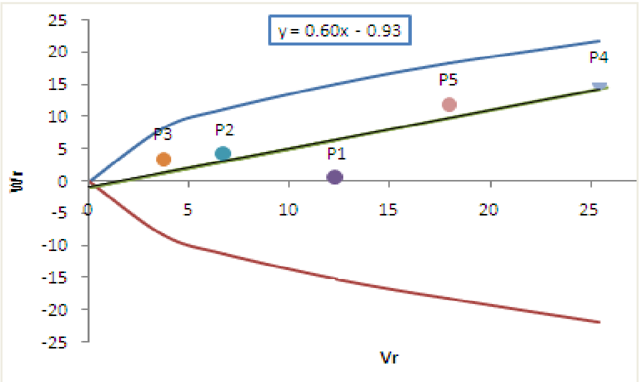

Figure 4a. Wr/Vr graphs for No. of green leaves/plant at Kafr El-Hamam (2014).

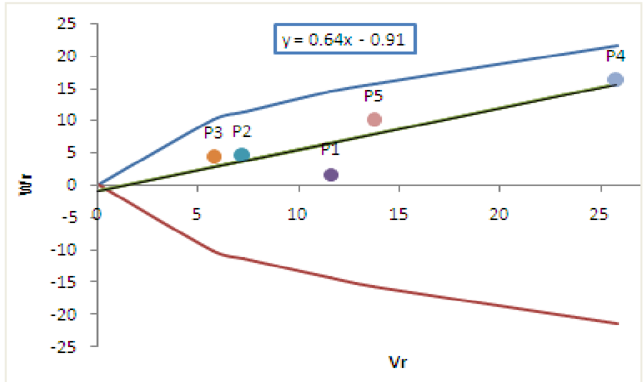

Figure 4b. Wr/Vr graphs for No. of green leaves/plant at Tag Al-Ezz (2014).

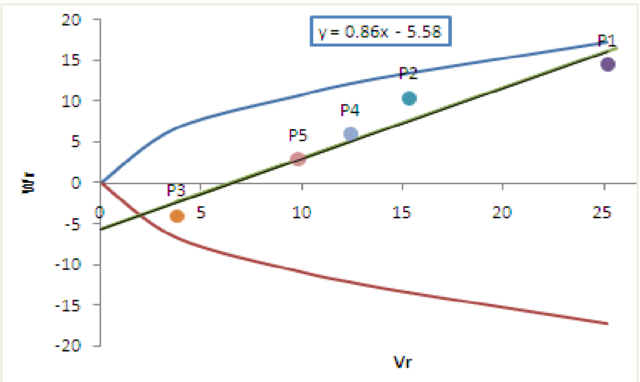

Figure 5a. Wr/Vr graphs for head diameter at Kafr El-Hamam (2014).

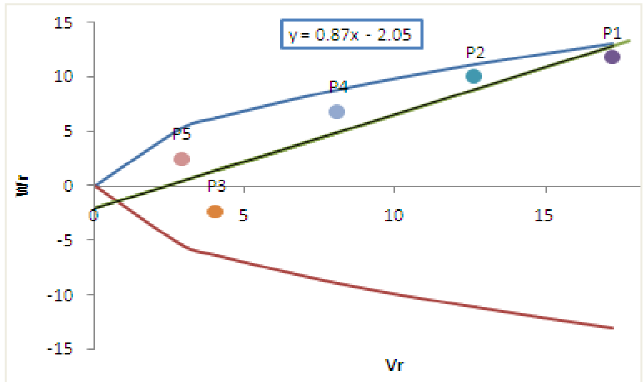

Figure 5b. Wr/Vr graphs for head diameter at Tag Al-Ezz (2014).

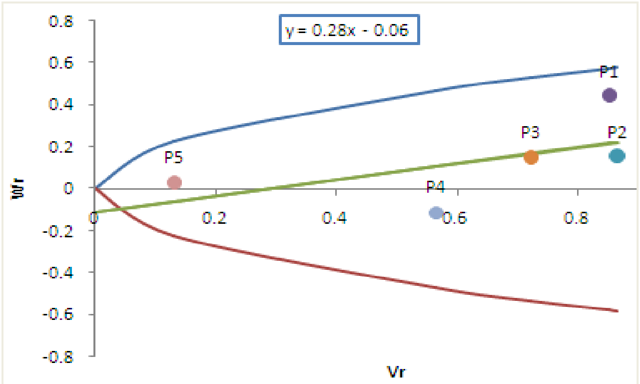

Figure 6a. Wr/Vr graphs for hundred seed weight at Kafr El-Hamam (2014).

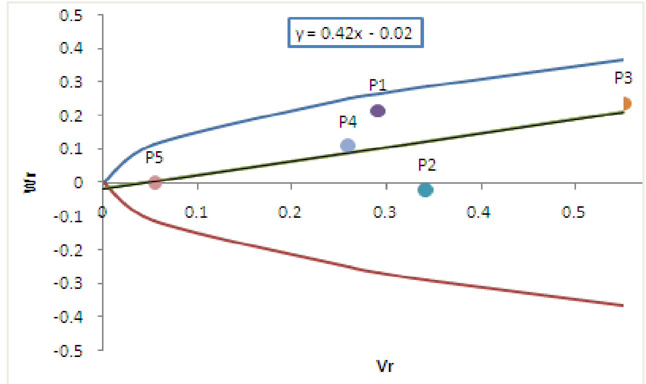

Figure 6b. Wr/Vr graphs for hundred seed weight at Tag Al-Ezz (2014).

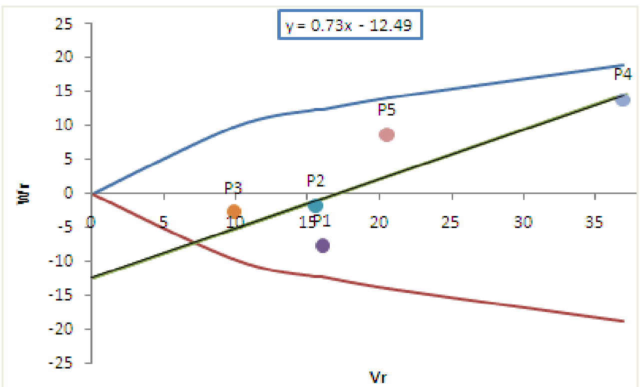

Figure 7a. Wr/Vr graphs for seed weight/plant at Kafr El-Hamam (2014).

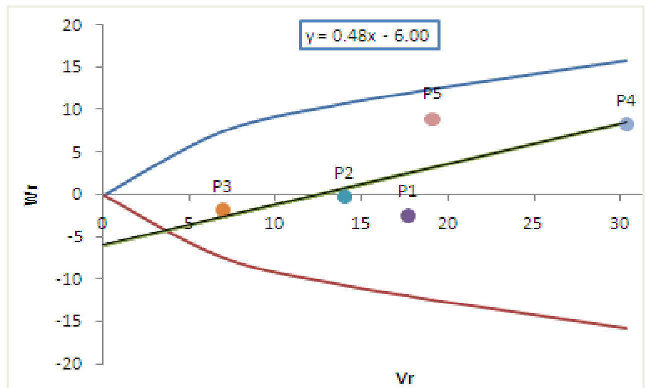

Figure 7b. Wr/Vr graphs for seed weight/plant at Tag Al-Ezz (2014).

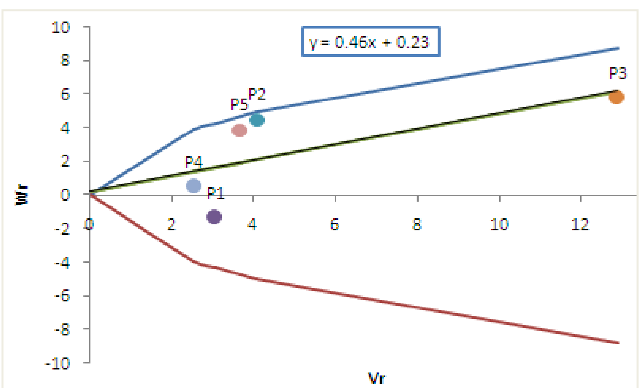

Figure 9a. Wr/Vr graphs for seed oil content at Kafr El-Hamam (2014).

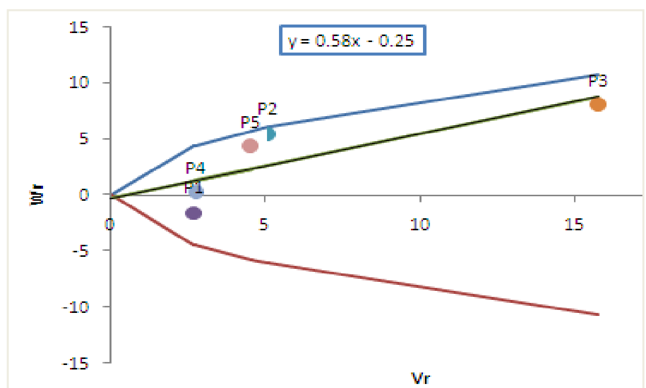

Figure 9b. Wr/Vr graphs for seed oil content at Tag Al-Ezz (2014).

In the contrary, the parental following genotypes, P_3 for earliness traits and seed oil content, P_4 for plant height, P_5 for number of green leaves plant^{-1}, P_2 and P_1 for head diameter, P_1 and P_2 for 100- seed weight, P_4 for seed weight plant^{-1} at Kafr El-Hamam, whereas, P_4 and P_3 for days to 50% flowering, P_3 and P_2 for days to physiological maturity, P_1 for plant height, P_4 for number of green leaves plant^{-1}, P_1 and P_2 for head diameter, P_3 for 100- seed weight, P_4 for seed weight plant^{-1} and P_3 for seed oil content at Tag Al-Ezz, contained the recessive genes for these traits which might be due to be farthest ones from the origin of regression graph.

The relative efficiency: The relative efficiency based on F. Test of half diallel's analyses for all studied traits at Kafr El-Hamam and Tag Al-Ezz is presented in Table (5). For additive and dominance gene effects and error mean squares, insignificant F-test was detected between Griffing (1956) and Jones (1965), Griffing (1956) and Gardner and Eberhart (1966) and Jones (1965) and Gardner and Eberhart (1966)' analyses used for all traits at both locations. This confirmed that these methods are statistically identical.

On the other hand, for comparison between Hayman (1954) and each of Griffing (1956), Gardner and Eberhart (1966) and Jones (1965) the results of dominance gene effects indicated that significant F. test was detected for days to 50% flowering, days to physiological maturity, plant height and seed oil content at both locations and hundred seed weight at Kafr El-Hamam, indicating method of Hayman (1954) was differed from the other methods used in this respect. Also, insignificant F. test in this concern was obtained between Hayman (1954) and each of Griffing (1956), Gardner and Eberhart (1966) and Jones (1965) for the other traits. Moreover, additive gene effect and error variance was insignificant and statistically identical or similar.

From above comparison, plant breeder should decide based on the purpose of analysis desired to success in reaching desirable breeding goals. Since, Griffing method 2 (1956) will be relatively easy to estimate of general combining ability effects for each parent and specific combining ability effects for each cross. However, Gardner and Eberhart (1966) method appears to have some advantages over the others, as partitioned the total sum of squares of heterosis into average, general and specific heterosis effect as well as gave information about combining ability of the parents, and also it cleared a simple relationship between heterosis (h_{ij}) and specific combining ability (s_{ij}). Moreover, Hayman (1954) analysis may be gave more information over the others about genetic component with it is computationally complicated. Similar results were reported by Nawar (1985).

Table 5. Relative efficiency of half diallel's analyses based on F-test for all studied traits at Kafr El-Hamam and Tag Al-Ezz.

Half diallel's analyses	Variance	Days to 50% flowering	Days to physiological maturity	Plant height	No. of green leaves/plant	Head diameter /plant	Hundred seed weight	Seed yield/plant	Seed oil content
Kafr El-Hamam									
Griffing χ Jones	Additive	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Griffing χ Gardner		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Griffing χ Hayman		1.11	1.35	1.17	1.32	1.87	1.34	1.42	1.90
Jones χ Gardner		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Jones χ Hayman		1.11	1.35	1.17	1.32	1.87	1.34	1.42	1.90
Gardner χ Hayman		1.11	1.35	1.17	1.32	1.87	1.34	1.42	1.90
Griffing χ Jones	Dominance	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Griffing χ Gardner		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Griffing χ Hayman		4.02*	3.28*	3.73*	2.73	2.70	3.05*	2.81	3.66*
Jones χ Gardner		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Jones χ Hayman		4.02*	3.28*	3.73*	2.73	2.70	3.05*	2.81	3.66*
Gardner χ Hayman		4.02*	3.28*	3.73*	2.73	2.70	3.05*	2.81	3.66*
Griffing χ Jones	Error	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Griffing χ Gardner		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Griffing χ Hayman		1.03	1.06	1.05	1.06	1.00	1.00	1.02	1.00
Jones χ Gardner		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Jones χ Hayman		1.03	1.06	1.05	1.06	1.00	1.00	1.02	1.00
Gardner χ Hayman		1.03	1.06	1.05	1.06	1.00	1.00	1.02	1.00
Tag Al Ezz									
Griffing χ Jones	Additive	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Griffing χ Gardner		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Griffing χ Hayman		1.07	1.31	1.11	1.49	2.34	1.91	1.04	1.86
Jones χ Gardner		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Jones χ Hayman		1.07	1.31	1.11	1.49	2.34	1.91	1.04	1.86
Gardner χ Hayman		1.07	1.31	1.11	1.49	2.34	1.91	1.04	1.86

Griffing χ Jones	Dominance	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Griffing χ Gardner		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Griffing χ Hayman		3.97*	3.21*	3.73*	2.70	2.95	2.97	2.69	3.49*
Jones χ Gardner		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Jones χ Hayman		3.97*	3.21*	3.73*	2.70	2.95	2.97	2.69	3.49*
Gardner χ Hayman		3.97*	3.21*	3.73*	2.70	2.95	2.97	2.69	3.49*
Griffing χ Jones	Error	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Griffing χ Gardner		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Griffing χ Hayman		1.00	1.02	1.04	1.00	1.29	1.00	1.03	1.00
Jones χ Gardner		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Jones χ Hayman		1.00	1.02	1.04	1.00	1.29	1.00	1.03	1.00
Gardner χ Hayman		1.00	1.02	1.04	1.00	1.29	1.00	1.03	1.00

*and ** significant at 0.05 and 0.01 levels of probability, respectively

Superior parents with good combining ability and performance: The parent (P_4) was behaved as the best general combiners for early flowering, physiological maturity and plant height as indicated by its highest negative GCA effect and shortest flowering and physiological maturity time as well as dwarf parent (Table 6 and 7), signifying that this parent possessed more decreasing alleles towards earliness and dwarfness. The superior parents with valuable positive GCA effects and hence good performance were P_3 for No. of green leaves plant^{-1}, head diameter and seed weight plant^{-1} at both locations, P_3 and P_2 for hundred seed weight, P_5 and P_4 for seed oil content at Kafr El-Hamam and Tag Al-Ezz, respectively. In this regard, **Khan *et al.* (2008)** reported that genotypes with high positive GCA estimates for seed weight/plant are good candidates to be used as parents in a population improvement program.

Table 6. Mean comparisons of all studied traits for sunflower parents and their F_1 crosses at Kafr El-Hamam (K) and Tag Al-Ezz (T) in 2014 season

Genotype	Days to 50%flowering, day		Days to physiological maturity, day		Plant height, cm		No. of green leaves/plant	
	K	T	K	T	K	T	K	T
P_1	55.33	47	89.67	85	166.7	155.87	25.67	23
P_2	57	50	103.33	98.67	185.53	173.5	27.67	24.33
P_3	60.33	54.33	110.67	106.33	194.5	183.7	31.33	28
P_4	47.33	40.67	86.67	82.33	148.93	140.57	20.67	17.23
P_5	50.67	44.33	98.67	93	168.67	156.97	22	19.33
$P_1\chi P_2$	52	45.67	92.67	88	181.17	174.37	32.33	29.13
$P_1\chi P_3$	53.67	46.33	96.33	91.33	173.23	161.37	34.33	32
$P_1\chi P_4$	55	47.67	84	80	147.73	136.13	33.67	30.33
$P_1\chi P_5$	48.33	41.33	93.33	88	159.9	148.8	33	29
$P_2\chi P_3$	54.33	47	99	94	173.33	156.6	34.33	31.23
$P_2\chi P_4$	55	47.67	86.33	81	168.73	155.93	31.33	28
$P_2\chi P_5$	52.67	44.67	92	87	155.73	146.5	29.33	26
$P_3\chi P_4$	49.33	42	98	92.67	166.07	153.97	30.33	27
$P_3\chi P_5$	51.67	44	92	87	167.33	156.47	31	27
$P_4\chi P_5$	49.33	41.33	86	81.67	164.37	154.13	27	23.67
LSD 5%	0.78	0.65	0.78	1	2.37	2.56	0.79	0.89
LSD 1%	1.05	0.87	1.05	1.35	3.2	3.45	1.06	1.21
Genotype	Head diameter plant^{-1}, cm		Hundred seed weight, g		Seed weight plant^{-1}, g		Seed oil content, %	
	K	T	K	T	K	T	K	T
P_1	14	10.47	5.7	3.73	31	24	40.52	42.55
P_2	18.93	14.03	6.91	4.95	32.57	26.33	38.64	39.54
P_3	23.23	18.33	6.97	4.44	34.57	28.9	35.48	36.58
P_4	16.27	10.97	6.61	4.25	26.69	21.78	41.13	42.72
P_5	18.2	13.73	7.36	4.85	28.77	22.9	41.34	42.54
$P_1\chi P_2$	19.33	14.03	7.28	4.98	35.33	29.4	41.91	43.87

$P_1 \chi P_3$	27.33	21.9	7.58	4.74	35.84	31.3	44.14	46.09
$P_1 \chi P_4$	22.33	14.93	8.15	5.01	41.87	35.57	44.75	46.49
$P_1 \chi P_5$	23.77	15.87	7.55	4.92	38.27	31.47	41.91	44.11
$P_2 \chi P_3$	28.07	22.17	9.18	6.34	42.03	35.27	37.58	39.42
$P_2 \chi P_4$	21.2	14.03	8.56	5.48	41.1	34.7	40.64	42.5
$P_2 \chi P_5$	24.9	17.13	7.75	5.06	38.03	32.1	42.17	43.98
$P_3 \chi P_4$	24.87	18.47	7.49	5.51	38.02	30.8	42.06	44.25
$P_3 \chi P_5$	26.27	18.3	8.23	5.44	40.64	34.33	37.58	38.89
$P_4 \chi P_5$	24.8	16.77	7.37	5.14	36.59	29.13	41.82	42.99
LSD 5%	0.43	0.54	0.13	0.15	0.85	1.15	0.5	0.54
LSD 1%	0.58	0.73	0.17	0.2	1.14	1.55	0.68	0.73

Table 7. General combining ability effects of five sunflower parents for all studied traits at Kafr El-Hamam (K) and Tag Al-Ezz (T) in 2014 season.

Parent	Days to 50%flowering		Days to physiological maturity		Plant height		No. of green leaves plant^{-1}	
	K	T	K	T	K	T	K	T
P_1	0.41	0.20	-2.54**	-2.44**	-1.91**	-1.36	1.01**	1.19**
P_2	1.60**	1.63**	1.89**	1.85**	5.89**	5.49**	0.72**	0.70**
P_3	1.84**	2.06**	6.17**	6.18**	8.60**	7.69**	2.15**	2.16**
P_4	-1.92**	-1.94**	-5.11**	-4.91**	-9.14**	-8.66**	-1.99**	-2.09**
P_5	-1.92**	-1.94**	-0.40	-0.68*	-3.44**	-3.16**	-1.90**	-1.97**
LSD gi 5%	0.42	0.35	0.42	0.53	1.27	1.37	0.42	0.48
LSD gi 1%	0.56	0.47	0.56	0.72	1.71	1.84	0.57	0.64
LSD gi-gj 5%	1.08	0.89	1.08	1.38	3.28	3.53	1.09	1.23
LSD gi-gj 1%	1.45	1.20	1.46	1.86	4.42	4.76	1.47	1.66

Parent	Head diameter plant^{-1}		Hundred seed weight		Seed weight plant^{-1}		Seed oil content	
	K	T	K	T	K	T	K	T
P_1	-1.80**	-1.26**	-0.44**	-0.40**	-0.46*	-0.49	1.30**	1.58**
P_2	-0.29*	-0.15	0.22**	0.26**	0.73**	0.71*	-0.73**	-0.82**
P_3	2.80**	3.01**	0.19**	0.14**	1.31**	1.47**	-1.76**	-1.83**
P_4	-1.10**	-1.47**	-0.04	-0.04	-0.80**	-0.78*	0.98**	1.01**
P_5	0.39**	-0.13	0.08*	0.05	-0.78**	-0.91**	0.21	0.06
LSD gi 5%	0.23	0.29	0.06	0.08	0.45	0.62	0.27	0.29
LSD gi 1%	0.31	0.39	0.09	0.11	0.61	0.83	0.36	0.39
LSD gi-gj 5%	0.59	0.74	0.17	0.21	1.17	1.59	0.69	0.74
LSD gi-gj 1%	0.80	1.00	0.23	0.28	1.58	2.15	0.93	1.00

Superior crosses with good performance and specific combing ability: It is worthy to appear as shown in Tables 6 and 8 that some correspondence between performance and SCA effects for the most traits at both locations.

Concerning the performance of all genotypes (Table 6), the data show that the earliest cross combinations were $P_1 \chi P_5$ for days to 50% flowering at both locations and $P_4 \chi P_5$ and $P_2 \chi P_4$ for days to physiological maturity at Kafr El-Hamam and Tag Al-Ezz research stations, respectively. The shortest hybrids were $P_1 \chi P_4$ at both contrasting locations.

The best cross combinations were $P_1 \chi P_3$ for No. of green leaves/plant at both locations, $P_2 \chi P_3$ for head diameter, hundred seed weight and seed weight/plant at both locations, $P_1 \chi P_4$ for seed oil content at both locations.

The specific combining ability values (SCA) of hybrids are presented in Table (8). The earliest crosses due to SCA effects were $P_3 \chi P_4$ at both locations for days to 50% flowering, $P_2 \chi P_4$ for days to physiological maturity at both locations. These results are in line with the finding of Ashok *et al.,* (2000) and Abd EL-Satar *et al.*, (2015), who found significant and negative SCA effects for physiological maturity in sunflower hybrids. However, the shortest crosses were $P_2 \chi P_5$ for plant height. The valuable positive SCA effects were detected at both locations in $P_1 \chi P_4$ for No. of green leaves/plant and seed weight/plant, $P_1 \chi P_3$ for head diameter and seed oil content. These results are in line with the findings of Bajaj *et al*., (1997), Naik *et al.,* (1999) and Abd EL-Satar *et al.*, (2015).

Table 8. Specific combining ability effects of ten sunflower F_1 crosses for all studied traits at Kafr El-Hamam (K) and Tag Al-Ezz (T) in 2014 season.

Cross	Days to 50%flowering		Days to physiological maturity		Plant height		No. of green leaves plant^{-1}	
	K	T	K	T	K	T	K	T
$P_1\chi P_2$	-2.81**	-1.76**	-0.59	-0.48	9.05**	13.25**	1.00*	0.88
$P_1\chi P_3$	-1.38**	-1.52**	-1.21**	-1.48**	-1.59	-1.95	1.57**	2.29**
$P_1\chi P_4$	3.71**	3.81**	-2.25**	-1.71**	-9.35**	-10.83**	5.05**	4.88**
$P_1\chi P_5$	-2.95**	-2.52**	2.37**	2.05**	-2.88*	-3.67*	4.29**	3.42**
$P_2\chi P_3$	-1.90**	-2.29**	-2.97**	-3.10**	-9.29**	-13.58**	1.86**	2.02**
$P_2\chi P_4$	2.52**	2.38**	-4.35**	-5.00**	3.85**	2.11	3.00**	3.04**
$P_2\chi P_5$	0.19	-0.62	-3.40**	-3.24**	-14.85**	-12.83**	0.90*	0.91
$P_3\chi P_4$	-3.38**	-3.71**	3.03**	2.33**	-1.52	-2.05	0.57	0.58
$P_3\chi P_5$	-1.05*	-1.71**	-7.68**	-7.57**	-5.95**	-5.06**	1.14*	0.46
$P_4\chi P_5$	0.38	-0.38	-2.40**	-1.81**	8.83**	8.97**	1.29**	1.37**
LSD Sij 5%	0.85	0.71	0.85	1.09	2.59	2.79	0.86	0.97
LSD Sij 1%	1.15	0.95	1.15	1.47	3.50	3.77	1.16	1.31
LSD sij-sik 5%	1.62	1.34	1.62	2.07	4.92	5.30	1.63	1.85
LSD sij-sik 1%	2.18	1.81	2.18	2.79	6.63	7.15	2.20	2.49
LSD sij-skl 5%	1.48	1.22	1.48	1.89	4.49	4.84	1.49	1.69
LSD sij-skl 1%	1.99	1.65	1.99	2.54	6.06	6.52	2.01	2.28
Cross	Head diameter plant^{-1}		Hundred seed weight		Seed weight plant^{-1}		Seed oil content	
	K	T	K	T	K	T	K	T
$P_1\chi P_2$	-0.80**	-0.64*	-0.01	0.13	-1.02*	-0.68	0.56*	0.68*
$P_1\chi P_3$	4.10**	4.07**	0.32**	0.02	-1.10*	0.46	3.83**	3.90**
$P_1\chi P_4$	3.00**	1.59**	1.12**	0.47**	7.03**	6.97**	1.69**	1.46**
$P_1\chi P_5$	2.95**	1.18**	0.41**	0.29**	3.42**	3.00**	-0.38	0.04
$P_2\chi P_3$	3.32**	3.23**	1.26**	0.95**	3.91**	3.22**	-0.71*	-0.37
$P_2\chi P_4$	0.35	-0.42	0.87**	0.27**	5.08**	4.90**	-0.39	-0.12
$P_2\chi P_5$	2.57**	1.33**	-0.06	-0.23**	2.00**	2.43**	1.91**	2.30**
$P_3\chi P_4$	0.93**	0.86**	-0.18*	0.42**	1.42**	0.24	2.06**	2.63**
$P_3\chi P_5$	0.84**	-0.65*	0.45**	0.27**	4.02**	3.90**	-1.65**	-1.78**
$P_4\chi P_5$	3.27**	2.30**	-0.18**	0.15	2.07**	0.95	-0.16	-0.52
LSD Sij 5%	0.47	0.59	0.13	0.16	0.93	1.26	0.55	0.59
LSD Sij 1%	0.63	0.79	0.18	0.22	1.25	1.70	0.74	0.79
LSD sij-sik 5%	0.89	1.11	0.25	0.31	1.76	2.39	1.04	1.12
LSD sij-sik 1%	1.20	1.50	0.34	0.42	2.37	3.22	1.40	1.51
LSD sij-skl 5%	0.81	1.02	0.23	0.28	1.60	2.18	0.95	1.02
LSD sij-skl 1%	1.09	1.37	0.31	0.38	2.16	2.94	1.28	1.37

Degree of Heterosis: Highly significant mean squares for parents *vs.* crosses were detected for all the studied traits at both locations as an indication of average heterosis as seen in Table (2). The largest heterotic magnitude expressed by the all traits as the deviation of particular F_1's mean values were significantly higher than parental means for all traits except days to flowering, days to physiological maturity and plant height where the parental means were significantly higher than F_1's mean values (Table 2). Significant interaction between mean squares due to parents *vs.* crosses and location were obtained for all traits (Table 3). These results indicated that the heterotic effects were affected the location changes.

Heterosis: For days to 50% flowering and days to physiological maturity, the crosses tended to deviate towards earliness especially at Tag Al-Ezz. Earliness if found in sunflower is favorable. Concerning heterosis relative to mid parent as shown in Table 9, over dominance was observed at both locations in earliness crosses P_1 χ P_5 (-8.81) at Kafr El-Hamam and P_3 χ P_4 (-11.58) at Tag El-Ezz for days to 50 % flowering as well as P_3 χ P_5 at both locations for days to physiological maturity. These crosses have highly significant negative heterosis relative to mid parents with high a potence ratio exceeding unity. The shortest crosses were detected in $P_2 \chi P_5$ (-12.06) at Kafr El-Hamam and $P_2 \chi P_3$ (-12.32) at Tag El-Ezz, due to presence of over dominance in the previous crosses where their potence ratio exceeding unity.

Over dominance as potence ratio pointed out, was detected in crosses $P_1 \chi P_4$ for No. of green leaves plant^{-1} and seed weight plant^{-1} at both locations, $P_2 \chi P_3$ for hundred seed weight, $P_1 \chi P_3$ for seed oil content at both locations and $P_1 \chi P_5$ at Kafr El-Hamam and $P_1 \chi P_3$ at Tag El-Ezz for head diameter.

Heterobeltiosis: Over dominance for heterobeltiosis as shown in Table 9 was observed at Kafr El-Hamam in the earliest crosses $P_1 \chi P_2$ (-6.02) and $P_1 \chi P_5$ (-6.77) at Tag El-Ezz for days to 50 % flowering and $P_2 \chi P_5$ and $P_3 \chi P_5$ at both locations for days to physiological maturity, since their heterobeltiosis values were highly significant negative with high potence ratio exceeding unity. The shortest crosses were detected in $P_2 \chi P_5$ at at Kafr El-Hamam and $P_2 \chi P_3$ at Tag El-Ezz, suggesting presence of over dominance as potence ratio pointed out.

Over dominance for heterobeltiosisas as potence ratio pointed out, was detected in the promising crosses $P_1 \chi P_4$ for No. of green leaves plant^{-1}, head diameter and seed weight plant^{-1} at both locations, $P_2 \chi P_3$ at both location for hundred seed weight as well as $P_1 \chi P_3$ at Kafr El-Hamam and $P_1 \chi P_4$ at Tag El-Ezz for seed oil content.

Table 9. Heterosis of ten sunflower F_1 crosses over mid parent (M.P.) and better parent (B.P.) as well as potence ratio (P) for all studied traits at Kafr El-Hamam (K) and Tag El-Ezz (T) in season 2014.

Cross	Days to 50%flowering						Days to physiological maturity					
	K			T			K			T		
	M.P	P	B.P	M.P	P	B.P	M.P	P	B.P	M.P	P	B.P
$P_1 \chi P_2$	-7.42**	5.00	-6.02**	-5.84**	1.89	-2.84**	-3.97**	0.56	3.35**	-4.17**	0.56	3.53**
$P_1 \chi P_3$	-7.20**	1.67	-3.01**	-8.55**	1.18	-1.42	-3.83**	0.37	7.43**	-4.53**	0.41	7.45**
$P_1 \chi P_4$	7.14**	-0.92	16.20**	8.75**	-1.21	17.21**	-4.73**	2.78	-3.08**	-4.38**	2.75	-2.83*
$P_1 \chi P_5$	-8.81**	2.00	-4.61**	-9.49**	3.25	-6.77**	-0.88	0.19	4.09**	-1.12	0.25	3.53**
$P_2 \chi P_3$	-7.39**	2.60	-4.68**	-9.90**	2.38	-6.00**	-7.48**	2.18	-4.19**	-8.29**	2.22	-4.73**
$P_2 \chi P_4$	5.43**	-0.59	16.20**	5.15**	-0.50	17.21**	-9.12**	1.04	-0.38	-10.50**	1.16	-1.62
$P_2 \chi P_5$	-2.17**	0.37	3.95**	-5.30**	0.88	0.75	-8.91**	3.86	-6.76**	-9.22**	3.12	-6.45**
$P_3 \chi P_4$	-8.36**	0.69	4.23**	-11.58**	0.80	3.28**	-0.68	0.06	13.08**	-1.77	0.14	12.55**
$P_3 \chi P_5$	-6.91**	0.79	1.97*	-10.81**	1.07	-0.75	-12.10**	2.11	-6.76**	-12.71**	1.90	-6.45**
$P_4 \chi P_5$	0.68	-0.20	4.23**	-2.75**	0.64	1.64*	-7.19**	1.11	-0.77	-6.84**	1.13	-0.81
LSD 5%	1.51	-	1.75	1.25	-	1.45	1.51	-	1.75	1.93	-	2.23
LSD 1%	2.04	-	2.36	1.69	-	1.95	2.04	-	2.36	2.61	-	3.01

Cross	Plant height						No. of green leaves plant^{-1}					
	K			T			K			T		
	M.P	P	B.P	M.P	P	B.P	M.P	P	B.P	M.P	P	B.P
$P_1 \chi P_2$	2.87	-0.54	8.68**	5.88*	-1.10	11.87**	21.25**	5.67	16.87**	23.10**	8.20	19.73**
$P_1 \chi P_3$	-4.08	0.53	3.92	-4.96*	0.60	3.53	20.47**	2.06	9.57**	25.49**	2.60	14.29**
$P_1 \chi P_4$	-6.39**	1.14	-0.81	-8.15**	1.58	-3.15	45.32**	4.20	31.17**	50.79**	3.54	31.88**
$P_1 \chi P_5$	-4.64*	7.92	-4.08	-4.87	13.85	-4.53	38.46**	5.00	28.57**	37.01**	4.27	26.09**
$P_2 \chi P_3$	-8.78**	3.72	-6.58*	-12.32**	4.31	-9.74**	16.38**	2.64	9.57**	19.36**	2.76	11.55**
$P_2 \chi P_4$	0.90	-0.08	13.29**	-0.70	0.07	10.93**	29.66**	2.05	13.25**	34.72**	2.03	15.07**

$P_2\chi P_5$	-12.06**	2.53	-7.67**	-11.34**	2.27	-6.67*	18.12**	1.59	6.02**	19.08**	1.67	6.85**
$P_3\chi P_4$	-3.29	0.25	11.50**	-5.04*	0.38	9.53**	16.67**	0.81	-3.19**	19.38**	0.81	-3.57**
$P_3\chi P_5$	-7.85**	1.10	-0.79	-8.14**	1.04	-0.32	16.25**	0.93	-1.06	14.08**	0.77	-3.57**
$P_4\chi P_5$	3.51	-0.56	10.36**	3.61	-0.65	9.65**	26.56**	8.50	22.73**	29.44**	5.13	22.41**
LSD $_{5\%}$	4.60	-	5.31	4.95	-	5.72	1.53	-	1.77	1.73	-	2.00
LSD $_{1\%}$	6.20	-	7.16	6.68	-	7.72	2.06	-	2.38	2.33	-	2.69

Cross	Head diameter plant^{-1}						100- seed weight					
	K			T			K			T		
	M.P	P	B.P	M.P	P	B.P	M.P	P	B.P	M.P	P	B.P
$P_1\chi P_2$	17.41**	1.16	2.11**	14.56**	1.00	0.00	15.44**	1.61	5.36**	14.78**	1.05	0.61**
$P_1\chi P_3$	46.82**	1.89	17.65**	52.08**	1.91	19.45**	19.65**	1.96	8.75**	16.08**	1.86	6.84**
$P_1\chi P_4$	47.58**	6.35	37.30**	39.35**	16.87	36.17**	32.36**	4.38	23.25**	25.65**	3.94	17.96**
$P_1\chi P_5$	47.62**	3.65	30.59**	31.13**	2.31	15.53**	15.65**	1.23	2.63**	14.73**	1.13	1.51**
$P_2\chi P_3$	33.12**	3.25	20.80**	36.97**	2.78	20.91**	32.31**	70.79	31.71**	35.04**	6.37	27.99**
$P_2\chi P_4$	20.45**	2.70	11.97**	12.27**	1.00	0.00	26.61**	12.12	23.89**	19.09**	2.50	10.63**
$P_2\chi P_5$	34.11**	17.27	31.51**	23.41**	21.67	22.09**	8.62**	2.73	5.30**	3.33**	3.06	2.22**
$P_3\chi P_4$	25.91**	1.47	7.03**	26.05**	1.04	0.73	10.26**	3.87	7.41**	26.78**	12.46	24.12**
$P_3\chi P_5$	26.79**	2.21	13.06**	14.14**	0.99	-0.18	14.89**	5.52	11.87**	17.27**	3.91	12.31**
$P_4\chi P_5$	43.91**	7.83	36.26**	35.76**	3.19	22.09**	5.49**	1.03	0.14	13.01**	1.98	6.05**
LSD $_{5\%}$	0.83	-	0.96	1.04	-	1.20	0.24	-	0.27	0.29	-	0.34
LSD $_{1\%}$	1.12	-	1.29	1.40	-	1.62	0.32	-	0.37	0.39	-	0.45

Cross	Seed weight plant^{-1}						Seed oil content					
	K			T			K			T		
	M.P	P	B.P	M.P	P	B.P	M.P	P	B.P	M.P	P	B.P
$P_1\chi P_2$	11.17**	4.53	8.50**	16.82**	3.63	11.65**	5.90**	2.48	3.44**	6.89**	1.88	3.11**
$P_1\chi P_3$	9.30**	1.71	3.65**	18.34**	1.98	8.30**	16.16**	2.44	8.94**	16.48**	2.19	8.31**
$P_1\chi P_4$	45.14**	6.05	35.05**	55.37**	11.44	48.19**	9.60**	12.78	8.78**	9.03**	44.42	8.81**
$P_1\chi P_5$	28.05**	7.52	23.44**	34.19**	14.58	31.11**	2.40**	2.38	1.38*	3.69**	235.50	3.67**
$P_2\chi P_3$	25.21**	8.44	21.58**	27.70**	5.96	22.03**	1.39**	0.33	-2.74**	3.56**	0.91	-0.32
$P_2\chi P_4$	38.71**	3.91	26.20**	44.23**	4.68	31.77**	1.89**	0.60	-1.20*	3.32**	0.86	-0.52
$P_2\chi P_5$	24.01**	3.88	16.79**	30.39**	4.36	21.89**	5.46**	1.61	2.01**	7.16**	1.96	3.39**
$P_3\chi P_4$	24.12**	1.88	9.98**	21.54**	1.53	6.57**	9.79**	1.33	2.25**	11.58**	1.50	3.57**
$P_3\chi P_5$	28.32**	3.09	17.55**	32.56**	2.81	18.80**	-2.16**	-0.28	-9.09**	-1.70**	-0.23	-8.58**
$P_4\chi P_5$	31.93**	8.53	27.17**	30.40**	12.16	27.22**	1.40**	5.51	1.14*	0.84	3.82	0.62
LSD $_{5\%}$	1.64	-	1.90	2.23	-	2.58	0.97	-	1.12	1.04	-	1.21
LSD $_{1\%}$	2.22	-	2.56	3.01	-	3.48	1.31	-	1.51	1.41	-	1.63

* and ** refers to significant at 5% and highly significant at 1%, respectively

CONCLUSIONS

For above mentioned results, it can be concluded that variance of additive, non-additive and experimental error for all studied traits computed by Griffing (1956), Gardner and Eberhart (1966) and (Jones, 1965) was numerically identical; and it was confirmed by F. test. Whereas, Hayman's analysis differed from the other analyses. Partial dominance with additive type of gene action with high to medium heritability for days to 50% flowering, days to physiological maturity, plant height, head diameter, No. of green leaves/plant and seed oil content suggested effective selection for these traits in early generation while over dominance for hundred seed weight and seed weight plant^{-1} suggested that heterosis breeding may be effective for improvement in these traits. Comparing of cross combinations on the basis of mean performance and desirable heterotic response as well as SCA effects of hybrids, revealed that $P_1 \chi P_4$ for seed weight plant^{-1} and the most of the yield associated traits at both locations and $P_3 \chi P_4$ for earliness in flowering and $P_2 \chi P_4$ for earliness in maturity at both locations were identified as the best crosses.

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