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COMPARISON BETWEEN SOME METHODS OF DIALLEL CROSS ANALYSIS IN MAIZE

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ABSTRACT

A half diallel set of crosses involving 8 inbred lines of maize along with two commercial hybrids (SC 10 and SC Pioneer 30k8) were evaluated at two different sowing dates (2/5/2014 and 1/6/2014) using RCBD design with three replications at the Agricultural Research and Experimental Station of the Faculty of Agriculture, Moshtohor, Benha University to determine combining ability and gene action for grain yield and its components. Significant planting date mean squares were detected, with a higher magnitude at early sowing date compared to that at late one. Genotypes as well as their components (parents, crosses and parents vs crosses) mean squares reached the significance level of probability for most studied traits. Significant mean squares due to general and specific combining ability (GCA (a) and SCA (b)) were obtained for all the studied traits using Griffing's methods (M 2 and M 4) and method of Jones at early, late and across sowing dates for most studied traits. Also, low GCA/ SCA ratio using Griffing's methods and a/b ratio using Jones method showed that non-additive type of gene action was the more important part of the total genetic variability for most studied traits in both and across planting dates. The parental inbred lines P3 and P7 seemed to be the best combiner for grain yield plant-1 as well as one or more of its components. The most desirable inter- and intera-allelic interactions were presented in both methods of Griffing by the F1 hybrids; P1xP7, P2xP8, P3xP4, P3xP7, P1xP8, P2xP3, P2xP8, P3xP4, P3xP7, P4xP7, P5xP6, P5xP8 and P6xP7 for grain yield plant-1. The crosses P3xP4, P3xP7, P6xP7, P5xP6, P2xP3, P1xP7, P4xP7, P2xP8, P1xP6 and P1xP7 gave significantly positive superiority in grain yield over SC10 and SC 30K8 in the combined analysis. Also, the three crosses P3xP7, P3xP4 and P5xP6 in the combined analysis were out yielded by (26.37 and 36.56%), (22.03 and 31.87%), (16.16 and 25.56%) over SC 10 and SC Pioneer 30K8, respectively. Highly significant and larger in magnitude values of dominance component (H1) were obtained for all traits in both sowing dates. Significant (h2) values were detected for all the studied traits. Low heritability values were detected for all studied traits. Values of H2/4H1was largely deviated from 0.25 were obtained for 100-kernel weight in both planting dates and No. of kernels row-1 at early sowing date. The same trend was detected by F values. Over-dominance was obtained for all traits. The parental inbred line P5 at early sowing date and P8 and P1 at late planting date for grain yield plant-1 seemed to carry the most dominant genes responsible for the expression of this trait. However, P4 for grain yield plant-1 had recessive genes. The correlation analysis revealed a strong relation between the four methods used in this study for estimation of error variance for all studied traits.

Key words: *Maize, Diallel analysis, Gene action, Combining ability.*

INTRODUCTION

To improve the productivity of maize more information about type of gene action is needed for successful breeding programs. Diallel analysis techniques is the choice of providing such detailed genetic information for type of gene action and identify the proper breeding materials that show great promise for success (Lonnquit and Gardner 1961).

To establish a sound basis for any breeding program, aimed at achieving high yield, breeders must have information on the nature of combining ability of parents and their behavior in hybrid combinations (Chawla and Gupta 1984). The genetic parameters general combining ability (GCA) and specific combining ability (SCA) were defined by Sprague and Tatum (1942). Both GCA and SCA effects should be taken into consideration when planning maize breeding programs to produce and release new inbred lines and crosses (Gardner 1967).

The diallel cross design is widely and extensively used for estimating the type of gene action. Several methods have been devised in this respect to estimate the genetic components in plant populations; little information however is available about comparing and relative efficiency of these methods. The analyses of methods of diallel cross in the present investigation were chosen because they are widely used and applied simulantaneously to the same basic population with one restriction that the number of crosses, including parents, in each should be the same. Thus the methods of analysis can be compared on the basis of their return in terms of information yielded (Dawood *et al* 1994) and (Nawar 1985). The objectives were (1) to estimate the magnitude of both general combining ability (GCA) and specific combining ability (SCA) mean squares and effects and their interaction with two sowing dates and (2) to make a comparison between some methods of genetic analysis for the relative efficiency.

MATERIALS AND METHODS

In 2013 season, eight inbred lines of white maize (*Zea mays* L.), Moshtohor P_1 (24-A), P_2 (7-A), P_3 (72-B), P_4 (122-B), P_5 (126-A), P_6 (79-N), P7 (18-A) and P8 (85-C) with different yielding abilities were split planted in May 8^{th}, 15^{th} and 22^{th}. These parents were crossed in a diallel fashion, excluding reciprocals. In 2014 season, two adjacent experiments were undertaken in two different sowing dates (2^{nd} May and 1^{st} June) at the Agricultural Research and Experimental Station of the Fac. of Agric., Moshtohor. Each experiment included the eight inbred lines and their (F_1) hybrids (28) along with the two check varieties SC. Pioneer 30K8 and SC 10. A randomized complete block design with three replications was used. Each plot consisted of two ridges of five meters length and 70 cm width. Hills were spaced at 25 cm with three kernels per hill on one side of the ridge. The seedlings were thinned to one plant per hill. The cultural practices were followed as usual for ordinary maize field in the area. Observations on 15 guarded plants in each plot were recorded to evaluate ear length (cm), ear diameter (cm), No. of rows ear^{-1}, No. of kernels row^{-1}, 100-kernel weight (g) and grain yield plant^{-1} (g) which was adjusted at 15.5% grain moisture. General and specific combining ability (GCA and SCA) mean squares and effects were estimated according to Griffing's (1956) diallel cross analysis designated as method 2 and 4 model I. The genetic parameters described by Hayman (1954 a and b) and Jones (1965) were also estimated. The data were also subjected to (Wr), (Vr) regression analysis to determine gene action as described by Jinks (1954). The combined analysis of the two experiments was carried out whenever homogeneity of mean squares was detected (Gomez and Gomez 1984). The relative superiority expressed as the percentage deviation of the F_1 mean performance from the two check hybrids (SC pioneer 30K8 and SC10).

RESULTS AND DISCUSSION

The mean squares due to planting date in both Griffing's methods 2 and 4 using Griffing's Method 2 (M2) and Griffing's Method 4 (M4) were significant for all studied traits with higher mean values for early planting date than those in late one (Tables 1and 2). The increase of mean values in early planting date may be due to the prevailed favorable temperature and day length leading to better vegetative growth, yield and its components of corn plant. Therefore, early planting date seemed to be non-stress environment. Such results are in good agreement with those reported by EL-Hosary et al (2006 and 2011).

The results indicated significant differences among genotypes (M2) of the present diallel study in both sowing dates as well as the combined analysis which was necessary for further analysis (Table 1). This indicates the wide diversity between the parental materials used in the present study. Significant genotypes x planting date mean squares were obtained for all studied traits, except No. of rows ear-1, revealing that the performance of genotypes differed from planting date to another. Genotypes were partitioned into parents (P), hybrids (F1) and parents vs. hybrids (P vs F1) items. Parents, crosses and parents vs crosses mean squares and their interactions with planting date were significant for all traits, except parents mean squares at late planting date, parents x planting dates and parents vs F1 mean squares for ear diameter, P vs F1 x planting date for ear length as well as, planting date x its portioning (PxD, F1xD and P vs. F1xD) for No. of rows ear-1 (Table 1). For crosses (F1) in Griffing method 4 (M 4) showed significant mean squares for all traits. Significant F1 x sowing date mean squares were obtained for all studied traits using M 4, except No. of rows ear-1 (Table 1), revealing that the performance of genotypes differed from sowing date to another.

Mean performance

The crosses P1xP4 in early planting date and combined data and P1xP8 in early planting date for ear length, P2xP3, P2xP8, P3xP4 and P6xP7 in both planting dates and the combined analysis for No. of rows ear-1, P1xP4, P1xP6, P2xP3 and P3xP7 in early planting and the combined analysis for No. of kernels row-1, P3xP4 in both plant dates as well as the combined analysis and P1xP6, P3xP4, P3xP7, P5xP6 and P6xP7 in both planting dates and the combined analysis for grain yield plant-1, had a significant superiority over the best check hybrid (Table 2). These hybrids

Table 1. Preliminary ANOVA in an 8 parent diallel cross of maize at each and across planting dates for all studied traits.

SOV	df	Mean squares					
		Ear length	Ear diameter	No. of rows ear^{-1}	No. of kernels row^{-1}	100- kernel weight	Grain yield plant $^{-1}$
Analysis using Griffing's method 2							
planting date - 02/05/2013 (Early planting date)							
Replication	2	0.43	0.10	0.17	3.94	1.42	41.62**
Genotype (G)	35	20.63**	2.30**	9.99**	91.57**	49.28**	6333.29**
Parent (P)	7	2.81**	0.37**	1.82**	43.87**	21.51**	497.55**
Crosses (F_1)	27	6.57**	0.29**	2.92**	26.36**	28.26**	2023.29**
P *vs.* F_1	1	524.97**	70.23**	258.23**	2186.37**	811.21**	163553.52**
Error	70	0.30	0.09	0.29	2.08	2.12	7.77
planting date - 1/06/2013 (Late planting date)							
Replication	2	1.03	0.06	0.13	3.53	0.003	30.94*
Genotype (G)	35	24.04**	2.60**	10.37**	104.2**	40.01**	3823.10**
Parent (P)	7	2.03**	0.11	2.81**	5.38*	7.38**	83.29**
Crosses (F_1)	27	9.51**	0.39**	2.66**	24.77**	29.46**	1183.41**
P *vs.* F_1	1	570.25**	79.45**	271.32**	2941.09**	553.10**	101273.24**
Error	70	0.41	0.10	0.35	2.20	1.96	8.77
Combined over 2 sowing dates							
planting date (D)	1	156.35**	9.88**	4.48**	631.84**	1003.22**	64162.21**
Rep/D	4	0.73	0.08	0.15	3.74	0.71	36.28**
Genotype (G)	35	41.94**	4.70**	20.21**	181.71**	78.60**	9554.89**
Parent (P)	7	1.03**	0.31**	4.47**	34.29**	14.31**	460.44**
Crosses (F_1)	27	13.56**	0.47**	5.43**	37.79**	48.10**	2595.74**
P *vs.* F_1	1	1094.75**	149.54**	529.47**	5099.54**	1352.00**	261113.01**
G x D	35	2.72**	0.20**	0.15	14.08**	10.69**	601.50
P x D	7	3.81**	0.17	0.16	14.96**	14.58**	120.41**
F_1 x D	27	2.52**	0.21**	0.15	13.34**	9.62**	610.96**
P vs. F_1 x D	1	0.47	0.14	0.08	27.92	12.32*	3713.75**
Error	140	0.35	0.09	0.32	2.14	2.04	8.27
Analysis using Griffing's method 4							
planting date - 02/05/2013 (Early planting date)							
Rep	2	0.036	0.19	0.04	1.97	1.29	38.27*
Crosses (F_1)	27	6.57**	0.29**	2.91**	26.36	28.26**	2023.29**
Error	54	0.19	0.11	0.24	2.39	2.489	8.01
planting date - 1/06/2013 (Late planting date)							
Rep	2	1.24	0.13	0.45	2.61	0.001	41.35*
Crosses (F_1)	27	9.51**	0.39**	2.67**	24.77	29.47**	1183.41**
Error	54	0.48	0.12	0.09	2.77	2.329	9.91
Combined over 2 sowing dates							
Sowing date (D)	1	114.59**	6.73**	3.00**	387.19**	875.45**	63564.27**
Rep/D	4	0.64	0.16	0.04	2.29	0.64	39.81**
Crosses (F_1)	27	13.56**	0.47**	5.43**	37.79**	48.10**	2595.74**
F1 x D	27	2.52**	0.21*	0.15	13.34**	9.62**	610.96**
Error	108	0.34	0.11	016	2.59	2.41	8.960

* $p < 0.05$; ** $p < 0.01$

Table 2. Mean performance of all studied genotypes at each and across planting dates for all studied traits as well as grain yield superiority over SC Pioneer 30k8 and SC 10 for the combined data.

Genotypes	Ear length (cm)			Ear diameter (cm)			No. of rows ear^{-1}		
	D1	D2	C.	D1	D2	C.	D1	D2	C.
P_1	10.59	10.28	10.44	2.24	2.21	2.22	10.38	10.13	10.26
P_2	11.25	8.97	10.11	2.03	1.80	1.91	8.30	7.67	7.98
P_3	12.75	10.38	11.56	2.70	1.86	2.28	10.83	10.80	10.82
P_4	12.75	8.79	10.77	2.93	2.31	2.62	10.40	10.33	10.37
P_5	12.28	8.88	10.58	2.85	2.25	2.55	10.00	10.00	10.00
P_6	12.00	9.25	10.63	3.06	1.98	2.52	10.10	9.33	9.72
P_7	10.43	10.73	10.58	2.70	2.22	2.46	10.63	10.27	10.45
P8	10.73	10.50	10.61	2.48	2.16	2.32	10.17	9.40	9.78
Mean of parents	11.60	9.72	10.66	2.62	2.10	2.36	10.10	9.74	9.92
P_1xP_2	14.30	13.80	14.05	4.20	4.00	4.10	13.20	13.00	13.10
P_1xP_3	15.50	13.50	14.50	4.60	4.27	4.43	13.20	13.30	13.25
P_1xP_4	20.00	19.38	19.69	4.70	4.57	4.63	13.45	13.30	13.38
P_1xP_5	15.60	15.40	15.50	4.50	4.20	4.35	13.10	12.60	12.85
P_1xP_6	16.00	15.30	15.65	4.65	4.43	4.54	14.80	14.27	14.53
P_1xP_7	18.20	18.00	18.10	4.60	4.33	4.47	13.20	12.90	13.05
P_1xP_8	19.20	15.00	17.10	4.90	4.63	4.77	14.40	13.73	14.07
P_2xP_3	17.00	15.75	16.38	4.00	4.47	4.23	16.00	16.00	16.00
$P_2x\ P_4$	15.40	15.20	15.30	4.75	4.32	4.53	12.60	12.00	12.30
P_2xP_5	15.70	14.80	15.25	4.60	4.27	4.43	12.60	12.20	12.40
P_2xP_6	17.00	17.00	17.00	4.40	3.80	4.10	13.75	13.65	13.70
P_2xP_7	17.90	15.00	16.45	4.30	4.23	4.27	12.60	12.20	12.40
P_2xP_8	17.80	17.38	17.59	4.90	3.97	4.43	14.60	14.40	14.50
P_3xP_4	17.70	15.80	16.75	4.80	4.40	4.60	14.90	14.13	14.52
P_3xP_5	14.20	11.25	12.73	4.40	4.33	4.37	14.40	13.60	14.00
P_3xP_6	16.50	14.50	15.50	4.70	4.47	4.58	13.60	13.40	13.50
P_3xP_7	16.50	14.25	15.38	4.20	3.70	3.95	14.00	13.60	13.80
P_3xP_8	17.30	15.30	16.30	4.80	3.90	4.35	13.75	13.30	13.53
P_4xP_5	16.30	14.50	15.40	4.70	4.20	4.45	12.60	12.93	12.77
P_4xP_6	17.45	13.30	15.38	4.50	3.93	4.22	13.60	13.57	13.58
P_4xP_7	16.25	13.60	14.93	4.00	4.00	4.00	13.90	13.33	13.62
P_4xP_8	18.45	14.90	16.68	4.80	3.67	4.24	13.70	13.70	13.70
P_5xP_6	20.20	18.20	19.20	4.70	4.37	4.53	13.00	12.80	12.90
P_5xP_7	17.00	13.90	15.45	4.30	4.17	4.23	13.10	13.17	13.13
P_5xP_8	16.70	16.60	16.65	4.70	4.50	4.60	14.10	14.47	14.28
P_6xP_7	17.50	17.25	17.38	5.13	4.71	4.92	16.65	15.87	16.26
P_6xP_8	15.65	12.75	14.20	3.90	3.09	3.50	13.50	13.50	13.50
P_7xP_8	15.90	15.35	15.63	5.00	3.60	4.30	14.70	14.60	14.65
SC Pioneer 30 k 8	17.30	15.90	16.60	4.70	4.30	4.50	13.10	13.00	13.05
SC 10	18.20	18.80	18.50	5.00	3.83	4.42	13.55	12.80	13.18
Mean of crosses	16.90	15.25	16.07	4.56	4.16	4.36	13.82	13.55	13.69
Mean of Genotypes	15.72	14.02	14.87	4.13	3.70	3.92	12.99	12.71	12.85
L.S.D 5%	0.88	1.04	0.95	0.48	0.50	0.49	0.88	0.97	0.91
L.S.D 1%	1.17	1.38	1.25	0.64	0.67	0.64	1.17	1.28	1.19

Table 2. Cont.

Genotypes	No. of kernels row^{-1}			100-kernel weight (g)			Grain yield plant^{-1} (g)			Relative superiority% In combined data for grain yield plant^{-1}	
	D1	D2	C.	D1	D2	C.	D1	D2	C.	over S C Pioneer 30K8	over S C 10
P_1	19.35	18.75	19.05	25.83	25.00	25.42	60.00	51.67	55.83		
P_2	23.80	18.50	21.15	27.67	26.00	26.83	61.25	44.58	52.92		
P_3	30.60	19.50	25.05	28.00	21.00	24.50	92.53	59.18	75.86		
P_4	19.98	15.70	17.84	25.50	24.50	25.00	58.07	42.96	50.51		
P_5	26.88	20.25	23.57	33.00	25.50	29.25	86.23	55.25	70.74		
P_6	21.34	18.15	19.74	31.00	24.00	27.50	65.83	52.00	58.92		
P_7	23.89	19.20	21.54	26.67	25.50	26.08	73.67	52.48	63.08		
P8	21.02	18.68	19.85	26.17	25.00	25.58	63.67	51.48	57.58		
Mean of parents	23.36	18.59	20.97	27.98	24.56	26.27	70.16	51.20	60.68		
P_1xP_2	31.07	29.00	30.03	34.00	33.67	33.83	142.85	117.67	130.26	-5.96**	-12.98**
P_1xP_3	29.70	26.00	27.85	38.50	30.50	34.50	151.50	100.67	126.08	-8.98**	-15.77**
P_1xP_4	38.00	36.10	37.05	32.00	28.50	30.25	160.00	131.60	145.80	5.26**	-2.60
P_1xP_5	33.10	31.90	32.50	33.50	33.00	33.25	146.80	140.23	143.52	3.61*	-4.12**
P_1xP_6	35.50	33.30	34.40	35.50	31.50	33.50	190.52	138.33	164.43	18.70**	9.84**
P_1xP_7	34.00	31.80	32.90	38.50	35.00	36.75	173.00	138.67	155.83	12.50**	4.11**
P_1xP_8	33.50	27.90	30.70	35.50	31.50	33.50	168.67	118.33	143.50	3.59*	-4.13**
P_2xP_3	36.00	34.50	35.25	30.00	29.00	29.50	170.33	160.00	165.17	19.24**	10.34**
$P_2x P_4$	31.35	29.40	30.38	35.00	28.00	31.50	140.67	96.17	118.42	-14.51**	-20.89**
P_2xP_5	29.30	28.30	28.80	34.50	29.50	32.00	124.00	105.80	114.90	-17.05**	-23.24**
P_2xP_6	35.30	30.40	32.85	32.00	27.50	29.75	156.87	113.80	135.33	-2.30	-9.59**
P_2xP_7	31.40	31.00	31.20	32.00	29.50	30.75	127.17	111.20	119.18	-13.96**	-20.38**
P_2xP_8	32.10	31.00	31.55	39.50	29.00	34.25	191.77	129.42	160.59	15.93**	7.28**
P_3xP_4	34.90	32.80	33.85	40.00	35.50	37.75	206.67	158.67	182.67	31.87**	22.03**
P_3xP_5	31.80	23.90	27.85	33.00	26.00	29.50	152.00	84.73	118.37	-14.55**	-20.92**
P_3xP_6	38.00	28.35	33.18	33.00	26.50	29.75	170.67	104.75	137.71	-0.59	-8.00**
P_3xP_7	41.50	28.50	35.00	38.50	36.50	37.50	230.00	148.33	189.17	36.56**	26.37**
P_3xP_8	30.90	30.70	30.80	33.00	32.00	32.50	135.21	127.68	131.45	-5.11**	-12.19**
P_4xP_5	31.50	31.35	31.43	39.50	33.00	36.25	158.40	129.90	144.15	4.06*	-3.70*
P_4xP_6	35.50	31.20	33.35	36.50	27.50	32.00	173.93	117.70	145.82	5.27**	-2.59
P_4xP_7	35.00	33.80	34.40	36.00	31.50	33.75	184.57	139.20	161.88	16.87**	8.15**
P_4xP_8	35.30	32.90	34.10	33.50	28.50	31.00	162.33	124.90	143.62	3.68*	-4.06**
P_5xP_6	40.40	36.10	38.25	37.00	33.00	35.00	193.33	154.53	173.93	25.57**	16.20**
P_5xP_7	33.70	32.60	33.15	28.50	24.00	26.25	121.63	103.00	112.31	-18.92**	-24.97**
P_5xP_8	35.80	35.60	35.70	30.50	27.50	29.00	151.10	144.37	147.73	6.65**	-1.31
P_6xP_7	35.30	32.10	33.70	34.00	28.00	31.00	198.67	140.53	169.60	22.44**	13.30**
P_6xP_8	34.40	30.75	32.58	31.50	28.50	30.00	147.33	110.00	128.67	-7.11**	-14.04**
P_7xP_8	32.70	30.75	31.73	33.00	26.00	29.50	155.33	105.83	130.58	-5.73**	-12.76**
SC Pioneer 30 k 8	32.70	31.10	31.90	36.50	32.00	34.25	149.64	127.40	138.52		
SC 10	33.00	30.90	31.95	38.00	33.00	35.50	167.38	132.00	149.69		
Mean of crosses	34.18	31.14	32.66	34.57	30.01	32.29	163.76	124.86	144.31		
Mean of Genotypes	31.77	28.35	30.06	33.11	28.80	30.95	142.96	108.49	125.72		
L.S.D 5%	2.34	2.41	2.34	2.36	2.27	2.29	4.53	4.81	4.60		
L.S.D 1%	3.10	3.19	3.07	3.14	3.02	3.00	6.00	6.38	6.03		

Where; D1= early planting date, D2 = late planting date, C. = Combined, * $p< 0.05$; ** $p< 0.01$

exhibited a significant increase of two or more of contributing traits to grain yield. The fluctuation of hybrids from sowing date to another was detected for most traits. These results may be due to significant interaction between hybrids and sowing date (Table 2)

Superiority expressed as the percentage deviation of F_1 mean performance from SC10 and Pioneer 30K8 means is presented in Table (2). The crosses P3xP4, P3xP7, P6xP7, P5xP6, P2xP3, P1xP7, P4xP7, P2xP8, P1xP6 and P1xP7 gave a significant and positive superiority over SC10 and SC 30K8 in the combined analysis. Also, the three crosses P3xP7, P3xP4 and P5xP6 gave the highest superiority in the combined analysis being (26.37 and 36.56%), (22.03 and 31.87%), (16.16 and 25.56%) over SC 10 and SC 30K8, respectively. Hence, it could be concluded that these crosses offer possibility for improving grain yield in maize.

Combining ability mean squares

Significant mean squares for general (GCA) and specific (SCA) combining ability were obtained for all the studied traits in Griffing's method 2 (M2) and method 4 (M 4) at early and late sowing dates and across them except, GCA in early date and combined analysis for ear diameter at M4. (Table 3). Also, the (a) component, which primary test the significance of additive and (b) component which indicates the presence of non-additive effects (Table 4) was significant for all traits in both sowing dates as well as the combined analysis, revealing that both types of gene action were involved in determining the performance of hybrids (F_1) progeny. This finding coincided with that already reached from the combining ability analysis. Hence, both additive and non-additive genetic components were important in the inheritance of all the studied traits.

If both GCA or (a) and SCA or (b) mean squares are significant, one may ask which type and or types of gene action are more important in determining the performance of single-cross progeny. To overcome such situation the size of mean squares can be used to assume the relative importance of general and specific combining ability mean squares which were highly significant. Hence, GCA/ SCA ratio in Griffing's methods and a/b ratio in Jones method was used as a measure to reveal the prevailed type of genetic variance involved. It is evident that non-additive type of gene action was the more important part of the total genetic variability for all studied traits in both and across planting dates in the three methods, except No. of rows ear^{-1} in both planting dates and ear diameter in late planting and No. of kernels row^{-1} in early sowing date at M4 where additive and non-additive were of equal importance. The genetic variance was previously reported to be mostly due to non-additive for No. of kernels row^{-1} by Amer (2003) and Shafey *et al* (2003) and grain yield plant^{-1} by Amer (2003); Mosa (2003); Shafey *et al* (2003); EL-Hosary and EL-Badawy (2005); El-Hosary *et al* (2006) and EL-Hosary and Elgammaal (2013). On the other hand, the additive genetic variance was previously reported to be the most

Table 3. Combining ability mean squares using Griffing's methods 2 and 4 for yield and its components of 28 maize F_1's evaluated at two sowing dates as well as the combined analysis across sowing dates.

Item	df	Ear length	Ear diameter	No. of rows ear^{-1}	No. of kernels row^{-1}	100- kernel weight	Grain yield $plant^{-1}$
Combining ability mean squares using griffing's method 2							
Sowing date - 02/05/2013 (Early planting date)							
GCA	7	0.89**	0.10**	1.15**	12.69**	3.05**	598.99**
SCA	28	8.37**	0.93**	3.88**	34.98**	19.77**	2489.12**
Error	70	0.10	0.03	0.10	0.69	0.71	2.59
GCA / SCA		0.11	0.10	0.30	0.36	0.15	0.24
Sowing date - 1/06/2013 (Late planting date)							
GCA	7	0.41**	0.11**	1.00**	3.18**	4.88**	60.35**
SCA	28	9.73**	1.05**	4.07**	42.63**	15.45**	1577.87**
Error	70	0.14	0.03	0.12	0.73	065	2.92
GCA / SCA		0.12	0.10	0.25	0.07	0.32	0.04
Combined across 2 sowing dates							
GCA	7	0.87**	0.10**	2.12**	6.65**	4.50**	484.44**
SCA	28	17.26**	1.93**	7.89**	74.05**	31.62**	3860.09**
GCAxD	7	1.14**	0.11**	0.03	9.22**	3.43**	174.90**
SCA xD	28	0.85**	0.06**	0.06	3.56**	3.60**	206.90**
Error	140	0.12	0.03	0.11	0.71	0.68	2.76
GCA/ SCA		0.05	005	0.27	0.09	0.14	0.13
GCA x D / GCA		1.60	1.11	0.01	1.39	0.76	0.36
SCA x D / SCA		0.05	0.03	0.01	0.05	0.11	0.05
Combining ability mean squares using griffing's method 4							
Sowing date - 02/05/2013 (Early planting date)							
GCA	7	1.26**	0.05	1.02**	11.47**	5.96**	844.19**
SCA	20	2.51**	0.11**	00.95**	7.85**	10.63**	615.01**
Error	54	0.064	0.04	0.079	0.80	0.83	2.67
GCA / SCA		0.502	0.49	1.07	1.46	0.56	1.37
Sowing date - 1/06/2013 (Late planting date)							
GCA	7	1.58**	0.15**	0.90**	7.62**	8.69**	69.88**
SCA	28	3.73**	0.13**	0.88**	8.48**	10.22**	508.08**
Error	54	0.16	0.038	0.03	0.92	0.78	3.30
GCA / SCA		0.42	1.15	1.02	0.89	0.85	0.14
Combined across 2 sowing dates							
GCA	7	2.09**	0.06	1.89**	11.94**	12.64**	645.71**
SCA	20	5.37**	0.19**	1.78**	12.82**	17.22**	942.09**
GCAxD	7	0.75**	0.14**	0.23	7.14**	2.02*	268.37**
SCA xD	20	0.87**	0.05	0.06	3.50**	3.62**	181.00**
Error	108	0.11	0.04	0.05	0.86	0.80	2.99
GCA/ SCA		0.39	0.32	1.07	0.93	0.73	0.69
GCA x D / GCA		0.36	2.27	0.01	0.59	016	0.42
SCA x D / SCA		0.16	0.25	0.03	0.27	0.21	0.19

* $p < 0.05$; ** $p < 0.01$

Table 4. Jone's analysis of combining ability mean squares for all studied traits in an 8-parent diallel cross of maize.

Item	df	Ear length	Ear diameter	No. of rows ear^{-1}	No. of kernels row^{-1}	100- kernel weight	Grain yield plant $^{-1}$
Sowing date - 02/05/2013 (Early planting date)							
a	7	0.89**	0.10**	1.15**	12.69**	3.05**	598.99**
b	28	8.37**	0.93**	3.88**	34.98**	19.77**	2489.12**
b1	1	174.99**	23.41**	86.08**	728.79**	270.40**	54517.84**
b2	7	1.55**	0.11**	0.57**	16.58**	12.20**	442.64**
b3	20	2.43**	0.10**	0.92**	6.73**	9.89**	603.96**
Error	70	0.10	0.03	0.10	0.69	0.71	2.59
Sowing date - 1/06/2013 (Late planting date)							
a	7	1.12**	0.11**	1.00**	3.18**	4.88**	60.35**
b	28	9.73**	1.05**	4.07**	42.63**	15.45**	1577.87**
b1	1	190.08**	26.48**	90.44**	980.36**	184.37**	33757.75**
b2	7	1.29**	0.08**	1.03**	6.97**	7.03**	42.09**
b3	20	3.67**	0.12**	0.82**	8.22**	9.95**	506.40**
Error	70	0.14	0.03	0.12	0.73	0.65	2.92
Combined across 2 sowing dates							
A	7	0.87**	0.10**	2.12**	6.65**	4.50**	484.44**
B	28	17.26**	1.93**	7.89**	74.05**	31.62**	3860.09**
b1	1	364.92**	49.85**	176.49**	1699.85**	450.67**	8737.67**
b2	7	1.72**	0.09*	1.53**	20.04**	14.78**	342.06**
b3	20	5.31**	0.18**	1.69**	11.66**	16.57**	932.53**
a x planting date	7	1.14**	0.11**	0.03	9.22**	3.43**	174.90**
b x planting date	28	0.85**	0.06	0.06	3.56**	3.60**	206.90**
b1 x planting date	1	0.16	0.05	0.03	9.31**	4.11**	1237.92**
b2 x planting date	7	1.13**	0.10**	0.06	3.50**	4.46**	142.67**
b3 x planting date	20	0.79**	0.04	005	3.30**	3.27**	177.83**
Error	140	0.12	0.03	0.11	0.71	0.68	2.76

Where; * $p< 0.05$; ** $p< 0.01$, a= additive effects, b= total non-additive (dominance) effects, b1= mean deviation of F_1's from their mid-parents, b2= Test if there is equal or unequal distribution among parents and b3= Existence of unique dominance of each F_1, i.e., presence of considerable amount of heterotic effect specific to some crosses.

prevalent for No. of rows ear^{-1} by Amer (2003); Mosa (2003); EL-Hosary and EL-Badawy (2005) and 100-kernel weight by Dubey *et al* (2001); Shafey *et al* (2003); EL-Hosary and EL-Badawy (2005) and EL-Badawy *et al* (2010) and EL-Hosary (2014).

It is fairly evident that ratio for additive x sowing date (D)/ additive was higher than of non-additive x D/non-additive for most studied traits.

This result indicated that additive effects were more influenced by sowing date than non-additive genetic effects.

This finding confirms those obtained above from the ordinary analysis of variance. The interactions between both types of gene action and environment were reported to be significant for grain yield plant^{-1} and its components (Mosa 2003, Motawei 2005, Sedhom *et al* 2007, EL-Badawy *et al* 2010, EL-Hosary and Elgammal 2013 and EL-Hosary 2014).

Item b_1 was highly significant for all studied traits under both and across planting dates, meaning significant differences between mean of parental inbred lines and their F_1 hybrid; it only reaches the significant level of probability of dominance deviation of the genes that predominate in one direction. These results coincided with those already reached for corresponding parent *vs* F_1 mean squares (Table 1).

The significant (b2) values were obtained for all traits in both sowing dates as well as combined analysis. Therefore, asymmetry of gene distribution for these traits having significant dominance might be indicated. Finally, item b3 was significant for all studied traits indicating the existence of inconsistent allelic and or non-allelic interaction for such traits or showing dominance effects specific to individual crosses (Kersey 1965 and Mather and Jinks 1971).

The mean squares due to interaction between sowing date and both types of gene action (a and b) were significant for all studied traits, except No. of rows ear^{-1} for both types and ear diameter for b. Such results indicated that the magnitude of additive and non- additive types of gene action changed from planting date to another. This finding coincided with those already reached for the corresponding GCA and SCA with sowing date mean squares (Table 3).

For ear length and ear diameter, insignificant mean squares due to interaction between (b_1) and sowing date were detected, indicating that mean deviation of the F_1's from their mid-parent values was stable from sowing date to another. However, the other traits showed significant interaction, indicating that this component was changed from sowing date to another.

Significant mean squares due to interaction between (b_2) and sowing date were detected for all traits, revealing that (b_2) component differ from sowing date to another.

Significant mean squares due to interaction between (b_3) and sowing dates were detected for all traits, except for ear diameter, indicating that (b_3) component differed from sowing date to another.

The half diallel analysis of Hayman method provided six genetic statistical parameters; these components are D, H1, H2, h^2, F and E (Table 5). Also, several ratios were derived as given by Hayman (1954b) and Jinks (1954) methods to provide further genetic information about each trait.

For No. of rows ear^{-1} in both planting dates, No. of kernels row^{-1} and 100-kernel weight in early sowing date, the additive component (D) reached the significant level of probability. For the other cases, the (D) value was insignificant, inspite of a highly significant GCA and/or (a) values were obtained. Dominance may have a role in both parameters GCA and (a) as emphasized by Jinks (1954). Also, the (a) component as it is well known considered as a measure of only additive variation if dominance is absent (Mather and Jinks 1971). In addition, the computed t^2 was highly significant and of large magnitude for most traits (Table 5). Moreover, the regression coefficients of the parental off-spring covariance (Wr) on the parental array variance (Vr) were less than unity for these traits, revealing the presence of complementary type of epistasis. In general the decrease of (Wr) disproportionably more than (Vr) leading to an inflation in the relative magnitude of dominance to additive components (Hayman 1954b, Hayman and Mather 1955 and Mather and Jinks 1971). Therefore, contradiction in magnitude detected herein between (D) and both GCA and (a) estimates for ear length, ear diameter and grain yield plant^{-1} in both planting dates, No. of kernels row^{-1} and 100-kernel weight at late sowing date could be attributed to the great role of both allelic and non-allelic interaction genetic types on the expression of these cases.

Highly significant values and larger in magnitude for the dominance component (H1) were obtained for all traits in both sowing dates. These results indicate that the largest part of the total genetic variability associated with all traits was a result of dominance (Table 5).

Significant (h^2) values were detected for all the studied traits, indicating that dominance was unidirectional. This finding confirms the previous results shown by par. *Vs* crosses and (b_1) parameters illustrated in Tables (1and4).

The relative magnitude of D and H1 was estimated as a weighed measure of the average degree of dominance at each locus. The results indicated presence of over-dominance for all studied traits.

The average frequency of negative vs positive allels in the parental population could be detected by computing the ratio H2/4H1. Values that largely deviated from 0.25 were obtained only for 100-kernel in both planting dates and No. of kernels/ row at early sowing date, revealing that negative and positive allels were unequally distributed among the parents. Moreover, significantly positive F value was detected in these traits, indicating symmetry with dominance allels being more frequent. The same conclusion was obtained by K_D/F_R.

Low heritability values in narrow-sense were detected (Table 5). This finding reveals that response to selection would be achieved in the late segregating generations of crosses.

Table 5. Hayman's analysis for all studied traits at each planting date.

	Ear length		Ear diameter		No. of rows ear^{-1}	
Genetic parameter	D1	D2	D1	D2	D1	D2
D	0.84	0.53	0.09	0.01	0.51	0.82*
F	1.56	0.92	0.12	0.00	0.40	1.12
H1	23.01**	27.30**	2.24**	2.52**	10.13**	10.78**
H2	21.86**	26.35**	2.19**	2.47**	9.75**	10.08**
h^2	86.08**	93.49**	11.51**	13.02**	42.32**	44.46**
E	0.10	0.14	0.03	0.03	0.10	0.12
$(H1/D)^{0.5}$	5.25	7.16	4.86	22.00	4.46	3.62
(H2/4H1)	0.24	0.24	0.24	0.25	0.24	0.23
KD/Kr	1.43	1.27	1.31	1.02	1.19	1.47
h^2(n.s)	0.04	0.04	0.02	0.04	0.09	0.07
YD	10.54	8.96	2.39	1.97	9.15	8.63
Yr	13.13	10.71	2.94	2.25	11.28	11.41
R	-0.88**	-0.89**	-0.98**	-0.94**	-0.89**	-0.96**
t^2	17.94**	18.91**	4.34	21.36**	5.17**	9.56**
B	0.28	0.20	0.52	0.44	0.42	0.43
	No. of kernels row^{-1} 100		-kernel weight		Grain yield $plant^{-1}$	
Genetic Parameter	D1	D2	D1	D2	D1	D2
D	13.91**	1.05	6.47*	1.82	162.95	24.64
F	20.92*	4.2	14*	4.39	211.80	27.80
H1	99.97**	110.7**	65.9**	52.1**	6772.00**	4214.00**
H2	87.94**	105.4**	57**	46.7**	6389.00**	4181.00**
h^2	358.4**	482.2**	133.78**	90.5**	26832.00**	16614.00**
E	0.71	0.74	0.70	0.64	2.90	3.13
$(H1/D)^{0.5}$	2.68	10.28	3.19	5.34	6.45	13.08
(H2/4H1)	0.22	0.24	0.22	0.22	0.24	0.25
KD/Kr	1.78	1.48	2.02	1.58	1.22	1.09
h^2(n.s)	0.1	0.04	0.05	0.10	0.09	0.01
YD	11.99	14.18	26.2	23.70	-93.20	85.63
Yr	43.78	25.03	31.6	26.00	270.50	13.34
R	-0.74*	-0.84*	-0.6*	-0.80*	-0.40	-0.41
t^2	1.9	3.05**	0.24	9.23**	7.93**	2.64*
B	0.41	0.38	0.12	0.10	0.17	-0.11

* $p< 0.05$; ** $p< 0.01$

Where: E= the expected environmental component of variation, D= Variation due to additive effect, F= Refers to relative frequencies of dominant *Vs* recessive genes in the parents, H1 = component of variation due to dominance effects, H2 = Component of variation due to non-additive effects, h^2= Overall dominance gene effects of the heterozygous loci in all crosses, $(H1/D)^{0.5}$ = mean degree of dominance at each locus over all loc, H2/4H1 = measures the average frequency of positive versus negative alleles at loci exhibiting dominance, KD/KR = the ratio of total number of dominant to receive allels in the parents and h^2 (ns) = narrow sense heritability.

Graphical analysis

Graphical presentation (Wr,Vr) in Figures (1 to 6), the regression coefficient "b" of (Wr/Vr) is different from unity, indicating that a complementary type of epistasis was involved. With the exception of grain yield plant^{-1} at late planting date, a significant negative intercept was obtained, revealing over-dominance. Significantly positive intercept was obtained for grain yield plant^{-1} in late planting, suggesting partial dominance. Presence of over dominance from Hayman's parameter $(H_1/D)^{0.5}$ was detected . This contradiction between both types of analysis might be a logical result of the presence of complamentary type of nonallelic interaction which inflated the ratios of (H1to D) and distorted the (Vr,Wr) graphs (Hayman 1954b, and Mather and Jinks 1971). The array points were widely scattered for all characters, indicating genetic diversity among the parents.

The appreciable negative correlation coefficient between (Yr) and (Wr+Vr) obtained for all traits, except grain yield plant^{-1}, indicated that increasers genes were dominant over decreasres.

The parental inbred line P3 for ear length, P4 and P6 for ear diameter, P1 for No. of rows ear^{-1}, P2 for No. of kernels row^{-1} in both planting dates, P6 in early sowing date and P2 and P8 in late planting for 100-kernel weight and P5 in early sowing date and P8 and P1 in late planting date for grain yield plant^{-1}, seemed to carry the most dominant genes

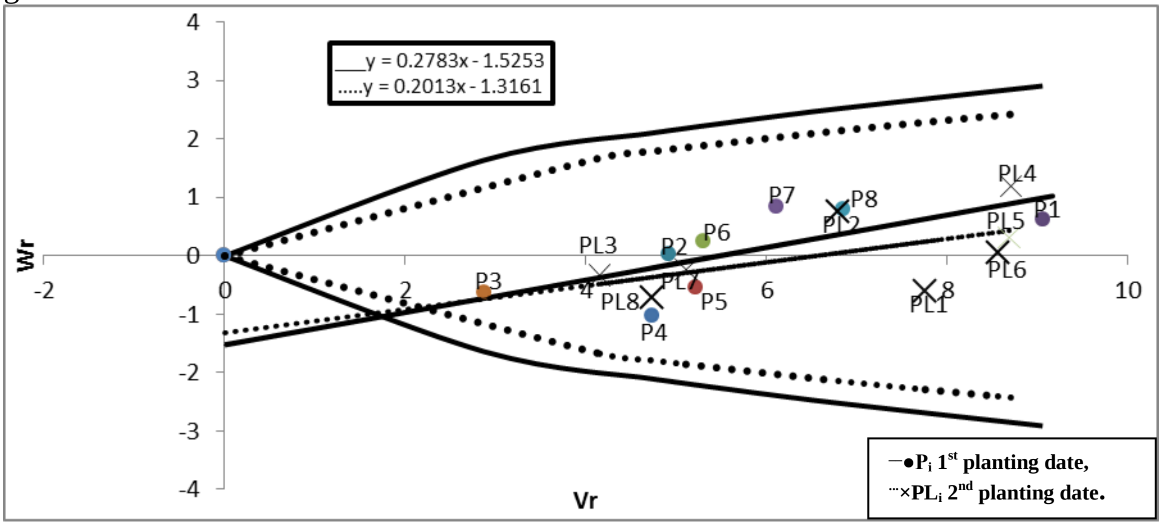

Fig 1. Wr/vr graphs for ear length at early and late planting date.

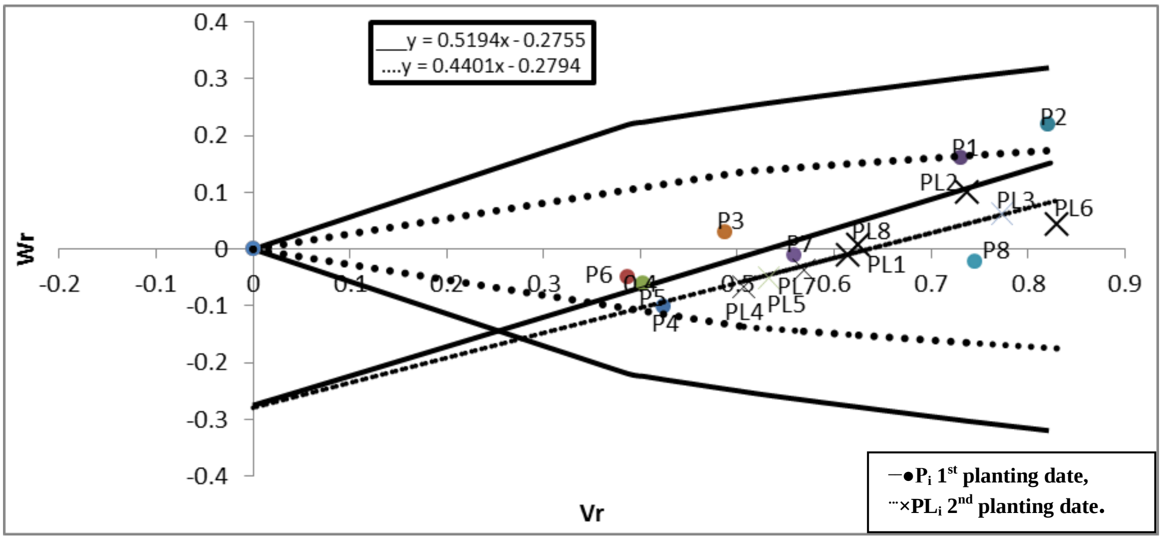

Fig 2. Wr/vr graphs for ear diameter at early and late planting date.

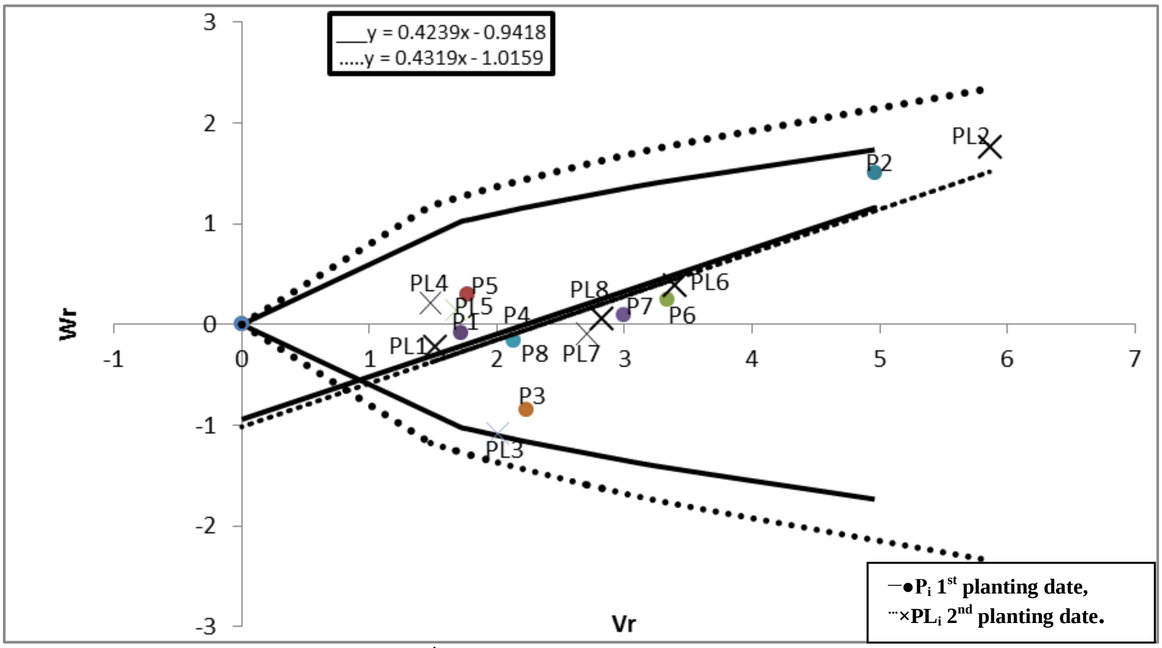

Fig 3. Wr/vr graphs for No. of rows ear^{-1} at early and late planting date.

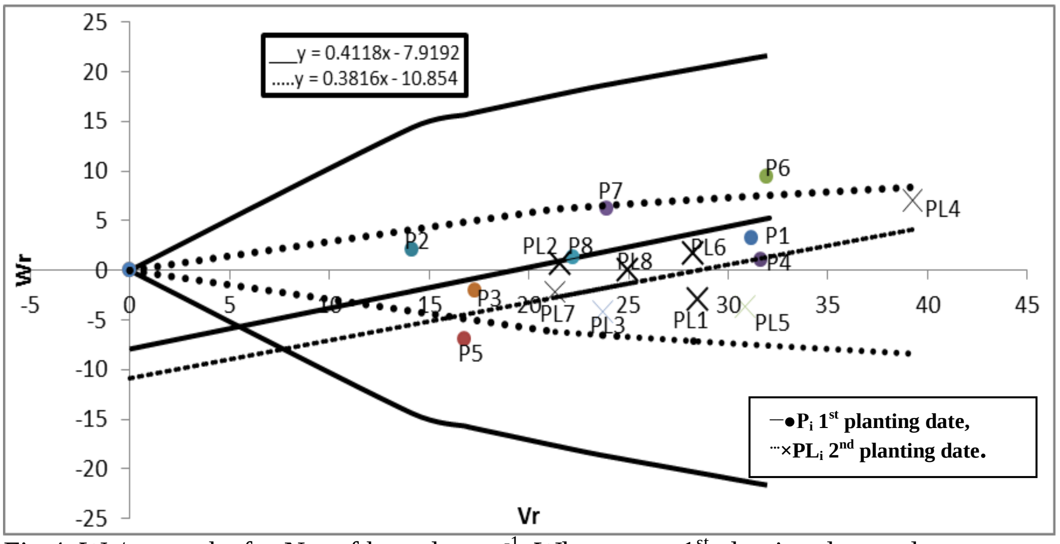

Fig 4. Wr/vr graphs for No. of kernels row^{-1}. Where, __● 1st planting date and ...× 2nd planting date.

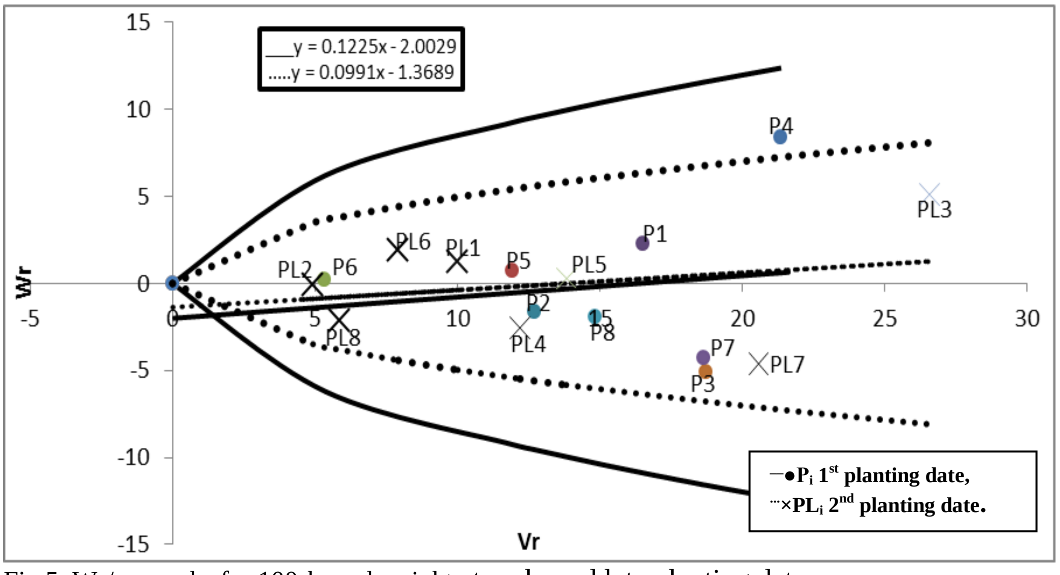

Fig 5. Wr/vr graphs for 100-kernel weight at early and late planting date.

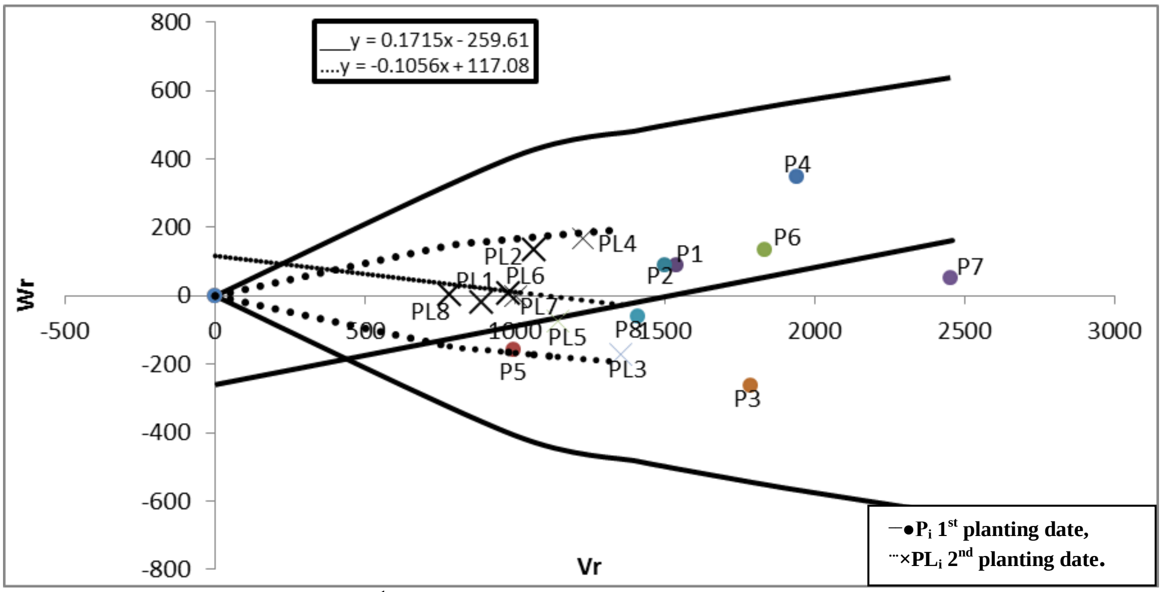

Fig 6. Wr/vr graphs for grain yield^{-1} at early and late planting date.

responsible for the expression of these traits. However, the parental inbred lines; P1 for ear length, P2 for ear diameter as well as No. of rows ear^{-1}; P6 for No. of kernels row^{-1} and P4 for grain yield plant^{-1} in both sowing dates and P4 and P3 for 100-kernel weight in early and late sowing dates, respectively, had a high concentration of recessive genes for these traits.

Combining ability effects

Estimates of GCA effects ($\hat{g}_i$) in individual parental inbred lines for each trait combined across two sowing dates in both Griffing's methods (M 2 and M4) are presented in Table (6). The parental inbred line P1 for 100-kernel weight, P3 for No. of rows ear^{-1} and grain yield plant^{-1}, P4 for ear length, 100-kernel weight and grain yield plant^{-1}, P6 for ear length,, No. of rows ear^{-1}, No. of kernels row^{-1} and grain yield plant^{-1}, P7 for No. of rows ear^{-1} and grain yield plant^{-1} and P8 for No. of rows ear showed significant positive ($\hat{g}_i$) effects in both methods. These results indicated that these parental inbred lines possess favorable genes and that improvement in respective traits may be attained if they are used in a hybridization program.

Table 6. General combining ability effects for parents in the combined analysis of each method of Griffing (methods 2 and 4).

Parent	Ear length		Ear diameter		No. of rows ear^{-1}	
	M2	M4	M2	M4	M2	M4
P1	0.16**	0.34**	0.05*	0.13	-0.09*	-0.26**
P2	-0.16**	-0.08	-0.13**	-0.07	-0.53**	-0.24**
P3	-0.32**	-0.83**	-0.02	0.00	0.46**	0.46**
P4	0.18**	0.27**	0.07**	0.02	-0.11**	-0.33**
P5	-0.25**	-0.39**	0.08**	0.07	-0.33**	-0.58**
P6	0.17**	0.30**	0.02	-0.02	0.18**	0.36**
P7	0.06	0.13	-0.02	-0.07	0.21**	0.18**
P8	0.15**	0.27**	-0.04*	-0.06	0.21**	0.40**
L.S.D(0.05) gi	0.08	0.25	0.04	ns	0.08	0.18
L.S.D(0.01) gi	0.10	0.34	0.05	ns	0.10	0.24
L.S.D(0.05) gi-gj	0.15	0.38	0.08	ns	0.14	0.27
L.S.D(0.01) gi-gj	0.20	0.51	0.10	ns	0.19	0.36
Parent	No. of kernels row^{-1}		100-kernel weight		Grain yield plant^{-1}	
	M2	M4	M2	M4	M2	M4
P1	-0.70**	-0.53	0.79**	1.59**	-1.04**	-0.12
P2	-0.82**	-1.43**	-0.33**	-0.74**	-8.18**	-11.05**
P3	0.33**	-0.81**	0.14	0.83**	7.08**	6.74**
P4	-0.03	0.99**	0.39**	1.08**	1.19**	5.36**
P5	0.42**	-0.16	0.12	-0.80**	-3.51**	-9.21**
P6	0.72**	1.61**	-0.26**	-0.84**	4.18**	7.55**
P7	0.46**	0.57	-0.09	-0.09	3.32**	4.73**
P8	-0.37**	-0.25	-0.76**	-1.05**	-3.02**	-4.00**
L.S.D(0.05) gi	0.19	0.71	0.19	0.68	0.38	1.31
L.S.D(0.01) gi	0.26	0.94	0.25	0.90	0.50	1.74
L.S.D(0.05) gi-gj	0.37	1.07	0.36	1.03	0.73	1.98
L.S.D(0.01) gi-gj	0.48	1.41	0.47	1.36	0.95	2.63

* $p< 0.05$; ** $p< 0.01$

Specific combining ability effects ($\hat{S}_{ij}$) for the studied twenty eight cross combinations were computed for all studied traits across two sowing dates using both Griffing's methods (M2 and M4) are presented in Table (7). The most desirable inter- and intera-allelic interactions were presented in both methods (M2 and M4) by F_1 hybrids; P1xP4, P1xP7, P2xP3, P2xP6, P3xP4, P3xP8, P5xP6, P5xP8 and P6xP7 for ear length, P1xP8 and P6xP7 for ear diameter, P1xP6, P2xP3, P2xP8, P3xP4, P3xP5, P5xP8 and P6xP7 for No. of rows ear^{-1}, P1xP4, P2xP3, P3xP7, P5xP6 and P6xP7 for No. of kernels row^{-1}, P1xP7, P2xP8, P3xP4, P3xP7, P1xP8, P2xP3, P2xP8, P3xP4, P3xP7, P4xP7, P5xP6, P5xP8 and P6xP7 for grain yield plant^{-1}. The previous crosses might be prime importance in breeding program for traditional breeding procedures.

The values of correlation coefficients between both Griffings methods of analysis (M2 and 4) for ($\hat{g}_i$) and ($\hat{S}_{ij}$) effects are presented in Table (8). The correlation coefficient between ($\hat{g}_i$) and ($\hat{S}_{ij}$) effects in the two methods was highly significant for all traits, revealing a strong relation between the two Griffing methods in estimating ($\hat{g}_i$) and ($\hat{S}_{ij}$) effects. This finding confirms the results already shown by ($\hat{g}_i$) and ($\hat{S}_{ij}$) effects (Tables 6 and 7).

The correlation coefficient of additive and/or non-additive effects derived from four methods of diallel analysis across all traits in both planting dates as well as the combined analysis were highly significant, indicating the strong relation between these methods in estimating additive and non-additive genetic variance (Table 9).

Also, the correlation coefficient values for error mean squares between the four methods of all traits were significant between these methods, revealing the strong relation between the four methods in estimation of error variance. Consequently, when costs, efforts and time needed for conducting the experiments and analyses the collected data are taken into consideration, the perferability will be for Griffing method-4. In this respect, Nawar (1985) compared between seven analyses of diallell crosses in maize including the two Griffing's methods (2 and 4), Model II; the modified diallel cross by Matzinger and Kempthorne (1956) method, Gardner (1967) method, the half diallel cross of Jones (1965), the diallel method by Aksel and Johnson (1959), the regression method (wr/vr) of Jinks (1954) and Hayman (1954 a and b) method. He reported that the genetic analysis carried out by different methods of analysis of diallel crosses in general gave a similar picture with respect to gene action. Also, in case of grain yield per plant and silking date, the additive and dominance genetic effects were important in the expression of these traits. Moreover, the two half diallel methods, Gardner's (1967) method, regression method analysis (wr/vr) and Matzinger and Kempthorne (1956) method may be more informative than the two Griffing's methods; however, they are more complicated since a high seed computer facilities are needed to do the calculations.

Tble 7. Specific combining ability effects for crosses in the combined analysis for Griffing method 2 (M2) and method 4 (M4).

	Ear length		Ear diameter		No. of rows ear^{-1}		No. of kernels row^{-1}		100-kernel weight		Grain yield plant^{-1}	
Cross	M2	M4	M2	M4	M2	M4	M2	M4	M2	M4	M2	M4
P1xP2	-0.82**	-2.28**	0.27*	-0.32	0.87**	-0.09	1.49**	-0.67	2.43**	0.69	13.76**	-2.87
P1xP3	-0.21	-1.09**	0.49**	-0.05	0.03	-0.64**	-1.84**	-3.47**	2.62**	-0.21	-5.68**	-24.84**
P1xP4	4.47**	3.00**	0.60**	0.12	0.72**	0.28	7.73**	3.93**	-1.88**	-4.71**	19.93**	-3.75*
P1xP5	0.72**	-0.53	0.30**	-0.21	0.42*	0.01	2.72**	0.53	1.39**	0.16	22.35**	8.54**
P1xP6	0.45*	-1.07**	0.56**	0.08	1.60**	0.75**	4.32**	0.66	2.02**	0.45	35.56**	12.69**
P1xP7	3.01**	1.55**	0.52**	0.04	0.08	-0.56**	3.08**	0.20	5.10**	2.95**	27.83**	6.92**
P1xP8	1.91**	0.41	0.84**	0.34*	1.09**	0.24	1.71**	-1.18	2.53**	0.66	21.84**	3.32*
P2xP3	1.98**	1.22**	0.47**	-0.05	3.22**	2.09**	5.68**	4.83**	-1.26*	-2.88**	40.55**	25.17**
P2xP4	0.41	-0.96**	0.68**	0.22	0.08	-0.83**	1.17*	-1.84*	0.49	-1.13	-0.31	-20.20**
P2xP5	0.79**	-0.35	0.57**	0.07	0.41	-0.47*	-0.87	-2.27**	1.26*	1.25	0.87	-9.15**
P2xP6	2.12**	0.71*	0.30**	-0.17	1.20**	-0.11	2.89**	0.01	-0.61	-0.96	13.61**	-5.48**
P2xP7	1.68**	0.33	0.50**	0.04	-0.14	-1.23**	1.50**	-0.61	0.22	-0.71	-1.68	-18.81**
P2xP8	2.72**	1.33**	0.69**	0.20	1.96**	0.65**	2.68**	0.56	4.39**	3.75**	46.07**	31.34**
P3xP4	2.02**	1.24**	0.64**	0.22	1.32**	0.69**	3.49**	1.01	6.26**	3.55**	48.68**	26.25**
P3xP5	-1.58**	-2.13**	0.39**	-0.07	1.02**	0.43*	-2.97**	-3.84**	-1.71**	-2.82**	-10.93**	-23.47**
P3xP6	0.78**	-0.04	0.67**	0.25	0.02	-1.01**	2.06**	-0.29	-1.09*	-2.53**	0.73	-20.89**
P3xP7	0.76**	0.00	0.07	-0.34*	0.28	-0.53**	4.15**	2.57**	6.49**	4.47**	53.04**	33.38**
P3xP8	1.60**	0.79**	0.49**	0.05	0.00	-1.03**	0.78	-0.81	2.17**	0.43	1.66	-15.60**
P4xP5	0.60**	-0.55	0.39**	-0.01	0.35	-0.01	0.97	-2.06*	4.79**	3.68**	20.75**	3.69*
P4xP6	0.15	-1.26**	0.22	-0.15	0.66**	-0.14	2.60**	-1.91*	0.91	-0.53	14.73**	-11.41**
P4xP7	-0.19	-1.54**	0.04	-0.32	0.66**	0.07	3.91**	0.18	2.49**	0.47	31.65**	7.48**
P4xP8	1.47**	0.07	0.30**	-0.09	0.74**	-0.06	4.44**	0.70	0.42	-1.32	19.73**	-2.05
P5xP6	4.41**	3.22**	0.52**	0.12	0.21	-0.57**	7.04**	4.14**	4.19**	4.34**	47.54**	31.28**
P5xP7	0.77**	-0.36	0.25*	-0.13	0.40	-0.16	2.20**	0.07	-4.73**	-5.16**	-13.22**	-27.52**
P5xP8	1.88**	0.70*	0.65**	0.22	1.55**	0.77**	5.59**	3.44**	-1.31*	-1.45	28.54**	16.64**
P6xP7	2.27**	0.87**	1.00**	0.65**	3.02**	2.03**	2.46**	-1.15	0.39	-0.37	36.38**	13.00**
P6xP8	-0.99**	-2.44**	-0.40**	-0.78**	0.26	-0.95**	2.16**	-1.45	0.07	-0.41	1.79	-19.19**
P7xP8	0.54*	-0.85**	0.45**	0.06	1.37**	0.38	1.58**	-1.26	-0.60	-1.66*	4.56**	-14.45**
LSD5% (sij)	0.43	0.56	0.22	0.32	0.41	0.39	1.06	1.56	1.04	1.51	2.09	2.91
LSD1% (sij)	0.56	0.75	0.29	0.43	0.54	0.52	1.39	2.07	1.36	2.00	2.74	3.85
LSD5% (sij-sik)	0.64	0.86	0.33	0.50	0.61	0.60	1.57	2.38	1.53	2.30	3.09	4.44
LSD1% (sij-sik)	0.84	1.14	0.43	0.66	0.80	0.79	2.06	3.16	2.01	3.05	4.05	5.89
LSD5% (sij-skl)	0.21	0.77	0.11	0.44	0.20	0.54	0.52	2.13	0.51	2.06	1.03	3.97
LSD1% (sij-skl)	0.28	1.02	0.14	0.59	0.27	0.71	0.69	2.83	0.67	2.73	1.35	5.26

Table 8. Correlation coefficient for GCA and SCA effects between Griffings methods of analysis (Method 2 and 4) in the combined analysis.

Combining ability effect	Ear length	Ear diameter	No. of rows ear^{-1}	No. of kernels row^{-1}	100-kernel weight	Grain yield plant^{-1}
GCA effect r	0.95**	0.77**	0.86**	0.67**	0.87**	0.94**
SCA effect r	0.98**	0.98**	0.95**	0.92**	0.95**	0.98**

* $p < 0.05$; ** $p < 0.01$

Table 9: Correlation coefficients for the mean squares of GCA, SCA, GCA/SCA ratio and error among the four methods of analysis for the studied traits.

Method of diallel	GCA	SCA	GCA xD	SCA xD	GCA/SCA	GCA xD/SCA	SCAxD/SCA	Error
G2 *vs* G4	0.999**	0.995**	0.996**	0.996**	0.808**	0.420	0.446	1.00**
G2 *vs* Jones	1.000**	1.000**	1.000**	1.000**	0.999**	1.000**	1.000**	1.00**
G2 *vs* Hayman	0.997**	1.000**			0.643**			1.00**
G4 *vs* jones	0.999**	0.995**	0.999**	0.999**	0.710**	0.411	0.451	1.00**
G4 *vs* hayman	0.995**	0.813**			0.365			0.99**
Jones *vs* Hayman	0.997**	1.000**			0.643*			1.00**

* $p < 0.05$; ** $p < 0.01$

REFFERENCES

Aksel, R. and L.P.V. Johnson (1959). Analysis of diallel cross: A worked example. Advancing frontiers. Pl. Si 2: 37-53.

Amer, E.A. (2003). Diallel analysis for yield and its components of maize under two different locations. Minufiya J. Agric. Res.28 (5): 1363-1373.

Chawla, H.S. and V.P. Gupta (1984). Index India-Agric. Calcutta Agric. Soc. Indian, 28(4): 261-265.

Dawood, M.I., A.A. Nawar and A.M. Shehata (1994). Comparison between two methods of diallel cross analysis in maize (*Zea mays* L.). Menofiya J. Agric. Res. 19 (5): 2363-2378.

Dubey, R.B., V.N. Joshi and N.K. Pandiya (2001). Heterosais and combining ability for quality, yield and maturity traits in conventional and non-conventional hybrids of maize (*Zea mays* L.). Indian J. of Genetic and Plant Breed. 61(4): 353- 355.

EL-Badawy, M.EL.M., A.S. Sedhom, A.M. Morsy and A.A.A. EL-Hosary (2010). Combining ability in maize (*Zea mays* L.) under two nitrogen rates and genetic distance determined by RAPD. Proc. of the 12th Int. Conf. Agron., 20-22 Sep., El-Arish: 106-129.

EL-Hosary A.A.A. (2014). Relative values of three different testers in evaluating combining ability of new maize inbred lines. International J. of Plant Breed. and Genetics 8(2): 57-65.

EL-Hosary A.A.A. and A.A. Elgammaal (2013). Utilization of line x tester model for evaluating the combining ability of some new white maize inbred lines. Egypt. J. Plant Breed. 17(1): 72-79.

EL-Hosary, A.A. and M.EL.M. EL-Badawy (2005). Heterosis and combining ability in yellow corn (*Zea mays* L.) under two nitrogen levels. Proceeding of the 11th Conf. Agron. Fac. Agric., Assiut Univ.14-15 November, Egypt 89-99.

EL-Hosary, A.A., M.EL.M EL-Badawy and Y.M. Abdel-tawab (2006). Genetic distance of inbred lines and prediction of maize single-cross performance using RAPD and SSR markers. Egypt. J. Genet. Cytol. 35: 209-224.

EL-Hosary, A.A., M.EL.M. EL-Badawy and A.A.A. EL-Hosary (2011). Combining ability in maize under two sowing dates and comparison between methods of genetic analysis. Egypt. J. Plant Breed. 15 (5): 213-232.

Gardner, C.O. (1967). Simplified methods for estimating constants and computing sums of squares for a diallel cross analysis. Reprint from Fitotecania Latininoamerica 4: 1-12.

Gomez, K.N. and A.A. Gomez (1984). Statistical Procedures for Agricultural Research. John.Wiley and Sons. Inc., New York, 2nd ed.

Griffing, B. (1956). Concept of general and specific combining ability in relation to diallel crossing systems. Aus. J. of Biol. Sci. 9: 463-493.

Hayman, B. I. (1954a). The analysis of variance of diallel tables. Biometrics 10: 235-244.

Hayman, B. I. (1954b). The theory and analysis of diallel crosses. Genetics 39: 789-809.

Hayman, B. I. and K. Mather (1955). The description of gene interaction in continuous variation, Biomerics 10: 69-82.

Jinks, J. L. (1954). The analysis of continuous varation in a diallel cross of *Nicotiana rustica* varieties. Genetics 39: 767-788.

Jones, R. M. (1965). Analysis of variance of the half diallel table. Heredity 20: 117-121.

Kearsy, M.J. (1965). Biometrical analysis of a random mating population: A comparison of five experimental designs. Heredity 20: 205-235.

Lonnquit, J.H. and C.D. Gardner (1961). Heterosis in intervarietal crosses in maize and its implications in breeding procedures. Crop Sci. 1: 179-183.

Mather, K. and J.L. Jinks (1971). Biometrical Genetics. (2nd ed.), Chapman and Hall Ltd. London.

Matzinger, D. F. and O. Kempthorne (1956). The modified diallel table with partial inbreeding and interactions with environment. Iowa State College. Ames. Journal Paper. N. J. 3053. U.S.A.

Mosa, H.E. (2003). Combining ability of eight yellow maize (*Zea mays* L.) inbred lines for different characters in diallel crosses. J. Agric. Res. Tanta Univ. 31(4-A) 604-614.

Motawei, A.A. (2005). Combining ability and heterotic effect of nine maize inbred lines *via* diallel cross analysis. Minufiya J. Agric. Res. 30(1): 197 – 214.

Nawar, A.A. (1985). A comparison between seven analysis methods of diallel crosses in maize (*Zea mays* L.). Minufiya J. Agric. Res. 10(2): 739-758.

Sedhom A.S., M.EL.M. EL-Badawy, A.M. Morsy and A.A.A. EL-Hosary (2007). Diallel analysis and relationship between molecular polymorphisms and yellow maize hyprid performance. Annals of Agric. Sci., Moshtohor 45(1): 1-20.

Shafey, S.A., H.E. Yassien, I.E.M.A.El-Beially and O.A.M. Gad-Alla (2003). Estimation of combining ability and heterosis effects for growth, earliness and yield in maize (*Zea mays* L.). J. Agric. Sci. Mansoura Univ. 28 (1): 55-67.

Sprague, G.F. and L.A. Tatum (1942). General *vs* specific combining ability in single crosses of corn. J. Am Soc. Agron. 34: 923-932.

مقارنة بين بعض طرق تحليل الهجن التبادلية فى الذرة الشامية

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تم تقييم ثمانية سلالات مرباه داخليا من الذرة الشامية و الهجن التبادلية بينهم (ماعدا العكسية) فى تصميم القطاعات الكاملة العشوائية بثلاث مكررات تحت ميعادين من الزراعة (5/2/ 2014 و 6/1/ 2014) فى مزرعة مركز البحوث الزراعية الخاصة بكلية الزراعة – جامعة بنها و تم تقدير القدرة على التآلف و الفعل الجينى لصفات المحصول و مكوناته. كان التباين الراجع الى ميعادى الزراعة معنويا فى كل الصفات المدروسه و كان المتوسط العام للميعاد الاول للزراعة اكبر من الميعاد المتأخر. و كان التباين الراجع الى التراكيب الوراثية و مكوناتها (الاباء، الهجن ، الآباء مقابل الهجن) معنويا لمعظم الصفات تحت الدراسة. كان التباين الراجع الى القدره العامه و الخاصة على الائتلاف المقدر بطريقتى جرفينج (الطريقة الثانية و الرابعة) و طريقة جونز معنويا فى معظم الصفات تحت الدراسة فى كل ميعاد

زراعه على حده و كذلك التحليل المشترك للميعادين. و كانت النسبة بين تباين القدرة العامة و تباين القدره الخاصة اقل من الوحده فى كل الصفات تحت الدراسة مما يدل على ان الفعل الجينى غير المضيف هو المتحكم فى وراثة تلك الصفات فى كل ميعاد زراعة و كذلك التحليل المشترك. أظهرت السلالات الابوية رقم 3 و 7 قدره جيدة عامة على الائتلاف لصفة محصول الحبوب / نبات و واحد او اكثر من مكوناته. أعطت الهجن P1xP7 , P2xP8 , P3xP4 , P3xP7 , P1xP8 , P2xP3 , P2xP8 , P3xP4 , P3xP7, P4xP7 , P5xP6 , P5xP8 و P6xP7 تأثيرات قدرة خاصة على التآلف عالية المعنوية لمحصول الحبوب / نبات. و حققت الهجن P3xP4 , P3xP7 , P6xP7 , P5xP6 , P2xP3 , P1xP7 , P4xP7 , P2xP8 , P1xP6 و P1xP7 تفوقا معنويا على صنفى المقارنة (بيونير 30ك8 و فردى 10) فى التحليل المشترك لصفة محصول الحبوب/ نبات. و بلغ مقدار التفوق فى اعلى ثلاثة هجن (P3xP7 , P3xP4 و P5xP6) حوالى (26.37 و 36.56)، (22.03 و 31.87)، (16.16و 25.56%) بالمقارنة الهجين الفردى 10 و الهجين الفردى بيونير 30ك8، على التوالى. كان تأثير السيادة (H1) معنوى لكل الصفات المدروسه تحت ميعادى الزراعة و كان اكبر من الجزء المضيف. و كانت (h2) معنوية لكل الصفات المدروسة. و كانت درجة التوريث منخفضة فى كل الصفات تحت الدراسة. كانت الاليلات المتنحية و السائدة غير متساوية فى الأباء لمعظم الصفات و ذلك بأستخدام (H2/4H1) و قيمة (F). و كانت السيادة الفائقة ذات التأثير الاكبر فى كل الصفات. أظهرت السلالة رقم 5 فى الميعاد المبكر و رقم 8 و رقم 1 فى الميعاد المتأخر انها تحمل معظم الاليلات السائدة لصفة المحصول/ نبات بينما السلالة رقم 4 كانت تحمل معظم الأليلات المتنحية. كان مقدار معامل الأرتباط بين القدرة على التآلف و الخطأ المقدرين بالأربعة طرق (جريفنج الطريقة الثانية و الرابعة و جونز و هايمن) موجبة وعالية المعنوية و هذا يرجع الى التشابه فى كفاءة تلك الطرق الاربعة فى تقديرهم للقدرة على التآلف و الخطأ التجريبى.