Int. J. Pure Appl. Sci. Technol., 20(2) (2014), pp. 33-43

International Journal of Pure and Applied Sciences and Technology

ISSN 2229 - 6107

Available online at [***www.ijopaasat.in***](http://www.ijopaasat.in)

Research Paper

Estimation of Combining Ability for Yield and its Components using Triallel Crosses in Maize

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(Received: 3-11-13; Accepted: 11-12-13)

Abstract: *The inbred lines of maize IK8, ZP-301, IK58, ZP707, OH40, DK17 and UN44052, and all 3-way crosses among them were used in this study. The seeds of genotypes (7 lines and 105, 3-way crosses) were planted at the field of Faculty of Agric. & Forestry College, Duhok University in 15 March 2012, using a randomized complete block design with three replications, to estimate variances and effects of all kinds of general and specific combining abilities for parents and 3-way crosses respectively, and to determine genetic performance which controls the inheritance of grain yield per plant and some of its components (plant height, ear height, number of days to silking, number of rows per ear, leaf area and 300 grain weight) using variance components from 3-way crosses analysis. The analysis of variance results for 3-way hybrids showed the presence of additive and non-additive effects for all studied characters, and the non-additive genetic effects (dominance and epistasis of this type) was more important in the inheritance of all studied characters, therefore the appropriate breeding method that can be adopted to improve these characters either the production of hybrid varieties or by recurrent selection for specific combining ability. The inbred lines OH40 and UN44052 characterized by significant general combining ability for more characters as parents and grandparents, and the hybrids (IK8xZP301) xZP707, (IK8xZP707) xZP301, (ZP301xDK17)xZP707 and (ZP301xUN44052) xZP707 perform well for grain yield per plant and could be used in future breeding programs.*

Keywords: Triallel Crosses, Combining Ability, Maize, Yield Components.

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1. Introduction

Maize of important food crops in the world after wheat and rice, grown in importance quickly as a crop provides raw materials for industry. One of the primary goals of most of the maize breeding programs for the development of high-yield varieties and adapted to a wide range of environmental conditions, and is the breeding of improved varieties sustained action and needs to be comprehensive information about the mechanism that controls the grain yield and its components of other characters. The method of diallel cross proposed by (Griffing, 1956) one of the ways of identifying the genetic nature for quantitative characters of the crops including maize, which help the breeders in identify the strategy and methods of selection, while the methods of triallel and double cross analysis proposed by (Rawlings and Cockerham, 1962 a and b) and analysis of (Hinkelman, 1965) for partial triallel hybridization, they are useful in display triallel and doudle cross hybrids in the suitable statistical and genetically analysis from which to obtain information more clearly. (Wright, 1966) apply triallel analysis method in maize and received significant differences to the required sources of variation are all tested and for all studied characters, as well as attempts were conducted by (Ponnuswamy, 1971) and (Ponnuswamy and Das, 1973) for the development of models and suitable analysis methods to study the development of lines and quantitative genetics breeds in three-way hybridization. In maize crop many studies have dealt with the subject of combining ability and gene action, as (Vafias and Ipsilandis, 2005) found from their study of the 3-way hybrids in maize, that the sources of variation 1-Line General, 1-Line Order, 2-Line Order, 2-Line Specific, 3-Line specific and 3-Line Order were all highly significant for grain yield character, and some pure lines and single crosses have had good combining ability (general and specific, respectively) in increas0ing grain yield, and can be utilized in future breeding programs. (Ojo *et al*., 2007), when studied diallel crosses in maize, found that mean squares of general combining ability was significant at the level of probability 1% for grain yield, and at the level of probability of 5% for the ear length, but for specific combining ability was not significant for all characters, and two pure lines only gave general combining ability effect in the desired direction, and (Pajic *et al*., 2008), when carries out half diallel cross in maize, found the importance of both additive and non-additive gene effects influencing grain yield, as they obtain mean square values for general and specific combining abilities significant and close with each other. (Rangel *et al.*, 2008) and (Dawod *et al*., 2009) conducted studies included testing of gene action, which controls the grain yield using half diallel crosses, and it appeared that grain yield per plant is under control of dominance gene effect, while (Al-Ahmad *et al*., 2012) proposed that additive gene action was controlling with inheritance of most studied characters of maize.

The aim of the research, to estimate variances and effects of both general and specific combining abilities (of various kinds) for seven pure lines of maize and their three-way hybrids, and identify the genetic behavior, which controls the inheritance of grain yield and its components to take advantage of it in breeding programs for this crop.

2. Materials and Methods

Seven pure lines of maize: (1) IK8, (2) ZP-301, (3) IK58, (4) ZP707, (5) OH40, (6) DK17 and (7) UN44052 were mated in a diallel fashion according to Method 2 of (Griffing, 1956) during spring season of 2010. The seven pure lines and their 21 F_1'swere planted during spring season 2011at the field of Faculty of Agric. & Forestry College, Duhok University and all possible three-way crosses among them done according to the method outlined by (Rawlings and Cockerham, 1962a) to obtain 105 three-way hybrids. The resulting 105three-way hybrids along with their parents were planted at the same field in 15 March 2012, using a randomized complete block design with three replications. Each plot consisted of one row of 5m length. The spacing between rows was 0.75 m and plant to plant was 0.20 m. One plant per hill was maintained. Fertilizers were applied at the rate of 680 kg per hectare of NPK (18:23:0) before planting, and N as urea at the rate of 200 kg per hectare, a month after planting.

Observations were recorded on ten randomly selected guarded plants from each plot for plant height (cm) (PH), ear height (cm) (EH), number of days to silking (NDS), number of rows per ear (NRE),leaf area (cm^2) (LA),300 grain weight (gm) (300 gw) and grain yield per plant (gm) (GYP).

Data of parents, hybrids and all genotypes (parents and hybrids) (each alone), for all studied traits, were subjected to analysis of variance according to the method of experimental design used, and comparisons between means were done according to Duncan's Multiple Range Test Method (Gomez and Gomez, 1983). The data of three-way hybrids subjected to analysis of variance according to the method of (Rawlings and Cockerham, 1962a) (Fixed Model), (proportional contribution of each source of variation estimated as percent of its sum square to total sum square of hybrids), and general combining ability (gca) effects of two kinds was estimated, the first (h_i) (i as grandparent) and the second (g_i) (i as parent). All kinds of specific combining ability (sca) effects also estimated as follows: (1) the first specific of two lines (d_{ij}) (i and j as grandparents), (2) the second specific of two lines (S_{ij}) (i as grandparents and j as parent) and (3) the specific effects of three lines (t_{ijk}), and their significant from zero was tested. Also the variances of effects (general and specific) of all kinds for each line was estimated, $\sigma^2 h_i$ (for general and I grandparent), $\sigma^2 g_i$ (for general and i parent), $\sigma^2 d_{i.}$ (for specific of 1st kind and i grandparent), $\sigma^2 S_{i.}$ (for specific of 2nd kind and i grandparent), $\sigma^2 S_{.i}$ (for specific of 2nd kind and i parent), $\sigma^2 t_{i..}$ (for three lines specific and i grandparent) and $\sigma^2 t_{..i}$ (for three lines specific and i parent) using the methods explained by (Singh and Chaudhary, 2007). All statistical and genetically analysis were performed by using SAS (Statistical Analysis System V. 9) and Microsoft Office Excel 2003.

3. Results and Discussion

Analysis of variance of genotypes data (parents and all possible 2-way cross hybrids), parents and hybrids (each alone) for studied characters presented in Table 1. It was shown that mean square of genotypes, parents, hybrids and parents vs hybrids was highly significant for all characters. The highly significant mean square of genotypes indicating genetic differences among them, and this requires partitioning of hybrids mean square to its components according to the method of (Rawlings and Cockerham, 1962a), to identify the nature of gene action that controls the genetic inheritance of characters under study. The results of this partitioning illustrated in Table 2, and it is noted that mean square for all sources of variations (1-line general, 2-line specific, 3-line specific, 1-line order, 2-line.

Table (1): ANOVA of genotypes data for grain yield and some of its components in maize

Source	Df	MS						
		PH	EH	NDS	NRE	LA	300 gw	GYP
Reps.	2	88.009	21.851	38.467	0.517	2315.9	99.765	235.75
Genotypes	111	1533.3**	605.5**	30.96**	5.84**	33329.9**	270.9**	4148.67**
Parents (P)	6	416.21**	1013.1**	15.30**	4.19**	14536.7**	59.04**	1021.54**
P vs H	1	26606.4**	4431.6**	6.864**	20.1**	273139.5**	2957.2**	68997.4**
Hybrids (H)	104	1550.1**	685.9**	110.4**	5.23**	31089.5**	265.5**	3547.55**
Error	208	7.333	9.88	1.425	0.322	189.09	1.269	3.911

(**) significant at 1% level

Table (2): ANOVA of 3-way crosses data for grain yield and some of its components in maize

Source	Df	MS						
		PH	EH	NDS	NRE	LA	300 gw	GYP
Hybrids (H)	104	1550.1**	685.9**	110.4**	5.23**	31089.5**	265.5**	3547.55**
1 line	(6)	1073.6**	340.2**	186.0**	6.74**	16914.5**	245.2**	2292.23**

general								
2 line specific	(14)	939.06**	717.1**	174.6**	6.23**	37373.2**	300.2**	4719.82**
3 line specific	(14)	1890.62**	614.9**	64.81**	4.67**	18867.8**	315.6**	1747.80**
1 line order	(6)	541.48**	406.9**	116.4**	10.1**	20103.1**	436.3**	9289.83**
2 line order a	(14)	1473.2**	732.7**	58.52**	2.89**	24778.2**	320.7**	1905.27**
2 line order b	(15)	1789.5**	840.8**	150.5**	6.82**	37181.2**	243.5**	3931.49**
3 line order	(35)	1840.8**	723.9**	92.47**	4.21**	37691.9**	193.2**	3521.71**
Error	208	2.444	3.293	0.475	0.107	63.033	0.423	1.304
Proportional contribution of the following sources to total variance of hybrids								
1 line general		3.996	2.861	9.721	7.434	3.139	5.328	3.728
2 line specific		8.156	14.073	21.296	16.039	16.182	15.221	17.909
3 line specific		16.419	12.069	7.903	12.019	8.169	16.001	6.632
1 line order		2.015	3.423	6.082	11.153	3.731	9.481	15.108
2 line order a		12.795	14.377	7.136	7.435	10.729	16.259	7.229
2 line order b		16.651	17.678	19.670	18.813	17.249	13.227	15.984
3 line order		39.967	35.519	28.191	27.106	40.801	31.727	33.409

(**) significant at 1% level

order a, 2-line order b and 3-line order) was highly significant for all characters, indicated the presence of additive, non-additive and epistasis effects for all studied characters, as the two sources 1-line general and 1-line order considered as evidence of additive effects and epistasis of additive types, the two sources 2-line specific and 2-line order a considered as evidence of dominance effects and epistasis of dominance type, while the sources 3-line specific and 3-line order considered as evidence of additive x dominance effects. It was shown from Table 2, that the proportional contribution of the two sources 1- line general and 1-line order to total variance of hybrids was less than it is in other sources of variation, this shows that non-additive genetic effects (dominance and epistasis of this type) was more important in the inheritance of all studied characters. Table 3., illustrates the range and means of parents and 3-way cross hybrids for grain yield and some of its components in maize, and it is clear that there were significant differences among parents and 3-way hybrids for all characters. It seems that the highest values in the 3-way hybrids was more

Table (3): Range and means of parents and 3-way cross hybrids for grain yield and some of its components in maize

Traits	Range of parents		Parents mean	Range of hybrids		Hybrids mean	General mean
	Lower	higher		Lower	higher		
PH	127.667 c (ZP707)	157.222 a (IK8)	144.476	121.333p (46)1	227.333 a (15)6	181.238**	178.941
EH	54.667 e (UN44052)	102.333 a (IK8)	74.952	64.000 e (13)2	115.667 a (35)7	89.956**	89.018
NDS	72.667 b (UN44052)	77.667 a (ZP707)	74.238	67.333 x (14)7	78.333 a (35)7	73.648**	73.685
NRE	12.667 c (ZP707)	16.000 a (IK8)	14.571	12.000 i (46)7	18.667 a (12)4	15.581**	15.518

LA	362.037 f (ZP707)	571.867 a (IK8)	460.206	405.623v (14)2	976.407 a (24)5	577.993**	570.631
300 gw	34.580 d (ZP301)	48.367 a (UN44052)	42.917	39.560 p (45)6	78.363 a (14)2	55.173**	54.407
GYP	33.063 e (ZP301)	81.250 a (IK8)	48.605	42.917 u (16)5	179.027 a (14)7	107.805**	104.105

(**) significant at 1% level vs parents mean.

than their counterparts in parents with high percent for all characters, and also noted that the general mean of 3-way hybrids was higher than that in the parents and the general mean of genotypes, This indicates that there are indicators for significant desirable heterosis in many 3-way hybrids, which in turn is an indication of the importance of dominance gene action and epistasis of dominant type to the inheritance of all these characters. The pure line IK8 surpassed other lines by giving higher values for characters PH, EH, NRE, LA and GYP, and the 3-way hybrids (15)6, (35)7, (12)4, (24)5, (14)2 and (14)7 characterized by higher mean values for PH, EH, NRE, LA, 300 gw and GYP respectively, while the line UN44052 and hybrid (14)7 appeared more earliest maturity, as they gave the lowest number of days to silking. General combining ability effects of pure lines of maize of two types (h_i, as grandparent and g_i, as parent) for different characters presented in Table 4.It was noted that the following pure lines showed significant desirable general combining ability effects, whether used as father or grandfather: IK58, OH40 and DK17 for PH, UN44052 for EH and LA, DK17 and UN44052 for NDS, IK8 and OH40 for NRE, ZP301 and ZP707 for 300 gw and ZP301, ZP707 and OH40 for GYP. On the other hand, the overall performance of the

Table (4): General combining ability effects of parents for studied traits

Parents	Characters						
	PH	EH	NDS	NRE	LA	300 gw	GYP
as grandparent (h_i)							
1. IK8	-1.481	-3.609	-0.681*	0.171*	-6.299	-3.502	-7.176
2. ZP301	-1.195	-0.281	2.248	0.043*	-19.016	2.081*	8.402*
3. IK58	1.238*	-0.705	-1.114*	-0.162	8.759*	-1.893	-8.491
4. ZP707	-5.176	0.305*	1.086	-0.081	-9.966	2.249*	2.840*
5. OH40	0.843*	-0.738	1.014	0.300*	-2.174	0.461*	0.288*
6. DK17	6.257*	2.400*	-2.048*	-0.090	20.680*	0.539*	-1.084
7.UN44052	-0.486	2.629*	-0.505*	-0.181	8.016*	0.063	5.219*
SE (h_i)	0.173	0.201	0.076	0.036	0.879	0.072	0.126
as parent (g_i)							
1. IK8	-0.548	-0.200	1.424	0.733*	33.423*	0.469*	9.313*
2. ZP301	-5.252	-3.957	1.000	0.024	-47.326	3.571*	5.662*
3. IK58	6.048*	2.390*	1.857	0.400*	-5.476	3.210*	9.077*
4. ZP707	-5.490	-3.895	0.990	0.338*	9.157*	0.945*	7.926*
5. OH40	5.805*	1.490*	-0.167*	0.109*	4.326*	-2.066	6.733*
6. DK17	1.143*	-0.486	-3.809*	-0.776	-0.630	-2.763	-19.413
7.UN44052	-1.705	4.657*	-1.295*	-0.829	6.527*	-3.3866	-19.299
SE (g_i)	0.223	0.259	0.098	0.047	1.134	0.093	0.163

(*) significant from zero in desirable direction

following pure lines as parents was best, IK58 for EH, NRE, 300 gw, and GYP, IK8 for LA, 300 gw and GYP, OH40 for EH, NDS and LA and ZP707 for LA and NRE, while the overall performance of lines was better as grandparents for the following cases, IK8 for NDS, IK58 for LA, ZP301 for NRE, ZP707 for EH, DK17 for EH, LA, and 300 gw, OH40 for 300 gw and UN44052 FOR GYP. Table 5 showed two-line specific effect of first kind d_{ij} (i and j as grand-parents) for studied characters, and it is noted that the effect was significant desirable in 9 combination for PH and EH, 11 combination for NDS and LA and

10 combination for NRE, 300 gw and GYP. The two combinations of lines d_{12} and d_{56} characterized by significant desirable effects for more number of characters reached 6 for each including GYP, followed by combinations d_{17}, d_{25}, d_{35}, d_{36} and d_{47} as it surpasses all of them to five characters, including GYP. The 2-line specific effect of second kind S_{ij} and S_{ji} (one line as half parent and other as parent) for studied characters was presented in Tables 6 and 7, and of them seem that the effects was significant desirable from combinations between lines in both directions in 4, 4, 6, 8, 5, 9 and 7 cases of combinations for PH, EH, NDS, NRE, LA, 300 gw and GYP respectively, and the compatibility between the lines 1 and 2 was superior to six characters, followed by compatibility between 3 and 6, 4 and 7, 1 and 7 and 2 and 6. The results of the specific combining ability effects of the 3-way hybrids illustrated in the table 8. It is clear that specific effect was significant desirable in 49, 54, 51, 40, 52, 41, and 47 3-way hybrids out of 105 hybrids for PH, EH, NDS, NRE, LA, 300gw and GYP respectively, and the best hybrids, with higher effect value, for these characters respectively, (14)6 (49.614), (23)5 (40.687). (24)5 (-24.398), (12)4 (2.712), (13)4 (319.259), (13)5 (48.84) and (12)3 (95.991).

For the purpose of identifying the preferred three pure lines give the best 3-way hybrid for each character, the bilateral consensus d_{ij}, S_{ij} and S_{ji} (Tables 5, 6 and 7) of the two lines had a top general effects (as parent and grandparent) (Table 4) with other lines should be tested (Ponnuswamy*et al*., 1974). The lines which gives desirable bilateral consensus selected and then determination the best 3-way hybrids in the appropriate order after noting the specific combining ability effects (t_{ijk})presented in Table 8. On this basis noted for PH, the pure lines 3 and 6 had a higher desirable general effects (as parents and grandparents), and their bilateral consensus (d_{ij}, S_{ij} and S_{ji}) were

Table (5): Two-line specific effect of first kind (I and j as grand-parents) for studied characters

d_{ij}	PH	EH	NDS	NRE	LA	300 gw	GYP
d_{12}	6.226*	1.929*	1.578	0.219*	17.184*	8.725*	19.165*
d_{13}	-3.289	2.693*	-0.211*	-0.170	46.544*	-5.340	-5.198
d_{14}	-3.304	-7.174	-1.993*	0.322*	10.429*	2.527*	-7.135
d_{15}	-9.252	-6.252	-2.411*	-0.374	-50.129	-4.707	-8.545
d_{16}	-1.207	2.329*	0.426	-0.863	-13.489	-4.329	-12.143
d_{17}	10.826*	6.474*	2.611	0.867*	-10.540	3.124*	13.856*
d_{23}	-5.115	-6.222	-3.707*	0.219*	-63.414	-4.142	-19.091
d_{24}	-0.241	1.819*	2.048	-0.067	48.381*	-5.432	7.447*
d_{25}	0.107	3.741*	3.000	0.681*	23.083*	3.383*	3.006*
d_{26}	4.281*	-1.937	0.689	-0.067	-16.235	3.504*	8.693*
d_{27}	-5.259	0.670*	-3.607*	-0.985	-8.999	-6.039	-19.219
d_{34}	2.337*	7.656*	-0.704*	-0.937	-38.924	3.976*	-5.913
d_{35}	7.889*	-0.441	2.174	0.329*	62.587*	2.426*	3.318*
d_{36}	2.026*	-0.656	3.178	0.804*	17.617*	5.577*	26.667*
d_{37}	-3.848	-3.029	-0.729*	-0.244	-24,411	-2.497	0.218
d_{45}	3.522*	-0.919	-1.589*	-0.104	-74.507	-1.662	-3.673
d_{46}	-7.452	-0.411	-1.122*	0.333*	5.173*	-5.632	-10.419
d_{47}	5.137*	-0.970	3.359	0.452*	49.448*	6.222*	19.694*
d_{56}	3.470*	3.844*	-1.356*	-0.326	25.699*	1.125*	3.623*
d_{57}	-5.737	0.026	0.181	-0.207	13.268*	-0.566	2.071*
d_{67}	-1.119	-3.170	-1.815*	0.119*	-18.765	-0.245	-16.619
SE (d_{ij})	0.347	0.403	0.153	0.073	1.764	0.145	0.254

(*) significant from zero in desirable direction

Table (6): 2-line specific effect of second kind (i as half parent and j as parent) for studied characters

S_{ij}	PH	EH	NDS	NRE	LA	300 gw	GYP
S_{12}	12.859*	1.718*	2.204	0.154*	63.942*	0.302*	8.482*
S_{13}	-13.373	-0.934	-5.465*	-1.074	72.129*	-17.154	-38.631
S_{14}	1.709*	-6.559	-2.640*	-0.458	-30.153	5.428*	-20.471
S_{15}	-28.711	-9.739	-2.072*	-0.413	-98.329	-5.581	-34.523
S_{16}	6.732*	8.497*	3.142	-0.346	31.849*	-1.626	11.248*
S_{17}	23.354*	3.109*	5.105	2.133*	-16.959	9.110*	56.931*
S_{23}	-12.194	-7.917	-8.046*	-0.445	-38.496	-12.942	-43.648
S_{24}	-3.921	12.981*	1.339	-0.927	64.857*	-9.120	-6.154
S_{25}	-2.152	-0.972	7.069	1.035*	17.004*	7.271*	-8.463
S_{26}	17.592*	2.472*	5.168	1.065*	23.502*	10.961*	42.843*
S_{27}	-3.406	-2.569	-2.883*	-0.123	-22.298	-2.632	15.350*
S_{34}	6.757*	21.442*	-0.408*	-1.958	-111.788	5.893*	-19.158
S_{35}	-1.885	-13.395	1.781	0.467*	99.893*	4.859*	-14.816
S_{36}	14.243*	0.285	6.402	2.043*	25.178*	12.317*	58.268*
S_{37}	-10.297	-8.477	-0.954*	0.170*	-5.317	0.170*	28.268*
S_{45}	0.469*	-2.593	2.075	0.379*	-110.623	6.899*	-1.312
S_{46}	-8.805	1.239*	-0.178*	1.086*	57.131*	-3.211	5.764*
S_{47}	6.035*	-5.889	5.095	1.712*	49.982*	13.287*	63.228*
S_{56}	12.564*	12.874*	1.029	0.956*	47.454*	6.708*	35.246*
S_{57}	-3.652	0.963*	1.215	0.574*	25.833*	5.645*	37.896*
S_{67}	-0.814	-5.654	-0.319*	1.499*	-16.817	6.097*	25.073*
SE (S_{ij})	0.314	0.365	0.139	0.066	1.596	0.131	0.229

(*) significant from zero in desirable direction

Table (7): 2-line specific effect of second kind (j as half parent and i as parent) for studied characters

S_{ji}	PH	EH	NDS	NRE	LA	300 gw	GYP
S_{21}	6.034*	6.565*	4.973	0.097*	-3.032	1.766*	8.350*
S_{31}	0.518*	-10.367	1.707	-0.152	-43.132	-6.385	-7.836
S_{41}	-10.132	7.624*	-1.998*	0.033	-1.888	-1.858	-9.859
S_{51}	27.376*	2.745*	-2.953*	-0.688	13.052*	3.504*	7.558*
S_{61}	-18.518	-13.039	-2.506*	-0.568	-49.425	0.040*	-19.470
S_{71}	-5.267	5.963*	0.734	1.293*	85.077*	2.137*	19.762*
S_{32}	-5.228	-6.030	-5.642*	-0.716	-103.014	-5.463	-32.385
S_{42}	0.729*	-2.099	1.296	0.623*	17.629*	2.711*	10.443*
S_{52}	-12.157	4.332*	2.420	0.318*	0.807	-0.477	3.999*
S_{62}	9.667*	3.506*	1.668	-0.266	-19.334	1.819*	12.986*
S_{72}	-5.869	-0.895	-1.356*	-0.072	40.557*	1.035*	-2.384
S_{43}	-10.808	-10.274	-0.855*	-0.471	-2.268	3.723*	9.821*
S_{53}	2.477*	9.356*	0.977	0.020	-33.156	2.139*	-17.096
S_{63}	3.602*	7.016*	6.165	0.816*	41.239*	1.608*	34.248*
S_{73}	8.774*	-0.107	-1.665*	-0.008	-75.230	-7.294	-8.021
S_{54}	-3.685	0.124	-1.531*	0.446*	-74.879	-3.529	-1.344
S_{64}	-1.214	8.687*	1.032	0.705*	1.788*	-1.110	5.655*
S_{74}	5.780*	-2.062	0.208	0.235*	35.320*	4.981*	28.812*
S_{65}	-3.939	-7.729	-0.655*	0.009	8.796*	3.873*	-4.401
S_{75}	5.390*	3.333*	0.807	-0.491	-34.370	-0.187	6.996*
S_{76}	-6.318	-9.771	2.804	0.253*	-47.592	5.701*	0.051
SE (S_{ji})	0.314	0.365	0.139	0.066	1.596	0.131	0.229

(*) significant from zero in desirable direction

Table (8): 3-line specific effects for studied characters

Hybrids	PH	EH	NDS	NRE	LA	300 gw	GYP
(12)3	28.027*	10.358*	11.805	1.451*	-82.897	32.422*	95.991*
(12)4	-4.790	-24.629	6.462	2.712*	-51.974	8.255*	59.448*
(12)5	12.899*	3.784*	-9.680*	-1.067	128.837*	2.226*	29.549*
(12)6	-30.293	-10.919	-12.016*	-0.278	-96.383	-16.185	-78.832
(12)7	-10.402	14.700*	-4.443*	-3.516	38.051*	-12.521	-97.454
(13)2	-21.123	0.827*	-5.261*	-1.203	-71.557	-5.934	-37.892
(13)4	-6.721	-18.763	1.693	2.337*	319.259*	-8.609	45.774*
(13)5	32.714*	32.534*	3.759	1.429*	-83.405	48.84*	90.714*
(13)6	-18.529	-7.738	-5.433*	-0.662	-52.581	-8.538	-41.091
(13)7	-7.097	5.936*	-1.555*	-2.215	-2.616	-4.868	-92.795
(14)2	-0.651	3.087*	4.049	0.885*	49.059*	5.496*	21.488*
(14)3	-11.848	-2.434	-6.987*	-1.169	-117.397	30.761*	-25.088
(14)5	35.454*	-4.743	3.380	1.609*	263.595*	20.706*	44.457*
(14)6	49.614*	14.831*	1.729	-0.278	-137.494	2.999*	-0.531
(14)7	-37.999	1.871*	-9.355*	-5.331	-140.424	-25.471	-120.252
(15)2	19.164*	-22.557	3.749	0.839*	105.635*	4.926*	39.417*
(15)3	-2.538	2.057*	5.004	0.654*	83.768*	11.239*	49.296*
(15)4	-30.587	12.199*	-0.779*	-0.325	6.667*	-6.322	-10.827
(15)6	16.508*	4.651*	-4.655*	-1.834	-152.317	-8.310	-68.558
(15)7	-53.050	-15.860	-7.985*	-1.877	-127.843	-12.161	-107.308
(16)2	-26.119	-0.451	-6.274*	-1.032	12.525*	-8.329	-36.998
(16)3	27.212*	13.010*	9.374	2.071*	108.304*	20.635*	74.099*
(16)4	-12.517	-17.083	0.216	0.962*	16.439*	-6.043	3.936*
(16)5	43.667*	-0.873	2.158	-0.826	37.778*	8.474*	30.939*
(16)7	-30.013	17.705*	-9.226*	-3.924	-79.187	-15.875	-95.623
(17)2	28.793*	18.577*	3.022	0.468*	-95.194	3.798*	12.377*
(17)3	34.082?*	8.760*	3.476	-0.077	68.736*	15.219*	19.028*
(17)4	-6.468	25.959*	-0.021	-0.207	14.995*	-9.441	-14.593
(17)5	1.047*	-26.308	3.635	1.369*	84.003*	11.193*	46.247*
(17)6	-29.027	-21.129	-5.267*	0.109	-20.557	-7.353	-16.09
(23)1	-10.541	15.479*	-1.901*	0.654*	-19.220	4.281*	26.979*
(23)4	8.784*	-38.717	1.948	2.546*	4.327*	4.751*	8.646*
(23)5	40.362*	40.687*	0.519	1.054*	49.903*	3.567*	75.862*
(23)6	-68.516	-17.794	-16.891*	-4.334	46.124*	-29.030	-96.144
(23)7	14.871*	11.867*	0.001	-1.219	-8.866	-1.187	-63.759
(24)1	7.649*	-20.895	-0.485*	1.339*	12.153*	-1.291	-18.612
(24)3	15.957*	-11.772	2.624	0.719*	183.223*	-5.005	55.778*
(24)5	-18.119	19.169*	-24.398*	-3.321	-40.118	-22.148	-73.900
(24)6	8.072*	10.868*	0.400	-1.172	-127.939	-2.904	-30.583
(24)7	-12.254	23.228*	3.663	-2.558	36.619*	0.535*	-50.178
(25)1	-3.226	0.772*	2.923	-1.068	-50.050	-4.457	16.494*
(25)3	38.305*	10.052*	7.245	1.099*	-94.035	24.991*	-5.152
(25)4	24.399*	-18.995	-0.765*	0.550*	40.345*	6.197*	24.700*
(25)6	-46.664	-20.645	-10.688*	-2.172	-51.939	-15.009	-60.415
(25)7	-35.935	-23.170	1.996	-0.549	100.101*	-19.444	-66.973
(26)1	0.079	2.238*	2.515	-0.049	29.899*	-0.146	7.323*
(26)3	-12.409	-13.402	1.763	-0.558	122.709*	4.609*	-15.484
(26)4	35.672*	0.649	4.378	0.097	-198.285	11.575*	13.149*
(26)5	-24.333	-4.702	-3.842*	1.058*	78.050*	5.561*	58.089*
(26)7	40.973*	21.654*	-8.096*	-2.336	-8.269	-14.859	-73.439

(27)1	6.112*	7.591*	-2.971*	-0.901	26.914*	2.603*	-30.289
(27)3	-14.297	-13.448	7.680	1.275*	-1.623	14.525*	36.969*
(27)4	3.629*	-25.772	9.622	-0.424	-119.206	19.815*	25.451*
(27)5	13.288*	14.067*	-7.550*	0.568*	32.692*	-12.202	31.995*
(27)6	-15.420	2.704*	-16.003*	-1.321	-29.624	-22.233	-84.637
(34)1	19.819*	12.957*	7.562	-1.336	66.113*	4.599*	24.011*
(34)2	7.409*	8.434*	3.040	1.348*	83.616*	15.753*	7.970*
(34)5	-13.731	11.178*	-5.995*	-1.678	-63.444	-22.057	-4.964
(34)6	-3.256	-5.025	-13.053*	-3.074	-138.642	-17.708	-80.438
(34)7	18.292*	25.057*	3.182	0.224*	-8.273	-8.129	-39.499
(35)1	-0.592	-16.025	-2.957*	0.404*	67.963*	1.821*	-21.409
(35)2	7.391*	5.142*	4.109	0.005	-66.824	1.875*	34.135*
(35)4	-6.494	-15.184	0.503	0.805*	54.737*	-5.346	5.324*
(35)6	-34.196	-9.187	-14.067*	-4.593	260.339*	-24.982	-124.366
(35)7	-9.592	-10.656	2.256	1.715*	-60.737	2.738*	-18.166
(36)1	-3.583	4.836*	-4.346*	-0.466	-27.561	-6.368	-33.531
(36)2	29.349*	-5.622	1.919	0.505*	-0.917	-2.041	4.688*
(36)4	-31.517	-29.671	-4.335*	1.129*	287.399*	4.433*	17.129*
(36)5	0.889*	37.196*	7.319	0.294*	-154.863	-8.906	31.425*
(36)7	42.352*	15.371*	0.848	-1.294	-0.244	1.646*	-25.476
(37)1	-2.217	-15.020	2.446	0.812*	-86.271	0.880*	13.715*
(37)2	-21.165	-10.409	-3.358*	-0.550	60.997*	-7.512	-5.020
(37)4	-7.894	-23.776	-9.479*	0.071	167.228*	-18.406	-56.507
(37)5	33.177*	31.279*	8.556	-1.400	3.545*	-0.381	36.833*
(37)6	-26.915	30.347*	-5.753*	-0.835	6.486*	1.870*	-43.676
(45)1	8.505*	11.119*	0.312	-0.096	4.766*	-1.609	-10.833
(45)2	-0.452	-5.321	-4.599*	-0.981	-50.228	-5.889	-22.959
(45)3	-20.848	-9.517	3.805	0.034	101.943*	-3.776	23.056*
(45)6	-18.034	-22.339	2.409	-1.283	-101.925	-0.708	-18.986
(45)7	36.190*	9.223*	0.769	-0.808	-45.913	-3.183	-66.187
(46)1	6.292*	4.258*	-4.874*	-0.262	-103.365	1.422*	6.187*
(46)2	-22.049	-3.807	0.415	-0.444	-110.235	-5.502	12.685*
(46)3	8.920*	14.177*	4.212	1.192*	-51.281	4.089*	7.258*
(46)5	16.759*	-6.192	-9.208*	-2.562	256.102*	-18.026	-49.080
(46)7	-2.754	7.196*	-4.434*	-3.113	154.687*	-19.630	-115.752
(47)1	-45.139	-6.080	-2.138*	0.516*	30.029*	-3.156	4.891*
(47)2	19.641*	-6.742	-2.585*	-0.666	5.087*	-7.098	-14.535
(47)3	27.235*	7.631*	4.685	0.654*	-43.428	2.874*	3.209*
(47)5	-11.749	5.743*	-8.027*	-2.089	89.641*	-11.516	-43.131
(47)6	28.228*	-0.343	1.872	-0.654	-96.160	1.893*	2.067*
(56)1	-17.824	-8.742	2.719	1.404*	31.977*	6.800*	24.042*
(56)2	6.562*	16.549*	-3.404*	0.139*	36.437*	0.881*	-20.075
(56)3	11.693*	-2.666	-3.982*	-1.021	-107.260	-1.549	-6.257
(56)4	7.543*	-1.485	2.859	0.726*	-12.798	0.435*	21.593*
(56)7	-9.675	-11.536	-3.916*	-3.030	80.794*	-25.981	-101.605
(57)1	18.209*	12.179*	-2.267*	-0.484	-38.483	-0.341	3.359*
(57)2	-32.952	7.874*	-2.459*	-0.083	-17.625	-2.143	-28.699
(57)3	-1.862	9.381*	-1.899*	0.442*	31.615*	-1.183	11.981*
(57)4	-1.167	-11.480	-1.729*	-0.165*	46.881*	-1.700	-37.925
(57)6	8.381*	-26.264	5.580	-2.913	5.012*	-8.056	-24.899
(67)1	16.403*	2.355*	3.677	-0.539	51.869*	-1.060	-4.847
(67)2	6.192*	-8.242	4.684	0.565*	56.284*	12.081*	27.709*
(67)3	-20.019	-7.888	-4.362*	-0.957	-23.473	-0.261	-8.047

(67)4	0.995*	13.682*	-0.568*	-1.026	-1.741	-12.308	-41.995
(67)5	-8.185	2.650*	-5.657*	0.623*	-94.168	-5.643	-22.445
SE (t_{ijk})	0.617	0.716	0.272	0.129V	3.131	0.257	0.450

(*) significant from zero in desirable direction

Significant and desirable with lines 2, 4 and 5. Accordingly, comparison of specific combining ability effect values of the 3-way hybrids which includes two lines(3 and 6) with any of the lines (2, 4, or 5) indicate that the best 3-way hybrids for this character were in the orders, (36)2, (36)5, (46)3 and (56)3. In the same way the best 3-way hybrids (in suitable orders) for other characters could be determinate, as follows:

- For EH, The best general combiner two lines were 6 and 7, their bilateral consensus (d_{ij}, S_{ij} and S_{ji}) were significant and desirable with lines 1, 2 and 5. Then the best 3-way hybrids for this character were in the orders, (16)7, (26)7, (27)6, (67)1 and (67)5.

- For NDS, The best general combiner two lines were 6 and 7, their bilateral consensus (d_{ij}, S_{ij} and S_{ji}) were significant and desirable with lines 2, 3, 4 and 5. Then the best 3-way hybrids for this character were in the orders, (26)7, (27)6, (37)6, (46)7, (56)7, (67)3 and (67)4.

- For NRE, The best general combiner two lines were 1 and 5, their bilateral consensus (d_{ij}, S_{ij} and S_{ji}) were significant and desirable with lines 2, 3, 4 and 7. Then the best 3-way hybrids for this character were in the orders, (14)5, (15)2, (15)3, (17)5 and (35)1.

- For LA, The best general combiner two lines were 1 and 7, their bilateral consensus (d_{ij}, S_{ij} and S_{ji}) were significant and desirable with lines 2 and 5. Then the best 3-way hybrids for this character were in the orders, (12)7, (17)4, (27)1 and (47)1.

- For 300 gw, The best general combiner two lines were 2 and 4, their bilateral consensus (d_{ij}, S_{ij} and S_{ji}) were significant and desirable with lines 1, 3, 6 and 7. Then the best 3-way hybrids for this character were in the orders, (12)4, (14)2, (23)4, (24)7, (26)4, (27)4 and (34)2.

- For GYP, The best general combiner two lines were 2 and 4, their bilateral consensus (d_{ij}, S_{ij} and S_{ji}) were significant and desirable with lines 1, 6 and 7. Then the best 3-way hybrids for this character were in the orders, (12)4, (14)2, (26)4, (27)4 and (46)2.

It was concluded from the above results that non-additive genetic effects (dominance and epistasis of this type) was more important in the inheritance of all studied characters, therefor the appropriate breeding method that can be adopted to improve these characters either the production of hybrid varieties or by recurrent selection for specific combining ability. The results also showed that the two lines 5 and 7 showed significant desirable general combining ability effects for more number of characters, whether used as parents or grandparents, followed by lines 2, 4 and 6, and the 3-way hybrids (12)4, (14)2, (26)4 and (27)4 perform well for 300gw and GYP, and it can take advantage of this valuable genotypes in future breeding programs.

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