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Research Article

Evaluation of Bread Wheat Crosses via Line X Tester Mating Design

El-Gammaal A.A.[1], R.M. konber.[2] and A.M. Magd.[1]
[1]Crop Sci. Dep., Faculty of Agric, Tanta University, Egypt
[2]Wheat Research Department, Gemmeiza ARS, FCRI, ARC, Egypt

*Corresponding Author
El-Gammaal A.A

Abstract: Nine lines and four testers of wheat (*Triticum aestivum* L.) were crossed by line x tester model to give 36 top crosses during growing season 2014/2015. In 2015/2016 season, the lines, testers and 36 F_1's were planted in a randomized complete block design with three replicates. The results indicated that, mean squares of replication were significant or highly significant for all studied traits, except for days to heading. highly significant differences among genotypes for all the studied traits. Partitioning sum of squares due to genotypes revealed highly significant differences among parents, crosses and parents vs. crosses for all the studied traits, except for 1000-grain weight for parents vs. crosses. Crosses was partitioned into lines, testers and line x testers interaction, the mean squares of lines, testers and line x testers showed significant or highly significant values for all the studied traits, except for grain yield/plant for lines also, days to maturity and number of grains/spike for testers. The ratio of σ^2gca/σ^2sca showed values less than the unity for all studied traits. The line parent (L_7) considered as a good combiner parent for earliness, grain yield and most of its components. The cross; L_9 x T_4 showed significant of specific combining ability effects values in desirable direction for earliness, grain yield and most of its components. The cross; L_7 x T_4 had desirable and significant heterosis effects over mid and better parents for earliness, grain yield and most of its components.
Keywords: combining ability, line x tester, gene action and wheat.

INTRODUCTION

Wheat is the major cereal crop in Egypt as well as all over the world. With increasing population, it could hardly satisfy only 55% of the local requirement. This increasing gap between wheat production and consumption could not be achieved only through extending the wheat area due to limited cultivated area of Egypt. Thus, it needs to increase the productivity of unit area through adapting efficient breeding program. Moreover the genetically approach of studying growth attributes, at various stages, could help in understanding the genetic variabilities of wheat growth and development, that have impact on earliness. Exploitation of such genetic information, related to growth, may cause further breakthrough in yield level (Srivastava and Nema, 1993).

The success of any plant breeding program depends largely upon a better understanding of genetic basis of yield and its contributing characters. Information about growth analysis, chlorophyll contents in leaf, heterosis, general and specific combining abilities and the types of genet action may help the wheat breeder to formulate the most efficient breeding procedure to achieve maximum genetic improvement among a particular set of genotypes. Development of commercial F_1 hybrid wheat may be one way of increasing yield. The most important factor in determining the feasibility of hybrid wheat is the nature and the amount of heterosis together with the development of plant type which make cross pollination more easy and applicable.

The ability of some crop cultivars to perform well over a wide range of environmental conditions has been long appreciated by the agronomist and plant breeder. The understanding of genotypes by environment interaction in plant breeding is a matter of great interest, since genotype by environment interaction usually hamper selection of the genotypes which consistently show superior performance over a series of environments, where the genotype–environment interaction variance could be portioned

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into its components to minimize its size for unbiased estimation and selection of genotypes.

Therefore, the main objective of this study was to develop new promising wheat genotypes that are able to produce high yield this was approached through, identification of superior parents and their crosses from a 9 lines × 4 testers of wheat parental genotypes, estimation of combining ability effects for grain yield and some related agronomic traits and estimation of heterosis over mid and better parent and potence ratio for yield and some related agronomic traits.

MATERIALS AND METHODS

This investigation was carried out at Gemmeiza Agriculture Research Stations, Agriculture Research Center (ARC), Egypt, during the two successive seasons 2014/2015 and 2015/2016. Nine lines and four testers of wheat (*Triticum aestivum* L.) were used. In 2014/2015 season, the four testers were crossed with the nine lines to produce the F_1 hybrids. In 2015/2016 season, seed of the four testers, nine lines and F_1 hybrids of the 36 top crosses were planted in a randomized complete block design with three replicates. Each parent and F_1 was represented by two rows per replicate. Each row was 1.5 m long, and spaces between rows were 30 cm with 15 cm between plants. All the recommended agronomic practices for wheat production were applied at the proper time. Data were recorded on 10 random competitive plants from each row for days to heading (day), days to maturity (day), number of spikes/plant, number of grains/spike, 1000-grain weight (g) and grain yield/plant (g). The obtained data for each character were analyzed on plot mean basis. Statistical procedures used in this study were done to the analysis of variance for randomized complete blocks design as outlined by Cochran and Cox (1957). An ordinary analysis of variance was performed for the data collected from top crosses to test the differences and significance of all genotypes. When differences among top crosses were significant, the line x tester analysis according to Kempthorne (1957), was done to estimate variance due to general and specific combining abilities of the tested lines, testers and line x testers interaction as well as various types of the gene effects. General GCA and specific SCA combining ability effects was calculating according to Singh and Chaudhary (1977). Heterosis as proposed by Mather and Jinks (1982).

RESULTS AND DISCUSSION

Mean squares of different wheat genotypes for all studied traits are presented in Table 1. Results indicated that, replications mean squares were significant or highly significant for all studied traits, except for days to heading. Genotypes, parents and crosses mean squares were highly significant for all studied traits, reflecting the diversity of the parents for these studied traits and that these diversity could be transmitted to the progenies. parents vs. crosses mean squares were highly significant for all studied traits, except for 1000-grain weight, indicating the presence of hybrid vigor for the studied wheat genotypes**.**

Mean squares of lines were highly significant for all studied traits, except grain yield/ plant, while mean squares of testers were highly significant for days to maturity and no. of grain / spike. Lines x testers mean squares were highly significant for all studied traits, indicating that the testers were significantly different from each other in top crosses. Moreover, the inbred lines significantly differed in their behavior from top cross to anther**.**

The ratio of σ^2gca/σ^2sca showed values less than the unity for all studied traits, indicating that non-additive gene effects play an important role in controlling the inheritance of these traits, so selection would be done in late segregating generations using bulk method. The obtained results were in good harmony with those reported by El-Borhamy (2005) who reported that, the GCA/SCA ratio revealed the importance role of non-additive genetic variance in the inheritance for grain yield / plant and its components. Abdel nour, Nadya *et al.,* (2011) reported that, the non-additive gene effects were larger than those of the additive ones and played the major role in the inheritance for grain yield and its components; 1000-grain weight, no. of grain / spike and no. of spikes / plant. Saren *et al* (2018) reported that the non-additive components were greater than additive components for days to heading, 1000-grain weight and grain yield per plant. Farooq *et al* (2019) reported that, the GCA/SCA ratio less the unity for thousand-grain weight and grain yield per plant.

Table 1: Observed mean squares from ordinary analysis of variance for all studied traits.

S.O.V	d.f	Days to heading	Days to maturity	No of spikes / plant	No of grain / spike	1000-grain weight	Grain yield/ plant
Replications	2	3.231	4.925**	64.714*	52.17*	86.43**	299.068*
Genotypes	48	26.042**	3.241**	75.831**	526.104**	280.861**	618.339**
Parents (P)	12	46.286**	5.363**	97.714**	1104.701**	144.228**	1142.077**
Crosses (C)	35	17.029**	1.893**	66.403**	320.403**	335.7**	348.01**
P vs. C	1	98.564**	24.983**	143.225**	782.481**	1.088	3795.002**
Lines (L)	8	36.417**	3.375**	52.898**	469.148**	307.578**	103.917
Testers (T)	3	29.383**	1.491	102.157**	14.676	180.833**	376.802**
L x T	24	9.022**	1.449**	66.435**	309.037**	364.432**	425.775**
Error	96	2.940	0.654	15.228	14.705	16.294	87.082
σ^2gca	-	0.642	0.031	0.098	1.772	1.442	5.386
σ^2sca	-	2.027	0.265	17.069	98.111	116.046	112.898
σ^2gca/σ^2sca	-	0.316	0.116	0.005	0.018	0.012	0.047

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

Estimates of general combining ability effects for all studied traits are presented in Table 2. For days to heading, the parents (L_2), (L_3), (L_7) and (T_2) exhibited significant of general combining ability effects for earliness. For days to maturity, the line parent (L_1) and (L_2) considered as a good combiner parent for earliness. Regarding to no. of spikes / plant, the parents (L_4) and (T_2) showed significant and desirable of general combining ability effects. Concerning no. of grain / spike, the line parent (L_2), (L_3), (L_6), (L_7), (L_8) and (L_9) showed significant of general combining ability effects in positive direction. For 1000-grain weight, the parents (L_1), (L_5), (L_7) and (T_4) exhibited significant and positive of general combining ability effects. Regarding to grain yield/ plant, the tester parent (T_1) showed significant of general combining ability effects in positive direction, which may indicated that this parent considered as good combiner one for the traits mentioned above.

Table 2: Estimates of general combining ability effects for all studied traits.

parents		Days to heading	Days to maturity	No of spikes / plant	No of grain / spike	1000-grain weight	Grain yield/ plant
Lines							
L_1		0.528	-0.528*	-1.213	-7.120**	5.000**	-0.972
L_2		-2.222**	-0.778**	-2.213*	4.546**	-3.833**	-1.972
L_3		-1.056*	-0.028	-2.713*	2.546**	2.125	-6.056*
L_4		2.444**	0.222	2.870*	-7.954**	1.833	-0.556
L_5		1.278*	0.222	0.537	-9.287**	3.833**	2.528
L_6		-0.639	0.056	2.120	3.880**	-8.583**	2.111
L_7		-2.472**	-0.361	-2.130	4.213**	4.458**	0.444
L_8		0.194	1.056**	1.037	2.296**	1.917	4.028
L_9		1.944**	0.139	1.704	6.880**	-6.750**	0.444
LSD	0.05	0.980	0.462	2.230	2.192	3.307	5.334
	0.01	1.297	0.612	2.959	2.955	3.053	7.058
Testers							
T_1		-0.259	-0.009	-0.565	-0.287	0.148	5.167**
T_2		-1.148**	-0.083	2.769**	0.157	-1.222*	0.278
T_3		0.037	-0.232	-0.417	-0.806	-2.463**	-3.093
T_4		1.370**	0.324*	-1.787*	0.935	3.537**	-2.352
LSD	0.05	0.653	0.308	1.487	1.461	1.195	3.556
	0.01	0.865	0.408	1.968	1.933	1.581	4.705

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

Estimates of specific combining ability effects of all wheat parental combinations were computed for all studied traits are presented in Table 3. The results showed that, crosses; L_9 x T_3 and L_9 x T_4 for days to heading and the cross (L_4 x T_2) for days to maturity showed significant of specific combining ability effects values in negative and desirable direction. The crosses; L_4 x T_2, L_7 x T_3 and L_7 x T_4 showed significant of specific combining ability effects values in positive direction for no. of spikes / plant. The crosses; L_1 x T_3, L_3 x T_4, L_5 x T_1, L_5 x T_2, L_7 x T_1, L_8 x T_3 and L_9 x T_4 showed significant of specific combining ability effects values in positive direction for no. of grain / spike. For 1000-grain weight, the crosses; L_1 x T_2, L_3 x T_3, L_4 x T_3, L_5 x T_1, L_5 x T_4, L_6 x T_3, L_7 x T_2, L_7 x T_3, L_8 x T_4 and L_9 x T_1 exposed significant of specific combining ability effects in positive direction. The crosses; L_5 x T_1, L_6 x T_3, L_7 x T_4, L_8 x T_2 and L_9 x T_4 showed significant of specific combining ability effects values in positive direction for grain yield/ plant.

Table 3: Estimates of specific combining ability effects for all studied traits.

Crosses		Days to heading	Days to maturity	No of spikes / plant	No of grain / spike	1000-grain weight	Grain yield/ plant
Line-1	T-1(1)	-0.491	0.009	0.731	3.787	0.519	-1.250
	T-2(2)	-0.269	0.083	-3.935	2.343	11.222**	3.639
	T-3(3)	1.880	0.898	2.583	15.639**	-9.870**	6.676
	T-4(4)	-1.120	-0.991	0.620	-21.769**	-1.870	-9.065
Line-2	T-1(5)	-1.407	-0.407	1.398	2.787	-4.315	-0.917
	T-2(6)	-0.519	-0.333	-3.269	-2.324	-0.611	-7.028
	T-3(7)	0.630	0.815	0.250	-2.694	1.296	-0.324
	T-4(8)	1.296	-0.074	1.620	2.231	3.630	8.269
Line-3	T-1(9)	-1.574	-0.157	1.565	-10.213**	0.394	-3.833
	T-2(10)	-1.019	0.583	-1.769	-1.324	-3.236	3.056
	T-3(11)	0.463	-0.269	-3.250	-1.028	8.338**	-6.241
	T-4(12)	2.130*	-0.157	3.454	12.565**	-5.495*	7.019
Line-4	T-1(13)	1.593*	0.926*	-2.352	1.287	-6.981**	1.667
	T-2(14)	-0.852	-1.333**	10.315**	1.176	-2.611	6.556
	T-3(15)	-0.037	-0.852	-6.500**	-1.528	9.630**	-5.741
	T-4(16)	-0.704	1.259**	-1.463	-0.935	-0.037	-2.481
Line-5	T-1(17)	0.426	-0.741	-3.352	5.287*	13.685**	31.917**
	T-2(18)	-1.019	0.333	5.6488	13.509**	-19.611**	-9.861
	T-3(19)	1.796	0.481	1.833	-7.861**	-9.037**	-9.824
	T-4(20)	-1.204	-0.074	-4.130	-10.935**	14.963**	-12.231*
Line-6	T-1(21)	0.009	0.426	-0.602	0.454	3.102	-4.333
	T-2(22)	0.231	0.167	-2.935	1.343	-0.528	-6.111
	T-3(23)	-0.954	-0.685	4.250	-2.028	6.046*	15.593**
	T-4(24)	0.713	0.093	-0.713	0.231	-8.620**	-5.148
Line-7	T-1(25)	-0.824	-0.157	0.648	11.787**	-17.606**	-12.667*
	T-2(26)	-0.269	-0.417	-7.019**	-1.324	16.097**	-9.444
	T-3(27)	-1.454	0.065	1.167*	-9.361**	11.838**	7.259
	T-4(28)	2.546*	0.509	5.204*	-1.102	-10.329**	14.852**
Line-8	T-1(29)	1.176	-0.241	5.815	-9.296**	-2.731	-4.583
	T-2(30)	-0.269	0.167	-1.852	-4.407*	2.972	11.972*
	T-3(31)	0.546	-0.019	2.667	13.556**	-12.454**	5.343
	T-4(32)	-1.454	0.093	-6.630**	0.148	12.213**	-12.731*
Line-9	T-1(33)	1.093	0.343	-3.852**	-5.880**	13.935**	-6.000
	T-2(34)	3.981**	0.750	4.815	-8.991**	-3.694	7.222
	T-3(35)	-2.870**	-0.435	-3.000	-4.694*	-5.787	-12.741*
	T-4(36)	-2.204**	-0.657	2.037	19.565**	-4.454*	11.519*
LSD	s_{ij} 0.05	1.960	0.924	4.460	4.384	4.614	10.668
	s_{ij} 0.01	20594	1.223	5.903	5.801	6.106	14.116

(*) and (**) significant at 0.05 and 0.01 levels probability, respectively.

Means performance of the nine lines, four wheat testers and their F1 crosses for all studied traits are presented in Table 4. Concerning days to heading, the parental line L2 and the crosses; L_2 x T_1, L_2 x T_2, L_7 x T_2 and L_7 x T_3 were the earlies parents and crosses. For days to maturity, the parental tester T_1 and top cross; L_1 x T_4, L_2 x T_1, L_2 x T_2 and L_4 x T_2 were the latest parents and crosses for days to maturity. The parental line L_1 and the crosses; L_4 x T_2, L_5 x T_2 and L_9 x T_2 for no. of spikes / plant and the parental line L_5 and crosses; L_3 x T_4, L_7 x T_1 and L_9 x T_4 for no. of grain / spike showed the highest values for this trait. Regarding to 1000-grain weight, the parental line L_7 and top crosses; L_5 x T_1, L_7 x T_2 and L_8 x T_4 showed the highest values for this trait. For grain yield / plant, the parental tester T_2 and the crosses; L_5 x T_1, L_6 x T_3 and L_8 x T_2 showed the highest values for this trait.

Table 4: Means of lines, testers and their F_1 crosses for all studied traits.

	Genotypes	Days to heading (day)	Days to maturity (day)	No of spikes / plant	No of grain / spike	1000-grain weight (g)	Grain yield / plant (g)
	L1	97.67	154.00	29.33	72.00	48.00	74.67
	L2	83.67	151.33	16.67	85.33	48.00	80.00
	L3	92.00	153.33	20.67	55.00	42.67	51.67
	L4	94.67	153.00	14.67	81.00	44.67	50.00
	L5	94.00	153.00	10.33	97.00	53.67	55.00
	L6	90.33	152.00	10.67	81.33	39.00	35.00
	L7	92.67	154.00	11.33	26.67	59.00	20.00
	L8	92.00	154.00	12.33	66.33	42.33	35.00
	L9	88.67	151.33	17.00	55.67	37.00	35.00
	T1	85.00	149.67	17.33	92.33	48.03	60.00
	T2	94.33	153.33	26.00	79.00	35.67	86.67
	T3	93.67	153.33	17.33	55.00	54.33	63.33
	T4	89.67	154.00	16.67	61.33	43.83	50.00
Line-1	T-1(1)	89.33	151.33	13.67	61.00	51.33	45.00
	T-2(2)	88.67	151.33	12.33	60.00	60.67	45.00
	T-3(3)	92.00	152.00	15.67	72.33	38.33	44.67
	T-4(4)	90.33	150.67	12.33	36.67	52.33	29.67
Line-3	T-1(5)	85.67	150.67	13.33	71.67	37.67	44.33
	T-2(6)	85.67	150.67	12.00	67.00	40.00	33.33
	T-3(7)	88.00	151.67	12.33	65.67	40.67	36.67
	T-4(8)	90.00	151.33	12.33	72.33	49.00	46.00
Line-4	T-1(9)	86.67	151.67	13.00	56.67	48.33	37.33
	T-2(10)	86.33	152.33	13.00	66.00	43.33	39.33
	T-3(11)	89.00	151.33	8.33	65.33	53.67	26.67
	T-4(12)	92.00	152.00	13.67	80.67	45.83	40.67
Line-5	T-1(13)	93.33	153.00	14.67	57.67	40.67	48.33
	T-2(14)	90.00	150.67	30.67	58.00	43.67	48.33
	T-3(15)	92.00	151.00	10.67	54.33	54.67	32.67
	T-4(16)	92.67	153.67	14.33	56.67	51.00	36.67
Line-6	T-1(17)	91.00	151.33	11.33	60.33	63.33	81.67
	T-2(18)	88.67	152.33	23.67	69.00	28.67	35.00
	T-3(19)	92.67	152.33	16.67	46.67	38.00	31.67
	T-4(20)	91.00	152.33	9.33	45.33	68.00	30.00
Line-7	T-1(21)	88.67	152.33	15.67	68.67	40.33	45.00
	T-2(22)	88.00	152.00	16.67	70.00	35.33	38.33
	T-3(23)	88.00	151.00	20.67	65.67	40.67	56.67
	T-4(24)	91.00	152.33	14.33	69.67	32.00	36.67
Line-8	T-1(25)	86.00	151.33	12.67	80.33	32.67	35.00
	T-2(26)	85.67	151.00	8.33	67.67	65.00	33.33
	T-3(27)	85.67	151.33	13.33	58.67	59.50	46.67
	T-4(28)	91.00	152.33	16.00	68.67	43.33	55.00
Line-9	T-1(29)	90.67	152.67	21.00	57.33	45.00	46.67
	T-2(30)	88.33	153.00	16.67	62.67	49.33	58.33
	T-3(31)	90.33	152.67	18.00	79.67	32.67	48.33
	T-4(32)	89.67	153.33	7.33	68.00	63.33	31.00
Line-9	T-1(33)	92.33	152.33	12.00	65.33	53.00	41.67
	T-2(34)	94.33	152.67	24.00	62.67	34.00	50.00
	T-3(35)	88.67	151.33	13.00	66.00	30.67	26.67
	T-4(36)	90.67	151.67	16.67	92.00	38.00	51.67
LSD 0.01		2.74	1.29	6.24	6.13	6.45	14.93
0.05		3.59	1.69	8.18	8.04	8.47	19.58

The estimations of heterosis percentage over mid, better parent and patience ratio in wheat crosses for all studied traits. are presented in Table 5. For days to heading, significant or highly significant and negative heterosis effects over mid and better parents were detected for wheat crosses; L_1 x T_2, L_3 x T_2, L_3 x T_3, L_4 x T_2, L_5 x T_2, L_7 x T_2, L_7 x T_3 and L_8 x T_2. On the other hand, significant or highly significant negative heterosis values over mid parents were detected for crosses; L_1 x T_3, L_1 x T_4, L_2 x T_2, L_6 x T_2, L_6 x T_3, L_7 x T_1, L_8 x T_3 and L_9 x T_3. These heterotic effects were due to partial dominance (P > -1). Regarding days to maturity, the crosses; L_1 x T_2, L_1 x T_3, L_1 x T_4, L_3 x T_3, L_3 x T_4, L_4 x T_2, L_4 x T_3, L_7 x T_2 and L_7 x T_3 showed significant or highly significant and negative heterosis effects over mid and better parents. On the other hand, significant or highly significant negative heterosis values over mid parents were detected for crosses; L_2 x T_2, L_2 x T_4, L_5 x T_4, L_6 x T_3 and L_7 x T_4. These heterotic effects were due to partial dominance (P > -1). For no. of spikes / plant, significant or highly significant and positive heterosis effects over mid parents were detected for wheat crosses; L_4 x T_2, L_5 x T_2, L_6 x T_3 and L_8 x T_1. These heterotic effects were due to partial dominance (P <+1). Regarding to no. of grain / spike, the crosses; L_3 x T_3, L_3 x T_4, L_7 x T_4, L_8 x T_3, L_9 x T_3 and L_9 x T_4 showed significant or highly significant and positive heterosis effects over mid and better parents. On the other hand, significant or highly significant positive heterosis values over mid parents were detected for crosses; L_2 x T_2, L_2 x T_4, L_5 x T_4, L_6 x T_3 and L_7 x T_4. These heterotic effects were due to partial dominance (P <+1). For 1000-grain weight, the crosses; L_1 x T_2, L_5 x T_1, L_5 x T_4, L_8 x T_2 and L_8 x T_4 showed significant or highly significant and positive heterosis effects over mid and better parents. While, significant or highly significant positive heterosis values over mid parents were detected for crosses; L_1 x T_4, L_4 x T_4, L_7 x T_2 and L_9 x T_1. These heterotic effects were due to partial dominance (P <+1). Concerning grain yield / plant, highly significant positive heterosis over mid and better-parents were obtained by wheat cross; L_5 x T_1 . While, highly significant positive heterosis values over mid parents were detected for cross; L_7 x T_4. These heterotic effects were due to partial dominance (P <+1). These results are similar to those obtained by Khan and Habib (2004), Ahmad *et al.,* (2006), Ismail (2015) and Saren *et al.,* (2018).

Table 5: Heterosis percentage over mid, better parent and potence ratio in wheat crosses for all studied traits.

No of spikes / plant			Days to maturity			Days to heading			Crosses	
potence ratio	Heterosis		potence ratio	Heterosis		potence ratio	Heterosis			
	BP	MP		BP	MP		BP	MP		
-0.66	-53.39**	-41.41**	-0.01	1.11*	-0.33	-0.05	5.09**	-2.20	T-1(1)	Line-1
-1.05	-57.96**	-55.43**	-0.03	-1.30**	-1.52**	-0.16	-6.00**	-7.64**	T-2(2)	
-0.52	-46.57**	-32.83**	-0.02	-0.87*	-1.08**	-0.08	-1.78	-3.84**	T-3(3)	
-0.73	-57.96**	-46.39**	-0.04	-2.16**	-2.16**	-0.07	0.74	-3.57**	T-4(4)	
-0.42	-23.08	-21.59	0.00	0.67	0.11	0.03	2.39	1.58	T-1(5)	Line-2
-0.72	-53.85**	-43.75**	-0.02	-0.44	-1.09**	-0.08	2.39	-3.74**	T-2(6)	
-0.54	-28.85	-27.47	-0.01	0.22	-0.43	-0.02	5.18**	-0.76	T-3(7)	
-0.52	-26.03	-26.03	-0.02	0.00	-0.87*	0.08	7.57**	3.84**	T-4(8)	
-0.58	-37.11*	-31.58*	0.00	1.34**	0.11	-0.04	1.96	-2.07	T-1(9)	Line-3
-0.80	-50.00**	-44.29**	-0.01	-0.65	-0.65	-0.15	-6.16**	-7.34**	T-2(10)	
-1.03	-59.70**	-56.16**	-0.03	-1.30**	-1.30**	-0.08	-3.26*	-4.13**	T-3(11)	
-0.48	-33.87*	-26.78	-0.02	-0.87*	-1.08**	0.03	2.60	1.28	T-4(12)	
-0.15	-15.35	-8.31	0.02	2.22**	1.10**	0.08	9.80**	3.89**	T-1(13)	Line-4
0.80	17.96	50.82**	-0.03	-1.52**	-1.63**	-0.10	-4.59**	-4.76**	T-2(14)	
-0.62	-38.43*	-33.31	-0.03	-1.31**	-1.41**	-0.05	-1.78	-2.30	T-3(15)	
-0.16	-14.04	-8.55	0.00	0.44	0.11	0.01	3.35*	0.54	T-4(16)	
-0.29	-34.62	-18.08	0.00	1.11*	0.00	0.04	7.06**	1.68	T-1(17)	Line-5
0.42	-8.96	30.31*	-0.01	-0.44	-0.55	-0.12	-5.67**	-5.84**	T-2(18)	
0.33	-3.81	20.54	-0.01	-0.44	-0.55	-0.02	-1.07	-1.24	T-3(19)	
-0.50	-44.03*	-30.89	-0.02	-0.44	-0.76*	-0.02	1.48	-0.91	T-4(20)	
0.19	-9.58	11.93	0.02	1.78**	0.99**	0.02	4.32*	1.15	T-1(21)	Line-6
-0.13	-35.88**	-9.08	-0.01	0.00	-0.44	-0.10	-2.58	-4.69**	T-2(22)	
0.77	19.27	47.64*	-0.02	-0.66	-1.09**	-0.09	-2.58	-4.35**	T-3(23)	
0.08	-14.04	4.83	-0.01	0.22	-0.44	0.02	1.48	1.11	T-4(24)	
-0.19	-26.89	-11.58	-0.01	1.11*	-0.33	-0.07	1.18	-3.19*	T-1(25)	Line-7
-0.80	-67.96**	-55.37**	-0.03	-1.52**	-1.73**	-0.17	-7.55**	-8.37**	T-2(26)	
-0.12	-23.08	-6.98	-0.03	-1.30**	-1.52**	-0.16	-7.55**	-8.05**	T-3(27)	
0.24	-4.02	14.29	-0.02	-1.08	-1.08**	0.00	1.48	-0.19	T-4(28)	
0.71	21.18	41.60*	0.01	2.00**	0.55	0.05	6.67**	2.45	T-1(29)	Line-8
-0.19	-35.88**	-13.02	-0.01	-0.22	-0.43	-0.11	-3.99**	-5.19**	T-2(30)	
0.37	3.87	21.38	-0.01	-0.43	-0.65	-0.05	-1.82	-2.70*	T-3(31)	
-0.86	-56.03**	-49.45**	-0.01	-0.44	-0.44	-0.03	0.00	-1.28	T-4(32)	
-0.60	-30.76	-30.09	0.02	1.78**	1.22**	0.13	8.62**	6.33**	T-1(33)	Line-9
0.19	-7.69	11.63	0.00	0.89*	0.22	0.06	6.38**	3.09*	T-2(34)	
-0.48	-24.99	-24.26	-0.01	0.00	-0.66	-0.06	0.00	-2.74**	T-3(35)	
-0.02	-1.94	-0.98	-0.01	0.22	-0.65	0.03	2.26	1.68	T-4(36)	
-	6.24	5.40	-	1.29	1.11	-	2.74	2.37	LSD0.05	
-	8.18	7.09	-	1.69	1.46	-	3.59	3.11	0.01	

(*) and (**) significant at 0.05 and 0.01 levels probability, respectively.

Table 5: Cont.

Grain yield / plant			1000-grain weight			No of grain / spike			Crosses	
potence ratio	Heterosis		potence ratio	Heterosis		potence ratio	Heterosis			
	BP	MP		BP	MP		BP	MP		
-0.60	-39.73**	-33.17**	0.14	6.87	6.90	-0.46	-33.93**	-25.76**	T-1(1)	Line-1
-0.82	-48.08**	-44.22**	0.78	26.40**	45.02**	-0.39	-24.05**	-20.53**	T-2(2)	
-0.65	-40.18**	-35.26**	-0.53	-29.45**	-25.09**	0.24	0.46	13.91**	T-3(3)	
-0.87	-60.27**	-52.40**	0.27	9.02	13.97*	-0.83	-49.07**	-44.99**	T-4(4)	
-0.64	-44.59**	-36.67**	-0.43	-21.57**	-21.55**	-0.37	-22.38**	-19.32**	T-1(5)	Line-2
-1.15	-61.54**	-60.00**	-0.08	-16.67*	-4.39	-0.36	-21.48**	-18.46**	T-2(6)	
-0.87	-54.16**	-48.83**	-0.39	-25.14**	-20.51**	-0.11	-23.04**	-6.41	T-3(7)	
-0.48	-42.50**	-29.23**	0.13	2.08	6.72	-0.02	-15.23**	-1.36	T-4(8)	
-0.62	-37.78**	-33.14**	0.12	0.62	6.57	-0.37	-38.62**	-23.07**	T-1(9)	Line-3
-0.69	-54.62**	-43.14**	0.19	1.55	10.62	-0.03	-16.46**	-1.49	T-2(10)	
-0.97	-57.89**	-53.62**	0.19	-1.21	10.66	0.38	18.78**	18.78**	T-3(11)	
-0.39	-21.29	-20.00	0.12	4.56	5.97	0.73	31.53**	38.69**	T-4(12)	
-0.22	-19.45	-12.13	-0.24	-15.32*	-12.25*	-0.63	-37.54**	-33.46**	T-1(13)	Line-4
-0.46	-44.24**	-29.27**	0.16	-2.24	8.71	-0.54	-28.40**	-27.50**	T-2(14)	
-0.76	-48.41**	-42.35**	0.19	0.63	10.44	-0.34	-32.93**	-20.10**	T-3(15)	
-0.53	-26.66	-26.66*	0.30	14.17	15.25*	-0.36	-30.04**	-20.37**	T-4(16)	
0.81	36.12**	42.03**	0.47	18.00**	24.54**	-0.71	-37.80**	-36.27**	T-1(17)	Line-5
-0.83	-59.62**	-50.59**	-0.60	-46.58**	-35.82**	-0.39	-28.87**	-21.59**	T-2(18)	
-0.87	-49.99**	-46.47**	-0.59	-30.06**	-29.63**	-0.60	-51.89**	-38.59**	T-3(19)	
-0.82	-45.45**	-42.86**	0.72	26.70**	39.49**	-0.70	-53.27**	-42.74**	T-4(20)	
-0.08	-25.00*	-5.26	-0.13	-16.03*	-7.32	-0.39	-25.63**	-20.91**	T-1(21)	Line-6
-0.52	-55.77**	-36.99**	-0.10	-9.41	-5.37	-0.25	-13.93**	-12.68**	T-2(22)	
0.24	-10.52	15.26	-0.22	-25.14**	-12.85*	-0.06	-19.25**	-3.66	T-3(23)	
-0.23	-26.66	-13.72	-0.43	-26.99**	-22.73**	-0.04	-14.34**	-2.33	T-4(24)	
-0.17	-41.67**	-12.50	-0.71	-44.63**	-38.95**	0.45	-13.00**	35.01**	T-1(25)	Line-7
-0.46	-61.54**	-37.51**	0.60	10.17	37.32**	0.38	-14.34**	28.08**	T-2(26)	
0.16	-26.31*	12.01	0.10	0.85	5.00	0.65	6.67	43.68**	T-3(27)	
0.80	10.00	57.14**	-0.27	-26.56**	-15.72**	0.80	11.97*	56.07**	T-4(28)	
-0.03	-22.22	-1.75	-0.01	-6.31	-0.40	-0.48	-37.91**	-27.73**	T-1(29)	Line-8
-0.06	-32.70**	-4.12	0.49	16.54*	26.49**	-0.25	-20.67**	-13.75**	T-2(30)	
-0.03	-23.69	-1.70	-0.58	-39.87**	-32.40**	0.57	20.11**	31.33**	T-3(31)	
-0.46	-38.00*	-27.06	0.92	44.49**	47.01**	0.13	2.52	6.53	T-4(32)	
-0.19	-30.55*	-12.27	0.44	10.35	24.66**	-0.19	-29.24**	-11.72**	T-1(33)	Line-9
-0.25	-42.31**	-17.81	-0.13	-8.11	-6.43	-0.12	-20.67**	-6.93	T-2(34)	
-0.71	-57.89**	-45.75**	-0.55	-43.55**	-32.84**	0.38	18.56**	19.27**	T-3(35)	
0.37	3.34	21.58	-0.11	-13.30	-5.98	1.09	50.01**	57.26**	T-4(36)	
-	14.93	12.93	-	6.45	5.58	-	6.13	5.31	LSD0.05	
-	19.58	16.95	-	8.47	7.32	-	8.04	6.96	0.01	

(*) and (**) significant at 0.05 and 0.01 levels probability, respectively.

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