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GENETICAL ANALYSIS OF DIALLEL CROSS IN BREADWHEAT UNDER DIFFERENT ENVIRONMENTAL CONDITIONS IN EGYPT. 1. F_1 AND PARENTS

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ABSTRACT

This study was conducted in three different locations in Egypt, i.e., Ismailia, Nobaria and Gemmeiza Research Stations. F_1s of 15 wheat crosses produced from 6 half-dialleles in addition to their six parents were statistically and graphically analysed to detect the genetic effects governing 5 quantitative characters. Results for gca, sca and heterosis differed from one location to another according to the parental genotypes and the environmental conditions in these locations. The parents Agent and Sakha 69 showed the best gca in F_1 for plant height, spike length and 100-grain weight, while for number of grains/spike and grain yield/plant Sakha 92, Baart and Sakha 69 were the best. The best combinations for sca were the cross 7 for plant height at Ismailia and Nobaria cross 11 for spike length and grain yield/plant in all locations and in combined analysis. Cross 5 for grains/spike at Ismailia, cross 1 for 100-grain weight at all locations and in pooled analysis. The MP and BP heterotic effects were high for some crosses and differed from location to another and in combined analysis. All characters were controlled by both additive and nonadditive gene effects in all three locations in F_1 with unequal allele frequency of the parents. Asymmetrical distribution of positive and negative alleles among the parents and F_1 at all locations were detected for all traits. Overdominance or partial dominance were exhibited for some traits at different locations with the excess of dominant genes. One, two or more pairs of genes controlled the inheritance of these traits. Narrow sense heritability was relatively high or moderate for some trait at different locations. The r value was positive and significant only for 100-grain weight at Ismailia (0.93) and negative for plant height at Gemmeiza (– 0.89). In the Wr–Vr graphs, the parents showed variation in the dominant and recessive positions for all traits at all locations. Grain yield/plant in F_1 was phenotypically and genotypically correlated with plant height and the 100-grain weight at Gemmeiza, phenotypically only with spike length at Ismailia and Gemmeiza, and with number of grains/spike at Gemmeiza. Also there was a genotypical correlation only with the 100-grain weight at Ismailia.

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The improvement of wheat yield depends on a better understanding of the type of the gene action. Evaluation of genotype performance in different environments is important in plant breeding. The differential response of genotypes when subject to different environments possess a major problem relating phenotypic performance to genetic constitution and makes it difficult to decide which genotype should be selected. It is important to understand more fully the nature of genotype x environment (G x E) interaction to make testing and selection of genotypes more efficient. The combining ability and heterosis were studied by many investigators [1–4] who reported the importance of gca with heterotic effects for plant height and spike length while sca was more important for 100-grain weight and grain yield/plant. Jhorar et al. [5] and Yadav and Singh [6] found that both gca x environments as well as sca x environments interactions were significant for plant height, grains/spike and grain yield/plant with heterotic effects in F_1. Both additive and nonadditive gene actions affected the inheritance of plant height, grains/spike, 100-grain weight and grain yield/plant in F_1 hybrids [7, 8]. Narrow sense heritability values varied for the traits studied and depending on environments [7, 9, 10].

The present investigation aims to understand the genetic behaviour of several traits in half-diallel crosses of breadwheat in 15 F_1 and 6 parents at three locations. These studies included general and specific combining ability, heterosis, the nature of genetic variance components, and correlation between the traits at different locations.

MATERIALS AND METHODS

Six varieties of breadwheat (*Triticum aestivum* L.) 4 local i.e. Sakha 69, Giza 157, Giza 160 and Sakha 92; and 2 exotic from Mexico, i.e. Agent and Baart, were chosen on the basis of their wide variabilities. In winter 1990 a half set of the crosses involving the six parents was planted at three locations: Ismailia, Nobaria and Gemmeiza Research Stations. In winter 1991, ten seeds of each F_1 and parents were sown at the same locations in randomized complete block design with three replications in 3 m long rows, spaced 30 cm apart, with the space between plants in each row 10 cm. Data were recorded in a random sample of 20 guarded plants from the parents and F_1. Five quantitative characters were studied.

Combining ability was determined using the Griffing [11] Model 1 method 2, heterosis as per [12] and genetic variance components and heritability were determined according to Hayman [13]. The graphical analysis of the diallel crosses was carried out following Jinks [14]. Phenotypic and genotypic correlation coefficients were determined by the method of Singh and Chaudhary [15].

RESULTS AND DISCUSSION

Analysis of variance for the characters studied in F_1 (Table 1) showed highly significant mean squares of genotypes for all traits at all three locations and also from the combined

Table 1. Analysis of variance (MS) for five traits in F_1 of wheat

Source	Location	d.f.	Plant height	Spike length	Grains per spike	Grain yield per plant	100-grain weight
Replications	Ismailia	2	0.132	0.178	31.842	0.011	0.005
	Nobaria	2	2.161	0.473*	5.781	0.362	0.069
	Gemmeiza	2	2.624	0.108	1.028	0.050	0.019
Genotypes	Ismailia	20	60.030**	3.271**	120.058**	12.269**	0.825**
	Nobaria	20	24.243**	1.436**	65.411**	23.123**	0.938**
	Gemmeiza	20	73.643**	1.375**	91.384**	68.021**	2.259**
Error	Ismailia	40	0.414	0.213	20.061	3.424	0.051
	Nobaria	40	1.259	0.100	11.936	2.169	0.074
	Gemmeiza	40	1.508	0.168	14.978	3.158	0.071
Locations		2	39374.919**	307.085**	3216.608**	7636.579**	32.612**
Replications x locations		6	1.690**	0.352	12.942	0.722	0.073
Genotypes		20	72.571**	2.748**	120.421**	51.168**	1.780**
Locations x genotypes		40	42.680**	1.705**	78.046**	27.339**	1.000**
Error		120	1.057	0.198	15.689	3.083	0.084

data, which indicated the presence of true differences among the genotypes. The genotype x environment interactions were also highly significant.

Analysis of variance for general and specific combining ability (gca, sca) are given in Table 2. All variations at different locations and their combined data were significant or highly significant for gca and sca effects at all locations except for grain yield gca at Ismailia. The gca effects in F_1 of the diallel cross mating design are given in Table 3. The good combiner parents for F_1 at the three locations and in combined analysis over the locations were: Sakha 69 for plant height, except at Ismailia location where Agent was the best. Agent and Sakha 92 and Giza 157 for spike length; Sakha 92, Baart and Sakha 69 for grains/spike and for grain yield/plant; and Sakha 69 and Sakha 92 and Giza 160 for 100-grain weight.

Specific combining ability (Table 4) for plant height in the F_1 hybrids of the crosses 7, 11 and 2 at Ismailia, Nobaria and also the pooled analysis of all the locations were superior for this trait. At Gemmeiza, the crosses 11, 4 and 1 were the best. These results agree with earlier reports [16, 17]. For spike length the crosses 11 and 15 were the best at all locations. Similar results were reported by Noor et al. [1] and Salem and Hassan [18]. For grains/spike, locations gave different results. The cross 5 at Ismailia; crosses 15 and 1 at Nobaria; cross 11

Table 2. Analysis of variance (MS) of general combining ability (gca) and specific combining ability (sca) in F_1 generation of wheat

Source	Location	d.f.	Plant height	Spike length	No. of grains per spike	Grain yield per plant	100-grain weight
Gca	Ismailia	5	164.642**	7.724**	268.232**	9.578	1.184**
	Nobaria	5	29.204**	1.305**	92.880**	66.511**	0.249
	Gemmeiza	5	41.802**	2.062	171.171**	161.430**	3.650**
Sca	Ismailia	15	25.158**	1.831**	70.667**	13.166**	0.706**
	Nobaria	15	22.605**	1.479**	56.209**	8.661**	1.168**
	Gemmeiza	15	84.264**	1.146**	64.629**	36.883**	1.795**
Error	Ismailia	40	0.138	0.059	6.687	1.141	0.017
	Nobaria	40	0.417	0.033	3.977	0.723	0.025
	Gemmeiza	40	0.502	0.056	5.012	1.053	0.024
Gca		5	95.987**	5.362**	269.287**	108.753**	1.502*
Sca		15	64.766**	1.877**	70.799**	31.973**	1.873**
Locations x gca		10	79.838**	2.737**	131.391**	64.362**	1.378**
Locations x sca		30	33.628**	1.362**	60.264**	14.999**	0.874
Error		40	1.057	0.198	15.689	3.083	0.084

at Gemmeiza, and crosses 1 and 6 in the pooled analysis were the best for this trait. These results agree with those of [10, 19]. Cross 11 for grain yield/plant and the cross 1 for 100-grain weight were the best at all locations. These results agree with those reported earlier [1, 3, 6, 10].

The data on MP and BP heterosis in F_1 are presented in Table 5. Crosses 7 and 15 at Ismailia, crosses 2 and 8 at Nobaria, and cross 11 at Gemmeiza as well as in pooled analysis showed significant positive heterotic for plant height. These results agree with those of [5, 7]. For spike length, hybrids 12 and 15 at Ismailia, 9 at Nobaria, 13 and 12 at Gemmeiza, and 11 and 15 in the pooled analysis were the best. For grains/spike the hybrids 5 at Ismailia, 15 at Nobaria, 11 and 2 at Gemmeiza, and 8 in the pooled analysis showed highly heterotic effects. For grain yield/plant, the best hybrids were 4 and 11 at Ismailia, 11 and 2 at Nobaria, 12 at Gemmeiza and hybrid 11 in pooled analysis. Hybrid 3 at Ismailia, 1 at Nobaria and in pooled analysis and 15 and 9 at Gemmeiza showed best heterosis for grain size. These results agree with some of the earlier reports for grains/spike, grain yield/plant, and 100-grain weight.

Table 3. General combining ability effects in F_1 generation

Parent variety		Ismailia					Nobaria				
		plant height	spike length	grains per spike	grain yield per plant	100-grain weight	plant height	spike length	grains per spike	grain yield per plant	100-grain weight
Sakha 69		-0.083	-0.298^{**}	-2.164^{*}	-0.058	-0.295^{**}	1.735^{**}	0.030	1.377^{*}	-0.056	0.076
Giza 157		-0.633^{**}	-0.070	-2.195^{*}	-0.504	-0.248^{**}	0.639^{**}	0.369^{**}	2.326^{**}	0.248	0.096
Giza 160		-3.747^{**}	-0.952^{**}	-3.460^{**}	0.110	0.214^{**}	-1.442^{**}	-0.21^{**}	-3.287^{**}	-2.363^{**}	0.075
Agent		4.419^{**}	0.401^{**}	-0.294	-0.372	0.049	-0.518^{*}	-0.279^{**}	-0.159	2.067^{**}	-0.082
Sakha 92		-0.385^{**}	0.346^{**}	4.898^{**}	1.202^{**}	-0.124^{**}	0.133	-0.014	0.639	-1.419^{**}	-0.156^{**}
Baart		0.428^{**}	0.573^{**}	3.215^{**}	-0.379	-0.186^{**}	-0.547^{*}	0.107	-0.896	1.342^{**}	-0.009
LSD gi	5%	0.242	0.158	1.686	0.775	0.085	0.421	0.119	1.301	0.554	0.103
	1%	0.324	0.212	2.256	1.037	0.114	0.563	0.159	1.740	0.741	0.137
LSD gi–gj	5%	0.375	0.245	2.613	1.079	0.131	0.562	0.184	2.015	0.859	0.159
	1%	0.50	0.329	3.496	1.444	0.176	0.873	0.247	2.696	1.149	0.212

The estimates of genetic components of variation in the F_1 of diallel cross for the traits studied at three locations are given in Table 6. D values were highly significant for plant height only at Ismailia, while for spike length, grains/spike and 100-grain weight, D values were significant at Ismailia and Gemmeiza. D values for grain yield/plant were significant at Nobaria and Gemmeiza. These results indicate that the additive gene effects played a major role in the inheritance of these characters. The highly significant H1 values for all traits at all locations in F_1 indicates the importance of the dominant gene action in the inheritance of these traits. H2 values were highly significant for all traits at all locations and were smaller than H1 values, indicating unequal allele frequency in the parents. The h values were highly significant for all traits at Ismailia and Nobaria, except for grain yield/plant. At Gemmeiza this value was significant for all traits except for plant height and spike length, indicating that the dominance effect is due to heterozygosity. The F values were not significant for all traits at all locations except for 100-grain weight at Ismailia. Values of $(H1/D)^{1/2}$ were higher than unity for some traits at all the locations, indicating overdominance in F_1. For some traits, this value was equal to or less than unity, indicating complete or partial dominance. These results are in good harmony with those of graphical analysis. Values of H2/4H1 at all locations for all the traits were less than 0.25, revealing asymmetric distributions of positive and negative alleles among the parents and in F_1.

of wheat at three locations and pooled analysis

Gemmeiza					Pooled analysis				
plant height	spike length	grains per spike	grain yield per plant	100-grain weight	plant height	spike length	grains per spike	grain yield per plant	100-grain weight
1.909**	- 0.037	1.982**	1.862**	- 0.075	1.187**	- 0.125**	0.402	0.589**	0.128**
- 0.274	0.028	- 1.877*	- 0.808*	- 0.637**	- 0.089	0.114**	- 0.585	- 0.280	- 0.256**
0.184	- 0.251**	- 4.060**	- 3.646**	- 0.075	- 0.1668**	- 0.495**	- 3.599**	- 1.946**	0.078**
0.195	0.560**	2.553**	3.352**	0.460**	1.365**	0.218**	0.698	1.787**	0.106**
0.197	- 0.205**	- 0.754	1.153**	0.352**	- 0.018	0.075	1.593**	0.187	0.014
- 2.210**	- 0.094	2.156**	- 1.912**	- 0.036	- 0.776**	0.214**	1.490**	- 0.337	- 0.069**
0.462	0.146	1.460	0.669	0.100	0.217	0.081	0.856	0.385	0.055
0.618	0.195	1.954	0.895	0.134	0.289	0.109	1.145	0.514	0.074
0.715	0.239	2.262	1.036	0.491	0.335	0.129	1.326	0.572	0.150
0.957	0.320	3.026	1.387	0.654	0.449	0.172	1.774	0.766	0.201

Values of $(4DH1)^{1/2} + F/(4DH1)^{1/2}-F$ for all traits at all the locations show that the proportions of dominant alleles are greater in the parents than the recessive alleles in F_1, except for spike length and grain yield/plant at Ismailia, grains/spike and 100-grain weight at Nobaria, and plant height at Gemmeiza. This conclusion is also supported by the fact that the value of (H2/4H1) was less than 0.25. Values of h/H2 suggested that one, two or more genes controlled the inheritance of all the traits studied at the three locations.

Narrow sense heritability was relatively high for plant height and spike length at Ismailia, and grain yield/plant at Nobaria. At Gemmeiza, moderate value of heritability for grain yield/plant was observed. Similar results were obtained for the mode of gene action, number of genes and narrow sense heritability by earlier workers [4, 6, 20].

The correlation coefficient (r) values between Yr and Wr + Vr were nonsignificant for almost all characters in F_1 at all locations, indicating ambidirectional dominance for these characters. The significant positive value for 100-grain weight (0.93) at Ismailia indicates that dominant genes were operating toward increasing grain size. Significant negative value was obtained for plant height at Gemmeiza (– 0.89), indicating that the dominant genes were operating towards decreasing plant height. The square values $(r)^2$ were less than unity in all locations for all traits, suggesting that none of the parental lines was completely dominant or recessive for the genes controlling any of these characters.

Table 4. Specific combining ability effects in F_1 generation of wheat at three locations and in pooled analysis

Cross No.	Cross	Ismailia					Nobaria				
		plant height	spike length	grains per spike	yield per plant	100-grain weight	plant height	spike length	grains per spike	yield per plant	100-grain weight
1	Sakha 69 x Giza 157	-0.887**	0.103	-3.404	-0.411	0.425**	1.077*	1.303**	8.192**	0.639	1.516**
2	Sakha 69 x Giza 160	1.621**	-0.005	-1.798	-0.831	0.208*	3.796**	0.240	-0.377	-2.652**	-0.367**
3	Sakha 69 x Agent	3.922**	0.128	-6.600**	-0.450	0.608**	-0.861	-0.202	0.527	-0.203	0.489**
4	Sakha 69 x Sakha 92	-1.275**	0.454*	-5.464**	4.383**	0.726**	-2.778**	-0.737**	-2.370	0.124	0.109
5	Sakha 69 x Baart	-0.181	0.023	7.305	-0.581	0.274**	2.023**	-0.510**	-2.059	1.700**	-0.633**
6	Giza 157 x Giza 160	1.934**	-1.683**	1.979	-0.780	-0.206*	2.342**	-0.034	2.251	-2.756**	-0.086
7	Giza 157 x Agent	5.422**	0.743**	-0.425	-0.139	-0.268**	2.168**	-0.049	-0.189	-0.789	-0.252*
8	Giza 157 x Sakha 92	-0.291	0.076	-0.225	-0.895	0.100	1.691**	-0.513**	-2.419	0.227	-0.079
9	Giza 157 x Baart	-1.504**	0.278	-3.718*	2.583**	0.246*	-2.337**	1.274**	-2.628	0.680	-0.419**
10	Giza 160 x Agent	-5.221**	-0.294	4.782	-0.323	-0.224*	-5.681**	0.175	-0.008	0.891	-0.093
11	Giza 160 x Sakha 92	2.556**	1.095**	-2.013	4.711**	-0.496**	2.665**	0.818**	-1.039	3.787**	-0.204
12	Giza 160 x Baart	1.853**	0.937**	-2.009*	-0.641	-0.158	-0.385	-0.014	-1.278	1.939**	1.375**
13	Agent x Sakha 92	-2.676**	-1.232**	-4.348**	-1.164	0.468**	2.541**	0.109	-1.501	-2.036**	0.035
14	Agent x Baart	-0.476	0.177	-5.521	1.984*	0.289**	1.954**	-0.678**	-1.366	0.718	0.006
15	Sakha 92 x Baart	3.444**	0.554**	-0.368	-1.672*	0.001	-0.831	0.365**	12.403**	-3.428**	0.044
	L.S.D. Sij, 5%	0.544	0.360	3.825	1.580	0.193	0.954	0.270	2.949	1.257	0.232
	1%	0.735	0.481	5.117	2.114	0.258	1.277	0.361	3.946	1.682	0.311
	L.S.D. Sij–Sik, 5%	0.993	0.650	6.913	2.856	0.349	1.726	0.48	5.331	2.272	0.421
	1%	1.329	0.870	9.249	3.821	0.467	2.709	0.653	7.133	3.040	0.563

(Contd.)

Table 4 (contd.)

Cross No.	Cross	Gemmeiza					Pooled analysis				
		plant height	spike length	grains per spike	yield per plant	100-grain weight	plant height	spike length	grains per spike	yield per plant	100-grain weight
1	Sakha 69 x Giza 157	5.263**	0.346	2.148	3.901**	0.909**	1.818**	0.584**	2.312	1.377**	0.949**
2	Sakha 69 x Giza 160	0.321	- 0.100	- 3.408*	- 2.367**	- 0.013	1.913**	0.045	- 1.861	- 1.950**	- 0.057
3	Sakha 69 x Agent	- 3.624**	- 0.157	- 0.463	0.519	- 0.222	- 0.187	- 0.077	- 2.179*	- 0.045	0.292**
4	Sakha 69 x Sakha 92	6.321**	- 0.862**	- 0.475	- 1.343	- 0.018	0.756**	- 0.382**	- 2.770**	1.055*	0.273**
5	Sakha 69 x Baart	- 0.068	0.082	0.429	- 0.621	- 0.223	0.591*	- 0.135	1.892	0.166	- 0.194**
6	Giza 157 x Giza 160	- 0.612	0.390*	1.846	- 3.788**	- 0.900**	1.221**	- 0.442**	2.023*	- 2.441**	- 0.397**
7	Giza 157 x Agent	- 0.219	- 0.067	1.670	2.241**	0.327**	2.457**	0.209*	0.352	0.438	- 0.064
8	Giza 157 x Sakha 92	3.521**	- 0.375*	- 7.821**	5.396**	- 0.441**	1.640**	- 0.271**	- 3.489**	1.576**	- 0.140*
9	Giza 157 x Baart	- 2.058**	- 0.668**	- 2.555	1.342	0.660**	- 1.967**	0.295**	- 2.967**	1.535**	0.163*
10	Giza 160 x Agent	2.752**	- 1.080**	0.652	3.077**	0.656**	- 2.716**	- 0.400**	1.808	1.215**	0.113
11	Giza 160 x Sakha 92	10.872**	0.543**	5.825**	2.335**	0.487**	5.364**	0.818**	0.924	3.611**	- 0.071
12	Giza 160 x Baart	0.890	0.746**	1.990	6.687**	0.745**	0.786**	0.556**	- 0.432	2.661**	0.654**
13	Agent x Sakha 92	0.182	1.018**	- 5.341**	- 0.904	0.067	0.016	- 0.035	- 3.730**	- 1.368**	0.145**
14	Agent x Baart	0.519	0.028	- 3.992*	- 1.650*	0.391**	0.666**	- 0.158	- 3.626**	0.351	0.228**
15	Sakha 92 x Baart	0.957	0.950**	- 6.294**	- 0.399	1.227**	1.603**	0.623**	1.914	- 1.833**	0.244**
	L.S.D. Sij, 5%	1.047	0.350	3.348	1.517	0.227	0.491	0.189	1.948	0.838	0.125
	1%	1.401	0.468	4.479	2.030	0.304	0.657	0.252	2.606	1.121	0.168
	L.S.D. Sij–Sik, 5%	1.893	0.632	5.985	2.743	0.411	0.887	0.341	3.508	1.515	0.227
	1%	2.533	0.846	8.008	3.670	0.549	1.265	0.456	4.694	2.027	0.304

Table 5. Heterosis in F_1 generation of wheat as percentage over mid-MP

Cross	Ismailia									
	plant height		spike length		grains per spike		yield per plant		100-grain weight	
	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP
Sakha 69 x Giza 157	1.85**	0.28	2.05**	– 4.44**	– 21.52**	– 23.91**	9.58**	7.91**	37.92**	33.19****
Sakha 69 x Giza 160	5.57**	– 0.75	2.73**	– 4.25**	– 13.01**	– 22.94**	9.89**	1.05	15.48**	– 2.51**
Sakha 69 x Agent	7.72**	– 0.13	2.25**	– 8.80**	32.23**	– 36.30**	2.07**	– 14.88**	47.09**	44.546**
Sakha 69 x Sakha 92	– 0.06	– 0.16	11.11**	3.38**	– 25.79**	– 37.06**	239.37**	185.91**	40.70**	37.84**
Sakha 69 x Baart	2.35**	1.45**	8.90**	1.64**	9.54**	– 0.53	16.26**	10.28**	36.02**	30.13**
Giza 157 x Giza 160	6.91**	2.01**	– 24.71**	– 33.95**	2.51	– 6.64	– 6.64**	– 12.91**	– 10.17**	– 26.29**
Giza 157 x Agent	10.78**	1.23*	5.76**	0.36	– 13.42**	– 20.95**	– 2.67**	– 17.82**	0.87**	– 4.22
Giza 157 x Sakha 92	2.25**	0.57	2.30**	1.59**	– 11.43**	– 26.76**	7.62**	– 8.17**	13.68**	12.02*
Giza 157 x Baart	0.76	– 1.65**	7.83**	7.45**	– 16.40**	– 26.16	135.70**	126.90**	18.13**	16.99**
Giza 160 x Agent	– 7.06**	– 18.59**	– 5.20**	– 20.49**	5.92**	– 11.10	6.60**	– 4.30**	– 5.87**	– 19.378**
Giza 160 x Sakha 92	6.60**	0.12	18.38**	3.22**	– 12.57**	– 32.80**	233.93**	203.23**	– 14.76**	– 29.23**
Giza 160 x Baart	5.91**	– 1.25*	19.80**	4.76**	– 8.12*	– 25.13**	– 0.88*	– 4.08**	– 6.27**	– 23.66
Agent x Sakha 92	– 3.10**	– 10.08**	– 5.10**	– 9.34**	– 23.15**	– 31.16**	4.88**	3.56*	30.71**	25.88*
Agent x Baart	0.85	– 5.74**	6.27**	1.19**	– 23.16	– 25.94	1.68**	– 11.32**	23.76**	16.44
Sakha 92 x Baart	7.80**	6.96**	15.36**	14.97	– 9.71**	– 16.34**	3.20	– 9.01**	13.44**	10.73**
L.S.D. 5%	0.91	1.06	0.60	0.69	6.40	7.39	2.94	3.40	0.23	0.41
1%	1.22	1.42	0.80	0.93	8.56	9.88	3.93	4.54	0.47	0.55

Table 5 (contd.)

Cross	Nobaria									
	plant height		spike length		grains per spike		yield per plant		100-grain weight	
	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP
Sakha 69 x Giza 157	2.98**	1.51	15.89**	14.97	21.71**	20.15**	0.18	– 3.60**	43.55**	40.33*
Sakha 69 x Giza 160	5.12**	2.11*	5.07**	0.38	1.11	– 6.48*	– 12.91**	23.79**	1.51**	– 0.63**
Sakha 69 x Agent	– 0.02	– 1.39	– 2.96**	– 3.6	1.97	1.80	– 2.73**	– 11.49**	18.15**	– 16.80
Sakha 69 x Sakha 92	– 0.80	– 2.58**	– 6.10**	– 6.35**	– 0.26	– 2.42	– 1.52	– 8.55**	3.64**	2.02**
Sakha 69 x Baart	3.11**	1.29	– 3.27**	– 3.35**	0.42	– 4.99	9.05**	6.73**	– 5.83**	– 7.39**
Giza 157 x Giza 160	4.17**	2.63**	6.92**	2.93**	7.70**	– 1.56	– 14.89**	– 27.94**	5.23**	5.08**
Giza 157 x Agent	3.32**	3.27**	– 0.42	– 0.50	0.99	– 0.14	– 6.59**	– 11.87**	– 0.86*	– 1.98**
Giza 157 x Sakha 92	3.94**	3.53**	– 0.06	– 0.59	0.32	– 3.08	– 2.88**	– 12.96**	1.45*	0.73**
Giza 157 x Baart	– 0.67	– 1.02	16.39**	15.56**	– 0.13	– 6.64*	2.53**	0.75	– 3.38**	– 3.96**
Giza 160 x Sakha 92	4.87**	– 6.32**	– 2.83**	– 1.0	– 1.71	– 9.22**	3.93**	– 16.08**	2.31**	1.30**
Giza 160 x Baart	4.41**	3.27**	10.21**	5.66**	0.27	– 5.33	21.58**	13.98**	– 1.59*	– 2.14**
Giza 160 x Baart	0.70	– 0.44	3.55**	– 1.00**	– 0.30	– 2.67	13.60**	– 2.41*	35.47**	34.84**
Giza 160 x Sakha 92	3.59	3.14	–0.37	–0.82	–1.86	–4.13	–12.10	–25.16	1.14	0.71
Agent x Baart	2.33**	1.92	– 6.37	– 6.97**	– 1.62	– 7.06*	3.12**	– 4.29**	3.11	2.57**
Sakha 92 x Baart	1.90*	1.87*	– 4.20**	4.01**	33.93**	29.42**	– 0.12	– 9.06**	2.47	2.36**
L.S.D. 5%	1.60	1.85	0.52	0.61	4.93	5.69	1.93	2.23	0.38	0.44
1%	2.14	2.48	0.70	0.82	6.60	7.62	2.59	2.99	2.59	0.59

and better parents (BP) at three locations and in pooled analysis

Gemmeiza									
plant height		spike length		grains per spike		yield per plant		100-grain weight	
MP	BP	MP	BP	MP	BP	MP	BP	MP	BP
8.61^{**}	6.93^{**}	0.64	0.43	1.44	-6.67^{*}	27.60^{**}	4.59^{**}	33.72^{**}	14.03^{**}
5.90^{**}	2.61^{*}	-1.24^{**}	-5.30^{**}	1.23^{*}	26.65^{**}	-4.20^{**}	-28.59^{**}	8.72^{**}	5.08^{**}
−1.60	−2.01	-3.05^{**}	-6.57^{**}	-6.73^{*}	-11.01^{**}	4.85^{**}	2.33	3.69	-1.99^{**}
14.03^{**}	8.40^{**}	-5.99^{**}	-9.71^{**}	-11.24^{**}	-11.98^{**}	−0.20	−7.40	9.43^{**}	6.28^{***}
2.01^{*}	−0.08	1.60^{**}	-1.58^{**}	-6.31^{*}	-11.27^{**}	3.33^{**}	-15.88^{**}	16.88^{**}	0.83^{2**}
4.47^{**}	2.78^{**}	3.52^{**}	-0.93^{**}	-8.56^{**}	-8.17^{*}	−0.18	-11.76^{**}	-15.74^{**}	-26.01^{**}
1.13	−0.84	-1.73^{**}	-5.11^{**}	−3.64	-15.06^{**}	23.05^{**}	−1.03	20.04^{**}	-2.271^{**}
10.78^{**}	6.90^{**}	-4.03^{**}	-8.02^{**}	-34.52^{**}	-40.22^{**}	44.41^{**}	26.15^{**}	−0.17	-16.90^{**}
-0.52^{**}	−1.04	-3.94^{**}	-7.14^{**}	-16.53^{**}	-26.91^{**}	28.55^{**}	27.43^{**}	52.10^{**}	50.03^{**}
6.15^{**}	2.43^{*}	-8.20^{**}	-15.03^{**}	1.54	-22.42^{**}	25.50^{**}	-7.92^{**}	28.34^{**}	17.48^{**}
20.85^{**}	18.50^{**}	8.61^{**}	8.43^{**}	12.84^{**}	-11.33^{**}	27.61^{**}	0.41	25.64^{**}	18.06^{**}
4.58^{**}	3.42^{**}	9.99^{**}	8.84^{**}	3.33	-21.48^{**}	62.08	44.37^{**}	-50.67^{**}	33.90^{**}
5.60^{**}	−0.01	10.21^{**}	2.16^{**}	-25.85^{**}	-28.68^{**}	4.55^{**}	-5.15^{**}	34.19^{**}	30.48^{**}
0.47	-1.99^{*}	1.98^{**}	-4.69^{**}	-19.45^{**}	-20.08^{**}	2.22	-18.33^{**}	36.66^{**}	12.46^{**}
6.72^{**}	3.55^{**}	4.78^{**}	3.85^{**}	-29.68^{**}	-32.86^{**}	10.88^{**}	-3.95^{*}	61.93^{**}	36.31^{**}
1.75	2.03	0.75	0.87	5.54	6.40	2.54	2.93	0.48	0.56
2.34	2.71	1.01	1.16	7.42	8.57	3.39	4.72	0.65	0.76

Table 5 (contd.)

Pooled analysis									
plant height		spike length		grains per spike		yield per plant		100-grain weight	
MP	BP	MP	BP	MP	BP	MP	BP	MP	BP
4.89^{**}	3.33^{**}	6.49^{**}	4.97^{**}	3.09	−0.06	13.67^{**}	3.74^{**}	38.93^{**}	31.72^{**}
5.52^{**}	1.67^{**}	1.99^{**}	-2.96^{*}	-5.36^{**}	-17.61^{**}	-7.38^{**}	-24.53^{**}	-7.38^{**}	2.70^{**}
1.20^{**}	−0.27	−1.68	-5.73^{*}	-11.08^{**}	-14.12^{**}	1.39	-4.86^{**}	1.39^{**}	16.73^{**}
4.94^{**}	2.22^{**}	-1.77^{**}	−1.95	-12.11^{**}	-16.62^{**}	12.25^{**}	5.59^{**}	19.51^{**}	18.15^{**}
2.52^{**}	1.19^{*}	1.62^{**}	1.6	1.04	−1.87	6.66^{**}	2.69^{**}	12.28^{**}	6.33^{**}
4.88^{**}	2.55^{**}	-2.04^{**}	-2.03^{**}	6.42^{**}	-4.90^{*}	-8.34^{**}	-19.93^{**}	-5.55^{**}	-14.59^{**}
4.24^{**}	1.21^{*}	1.69^{**}	−1.1	-4.72^{**}	-10.58^{**}	7.13^{**}	-6.85^{**}	6.55^{**}	−1.72
6.12^{**}	4.93^{**}	0.11	-1.14^{**}	16.08^{**}	-20.39^{**}	20.09^{**}	17.47^{**}	8.64^{**}	1.89^{**}
−0.29	−0.50	6.43^{**}	5.48^{**}	-12.91^{**}	-15.41^{**}	20.22^{**}	18.92^{**}	11.55^{**}	11.41
-1.15^{**}	-6.09^{**}	-3.58^{**}	-11.85^{**}	1.57	-14.14^{**}	14.15^{**}	11.41^{**}	-2.66^{**}	-4.76^{**}
11.10^{**}	9.86^{**}	11.60^{**}	5.99^{**}	-6.57^{**}	-17.30^{**}	39.91^{**}	19.93^{**}	10.51^{**}	6.26^{**}
3.33^{**}	0.83	10.00^{**}	4.17^{**}	−1.70	-16.52^{**}	33.44^{**}	17.72^{**}	10.37	-0.34^{**}
2.72^{**}	-1.35^{**}	0.35	-3.61^{**}	-16.55^{**}	-18.09^{**}	-3.24^{**}	-13.73^{**}	22.32^{**}	20.15
1.30^{**}	-1.44^{**}	0.20	-3.46^{**}	-14.46^{**}	-14.94^{**}	7.27^{**}	-7.59^{**}	19.65^{**}	10.21^{**}
5.06^{**}	3.65^{**}	10.55^{**}	10.21^{**}	−2.45	-4.79^{*}	-2.43^{**}	-5.57^{**}	24.88^{**}	16.96^{**}
0.82	0.94	0.36	0.41	3.25	3.75	1.43	1.63	0.21	0.27
1.10	1.27	0.48	0.56	4.34	5.02	1.91	2.36	0.31	0.36

Table 6. Estimates of genetic components in F_1 generation of a 6 X 6 diallel cross of wheat at three location

Genetic component	Ismailia					Nobaria		
	plant height	spike length	grains per spike	yield per plant	100-grain weight	plant height	spike length	grains per spike
D	31.13 ± 4.04**	1.02 ± 0.37**	60.62 ± 9,53**	– 0.87 ± 3.14	0.32 ± 0.07**	3.44 ± 3.58	0.11 ± 0.26	7.18 ± 12.56
H1	31.78 ± 10.25**	2.04 ± 0.96**	– 69.54 ± 24.20**	15.13 ± 7.99**	1.00 ± 0.18**	27.76 ± 9.11**	2.00 ± 0.68**	65.38 ± 31.88**
H2	31.15 ± 9.16**	1.70 ± 0.84**	62.09 ± 21.62**	13.64 ± 7.13*	0.61 ± 0.16**	26.61 ± 8.13**	1.65 ± 0.60**	62.98 ± 28.48**
h	61.57 ± 6.16**	2.12 ± 0.57**	428.83 ± 14.55**	21.34 ± 4.80**	3.27 ± 0.11**	67.18 ± 5.47**	1.88 ± 0.40**	58.22 ± 19.17**
F	5.46 ± 9.67	– 0.20 ± 0.92	30.25 ± 23.29	– 1.64 ± 7.66	0.47 ± 0.17**	– 0.81 ± 8.76	0.15 ± 0.65	– 7.34 ± 30.68
E	0.13 ± 1.52	0.07 ± 0.14	6.87 ± 3.60	1.08 ± 1.13	0.01 ± 0.02	0.43 ± 1.35	0.03 ± 9.10	3.18 ± 4.74
(H/D)$^{1/2}$	1.01	1.41	1.07	4.14	1.74	2.83	4.16	3.01
(H2/4H1)	0.24	0.20	0.22	0.22	0.15	0.24	0.20	0.24
KD/KR	1.19	0.87	1.60	0.63	2.41	0.92	1.36	0.71
h^2/HR	1.97	1.25	6.90	1.56	6.33	2.52	1.14	0.92
h^2 (n.s.)	62.41	61.29	54.78	19.99	41.75	21.04	26.12	30.13
r	0.55	– 0.29	0.77	0.03	0.93**	– 0.64	0.10	0.00
r^2	0.30	0.08	0.60	0.01	0.88	0.41	0.01	0.00

(Contd.)

Table 6 (contd.)

Genetic component	Nobaria		Gemmeiza				
	yield per plant	100-grain weight	plant height	spike length	grains per spike	yield per plant	100-grain weight
D	$12.39 \pm 1.75^{**}$	-0.01 ± 0.21	16.55 ± 13.43	$0.55 \pm 0.19^{**}$	$58.56 \pm 13.19^{**}$	$37.05 \pm 0.33^{**}$	$0.46 \pm 0.17^{**}$
H1	$10.50 \pm 4.44^{**}$	$1.48 \pm 0.53^{**}$	$110.95 \pm 34.10^{**}$	$1.45 \pm 0.49^{**}$	$79.04 \pm 33.49^{**}$	$43.08 \pm 8.47^{**}$	$2.13 \pm 0.44^{**}$
H2	$9.34 \pm 3.97^{**}$	$1.41 \pm 0.48^{**}$	$78.86 \pm 30.46^{**}$	$1.33 \pm 0.43^{**}$	$56.33 \pm 29.92^{**}$	$39.72 \pm 7.57^{**}$	$1.80 \pm 0.39^{**}$
h	-0.34 ± 2.67	$1.70 \pm 0.32^{**}$	56.75 ± 20.50	0.12 ± 0.29	$22.21 \pm 20.14^{**}$	$189.42 \pm 5.09^{**}$	$13.11 \pm 0.26^{**}$
F	2.96 ± 4.28	-0.02 ± 0.51	37.10 ± 32.81	0.41 ± 0.47	57.93 ± 32.23	16.55 ± 8.15	0.07 ± 0.42
E	0.69 ± 0.66	0.02 ± 0.08	0.52 ± 0.57	0.05 ± 0.07	4.77 ± 4.98	1.00 ± 1.26	0.02 ± 0.06
$(H/D)^{1/2}$	0.92	8.31	2.58	1.61	1.16	1.07	2.13
(H2/4H1)	0.22	0.23	0.17	0.22	0.18	0.23	0.21
KD/KR	1.29	0.86	0.52	1.58	2.48	1.52	1.07
h^2/HR	-0.03	1.20	0.72	0.09	3.86	4.76	7.28
h^2 (n.s.)	63.61	11.94	22.17	26.16	35.53	52.17	43.46
r	0.49	-0.19	-0.89^{**}	0.25	-0.61	-0.49	-0.53
r^2	0.08	0.03	0.80	0.06	0.37	0.42	0.28

The parents in the Wr–Vr graphs showed variation in the dominance or recessive nature of all the traits at all locations in F_1. These variations agree with those obtained from statistical analysis (Table 6). For example, the parent Sakha 92 at Ismailia and Nobaria in F_1 displayed an excess of dominant genes for plant height while the same parent Sakha 92 showed more recessive genes for number of grains/spike at Ismailia. The regression lines indicated various degree of dominance, i.e. overdominance, complete, and partial dominance. These results agree with those of [7, 8].

The phenotypic and genotypic correlation coefficients between the characters studied in F_1 are presented in Table 7. Grain yield/plant in F_1 was correlated positively phenotypically and genotypically with plant height (0.395 and 0.141) and 100-grain weight (0.452 and 0.213) also at Gemmeiza. Grain yield/plant was also correlated positively with spike length at Ismailia and Gemmeiza, giving the r values of 0.195 and 0.302, respectively, and with number of grains/spike at Gemmeiza (0.297). Grain yield/plant was correlated genotypically with 100-grain weight at Ismailia (0.189). Phenotypic and genotypic correlation coefficients between the remaining traits followed patterns similar to those of these traits.

Table 7. Phenotypic (P) and genotypic (G) correlation in F_1 generation of crosses of wheat at three locations

Character		Ismailia				Nobaria				Gemmeiza			
		spike length	grains per spike	100-grain weight	yield per plant	spike length	grains per spike	100-grain weight	yield per plant	spike length	grains per spike	100-grain weight	yield per plant
Plant height	P	0.576**	0.064**	-0.070	-0.070	0.180*	0.297**	0.045	0.008	0.118	-0.047	0.290**	0.395**
	G	0.186*	-0.027	0.025	0.034	-0.002	-0.134	-0.018	0.002	0.069**	0.019	-0.101	-0.141*
Spike length	P		0.268**	0.270**	0.195**		0.431**	0.260**	0.129		0.189**	0.279**	0.302**
	G		-0.063	0.082	0.117		-0.076	-0.088	0.022		0.083	0.091	0.015
No. of grains/spike	P			-0.465**	-0.056			0.210**	0.030			-0.085	0.297**
	G			0.216**	0.034			-0.099	-0.014			0.036	-0.129
100-grain weight	P				0.007				0.073				0.452**
	G				0.189**				0.114				0.213**

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