J. Agric. Sci. Mansoura Univ., 27(10): 6929 - 6939, 2002

USING OF PARTIAL DIALLELE ANALYSIS TO ESTIMATE HETEROSIS, INBREEDING DEPRESSION AND COMBINING ABILITY IN DRY BEANS (*Phaseolus vulgaris* L.).

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ABSTRACT

Heterosis, inbreeding depression and combining ability has been estimated and studied in a partial diallel analysis in 12 crosses including 8 bean parents, *Phaseolus vulgaris* L., and their F_2 generations. These materials were evaluated for number of days to 50% flowering, number of days to dry harvesting, seed index (1000 seed weight), seed yield per plant and protein content. Six crosses showed positive heterosis for seed yield per plant. Parents in each of these heterotic crosses differed in growth habits, seed size and geographical origin. Significant differences in all characters were found among the F_1 hybrids and F_2 generations except for protein content. Some F_2 generations outperformed the corresponding F_1 hybrids. For general combining ability (GCA), significant differences were obtained in four characters. Three characters showed significant differences for specific combining ability (SCA).

INTRODUCTION

Large variation is commonly found in dry bean cultivars, *Phaseolus vulgaris* L., in growth habit, maturity and yield characteristics, including seed size and colour. Heterosis, inbreeding depression, general (GCA) and specific (SCA) combining ability have been previously reported (Filipetti 1998; Saxena and Sharma 1992; Dobariya *et al.* 1992). Data on previously mentioned estimates are of interest to all plant breeders. Yield and some related characters of F_1 showing heterosis, inbreeding depression, GCA and SCA effects can be important measures of the convenient yield potential of the crop. Selection in early generations requires an understanding of expected levels of those previously mentioned measures and exploiting them on a commercial scale to be profitable to the growers through producing new local dry bean varieties. Exploitation of heterosis, inbreeding depression and combining ability in some mating designs like partial diallel involving some local varieties along with some introduced varieties, which have good horticultural characters, may be useful in selecting the best F_1 hybrids with good criteria. These materials could be included in an advanced selection program of dry bean improvement leading to new local varieties. The objective of the current paper was to estimate the combining ability and hybrid performance as well as inbreeding depression in a partial diallel design including eight bean genotypes from different agroclimatic regions.

MATERIALS AND METHODS

Eight lines and varieties of bean (*Phaseolus vulgaris* L.) namely Serbo, Helda and Limka (climbing growth habit), Giza6, Giza3, Bronco, HAB53 and HAB20 (bush growth habit) and their F_1 crosses and F_2 generations were grown in a randomized complete block design with three replications at Kaha Vegetable Research Farm, Kaliobia governorate during Summer season of years 1999 and 2000. The thirty-two genotypes (8 parents, 12 F_1 crosses and 12 F_2 generations) were grown in three rows per plot of 4 meters long and 60 cm between rows. The plants were spaced at 20 cm within rows. Normal horticultural bean practices were applied. Data were recorded on ten randomly selected plants for five characters namely, number of days to 50% flowering, number of days to dry harvesting, seed index (1000 seed weight), seed yield per plant and protein content. Data were statistically analyzed for the study of combining ability according to Singh and Chaudhary (1977).

RESULTS AND DISCUSSION

Mean square values of F_1 hybrids, general combining ability (GCA) and specific combining ability (SCA) are shown in Table (1). Differences among F_1s for all traits were significant except for protein content in both 1999 and 2000 seasons. General combining ability (GCA) mean squares were significant for all traits in both 1999 and 2000 seasons except for protein content. In regard to specific combining ability (SCA) there were significant differences for number of days to dry harvesting, seed index and seed yield per plant in both seasons. The data and results were in agreement with Filipetti (1998) who found significant GCA and SCA of hybrids for seed protein content in faba bean seeds (*Vicia faba* L.) and Rosaiah *et all.* (1994) who found good GCA for seed index and the seed yield in mung bean.

The mean squares for F_1 hybrids and F_2 generations in both 1999 and 2000 seasons are shown in Table (2). There were significant differences for all the studied characters except for protein content in both years of study. This result was in line with those reported by Gutierrez and Singh (1985). Mean performance of parents during the two seasons are shown in Table (3).

Estimates of the general combining ability (GCA) effects for individual parental lines of each trait are presented in Table (4). The GCA effects computed herein differed significantly in most traits. The parental varieties Serbo, Giza6, Giza3, Bronco and HAB53 had positive (GCA) effects for number of days to 50% flowering during 1999 and 2000 seasons proving that they are good combiners for this trait. These results were in accordance with El-Hossary *et al.* (1984) on field bean. The varieties Serbo, Giza3 and HAB53 exhibited positive (GCA) effects for number of days to dry harvesting in 1999 and 2000 seasons. In respect to seed index (1000 seed weight), the varieties Giza6, Giza3, HAB20 and Bronco had shown positive (GCA) effects in the two seasons, which was in line with the results reported by Singh *et al.* (1992) on common beans. Seed yield per plant had shown positive (GCA) effects in

Table (1): Mean squares for genotypes (F_1 hybrids), general combining ability (GCA) and specific combining ability (SCA) of partial diallel cross of dry bean during 1999 and 2000 seasons.

Source	df	Mean square									
		Number of days to 50% flowering		Number of days to dry harvesting		Seed index (1000 seed weight) (g)		seed yield per plant (g)		Protein content %	
		1999	2000	1999	2000	1999	2000	1999	2000	1999	2000
Genotypes	11	19.172*	17.869*	29.444*	28.028*	5241.754*	5284.874*	85.116*	88.118*	13.287	12.889
GCA	7	25.837*	25.486*	34.162*	38.807*	2979.267*	3103.208*	84.651*	81.587*	9.499	11.550
SCA	4	7.508	4.538	21.189*	9.164*	9201.106*	9102.790*	85.931*	99.549*	19.917	15.232
Error	22	6.043	6.088	1.437	2.020	647.214	636.218	28.917	28.689	7.560	7.573

* Significant at 5% level.

Table (2): Mean squares for genotypes (F_1 and F_2 generations) of dry bean during 1999 and 2000 seasons.

Source	Df	Mean square									
		Number of days to 50% flowering		Number of days to dry harvesting		Seed index (1000 seed weight) (g)		seed yield per plant (g)		Protein content %	
		1999	2000	1999	2000	1999	2000	1999	2000	1999	2000
Genotypes	23	19.033*	17.538*	22.435*	21.897*	6131.179*	6199.597*	56.081*	57.936*	7.826	8.774
Error	46	3.677	3.821	0.852	1.268	405.300	399.046	17.793	17.599	4.555	5.060

* Significant at 5% level.

Table (3): Mean performance of eight parents involved in the mating design.

Serial number	Genotype	Number of days to 50% flowering		Number of days to dry harvesting		Seed index (1000 seeds weight) (g)		seed yield per plant (g)		Protein content %	
		1999	2000	1999	2000	1999	2000	1999	2000	1999	2000
1	Serbo	46	48	91	91	310.000	309.000	17.800	17.369	20.826	19.370
2	Giza 6	46	47	96	98	479.670	474.000	8.867	9.519	21.625	20.555
3	Giza 3	55	53	94	95	389.830	383.000	7.667	8.511	20.045	20.318
4	Bronco	53	54	100	98	249.330	244.000	13.767	12.400	21.172	20.304
5	Hab 53	45	45	98	100	315.330	317.000	13.667	13.658	21.699	20.142
6	Hab 20	45	45	97	98	363.670	361.670	14.167	15.400	19.223	18.176
7	Helda	50	52	90	91	576.670	578.000	17.767	17.575	20.293	18.014
8	Limka	54	55	94	95	332.170	330.670	15.400	16.700	20.644	20.554

Table (4): General combining ability (GCA) effects of parents induced in partial diallel cross of dry bean during 1999 and 2000 seasons.

Serial number	Genotype	Number of days to 50% flowering		Number of days to dry harvesting		Seed index (1000 seed weight) (g)		seed yield per plant (g)		Protein content %	
		1999	2000	1999	2000	1999	2000	1999	2000	1999	2000
1	Serbo	3.004	2.734	0.627	1.149	-0.320	-2.603	-0.978	-0.702	-0.991	0.358
2	Giza 6	0.663	1.183	-0.502	1.518	49.633	49.756	2.807	2.670	1.865	1.444
3	Giza 3	1.671	3.526	1.210	4.024	15.826	15.694	8.253	7.910	0.343	1.827
4	Bronco	0.996	1.391	-4.502	-3.024	9.295	10.230	8.286	8.242	2.809	2.941
5	Hab 53	0.671	0.567	0.627	0.649	-19.137	-16.258	1.585	1.638	0.221	0.426
6	Hab 20	-1.671	-3.317	1.831	-0.315	0.083	1.267	-3.609	-3.693	-1.222	-1.845
7	Helda	-1.329	-1.974	-0.456	-2.809	-39.558	-39.828	-9.618	-9.233	-1.529	-2.103
8	Limka	-4.004	-4.109	1.165	-1.190	-15.822	-18.258	-6.725	-6.831	-1.497	-3.048
CD at 5%		3.197	3.418	2.689	4.066	58.901	58.839	0.845	2.929	2.036	1.433

both 1999 and 2000 seasons for the varieties Giza3, Giza6, HAB53 and Bronco. These results were in agreement with those obtained by White *et al.* (1994) who reported positive (GCA) effect for yield on common beans (*Phaseolus vulgaris* L.). In regard to protein content, the varieties Giza3, Giza6, Bronco and HAB53 had shown positive (GCA) effects in 1999 and 2000 seasons. Similar results were obtained by Dasgupta *et al.* (1998) who stated good general combiners for protein content in mung bean. On the other hand, the varieties had shown negative (GCA) effects in the two seasons were HAB20, Helda and Limka for number of days to 50% flowering; Helda, Limka and Bronco for number of days to dry harvesting; Serbo, HAB53, Helda and Limka for seed index; Serbo, HAB20, Helda and Limka for seed yield per plant and HAB20, Helda and Limka for protein content.

The values of means and heterosis over high parent for the F_1 crosses are given in Table (5 a and b). One out of 12 crosses namely (1 x 5) showed positive heterosis for number of days to 50% flowering in 1999 and 2000 seasons. The same previous mentioned cross of 12 crosses showed positive heterosis for number of days to dry harvesting in 2000 season only. For seed index 8 out of 12 crosses had positive heterosis in both seasons. These 8 crosses were (1 x 4), (1 x 5), (1 x 6), (2 x 5), (2 x 6), (3 x 6), (4 x 8) and (5 x 8). Additionally, the crosses (1 x 5), (2 x 6), (2 x 7), (3 x 6), (4 x 8) and (5 x 8) had shown the same result for seed yield per plant. Meaningful, all crosses had positive heterosis in the two experimental seasons for protein content.

The highest heterosis was shown by the following crosses, (1 x 5) for number of days to 50% flowering in both seasons; (1 x 5) for number of days to dry harvesting in 2000 season only (the second season); and (4 x 8) for seed yield per plant, this was true in both 1999 and 2000 seasons.

The results were in accordance with those recorded by Aher *et al.* (2000) for yield of mung beans and its components and Vikas *et al.* (1999) for days to 50% flowering and dry harvesting of mung beans (*Vigna radiata*). For seed index (1000 seed weight), the highest positive heterosis was observed in both seasons for the cross (5 x 8). The obtained result was in agreement with that reported by Gutierrez and Singh (1985) on bush beans (*Phaseolus vulgaris* L.).

Mean performance and inbreeding depression effects of F_2 generations in 1999 and 2000 seasons are shown in Table (6 a and b). Some heterotic crosses namely (1 x 4) and (5 x 8) for seed index; (1 x 5) for number of days to 50% flowering; (1 x 5), (2 x 6), (2 x 7), (4 x 8) and (5 x 8) for seed yield per plant; (1 x 5), (2 x 7), (3 x 6) and (5 x 8) for protein content in both 1999 and 2000 seasons and (1 x 5) for number of days to dry harvesting in 2000 season did not exhibit inbreeding depression. This might suggest that heterosis in these crosses was probably due to complementary favorable genes with additive effects. Moreover, positive effects of inbreeding in crosses that had no heterosis or negative estimates were recorded in the two seasons. That was for number of days to 50% flowering and for number of days to dry harvesting in the crosses (1 x 4), (1 x 6), (2 x 5), (2 x 6), (2 x 7), (3 x 6), (3 x 8), (4 x 7) and (4 x 8). While it was for seed index (1000 seed

Table (5a): Mean performance (M) and heterosis (H%) over high parent (HP) of F_1 crosses during 1999 season.

Cross	Number of days to 50% flowering		Number of days to dry harvesting		Seed index (1000 seed weight) (g)		seed yield per plant (g)		Protein content %	
	M	H%	M	H%	M	H%	M	H%	M	H%
1 x 4	47	-10.962	92	-7.358	398.067	28.409	14.800	-16.854	21.703	6.950
1 x 5	46	2.222	93	-5.102	349.433	10.815	21.567	21.161	26.317	27.482
1 x 6	42	-5.926	93	-4.124	407.800	12.135	9.823	-44.813	23.463	15.620
2 x 5	44	-4.348	91	-4.861	481.433	0.368	7.269	-46.813	22.990	11.366
2 x 6	45	-2.899	95	-0.694	487.267	1.584	18.723	32.162	21.774	0.346
2 x 7	47	-5.333	90	-6.250	428.800	-25.642	23.780	33.844	26.003	22.818
3 x 6	46	-16.364	92	-5.155	426.400	9.381	16.847	18.915	26.949	34.441
3 x 7	50	-0.667	93	-1.064	386.000	-33.064	17.377	-2.197	23.459	10.802
3 x 8	47	-12.963	83	-11.348	371.733	-4.642	12.777	-17.035	24.007	19.767
4 x 7	45	-15.094	90	-9.030	402.000	-30.289	15.637	-11.990	21.573	1.892
4 x 8	42	-22.840	90	-9.699	395.067	18.935	23.607	53.290	26.723	28.316
5 x 8	50	-8.025	87	-10.884	451.733	35.995	22.270	44.610	26.557	28.641
CD at 5%	4.163		2.030		43.081		9.106		4.656	

Table (5b): Mean performance (M) and heterosis (H%) over high parent (HP) of F_1 crosses during 2000 season.

Cross	Number of days to 50% flowering		Number of days to dry harvesting		Seed index (1000 seed weight) (g)		seed yield per plant (g)		Protein content	
	M	H%	M	H%	M	H%	M	H%	M	H%
1 x 4	46	-14.815	91	-7.796	396.167	28.209	14.487	-16.595	27.666	34.593
1 x 5	49	1.389	92	1.465	347.800	9.716	22.050	26.950	21.339	10.165
1 x 6	43	-9.722	89	-1.832	406.857	12.494	9.767	-43.770	26.032	26.653
2 x 5	45	-5.633	90	-7.850	479.333	1.125	7.080	-48.162	21.745	19.636
2 x 6	46	-3.520	95	-2.731	486.367	2.609	17.860	15.974	22.104	7.541
2 x 7	48	-7.643	92	-5.802	431.000	-25.433	23.190	31.949	22.746	12.927
3 x 6	46	-13.836	92	-3.158	426.013	11.231	16.690	8.377	24.695	21.628
3 x 7	50	-6.289	94	-1.053	384.333	-33.506	17.333	-1.375	25.458	25.298
3 x 8	47	-15.152	84	-11.930	371.133	-3.098	12.233	-26.747	25.036	23.222
4 x 7	47	-13.580	92	-6.101	398.167	-31.113	14.303	-18.615	23.212	12.928
4 x 8	43	-21.818	88	-7.018	391.767	18.477	23.467	40.519	21.154	4.185
5 x 8	51	-7.273	88	-7.368	449.000	35.785	22.500	34.731	24.600	19.681
CD at 5%	4.178		2.407		42.714		9.070		4.660	

Table (6a): Mean performance (M) and inbreeding depression (ID%) of F_2 generation during 1999 season.

Cross	Number of days to 50% flowering		Number of days to dry harvesting		Seed index (1000 seed weight) (g)		seed yield per plant (g)		Protein content %	
	M	ID%	M	ID%	M	ID%	M	ID%	M	ID%
1 x 4	48	2.289	94	1.715	338.866	-14.872	15.292	3.322	23.881	10.036
1 x 5	46	-0.543	94	0.896	331.049	-5.261	18.650	-13.524	23.226	-11.745
1 x 6	44	3.740	94	0.627	372.318	-8.701	12.903	31.355	22.610	-3.633
2 x 5	45	1.705	94	3.102	439.467	-8.717	9.268	27.500	22.581	-1.781
2 x 6	45	0.933	96	0.612	454.468	-6.731	15.120	-19.244	22.784	4.639
2 x 7	48	0.704	92	1.667	478.485	11.587	18.549	-22.000	23.969	-7.821
3 x 6	48	4.348	94	1.902	401.575	-5.822	13.882	-17.599	23.291	-13.571
3 x 7	51	2.852	93	-1.064	434.625	12.597	15.047	-13.408	22.284	-5.010
3 x 8	51	7.979	89	6.400	366.367	-1.444	12.155	-4.865	22.921	-4.524
4 x 7	48	7.222	93	2.298	407.500	1.368	15.368	-1.715	23.286	7.941
4 x 8	48	14.200	93	3.796	342.908	-13.202	19.095	-19.112	23.224	-13.093
5 x 8	50	-0.168	92	4.962	387.742	-14.166	18.402	-17.370	23.179	-12.719
CD at 5%	3.153		1.518		33.106		6.937		3.510	

Table (6b): Mean performance (M) and inbreeding depression (ID%) of F_2 generation during 2000 season.

Cross	Number of days to 50% flowering		Number of days to dry harvesting		Seed index (1000 seed weight) (g)		seed yield per plant (g)		Protein content %	
	M	ID%	M	ID%	M	ID%	M	ID%	M	ID%
1 x 4	49	5.435	93	2.206	336.333	-15.103	14.686	1.373	23.349	9.419
1 x 5	45	-7.021	94	1.625	330.400	-5.003	18.782	-14.822	23.992	-7.840
1 x 6	45	3.654	93	1.636	371.096	-8.790	13.076	33.880	19.920	-8.393
2 x 5	45	1.679	94	4.815	437.417	-8.745	9.334	31.840	21.559	-2.464
2 x 6	46	0.547	97	1.579	452.101	-7.045	15.160	-15.119	23.619	3.840
2 x 7	49	1.551	93	1.268	478.500	11.021	18.369	-20.791	23.793	-3.656
3 x 6	47	3.650	94	2.536	399.174	-6.300	14.323	-14.184	23.686	-6.961
3 x 7	51	3.020	94	-0.532	432.417	12.511	15.188	-12.376	22.674	-9.437
3 x 8	50	7.857	89	6.773	363.984	-1.926	11.419	-6.653	22.824	-1.671
4 x 7	50	6.964	94	1.263	404.583	1.612	13.979	-2.269	23.495	11.070
4 x 8	49	13.372	93	4.717	339.551	-13.328	19.008	-18.999	23.615	-4.006
5 x 8	51	-0.980	93	5.303	386.418	-13.938	18.840	-16.269	22.443	-18.876
CD at 5%	3.215		1.851		32.849		6.899		3.699	

5weight) in the crosses (2 x 7), (3 x 7) and (4 x 7). As well as, the same was for seed yield per plant in crosses (1 x 4), (1 x 6) and (2 x 5).

The results show obviously desirable transgressive segregation occurred in those previously mentioned crosses. That means the two parents in each cross carry different genes responsible for the inheritance of the characters and they can be used in recurrent selection program for improving common beans.

Whatever the causes, these results were in line with records of Gutierrez and Singh (1985) who reported that highly heterotic crosses without inbreeding depression and those with positive inbreeding effects apparently had retained or increased favorable genotypic combinations in their F_2s.

It could be concluded that there were different results obtained, where some crosses and parents had shown fluctuated data i.e. high in season and low in subsequent season. This was in agreement with Gutierrez and Singh (1985) who mentioned that could be due to interaction between genotypes and environment (G x E). That also leads to the high importance of estimation of (G x E) in breeding programs. It is worth to mention here that the good combiners were the varieties Giza6, Giza3 and HAB20 for seed index; Giza6, HAB53, Bronco and Giza3 for seed yield per plant as well as Giza3, Giza6, HAB53 and Bronco for protein content. These good combiners could be useful in improving seed size, higher yield and protein content. The best heterotic crosses were (1 x 4) and (5 x 8) for seed index (1000 seed weight) and (4 x 8) and (5 x 8) for seed yield per plant. The best transgressive segregated F_2s that outperformed their F_1 crosses were (2 x 7), (3x7) and (4 x 7) for seed index (1000 seed weight) and (1x4), (1 x 6) and (2 x 5) for seed yield. These best F_1s and F_2s previously mentioned could be involved in advanced selection program to improve seed size, seed yield and to introduce new local dry bean varieties.

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استخدام تحليل Partial diallel فى تقدير قوة الهجين و التدهور الراجع للتربية الذاتية و القدرة على التآلف فى الفاصوليا الجافة (*Phaseolus vulgaris* L.)

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تم تقدير قوة الهجين و التدهور الراجع للتربية الذاتية و القدرة على التآلف فى ١٢ هجين جيل اول الناتجة من ٨ آباء من الفاصوليا (*Phaseolus vulgaris L.*) و نسلهم فى الجيل الثانى لهم. تلك المواد الوراثية قد قيمت لصفات عدد الأيام حتى الإزهار و عدد الأيام حتى الجمع الجاف و وزن ١٠٠٠ بذرة و محصول النبات من البذور الجافة و محتوى البروتين. و قد أظهرت ٦ هجن منها قوة هجين موجبة بالنسبة لصفة محصول النبات من البذور الجافة. و قد كانت أباء هذه الهجن مختلفة فى طبيعة نموها و حجم بذورها و اصلها الجغرافى. و قد ظهرت فروق معنوية فى كل الصفات بين هجن الجيل الأول و نسلهم فى الجيل الثانى باستثناء صفة محتوى البروتين. بينما تفوق بعض الجيل الثانى على الجيل الأول الخاص بهم. و قد أظهرت القدرة العامة على التآلف فروقا معنوية فى أربعة صفات بينما ظهرت فى ثلاثة صفات فقط بالنسبة للقدرة الخاصة على التآلف.