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Estimation of Better Parent and Economic Heterosis for Yield and Associated Traits in Common Beans

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ABSTRACT

Objective: A study to estimate better parent and economic heterosis in an 8x8 diallel crosses of common beans (*Phaseolus Vulgaris L.*) was undertaken at Mandura, North Western Ethiopia.
Methodology and Results: Eight parents and their 28 F_1 diallel crosses were grown in a randomized complete block design. Yield and its components, architectural, and phenological traits were considered. Statistically significant differences were observed between the 36 genotypes for most of the traits studied. Analysis of better parent and economic heterosis respectively revealed 16 and 14 crosses out of 28 showed significant heterosis for yield per plant. Among which 12 and 7 crosses in the same order were positive. The extent of better parent heterosis for yield ranged from -31.14% (Dimtu x Tabor) to 114.1% (MAM-41 x Tabor). The maximum economic heterosis (60.58 %) was observed from the hybrid MAM-41 x Tabor .Significant ($P \leq 0.05$ or $P \leq 0.01$) better parent heterosis was also observed for yield-associated traits.
Conclusions and recommendation: In this study, expression of significant better parent heterosis for grain yield and other important traits was frequent in combinations of parents from different growth habits (MAM-41 x Tabor, Roba-1 x SK 93263), seed color (Tabor x Red wolayta, BELDAKMI RR 5 x SK 93263, Dimtu x Zebra), and seed size (Roba-1 x Tabor). The extent of percent better parent and economic heterosis like in the cross MAM-41 x Tabor with 114.103 % seed yield better parent heterosis and 60.6 % economic heterosis suggested that this hybrid could be further considered in the breeding program aiming both for segregant breeding and hybrid development.
Key Words: Better parent heterosis, diallel, economic heterosis, *Phaseolus vulgaris* L.

INTRODUCTION

Common beans (*Phaseolus Vulgaris L.*) are an important legume crop for direct food consumption and market transactions in the regions of Eastern, Central, and Southern Africa. They are recognized as the second most important source of human dietary protein and the third most important source of calorie of all the agricultural commodities produced in the region (Schoonhoven & Voysest, 1991; Kemani, 1999). The crop is mainly cultivated by small holders and being used as an inexpensive source of protein and an important source of cash, (Pachico, 1993; CIAT, 1995). Despite the role beans are playing, its productivity is quite low in this region. For example, the national average in Ethiopia is 0.9 tons per hectare (Negash, 2007). It is constrained by several biotic and abiotic factors (Katungi et al., 2010). Any breeding strategy aiming to develop improved varieties with required merits in productivity, market preference, and nutrition should target those major constraints. The success of common bean breeding programs is intimately related to the appropriate choice of divergent parents which, when crossed, must provide wide genetic variability to be used for selection. Diallel analysis provides a systematic approach for the detection of appropriate parents and crosses as it allows estimation of different genetic parameters including the expression of heterosis in early generations. Greater bean grain yield could be obtained by hybridizing superior cultivars.

Heterosis, which is the superiority in performance (increased vigour, size, fruitfulness, speed of development, resistance to pests, or to climatic rigors of any kind) of hybrid individuals compared with their parents (Shull, 1952) has been reported for a wide range of crop species including both self and cross-pollinated crops. Expression of heterosis for various agronomical characters in beans has been determined by several investigators. It was confirmed in various studies that genetic divergence plays a significant role in the expression of heterosis. In a nine-parent diallel cross of common beans carried out at Centro International de Agricultura Tropical head quarter (CIAT, 1984), better parent yield heterosis was as high as 35.9%, and an increasing heterotic value was noted in crosses between parents of increasingly divergent growth habit. Nienhuis and Singh (1983) tested F_1 hybrids of bush beans (*Phaseolus vulgaris* L.) and found significant better parent yield heterosis in 17 of the 36 families. In another study involving bean lines of different growth habits, Nienhuis and Singh (1986) reported, significant better parent yield heterosis and it was as high as 29.5 percent.

The present study was executed to estimate the level of percent better parent heterosis and economic heterosis among diallel cross F_1 hybrids of eight common bean varieties. This information would be useful to investigate the performance and relationship of F1 hybrids and parents and to select suitable parents and population for designing an effective breeding programme.

MATERIALS AND METHODS

The study was conducted at Mandura, Northwestern Ethiopia in 2006. Eight parents and their 28 F_1 diallel crosses were studied in two replicates of randomized complete block design. Diallel crosses were made by hand at Melkassa Agricultural Research Center in the central rift valley of Ethiopia during the dry season (March to June, 2005) under furrow irrigation and during the rainy season (July to September, 2005) to ensure enough F_1 seed for planting. The parents were from different heterotic groups based on seed color, shape and size, and growth habit, Table 1.

Table 1 : Description of the parental varieties for the 8x8 diallel crosses of common beans

Nº	Parent	Status/Origin	Seed color	Seed shape	Seed size	Growth H
1.	Roba-1	Released-1990	Cream	Elongated	Small	Ind. bush
2.	Dimtu	Released-2003	Red	Round	Small	Ind. bush
3.	Zebra	Released-1999	Carioca	Round	Medium	Ind. bush
4.	MAM-41	Released-2003	Cream	Round	Medium	Ind. Prost
5.	BELDAK	CIAT	Cr. Pinto	Round	Medium	Ind. Prost
6.	SK 93263	CIAT	White	Round	Medium	Ind. Prost
7.	Tabor	Released-1999	Cream	Elongated	Medium	Ind. Bush
8.	Red wolayta	Released-1974	Red	Elongated	Medium	Ind. bush

Cr. pinto = Cream pinto, Ind. bush = Indeterminate bush, Ind. prost = Indeterminate prostrate, Growth H= Growth habit, BELDAK = BELDAKMI RR 5, Seed size based on 100 seed weight: 1 to 24 g = small seed; 25 to 39 g = medium seed; 40 g and above = large seed.

A plot with two 1 m long rows spaced 60 cm apart was used. This wider row spacing was used to facilitate furrow supplemental irrigation when needed. Intra-row plant-to-plant spacing was 10 cm. Two seeds were hand planted per hill and the stand thinned to one plant per hill 10 days after emergence to maintain optimum plants per plot. Standard agronomic and plant protection treatments were used uniformly across the plots for the duration of the experiment. Parameters were measured on plant and plot basis. Phenological traits (days to 50 % flowering and days to 75 % maturity) and 1000 seed weight were recorded on plot basis and all other agronomic traits were measured on plant basis. A random sample of five plants from each plot and a random sample of five pods from each of the five plants were considered to collect data for plant-based parameters. The data were subjected to analysis of variance (ANOVA) according to Steel and Torrie (1980) and it was computed using SAS statistical software (SAS, 2004). Existence of significant difference among genotypes justifies further analysis.

Heterosis measures , like better parent heterosis (BPH) and economic heterosis (SH) in percent, both having commercial breeding implication, particularly for self-pollinated crops, were calculated for those characters which showed significant difference between genotypes (crosses plus parents) following the method suggested by Falconer and Mackay (1996):

BPH (%) = $((F_1 - BP)/BP)*100$

SH (%) = $((F_1 - SH)/SH)*100$

Where, F_1 = Mean value of the F_1 cross

BP = Mean value of the better parent

SH = Mean value of the standard check or economic variety to the study area

Tests for significance of heterosis were made using t-test Standard error of the differences between heterosis was calculated as follows:

SE (d) for BP or SH = $\pm\sqrt{2Me/r}$

Where, SE (d) is standard error, Me is error mean square and r is the number of replications and the t obtained was tested against the tabular t-value at error degree of freedom.

t (better parent) = BPH/SE (d), and

t (economic) = SH/SE(d)

RESULTS AND DISCUSSION

Results of ANOVA revealed statistically significant differences ($P \leq 0.01$ or $P \leq 0.05$) between the 36 genotypes were observed for number of days to flowering and maturity, number of nodes on the main axis, plant height, pod length, number of seeds per pod, number of seeds per plant and 1000-seed weight (Table 2). Statistically significant difference among the parents and crosses were observed for phenological, some architectural, and yield component traits. Average heterosis, which is a one degree of contrast between the mean of the parents and the mean of the crosses, was significant for phenological, yield and yield component traits suggesting the presence of directional dominance for the expression of these traits. Mean performance of the parents showed that Roba-1 performed well in architectural traits (number of branches and nodes and pod length), in yield and yield components such as number of pods per plant, seeds per pod and seeds per plant (Table 3). It was also one of the earliest parent taking 85 days to maturity as compared to the late maturing varieties like Red wolayta, although it was late flowering. Thus, it had relatively short pod filling period (the period from flowering to maturity) as a result it has smaller seeds. Dimtu had poor value for the architectural traits and showed reasonably good performance for yield and yield components. It was intermediate in maturity. Zebra had the highest seed yield per plant (20.8 gram) and it was reasonably good in architectural traits such as plant height, internodes length, pod length, and number of nodes on the main axis. MAM-41 was intermediate in flowering, but late maturing, and had pods with the maximum diameter and hence larger seeds with 1000-seed weight of 305 gram as compared to that of Roba-1 (200 gram). BELDAKMI RR 5 was one of the best parents in yield and yield components and in architectural traits like plant height and number of nodes on the main axis. SK 93263 was the earliest to flower and mature. Tabor produced the longest pods, large number of branches on the main axis and showed generally good performance in yield component traits. Red wolayta was the latest maturing parent. It had large number of nodes and branches on the main axis and larger pod size.

Table 2: Mean squares due to genotypes, parents, crosses, average heterosis and error for yield and associated traits of common beans

	Mean squares				
Parameters	**Genotype (35)**	**Parent (7)**	**Crosse (27)**	**Av. H (1)**	**Error (35)**
DF	38.86**	39.92**	34.58**	147.05**	8.41
DM	12.58***	4.96	7.78*	195.57**	2.83
BR	0.94	0.69	0.93	2.72	0.94
IL	1.14	1.45	1.10	0.0004	0.73
ND	1.85*	4.45*	1.25	0.011	1.07
PH	0.03***	0.06***	0.02**	0.009	0.006
PL	1.16***	1.81**	1.02***	0.35	0.36
PD	0.004	0.005	0.004	0.002	0.003
PPP	30.84	13.66	33.59	76.89	24.01
SPOD	1.20***	2.42**	0.89***	1.26*	0.22
SPP	1110.1**	586.66	1202.76**	2272.0*	520.87
TSW	4387.1**	5534.82*	4187.03***	1754.86	500.44
GYP	48.89	20.14	49.88	223.46*	51.48

Av. H = Average heterosis. *, **, *** = significant difference at $P \leq 0.05$, $P \leq 0.01$ and, $P \leq 0.001$ respectively. Numbers in parenthesis represent respective degree of freedoms. DF = Days to flowering, DM = days to maturity, BR = Number of branch, IL = Internodes length, ND = Number of nodes, PH = Plant height, PL = Pod length, PD = Pod diameter, PPP = Number of pods per plant, SPOD = Number of seeds per pod, SPP = Number of seeds per plant, TSW = 1000-seeds weight, GYP = Seed yield per plant.

Analysis of better parent heterosis revealed sixteen crosses out of twenty-eight were showed significant heterosis for seed yield per plant. Among which twelve were positive. The maximum positive better parent heterosis (114.103 %) for seed yield was observed in the cross MAM-41 x Tabor while the minimum better parent heterosis (-31.138 %) was obtained from the cross Dimtu x Tabor. These were also the crosses with the highest and lowest seed yield per plant, respectively. The expression of bean yield better parent heterosis was reported by several workers (Foolad and Bassiri, 1983; Singh and Saini, 1983; CIAT, 1984; Nienhuis and Singh 1986; Patil and Chaudhari 1986). Significant economic heterosis was observed in fourteen crosses for seed yield per plant, among which seven were positive.

Table 3: Mean value of yield and associated traits for the 36 genotypes (8 parents and their 28 F_1 diallel crosses) of common beans

Progeny	DF	DM	BH	IL	ND	PH	PL	PD	PPP	SPD	SPP	TSW	GYP
1X2	49.0	83.0	3.7	9.71	13.9	1.16	10.4	0.62	20.20	5.40	106.60	225	27.7
1X3	47.0	81.0	4.2	9.32	15.5	1.27	10.1	0.64	26.20	5.39	111.20	245	30.1
1X4	42.5	81.0	2.4	8.75	13.4	1.02	10.1	0.61	15.60	4.80	70.60	270	18.6
1X5	43.0	82.5	3.1	8.04	14.3	1.15	10.5	0.53	20.10	5.08	90.30	265	24.0
1X6	38.5	80.5	4.2	8.37	13.2	1.10	9.9	0.63	27.00	5.42	111.80	265	27.0
1X7	49.0	85.0	3.5	8.64	13.3	1.10	10.9	0.53	24.20	5.72	129.30	205	26.1
1X8	48.5	84.5	3.8	7.76	14.5	1.09	9.9	0.55	24.20	5.07	108.50	200	19.8
2X3	48.5	85.0	3.6	9.94	14.1	1.34	10.0	0.57	25.70	4.77	108.40	240	23.3
3X4	46.0	84.0	3.0	8.82	15.2	1.25	9.3	0.63	20.70	4.98	74.30	260	18.6
2X5	39.0	81.0	3.5	8.33	14.5	1.14	9.5	0.65	23.70	4.64	71.40	270	18.5
2X6	41.5	82.0	2.6	9.72	13.6	1.24	8.9	0.65	19.10	3.87	62.90	300	17.9
2X7	52.0	88.0	1.9	9.11	13.6	1.17	9.9	0.61	13.60	4.33	57.90	235	11.5
2X8	52.5	87.5	3.3	8.97	14.0	1.17	9.9	0.57	20.20	4.87	84.70	200	14.6
3X4	43.5	84.5	3.5	9.02	14.9	1.26	8.8	0.60	19.70	4.12	62.80	310	18.7
3X5	38.5	83.5	2.7	9.30	16.3	1.46	8.6	0.68	20.90	3.60	61.40	335	20.8

3X6	40.5	83.5	2.1	9.86	14.4	1.36	8.6	0.62	18.80	3.52	48.80	330	15.3
3X7	45.5	84.5	3.2	8.99	14.9	1.27	9.6	0.54	24.50	4.54	95.80	260	24.5
3X8	43.0	85.0	3.3	9.85	14.1	1.30	9.2	0.53	28.90	4.48	115.10	235	25.8
4X5	41.0	84.5	1.8	9.64	14.6	1.32	8.7	0.66	14.20	3.76	41.70	330	14.8
4X6	46.0	84.0	3.0	10.10	13.6	1.30	9.4	0.61	20.00	3.88	64.80	375	22.1
4X7	46.5	81.5	4.7	7.85	14.6	1.35	10.2	0.58	28.90	5.23	123.10	270	33.4
4X8	41.5	84.5	3.5	8.12	14.2	1.21	8.8	0.63	24.00	4.30	73.60	280	21.0
5X6	42.0	81.0	2.9	9.20	14.0	1.27	9.5	0.65	16.30	4.00	49.30	360	16.4
5X7	40.5	83.5	2.9	9.29	14.4	1.27	10.8	0.65	19.30	5.18	79.70	290	22.3
5X8	40.5	83.5	2.6	8.14	14.0	1.14	10.2	0.61	18.00	4.76	78.90	270	19.6
6X7	39.5	81.5	2.6	9.92	12.5	1.17	10.3	0.59	16.80	5.21	68.70	285	19.6
6X8	40.5	80.5	3.0	9.21	13.0	1.10	8.9	0.60	21.60	3.55	62.40	295	17.0
7X8	49.5	85.0	2.7	10.60	13.8	1.35	11.0	0.60	21.50	5.68	103.00	225	21.5
Roba-1(1)	51.0	86.0	3.1	7.78	14.8	1.10	10.5	0.55	19.80	6.07	99.10	200	18.8
Dimtu (2)	52.5	87.5	3.0	8.82	13.9	1.25	9.1	0.61	19.00	4.88	80.40	215	16.7
Zebra (3)	46.5	89.0	2.1	9.54	14.8	1.35	8.8	0.61	17.80	3.98	72.90	265	20.8
MAM-41 (4)	48.0	88.0	2.8	9.62	14.1	1.27	9.3	0.71	15.20	4.12	54.10	305	15.3
BELDAKMIRR5(5)	41.5	88.0	2.5	9.43	16.5	1.61	8.8	0.66	24.10	2.78	63.70	305	20.6
SK 92263 (6)	40.5	85.0	1.5	10.30	11.8	1.17	8.4	0.58	17.30	3.04	47.20	345	15.8
Tabor (7)	49.5	86.0	3.0	9.32	12.5	1.11	11.0	0.61	19.30	5.26	80.00	225	15.6
Red wolaita (8)	51.0	89.5	3.2	7.99	15.1	1.15	10.4	0.61	17.30	4.51	56.50	225	11.2
Mean	44.90	84.29	3.01	9.09	14.16	1.23	9.7	0.61	20.66	4.58	79.75	269.86	20.15
LSD (5%)	5.89	3.42	1.97	1.74	2.10	0.16	1.2	0.12	9.95	0.95	46.33	45.41	14.57

DF=Days to flowering, DM=days to maturity, BH=Number of branch, IL=Internodes length, ND=Number of nodes, PH=Plant height, PL=Pod length, PD=Pod diameter, PPP=Number of pods per plant, SPD=Number of seeds per pod, SPP=Number of seeds per plant, TSW=1000-seeds weight, GYP=Seed yield per plant.

The maximum economic heterosis (60.58 %) was observed in the cross MAM-41 x Tabor (Table 4). Significant better parent heterosis was observed in most of the crosses for number of pods per plant. It ranged from -41.079 % (MAM-41 x BELDAKMI RR 5) to 62.36 % (Zebra x Red wolayta). Higher number of pods per plant over the better parent was reported by Foolad and Bassiri (1983) and Singh and Saini (1983). In contrast to the present study, however, non-significant better parent heterosis for the same trait was reported by Melaku (1993) and Gutierrez and Singh (1985). Only two crosses (Zebra x Red wolayta and MAM-41 x Tabor) gave significantly higher ($P \leq 0.05$) number of seeds per plant (57.89 %, 53.87 in that order) than the best parent. Although not significant, thirteen crosses produced large number of seeds per plant than the best parent. Melaku (1993) and Foolad and Bassiri (1983) reported significant positive better parent heterosis in one cross and five crosses, respectively for the trait. Significant better parent heterosis was observed in all except five crosses for number of seeds per pod. However, only four crosses exhibited significant positive better parent heterosis, among which the hybrid BELDAKMI RR 5 x SK 93263 (31.71 %) showed the maximum value for the trait. The cross MAM-41 x Tabor which showed significant positive better parent heterosis for seed yield per plant, number of pod per plant and seeds per plant here exhibited non-significant negative better parent heterosis for number of seeds per pod. Non-significant better parent heterosis was observed in all of the crosses for 1000-seed weight. Only seven crosses had larger seeds than the better parent did. The value of better parent heterosis for 1000-seed weight ranged from -23.19 % (Roba-1 x SK93263) to 9.84 % (Zebra x BELDAKMI RR 5). Highly significant ($P \leq 0.01$) better parent heterosis was obtained in almost all crosses for pod length (Table 5), among which only three were positive. The value of percent better parent heterosis for pod length ranged from -15.50 % (MAM-41 x Red wolayta) to 9.54 % (Dimtu x Zebra). Although not significant, Melaku (1993) reported nine crosses out of twenty-eight produced pods shorter than the better parent. Highly significant better parent heterosis for pod diameter was observed in all the crosses except one. However, only six crosses produced pods with greater diameter than the better parent did. The maximum better parent heterosis for pod diameter was obtained from the cross Roba-1x SK93263 (8.70 %). This result go with the work of Patil and Chaudhari (1986), who reported that about half of the twenty eight crosses exhibited negative significant better parent heterosis for pod diameter. Contrary to the present study, however, Singh and Saini (1983) reported positive and significant better parent heterosis for pod diameter in all the crosses studied. All the crosses manifested very highly significant better parent heterosis for plant height. However, only four of them were taller than the tallest parent. The cross Tabor x Red wolayta (17.24 %) exhibited the maximum better parent heterosis. This result is in agreement with that of Melaku (1993), who reported the expression of better parent heterosis for plant height in beans.

Table 4: Percent better parent heterosis for grain yield and yield components, and economic heterosis for grain yield in an 8x8 diallel cross population of common beans

Crosses	PPP	SPD	SPP	TSW	GYP	SHGYP
1X2	2.020	-10.994**	7.568	4.651	47.340**	33.173**
1X3	32.323**	-11.159**	12.210	-7.547	44.712**	44.712**
1X4	-21.212**	-20.883**	-28.759	-11.475	-1.064	-10.577
1X5	-16.598**	-16.268**	-8.880	-13.115	16.505*	15.385*
1X6	36.364**	-10.664**	12.815	-23.188	43.617**	29.808**
1X7	22.222**	-5.670**	30.474	-8.889	38.830**	25.481**
1X8	22.222**	-16.367**	9.485	-11.111	5.319	-4.808
2X3	35.263**	-2.295**	34.826	-9.434	12.019	12.019
3X4	8.947	1.926**	-7.587	-14.754	11.377	-10.577
2X5	-1.660	-4.918**	-11.194	-11.475	-10.194	-11.058
2X6	0.526	-20.697**	-21.766	-13.044	7.186	-13.942
2X7	-29.534**	-17.757**	-27.985	4.444	-31.138**	-44.712**
2X8	6.316	-0.266	5.348	-11.111	-12.575	-29.808**
3X4	10.674*	0.000	-13.855	1.639	-10.096	-10.096
3X5	-13.278*	-9.570**	-15.775	9.836	0.000	0.000
3X6	5.618	-11.580**	-33.059	-4.348	-26.442**	-26.442**
3X7	26.943**	-13.688**	19.750	-1.887	17.788*	17.788*
3X8	62.360**	-0.665	57.888*	-11.321	24.038**	24.038**
4X5	-41.079**	-8.811**	-22.921	8.197	-28.155**	-28.846**
4X6	15.607**	-5.898**	19.778	8.696	39.873**	6.250
4X7	49.741**	-0.513	53.875*	-11.475	114.103**	60.577**
4X8	38.728**	-4.656**	30.265	-8.197	37.255**	0.962
5X6	-32.365**	31.709**	-22.606	4.348	-20.388**	-21.154**
5X7	-19.917**	-1.445**	-0.375	-4.918	8.252	7.212
5X8	-25.311**	5.543**	23.862	-11.475	-4.854	-5.769
6X7	-12.953*	-0.875	-14.125	-17.391	24.051**	-5.769
6X8	24.855**	-21.197**	10.442	-14.493	7.595	-18.269*
7X8	11.399*	7.985**	28.750	0.000	37.821**	3.365
Cross mean	21.21	4.65	82.75	272.5	21.09	
Parent mean	18.73	4.33	69.24	260.63	16.85	
Av. H	2.48	0.32	13.51	11.87	4.24	

*, ** shows percent heterosis significantly different from zero at P≤0.05 and P≤0.01 level of significance, respectively. SHGYP = economic heterosis for seed yield per plant, Av. H = Average heterosis, PD = Pod diameter, Number of pods per plant, SPD = Number of seeds per pod, SPP = Number of seeds per plant, TSW = 1000-seeds weight, 1 = Roba-1, 2 = Dimtu, 3 = Zebra, 4 = MAM-41, 5 = BELDAKMI RR 5, 6 = SK 93263, 7 = Tabor, 8 = Red wolayta.

Table 5: Percent better parent heterosis for Phenological and architectural traits in an 8 x 8 diallel crosses population of common beans

Crosses	DF	DM	BR	IL	ND	PH	PL	PD
1X2	-3.9220	-3.488*	19.355**	10.075**	-6.081**	-7.674**	-0.525	1.961**
1X3	1.0753	-5.814**	35.484**	-2.275*	4.730**	-5.721**	-3.392**	4.762**
1X4	-11.460**	-5.814**	-22.581**	-9.104**	-9.459**	-20.063**	-3.793**	-13.662**
1X5	3.6145	-4.070*	0.000	-14.725**	-13.333**	-28.314**	0.459	-20.121**
1X6	-4.9380	-5.294**	35.484**	-18.543**	-10.811**	-6.474**	-5.350**	8.696**
1X7	-1.0100	-1.163	12.903**	-7.275**	-10.135**	-1.448**	-0.936	-12.829**
1X8	-4.9020	-1.744	18.750**	-2.941**	-3.974**	-5.199**	-5.111**	-10.311**
2X3	4.3011	-2.857	20.000**	4.203**	-4.730**	-0.594**	9.541**	-7.680**
3X4	-4.1670	-4.000*	0.000	-8.314**	7.801**	-1.810**	-0.311	-11.972**
2X5	-6.0240*	-7.429**	16.667**	-11.661**	-12.121**	-28.998**	4.045**	-1.513**
2X6	2.4691	-3.529*	-13.333**	-5.409**	-2.158*	-0.560**	-2.374**	6.209**
2X7	5.0505	2.326	-36.667**	-2.210*	-2.158*	-6.395**	-9.900**	-0.654
2X8	2.9412	0.000	3.125**	1.666	-7.285**	-6.395**	-5.384**	-7.026**
3X4	-6.4520*	-3.977*	25.000**	-6.267**	0.676	-6.464**	-5.782**	-15.915**
3X5	-7.2290*	-5.114**	8.000**	-2.516**	-1.212	-9.459**	-2.621**	2.118**
3X6	0.0000	-1.765	0.000	-4.040**	-2.703*	0.892**	-1.719**	2.135**
3X7	-2.1510	-1.744	6.667**	-5.776**	0.676	-5.944**	-12.364**	-11.658**
3X8	-7.5270*	-4.494*	3.125**	3.260**	-6.623**	-3.566**	-11.641**	-13.584**
4X5	-1.2050	-3.977*	-35.714**	0.135	-11.515**	-17.735**	-6.726**	-7.746**
4X6	13.580**	-1.176	7.143**	-1.605	-3.546**	2.124**	0.955	-14.789**
4X7	-3.1250	-5.233**	56.667**	-18.375**	3.546**	6.137**	-7.500**	-18.592**
4X8	-13.540**	-3.977*	9.375**	-15.631**	-5.960**	-4.642**	-15.499**	-11.268**
5X6	3.7037	-4.706**	16.000**	-10.536**	-15.152**	-21.033**	7.353**	-1.362**
5X7	-18.180**	-2.907	-3.333**	-1.474	-12.727**	-21.220**	-1.536*	-1.967**
5X8	-2.4100	-5.114**	-18.750**	-13.718**	-15.152**	-29.247**	-1.900**	-7.262**
6X7	-2.4690	-4.118**	-13.333**	-3.473**	0.000	-0.511**	-6.718**	-3.454**
6X8	0.0000	-5.294**	-6.250**	-10.439**	-13.907**	-6.303**	-14.175**	-2.619**
7X8	0.0000	-1.163	-15.625**	13.541**	-8.609**	17.244**	-0.1545	-2.128**
Cross mean	44.13	83.41	3.12	9.09	14.16	1.23	9.71	0.60
Parent mean	47.56	87.38	2.65	9.10	14.19	1.25	9.54	0.62
Av. H	-3.4	-3.97	0.53	-0.01	-0.03	-0.02	0.17	-0.02

*, ** shows percent heterosis significantly different from zero at P≤0.05 and P≤0.01 level of significance, respectively. Av. H = Average heterosis. DF = Days to flowering, DM = days to maturity, BR = Number of branches on the main axis, IL = Internodes length, ND = Number of nodes on the main axis, PH = Plant height, PL = Pod length, 1 = Roba-1, 2 = Dimtu, 3 = Zebra, 4 = MAM-41, 5 = BELDAKMI RR 5, 6 = SK 93263, 7 = Tabor, 8 = Red wolayta.

Significant better parent heterosis was exhibited almost by all crosses for number of nodes on the main axis, among which only three had greater number of nodes than the better parent. The cross Zebra x MAM-41 (7.80%) had the maximum better parent heterosis for number of nodes. Significant better parent heterosis was observed for internodes length in all except four crosses. Only four of them had larger internodes length than the better parent. The value of better parent heterosis for the trait ranged from -18.54% (Roba-1x SK93263) to 13.54% (Tabor x Red wolayta), this was the cross that showed maximum better parent heterosis for plant height. Twenty-five out of the twenty-eight crosses exhibited very highly significant better parent heterosis for number of branches on the main axis. Sixteen of them had larger number of branches than the better parent. The cross MAM-41 x Tabor (56.67 %) exhibited the maximum better parent heterosis for number of branches. This was the cross with the highest grain yield. Seven and eighteen crosses out of twenty-eight showed significant negative better parent heterosis for days to flowering and maturity, respectively (Table 5). Such crosses are useful when earliness is the major objective of the breeding program. This result is in agreement with the work of Foolad and Bassiri (1983), who reported significant negative better parent heterosis in seven out of twelve crosses studied. The maximum better parent heterosis for number of days to maturity (early maturing) was exhibited by the cross Dimtu x BELDAKMI RR 5 (-7.43 %) whereas the cross Dimtu x Tabor took 88 days (the maximum positive better parent heterosis, 2.33 %) to mature among the crosses studied. Generally, in this study, average heterosis was positive for yield and all yield components and for some architectural traits like number of branches on the main axis and pod length. However, it was negative for the phenological traits. Thus, in general dominance increased seed yield per plant by 4.24 gram, number of pods per plant, seeds per pod and seeds per plant by 2.48, 0.32, and 13.51, respectively; number of branches on the main axis by 0.53 and pod length by 0.17 cm, and it reduced days to flowering and maturity by 3.4 and 4 days, respectively. In the present study, expression of significant better parent heterosis for grain yield and other traits was frequent in combinations of parents from different growth habits (MAM-41 x Tabor, Roba-1x SK93263), seed color (Tabor x Red wolayta, BELDAKMI RR 5 x SK93263, Dimtu x Zebra), and seed size (Roba-1x Tabor). This result supports the findings of previous workers who reported the importance of genetic diversity for the expression of heterosis (Foolad and Bassiri, 1983; CIAT, 1984; Gutierrez and Singh, 1985; Nienhuis and Singh, 1986; Melaku, 1993). In conclusion, the extent of percent better parent and economic heterosis like in the cross MAM-41 x Tabor with 114.103 % seed yield better parent heterosis and 60.6 % economic heterosis suggested that this hybrid could be further considered in the breeding program aiming both for segregant breeding and hybrid development.

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