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Heterosis for Yield and Yield Related Characters in Maize (*zea mays* l.)

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ABSTRACT

The heterosis studies were conducted using 10 parents and their 45 hybrids obtained from a half-diallel mating for eleven grain yield and yield components over two locations and two seasons. The results indicated that for most of the characters, the role of non-additive gene action is predominant. Hence, a breeder should exploit the non-additive gene action through exploitation of heterosis. Heterosis for most of the hybrids was accomplished for ear length, ear girth, number of kernel rows per ear, number of kernels per row and 100 kernel weight. Hence, improvement in these characters ensures higher yield. Since the present investigation is carried out at two locations and two seasons for 45 hybrids the best performing hybrids should be tried at multilocatoins and seasons before the commercial exploitation in the farmer's field.

Key words : Heterosis, Locations, Maize, Seasons,Yield.

Maize (*Zea mays* L.) occupies a very prominent position among cultivated crops from the plant breeders point of view, due to the fact that many of the basic and important concepts that have revolutionized the breeding methodologies are the outcome of research carried out in maize. The first commercial hybrid in crop plants was produced by Jones in 1917 in maize and it is considered a land mark in crop breeding programme. It provided an impetus to explore the possibility of commercial exploitation of heterosis, thus the new era of hybrid production started. Though the crop is grown extensively, grain yields are not commensurate with the area reflecting low productivity level, since exploitation of heterosis of the recent hybrids is low and even this small superiority is not reflected on the farmer's fields, consequently leading to yield stagnation. Hence, the need of the hour is to develop new hybrids superior from time to time to the existing ones. Exploitation of heterosis is newly developed potential inbreds of maize is instrumental in overcoming these problems and to make significant impact in increasing production.

Knowledge of genetic architecture of yield and yield components will help to demarcate the better crosses. Ever since, Sprague and Tatum (1942) had given the concept of combining ability in crop breeding, it has attained paramount importance in breeding experiments for isolating potential parental lines and superior performing hybrids. These concepts facilitate in determination of the type of gene action controlling particular character which ultimately helps the breeder to formulate suitable breeding programme in exploiting heterosis for higher yields.

The expression of heterosis depends on the level of dominance controlling the trait. Therefore, grain yield in maize is expected to exhibit heterosis as a consequence of partial to complete dominance of genes controlling the trait. On the other hand, the expression of heterosis also depends on the level of genetic divergence between parents; *i.e.,* differences in allele frequencies are necessary for the expression of heterosis. The present work aims to evaluate the expression of heterosis in crosses following the diallel mating scheme.

MATERIAL AND METHODS

The experimental material comprised of ten promising elite genotypes *viz.,* P_1, P_3, P_5, P_7 and P_9 lines are of flint grain type and the remaining five lines P_2, P_4, P_6, P_8 and P_{10} are of dent grain type and 45 single crosses obtained by diallel mating of parental lines. The details of parental lines are given below:

Reciprocal crosses were avoided presuming absence of cytoplasmic influence in the experiemental material. The single crosses, along with parents and two checks were evaluated during *kharif,* 2002 and rabi*,* 2002-03 at Hyderabad and Palem in CRBD with three replications. The plot size of each entry was a single row of five metre length, with a spacing of 75 cm and 20 cm between inter row and intra rows respectively. Initially two to three seeds per hill were sown and after germination, the population was thinned out to a single seedling per hill. Border rows were planted to eliminate the border effect. Usual recommended package of practices and cultural practices were adopted to maintain a good crop. The data were recorded on days to 50 per cent tasseling, days to 50 per cent silking, plant height, ear height, ear length, ear girth, number of kernel rows per ear, number of kernels per row, 100 kernel weight, grain yield per plot and protein content. In the present investigation the combining ability analysis was worked out according to method-II, model-I (Fixed effects model) given by Griffing (1956) and heterotic behaviour of 45 hybrids was estimated as heterosis (over mean of the parents), heterobeltiosis (over superior parent) and standard heterosis (over high yielding check) at two locations *viz.,* Hyderabad and Palem and in two seasons *kharif* 2002 and *rabi* 2002-03.

RESULTS AND DISCUSSION

Heterosis was widely used by maize breeders to produce uniformly productive hybrids. In the present investigation heterotic behavior of 45 hybrids was estimated (Table 1) as heterosis (over mean of the parents) heterobeltiosis (over superior parent) and standard heterosis (over high yielding check) at two locations *viz.,* Hyderabad and Palem and in two seasons. Days to 50 per cent tasseling and days to 50 per cent silking indicates the earliness of genotype in maize. Earliness is a desirable character as it requires less water requirement due its short duration. It also facilitates multicropping systems. Heterosis for earliness was reported by Mukherje *et al.* (1971), Daniel and Bajbay (1976), Dhillon and Singh (1977a), Hussaballa *et al.* (1980) and Aliu *et al.* (2008). Crossa *et al.* (1990), Mandal (1996), Satyanarayana and Sai Kumar (1996), Venkatesh (1997) and Premlatha and Kalamani, (2010). In the present investigation also many crosses exhibited heterosis for days to 50 per cent tasseling and days to 50 per cent silking. However the cross combinations, P_1 x P_7, P_1 x P_8 and P_1 x P_9 registered significant level of heterosis and heterobeltiosis. These hybrids were earlier than the early maturing parent and will be useful under rainfed cultivation.

Heterosis and heterobeltiosis for plant height was found to be positively significant in crosses, P_1 x P_3, P_1 x P_6, P_2 x P_4 and P_2 x P_5. The parental lines, P_1 and P_2 were medium tall and most of the cross combination with these parents exhibited heterosis. Thus in breeding for medium tall hybrids, inclusion of atleast one medium tall parent is desirable. It is possible to have more fodder in addition to grain yield with medium tall stature. Increase in plant height of hybrids was also reported by Mabo (1977), Todorov (1981), Corssa *et al.* (1987), Beck *et al.* (1990), Bhantnagar *et al.* (1993) and Ikramullah. (2011).

Verma and Singh (1980), Nawar and Khamis (1983), Lin and Chen (1986), Tomov and Min (1990), Ojo et al. (2007) and Venkatesh (1997) reported heterosis for ear length. In the present investigation also all the hybrids possessed higher ear length. Out of 45 hybrids evaluated, P_1 x P_2, P_2 x P_5 and P_2 x P_6 exhibited higher heterosis and heterobeltiosis. Increase in ear length in useful to have higher number of kernels per row of the ear resulting in higher yield.

Ear girth is an important character which associates more number of rows in the ear and more number of kernels per ear. Maximum level of heterosis was observed in cross combinations, P_3 x P_{10}, P_5 x P_6, P_5 x P_{10} and P_9 x P_{10}. Such heterotic crosses for ear girth have also been reported by Yurankova *et al.* (1989), Mandal (1996), Venkatesh (1997) and Abdel-Moneam *et al.* (2009).

Number of kernel rows per ear and number of kernels per row are the important components of grain yield. P_1 x P_8, P_1 x P_{10}, P_2 x P_4, P_2 x P_5 and P_4 x P_{10} exhibited highest heterosis for number of kernel rows per ear. P_1 x P_2, P_1 x P_8, P_2 x P_5, P_2 x P_6, P_2 x P_7 and P_2 x P_8 possessed more number of kernels per row at two locations and in two seasons. In respect of 100 kernel weight, the heterosis and heterobeltiosis was in positive direction. The hybrids, P_4 x P_7, P_2 x P_9, and P_1 x P_3 had higher *per se* performance. The above hybrids registered significant heterosis. These crosses involved one

Table 1. Estimates of per cent of heterosis (h_1), heterobeltiosis (h_2) and standard heterosis (h_3) against a) Madhuri b) DHM-105 for yield and yield components in maize.

Crosses	*Kharif 2002* Hyderabad				*Kharif 2002* Palem			
	h1	h2	h3 a	h3 b	h1	h2	h3 a	h3 b
1) Days to 50 per cent tasselling								
P1 x P7	-7.5630**	-5.1724**	22.2222**	7.8431**	-7.4380**	-5.0847**	19.1489**	9.8039**
P1 x P8	-12.6050**	-10.3448**	15.5556**	1.9608	-15.0000**	-12.0690**	8.5106**	0.0000
P1 x P9	-14.0496**	-13.3333**	15.5556**	1.9608	-17.0732**	-16.3934**	8.5106**	0.0000
2) Days to 50 per cent silking								
P1 x P7	-8.8000**	-6.5574**	18.7500**	5.5556**	-6.3492**	-4.8387**	20.4082**	11.3208**
P1 x P8	-12.0000**	-9.8361**	14.5833**	1.8519	-15.2000**	-13.1148**	8.1633**	0.0000
P1 x P9	-14.9606**	-14.2857**	12.5000**	0.0000	-15.6250**	-15.6250**	10.2041**	1.8868
3) Plant Height								
P1 x P3	100.0000**	100.0000**	-3.0303**	-21.9512**	93.1034**	86.6667**	-6.6667**	-30.0000**
P1 x P6	94.1176**	83.333**	0.0000	-19.5122**	87.5000**	76.4706**	0.0000**	-25.0000**
P2 x P4	100.0000**	87.5000**	-9.0909**	-26.8293**	85.7143**	85.7143**	-13.3333**	-35.0000**
P2 x P5	106.2500**	83.3333**	0.0000	-19.5122**	58.9404**	48.1481**	-20.0000**	-40.0000**
4) Ear Length								
P1 x P2	61.8182**	48.3333**	22.7586**	-3.7838**	83.3333**	65.0000**	6.4516**	-4.6243**
P2 x P5	67.2727**	57.3333**	26.8966**	-0.5405	80.5406**	59.0476**	7.7419**	-3.4683*
P2 x P6	64.5455**	50.8333**	24.8276**	-2.1622	87.0588**	76.6667**	2.5806	-8.0925**
5) Ear girth								
P3xP10	43.8095**	25.8333**	37.0226**	-10.1191**	8.3333**	8.3333**	30.0000**	-12.1622**
P5xP6	26.2222**	18.3333**	28.8556**	-15.4762**	32.0000**	32.0000**	32.0000**	-10.8108**
P5xP10	49.7436**	39.0476**	32.4864**	-13.0952**	9.0909**	0.0000**	20.0000**	-18.9189
P9xP10	45.6410**	35.2381**	28.8566**	-15.4762**	24.4444**	16.6667**	40.0000**	-5.4054**
6) Number of Kernel rows per ear								
P1xP8	23.0769**	14.2857**	33.3333**	0.0000	23.0769**	14.2857**	33.3333**	0.0000
P1xP10	33.3333**	33.3333**	33.3333**	0.0000	33.3333**	33.3333**	33.3333**	0.0000
P2xP4	23.0769**	14.2857**	33.3333**	0.0000	23.0769**	14.2857**	33.3333**	0.0000
P2xP5	23.0769**	14.2857**	33.3333**	0.0000	23.0769**	14.2857**	33.3333**	0.0000
P4xP10	33.3333**	33.3333**	33.3333**	0.0000	33.3333**	33.3333**	33.3333**	0.0000
7) Number of Kernels per row								
P1xP2	63.6364**	60.7143**	25.0000**	12.5000***	86.0465**	73.9130**	37.9310**	14.2857**
P1xP8	69.2308**	62.9630**	23.2222**	10.0000**	58.3333**	52.0000**	31.0345**	8.5714**
P2xP5	54.3860**	51.7241**	22.2222**	10.0000**	86.0465**	73.9130**	37.9310**	14.2857**
P2xP6	59.2593**	53.5714**	19.4444**	7.5000**	95.0000**	95.0000**	34.4828**	11.4286**
P2xP7	61.5385**	50.0000**	16.6667**	5.0000**	90.2439**	85.7143**	34.4828**	11.4286**
P2xP8	62.2642**	53.5714**	19.4444**	7.5000**	77.7778**	60.0000**	37.9310**	14.2857**
8) Grain yield								
P1xP8	104.7103**	97.1449**	254.4294**	25.4542**	115.2542**	101.5873**	31.3793**	24.9180**
P2xP5	95.4118**	94.9616**	230.6931**	17.0525**	148.2540**	128.6550**	34.8276**	28.1967**
9) Protein content								
P3xP9	41.6089**	37.7868**	-5.1996**	15.1071**	42.5000**	38.6486**	-4.7354**	15.6708**
P4xP9	49.7126**	48.6448**	-3.2498**	17.4746**	50.0720**	49.0000**	-3.1569**	17.5874**

* Significant at 5 % level, ** Significant at 1 % level

Table 1. cont....

Crosses	*Rabi 2002* Hyderabad				*Rabi 2002* Palem			
	h1	h2	h3		h1	h2	h3	
			a	b			a	b
1) Days to 50 per cent tasselling								
P1 x P7	-6.6667**	-5.9701**	21.1538**	8.6207**	-8.9552**	-7.5758**	15.0943**	1.6667
P1 x P8	-10.448**	-9.0909**	15.3846**	3.4483*	-8.9552**	-7.5758**	15.0943**	1.6667
P1 x P9	-11.111**	-10.4478**	15.3846**	3.4483*	-1.4706	-1.4706	26.4151**	11.6667**
2) Days to 50 per cent silking								
P1 x P7	-5.0360**	-4.3478**	22.2222**	10.0000**	-7.9137**	-7.2464**	16.3636**	3.2258**
P1 x P8	-8.6957**	-7.3529**	16.6667**	5.0000**	-8.6957**	-7.3529**	14.5455**	1.6129
P1 x P9	-11.429**	-11.4286**	14.8148**	3.3333	-1.4286	-1.4286	25.4545**	11.2903**
3) Plant Height								
P1 x P3	78.3784**	73.6842**	0.0000	-23.2558**	83.0303**	77.6471**	-8.4848	-28.0592**
P1 x P6	78.9474**	70.0000**	3.0303**	-20.9302**	84.4118**	78.8889**	-2.4242**	-23.3333**
P2 x P4	83.3333**	73.6842**	0.0000**	-23.2558	85.4545**	80.0000**	-7.2727**	-27.1429**
P2 x P5	91.4894**	74.7573**	9.0909**	-16.2791**	72.9412**	63.3333**	-10. 9091**	-30.0000**
4) Ear Length								
P1 x P2	48.2353**	41.0448**	18.1250**	-7.8049**	66.3636**	52.5000**	5.7803**	-3.6842
P2 x P5	52.6718**	41.8440**	25.0000**	-2.4390*	64.1256**	48.7805**	5.7803**	-3.6842**
P2 x P6	48.2890**	37.3239**	21.8750**	-4.8780**	62.8959**	48.7603**	4.0462**	-5.2632**
5) Ear girth								
P3xP10	36.8000**	14.0000**	31.5385**	-5.0000**	5.2632**	3.4483**	18.1102**	-7.9755**
P5xP6	29.3651**	24.4275**	25.3846**	-9.4444**	28.0335**	26.4463**	20.4725**	-6.1350**
P5xP10	48.4163**	35.5372**	26.1538**	-8.8889**	8.7453**	-1.3793**	12.5984**	-12.2699**
P9xP10	46.1884**	32.5203**	25.3846**	-9.4444**	20.8955**	11.7241**	27.5591**	-0.6135**
6) Number of Kernel rows per ear								
P1xP8	23.0769**	14.2857**	33.3333**	0.0000	23.0769**	14.2857	33.3333**	0.0000
P1xP10	33.3333**	33.3333**	33.3333**	0.0000	33.3333**	33.3333**	33.3333**	0.0000
P2xP4	23.0769**	14.2857**	33.3333**	0.0000	23.0769**	14.2857**	33.3333**	0.0000
P2xP5	23.0769**	14.2857**	33.3333**	0.0000	23.0769**	14.2857**	33.3333**	0.0000
P4xP10	33.3333**	33.3333**	33.3333**	0.0000	33.3333**	33.3333**	33.3333**	0.0000
7) Number of Kernels per row								
P1xP2	63.9344**	61.2903**	25.0000**	21.9512**	57.8947**	50.0000**	28.5714**	7.1429**
P1xP8	58.0645**	58.0645**	22.5000**	19.5122**	34.5455**	23.3333**	5.7143**	-11.9048**
P2xP5	53.8462**	42.8571**	25.0000**	21.9512**	42.8571**	37.9310**	14.2857**	-4.7619**
P2xP6	55.5556**	48.4848**	22.5000**	19.5122**	51.8519**	51.8519**	17.1429**	-2.3810
P2xP7	63.3333**	63.3333**	22.5000**	19.5122**	50.9434**	48.1481**	14.2857**	-4.7619*
P2xP8	60.6557**	58.0645**	22.5000**	19.5122**	53.8462**	48.1481**	14.2857**	-4.7619*
8) Grain yield								
P1xP8	83.4297**	76.2963**	144.1026**	-1.8557	93.4579**	87.3303**	223.4375**	2.7295
P2xP5	46.3768**	37.4150**	107.1795**	-16.7010**	85.7143**	78.2258**	245.3125**	9.6774
9) Protein content								
P3xP9	41.8685**	38.1402**	-4.5624**	15.6885**	41.8508**	38.2234**	-4.6425**	15.7835**
P4xP9	49.7135**	48.6486**	-2.7002**	17.9458**	49.3200**	47.9433**	-3.1569**	17.5874**

* Significant at 5 % level, ** Significant at 1 % level

parent having higher kernel weight, atleast one divergent parent with superior performance *per se* must be included as one of the parent.

All the hybrids exhibited their superiority over the mean of their parents and better parent. The cross combinations, P_1 x P_8 and P_2 x P_5 had registered higher heterosis for grain yield at two locations over two seasons. Varying levels of heterosis was reported by Krowlinowski (1971), Mabo (1977), Verma and Singh (1980), Younis *et al.* (1987), Debnath and Sarkar (1990), Murali Krishna and Patil (1992), Appunu (2002), Camilo *et al.* (2008) and Alam *et al.* (2008).

Hybrids with higher protein content are useful and essential to overcome the problem of malnutrition in the developing countries. Breeding for higher protein content increases the nutritional value of maize and this possibility was demonstrated by Woodworth (1952). Thereafter, many workers reported heterotic performance of hybrids for protein. Recently heterosis for protein content was reported by Wang *et al.* (1998) and Konark *et al.* (1999). Generally protein *per cent* ranges from 7.2 to 10.1. In the present study, the crosses, P_3 x P_9 and P_4 x P_9 expressed higher significant heterosis for protein per cent. Hybrids with higher protein content are useful and essential to overcome the problem of malnutrition in the developing countries.

LITERATURE CITED

Abdel-Moneam M A, Attia A N, El-Emery M I and Fayed E A 2009 Combining ability and heterosis for some agronomic traits in crosses of maize. *Pakistan Journal of Biological Sciences,* 12 (5):433-8.

Aliu S, Fetahu Sh and Salillari A 2008 Estimation of heterosis and combining ability in maize (*Zea mays L.)* for ear weight using the diallel crossing method. *Latvian Journal of Agronomy,* 11: 7-12.

Alam A K M M, Ahmed S , Begum M and Sultan M K 2008 Heterosis and combining ability for grain yield and its contributing characters in maize. *Bangladesh Journal of Agricultural Research,* 33(3): 375-379.

Beck D L, Vasal S K and Crossa J 1990 Heterosis and combining ability of CIMMYT's tropical and intermediate maturity maize (*Zea mays* L.) *germplasm*. *Maydica,* 35:279 – 285.

Bhatnagar S K, Ranwah B R and Sundersan R 1993 Heterosis in early exotic maize, *Indian Journal of Genetics and Plant Breeding,* 53:94-96.

Camilo De, Lelis Morello, José Branco De, Miranda Filho and E Josué Maldonado Ferreira 2008. Heterosis and combining ability among varieties of maize in acid soil *Pesquisa Agropecuária Tropical,* 32 (2): 89-95.

Crossa J, Vasal S K and Beck D L 1990 Combining ability estimates of CIMMYT's tropical late yellow maize germplasm. *Maydica,* 35:273-278.

Daniel L and Bajbay I 1976 Analysis of agronomic characters in a diallel cross of nine genotypes of sweetcorn (*Zea mays* L.) II Diallel analysis. *Zoldsegetermloztesi kutato interzet Bulletinje,* 11: 53-63.

Debanath S C and Sarkar K R 1990 Combining ability analysis of grain and some of its attributes in maize (*Zea mays* L.). *Indian Journal of Genetics and Plant Breeding,* 50: 57-61.

Dhillon B S and Singh J 1977 Inheritance of grain yield and other quantitative traits in maize. Experimental Agriculture 13: 253-256.

Griffing B 1956 A generalized treatment of the use of diallel crosses in quantitative inheritance. *Heredity,* 10: 31-50.

Hassaballa E S, EI-Morshidy M A and Khalifa M A 1980 Genitical analysis of diallel crosses in Maize Research Bulletin 1294:8.

Ikramullah, Iftikhar Hussain Khalil, Muhammad Noor and Mohammad Kausar Nawaz Shah 2011. Heterotic effects for yield and protein content inwhite quality protein maize. *Sarhad Journal of Agriculture,* 27: 3-8.

Konark C, Unay A, Serter E and Basal H 1999 Estimation of combining ability effects, heterosis and heterobeltiosis by line x tester method in maize. *Turkish Journal of Field Crops,* 4: 1-9

Krowlinowski Z 1973 Assessment of gca and sca of maize inbred lines crosses in a diallel system. *Plant Breeding Abstracts,* 44:5114.

Lin S F and Chen C 1986 Studies on combining ability for major agronomic characters in maize (*Zea mays* L.). *Journal of Agriculture Association*, China No. 136:6-14.

Mabo Z H P 1977 Heterosis in maize hybrids in relation to the number of grain rows in the parental forms. *Plant Breeding Abstracts,* 50:4939.

Mukherje B K, Dhawan N L and Singh N N 1971 Heterosis in intervarietal crosses in maize (*Zea mays* L.). *Indian Journal of Agricultural Sciences,* 41: 489 – 494.

Muralikrishna S and Patil S J 1992 Study of inbreeding depression, heterosis and their relationships with combing ability in maize (*Zea mays* L.). *in :* Maize Research in North Karnataka, UAS Dharwad.

Nawar A A and Khamis M N 1983 Influence of date of planting on the expression of general and specific combining ability in maize. *Minufiya Journal of Agriculture Research,* 7:85-100.

Ojo G O S, Adedzwa1 D K and Bello L L 2007. Combining ability estimates and heterosis for grain yield and yield components in maize (*Zea mays L.*). *Journal of Sustainable Development in Agriculture and Environment,* 3:49-57

Premlatha M and Kalamani K 2010. Heterosis and combining ability studies for grain yield and growth characters in maize (*Zea mays* l.). *Indian Journal of Agricultural Research,* 44 (1): 62 – 65.

Satyanarayana E and Saikumar R 1996 Genetic variability of yield and maturity components in maize hybrids. *Current Research,* 25:10-16.

Shull G H 1952 Beginning of the heterosis concept. Heterosis lowa State Press, Ames.

Sprague G F and Tatum L A 1942 General vs. Specific combining ability in single crosses of corn. *Journal of American Society of Agronomy,* 34: 923-932

Todorov G 1981 Expression of heterosis in F1 maize for plant growth, photosynthesizing leaf area and dry matter accumulation. Rasteniev dni-Nauki 18: 30-36.

Tomov N and Do-Ngo-Min 1990 Expression of heterosis in maize. Rasteniev dni-nauki 27: 20-26.

Verma R K and Singh T P 1980 Heterosis and combining ability studies for certain quantitative traits in popcorn. *Mysore Journal of Agricultural Sciences,* 14: 15-17.

Wang Z H, Wang Yi Bo, Wang Y P, Zhang X and shugin M 1998 Analysis of heterosis and its correlation in maize. *Journal of Henan Agricultural Sciences,* 2: 3-6.

Younis S E A, Omra M K, Saleh F M and Saba M F 1987 Heterosis in dry matter and grain yield per plant under drought in varietal cross among populations. *Assiut Journal of Agricultural Sciences,* 19: 239 – 256.

Yurankova S I, Tsitok U O, Rusinava V U and Lemesh V A 1989 Features of the expression of heterosis for yield components in first generation maize hybrids. Vestsi Akad Navuk Belaruskai SSR. Biyalagi Chynkh Navuk 2: 40-44.

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