Pak. J. Bot., 47(6): 2387-2390, 2015.

THE EVALUATION OF HETEROSIS FOR ROMANIAN MAIZE GERMPLASM

BONEA DORINA[1*] AND URECHEAN VIORICA[2]

[1]*Faculty of Agriculture and Horticulture, University of Craiova, no 19, Libertatii street, 200583, Dolj, Romania*
[2]*Agricultural Research and Development Station Şimnic, no. 54, Balceşti road, 200721, Dolj, Romania*
**Corresponding author e-mail: dbonea88@gmail.com*

Abstract

In this study, five inbred maize lines and ten F1 cross combinations were evaluated in a completely randomized block, in three recursions, placed in unirrigable conditions at the Agricultural Research Development Station (ARDS) Simnic, in 2009. After the heterosis of the F1 cross combinations was evaluated, high genetic differences between parents were noticed. The obtained results suggested that among the six studied parameters, only two – the grain yield and the plant height – are relevant for an objective evaluation of heterosis phenomenon. It is recommended that the 4 x 5 and 1 x 5 cross combinations which recorded (for most of the analyzed parameters) the highest degrees of occurrence, both for heterosis over mid parent and for heterobeltiosis, should be used in the maize breeding program to exploit the hybrid vigor.

Key words: F1 cross combinations, Heterobeltiosis, Inbred lines, Maize.

Introduction

The heterosis, or hybrid vigour was defined by Shull (1952) as „the interpretation of increased vigor, size, fruit fulness, speed of development, resistance to disease and to insect pests, or to climatic rigors of any kind manifested by crossbred organisms as compared to corresponding inbreds, as the specific results of unlikeness in the constitution of the uniting parental gametes" (Reif *et al.*, 2005).

The use of heterosis has determined a true revolution in maize cropping technology, countries which are great maize providers, among them, Romania, use only hybrids (simple, double or trilinear). In 2013, in Romania, the surface cropped by maize hybrids was of 2721,2 thousands hectares (Anon., 2013). The maize plant has a high potential for producing and exploiting the heterosis phenomenon. This could be the reason why the maize plant has the highest number of hybrids of any other plant species.

The *Zea mays* L. species is widely used as a model for selecting the main parameters of diagnosis of the heterosis effect (Haş, 2004). One of the main objectives of maize breeding is the study of genetic and molecular bases of heterosis, aiming at the most efficient identification of heterotic effect.

The manifestation of heterosis depends on the genetic divergence of two parental varieties, also genetic divergence of the parents is inferred from the heterotic patterns manifested in a series of cross combination (Hallauer & Miranda, 1988). The exploitation of hybrid vigor can be instrumental in increasing seed yield (Nasim *et al.,* 2014). Selection of parents is the most important stage in any breeding programe to develop new genotypes having desirable characters. One of the methods to achieve this purpose is heterosis (Ilker *et al.,* 2010; Khan *et al.,* 2010; Siddiqi *et al*., 2012).

Two main types of heterosis evaluation have been reported in literature, namely, the average heterosis (or mid parent heterosis, which is the increased vigor of the F1 over the mean of two parents) and heterobeltiosis (or better parent heterosis, which is the increased vigor of the F1 over the better parent) (Matziner *et al.*, 1962; Jinks, 1983).

The heterosis phenomenon with maize has been widely investigated. Hallauer & Miranda (1988), after studying the heterosis with grain yield maize up to 1979, have reported that the heterosis over mid parent varied from 3-6% to 72.0% while the heterobeltiosis varied from -9.9% to 43.0%.

Tollenaar *et al.* (2004) have reported an average heterosis of 167% for the grain yield, of 109% for the kernels per ear and of 12% for the thousand grain weight. Heterotic effects of varying degrees of maize grain yield and other parameters (maturity, plant height, ear height, kernels ear, 1000-kernels weight have also been reported by Bonea & Urechean (2003), Muhammad *et al.* (2003), Malik *et al.* (2004), Meseka *et al*. (2006), Alam *et al.* (2008), Aghaei *et al.* (2012).

The aim of this paper is to study the degree of heterosis occurrence with F1 cross combinations obtained from diallel crosses of some Romanian inbred lines and also to identify the best parameters for a proper evaluation of the heterosis effect.

Material and Method

This study was carried out at Agricultural Research Development Station (ARDS) Simnic, Dolj District, located at 44 ^{0}19' N, 23 ^{0}48' E, and 182 m altitude. The climatic regime of this area is continentally temperate, with a plain specific, with submediterranean influences. The average values of temperatures are between 10.5 and 11.5^{o}C and the rainfall reaches 520-550 l/m^{2}. The ARDS Simnic is located in the central part of Oltenia and it is a center of selecting breeding material for maize, sunflower and wheat. The soil of the station is luvosol and it has pH=6.0.

The biological material was represented by five Romanian inbred lines (from the national germplasm collection that belongs to National Agricultural Research and Development Institute - Fundulea) listed in Table 1 and ten F1 cross combinations resulted from diallel crosses of n(n-1)/2 type of these inbred lines (excluding the reciprocals).

Table 1. Names and codes of inbred lines.

Code	Inbred lines
1	Lc 257
2	Lc 402
3	Lc 403
4	Lc 404
5	Lc 406

This biological material was planted in field conditions in a complete randomized block in three recursions, in 2009. Climatically, the 2008-2009 crop year was favorable for maize crop.

Six biometrical and gravimetrical parameters were analyzed, as follows: the grain yield per hectare,the plant height (cm); the ear height (cm); the ear length, the kernels per ear and the thousand kernels weight. The results were processed by analyzing variance (Botu & Botu, 2010).

The degree of heterosis phenomenon occurrence with F1 cross combinations was studied with reference to two aspects of this phenomenon, that is heterosis over mid parent (MPH) and heterobeltiosis (BPH) using the following formula (Matziner *et al.*, 1962; Jinks, 1983):

Heterosis over mid parent (MPH%) = [(F1-MP)/MP] ×100 , where MP is mid parent;

Heterosis over better parent (heterobeltiosis: BPH%) = [(F1-BP)/BP] ×100, where BP is better parent.

The analysis of data recorded for MPH and BPH was made by adapting the classification made by Musteaţa *et al.* (2001) and Mihalachi (2013):

a) hybrid combinations with low level of heterosis occurrence (0 < H< 25%);
b) hybrid combinations with high level of heterosis occurrence (H > 25%).

Results and Discussion

The analysis of variance (Table 2) revealed that mean squares due to F1cross combinations and parents lines were highly significant for all the parameters, indicating that considerable genetic diversity for all parameters existed among the material under study. A high genetic variability provides an opportunity for breeders to select promising genotypes for specific parameters (Iqbal *et al.*, 2013).

Data for F1 cross combinations and for their parental lines are presented in Table 3. The grain yield was ranged between 6.01 t/ha (1 x 4) and 11.15 t/ha (1 x 3). The plant height ranged from 200 cm to 240 cm. The highest value was recorded with 1 x 5 cross combination. The ear height varied from 54 to 92 cm and, again, the 1 x 5 combination recorded the highest value. For the ear length there were recorded values between 18.3 and 25.3 cm, best values for 4 x 5 combination. The kernels per ear varied from 649 to 893, the best value for 2 x 4 cross combination. The 1000- kernels weight varied from 261 to 334 g, the best value for 3 x 4 cross combination.

The range of heterosis and heterobeltiosis is presented in Table 4.

Grain yield: For grain yield ten cross combinations recorded a high level of occurrence of positive heterosis and heterobeltiosis (Table 5). The heterotic and heterobeltiotic values ranged from +71.2% (1 x 4) to 213.9% (1 x 5) and from +50.2% (1 x 4) to 203.6% (1 x 5) respectively. These results are in accordance with Bonea (2001) and Aghaei *et al.* (2012), as they obtained similar heterosis values for this parameter.

Plant height: only four cross combinations recorded a high level of heterosis expression over mid parent and only one over the heterobeltiosis (Table 5). Heterosis over mid parent ranging from +10.3% (1 x 3) to +29.4% (2 x 5). The magnitude of heterobeltiosis varied from +1.0% (2 x 3) to +26.9% (1 x 5). These observations were generally analogous to the findings of Muhammad *et al.* (2003), Malik *et al.* (2004), Devi *et al.* (2007), Alam *et al.* (2008), Amanulah *et al.* (2011) and Farhan *et al.* (2012) as they observed a different ratio of heterotic values for plant height.

Ear height: six cross combinations recorded a high level of occurrence for positive heterosis over mid parent and five cross combination for heterobeltiosis (over better parent). In this case, the magnitude of heterosis over mid parents ranged from +8.6% (3 x 5) to +84.0% (2 x 5) and heterobeltiosis ranged from +9.5% (3 x 4) to +80.0% (2 x 5). These results are greatly supported by Muhammad *et al.* (2003), Devi *et al.* (2007), Alam *et al.* (2008), Amanullah *et al.* (2011), Farhan *et al.* (2012) who also observed varying levels of heterosis for this parameter.

Ear length: with this case, eight cross combinations recorded a high level of occurrence for positive heterosis over mid parent and seven cross combinations for heterobeltiosis (Table 5). The minimum hybrid vigour over mid parent was +6.3% (3 x 5) and maximum +57.1% (4 x 5) while the hybrid vigour over better parent ranged from +2.7% (2 x 3) to +55.2% (4 x 5). Similar results have alredy been reported by Bonea (2001) at ARDS Simnic area and Aghaei *et al.* (2012) under terminal water stress at Moghan region.

Table 2. Analyses of variance of 10 crosses among 5 inbred lines maize for grain yield and other parameters.

Source of variation	df	Mean squares					
		GY	PH	EH	EL	KRE	TKW
Total	44	362.71	26858.80	10737.30	717.10	1504561.80	52424.00
Replication	2	0.19	389.00	14.70	0.36	7938.13	580.80
Genotype (G)	14	344.02	21365.13	10172.60	437.40	1490702.80	46448.80
Error	28	18.51	5104.67	550.00	279.30	5920.87	5394.40
F test		37.20**	8.37**	36.90**	3.13**	503.40**	192.60**

** Significant at $p<0.01$

GY-grain yield; PH – plant height ; EH – ear height; EL-ear length; KRE- number of kernels per ear; TKW – 1000 kernels weight

Table 3. Mean values of studied parameters at F1 cross combination and parent lines.

Crosses and parents	Grain yield (t/ha)	Plant height (cm)	Ear height (cm)	Ear length (cm)	Kernels ear	1000-kernels weight (g)
1 x 2	7.62	200	54	22.0	767***	327**
1 x 3	11.15***	214	86***	21.6	731***	319**
1 x 4	6.01	210	83***	21.3	695	301
1 x 5	9.20**	240**	92***	21.0	764	298
2 x 3	7.95	201	71	19.0	812***	261
2 x 4	8.50	205	70	22.6	893***	262
2 x 5	10.01***	220	81**	21.6	865***	281
3 x 4	9.28**	220	80**	23.3	649	334***
3 x 5	10.33***	215	63	18.3	751***	290
4 x 5	9.87***	224	75	25.3*	850***	328**
1	3.03	189	65	16.0	343	279
2	4.09	154	45	13.0	544	234
3	4.81	199	73	18.5	720***	311*
4	4.00	166	46	16.3	475	231
5	2.83	186	43	16.0	265	260

*Significant differences at the 5% probability level; **Significant differences at the 1% probability level; ***Significant differences at the 0.1% probability level

Table 4. Heterotic and heterobeltiotic value for grain yield and other parameters of maize in F1 generation.

Croses	Heterosis type	Grain yield (t/ha)	Plant height (cm)	Ear height (cm)	Ear length (cm)	Kernels ear	1000-kernels weight (g)
1 x 2	MPH %	114.0	16.6	-1.8	51.7	70.9	27.0
	BPH%	86.0	5.8	-16.9	37.5	39.5	17.0
1 x 3	MPH%	184.4	10.3	24.6	25.2	37.5	8.0
	PBH%	131.8	7.5	17.8	16.7	1.5	2.0
1 x 4	MPH%	71.2	18.3	49.5	32.2	61.9	18.0
	BPH%	50.2	11.1	27.6	30.6	42.3	7.0
1 x 5	MPH%	213,9	28	70.3	31.2	151.3	10.0
	BPH%	203.6	26.9	41.5	31.2	122.7	6.0
2 x 3	MPH%	78.6	13.0	20.3	20.6	28.4	-4.0
	BPH%	65.2	1.0	-2.7	2.7	12.7	-16.0
2 x 4	MPH%	110.3	28.1	53.8	54.2	75.2	12.0
	BPH%	107.8	23.4	52.1	38.6	64.1	11.0
2 x 5	MPH%	189.3	29.4	84.0	48.9	113.8	13.0
	BPH%	144.7	18.2	80.0	35.0	59.0	8.0
3 x 4	MPH%	110.9	20.5	34.4	33.9	8.6	23.0
	BPH%	92.9	10.5	9.5	25.9	-9.86	7.0
3 x 5	MPH%	170.4	11.6	8.6	6.3	52.4	1.0
	BPH%	114.7	8.0	-13.6	-1.08	4.3	-6.0
4 x 5	MPH%	189.4	27.2	68.5	57.1	129.7	33.0
	BPH%	146.7	20.4	63.0	55.2	78.9	26.0

Table 5. The classification of F1 cross combinations according with heterosis occurrence groups based on studied parameters.

H type	Heterosis occurrence group	No. cross combination					
		Yield grain	Plant height	Ear height	Ear length	Kernels ear	1000-kernels weight
MPH	MPH >25%	10	4	6	8	9	2
	0< MPH<25%	-	6	3	2	1	7
	MPH <0	-	-	1	-	-	1
BPH	BPH >25%	10	1	5	7	6	1
	0< BPH <25%	-	9	2	2	3	7
	BPH <0	-	-	3	1	1	2

Kernels ear: The night F1 cross combination revealed positive heterosis a high level of occurrence and six cross combination showed heterobeltiosis for kernels ear (Table 5). The heterotic and heterobeltiotic values ranged from +8.6% (3 x 4) to +151.3% (1 x 5) and +1.5% (1 x 3) to +122.7% (1 x 5) respectively. Different ratio of heterotic value for kernels ear as they were observed by Alam *et al*. (2008) and Aghaei *et al.* (2012).

1000 - kernels weight: Two F1 cross combinations recorded a positive heterosis effect with a high degree of occurrence and one cross combination recorded a high degree of occurrence for heterobeltiosis (Table 5). The increase in 1000 - kernels weight ranged from +1.0% (3 x 5) to +33.0 % (4 x 5) and the heterobeltiosis ranged from +2.0% (1 x 3) to +26.0% (4 x 5). These results were generally analogous to the findings of Bonea (2001), Muhammad *et al*. (2003), Malik *et al.* (2004) and Alam *et al.* (2008) as they observed similar heterotic values for this parameter.

The highest degree of heterosis occurrence (H > 25), both over mid parent and over the better parent, for analyzed parameters, was shown with cross combinations 4x5 and 1x5.

Among the six biometrical and gravimetrical parameters that were studied, only the grain yield and plant height have recorded total positive occurrence (with no negative values) both for heterosis over mid parent and heterobeltiosis (Table 5). Similar results have been reported by Mihalachi (2013). As a result, we can state that the two parameters (the grain yield and the plants height) can be used as universal indicators of heterosis.

With the case of the other parameters that have been studied by us, the results of heterosis evaluation confirms the organo-specific nature of their manifestation. This type of manifestation allows the genotypical selection of high performance heterozygote cross combinations.

Conclusions

Our studies has demonstrated the importance of heterosis determination over the mid parent and over the best parent (heterobeltiosis) because it allows the identification of the best cross combinations as regards the highest levels of occurrence of the heterotic effect.

The value of the inbred lines used as parents cannot be appreciated only by their yielding capacity. Their specific capacity of crossing, that ensures a strong heterotic effect, is also of great importance.

Among the six studied parameters, only two – the grain yield and the plant height – are relevant for an objective evaluation of heterosis and can be used as universal indicators.

The 4 x 5 and 1 x 5 cross combinations recorded the best values of heterosis and heterobeltiosis for the analyzed parameters. As a result, we recommend these cross combinations to be used for further breeding programs.

References

Aghaei, Sh., S. Aharizad, M.R. Shiri and S.A. Mohammadi. 2012. Average heterosis of maize hybrids under terminal water stress at Moghan region. *Ann. Biological Res.*, 3(12): 5462-5465.

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

Amanullah, S. Jehan, M. Mansoor and M.A. Khan. 2011. Heterosis studies in diallel crosses of maize. *Sarhad J. Agric*., 27(2): 207-211.

Bonea, D. and V. Urechean. 2003. Reciprocal cross effects for grain yield and content of raw protein in the maize grain. Maize Genetics Cooperation, *Newsletter*, 77: 67.

Botu, I. and M. Botu. 2010. Tehnică experimentală în horticultură şi ecologie. Editura Conphys, Vâlcea.

Devi, B., N.S. Barua, P.K. Barua and P. Talukar. 2007. Analysis of mid parent heterosis in a variety diallel in rainfed maize. *Indian J. Genet. & Plant Breed*., 67(2): 67-70.

Farhan, A, A.S. Irfan Ahmed, R. Hidayat, N. Mohammad, Durrishahwar, Y.K. Muhammad, U. Ihteram and Y. Jianbing. 2012. Heterosis for yield and agronomic attributes in diverse maize germplasm *Aus. J. of Crop Sci.,* 6(3): 455-462.

Hallauer, A.R. and J.B. Miranda. 1988. *Quantitative Genetics in Maize Breeding*. 2nd ed. Iowa State University Press, Iowa, Ames. USA.

Haş, I. 2004. Heterozisul la porumb. In: *Porumbul: studiu monografic*. Bucureşti: Ed. Academiei Române, pp. 311-362.

Ilker, E., F. Aykuttonk and M. Tosun. 2010. Heterosis for yield and its components in bread wheat crosses among powdery mildew resistant and susceptible genotypes. *Pak. J. Bot.,* 42: 513-522.

Iqbal, M.S., A. Ghafoor, Inamullah and H. Ahmad. 2013. Genetic variation in yield performance for three years in *Nigella sativa* L. germplasm and its association with morpho-physiological traits and biochemical composition. *Pak. J. Bot.,* 45(6): 2065-2070.

Jinks, J.L. 1983. Biometrical genetics of heterosis. In: *Heterosis: Reappraisal of Theory and Practice*. (Ed.): R. Frankel, Springer-Verlag, Berlin, Heidelberg, Germany. pp. 1-46.

Khan, N.U., K.B. Masrwat, G. Hassan, F. Ullah, S. Batool, K. Makhdoom, W. Ahmad and H.U. Khan. 2010. Genetic variation and heritability for cottonseed, fibre and oil traits in *G. hirsutum* L. *Pak. J. Bot.,* 42: 615-625.

Anonymous. 2013. Date privind evoluția suprafețelor şi a producției în România http://www.madr.ro/ro/culturi-de-camp/cereale/porumb.html (accessed November 10, 2013).

Malik, Hn, S.I. Malik, S.R. Chaghtai and H.I. Javed. 2004. Estimates of heterosis among temperate, subtropical and tropical maize germplasm. *Asian J. of Plant Sci.,* 3(1): 6-10.

Matziner, D.F., T.J. Mannand and C.C. Cockerham. 1962. Diallel cross in *Nicotiana tabacum*. *Crop Sci*., 2: 238-286.

Meseka, S.K., A. Menkir, A.E.S. Ibrahim and S.O. Ajala. 2006. Genetic analysis of performance of maize inbred lines selected for tolerance to drought under low nitrogen. *Maydica*., 51(3-4): 487-495.

Mihalachi, A. 2013. Particularitățile manifestării efectului heterozis vegetativ şi reproductiv la hibrizi omologați de porumb. *Ştiința Agricolă*, 1:7-11.

Muhammad, B.A., R. Muhammad, S.T. Muhammad, H. Amer, M. Tariq and S. Muhammad. 2003. Hybrid vigour of some quantitative characters in maize (*Zea mays* L.). *Pak. J. Biol. Sci.,* 6(2): 139-141.

Musteata, S., S. Mistreț and L. Nujnaia. 2001. Ispol'zovanie zarodyvoj plazmy geterozisnoj gruppy Lancaster v selekcii rannespeloj kukuruzy. *Kukuruza i sorgo*, 1: 6-11.

Nasim, A., A. Farhatullah, N.U. Khan, M. Afzal and S.M. Azam. 2014. Combining ability and heterosis for yield and yield contributing traits in *Brassica rapa* (L.) ssp. *dichotoma* (Roxb.) Hanelt. *Pak. J. Bot.,* 46(6): 2135-2142.

Reif, J.C., A.R. Hallauer and A.E. Melchinger. 2005. Heterosis and heterotic patterns in maize. *Maydica,* 50: 215-223.

Shull, G.H. 1952. Beginnings of the heterosis concept. In: *Heterosis.* (Ed.): J.W. Gowen, Iowa State College Press, Ames, IA. pp. 14-48.

Siddiqi, M.H., S. Ali, J. Bakht, A. Khan, S.A. Khan and N. Khan. 2012, Evaluation of sunflower lines and their crossing combinations for morphological characters, yield and oil contents. *Pak. J. Bot.,* 44(2): 687-690.

Tollenaar, M., A. Ahmanzadeh and E.A. Lee. 2004. Physiological basis of heterosis for grain yield in maize. *Crop Sci.,* 44: 2086-2094.

(Received for publication 25 January 2014)