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HETEROSIS FOR GRAIN QUALITATIVE TRAIT AND YIELD IN ZP MAIZE HYBRIDS

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Abstract

Maize has a various utilization and the main goal of maize breeding is to obtain new hybrids that will outperform the existing hybrids with respect to a number of traits. Nine parent inbred lines and their eight F1 single crosses were grown in RCBD at two location with two replication during 2010 and 2011. In kernal sample protein, oil and starch content were determined by NIRS. Heterosis for yield and grain quality traits was estimated as mid parent (MPH) and better parent heterosis (BPH). The mid-parent heterosis for yield varied from 149,4% to 207,3%, averaged 173,6% in 2010, and from 139,2% to 190%, averaged 161,8% in 2011. The cross L6xL5 had the highest MPH for yield and the cross L1xL7 the higest BPH in both years. Starch content expressed a positive MPH and BPH heterosis in both years whereas oil content mainly expressed positive heterosis over the midparent. The values for MPH for starch content of crosses varied from 0,85% to 2,5% (2010), and 0.78% to 2,98% (2011), respectively. The cross L4xL2 had the higest MPH and BPH for starch in 2010 and the cross L9xL6 in 2011. On the other hand positive MPH for oil content ranged from 4,0% to 19.6% and 2,6% to 21,6% for 2010 and 2011, respectively. The F1 crosses expressed both positive and negative heterotic effect for protein content in both years, varied from -8,1% to 5,1% (2010) and -6,04% to 7,98% (2011), respectively. The cross L4xL2 had the higest positive MPH for protein content for both years and positive BPH for 2010. Generally, the cross L1xL7 gave high positive heterotic value for oil and starch content, positive value for protein content and high heterosis for yield.

Key words: *maize, heterosis, protein, oil, starch*

Introduction

Maize has a various utilization and the main goal of maize breeding is to obtain new hybrids that will outperform the existing hybrids with respect to a number of traits. In working towards this goal, particular attention is paid to grain yield as the most important agronomic traits. Good results have been achieved in increasing maize yield through the successful exploitation of heterosis. Maize has great potential for heterotic manifestation and its exploitation. This could be the reason that number of hybrid varieties in maize is much higher than any other varietals types i.e. open pollinated, double cross, synthetics or three way crosses. Heterosis can be defined as the difference between the hybrid performance and the mean value of the inbred parents, which is known as mid-parent heterosis. However, the highest value of the best parent for a trait of interest, or high parent heterosis, is also used mainly for self-pollinated crops where breeders are interested in finding a hybrid with better performance than either of the parents (Lamkey and Edwards, 1999). Mid-parent heterosis and beter-parent heterosis are important parameters as they provide information about the presence of dominance and over dominance type of gene action in the expression of various traits. The degree of heterosis depends on the relative performance of inbred parents and the corresponding hybrids.

Besides yield, the attention should be paid to the quality of kernel itself i.e. chemical composition, mainly if we take into consideration one of the most important maize uses as livestock feed. Also, the chemical constitution of the maize kernel not only defines its nutritional

value but also the ability to be used in industries. Kernels quality depends on outward factors influenced by the environment, management technology and genetic background (Fabrianac et al., 2006, Harrelson et al., 2008, Idikut et al., 2009). Based on the results of Reynolds et al (2005) the chemical composition of the grain of hybrids grown in the same location can vary significantly. Differences between hybrids emphasize the importance of genetic background and breeding as determinants of biochemical composition.

Material and methods

In this study a set of 8 hybrids of FAO maturity groups from 300 to 600 and their parental inbred lines was used. Hybrid H1 (L1×L7) belonged to FAO maturity group 300, H2 (L4×L2) belonged to FAO maturity group 400, H3 (L3×L7) and H4 (L9×L8) belonged to FAO maturity group 500, H5 (L9×L6), H6 (L3×L6), H7 (L3×L8) and H8 (L6×L5) belonged to FAO maturity group 600. From parental inbred lines L2 and L9 were from independent source germplasm, L1, L3 and L5 from BSSS heterotic group, and L4, L6, L7 and L8 from Lancaster germplasm. An experiment set up as randomized block design with two replications at two experimental fields of MRI, during 2010 and 2011. Four rows were planted for each genotypes, with 20 plants per row, resulting in a plant density of 67000 plants per ha. The identical cropping practices were applied for all genotypes in both locations during both years. Yield of each plot was used for calculation of grain yield per hectare (tha^{-1}) with 14% moisture. The protein, oil and starch content were determined by near-infrared reflectance spectroscopy NIR using Infratec 1241 grain analyzer (Foss Tecator, Sweden) and expressed in a percentage of dry mater.

Heterosis was determined as follows:
Mid-parent heterosis (%) = ((F1- MP)/MP) × 100
Best-parent hetrosis (%) = ((F1- BP)/BP) × 100
Where
F1 =Mean of F1 hybrid for a specific trait
MP=Mean of the two parents in a cross for a specific trait
BP= Mean of the best parent in a cross for a specific trait

Results and discussion

Hybrids yielded an overall mean of 12,1 tha^{-1}, with range from 10,60 to13,00 tha^{-1} in 2010 and range from 11,1 to 12,1 tha^{-1}, with average mean 11,5 tha^{-1} in 2011 (Table 1). Generally, the yield of hybrids and parental lines was lower in location 2 than location 1 in both years (data not shown). The highest yielding hybrids in both years was H5 (L9xL6), 13,0 tha^{-1} and 12,1 tha$^{-1,}$ respectively. Two hybrids, crosses between low x moderate yielding parental lines, had the lowest yield in 2010 (L4xL2), and H1 (L1xL7) in 2011.

The cross L6xL5 had the highest MPH for yield and the cross L1xL7 the higest BPH in both years. The mid-parent heterosis varied from 149,4% (L4xL2) to 207,3% (L6xL5), averaged 173,6% in 2010, and from 139,2% (L9xL6) to 190% (L6xL5), averaged 161,8% in 2011. The best parent heterosis ranged from 122,2% (L9xL8) to 195,55 (L1xL7), averaged 148,5% in 2010, and from 100% (L9XL8) to 177,5% (L1xL7), averaged 132.65% in 2011.

The various interactions between alleles of the parental lines resulting in different levels of heterosis in crosses. The hybrid with the highest yield, combination of two good yielding inbred lines, has the low MPH and low BPH in both years. All hybrids, as crosses between inbred lines from different heterotic group, has positive yield heterosis which is in agreement with another investigators, who commonly assumed that the combination of lines of different heterotic groups originates hybrids with higher chances of genetic expression of the target effects of hybridization (Troyer, 1999; Tollenaar et al., 2004).

Table 1. Yield and heterotic effect for yield in maize hybrids

crosses	Yield tha^{-1}		MPH%		BPH%	
	2010	2011	2010	2011	2010	2011
L1xL7	11,8	11,1	203,1	184,6	195,5	177,5
L4xL2	10,6	11,2	149,4	163,5	140,9	148,0
L3xL7	12,0	11,3	165,1	151,1	135,5	117,3
L9xL8	12,2	11,4	168,5	150,5	122,2	100,0
L9xL6	13,0	12,1	157,4	139,2	136,3	112,6
L3xL6	12,3	11,8	153,1	148,2	140,2	126,9
L3xL8	12,4	11,5	185,1	167,4	143,1	121,2
L6xL5	12,6	11,6	207,3	190,0	173,9	157,7

Maize as the other cereal crops is relatively poor in kernel protein content as usually varies from 8.0 to 11.0% according to FAO reports. The values of protein content varied between 9,2 to 10,4% in 2010 and from 9,9 to 11,5 in 2011. The cross L4xL2 (high x low protein line), had high protein content and the lowest grain yield, and cross L6xL5 (low x moderate protein line) the lowest protein content and high yield, in both years. That is in accordance to Prassana et al., (2001) who reported that the high yielding hybrids usually have lower protein content. The F1 crosses expressed both positive and negative heterotic effect for grain protein content, Table 2. The values for protein content in studied crosses showed positive heterosis over mid-parents in two hybrids in 2010, and four hybrids in 2011. On the other hand, the four crosses in our study showed negative heterosis below the best and mid-parents in both years. Similar results for protein content in maize kernel and heterotic effects in different cross combinations of maize hybrids have been reported by Lou et al. (2005) and Ikramullah et al (2011). In some hybrids heterotic effect acts in the opposite sense to the desired, that there is reduction of the grain protein content compared to parental lines. This shows the dominance of the alleles for low protein content. In spite of the observed negative heterosis, different combination with positive heterosis can be observed. This demonstrates the existence of bidirectional dominance for protein content in the different loci, with prevalence of loci with dominance for low protein content.

Table 2. Protein content and heterotic effect for protein content in maize hybrids

crosses	Protein content%		MPH%		BPH%	
	2010	2011	2010	2011	2010	2011
L1xL7	10,2	10,6	1,3	6.5	-1.9	4.9
L4xL2	10,4	11,3	5.1	5.12	5.1	-1.74
L3xL7	10,3	11,5	-1.9	7.98	-2.8	0
L9xL8	9,3	10,2	-8.1	1.96	-9.7	0
L9xL6	9,4	10,2	-3.78	-0.48	-5.52	-1.9
L3xL6	9,5	10,2	-5.9	-5.55	-10.3	-11.3
L3xL8	9,9	10,1	-5.26	-6.04	-6,6	-12.1
L6xL5	9,2	9,9	-6.5	-5.26	-8.9	-8.33

The results on heterosis for oil content indicated existence of the positive MP heterosis in 6 hybrids with range varying from 2,68 to 21,6%. Negative mid-parent heterosis was expressed in two hybrids only in 2010. Positive values for averaged mid parent heterosis revealed that the alleles for high oil content were dominant. The highest positive MP heterosis was expressed by a cross L3x L8 (19,6%) in 2010, as well as cross L4xL2 (21,6%) in 2011. The estimates of positive better parent heterosis were observed in one hybrid in 2010 and 5 hybrids in 2011. The cross L3xL8, combination of low x high oil lines, that expressed high mid-parent heterosis and positive better parent heterosis have also high oil content. At the same time this hybrid has negative values for MPH and BPH for protein content in both years. Meanwhile, hybrid L4xL2 (high x low oil line) had positive MPH for oil and protein content. The positive significant heterosis over better parent for oil content was also reported by Mittelmann et al.(2006), and Oliveira et al. (2006). Dubey et al. (2009) found that the heterosis over mid-parents and better parent was observed for seed oil content and grain yield per plant. Kaushik et al. (2004) studied the protein and oil concentration in heterotic crosses of maize and find out that from 72 crosses studied, 30 crosses exhibited heterosis for protein and oil concentration.

Table 3. Oil content and heterotic effect for oil content in maize hybrids

crosses	oil content%		MPH%		BPH%	
	2010	2011	2010	2011	2010	2011
L1xL7	4,15	4,65	10,1	19	-5,14	4,49
L4xL2	4.1	4.45	10,8	21.6	-5,23	11.95
L3xL7	4,35	3.95	16	1,28	-0,57	-11,2
L9xL8	4,0	5,0	-1,53	17,6	-9,55	13,6
L9xL6	3,85	4,1	-1.91	8,14	-4,8	0
L3xL6	3,6	3,85	0	11,59	-12,1	8,3
L3xL8	4,5	4,7	19,6	18,87	1,1	5,6
L6xL5	3,9	3,8	4,0	2,68	-4,9	-2,6

The highest starch content in 2010 had two crosses L4xL2 and L3xL6, and in 2011 cross L9xL6, Table 4. The mid-parent heterosis varied from 0,85% (L9xL8) to 2,5% (L4xL2), averaged 1,38% in 2010, and from 0,78% (L3xL7) to 2,98% (L9xL6), averaged 1,88% in 2011. That revealed that the genes with positive effect were dominant. The best parent heterosis ranged from 0,28% (L9xL8) to 2,1% (L4xL2), averaged 0,99% in 2010, and from 0,71% (L4xL2) to 2,83% (L9xL6), averaged 1,39% in 2011. The presence of better parent heterosis indicated that over dominance played important role in the expression of starch content. The cross L4xL2, low x high starch lines, that had the highest starch content, expressed also the highest midparent and better parent heterosis in 2010. The cross L9xL6 (high x moderate starch lines), that had the highest starch content also expressed the highest MPH and BPH in 2011. The significant positive mid parent, better parent and standard heterosis for starch content were reported by Devi and Pradhan (2004).

Table 4. Starch content and heterotic effect for starch content in maize hybrids

crosses	starch content%		MPH%		BPH%	
	2010	2011	2010	2011	2010	2011
L1xL7	70,45	71,3	1,29	2,51	0,78	1,56
L4xL2	71,5	70,7	2,5	2,1	2,1	0,71
L3xL7	71,3	70,9	1,42	0,78	0,84	0,56
L9xL8	70,6	70,9	0,85	0,99	0,28	0,85
L9xL6	71,2	72,5	1,06	2,98	0,99	2,83
L3xL6	71,5	72,2	1,27	2,41	1,13	2,4
L3xL8	71,2	71,3	1,49	1,42	0,70	1,13
L6xL5	71,3	72,3	1,13	1,83	1,13	1,12

Conclusion

The obtained results demonstrate that analyzed hybrids have values for protein, oil and starch content that are typically for maize genotypes that were not specifically selected from those traits.

Some of the hybrids expressed high heterosis for protein, oil and starch content along with moderate yield potentials. The genetic background of parental lines affecting the grain chemical composition of hybrids. The cross L1xL7 gave high positive heterotic value for oil and starch content, positive value for protein content and high heterosis for yield. The highest heterosis for protein content and the highest protein content, as well as high heterosis for oil and starch content but low yield and heterosis for yield had the cross L4xL,2, with different genetic background than other crosses. On other hand, the highest yielding hybrid L9xL6 had also the highest starch content and heterosis for starch content in 2011. Two hybrids, with similar genetic background, had moderate yield and yield heterosis, high protein content and negative heterosis for protein in 2010, moderate oil and starch content (L3xL7), and high yield and yield heterosis, moderate protein content and negative MPH and BPH for protein content, high oil content and heterosis for oil content, and moderate starch content (L3xL8), respectively. The utilization of maize for nutritional products, and ethanol demands a re-direction of breeding programs to modifying and increasing the kernel composition of starch, protein, and oil.

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References

Devi, T. R. and Pradhan H. S. (2004).Combining ability and heterosis studies in high oil maize (*Zea mays L.)* genotypes. Indian J. Genet., 64, 323-324.

Dubey, R.B., Joshi V.N., Manish V. (2009). Heterosis for nutritional quality and yield in conventional and non-conventional hybrids of maize (*Zea mays* L). Indian J. Genetics and Plant Breeding, 69, 109-114.

Fabijanac, D., Varga B., Svečnjak Z., Grbeša D. (2006). Grain Yield and Quality of Semiflint Maize Hybrids at Two Sowing Dates. Agriculturae Conspectus Scientifi cus, Vol. 71, No. 2, 45-50.

Harrelson, F.W., Erickson, G.E., Klopfenstein, T.J., Jackson, D.S. and Fithian, W.A. (2008). Influence of Corn Hybrid, Kernel Traits, and Growing Location on Digestibility. In: 2008 Beef Cattle Reports. p. 45-47, University of Nebraska, Dept. of Animal Science.

Idikut L., A.I. Atalay, S.N. Kara and A. Kamalak (2009). Effect of Hybrid on Starch, Protein and Yields of Maize Grain Journal of Animal and Veterinary Advances 8 (10), 1945-1947.

Ikramullah, I. Noor H. K., M., Shah M. K. N. (2011). Heterotic effects for yield and protein content in white quality protein maize. Sarhad J. Agric. Vol.27, No.3., 403-409.

Kaushik, S.K., Tripathi R.S., Ramkrishna K., Singhania, D.L. Rokadia P. (2004). An assessment of protein and oil concentration in heterotic crosses of maize (*Zea mays* L.). SABRAO J. Breeding and Genetics, 36, 35-38.

Lamkey, K. R. and Edwards J. W. (1999). The quantitative genetics of heterosis. p. 31-48. In: J.G. Coors and S. Pandey (ed.) Proceedings of the International Symposium on the Genetics and Exploitation of Heterosis in Crops, CIMMYT, Mexico City, Mexico, 17-22 Aug. 1997. ASA, CSSA, and SSSA, Madison, WI.

Lou, X., Zhu J., Zhang Q., Zang R., Chen Y., Yu Z. and Zhao Y. (2005). Genetic control of the opaque-2 gene and background polygenes over some kernel traits in maize (*Zea mays* L.). Genetica. 124, 291–300.

Mittelmann, A., Miranda Filho J.B., Lima G.J.M., Hara-Klein C., Silva R.M, Tanaka R.T. (2006). Diallel analysis of oil content in maize. Revista Brasileira de Agrociencia, 12, 139-143.

Oliveira, J.P., Chaves L.J., Duarte J.B., Ribeiro K.O., Brasil E.M. (2006). Heterosis for oil content in maize populations and hybrids of high quality protein. Crop Breeding and Applied Biotechnol., 6, 113-120.

Prasanna, B.M., Vasal S.K., Kassahun B., N Singh.N. (2001). Quality protein maize. Curr. Sci. 81**,** 1308-1319.

Reynolds, TL, Nemeth MA, Glenn KC, Ridley WP, Astwood JD (2005). Natural variability of metabolites in maize grain: differences due to genetic background. J. Agric. Food Chem. 53, 10061–10067.

Tollenaar, M, Ahmadzadeh A., Lee EA (2004). Physiological basis of heterosis for grain yield in maize. Crop Sci. 44, 2086-2094.

Troyer, AF (1999). Background of U.S. hybrid corn. Crop Sci. 39, 621-626.