NARDI FUNDULEA, ROMANIA
www.incda-fundulea.ro

ROMANIAN AGRICULTURAL RESEARCH, NO. 31, 2014
Print ISSN 1222-4227; Online ISSN 2067-5720

COMBINING ABILITY FOR YIELD IN MAIZE SYNTHETIC POPULATIONS OBTAINED FROM LOCAL POPULATIONS

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ABSTRACT

The objectives of the present study were to examine the combining ability for grain yield of seven maize (*Zea mays* L.) synthetic populations obtained from Transylvanian local populations and their potential use as source populations in breeding programmes. General combining ability (GCA) and specific combining ability (SCA) effects were calculated using inbred line x tester analysis. The experimental data were processed by variance analysis and the variance corresponding to certain genotypes was decomposed orthogonally and non-orthogonally. The highest values for the general combining ability were identified in the case of three synthetic populations (Tu SRR 5DR (6I) (5) and Tu Syn 3(per se) (3)), which indicated that these populations can be good combiners for grain yield. In maize synthetic populations, the GCA was more important than the SCA, indicating high additive variance of yield and suggesting genetic progress through selection.

Key words: general combining ability (GCA), specific combining ability (SCA), maize synthetic, grain yield; local population.

INTRODUCTION

Maize (*Zea mays* L.) synthetic populations are low-cost and stable varieties, obtained by cross pollination of a group of inbred lines. They are a viable alternative for situations where the use of hybrid seed and related inputs are too expensive. Although synthetic populations are generally less productive than heterotic hybrids, their main advantage is that the heterosis does not diminish significantly in F2 (Bernardo, 2002).

Besides the inbred lines, maize synthetics can be obtained from hybrids or local populations. Obtaining maize synthetics from local populations aims at enriching the gene pool with a large number of valuable genes derived from local population characteristic to some agricultural areas (Coe et al., 1988).

These positive aspects come to support the approach promoted by CIMMYT (1999) in order to obtain highly productive synthetic populations of maize, which is of great importance mainly in places where the use of hybrid seed is too expensive (especially in developing countries). From that year on, synthetic maize populations have acquired a special importance as objectives of research in the field (CIMMYT, 1999).

Breeders want to improve synthetic populations of maize for using them in obtaining superior inbred lines necessary for hybridisation programmes. The value of any maize population depends on its potential per se and on its combining ability in crossings (Gamble, 1962; Lamkey and Edwards, 1999). The per se value of synthetic populations of maize has been studied for many traits: productivity, earliness, resistance to falling (Gulea, 2011; Has, 2000; Liu et al., 1999), resistance to *Sesamia nonagrioides* Lef. and *Ostrinia nubilalis* (Velasco et al., 1999). It was found that most of these traits can be improved by several recurrent selection cycles (Carson, 2006; Gulea et al., 2008; Klenke et al., 1986).

The combining ability facilitates efficient utilization of populations in a breeding programme and identifies the crossings that

Received 15 January 2013; accepted 2 February 2014; First online: 10 April 2014. DII 2067-5720 RAR 2014-286

combine important agronomic traits, to develop new maize hybrids. For maize, the combination ability was studied in depth for inbred lines, having in view the following traits: grain yield, earliness, resistance to Northern leaf blight and to grey leaf spot (Legesse et al., 2009), resistance to insect attacks (Karaya et al., 2009), yield, plant height and ear height (Pfann et al., 2009), grain yield, plant height, ear position, percentage of damaged ears and of lodging and broken stalks (Kostetzer et al., 2009), days from emergence to silking, days from emergence to physiological maturity, plant height, ear height, area of ear leaf, ear length, area of flag leaf, number of rows per ear, number of kernels per row and grain yield (Zare et al., 2011), quality of protein (Machida et al., 2010; Pixley and Bjarnason, 1993; Scott et al., 2009), resistance to stem borers (Beyene et al., 2011).The populations of maize were less studied in terms of combining ability, except for some studies targeting local populations (Vacaro et al., 2002; de la Cruz-Lazaro et al., 2010).

In order to add new results to the research on combining ability, the objective of this work was to study seven maize synthetic populations, determining their combining ability for grain yield and potential use as source populations in breeding programmes.

MATERIAL AND METHODS

We studied top cross hybrids of the type “inbred line x synthetic population”, which resulted from the crossing between six synthetic maize populations obtained from local populations collected in Transylvania plus one traditional synthetic population obtained from maize inbred lines, and four early inbred lines used as tester, maternal forms. Two inbred lines were from the dentiformis convariety (belonging to two different heterotic groups), an inbred line belonged to the indurata convariety, and an inbred line to the aorista con-variety. There are no registered relationships between the tester inbred lines and the synthetic populations we studied (Table 1).

Table 1. Biologic material used for the study of combining ability

No.	Name	Component germplasm	Origin
Synthetic populations			
1	Turda Syn Mara (2)	Eight local populations, indurata type, from Mara Valley -Maramureş	ARDS Turda
2	Turda Syn 1 (3)	12 local populations from Transylvania, indurata type	ARDS Turda
3	Turda Syn 8 (4)	Local populations from Transylvania and Moldavia, indurata type	ARDS Turda
4	Turda SRR 2I(5D) (2)	Early Transylvanian local populations, indurata type	ARDS Turda
5	Turda SRR 5D(2I) (2)	Local populations from Transylvania, dentiformis type	ARDS Turda
6	Turda Syn3 (per se) (3)	Mid-early Transylvanian local populations, indurata type	ARDS Turda
7	Turda SRR 5DR(6I) (5)	12 inbred lines, dentiformis type	ARDS Turda
Inbreed lines			
1	TC 184 cmsC	Dentiformis type	ARDS Turda
2	TC 209	Dentiformis type	ARDS Turda
3	CO 255	Indurata type	Canada-Ontario
4	TD 233	Aorista type	ARDS Turda

The crossings were made in 2010 at ARDS Turda and the resulting hybrids (7x4=28) were studied for production capacity in yield trials in two experimental locations (Sângeorgiu of Mures and Turda), between 2011 and 2012, along with commercial hybrids used as controls (Table 2).

Table 2. Commercial hybrids

No.	Hybrid	Registration year, authors	Hybrid type
1	Turda Mold 188	2001, ARDS Turda and Institute for Maize of Moldova Republic	Early three-way crosses hybrid, FAO 290
2	Turda 165	2002, ARDS Turda	Early three-way crosses hybrid, FAO 270
3	Turda SU 181	2000, ARDS Turda and Saaten Union Company, Germania	Early, simple-cross hybrid, FAO 270
4	Turda 201	2002, ARDS Turda	Mid-Early three way crosses hybrid, FAO 340

The experimental data were processed by variance analysis and the variance corresponding to certain genotypes was decomposed orthogonally and non-orthogonally in: test hybrids, control hybrids and comparisons between the two groups (Basilio and Sprague, 1952; Has et al., 2010). For the synthesis of the data resulting from testing the synthetic populations, the values of gene effects were calculated for general and specific combining ability, as follows:

Test hybrids $(T_m \ x\ S_n) = \mu + \hat{g}_m + \hat{g}_n + \hat{s}_{m\ x\ n}$, where:

- μ = average effects of the system;

- $\hat{g}_m$ = effects of the general combining ability (GCA) (additive gene effects) of the tester inbred lines ;

- $\hat{g}_n$ = effects of the general combining ability (GCA) (additive gene effects) of the tested synthetic populations ;

- $\hat{s}_{m\ x\ n}$ = effects of the specific combining ability (SCA) (non-additive gene effects) of the tester inbred line ”m”, crossed with the tested synthetic population ”n” .

RESULTS AND DISCUSSIONS

Maize production capacity is the most important trait for research; the study of how synthetic populations transmit this character is to be taken into account for future use in programs which try to create inbred lines.

For all experimental conditions, the differences between genotypes (tested hybrids and control hybrids) were significant at $P<0.05$ or $P<0.01$. The comparisons between the tested hybrids groups and the control hybrid group were significant under all experimental conditions (Table 3).

Table 3. Variance analysis for yield potential of the studied hybrids

Variability cause	Tg. Mureş, 2011				Tg. Mureş, 2012			
	SS	DF	s^2	Significance	SS	DF	s^2	Significance
Total	104.3	95	1.10		88.81	95	0.94	
Replications	3.75	2	1.88		2.85	2	1.42	
Genotypes	78.10	31	2.52	**	70.27	31	2.26	**
hybrids T x S	64.48	(27)	2.39	**	50.95	(27)	1.89	**
commercial hybrids (H)	6.39	(3)	2.13	**	13.68	(3)	4.56	**
comparisons (T x S); H	7.23	(1)	7.23	**	5.63	(1)	5.63	**
Error	22.46	62	0.37		15.70	62	0.26	
Variability cause	Turda, 2011				Turda, 2012			
	SS	DF	s^2	Significance	SS	DF	s^2	Significance
Total	61.51	95	0.64		71.95	95	0.75	
Replications	0.88	2	0.44		2.05	2	1.03	
Genotypes	35.83	31	1.15	**	46.07	31	1.49	**
hybrids T x S	28.88	(27)	1.07	*	35.55	(27)	1.32	**
commercial hybrids (H)	0.62	(3)	0.20		6.62	(3)	2.20	**
comparisons (T x S); H	6.33	(1)	6.33	**	3.91	(1)	3.91	**
Error	24.80	62	0.40		23.83	62	0.39	

The experimental conditions (years and locations) provided differentiated testing conditions for the different genotypes (Table 4).

Table 4. General analysis of variance for yield potential of the hybrids “tester x synthetic population” (2 experimental years, 2 locations), compared with the control (commercial) hybrids

Variability cause	SS	DF	s^2	F	Significance
Experimental years (A)	47.09	1	16.79	138.49	**
Locations (L)	633.22	1	633.22	18624.3	**
Genotypes (G)	166.77	31	5.38	15.69	**
Locations x Years (LxY)	10.51	1	10.51	30.66	**
Genotypes x Years (GxY)	16.94	31	0.55	1.60	*
Genotypes x Locations (GxL)	35.24	31	1.14	3.32	**
Genotypes x Locations x Years (GxLxY)	9.06	31	0.29	0.86	
Error	85.93	248	0.34	0.00	

Comparing the average yields for the two years and two experimental sites, we find that the commercial hybrids surpassed the "tester line x synthetic" hybrids from the yield point of view, the differences being statistically significant. In the case of the "tester line x synthetic " hybrids, the highest average yield was recorded for the hybrids belonging to the synthetic population Tu SRR 5DR (6I) (5), which is statistically equal to the average yield of the of the control hybrids. Within this group of hybrids, the highest yields were recorded in crossings TC 184 cms C x Tu SRR 5DR (6I) (5) and TD233 x Tu SRR 5DR (6I) (5) (Table 5).

The following crossings also provided high yields, comparable to the control hybrids: TC 184 cms C x Tu Syn 1 (3), TC 184 cms C x Tu Syn 3 (per se) (3), TC 184 cms C x Tu Syn 8 (4), TC 184 cms C x Tu SRR 2I (5D) (2), TC 184 cms C x Tu Syn Mara (2) şi TD 233 x Tu SRR 5D (2I) (2) (Table 5).

Table 5. Yield potential of the crossings” tester x synthetic population” compared with control (commercial) hybrids (t ha^{-1})

Genotype	Tg. Mureş			Turda			Average for 2 years and 2 locations		
	2011	2012	Average	2011	2012	Average	t ha^{-1}	% compared to the average	% compared to the average of hybrids
TC 184 cmsC x Tu Syn Mara (2)	7.33	6.01	6.67	5.02	4.23	4.62	5.65	108.7	95.3
TC 209 x Tu Syn Mara (2)	6.52	4.76	5.64	4.75	3.62	4.19	4.91	94.4	82.8
CO 255 x Tu Syn Mara (2)	5.38	4.61	4.99	3.11	2.94	3.03	4.01	77.1	67.6
TD 233 x Tu Syn Mara (2)	6.49	5.13	5.81	4.06	4.17	4.12	4.96	95.4	83.6
Average			*5.78*			*3.99*	*4.88*	*93.8*	*82.3*
TC 184 cmsC x Tu Syn 1 (3)	7.82	7.23	7.53	4.89	4.58	4.73	6.13	117.9	103.4
TC 209 x Tu Syn 1 (3)	6.86	6.2	6.53	3.32	3.73	3.52	5.03	96.7	84.8
CO 255 x Tu Syn 1 (3)	5.73	4.9	5.31	3.13	2.77	2.95	4.13	79.4	69.6
TD 233 x Tu Syn 1 (3)	6.27	5.5	5.88	4.07	3.94	4	4.94	95.0	83.3
Average			*6.31*			*3.8*	*5.06*	*97.3*	*85.3*
TC 184 cmsC x Tu Syn 8 (4)	7.83	6.58	7.2	5.17	4.29	4.73	5.97	114.8	100.7
TC 209 x Tu Syn 8 (4)	6.55	5.69	6.12	3.17	2.99	3.08	4.6	88.5	77.6
CO 255 x Tu Syn 8 (4)	5.23	4.8	5.01	4.03	2.8	3.42	4.22	81.2	71.2
TD 233 x Tu Syn 8 (4)	6.87	6.41	6.64	3.62	3.56	3.59	5.11	98.3	86.2
Average			*6.24*			*3.71*	*4.98*	*95.8*	*84.0*

TC 184 cmsC x Tu SRR 2I(5D) (2)	7.53	6.82	7.17	4.73	4.44	4.59	5.88	113.1	99.2
TC 209 x Tu SRR 2I(5D) (2)	6.74	6.38	6.56	4.37	2.95	3.66	5.11	98.3	86.2
CO 255 x Tu SRR 2I(5D) (2)	6.23	5.01	5.62	3.61	3	3.3	4.46	85.8	75.2
TD 233 x Tu SRR 2I(5D) (2)	6.65	5.31	5.98	4.2	3.19	3.69	4.84	93.1	81.6
Average			*6.33*			*3.81*	*5.07*	*97.5*	*85.5*
TC 184 cmsC x Tu SRR 5D(2I) (2)	7.03	6.15	6.59	3.93	4.36	4.14	5.37	103.3	90.6
TC 209 x Tu SRR 5D(2I) (2)	7.93	6.54	7.24	3.65	2.82	3.23	5.23	100.6	88.2
CO 255 x Tu SRR 5D(2I) (2)	6.06	5.4	5.73	3.53	3.87	3.7	4.71	90.6	79.4
TD 233 x Tu SRR 5D(2I) (2)	7.06	6.57	6.81	4.06	4.3	4.18	5.5	105.8	92.7
Average			*6.59*			*3.81*	*5.2*	*100.0*	*87.7*
TC 184 cmsC x Tu Syn 3 (per se) (3)	8.04	6.53	7.28	4.71	4.96	4.83	6.06	116.5	102.2
TC 209 x Tu Syn 3 (per se) (3)	6.5	6.42	6.46	4.12	3.47	3.79	5.13	98.7	86.5
CO 255 x Tu Syn 3 (per se) (3)	6.27	5.37	5.82	3.87	3.39	3.63	4.73	91.0	79.8
TD 233 x Tu Syn 3 (per se) (3)	7.28	6.23	6.76	4.44	4.83	4.64	5.7	109.6	96.1
Average			*6.58*			*3.72*	*5.41*	*104.0*	*91.2*
TC 184 cmsC x Tu SRR 5DR (6I) (5)	8.2	7.26	7.73	4.86	4.28	4.57	6.15	118.3	103.7
TC 209 x Tu SRR 5DR (6I) (5)	8.34	6.8	7.57	4.55	3.21	3.88	5.73	110.2	96.6
CO 255 x Tu SRR 5DR (6I) (5)	7.43	6.12	6.78	4.05	3.8	3.92	5.35	102.9	90.2
TD 233 x Tu SRR 5DR (6I) (5)	8.67	6.97	7.82	4.51	4.06	4.28	6.05	116.3	102.0
Average			*7.47*			*4.16*	*5.82*	*111.9*	*98.1*
Average of hybrids "tester x synthetic"	*6.96*	*5.99*	*6.47*	*4.12*	*3.73*	*3.93*	*5.2*	*100.0*	*87.7*
Turda Mold 188	7.81	7.07	7.44	5.24	4.45	4.84	6.14	103.5	
Turda 165	8.6	7.14	7.87	4.91	4.41	4.66	6.27	105.7	
Turda SU 181	6.63	4.93	5.78	4.8	3.21	4.01	4.9	82.6	
Turda 201	8.09	7.71	7.9	4.62	5.28	4.95	6.42	108.3	
Average of commercial hybrids	*7.78*	*6.71*	*7.25*	*4.89*	*4.34*	*4.62*	*5.93*	*100.0*	
LSD 5%	0.96	0.80		1.01	0.99				
LSD 1%	1.28	1.07		1.35	1.32				
LSD 0.1%	1.67	1.40		1.76	1.72				

These results allow us to affirm that there is potential to create inbred lines of these synthetic populations, with which to obtain maize hybrids competitive in terms of yielding ability.

Analysing the effects of the general combining ability of synthetic populations and of the tester inbred lines, as well as the effects of the specific combining ability of tester inbred lines and the synthetic populations, one can note the existence of differences at the level of testers, tested synthetic populations and the non-additive effects (Tables 6 and 7).

Of the studied tester lines, the highest general combining ability was identified in line TC 184 cms C, while the lowest was found in line CO 255. Among the synthetic populations, the one with the most additive gene effects was Tu SRR 5DR (6I) (5), being followed by Tu Syn 3 (per se) (3). The lowest values of the general combining ability were recorded for synthetic populations Tu Syn Mara (2) and Tu Syn 8 (Table 6).

It seems that the history of creating synthetic populations out of local populations, the fact that they were not initially involved in an initial inbreeding process and that crossings and selection started with heterozygous forms kept the recessive genes in the population, with adverse effects, one of which being the lower value of the general combining ability. The usefulness of a particular cross in exploiting heterosis is judged by the specific combining ability (SCA) effect. In the case of SCA, the highest values were provided by the following hybrid combinations TC 184 cms C x Tu Syn 1 (3), TC 184 cms C x Tu Syn 8 (4), CO 255 x Tu SRR 5DR (6I)(5), TD 233 x Tu Syn 3(per se)(3) and TD 233 x Tu SRR 5D (2I)(2) (Table 7).

Table 6. General combining ability for yield of synthetic populations ($\hat{g}_n$) and tester inbred lines ($\hat{g}_m$) (t ha^{-1})

Specification	TC 184 cmsC	TC 209	CO 255	TD 233	Average synthetics	ĝn
Turda Syn Mara (2)	5.65	4.91	4.01	4.96	4.88	-0.32
Turda Syn 1 (3)	6.13	5.03	4.13	4.94	5.06	-0.14
Turda Syn 8 (4)	5.97	4.60	4.22	5.11	4.97	-0.23
Turda SRR 2I(5D) (2)	5.88	5.11	4.46	4.84	5.07	-0.13
Turda SRR 5D(2I) (2)	5.37	5.23	4.71	5.50	5.20	0.00
Turda Syn3 (per se) (3)	6.06	5.13	4.73	5.70	5.40	0.20
Turda SRR 5DR(6I) (5)	6.15	5.73	5.35	6.05	5.82	0.62*
Average testers	5.89	5.11	4.52	5.30	5.20	
ĝm	0.69*	-0.09	-0.680	0.10		

LSD 5% = 0.42

Table 7. Specific combining ability ($\hat{s}_{ij}$) for yield of the synthetic populations and tester inbred lines (t ha^{-1})

Specification	TC 184 cmsC	TC 209	CO 255	TD 233
Turda Syn Mara (2)	0.08	0.13	-0.19	-0.02
Turda Syn 1 (3)	0.39	0.07	-0.24	-0.21
Turda Syn 8 (4)	0.31	-0.28	-0.07	0.04
Turda SRR 2I(5D) (2)	0.12	0.14	0.07	-0.34
Turda SRR 5D(2I) (2)	-0.520	0.13	0.20	0.20
Turda Syn3 (per se) (3)	-0.03	-0.18	0.01	0.20
Turda SRR 5DR(6I) (5)	-0.35	0.00	0.22	0.13

LSD 5% = 0.42

We appreciate that these non-additive effects could be better exploited by recurrent selection for the combining ability, using as testers the inbred lines with which the synthetic populations gave successful combinations and high values for non-additive gene effects. These hybrid combinations could be better used by testing the inbreeding lines, from the synthetic populations, on tester inbred lines obtaining in this way, pairs of inbred lines with high heterosis due to the non-additive gene effects.

For the specific combining ability, high absolute values were obtained, but with “minus”, which is an indicator of combining incompatibility of the genotypes used for crossings: TC 184 cms C x Tu SRR 5D (2I)(2), TC 184 cms C x Tu SRR 5D (6I)(5), TD 233 x Tu SRR 5D (2I)(2) and TD 209 x Tu Syn 8 (4).

CONCLUSIONS

The highest values for the general combining ability were identified in the case of synthetic populations Tu SRR 5DR (6I) (5) and Tu Syn 3(per se)(3), which indicated that these populations can be good combiners for grain yield. For the tester inbred lines, the highest values of the GCA came from TC 184 cms C. In what regards the specific combining ability, the highest values were provided by the following hybrid combinations: TC 184 cms C x Tu Syn 1 (3), TC 184 cms C x Tu Syn 8 (4), CO 255 x Tu SRR 5DR (6I)(5), TD 233 x Tu Syn 3(per se)(3) and TD 233 x Tu

SRR 5D (2I)(2), which proves the very good compatibility of these genotypes.

In maize synthetic populations obtained from Transylvanian local populations, the GCA was more important than the SCA, indicating high additive variance of yield and suggesting potential genetic progress through selection. Population improvement programs, like reciprocal recurrent selection, which may allow to accumulate the fixable gene effects, as well as to maintain considerable variability and heterozygosity for exploiting non-fixable gene effects, should prove to be the most effective selection method.

Acknowledgement

This research is part of a scientific project financed by the University of Agriculture Sciences and Veterinary Medicine Cluj-Napoca with the title „*The study of phenotypical and genotypical value of some early maize synthetic populations*” (number 1216/7/2012 UASVM Cluj-Napoca).

REFERENCES

Basilio, A. R., and Sprague, G. F., 1952. *A Comparison of Variance Components in Corn Yield Trials: III. General and Specific Combining Ability and Their Interaction with Locations and Years.* Agronomy Journal, 44(9): 462-466.

Bernardo, R., 2002. *Breeding for Quantitative Traits in Plants*. Stemma Press, Woodbury, MN.

Beyene, Y., Mugo, S., and Gakunga, J., 2011. *Combining Ability of Maize (Zea mays L.) Inbred Lines Resistant to Stem Borers*. African Journal of Biotechnology, 10(23): 4759-4766.

CIMMYT. 1999. *Development, Maintenance, and Seed Multiplication of Open-Pollinated Maize Varieties.* 2nd ed., CIMMYT, Mexico, D.F.

Carson, M. L., 2006. *Response of a Maize Synthetic to Selection for Components of Partial Resistance to Exserohilum turcicum*. Plant Dis., 90: 910-914.

Coe, E. H., Jr., Neuffer, M. G. and Hoisington, D. A., 1988. *The Genetics of Corn*. In: G.F. Sprague and J.W. Dudley, editors, Corn and Corn Improvement, Third edition: 81-258. ISBN 0-89118-099-0.

De la Cruz-Lazaro, E., Castanon-Najera, G., Brito-Manzano, N. P., Gomez-Vazquez, A., Robledo-Torres, V., Lozano del Rio, A.J., 2010. *Heterosis and Combining Ability of Tropical Maize Populations (*In Spanish, with English abstract). Phyton (B. Aires), 79: 11-17.

Gamble, E. E., 1962. *Gene Effects in Corn (Zea mays L.): Separation and Relative Importance of Gene Effects for Yield.* Canadian Journal of Plant Science, 42(2): 339-348.

Gulea, A., Has, V., Lobontiu, I., Has, I., Oroian, I. and Pop, A., 2008. *„Per se” Value in Some Synthetic Varieties of Corn*, Bulletin of University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Agriculture, 65(1): 118-122.

Has, V., 2000. *Cercetări privind determinismul genetic al unor caractere calitative şi cantitative la porumbul zaharat* (In Romanian, Ph.D. Thesis). Academia de Stiinte Agricole si Silvice „Gheorghe Ionescu-Sisesti”, Bucureşti.

Has, I., Has, V., Muresan, E. and Ifrim, S., 2010. *Using Orthogonal and Non-Orthogonal Decompositions in Comparing of Some Groups of Genotypes* (In Romanian, with English abstract.). Analele I.N.C.D.A. Fundulea, 78(2): 5-16.

Karaya, H., Njoroge, K., Mugo, S. and Nderitu, H., 2009. *Combining Ability among Twenty Insect Resistant Maize Inbred Lines Resistant to Chilo partellus and Busseola fusca Stem Borers*. International Journal of Plant Production, 3(1): 115-126.

Klenke, J. R., Russel, W. A. and Guthrie, W. D., 1986. *Recurrent Selection for Resistance to European Corn Borer in a Corn Synthetic and Correlated Effects on Agronomic Traits*. Crop Science, 26(5): 864-868.

Kostetzer, V., Pinto Moreira, R. M. and. Ferreira, J. M., 2009. *Partial Dialell Cross between Landraces from Parana and Synthetic Varieties of Maize* (In Portuguese, with English abstract.). Pesquisa Agropecuaria Brasileira, 44(9): 1152-1159.

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

Legesse, B. W., Pixley, K. V. and Botha, A. M., 2009. *Combining Ability and Heterotic Grouping of Highland Transition Maize Inbred Lines*. Maydica, 54(1): 1-9.

Liu, X., Zheng, Y.L., Shi, Y.G., Xu, S.Z., Li, J.S. and Liu, J. L., 1999. *Comparison and Utilization of Genetic Variation for 4 Corn Synthetic Populations and Their Parent Populations.* (In Chinese, with English abstract.), Acta Agronomica Sinica, 25(2): 208-214.

Machida, L., Derera, J., Tongoona, P. and John MacRobert, 2010. *Combining Ability and Reciprocal Cross Effects of Elite Quality Protein Maize Inbred Lines in Subtropical Environments*. Crop Science, 50(5): 1708-1717.

Pfann, A.Z., Faria, M.V., de Andrade, A.A., do Nascimento, I.R., Faria, C.M.D.R. and Bringhentti, R.M., 2009. *Combining Ability in Corn Single-*

Cross Hybrids by Circulant Diallel (In Portuguese, with English abstract.). Ciencia Rural, 39(3): 635-641.

Pixley, K. V., and Bjarnason, M. S., 2002. *Stability of Grain Yield, Endosperm Modification, and Protein Quality of Hybrid and Open-Pollinated Quality Protein Maize (QPM) Cultivars*. Crop Science, 42: 1882-1890.

Scott, M. P., Peterson, J. M. and Hallauer, A. R., 2009. *Evaluation of Combining Ability of Quality Protein Maize Derived From Us Public Inbred Lines*. Maydica, 54(4): 449-456.

Vacaro, E, Neto, J.F.B., Pegoraro, D.G., Nuss, C.N., Conceição, L.D.H., 2002. *Combining Ability of Twelve Maize Populations*. Pesquisa Agropecuaria Brasileira, 37(1): 67-72.

Velasco, P., Malvar, R.A., Revilla, P., Butron, A. and Ordas, A., 1999. *Ear Resistance of Sweet Corn Populations to Sesamia nonagrioides (Lepidoptera: Noctuidae) and Ostrinia nubilalis (Lepidoptera: Pyralidae)*. Journal of Economic Entomology, 92(3): 732-739.

Zare, M., Choukan, R., Heravan, E.M., Bihamta, M.R. and Ordookhani, K., 2011. *Gene Action of Some Agronomic Traits in Corn (Zea mays L.) Using Diallel Cross Analysis*. African Journal of Agricultural Research, 6(3): 693-703.