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THE COMBINING ABILITY OF MAIZE (ZEA MAYS L.) INBRED LINES FOR GRAIN YIELD AND YIELD COMPONENTS

SUMMARY

A full diallel cross comprising ten (10) inbred lines was studied for different characters to determine the nature of gene action in parents and hybrid genotypes. The analysis of variance revealed significant differences for general combining ability (GCA) and specific combining ability (SCA) indicated the presence of additive as well as non-additive gene effects for controlling the traits. However, relative magnitude of these variances indicated that additive gene effects were more prominent for all the characters studied except grain yield/plant. The ratio of the components revealed that the magnitudes of SCA components were much higher than that of GCA in all crosses except number of kernel row per ear. A wide range of variability of GCA effects was observed among the parents. For grain yield (GY) parents L2, L5, L6, L7 and L9, showed significant positive GCA effect. Thirteen five crosses exhibited significant positive SCA effects for grain yield (GY).These crosses involved high× high, high× low and low × low general combining parents (GCA). Although the cross L6 × L10 involved low × high general combiners, exhibited the highest significant positive of SCA effect (14.14 tha^{-1}). The cross L1×L10 involved the two inbreed lines with lower general combiners and also showed the lower SCA effects (7.61tha^{-1}).

Keywords: Combining abilities, GCA, gene effects, maize, SCA

Abbreviations: GCA-general combining ability; SCA-specific combining ability

INTRODUCTION

The information on general combining ability (GCA) and specific combining ability (SCA) is important for hybrid development. Combining ability study of inbreeds and populations are important for hybrid breeding in order to understand the heterotic patterns of the germplasm. Many procedures have been used by plant breeders in attempt to increase the yield of maize (Geadelmann and Peterson, 1980; Aliu et al, 2008). The improvement of maize yields depends on the knowledge of the type of the gene action involved in its inheritance and also the genetic control of the related traits such as capacity of production (Rezaei et al., 2004). Grain yield of maize is a complex trait. It includes a number of

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components, which are inherited in a quantitative manner (Živanovic et al., 2006). The General Combining Abilities (GCA) and Specific Combining Abilities (SCA) effects are important indicators of potential value for inbred lines in hybrid combinations. The value of GCA tends to express Differences in GCA effects have been attributed to additive, interaction of additive x additive, and higher-order interactions of additive genetic effects in the base population, while differences in SCA effects have been attributed to dominant and epistatic gene effects (Spitko et al, 2010). Non additive gene effects for grain yield were found to be significant in maize (Kalla et al., 2001) which suggested that several combinations among parental lines by their mean performance and genetic nature had the potential for the development of more yielding and earlier genotypes. Evaluation of crosses among inbred lines is an important step towards the development of hybrid varieties in maize (Hallauer, 1990). This process ideally should be through evaluation of all possible crosses (diallel crosses), where the merits of each inbred line can be determined. Diallel crosses have been widely used in plant breeding to investigate combining abilities of the parental lines in order to identify superior parents for use in hybrid development programmes. Diallel mating design has been devised, also, in genetic research to investigate the inheritance of important traits among a set of genotypes and gene effects (Malik et al., 2005). Diallel crosses have been used in genetic research to determinate the inheritance of a trait among a set of genotypes and to identify superior parents for hybrid or cultivar development (Weikai Yan & Manjit Kang, 2003). Combining ability has been investigated by several authors in maize (Kang et al., 1995; Kim and Ayala, 1996; Betrán et al., 2002; Bhatnagar et al., 2004; Glover et al., 2005).The main objective of our study was to estimate General combining ability (GCA) and Specific combining ability (SCA) among these maize inbred lines and, consequently, to identify superior single-cross hybrids (SCH) developed from them.

MATERIAL AND METHODS

Plot Layout and Stand Establishment

Plant materials used as parents for crosses in this study were 10 selected superior maize inbred lines (Parents) (L1, L2, …L10) with medium maturity, originating from the Agriculture University of Tirana, Albania. Crosses among these inbred lines were based on a diallel. During the first 3 years, we evaluated adaptability of inbred lines to specific agro-ecological conditions of Kosovo, in the locality Ferizaj (580 m a.s.l). In the fourth year, we conducted diallel crosses (with 10 inbreds) following the method of Griffing (1956). The field experiments with F1 hybrids and their parents (10 diverse maize lines and their 45 F1 crosses) were conducted during the fifth year. The total of means of the single crosses was calculated based on formula: $Tx = \frac{p(p-1)}{2}$

Whereas*:*Tx is a total of means of the single crosses and *p* = number of parents

The experiments were based on a randomized complete block design (RCBD) with three replications. The distances between plants were 60×30 cm or 55.000 plants^{-1}. The experimental plots for each replication were 5.4 m^2. The seeds were sowing deep 3-5 cm. The standard agronomic practices were applied. Measurements on plot basis were recorded on the following agronomic traits: grain yield (GY) t ha^{-1}, ear length (EL) (cm), number of rows per ear (NRE), and number of kernels per row (NKR). Grain yield evaluation was performed by measurement of ears mass for each elementary plot using average sample from each replication, in order to calculate grain yield with 14% moisture. Analyses of other above mentioned traits were conducted using 10 ears per genotype from each replication.

Statistical analyses

Differences among observed individuals, within each combination, were analyzed using the mathematic model of Griffing (1956):

$$Xij = \mu+gi+gj+sij+e,$$

Xij – value of the progeny derived from the crossing of *i*-th female parent with *j*-th male parent

μ – grand mean,

gi – the GCA effects of the *i*-th female parent,

gj – the GCA effects of the *j*-th male parent,

sij – the SCA effects specific to the hybrid of the *i*-th female line and the *j*-th male line,

e – experimental error.

ANOVA for GCA and SCA was calculated as presented in Table 1.

Table1. Model of ANOVA for GCA and SCA according to Griffing's method 2 (Aliu et al.,2008)

Source	d.f.	S.S.
GCA	*n*-1	$\frac{1}{n+2}\left[\sum (y_{i.}+y_{ii})^2 - \frac{4}{n}y_{..}^2\right]$
SCA	$\frac{n(n-1)}{2}$	$\sum\sum y_{ij}^2 - \frac{1}{n+2}\sum(y_{i.}+y_{ii})^2 + \frac{2}{(n+1)(n+2)}y_{..}^2$
Error	$\left[\frac{n(n+1)}{2}-1\right]\times(r-1)$	$\frac{Total\ S.S. - Treatm.S.S. - Replic.S.S.^{*}}{r}$

Statistical analyses package were conducted using program – MSTAT-C , version 2.10(Russell, 1996).

RESULTS AND DISCUSSION

Analyses of variance revealed that mean square values were significant (LSDp=0.01) for the genotypes for all traits under study. Analysis of variances for combining ability (Table 1) revealed that both GCA and SCA variances were highly significant for all the characters studied indicating importance of additive as well as non-additive type of gene action in controlling the traits. Effect of a replication was insignificant for all analyzed traits and suggested uniformity of a soil and agronomic practice used. The ratio of the components revealed that the magnitudes of SCA components were much higher than that of GCA in all crosses except number of kernel row per ear. (Table 2).This indicated predominance of additive gene action for all the characters except kernel rows per ear (NKR). Debnath et al. (1988), Sanghi et al. (1983), Roy et al. (1998) and Das and Islam (1994) also reported predominance of non-additive gene action for grain yield in the same crop.

Table 2. Analysis of variance for combining ability of different characters in maize line

Source of Variation	Mean sum of squares				
	d.f	GY	EL	NRE	NKR
Replication	2	0.23	0.25	0.02	0.14
Crosses	44	13.78**	11.08**	42.17**	1.95**
GCA	9	10.36**	15.14**	8.75**	21.27**
SCA	44	74.00**	33.95**	47.42**	7.95**
Error	108	0.22	0.15	0.11	0.12
GCA/SCA		0.14	0.45	0.18	2.67

** Significant at p=0.05, p=0.01 level respectively.

The GCA effects and performance of the parents revealed that none of the parents were found to be a good general combiner for all the characters studied (Table 3). A wide range of variability of GCA effects was observed among the parents. For grain yield (GY) parents L2, L5, L6, L7 and L9, showed significant positive GCA effect and simultaneously possessed high mean value indicating that the performance of the parents could prove as a useful index for combining ability and suggesting they contributed good alleles and their importance in grain yield improvement. Roy et al. (1998) and Hussain et al. (2003) also have observed similar results. Grain Yield (GY), Ear length (EL), Number of row per ear (NRE) showed that ratio of GCA/SCA what led to conclusion that additive gene effects are importance in inheritance of this trait. El-Badawy (2013) and EL-Hosary and Elgammaal (2013) showed that the additive gene effects represented the major role in the inheritance of grain yield and other agronomic traits. Theoretically, additive gene effect can be fixed in pure lines, while non-additive can be expressed in hybrids.

Table 3. Estimates of general combining ability effects (GCA) and mean performance

	GY		EL		NRE		NKR	
Parents	Mean	GCA	Mean	GCA	Mean	GCA	Mean	GCA
L1	3.0	-0.05	12.7	0.023	13.0	-0.38	17.6	0.483**
L2	3.4	0.095	13.1	0.038*	12.0	-0.53	18.3	-0.056
L3	3.1	-0.21	13.2	0.336**	12.7	-0.74	19.7	0.078
L4	2.1	-0.72	17.2	0.113**	12.0	-0.74	16.7	-1.95
L5	4.5	0.14**	14.7	-0.91	14.7	0.424**	24.3	0.144**
L6	4.7	0.64**	12.2	-0.11	15.3	0.576**	15.7	-0.236
L7	4.8	0.35**	18.2	1.122**	15.3	-0.46	24.0	2.194**
L8	3.5	-0.03	13.1	0.062**	15.6	0.154**	17.0	0.65**
L9	3.3	0.08	15.2	0.258**	13.3	1.062**	15.3	-1.02
L10	4.0	-0.34	14.1	-0.92	15.3	0.664**	21.7	-0.28
LSD 0.05	0.11		0.02		0.01		0.12	
LSD 0.01	0.13		0.04		0.04		0.26	
SE (gi)	0.69		0.91		0.85		2.19	

*, ** significant at 0.05 and 0.01 probability levels, respectively

Parents (lines) L5, L6 and L10 showed significant negative GCA for Ear length (EL) and are good contributor and can be used in maize breeding for reducing ear length. Parent (line) L7 might is useful in developing new hybrid genotypes because was characterized with high GCA values (1.122) and suggesting it contributed good alleles for ear length. The largest significant (LSD*p*= 0.01) positive GCA effects for number of row per ear (NRE) were observed for the inbred lines L9 on value 1.062. Also, the other inbred lines L5, L6, L8 and L10 had the positive values but compare to line P9 the values were lower (Table 3). For number of kernels per row (NKR) was detected for L3, L5,L7 and L8 showed largest positive significant GCA effects for NKR suggesting usefulness in breeding programmes for the increase of this trait. It is the conformation of the earlier acknowledged fact that large SCA effect often includes one parent with large GCA effect and another with small GCA (Glover et al., 2005). Specific combining ability effects (SCA, effects are shown in Table 4. For grain yield generally the crosses showing significant positive of SCA effects also possessed high mean performance and significant negative SCA effects possessed low mean performance. This reflects that high value of the crosses indicated their potentiality. Thirteen five crosses exhibited significant positive SCA effects for grain yield (GY). These crosses involved high × high, high× low and low × low general combining parents (GCA).The average values of GY at all crosses were 10.8 tha^{-1}. Although the cross L6 × L10 involved low × high general combiners, exhibited the highest significant positive of SCA effect (14.14 tha^{-1}). The cross L1 × L10 involved the two inbreed lines with lower general combiners and also showed the lower SCA effects (7.61 tha^{-1}). The differences between these hybrid combinations were +6.53 tha^{-1} or expressed in relative values was 60.46%. While differences between the parents (MP) and hybrid combination (F_1) for GY were (d= F_1 –MP= +7.16 th$^{-1)}$. Ivy and Hawlader (2000) also reported that good general combining parents do not always show high SCA effects in their hybrid combinations. On the contrary, Paul and Duara (1991) reported that the parents with high GCA always produce hybrids with high estimates of SCA. Roy et al. (1998) also found significant positive SCA effects in high × low general combiners. Hybrid combination L6 x L10 and L1 x L4 showed largest positive significant (LSD*p*= 0.01) SCA effect for ear length (EL), while with lower SCA effects was characterized the combination L5 xL7 (15.9cm) The differences between hybrid combination L6 x L10 and L1 xL10 were 6.40 cm or expressed in relative values was 31.37%. The differences among the parents (MP) and hybrid combination (F_1) for EL were (d=F_1-MP=+6.06 cm) (Table 4). For NRE the average values were 16.7rows/ear. With higher SCA was determined the hybrid combination L5 xL9 (higher x higher of GCA) on value 19.2 rows/ear, while on minimal values was L7 xL10 (lower x higher) on value 14.3 rows/ear. The differences between combination for NRE were + 4.9 rows/ear or in relative values 29.34%.The differences among the parents (MP) and hybrid combination (F_1) for NRE were (d=F_1-MP=+2.8 rows/ear. For NKR, the crosses L6 x L10 exhibited higher significant SCA effects (45kernel/row) of the hybrid. In this crosses are involved low x low general combining parents. With low SCA was determined the combination L1 xL10 (29.5 kernel/row) and if compared this combination on L6 xL10, the differences between them are + 15 5 kernel/row or expressed in relative values are 41.11%. While the differences among the parents (MP) and hybrid combination (F_1) for NKR were (d=F_1-MP=+18.67 kernel/row). Aliu et al.,(2008), has studied some maize inbreed lines and from results found that it was not possible to prove the rule that inbreeds with good GCA usually had the good SCA. Results are presented in Table.4.

Table 4. Estimates of SCA and mean performance of the maize inbreed lines

	GY(tha^{-1})		EL (cm)		NRE (rows/ear)		NKR(kernel/ear)	
Crossing	Mean	SCA	Mean	SCA	Mean	SCA	Mean	SCA
L1x L2	12.01	2.11**	21.2	1.74**	14.4	-0.53	41.3	6.17**
L1x L3	11.73	2.15**	22.1	2.37**	14.3	-0.41	41.8	6.54**
L1x L4	10.45	1.37**	22.3	2.56**	16.5	1.86**	39.0	5.73**
L1 xL5	13.85	3.91**	22.2	3.6**	17.0	1.14**	41.4	6**
L1xL6	12.42	1.98**	21.4	2.12**	16.5	0.52*	40.4	3.12^{NS}
L1 xL7	9.00	-1.14	21.1	0.55*	14.9	0.006	40.5	4.97*
L1 xL8	12.93	3.16**	21.8	2.34**	16.1	0.51*	40.8	3.47^{NS}
L1xL9	11.69	1.81**	19.9	0.25^{NS}	18.3	1.79**	37.7	-5.4
L1 xL10	7.61	-1.84	15.9	-2.56	16.0	-0.11	29.5	2.61^{NS}
L2xL3	10.68	1.01**	21.6	2.12**	15.3	0.8**	37.4	4.97*
L2xL4	11.52	2.34**	20.9	1.39**	15.4	0.84**	37.7	6.08**
L2xL5	11.82	1.78**	20.9	2.34**	16.4	0.67**	39.9	0.09^{NS}
L2xL6	11.72	1.2**	20.8	1.44**	16.9	0.99**	34.5	6.33**
L2xL7	10.84	0.59**	21.6	1.07**	15.5	0.63**	43.2	7.44**
L2xL8	11.06	1.2**	21.5	1.96**	16.2	0.71**	42.8	4.25*
L2xL9	12.66	2.67**	21.7	1.87**	17.9	1.57**	37.9	-4.39
L2xL10	9.74	0.19^{NS}	17.0	-1.21	15.8	-0.16	30.0	1.71^{NS}
L3xL4	10.4	1.53**	20.2	0.48*	16.4	2.01**	34.6	-1.25
L3xL5	11.46	1.73**	20.9	2.08**	15.9	0.41*	33.7	0.36^{NS}
L3xL6	9.03	-1.2	20.0	0.37^{NS}	14.9	-0.81	34.9	1.79^{NS}
L3xL7	10.9	1.05**	21.4	0.57*	15.2	0.57**	38.8	5.07*
L3xL8	8.79	2.83**	21.3	1.53^{NS}	15.3	0.08	40.5	5.01*
L3xL9	11.49	1.81**	21.5	1.52**	17.5	1.31**	38.8	8.57**
L3xL10	10.9	1.65**	21.5	2.72**	15.1	-0.62	43.1	3.14^{NS}
L4xL5	10.41	1.17**	18.1	-0.49	14.9	-0.58	36.1	4.65*
L4xL6	11.96	2.23**	20.6	1.16**	16.6	0.93**	37.2	0.32^{NS}
L4xL7	11.51	2.08**	19.7	-0.93	14.6	-0.02	35.3	1.27^{NS}
L4xL8	8.26	-0.79	19.2	-0.37	14.5	-0.74	34.7	2.08^{NS}
l4xL9	9.45	0.28*	20.2	0.39^{NS}	16.6	0.41*	33.8	4.4*
L4xL10	10.97	2.22**	19.1	0.57*	15.7	-0.02	36.9	4.36*
L5xL6	12.41	1.82**	19.4	1.02**	16.7	-0.79	39.7	5.06*
L5xL7	10.51	0.21^{NS}	18.7	-0.94	15.0	0.98**	37.1	0.03^{NS}
L5xL8	11.65	1.74**	18.6	0.05^{NS}	17.4	1.84**	38.3	2.74^{NS}
L5xL9	9.65	-0.36	17.4	-1.32	19.2	0.47*	34.4	0.51^{NS}
L5xL10	8.82	-0.77	16.5	-1.06	17.4	0.32^{NS}	34.6	0.03^{NS}
L6xL7	12.52	1.72**	22.6	2.22**	16.3	-0.16^{NS}	38.4	1.74^{NS}
L6xL8	9.67	-0.74	19.7	0.31^{NS}	16.4	0.56**	36.8	1.62^{NS}
L6xL9	12.2	1.66**	21.3	1.72**	16.7	1.09**	40.9	7.43**
L6xL10	14.14	4.03**	22.3	4.12**	18.2	-0.65	45.0	10.78**
L7xL8	12.52	2.4**	21.8	2.38**	14.9	0.77**	44.5	6.92**
L7xL9	12.47	2.24**	21.6	0.77**	17.2	-1.69	38.6	2.73^{NS}
L7xL10	12.05	2.23**	20.8	1.23**	14.3	0.58**	39.9	3.22^{NS}
L8xL9	11.48	1.63**	22.2	2.55**	17.7	0.31	39.1	4.71*
L8xL10	10.47	1.04**	20.5	1.99**	17.0	0.4*	38.4	3.3^{NS}
L9xL10	11.04	1.49**	20.4	1.66**	18.0	0.39*	37.9	4.47*
LSD 0.05	0.26		0.43		0.38		4.25	
LSD 0.01	0.34		0.61		0.52		5.38	
SE (gi)	0.13		0.23		0.21		1.35	

*, ** significant at 0.05 and 0.01 probability levels, respectively

CONCLUSIONS

From the results it was concluded that the following parental lines L5, L6 and L7 were having good general combining ability for grain yield. These parents had resulted in the production on higher values. So, these inbred lines (parents) could be used extensively in hybrid breeding program with a view to increasing the yield level. Among the crossing combination L6xL10, L1xL5, and L1xL8 were found to be good specific combiners and these line could be used for heterosis breeding programs in maize and represent a highly valuable of genetic material.

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