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General and specific combining ability studies for leaf area in some maize inbreds in agroecological conditions of Kosovo

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ABSTRACT

In maize breeding one of the most important roles belongs to selection of parents with good combining abilities. The data associated with combining ability and heritability of particular characters can be obtained from diallels. The main objective of this study was to evaluate the leaf area (LA) of 10 inbred lines and their F1 hybrids. Based on a diallel (without reciprocals) GCA and SCA were calculated. The components of the genetic variance were calculated using Griffing's (1956) method 2. The maximum LA value was determined for the combination L6×L10 (788.6 cm^2), whereas the minimum for the combination L4×L5 (558.9 cm^2). The average value of F_1 generation was 678.8 cm^2 and the variation range was from +109.8 cm^2 to -119.9 cm^2. Both, the GCA and SCA for LA were significant at p=0.01. The highest value of GCA was obtained for L2 (+31.33), whereas the lowest for L4 (–38.07). The highest value of SCA was determined for L6×L10 (+156.73).

Key words: Maize, inbred lines, GCA, SCA, leaf area.

Abbreviations: LA, leaf area; GCA, general combining ability; SCA, specific combining ability; L, inbred line, F_1 generation; MP, middle parents; EP, experimental plots; SE, standard error.

IZVLEČEK

PROUČEVANJE SPLOŠNE IN POSEBNE KOMBINACIJSKE SPOSOBNOSTI LISTNE POVRŠINE NEKATERIH SAMOOPLODNIH LINIJ KORUZE V AGROEKOLOŠKIH RAZMERAH KOSOVA

V žlahtnjenju rastlin igra eno od najpomembnejših vlog selekcija roditeljev z dobrimi kombinacijskimi sposobnostmi za želene lastnosti, ki jih običajno ugotavljamo z dialelnimi križanji. Namen raziskave je bil ugotoviti kombinacijsko sposobnost 10 samooplodnih linij koruze ter njihovih križancev za listno površino (LP). Na osnovi njihovih dialelnih križancev (brez recipročnih križancev) je bila za LP izračunana splošna (SKS) in posebna (PKS) kombinacijska sposobnost. Komponente genetske variabilnosti so bile računane po metodi 2 Griffingovega modela (1956) računanja kombinacijskih sposobnosti. Največja LP je bila

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ugotovljena za križanec L6×L10, (788,6 cm^2), najmanjša pa za križanec L4×L5 (558,9 cm^2), medtem ko je bila povprečna vrednost vseh križancev 678,8 cm^2. Tako za SKS kot za PKS so bile ugotovljene statistično značilne razlike med križanci pri p=0,01. Največja vrednost SKS za LP je bila ugotovljena pri L2 (+31,33), najnižja pa pri L4 (–38,07), medtem ko je bila največja vrednost PKS ugotovljena za križanec L6×L10 (+156,73).

Ključne besede: koruza, samooplodne linije, splošna kombinacijska sposobnost, posebna kombinacijska sposobnost, listna površina.

1 INTRODUCTION

The leaf area is a one of the crucial factors in photosynthesis. It is especially important for maize (Sylvester *et al*., 1990). LA is closely associated with the transpiration process and other physiological characteristics of maize genotypes. Very important are also environmental factors and their interactions with plant characteristics and cultural practice.

In the literature, it is possible to find many researches in this field. Jevtić (1977) in his investigation found that the total surfaces of leaves/plant varied from 0.3-1.2 m^2. Ničiporović (1961), and Gotlin and Pucarić, (2000) concluded that level of the absorbed energy gets higher with increasing of LA with value 25.000 m^2/ha. Toming (1977), according to the data of Lapčević (1985), found out that participation of assimilated LA of maize more than 40-50.000 m^2/ha did not have any effect for increasing of using energy. In some maize inbred lines Aliu (2003, 2006) obtained average maximal and minimal values of LA 0.56-0.75 m^2, while Salillari *et al*., (2002) and Jakovljević (1989) at some inbred lines for LA obtained different values from 0.40-0.80 m^2 and 0.79 m^2, respectively. The present investigation was undertaken to characterize ten diverse lines and their 45 F1 hybrid combinations for their general (GCA) and specific (SCA) combining ability, and to identify leaf area (LA).

2 MATERIALS AND METHODS

Plant materials used as parents for crosses in this study were 10 selected superior maize inbred lines (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, especially in the area near 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 experiments were based on a randomized complete block design (RCBD) with three replications. The spacing was 60×30 cm or 55.000 plants per ha, experimental plots was 5.4 m^2 per each replications. The seeds were placed 3-5 cm deep. In order to determine LA we measured dimensions of the leaf blade growing from the same node as the ear. We measured 10 plants per replication; altogether 30 plants per combination. LA was determined according to the formula of Montgomery (1911): A = L×W×0.75, where *L* represents leaf length, *W* is leaf width and *0.75* is the factor used for determination of leaf area in maize. The same formula was also used by several other researchers such as Francis *et al*., (1969); Whigham *et al.,* (1974) and Pearce *et al.,* (1975). Genetic interpretations and analyses of similar experiments can be found in numerous papers such as Hayman (1954) and Griffing (1956).

Statistical analyses

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

$X_{ij} = \mu + gi + gj + s_{ij} + e$,

X_{ij} – 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,

s_{ij} – 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.

Table 1: Model of ANOVA for GCA and SCA according to Griffing's method 2 (Varghese *et al.*, 1976).

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	$\left[\frac{n(n+1)}{2}-1\right]\times(r-1)$	$\frac{Total\ S.S. - Treatm.S.S. - Replic.S.S.^*}{r}$

- - S.S. out of base ANOVA.

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

3 RESULTS AND DISCUSSION

The calculations showed that the hybrid combination L6×L10 was characterised by the largest leaf area (788.6 cm^2), while the smallest value was obtained for hybrid L4×L5, (558.9 cm^2) (Table 2). The average value of LA for all studied genotypes was 678.8 cm^2. The variation range between largest leaf area and smallest leaf area was 229.7 cm^2 or 35%, and this difference was significant at p=0.05 and p=0.01. All F1 hybrids had positive heterosis; the highest value was 48% above the mid parent value (data not shown). The coefficient of variation of the total LA for all genotypes was 3.33%, while SE = ±21.3. The highest variability of LA values are obtained for hybrids L6×L10, (96%) and L3×L4, (19%). These difference of LA among F1 generation were statistically significant at p=0.05 and p=0.01. The heterosis of LA is one of the commonest and most striking manifestations of hybrid vigour (Evans, 1993). Kojić (1982) obtained positive heterosis effect comparing with parents from 27.7-85.9%, while Bocanski (1995) found out that the inheritance of LA could be explained by over-dominance. Earlier genotypes developed smaller LA and they were below the mean value, while the genotypes with longer vegetation period had higher LA and were above mean value. Difference between the mean of all F1 hybrids and the mean of all parents (F1-MP) was 221.45 cm^2. This could be considered as a result of heterosis of F_1 generations.

Table 2: Leaf area of parents (diagonal, underlined) and their F1 hybrids (above diagonal).

	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	F1 Mean
L1	489.0	625.6	681.8	715.9	752.7	721.7	580.6	617.2	662.6	643.9	666,89
L2		467.4	737.9	726.8	744.9	757.3	723.1	741.4	761.2	652,0	718,91
L3			472.8	562.8	647.6	683.6	733.8	726,0	730,6	757,8	695,77
L4				470.4	558.9	621.5	626.6	620.4	593.5	605.2	625,73
L5					440.3	626.7	685.8	703.6	583.2	597.9	655,70
L6						392.6	709.4	712.3	682.0	788.6	700,34
L7							463,0	728.0	684.9	681.2	683,71
L8								477.0	702.8	717.8	687,60
L9									490.0	628.5	669,92
L10										412.0	674,77
Grand mean											677.93

LSD $_{p=0.05}$ =42.69, $_{p=0.01}$ =56.20.

The statistical analysis of combining ability indicates that there are significant differences among genotypes in both, GCA and SCA (Tab.3). Non-additive effects of genes have important influence in LA inheritance. The ratio between GCA and SCA was 0.40. A similar ratio (0.36) was obtained by Kojić (1982). Rutger et al. (1971) found that besides non-additive effects, an important role belonged also to additive variance, what was later confirmed also by Mason and Zuber (1976). As reported by Rojas and Sprague (1952), GCA is primarily associated with additive effects, whereas SCA is attributed to the non-additive genetic effects.

Table 3: ANOVA of GCA and SCA for leaf area.

Source	d.f.	S.S.	M.S.	F-Value
GCA	9	125598.06	13955.34	30.71**
SCA	45	1572243.67	34938.75	76.89**
SE	108	49076.53	454.41	

** - Significant at p=0.01

The GCA effects for LA showed significant variation between hybrid combination of parental lines. The highest GCA effect for LA was observed for L2 (+31.33) (Tab. 4), with significant differences based on value F, suggesting the dominant gene action regarding LA in F1. The lowest GCA value was denoted by L4 (-38.07). Large proportion between value F and differences among inbred lines for GCA were significant at p=0.05 and p=0.01 and have different intensity for heritage and variability. Kojić (1982) obtained for LA maximal and minimal values of GCA between +42.971 and -31.314. Malik *et al.*, (2004) published similar results for LA, GCA and SCA, using different genotypes, and obtained values between +41.32 and -20.27.

Table 4: GCA effects for LA (cm^2) in F1 generation.

Rank	Parent	GCA
1	L2	31.33
2	L8	16.15
3	L3	13.68
4	L7	6.71
5	L6	3.90
6	L9	-0.47
7	L1	-1.56
8	L10	-11.02
9	L5	-20.64
10	L4	-38.07
$LSD_{p=0.05}$ = 17.22		SE(gi) =11.3603
$LSD_{p=0.01}$ = 22.70		

Table 5: Specific combining ability (SCA) for leaf area in a diallel among 10 maize inbreds.

Rank	Genotypes	SCA	Homog. groups	Rank	Genotypes	SCA	Homog. groups
1	L6×L10	156,73	a*	24	L7×L9	39,60	efghijkl
2	L1×L5	135,88	ab	25	L6×L9	39,58	efghijkl
3	L1×L4	116,51	abc	26	L1×L3	30,62	fghijklm
4	L3×L10	116,09	abc	27	L1×L9	25,57	ghijklm
5	L2×L5	95,16	bcd	28	L4×L7	18,97	hijklmn
6	L2×L4	94,49	bcd	29	L1×L10	17,50	hijklmno
7	L2×L9	91,35	bcde	30	L4×L6	16,65	hijklmno
8	L2×L6	83,08	bcdef	31	L3×L5	15,50	hijklmno
9	L1×L6	80,30	cdef	32	L4×L10	15,24	hijklmno
10	L3×L9	78,36	cdefg	33	L3×L6	14,96	hijklmno
11	L3×L7	74,36	cdefg	34	L5×L6	4,42	iiklmnop
12	L8×L10	73,65	cdefg	35	L4×L8	3,34	ijklmnop
13	L5×L8	69,07	cdefgh	36	L9×L10	1,00	ijklmnopq
14	L7×L8	66,09	cdefgh	37	L4×L9	-6,94	jklmnopq
15	L5×L7	60,55	defgh	38	L2×L10	-7,32	kKlmnopq
16	L6×L7	59,80	defghi	39	L5×L10	-9,48	lmnopq
17	L3×L8	55,19	defghi	40	L4×L5	-21,50	mnopq
18	L2×L8	54,94	defghi	41	L1×L7	-33,10	mnopq
19	L2×L3	53,84	defghi	42	L5×L9	-34,70	nopq
20	L6×L8	53,20	defghi	43	L1×L8	-36,40	opq
21	L8×L9	48,10	defghij	44	L1×L2	-43,10	pq
22	L7×L10	46,46	defghijk	45	L3×L4	-51,79	q
23	L2×L7	46,08	defghijk				
	$LSDp$=0,05	54,46			$LSDp$=0,05	54,46	
	$LSDp$=0,01	71,80			$LSDp$=0,01	71,80	
	SE	128,52			SE	128,52	

* - the same letter indicate the same homogenous group.

The highest values of SCA was obtained for the hybrid L6×L10 (+156.73). This value was also significant for three other hybrids (L1×L5, L1×L4, L3×L10) (Tab. 5). The lowest value of SCA was estimated for the hybrid L3×L4 (-51.79). The total differences for maximum values for phenotype variability were 208.52 in favour for genotype L6×L10, while in second place, there was the combination L1×L5 (+135.88), which was not significantly different from the hybrid L6×L10. The effect of SE for SCA of crossing parents was 128.52. Different results for SCA of LA with significant differences for maximal (+111.71) and minimal (-96.71) values were obtained by Kojić (1982).

4 CONCLUSIONS

Results of our investigations indicate that there were significantly different combining abilities for leaf area among investigated inbred lines. All F1 hybrids expressed positive heterosis effect (for leaf area) regarding to their parents. The highest value of LA was found for L6×L10, while the lowest value for L4×L5. It was not possible to prove the rule that inbreds with good GCA usually had the good SCA. Namely, the inbred L2 had expressed the highest GCA for the investigated trait, but 2 out of 9 hybrids of this inbred showed negative value of SCA. On the other side, the highest value of SCA was found for hybrid L6×L10, but parental inbreds showed very low (3.90 for L6) or negative (-11.02 for L10) SCA. The investigation suggests that the some of the studied inbreds represent a highly valuable genetic material that could be successively used for further breeding.

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