P L A N T   B R E E D I N G

ESTIMATION OF HETEROSIS AND COMBINING ABILITY IN MAIZE (*Zea mays L.*) FOR EAR WEIGHT (EW) USING THE DIALLEL CROSSING METHOD

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Abstract
A diallel cross between inbred lines of maize (*Zea mays L.*) with medium maturity and an evaluation to estimate the genetic parameters for ear weight (EW) was carried out. The main objective of this study was to evaluate the ear weight of 10 inbred lines and their F_1 hybrids, based on a diallel cross (without reciprocals) General Combining Ability (GCA) and Specific Combining Ability (SCA). The components of the genetic variance, were calculated using Griffing's formula (1956), method 2, mathematic model I. X_{ij}=µ+gi+gj+s_{ij}+e, for EW to detect the relative importance of additive and non additive gene effects. Additive gene effects were more important than non additive since the ratio was 0.25 among GCA and SCA. The highest value for maximal EW was a heterozygote combination from the inbred lines L_6xL_{10} (xg = 376.2 g/ear), while the minimal average value obtained for the hybrid combination was L_1xL_{10} (240 g/ear). The variation between the largest and the smallest EW for the hybrid combination was 136.2 g or 45%. The grand experimental mean µ of F_1 generation was 308.1 g/ear. The differences for the EW of F_1 generation were ± 68.1 g/ear or 23%, compared with the value µ showing a high significance for EW. ANOVA's test for the combining ability of GCA and SCA effects were highly significant at the $p \leq 0.05$ and $p \leq 0.01$ level of probability, respectively.

Key words: Ear weight, combining ability – diallel analysis, maize inbred line.

Introduction
Many procedures have been used by plant breeders to an attempt to increase the ear weight of maize (Geadelmann and Peterson, 1980). The use of heterosis started in 1933 when in the USA approximately 1 % of the total farming acerage was planted with heterosis maze hybrids, while in 1953 the heterosis of the maize hybrids were expanded up to 96% (Sprague, 1962). The improvement of maize yields for ear weight depends on the knowledge of the type of the gene action involved in its inheritance and also the genetic control of related traits such as the capacity for production (Rezaei *et al*., 2004). Also the choice of the most efficient breeding program depends on the said information (Liao 1989, Pal & Prodham 1994). The effects of general Combining Abilities (GCA) and Specific Combining Abilities (SCA) are important indicators of potential value for inbred lines in hybrid combinations. Differences in GCA effects have been attributed to additive, the interaction of additive x additive, and the higher-order interactions of additive genetic effects in the base population, while differences in SCA effects have been attributed to non-additive genetic variance (Falconer, 1981). The concept of GCA and SCA has become increasingly important to plant breeders because of the widespread use of hybrid cultivars in many crops (Wilson *et al.*, 1978). The 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 the evaluation of all possible crosses (diallel crosses), where the merits of each inbred line can be determined. A Diallel analysis provides good information on the genetic identity of genotypes especially on dominance-recessive relations and some other genetic interactions. Diallel crosses have been used in genetic research to determine 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). The main objective of our study was to estimate the 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.

Materials and methods

The plant materials used for crosses in this study were taken from 10 selected superior maize inbred lines coded as: L_1, L_2… L_{10}, with medium maturity, originating from the Agriculture University of Tirana (AUT)- Albania (Table 1). All possible crosses among these inbred lines were made in a diallel crossing block. During a three year period the study investigated the adaptability of inbred lines to the specifics of this trait for agro - ecological conditions in Kosovo, especially in the area near Ferizaj (580 m a.s.l). After year four, ten (10) selected maize inbred lines were crossed using the diallel system (Griffing,1956), and in year five these genotypes were placed in experimental plots (EP) of hybrid combination (C) and a study on the General (GCA) and Specific (SCA) combining ability for Ear weight (EW) was conducted. Statistical analysis used the mathematical and statistical models "MSM" which involved randomized block design experiments (RBDE) with three replications, 45 hybrid combinations (C) x 3 replications (R) = 135 Experimental plots (EP). The experimental plot was 3 m long and 60 cm apart, with 30 cm plant to plant distance or 55000 plants per ha^{-1}. The experimental plots were 5.4 m^2 per each replication x 3R = 16.20 m^2, and the seeds were placed 3-5 cm deep and cultivated under intensive agro techniques, including the use of the fertilizer NPK (15:15:15) and UREA 46%. This number of plants per plot was used to cover the adjustment for plot yield. In order to determine the EW we measured the average of 10 ears or plants selected randomly from each plot (10 ear per plants x 3R =30 plants or in total 1350 plants). Genetic interpretations and analyses of similar experiments can be found in numerous papers such as Hayman, (1954), Griffing's (1956).

Statistical analyses

The diallel analysis ,as described by Griffing's (1956) method 2, mathematic model I (fixed model) is a systematic method of evaluating populations or select groups of inbred lines for combining ability in hybrid combination: $X_{ij}=\mu+gi+gj+s_{ij}+e$;

Where, X_{ij} = is the mean of i x j^{th} genotypes, μ = is the experimental grand mean, g_i and g_j = is the GCA effects of i-th female parent, effects of j-th male parent, S_{ij} = is the SCA effects specific to the hybrid of the i-th female line and the j-th male line , and e= is the experimental error.

The formula gives components of genetic variance and gene values for GCA and SCA mean squares calculated below: $gi=\frac{1}{p}+2(Ti+ii)-\frac{2}{p}GT$ and

$$S_{ij}\ X_{ij}-\frac{1}{p+2}(Ti+ii)+(Tj+jj)+\frac{2}{(p+1)x(p+2)}GT$$

Whereas Midparent heterosis (MPH) was calculated as: $MPH=\frac{F1-MP}{MP}x100$

Where,F_1 is the mean of the F_1 hybrid performance and $MP=\frac{P1+P2}{2}$, where P_1 and P_2 are the means of the inbred parents. Statistical analyses were calculated with the statistical program MSTAT-C version 2.10.

Results and Discussion

The results of the research reported great hybrid combinations and showed a significant genotypic effect on EW. The average value of EW for all studied genotypes was 308.1 g/ear. This is a relatively high weight that can guarantee higher productivity (yield), as result of the heterosis of F_1 generation and their heterotic structures are presented in Table 1. For the hybrid combination of inbred lines L_1xL_{10} the minimal average value was (Xg = 240 g/ear), while the maximal value obtained for the hybrid combination L_6xL_{10} was (Xg = 376.2 g/ear). The variation between extreme values was D= (L_6xL_{10}, xg = 376.2 g) – (L_1xL_{10}, xg = 240) =136.2 g or 45%, and this difference is highly significant at $p\leq$ 0.05 and 0.01. Distinctions' between blocks (repetitions) did not have significant effects for the probability level of $p\leq$ 0.05 and 0.01. The coefficient of the variation (CV) of the total EW for all genotypes of F_1 generation was 5.86%, while SE = ± 16.8. The total variability of genotypes for extreme values was ± 68 g/ear, highly significant differences were observed among parents and the hybrid combination for EW.

Table 1.Ear Weight of parents (diagonal, underlined) and their F_1 hybrids (above diagonal)

Line	L_1	L_2	L_3	L_4	L_5	L_6	L_7	L_8	L_9	L_{10}	F_1 Mean
L_1	81.3	305.8	324.1	310.0	365.1	353.0	251.0	356.3	334.2	240.1	315,5
L_2		95.3	297.8	319.0	324.4	325.0	355.4	338.8	350.2	248.1	319,8
L_3			65.6	276.3	307.4	244.8	308.1	329.0	310.0	294.3	295,7
L_4				74.1	271.0	313.9	299.8	241.9	259.3	291.7	279,6
L_5					132.6	321.0	310.4	326.0	252.4	249.6	291,9
L_6						44.5	341.7	289.9	304.6	376.2	328,1
L_7							160	362.3	346.7	344.1	351,0
L_8								78.5	347.0	306.0	327,0
L_9									71.1	299.3	309,3
L_{10}										113.1	264,0
μ value											308.16

LSD $p\leq 0.05=1.43$; $p\leq 0.01=1.73$

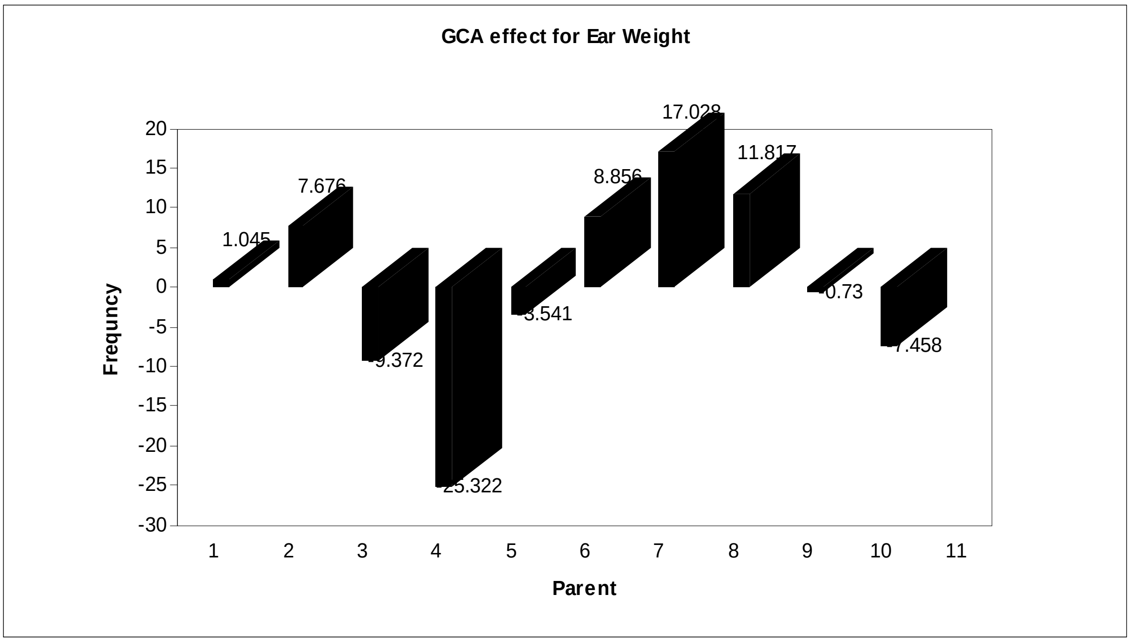
The difference between the mean of all F_1 hybrids and the mean of all parents (F_1-MP) was + 216 g/ear. The highest and the lowest values of average heterosis were observed for ear weight at all genotypes. All hybrid combinations had positive heterosis, the highest value was 150% above the average of the parents value. The highest variability of EW values were obtained for hybrids L_1xL_4 (xg = 245%) and L_2xL_{10} (xg = 77%), were statistically significant at $p\leq$ 0.05 and 0.01. Heterosis in EW is one of the commonest and most striking manifestations of hybrid vigour. The combining ability analyses of variance for EW were highly significant for differences observed for both GCA and SCA effects. A ratio of 0.25 for the variance components between GCA and SCA was observed. These values showed that additive gene effects were more important than non additive effects for EW. The are presented in Table 2.

Table 2. Estimated mean squares for GCA and SCA analyses for ear weight

Source	d.f	S.S	M.S	F-Value
GCA	9	49166.75	5462.9730	20.87**
SCA	45	981908.380	21820.1862	83.35**
E	108	28273.626	261.7928	

**Significant at the≤ 0.01 level of probability

The significance of GCA and their relatively high values were obtained in the inbred lines L_7 (+17.028), making it different from the inbred lines L_6 and L_8 and producing minimal differences compared with L_7. The lowest GCA value was observed at L_4 (-25.32), and compared with the maximal values for GCA (L_7), the variations were ± 42.35. Crossing maize lines for GCA (gi-gj) created a variance of 14.54, while the average value of inbred lines (Xij) for F_1 generation was 87.26. Large proportion of the value F and differences among inbred lines for GCA were significant at $p\leq$ 0.05 and 0.01, and have a different intensity for heritage and variability (Figure.1). The SCA effects for the EW in each parent and parental combination are presented in Table 3.



LSD $p\leq$ 0.05 = 12.35; $p\leq$0.01 =16.96; S.E (gi) =6.54

Figure 1.Estimated of GCA effects for Ear Weight

Table 3.Estimated of SCA effects for Ear Weight in a diallel among 10 maize inbreds

Parent	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}
P_1	-174.00	21.16	56.51	58.36	91.42	67.18	-43.01	67.56	58.00	-29.43
P_2	21.16	-159.9	23.61	60.76	44.35	32.52	54.75	43.42	67.31	-28.06
P_3	56.51	23.61	-141.8	35.04	44.36	-30.59	24.56	50.67	44.22	35.25
P_4	58.36	60.76	35.04	-151.1	23.98	54.45	32.14	-20.47	9.40	48.56
P_5	91.65	44.35	44.36	23.98	-136.3	39.87	21.00	41.94	-19.30	-15.34
P_6	67.18	32.52	-30.59	54.45	39.87	-158.3	39.93	-6.81	20.59	99.65
P_7	-43.01	54.75	24.56	32.14	21.00	39.93	-150.0	57.51	54.52	58.58
P_8	67.56	43.42	50.67	-20.47	41.94	-6.81	57.51	-159.9	59.86	26.06
P_9	58.00	67.31	44.22	9.40	-19.30	20.59	54.52	59.86	-163.12	31.61
P_{10}	-29.43	-28.06	35.25	48.56	-15.34	99.42	58.58	26.06	31.61	-113.3

LSD $p\leq0.05$ = 41.34; $p\leq0.01$= 54.49; S.E.(sij) =74.04

The results of the investigations for SCA also were highly significant at the $p\leq$ 0.01 level of probability. The highest specific combinations (SCA) were estimated for the hybrid combination L_6xL_{10} (+ 99.651), while the lowest value of SCA was obtained for the hybrid combination L_1xL_7 (-43.018). For SCA value, the second hybrid combination was L_1xL_5 (+ 91.423). The effect of SE (sij) for SCA of crossing parents was 74.04.

The study results show that both GCA and SCA effects are significant for ear weight trait, indicating that both additive and non-additive genetic actions were important combining of hybrids from the diallel crosses. Two factors are considered important for the evaluation of inbred lines in hybrid maize production - the characteristics of the line itself and the behaviour of the line in a particular hybrid combination (Malik *et al*., 2004). As a basic principle (Spargue and Tatum, 1942) emphasised that SCA is more important than GCA among selected inbred lines. For the GCA, the parent lines L_7 (+17.028), L_8 (+11.81) and L_6 (+8.85), had the best GCA, while for SCA the highest positive effect was produced by the hybrid combination L_6xL_{10} (99.65). Satisfactory performances were also obtained from the combination L_1x L_5 (91.42). This value showed variability between the investigative materials and productivity genotypes (Aliu, 2003). It was not possible to prove the rule that inbreds with good GCA usually had good SCA. Namely, the inbred L_7 and L_8 had the highest GCA for the investigated trait. On the other hand, the highest value of SCA was found for the hybrid L_6xL_{10}, but parental inbreds showed a very low SCA (8.85 for L_6) or negative (- 7.45 for

L_{10}). S.S. Sujiprihati *et al.*, 2001, interpreted, SCA as an indicator for the predominance of genes having dominance and epistatic effects while GCA as indicative for the predominance of genes having largely additive effects. However, EW was relatively more important than GCA among selected inbred lines. Additive gene effects were more important than non additive since the ratio in our results was 0.25 among GCA and SCA. The importance of additive and non-additive gene action was also reported by (Hansen *et al*., 1977, Beck *et al*., 1991, Alika., 1994, Sujiprihati *et al*., 2001). These conclusions are in agreement with the results of this study involving selected inbred lines. The capacity of maize for the production of ear weight is different in our study and similar results for EW with minimal differences from those obtained by Misovic, (1964). The values reported were from 30-500 g/ear. Whereas dominant gene action would favour the production of hybrids, the additive gene action as a standard selection procedure would be effective in bringing advantageous changes to the investigated traits. Maize genotypes with lower or higher ear weight are well known as qualitative and productive genotypes. Many authors as (Santos I., Miranda G. V *et al.*, 2005) analysed some maize cultivars for EW and obtained results up to 184.5 g /ear which could be used as very good materials in a breeding program. Other results obtained by Radic (1980), for EW showed a value with oscillation from 212 till 390 g/ear, and compared to our study the results show a minimal difference from + 28.1 and -13.3 g/ear, respectively. The local studies carried out by (Fetahu, 2001), with 16 genotypes for EW in the agro ecological conditions of Kosovo present results for some different genotypes with the experimental average value μ (255.17 g/ear) and compared with our results we have an increase of + 52.99 g /ear.

Conclusions

The results of our research indicate significantly different combining abilities for EW. It was shown that the all hybrid combinations expressed a positive heterosis effect for EW in regard to their parents. The inbred line with the highest value for GCA was the maize line L_7, $L_{8,}$ while for SCA was the combination $L_6xL_{10,}$ $L_1xL_{5.}$ The investigation suggests that some of the inbreds represent a highly valuable genetic material that could be successfully used for further breeding.

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HETEROZES UN KOMBINATĪVĀS SPĒJAS IZVĒRTĒJUMS KUKURŪZAS VĀLĪTES SVARAM (*ZEA MAYS L.*), IZMANTOJOT DIALĒLISKO KRUSTOŠANU

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Pētījuma mērķis bija novērtēt kukurūzas 10 inbrēdo līniju (*Zea mays L.*) vispārīgo un specifisko kombinatīvo spēju. Lai veiktu novērtējumu, salīdzināts vālītes masa inbrēdajām līnijām un to F_1 hibrīdiem, kas iegūti, izmantojot dialēlisko krustošanu (bez reciprokajām kombinācijām). Ģenētiskās mainības komponenti tika aprēķināti izmantojot Grifinga (Griffing's) formulu (1956) $X_{ij}=\mu+gi+gj+s_{ij}+e$, lai noteiktu aditīvo un neaditīvo gēnu efekta ietekmi uz vālītes masu. Konstatēts, ka aditīvo gēnu efekts bija lielāks par neaditīvo gēnu efekts, jo attiecība starp vispārīgo un specifisko kombinatīvo spēju bija 0.25. Lielākais vālītes masa iegūts no hibrīdās kombinācijas L_6xL_{10} (vālītes svars vidēji 376.2 g), mazākais – kombinācijai L_1xL_{10} (vālītes masa vidēji 240.0 g); izmēģinājumā vidēji F_1 paaudzē vālītes masa bija 308.1 g. Salīdzinot ar vecākaugu līnijām, vālītes masa F_1 hibrīdiem bija būtiski lielāks nekā vecākaugiem un tas vidēji izmēģinājumā bija +68.1 grami katrai vālītei. Ar varbūtību $p\leq 0.01$ tika konstatēti būtiski vispārīgās un specifiskās kombinatīvās spējas efekti.

CONSERVATION AND EVALUATION OF EX SITU AND IN VITRO COLLECTIONS OF ESTONIAN PLANT GENETIC RESOURCES

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Abstract

The Estonian government has responded to the global efforts for conservation and sustainable use of biological diversity by ratifying international agreements and establishing the National Programme on Plant Genetic Resources for Food and Agriculture. The collection, identification and conservation of plant genetic material of Estonian origin as well establishing the network are the essential activities of the National Programme. Since genetic resources provide the initial material for plant breeders and scientists, systematic detailed investigations and the improved use of genetic resources are required.

In this study evaluation of 13 oat and 59 potato accessions conserved in the Estonian ex situ and in vitro genebank was conducted. Descriptors for evaluation were selected from the Descriptor Lists developed by the working groups of the European Cooperative Programme for Plant Genetic Resources and promoted by Bioversity International. The results of the current study will be used in updating the databases of plant genetic resources and these data are applicable in plant breeding for further utilization of accessions.

Key words: genebank, plant breeding, oats, potato

Introduction

Genebanks are dedicated to conserve plant genetic resources, which guarantee their utilization in the future (Maxted et al., 1997). According to the international commitment arising from the ratification of the Convention on Biological Diversity (Convention on …), each country is responsible for conservation and sustainable use of plant genetic diversity as a local cultural and historical heritage to enhance the expediency of crop cultivation and ensure the sustainable development of society.

To realise these goals, the Estonian Government approved the National Programme for Plant Genetic Resources for Food and Agriculture (PGRFA) in 2002. The mandate of the programme is the collection, conservation, evaluation, characterization and documentation of plant genetic