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Genetic diversity and correlation estimates for grain yield and quality traits in Kosovo local maize (*Zea mays* L.) populations

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ABSTRACT

The aim of the presented investigation was to estimate the genetic diversity, and correlation analysis among yield and quality traits in twenty local maize populations. The experiment was based on randomized complete block design (RCBD) with three replications. In the study we compared grain yield, and quality traits such as protein, oil and starch content in grain. The results showed that there were significant differences among populations. The overall mean grain yield was 79.33 g plant^{-1} with the highest grain yield in population GBK-7 (105.13 g plant^{-1}). The protein and oil contents ranged between 11.02 to 13.02% and 2.56 to 5.57%, respectively. The starch content varied from 68.58 to 70.92%. The first two canonical discriminant functions were significant at $p < 0.01$. It is important to point out the great relevance of the first two discriminant functions justifying 95.80% of the variability among populations. There were also big differences regarding phenotypic correlations. The study suggests that the quality traits are phenotypically and genotypically highly variable and therefore very useful for breeding process

Key words: local maize populations, protein, oil, starch

IZVLEČEK

GENETSKA RAZNOLIKOST IN KORELACIJE MED PRIDELKOM ZRNJA IN KAKOVOSTNIMI LASTNOSTMI ZRNJA LOKALNIH POPULACIJ KORUZE (*Zea mays* L.) NA KOSOVEM

Namen raziskave je bil proučiti genetsko raznolikost in korelacije med pridelkom in nekaterimi kakovostnimi lastnostmi zrnja (vsebnost beljakovin, olja, škroba in pepela v zrnju) 20 lokalnih populacij koruze na Kosovem. Poskus je bil postavljen po metodi naključnih blokov v 3 ponovitvah. Za vse lastnosti so ugotovljene statistično značilne razlike med proučevanimi populacijami. Povprečni pridelek zrnja vseh populacij je znašal 79,33 g rastlino^{-1}, najvišji pridelek je imela populacije GBK-7 (105,13 g rastlino^{-1}). Vsebnost beljakovin se je gibala med 11,02 in 13,02 %, olja med 2,56 in 5,57 % in škroba med 68,58 in 70.92 %. Z diskriminantno analizo je ugotovljeno, da sta prvi dve komponenti pojasnili 95,80 % varabilnosti med populacijami. Med nekaterimi lastnostmi so za proučevane populacije ugotovili signifikantne korelacije. Glede na veliko genetsko variabilnost smatramo, da bi proučevane lokalne populacije lahko bile koristne v nadaljnjem žlahtnjenju genotipov koruze z dobrimi kakovostnimi lastnostmi zrnja.

Ključne besede: lokalne populacije koruze, Kosovo, pridelek zrnja, beljakovine, olje, škrob

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1 INTRODUCTION

Maize (*Zea mays* L.) is considered to be a major source of food for livestock and humans due to its relatively high content of proteins, oil, starch and some other important vitamins such as vitamin B and B12. Yellow maize can provide a substantial amount of vitamin A, and the maize germ is rich in vitamin E (Okoruwa *et al*., 1996).

The maize crop is considered to be an integral part of Kosovo's agricultural production system and has a potential to compete with other crops. In order to have access to the global market, there is a need to improve the yield quality with judicious use of inputs (Saleem *et al*., 2008).

Maize is commonly used in animal feed as an energy source for its high starch content (Oliveira *et al*., 2006). Several million people, particularly in developing countries, derive their protein and calorie requirements from maize. Some of the most important traits of interest in the maize market are protein and oil content. The protein content (PC) is a quantitative trait and several studies have pointed out that there is a great number of genes involved in its control (Mittelman *et al*., 2003). Protein is an expensive but necessary constituent of both food and feed. Grain protein quantity in ordinary maize is relatively low (80–110 g kg^{-1}) and of poor quality because of low levels of amino acids, lysine and tryptophan (Bjarnason and Vasal, 1992). Maize protein which ranges from 6 to 12% is regarded to be inferior because it is low in lysine and tryptophan (FAO, 1988). This may cause nutritional deficiencies when maize is used as an exclusive protein source, without the addition of supplements (Glover and Mertz, 1987). Some proteins in maize have anti-fungal qualities. The basis of resistance to fungal infection may lie with protein content, type, or distribution in the tissue (Guo *et al*., 1997).

The existence of genetic variability and the prospect of selection for protein content in maize have been demonstrated in several studies (Miću *et al*., 1995). Most of the oil is in the germ of the kernel. Oil and protein contents have been increased to levels almost twice as high as those of the original grain (Jugenheimer, 1961). High-oil corn (HOC) inbreds were first developed in 1896 and some hybrids containing 6–8% oil (Haumann, 1996), and affected by the size of embryo, maturity, and position of the kernel on the ear (Lambert 2001). Breeding studies in maize to enhance fatty acid composition started in 1970's; however, they have not continued. Research in this area dealt with different aspects of grain quality, focusing mainly on determination of the grain quality traits and characterization of maize genotypes in terms of fatty acid composition (Egesel *et al*., 2011).

The major use of HOC is in livestock feed because of its higher metabolizable energy value (Weber, 1987). The developing countries have more areas dedicated to maize cultivation than developed countries, but yield in the latter is about four times higher. While most production in developing countries is used for human consumption, in developed world, it is mainly used for animal feed and industry (FAO, 1988). As indicated earlier, maize has three possible uses such as food, feed for livestock and raw material for industry.

Maize is one of the most important grain crops in Kosovo, with over 60,000 hectares in production (MAFRD, 2010) where the area under local maize populations is more than 5%. In most cases, the cultivation of local populations is associated with their adaptability to specific environments and with their nutritional value. It is frequently used for human consumption as corn bread that can be consumed together with milk.

The main objective of the present study was to describe and analyze twenty local maize populations and to identify the quality traits with more differentiating ability.

2 MATERIAL AND METHODS

Plant material and experimental design: Twenty local maize populations (LMP), collected from different regions of Kosovo, were used in this study (Table 1). The experiment was carried out in a randomized complete block design with three replicates in Prishtina 42°38’29.76” N and 21° 07’16.49” E on 571 m of altitude in 2010. The climate of the region is semiarid with hot summers. The soil in the experimental area is classified as vertisol (black soil). Standard agronomic practices were used to provide adequate nutrition and keep the plots disease free. Each plot consisted of a row 5 m long with an inter and intra row plant spacing of 0.75 × 0.25 m, resulting in a population density of 53,000 plants ha^{-1}. Area of individual plots in each replication was 15 m^2.

Table 1. Geographical data of collected Kosovo local maize populations

Populations	Geographical origin	Longitude	Latitude	Elevation
GBK-1	Drenas	020º44´43"	42º41'50"	567
GBK-2	Malisheve	020º44´09"	42º28'12"	562
GBK-3	Malisheve	020º43´22"	42º27'56"	576
GBK-4	Drenas	020º45´53"	42º41'35"	694
GBK-5	Prishtine	021º04´00"	42º35'05"	810
GBK-6	Kamenice	021º31´32"	42º34'16"	766
GBK-7	Kamenice	021º25´32"	42º33'56"	812
GBK-8	Lipjan	021º07´20"	42º31'45"	551
GBK-9	Podujeve	021º12´12"	42º33'39"	598
GBK-10	Drenas	020º54´06"	42º34'50"	585
GBK-11	Vushtrri	021º59´26"	42º50'46"	557
GBK-12	Ferizaj	021º09´39"	42º22'15"	580
GBK-13	Suhareke	020º49´02"	42º21'45"	388
GBK-14	Vushtrri	020º58´30"	42º33'38"	518
GBK-15	Drenas	020º42´32"	42º39'21"	586
GBK-16	Drenas	020º42´46"	42º39'30"	565
GBK-17	Skenderaj	020º48´23"	42º45'00"	623
GBK-18	Skenderaj	020º47´39"	42º44'39"	597
GBK-19	Skenderaj	020º48´04"	42º44'39"	603
GBK-20	Shtime	020º07´06"	42º44'40"	610

***Laboratory studies*:** At harvest time, five random ears were selected from each plot, resulting in a total of 15 ears per individual population. Grains were carefully removed by hand. From each population, an equal number of grains was taken from each plot, mixed together in order to form a balanced sample and then subjected to analyses in the laboratory. The grains obtained were grounded to form a fine powder. The chemical analyses included protein content (PC), starch content (SC) and oil content (OC). Analyses were based on standard methods: PC was determined by the Kjeldahl, while OC was determined by extraction using Soxhlet method (using petroleum ether at boiling point 40-60 °C). Ash content of each sample was determined by drying samples at 550 °C.

Statistical analyses: All statistical analyses were performed with the SPSS software (version 15.0, SPSS Inc., 2006). Mean values and variation coefficients were used in the statistical analyses. Effects of the studied traits were evaluated by ANOVA. In order to asses the differentiation of local maize populations (LMP's) based on all variables that were measured, the Canonical Discriminant Analyses (CDA) was applied. CDA is a technique for classifying a set of observation into predefined classes. Relationship among different variables of the quality analyses were tested by Pearson's correlation test.

3 RESULTS AND DISCUSSION

Significant differences among the LMP's for grain yield and grain quality such as content of oil, protein, starch, ash and moisture were determined (Table. 2).

Table 2: Mean squares for grain yield and quality parameters of 20 Kosovo local maize populations

Sources of variation	d.f.	Yield per plant (g)		Oil Content (%)		Protein Content (%)		Starch Content (%)		Ash Content (%)		Moisture Content (%)	
LMP's	19	2.895	**	2.863	**	18.593	**	4.584	**	2.863	**	247.49	**
CV%		18.26		13.37		4.40		1.49		3.10		3.62	
Error	38	217.46		0.0019		0.0437		0.728		0.0019		0.003	

** Significant at $p = 0.01$.

The analysis of variance (ANOVA) showed that the LMP's differed in most characteristics (Table 3). Mean values of all measured characteristics are presented in Table 3. The mean values of the grain yield per plant at LMP's were 79.33 g plant^{-1}. It is evident from our results that local maize population GBK-7 had maximum grain yield per plant (105.13 g plant^{-1}) which is 25.8 g plant^{-1} or 32.52% higher than the mean values , whereas LMP's for GBK-13 had the lowest grain yield (59.62 g plant^{-1}) which is 19.71 g plant^{-1} or 24. 84% lower than the mean value (79.33 g plant^{-1}). High oil content maize is a special type that has been bred to have higher percent oil content (OC) than regular yellow maize. Typically, oil content of yellow maize varies from 3.5 to 4%. Ideally, high oil content maize should contain from 7 to 8% of oil (Heiniger, 1997). Kernel oil content is considered to be a quantitative trait controlled by numerous genes with small effects (Dudley, 1977). The data showed a relatively wide range among the LMP's for OC. The overall mean value for the OC was 4.44%. The genotype GBK-5 exhibited maximum OC value with 5.57%, while GBK-13 had the lowest OC value (2.56%). Different range of variation (5.26 and 7.17%) was observed by Berardo *et al*., (2009). Has *et al*., (2009) reported different values which varied from 0.04 to 12.3%. Significant values of OC were also reported by Saleem *et al*. (2008).

Table 3: Mean values of grain yield and quality characters in Kosovo local maize populations

Local maize populations	Ash content (%)	Oil content (%)	Moisture content (%)	Protein content (%)	Starch content (%)	Yield (plant^{-1}g)
GBK-1	1.44±0.020	4.37±0.032	14.48±0.030	13.02±0.215	68.58±0.535	69.69±1.060
GBK-2	1.38±0.028	4.53±0.316	14.14±0.040	11.69±0.049	69.87±0.640	88.97±9.763
GBK-3	1.33±0.080	3.83±0.520	14.56±0.005	12.50±0.205	70.70±0.362	102.55±7.230
GBK-4	1.38±0.025	4.01±0.198	14.84±0.085	11.75±0.280	70.96±0.753	93.30±5.863
GBK-5	1.39±0.055	5.57±0.456	14.16±0.045	11.59±0.176	69.97±0.761	86.29±14.657
GBK-6	1.34±0.051	4.30±0.445	14.85±0.020	11.72±0.200	70.19±0.223	82.08±21.328
GBK-7	1.34±0.035	4.78±0.413	14.14±0.040	11.32±0.202	70.43±0.355	105.13±11.017
GBK-8	1.28±0.045	4.31±0.518	14.50±0.078	11.05 ±0.435	72.15±1.162	82.43±4.787
GBK-9	1.35±0.015	4.49±0.181	14.67±0.075	11.02 ±0.258	70.02±0.920	99.86±8.741
GBK-10	1.35±0.032	4.27±0.208	14.45±0.005	11.64±0.081	70.23±0.309	78.34±17.001
GBK-11	1.34±0.043	4.37±0.457	14.56±0.046	11.59±0.134	70.92±0.453	69.83±17.969
GBK-12	1.31±0.052	4.40±0.705	14.07±0.015	11.15±0.223	70.68±0.850	75.77±17.339
GBK-13	1.36±0.030	2.56±0.181	16.42±0.111	11.99±0.161	70.36±0.420	59.62±16.243
GBK-14	1.36±0.023	4.66±0.408	14.61±0.077	11.92±0.217	70.34±1.125	78.43±3.458
GBK-15	1.45±0.070	4.44±0.866	14.19±0.043	12.49±0.308	68.63±1.341	85.47±16.479
GBK-16	1.43±0.032	4.89±0.394	14.24±0.062	12.52±0.070	67.39±0.747	67.36±29.061
GBK-17	1.38±0.026	4.67±0.050	14.01±0.075	11.86±0.160	69.41±0.660	72.67±15.445
GBK-18	1.36±0.060	5.25±0.728	14.10±0.010	11.67±0.081	69.33±1.236	67.21±14.839
GBK-19	1.37±0.023	4.85±0.496	14.63±0.026	12.11±0.209	69.24±1.400	74.39±18.798
GBK-20	1.41±0.047	4.34±0.699	14.18±0.095	11.60±0.081	70.40±1.013	47.33±10.565
Mean	1.36	4.44	14.48	11.81	69.90	79.33
CV %	3.10	13.37	3.62	4.40	1.49	18.26

The variation for protein content (PC) was found to be higher than the variation for OC. The ANOVA indicated that the differences among the LPM's for PC were highly significant (Table 3). The mean value of PC observed in the present study was 11.81%. Some of LMP's were identified with high grain PC ranging from 11.02 to 13.02%. This can be regarded as a relatively high level of PC. The LMP's also showed a high genetic variation (16.93%). The variation for the protein content has been well demonstrated by numerous studies. Has *et al*., (2009) at some LMP's reported variation from 11.2 to 15.6%; while Prasanna *et al*., (2001) presented different results which varied from 8.9 to 10.2%. From the data shown in Table 3 it is evident that the starch content (SC) of maize kernels depends to a very large extent on genotype of population. The starch content (SC) ranging between 67.39 and 72.15%, while the grand mean values of SC was 69.90%. There were significant differences at $p = 0.01$. Similar results (58.1 to 72%) for SC in different LMP were reported by Has *et al*., (2009). Also ash content (AC) ranged from 1.28 to 1.45%.

Table 4: Summary statistics for canonical discriminant standardized functions

	Discriminant functions					
	1	2	3	4	5	6
Eigenvalue	179.22	12.26	5.24	1.72	1.14	0.29
Percentage of variation	89.70	6.10	2.60	0.90	0.60	0.10
Cumulative percentage	89.70	95.80	98.40	99.30	99.90	100.00
Canonical correlation	0.99	0.96	0.91	0.79	0.73	0.47
Wilks' Lambda	0.00	0.002	0.021	0.132	0.360	0.771
Chi-square	535.17	296.24	177.31	93.04	46.98	11.97
df	114	90	68	48	30	14
Significance	<0.001	<0.001	<0.001	<0.001	0.025	0.608
Elements of Structure Matrix						
Ash Content (%)	0.003	0.291	-0.065	-0.209	-0.029	0.931 *
Oil Content (%)	-0.095	-0.005	0.133	-0.431	-0.145	0.876 *
Moisture (%)	0.789 *	-0.549	0.261	-0.019	-0.070	0.042
Protein Content (%)	0.053	0.752 *	0.503	-0.135	-0.188	-0.354
Starch Content (%)	0.015	-0.296	-0.004	0.685 *	0.471	-0.470
Grain yield (%)	-0.019	-0.082	0.092	0.506	-0.800 *	0.296

* Largest absolute correlation between each variable and any discriminant function

In table 4 the canonical discriminant functions are described, the eigenvalue, percentages of variation of each function and the cumulative variance of the six discriminant functions. Table presents as well the standardized elements of structure matrix. The first two canonical discriminant functions were significant at $p < 0.01$. It is important to point out the great relevance of the first two discriminant functions justifying 95.80% of the variability. The first discriminant function showed a significant positive correlation with the moisture (0.789) following by protein and starch content (0.053 and 0.015). But, the negative correlation (-0.019) was determined between first descriminant function and grain yiled (Table 5).

Table 5: Pearson's correlations between yield and grain quality traits

Trait	Yield	Oil Content (%)	Protein Content (%)	Starch content (%)	Ash Content (%)
Oil Content (%)	0.12				
Protein Content (%)	-0.19	-0.12			
Starch Content (%)	0.33 *	-0.15	-0.68 *		
Ash Content (%)	-0.30 *	0.17	0.69 *	-0.58 *	
Moisture Content (%)	-0.15	-0.80 **	0.09	0.14	-0.15

* = significant at $p = 0.05$. and $p = 0.01$

Maize breeders expect that kernel protein and oil content should be negatively correlated with plant yield. In our study, grain yield per plant was positively and significantly correlated with starch content ($r = 0.33$*), positively and nonsignificantly correlated with oil content ($r = 0.12$) and was negatively correlated with protein content ($r = -0.19$).

Also, the significant correlation was obtained between Ash content (AC) and protein content (PC) on value 0.69. Table 5. The possible cause for observed correlation was probably due to reduction of starch content in the grains.

The presented results are in partial agreement with the results of Has *et al*., (2009) and Salem *et al.*, (2008).

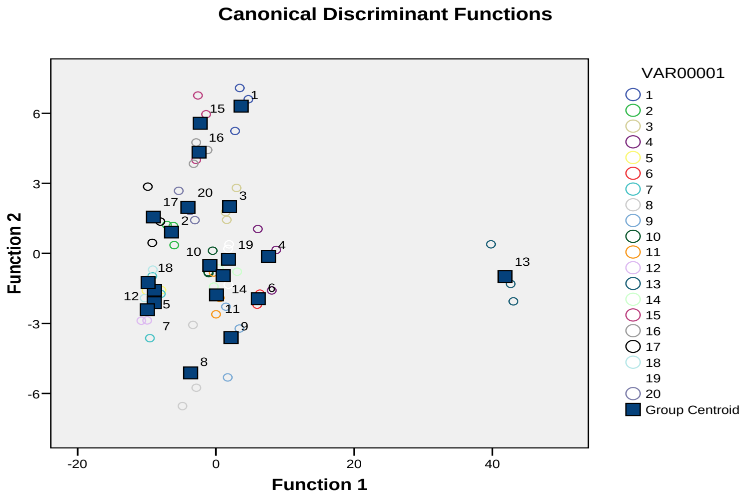

Figure 1: Canonical discriminant analyses of local maize populations by grain yield and quality characteristics applied (4 - 7 mismatches allowed at the 3' end of primers).

The canonical discriminant analysis of the traits is presented in Figure 1. The first canonical functions described 89.7% and a second canonical function is 6.1% of the existing variance. Ash content had the strongest influence in the Function 1, while the Functions 2 was mostly influenced by the oil content followed by protein content and starch content.

4 CONCLUSIONS

The study showed that there was a significant genetic variability for many traits among local maize populations. High variability was determined for PC, OC and SC. Positive and significant correlations were found between yield and starch contents. Negative correlation was found between yield and protein content. The first canonical function described 89.7% and a second canonical function is 6.1% of the existing variance. The investigated maize populations could be considered as a source of new genetic variability, and could be successfully used for the development of maize inbred lines in the Kosovo breeding program. The evaluation of plant genetic resources has been considered of prime importance, especially in those species having economic importance.

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