Notulae Scientia Biologicae

Genetic Diversity and Correlation for Grain Yield and Quality Traits in Local Maize (*Zea mays* L.)

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Abstract

The aim of the study was to estimate the genetic diversity and correlation analysis among yield and quality traits in 20 local maize populations. The study of variation included the quantity of grain yield, and quality traits such as protein, oil and starch content in grain. Results showed that there were significant differences among the populations. The mean grain yield of all populations was 79.33 g plant^{-1} and the highest in 'GBK-7' (105.13 g plant^{-1}). Protein and oil contents ranged between 11.02 to 13.02% and 2.56 to 5.57%, respectively and starch content varied from 68.58 to 70.92%. First two canonical discriminant functions were significant ($p<0.01$) and the relevance of the first two discriminant functions justifying 95.80% variability among populations. There were also big differences regarding phenotypic correlations. Study suggests that the quality traits are phenotypically and genotypically highly variable and therefore very useful for breeding program.

Keywords: local maize populations, protein, oil, starch

Introduction

Maize (*Zea mays* L.) is considered to be a major source of food for livestock and humans because of 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 Kosova's agricultural production system and has a potential to compete with other crops. In order to have access to the global market, there is 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, owing to its high starch content, which gives it priority over all other cultivated cereals (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 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 (Micu *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 to 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). However, the surface 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 also with their nutritional value because it is frequently used for human consumption as corn bread that can be consumed together with milk. In this way, the main objective of the present study and based on the descriptive results of twenty local maize populations the present paper tries to analyze of the mentioned maize local populations, and also the identification of the quality traits with more differentiating ability.

Materials and methods

Plant material and experimental design

Twenty local maize populations (LMP), collected from different regions of Kosova, were used in this study (Tab. 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. 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.

Tab. 1. Geographical data of investigated Kosovo local maize populations

Populations	Geographical origin	Longitude	Latitude	Elevation (m)
'GBK-1'	Drenas	20°44'43"	42°41'50"	567
'GBK-2'	Malisheve	20°44'09"	42°28'12"	562
'GBK-3'	Malisheve	20°43'22"	42°27'56"	576
'GBK-4'	Drenas	20°45'53"	42°41'35"	694
'GBK-5'	Prishtine	21°04'00"	42°35'05"	810
GBK-6	Kamenice	21°31'32"	42°34'16"	766
'GBK-7'	Kamenice	21°25'32"	42°33'56"	812
'GBK-8'	Lipjan	21°07'20"	42°31'45"	551
'GBK-9'	Podujeve	21°12'12"	42°33'39"	598
'GBK-10'	Drenas	20°54'06"	42°34'50"	585
'GBK-11'	Vushtrri	21°59'26"	42°50'46"	557
'GBK-12'	Ferizaj	21°09'39"	42°22'15"	580
'GBK-13'	Suhareke	20°49'02"	42°21'45"	388
'GBK-14'	Vushtrri	20°58'30"	42°33'38"	518
'GBK-15'	Drenas	20°42'32"	42°39'21"	586
'GBK-16'	Drenas	20°42'46"	42°39'30"	565
'GBK-17'	Skenderaj	20°48'23"	42°45'00"	623
'GBK-18'	Skenderaj	20°47'39"	42°44'39"	597
'GBK-19'	Skenderaj	20°48'04"	42°44'39"	603
'GBK-20'	Shtime	20°07'06"	42°44'40"	610

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 m².

Laboratory studies

At harvest time, five random ears were selected in each plot, giving 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 orders to form a balanced sample and then subjected to proximate 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 contents of each sample were determined by the dried of sample at 550°C.

Statistical analyses

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

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 (Tab. 2).

The analysis of variance (ANOVA) showed that the LMP's differed for most of the traits studied (Tab. 3). The mean values of the grain yield per plant at LMP's were 79.33 g plant[-1]. It is evident from the present 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 on code '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 values (79.33 g plant[-1]). High oil maize is a special type that has been bred to have higher percent oil content (OC) than regular yellow corn. Typically, oil content of yellow maize varies from 3.5 to 4%. Ideally, high oil 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

Tab. 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

Tab. 3. Means 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⁻¹g)
'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

Tab. 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

Tab. 5. Pearson's correlations among yield and grain quality traits of investigated populations

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

*means significant at *p*=0.05

this trait. The mean value of the OC was 4.44%. The genotype 'GBK-5' exhibited maximum OC on value 5.57%, while 'GBK-13' had the lowest value of OC (2.56%). Different ranges of variation (5.26 and 7.17%) were 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).

The variation in protein content (PC) was found to be higher than variation in OC. The ANOVA indicated that the differences among the LPM's for PC were highly significant (Tab. 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 of 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 Tab. 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) was with variation which ranged from 1.28 to 1.45%.

Tab. 4 described the canonical discriminant functions, the eigenvalue, percentages of variation of each function and the cumulative variance of the six discriminant functions. This table also shows the standardized elements of structure matrix. The first two canonical discriminant functions were significant (*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 (Tab. 5).

Maize breeders expect that kernel protein and oil content should be negatively correlated with yield per plant. In the present study, grain yield per plant was positively and significantly correlated with starch content (r=0.33*), nonsignificant and positively correlated with oil content (r=0.12) but it was nonsignificant and negatively correlated with protein content (r=-0.19) (Tab. 5). The possible cause of such relations between nutritional qualities with
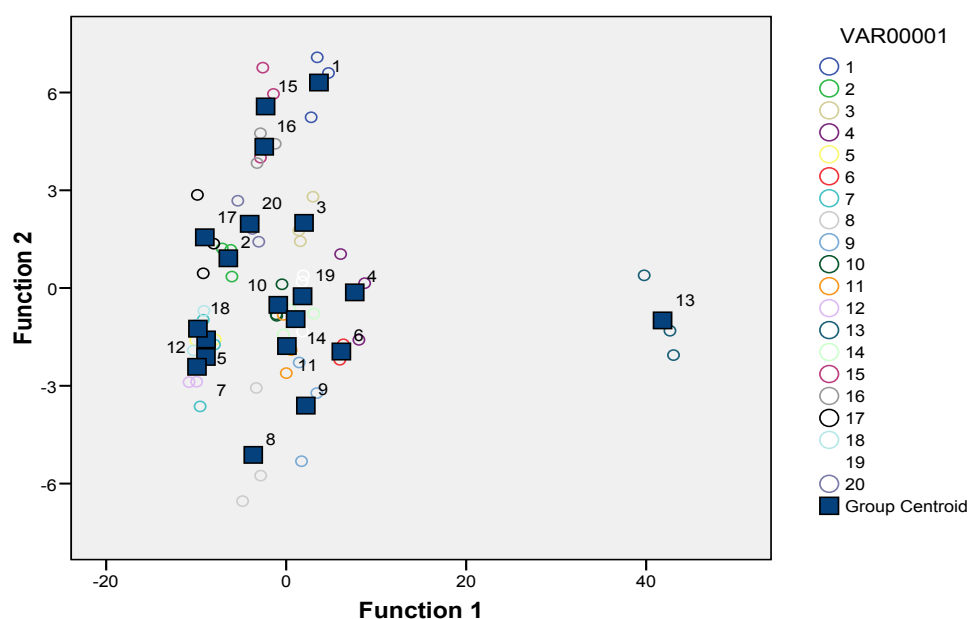
Canonical Discriminant Functions

Fig. 1. Canonical disriminant analyses of local maize populations by grain yield and quality characteristics

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yield was probably due to reduction of starch content in the grains. The present results are in partially agreement with the results of Has *et al*. (2009) and Saleem *et al*. (2008).

The canonical discriminant analysis of the traits is presented in Fig. 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 (OC) followed by protein content (PC) and starch content (SC).

Conclusions

The study showed that there was a significant genetic variability in many traits among studied 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 functions described 89.7% and a second canonical function is 6.1% of the existing variance. The investigated maize populations can be considered as a source of new genetic variability, and can be successfully used for the development of maize inbred in the further breeding program. The evaluation of germplasm resources has been considered of prime importance, especially on those species that have a further economic interest.

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