

VARIABILITY OF YIELD AND KERNEL QUALITY PARAMETERS OF POPCORN HYBRIDS (*ZEAMAYS L. EVERTA*) VARIJABILNOST PRINOSA I PARAMETARA KVALITETA ZRNA HIBRIDA KUKURUZA KOKIČARA (*ZEAMAYS L. EVERTA*)

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ABSTRACT

The experiment with 12 popcorn hybrids was set up according to the RCB design in three replicates. Examined traits were: grain yield (GY), popping volume (PV) and number of kernels per 10g (NK). ANOVA showed statistical differences among examined genotypes according to all three traits. Grain yield of the hybrids varied from 3.36 t/ha (ZPSK 645/1k) up to 6.07 t/ha (ZPSK 611k). The lowest popping volume had hybrid ZPSK 501k (27.33 cm³/g), which is considered unsatisfactory, while five hybrids had good popping volume over 38.00 cm³/g. Negative correlation was determined between GY and PV (-0.52), which although wasn't significant indicated that higher yielding hybrids often have lower popping volumes. Significant correlation was between GY and NK (-0.70*), and between NK and PV (0.66*). These results point out to the fact that breeding of popcorn is very complex process, for there is necessity of producing high yielding and good popping quality hybrids, which is mostly contradictory.

Key words: popcorn, grain yield, popping volume, number of kernels in 10 g.

REZIME

Definisanje visokog kvaliteta kukuruza kokičara zavisi od aspekta kako proizvođača, dorađivača tako i potrošača. Zbog toga se posebna pažnja u oplemenjivanju kukuruza kokičara posvećuje povećanju prinosa, ali sa zadržavanjem i povećanjem kvaliteta iskokanog i neiskokanog zrna. Oglad sa 12 hibrida kukuruza kokičara postavljen je po principu slučajnog bloka u 3 ponavljanja. Ispitivane su osobine: prinos zrna kukuruza, zapremina kokičavosti i broj zrna u 10 g. Analiza varijanse pokazala je da postoje statistički značajne razlike između posmatranih genotipova u pogledu sve tri osobine. Prinos zrna hibrida u ovom istraživanju, kretao se od 3,36 t/ha (ZPSK 645/1k) do 6,07 t/ha (ZPSK 611k). Najmanju zapreminu ostvario je hibrid ZPSK 501k (27,33 cm³/g), što se smatra izuzetno niskom zapreminom, dok je 5 hibrida imalo dobru zapreminu kokičavosti od preko 38,00 cm³/g. Najvišu zapreminu kokičavosti ostvario je ZPSK 649/1k sa 39,50 cm³/g. Šest hibrida iz ovog istraživanja imalo je krupno zrno, pet hibrida je bilo srednje krupnoće zrna, dok je hibrid ZPSK 501k (83 zrna u 10 g) bio sitnog zrna. Negativna korelacija utvrđena je između prinosa i zapremine kokičavosti (-0,52), koja iako nije bila značajna ukazuje na srednju jačinu zavisnosti između parametara i na to da prinostiji hibridi uglavnom imaju manju zapreminu kokičavosti. Značajna negativna korelacija utvrđena je između prinosa i broja zrna u 10 g (-0,70*), dok je značajna pozitivna korelacija bila je između broja zrna u 10 g i zapremine kokičavosti (0,66*). Ovakvi rezultati govore u prilog kompleksnosti procesa oplemenjivanja kukuruza kokičara.

Cljučne reči: kukuruz kokičar, prinos, zapremina kokičavosti, broj zrna u 10 g.

INTRODUCTION

Popcorn is the special flint type of maize, which is distinctive by its ability to form large "flake", as a response to heating of kernel. Therefore beside the yield itself as the major trait, quality of the popped kernel i.e. popping volume is important as much for this type of maize. Unlike the corn of the standard grain quality, the grain of popcorn mainly consists of the hard endosperm, built out of closely packed, polygonal starch granule, without aerated subspace, with the size 7-16µm. The grain explodes at the temperature of about 177°C, which is equal to the pressure of water vapor of 932 kPa (2,5t/cm²) inside of the grain. Popping volume is the genotype feature, determined by 4-5 major genes and several minor genes which contribute the quality of other traits such as shape, tenderness of the flake and pericarp dispersion during explosion (Ashman, 1983). In the moment of explosion of grain, overheated water turns into the vapor which makes the pressure and causes the spreading of starch grains into the fine film after the pericarp explodes (Hosney et al., 1983). In order to fulfill the maximum genetic potential in popping volume harvest should be performed in the full maturity of the grain and the moisture content of the grain should not exceed 16-18%. Drying of the grain should also be performed with maximum care to the moisture content between 13-14.5%, which gives the best popping results (Pajić et al., 2005). Low as well as the high moisture content in the grain

causes poor popping and low popping volume (Pajić et al., 2006a). Beside that, different alteration of pericarp, which occurs during the harvest and processing, lowers down the percentage of popped kernels and the popping volume.

Quality popcorn hybrids demand to have high and stabile yields as well as high popping volumes and quality flakes. As these two traits are in general in low dependency (Pajić et al., 2006b), or in negative correlation (Erić et al., 2003; Srdić and Pajić, 2007; Srdić and Pajić, 2008) that presents a great challenge to popcorn breeders to make high yielding and high quality popcorn hybrids.

The aim of this study was to determine variations in grain yield, popping volume and number of kernels per 10g in 12 popcorn hybrids in order to select high yielding and good quality hybrids.

MATERIAL AND METHOD

In this study 12 popcorn hybrids selected in Maize Research Institute Zemun Polje were used. Three of them were commercial hybrids (ZPSC 611k, ZPSC 614k and ZPTC 501k), while the other nine were experimental hybrids. The trial was set up according to the RCB design with three replicates in 2010. The size of the elementary plot was 7 m², with 40 plants per genotype in two rows, and the sowing density of 57.142 plants/ha.

Grain yield and the moisture content were measured at the harvest, and the grain yield was calculated to 14% grain moisture. Samples for popping volume were naturally dried down to 14% moisture. The shelling was performed manually in order to protect pericarp from damaging, which lowers down number of popped kernels and popping volume. Popping volume was determined by the standard procedure (MWVT- Metric Weight Volume Test), with the apparatus Cretors 2300w – Official Metric Wight Volume Tester, which performs popping of kernels with oil. The size of the kernel was measured by the number of kernels per 10g, and the classification is: large kernels (52-67); middle sized (68-75); small (76-105) and very small (>105 kernels in 10g) (Dumanović and Pajić, 1998).

Data were analyzed by analysis of variance (ANOVA) and the treatment means were compared using Fisher's least significant test – LSD (p<0.01). Average values of grain yield, popping volume and number of kernels per 10g were compared by Spearman's rank correlation coefficient (Zar, 1999).

RESULTS AND DISCUSSION

The average grain yield of twelve popcorn hybrids was 4.30 t/ha, and it varied from 3.36t/ha (ZPSC 646/1k) up to 6.07 t/ha for the standard and well known hybrid ZPSC 611k (Table 1.). The lowest average estimate of popping volume was 27.33 g/cm³ for the hybrid ZPTC 501k and three more hybrids had very low popping volume ranging from 31.67 up to 34.50 g/cm³ which is considered unsatisfactory (ZPSC 616k, ZPSC 644/1k and ZPSC 646/1k). Among those hybrids ZPSC 616k had the second highest average grain yield. Three popcorn hybrids had moderately high popping volumes from 37.00 -38.00 g/cm³ (ZPTC620/1k, ZPTC 730/1k and ZPSC 647/1k). Yields of those three hybrids were around the average estimate for the twelve hybrids in this experiment and in all cases above 4.00 t/ha. Popping volumes over 38.00 g/cm³ are considered satisfactory and five of our examined hybrids were in this category (ZPSC 611k, ZPSC 643/1k, ZPSC 645/1k, ZPSC 648/1k and ZPSC 649/1k). The highest popping volume was found in hybrid ZPSC 649/1k, while it is important to notice that this hybrid was among the lower yielding hybrids – below the average (3.91t/ha). This points to the fact that lower yielding hybrids usually have higher popping volumes and vice versa such in hybrid ZPSC 616k, which presents significant task to the popcorn breeders (Srdić and Pajić, 2007). Nevertheless one hybrid stood out among the examined genotypes – ZPSC 611k, for it had popping volume over 38.00 g/cm³ and the highest yield of all.

Table 1. Average values and LSD for grain yield, popping volume and number of kernels per 10g for 12 popcorn hybrids

Hybrid	GY (T/ha)	PV (g/cm ³)	NK 10 g
ZPSC 611k	6.07	A	38.17 BCD 62.67 F
ZPSC 616k	5.17	AB	31.67 G 62.33 F
ZPTC 501k	4.18	BCD	27.33 H 83.00 A
ZPTC 620/1k	4.76	BC	37.00 E 62.67 F
ZPSC 643/1k	3.49	CD	38.33 BC 71.67 BC
ZPTC 730/1k	4.14	BCD	37.67 CDE 66.67 E
ZPSC 644/1k	4.52	BCD	32.00 G 58.67 G
ZPSC 645/1k	3.36	D	38.83 AB 70.67 BC
ZPSC 646/1k	3.53	CD	34.50 F 70.00 BCD
ZPSC 6471k	4.36	BCD	37.17 DE 67.67 DE
ZPSC 648/1k	4.09	BCD	38.67 ABC 72.67 B
ZPSC 649/1k	3.91	BCD	39.50 A 69.67 CD
average	4.30		35.91 68.19
LSD _{0.01}	1.31	1.10	2.78

Number of kernels per 10 g showed the size of the popcorn kernels. Six hybrids had large sized kernels (ZPSC 611k, ZPSC 616k, ZPTC 620/1k, ZPTC 730/1k, ZPSC 644/1k and ZPSC 6471k), five were middle sized (ZPSC 643/1k, ZPSC 645/1k, ZPSC 646/1k, ZPSC 648/1k and ZPSC 649/1k), while ZPTC 501k (83 kernels in 10g) had small sized kernels (Table 1.).

Analysis of variance showed that there were statistical differences among hybrids concerning all three examined traits (Table 2.). Significant differences among hybrids according to the LSD test are especially noticeable in traits popping volume and number of kernels per 10g (Table 1). High influence of the genetic factor on the expression of the traits - grain yield and quality of the popped kernel is proven in many researches (Dofing et al., 1991; Zigler, 1994; Pajić et al., 2006b; Srdić and Pajić, 2007; Srdić and Pajić, 2008).

Table 2. ANOVA for grain yield, popping volume and number of kernels per 10g

Source of variation	d.f.	Mean Square		
		GY	PV	NK
Replication	2	0.76	0.09	0.11
Hybrid	11	1.78**	42.19**	23.18**
Error	22	0.26	0.19	1.20

** significant at the 0.01 probability level

The correlation between grain yield and popping volume determined by the Spearman's rank correlation coefficient, was negative. Although it was not significant it showed, as expected that higher yielding hybrids had lower popping volumes, and those that yielded less in general had higher popping volumes. In regard to that those two traits are in negative correlation (Erić et al., 2003; Srdić and Pajić, 2007) it presents great difficulty to the popcorn breeders, as the market demands high yielding and good popping volumes in popcorn hybrids.

Table 3. Rank correlation coefficient

	Grain yield	Popping volume
Popping volume	- 0.52	
Number of kernels per 10g	- 0.70*	0.66*

* significant at the 0.05 probability level

CONCLUSION

Defining the term of high quality of popcorn hybrids depends on the view of the producer, processor and the consumer of popcorn. That is why during breeding process, special attention is paid equally to the increase of the yield and maintaining and increasing the quality of the popped and unpopped kernel. Those demands are very difficult to accomplish as the yield and quality traits in popcorn are in general negatively correlated.

Grain yield of the hybrids in this research varied from 3.36 t/ha (ZPkok 8) up to 6.07 t/ha (ZPSC 611k). The lowest popping volume had hybrid ZPTC 501k (27.33 cm³/g), which is considered unsatisfactory, while five hybrids had good popping volume over 38.00 cm³/g. The highest popping volume had hybrid ZPSC 649/1k with 39.50 cm³/g. Hybrid ZPSC 611k, was the only hybrid with high yield and high popping volume over 38.00 g/cm³. Six hybrids had large sized kernels, five were middle sized, while ZPTC 501k (83 kernels in 10g) had small sized kernels. Analysis of variance showed that there were statistical differences among hybrids concerning all three examined traits.

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