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## EVALUATION OF AGRONOMIC AND SENSORY CHARACTERISTICS OF THE POPCORN KERNEL

### PROCENA AGRONOMSKIH I SENZORNIH KARAKTERISTIKE ZRNA HIBRIDA KUKURUZA KOKIČARA

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#### ABSTRACT

This research encompassed a total of 12 popcorn hybrids planted according to the RCBD in three replicates in Zemun Polje in 2016. The following traits were analyzed: grain yield (t/ha), kernel size, 1000 kernel weight, popping volume, percentage of unpopped kernels, and sensory characteristics (the appearance, taste, smell, tenderness, crispness, adhesiveness to the teeth, presence of pericarp and overall taste acceptability of popcorns). The analysis of variance showed significant differences between the popcorn hybrids with regard to the traits analyzed. The grain yield ranged from 4.78 t/ha (ZP 644/1k) to 7.38 t/ha (ZP 557/1k). The lowest popping volume was noticed in ZP 501k (28 cm<sup>3</sup>/g), whereas the highest popping volume was found in the lower-yielding hybrid ZP 544/1k (40.17 cm<sup>3</sup>/g). The percentage of unpopped kernels was very low and it ranged from 0.66% to 4.57%. The analysis of sensory characteristics of popcorns also showed differences between 12 popcorn hybrids.

**Key word:** popcorn hybrids, popping volume, grain yield, sensory characteristics.

#### REZIME

Kukuruz kokičar predstavlja specijalnu vrstu kukuruza tvrduca koji se najčešće koristi za ljudsku ishranu. Zbog toga je kod ove vrste kukuruza, pored prinosa, od izuzetnog značaja i kvalitet njegovog iskakanog zrna. Za ovaj rad je odabrano 12 hibrida kukuruza kokičara, koji su bili posejani po modelu RCBD u tri ponavljanja u toku 2016. godine. Ispitivane su sledeće osobine: prinos, karakteristike neiskakanog zrna – veličina zrna i apsolutna masa, zapremina kokičavosti i senzorne karakteristika kokice – izgled, ukus, miris, nežnost i hrskavost, lepljenje za zube, prisustvo perikarpa i opšta ocena. Prinos suvog zrna kretao se od 4,78 t/ha (ZP 644/1k) do 7,38 t/ha (ZP 557/1k). Najmanju zapreminu kokičavosti imao je hibrid ZP 501k (28 cm<sup>3</sup>/g), dok je najvišu zapreminu kokičavosti postigao hibrid ZP 544/1k (40.17 cm<sup>3</sup>/g). Procenat neiskakanog zrna bio je veoma nizak i kretao se od 0,66% do 4,57%. Veličina zrna određena je metodom broja zrna u 10 g i bila je u potpunoj saglasnosti sa apsolutnom masom zrna. Analizom varijanse utvrđena je varijabilnost između genotipova po svim analiziranim osobinama. Analiza senzornih karakteristika kokica pokazala je takođe da postoje razlike između ispitivanih hibrida, kao i da hibridi koji imaju kokice sa najpoželjnijim senzornim karakteristikama nisu oni koji su najprinosniji ili hibridi sa najvećom zapreminom kokičavosti. Rezultati ovog istraživanja ukazuju na to da u selekciji hibrida kukuruza kokičara treba podjednako obratiti pažnju na odabir visokoprinosnih genotipova, ali uz postizanje i zadržavanje visokog kvaliteta krajnjeg proizvoda – kokice.

**Ključne reči:** kukuruz kokičar, zapremina kokičavosti, prinos, senzorne karakteristike.

#### INTRODUCTION

Popcorn is a special type of flint corn primarily used for human consumption. Its production and consumption at the domestic and international level is rising mostly due to its valuable nutritive characteristics. Popcorn is consumed as a popular snack for its exceptional nutritional and functional properties, i.e. the average dietary fiber content of 17.79%, and low calorie count when prepared without oil or fat (Park *et al.*, 2000; Paraginski *et al.*, 2016). Moreover, this type of corn is equally attractive to producers and merchants (owing to its high profitability), as well as consumers, so the breeding of popcorn must meet all their demands (Soylu and Tekkanat, 2007; Silva *et al.*, 2010; Ribeiro *et al.*, 2012). Popcorn producers emphasize the use of high-yielding popcorn hybrids, whereas merchants and consumers pay increased attention to the quality of popped kernel, its volume and sensory characteristics. Therefore, the development of desirable sensory traits of popcorn is a topical issue at present. These traits are generally in a negative correlation, i.e. high-yielding popcorn hybrids usually produce low-popping volume of the flake (Rangel *et al.*, 2011; Srdić and Pajić, 2011; Pajić *et al.*, 2012; Cabral *et al.*, 2016). This poses a great challenge in popcorn breeding because certain factors favor one main trait at the expense of the other (Amaral *et al.*, 2016). Conversely, Sweley *et al.* (2012) found that some sensory

characteristics such as popcorn texture and softness are positively correlated with the popping volume.

The popping volume is highly depended on the chemical composition of the kernel, mostly the proportion of hard endosperm. On the other hand, the grain yield is positively correlated with the 1000 kernel weight, share of the soft starch and kernel size, which all decrease the popping expansion (Hallauer *et al.*, 2010). Amaral *et al.* (2016) suggested a trait-expanded popcorn volume per ha PV, which provides an advantageous option for the reliable acquisition of simultaneous gains in both major traits of economic interest in popcorn, i.e. grain yield and popping volume.

The purpose of this study is to evaluate the agronomic and sensory characteristics of 12 ZP popcorn hybrids. The evaluation of popcorn hybrids should provide valuable information on the commercially desirable traits of the hybrids analyzed.

#### MATERIAL AND METHOD

A total of 12 popcorn hybrids were selected for this research, 3 commercial (ZP 611k, ZP 614k and ZP 501k) and 9 experimental, which were planted according to the RCBD in three replicates in the nursery field in Zemun Polje in 2016. The sowing density was 57,142 plants/ha, in the elementary plot of 7 m<sup>2</sup>, with 40 plants per genotype sown in two rows. Manual harvesting was performed when the grain moisture content was

below 18%. The trashing of the material was also performed manually in order to minimize the pericarp damage. The grain moisture content of 14% was achieved by the natural air convection at room temperature in the laboratory. Moisture content was monitored by a Dickey-john GAK II moisture meter. At the grain moisture content of 14%, the standard samples of 250 g of each hybrid were popped, and the standard Metric Weight Volume Test (MWVT) procedure was applied using the Cretors 2300w – Official Metric Weight Volume Tester. Popping was performed with the standard amount of oil (150 ml).

The following agronomic traits were analyzed: grain yield (t/ha), kernel size (No. of kernels per 10 g), 1000 kernel weight, popping volume and the percentage of unpopped kernels. A total of eight sensory characteristics of popped flakes were evaluated, i.e. the appearance, taste, smell, tenderness, crispness, adhesiveness to the teeth, presence of pericarp and overall taste acceptability. At the end of the experiment, the average estimates of the traits analyzed were calculated. Sensory characteristics were evaluated by 18 voluntary panelists. Each panelist evaluated every sensory characteristic using a 1–9 score. The 9-point hedonic scale was applied ranging from 1 (extremely dislike), over 5 (neither like nor dislike) to 9 = extremely like.

The ANOVA was applied to analyze the results of grain yield obtained and other agronomic traits, as well as to establish differences between the genotypes. The comparisons between the average estimates computed were performed by the LSD tests.

## RESULTS AND DISCUSSION

The analysis of variance showed that 12 ZP hybrids differ significantly with regard to the traits analyzed: grain yield, popping volume, kernel size and percentage of unpopped kernel (Table 1). Consistent with the results obtained in this study, Soyulu and Tekkanat (2007) found significant differences between the genotypes analyzed according to the popping volume, percentage of unpopped kernels, kernel size, 1000 kernel weight, but also with respect to the flake size, protein content, test weight and sensory evaluation.

Table 1. ANOVA and mean squares for the grain yield, popping volume, grain size and percentage of unpopped kernels of the 12 ZP maize hybrids analyzed

Sources of variation	d.f.	Grain yield	Popping Volume	Kernel size	% of unpopped kernels
Replications	2	0.648	0.028	7.00	0.201
Genotype	11	1.547**	30.399**	134.39**	4.594**
Error	12	0.209	0.111	8.939	0.144

\*\* significant at the 0.01 probability level

The highest yielding popcorn hybrid was the experimental hybrid ZP 557/1k (7.38 t/ha). Its grain yield was significantly higher than those recorded in all other hybrids, even the commercial hybrid ZP 611k which immediately followed in yields (6.61 t/ha). The lowest grain yield was produced by ZP 644/1k (4.78 t/ha), which was also significantly lower than those recorded in all other hybrids. The popping volume ranged from 28 cm<sup>3</sup>/g (ZP 501k) to 40.17 cm<sup>3</sup>/g (ZP 544/1k). The best yielding hybrid (ZP 557/1k) was ranked eighth according to the popping volume. This confirms the ever-present hindrance in breeding high-yielding and high-popping volume popcorn hybrids found in many studies and in practical work, i.e. the negative correlation between the grain yield and popping volume

(Srdić and Pajić, 2011; Pajić et al., 2012). Conversely, the ranking of the hybrids ZP 611k and ZP 586/1k did not differ significantly according to the traits noted above. Both hybrids had very high estimates for these traits, i.e. ZP 611k was ranked second according to the yield and third according to the popping volume, whereas ZP 586/1k was the third best yielding hybrid and had the second best popping volume (Table 2). Some studies indicate that there is a positive correlation between grain yield and popping volume, although non-significant and of a low magnitude (Amaral et al., 2016). The percentage of unpopped kernels was very low and it ranged from 0.66% (ZP 586/1k) to 4.57% (ZP 501k). It was even lower in comparison with the research by Soyulu and Tekkanat (2007). These authors included our hybrid ZP 611k in the study, which also indicated favorable estimates consistent with those obtained for the ZP 611k hybrid in the present study. The number of kernels per 10 g indicates the size of the kernel. In this study, small kernels (> 76 kernels per 10g) were recorded in four hybrids (ZP 501k, ZP 645/1k, ZP 544/1k and ZP 644/1k). Five hybrids had midsize kernels (68-76), and three hybrids had large kernels (< 67) (ZP 611k, ZP 542/1k and ZP 657/1k). The 1000-kernel weight was presented only as a preliminary result, and without comparisons according to the LSD, as there were not enough replications. Nevertheless, this trait was completely in accordance with the kernel size. Featuring the largest kernels, the hybrid ZP 657/1k had the highest 1000-kernel weight. The kernel size, as well as the 1000-kernel weight, greatly influences the popping volume (Gökmen, 2004; Soyulu and Tekkanat 2007), and large-sized kernels mostly produce a lower popping volume due to the high percentage of soft endosperm (Gökmen, 2004; Pajić and Babić, 1991). In this experiment, it was also found that large-sized kernels of the hybrids 542/1k and ZP 657/1k had a very low popping volume of 35 cm<sup>3</sup>/g. The best popping volume was produced by smaller-sized kernels of the popcorn hybrid ZP 544/1k (Table 2).

Table 2. Mean estimates and LSD values of the grain yield, popping volume, grain size and percentage of unpopped kernels, as well as the mean estimates for the 1000 kernel weight of 12 ZP maize hybrids

Hybrid	Grain yield (t/ha)	Popping Volume (cm <sup>3</sup> /g)	Percentage of unpopped kernels	Kernel size (No. of kernels per 10g)	1000 kernel weight (g)
ZP 611k	6.61 b	38.33 abc	1.45 c	65.00 fgh	161.3
ZP 614k	6.49 bc	33.83 e	3.46 b	67.67 efg	151.9
ZP 501k	6.20 bcd	28.00 f	4.57 a	82.00 a	117.6
ZP 541/1k	5.79 cde	38.00 abc	1.17 cd	73.00 bcde	143.3
ZP 542/1k	5.71 de	35.67 cde	0.92 cd	62.33 gh	168.2
ZP 657/1k	5.29 ef	35.00 de	1.17 cd	60.00 h	167.3
ZP 544/1k	5.68 de	40.17 a	0.98 cd	77.33 abc	140.2
ZP 645/1k	5.43 def	38.00 abc	0.71 d	78.33 ab	127.5
ZP 546/1k	5.40 ef	37.00 bcd	0.73 d	70.33 def	138.4
ZP 644/1k	4.78 f	37.67 abcd	1.03 cd	76.00 bc	147.4
ZP 557/1k	7.38 a	36.67 bcd	0.72 d	72.67 cde	141.5
ZP 586/1k	6.50 bc	39.00 ab	0.66 d	73.33 bcd	154.1

Means followed by the same letter are not significantly different according to the LSD<sub>0.05</sub>

The analysis of the sensory characteristics of popcorn flakes showed that there are differences between 12 popcorn hybrids. The average estimates of sensory characteristics ranged from 5.86/9.00 (ZP 501k) to 7.90/9.00 points (ZP 542/1k) (Table 3). The hybrid ZP 542/1k also had the highest overall taste acceptability estimate (8.39), and the highest score in all analyzed traits, except in taste where it was ranked second. Conversely, this hybrid indicated moderate yielding performance and popping volume (Table 2). However, the lowest yielding hybrid ZP 644/1k was the second best according to the sensory characteristics (8.17 overall taste acceptability). The best yielding hybrid ZP 557/1k scored moderately high estimates of the average and overall taste acceptability (7.13 and 7.11 respectively), while the hybrid with the highest popping volume ZP 544/1k performed even poorer (6.67).

Among the experimental hybrids, ZP 586/1k indicated a very high yield and popping volume, as well as favorable sensory characteristics (7.39 for the overall taste acceptability).

The results of this experiment showed that popcorn breeding is high challenging relative to market demands. Nevertheless, various breeding methods could result in enhancing the yield, popping volume and sensory characteristics of popcorn hybrids.

Table 3. Mean estimates of sensory characteristics of 12 ZP maize hybrids

Hybrid	Appear.	Taste	Smell	Tender.	Crispiness	Adhesiv. to teeth	Pres. of pericarp	Overall taste acceptability	Average
ZP 611k	6.94	6.89	7.11	6.39	6.56	5.83	6.06	6.50	6.53
ZP 614k	6.61	7.00	7.17	6.50	6.33	6.44	6.17	6.83	6.63
ZP 501k	6.17	5.72	5.83	5.78	6.39	5.89	5.67	5.44	5.86
ZP 541/1k	6.28	7.11	7.06	6.39	6.78	6.72	6.61	6.61	6.69
ZP 542/1k	8.83	8.06	8.17	7.28	7.78	7.39	7.28	8.39	7.90
ZP 657/1k	7.00	7.61	7.50	6.78	7.11	7.17	6.83	7.17	7.15
ZP 544/1k	6.78	6.94	7.06	6.83	6.56	6.11	6.39	6.67	6.67
ZP 645/1k	6.28	7.06	7.00	6.78	6.83	6.39	6.22	6.89	6.68
ZP 546/1k	7.11	7.56	7.50	6.44	7.28	6.89	6.61	7.00	7.05
ZP 644/1k	8.22	8.22	7.94	6.89	7.67	7.22	6.67	8.17	7.63
ZP 557/1k	7.33	7.28	7.44	6.94	7.44	6.89	6.56	7.11	7.13
ZP 586/1k	6.94	7.83	7.50	7.33	7.44	6.94	6.67	7.39	7.26

## CONCLUSION

The results of this research confirmed that the popcorn genotype greatly affects the expression of the traits examined. There were significant differences between the experimental hybrids concerning all the traits analyzed. The hybrid that achieved the highest yield (ZP 557/1k – 7.38 t/ha) did not present such a satisfactory result regarding the popping volume (36.67 cm<sup>3</sup>/g). Moreover, the highest-yielding hybrids, with the highest popping volume, did not always possess the most attractive sensory characteristics. Conversely, the hybrids ZP 611k and ZP 586/1k performed very well according to the yield and popping volume, whereas the hybrid ZP 586/1k exhibited very good sensory characteristics. These results underscore the paramount importance of high-yielding genotypes and the quality of final products in the popcorn hybrid breeding.

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