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Agronomic traits of QPM maize hybrids adapted to temperate regions

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Abstract

In this paper agronomic characteristics of quality protein maize (QPM) hybrids adapted to temperate regions created in Maize Research Institut Zemun Polje are presented. Hybrid ZPQPM13 showed favorable traits for growing in these regions, and its grain yield was at the level of one of the leading ZP hybrids - ZP 606. However, grain moisture of this hybrid was 3% higher than that of ZP 606, pointing out to the tropical origin of its parental inbred lines. Namely, mother was obtained from F_1 cross between tropical and adapted lines, and father by marker assisted selection (MAS) from QPM line of tropical origin that was crossed and twice backcrossed with a commercial ZP line. In the future, in order to obtain even more adapted QPM hybrids, MAS program will continue with all the best commercial ZP inbred lines of all FAO groups.

Keywords: *Zea mays* L., *opaque2*, grain yield, grain moisture, lodging

Introduction

Maize kernel contains proportionally the highest quantity of proteins compared to the other cereals. However, its proteins are lacking two essential amino acids, lysine and tryptophan, that humans and monogastric animals cannot produce (Gernach et al., 2011). The malnutrition is the consequence of the fact that maize is a staple food in the undeveloped regions of the world. Homozygous recessive *opaque2* mutation (*o2o2*) leads to significant increase in these two amino acids, but this allele has several negative pleiotropic effects (soft kernel that crushes a lot, high incidence of lodging, susceptibility to insects and diseases) and could not be accepted commercially (Vasal, 2001). In CYMMIT (International Maize and Wheat Improvement Center) in Mexico City, by a large number of cycles of recurrent selection breeders succeeded to convert soft into hard endosperm of *o2o2* maize, and improve its agronomic traits to the level of the leading conventional hybrids (Vivek et al., 2008). Such maize was called Quality Protein Maize (QPM). Firstly developed QPM is of tropical origin, so there are constrains and difficulties to adapt it to temperate regions. Some researchers have shown positive effects in human and animal consumption with QPM (Krivanek et al., 2007; Mbuya et al., 2011). So far, a few attempts have been made to make temperate adapted QPM (Scot et al., 2009; Carena, 2013; Woral et al., 2015). In Maize Research Institute Zemun Polje we begun a QPM program in 2008, including developing new QPM lines from the crosses of tropical and commercial temperate lines, as well as marker assisted selection (MAS) for converting elite ZP inbred lines to their QPM versions (Ignjatović-Micić et al., 2013; Kostadinović et al., 2014). MAS have resulted in conversion of a line ZPL-5 of Lancaster origin, which is a father of series of the most commercial ZP hybrids (Kostadinović et al., 2016) to QPM (now called ZPL-5QPM). The rest of our commercial lines are in the last stages of conversion by MAS. Taking into consideration previously mentioned facts, the purpose of this research was an attempt to create the first ZPQPM hybrids well adapted to our climate and with agronomic traits at the level of commercial conventional hybrids.

Material and Methods

In 2015, by courtesy of M.P. Scott from Iowa State University, we have obtained a series of QPM lines (BQPM9, 10, 11, 12, 13, 15, 16 and 17) that were derived from two CYMMIT tropical lines and six lines released by Iowa State University (B91, 97, 98, 99, 100 and 113) and are adapted to the US corn belt (Worral et al., 2015). These lines were sawn in Zemun Polje in 2016 in two replications for evaluation of agronomic traits and adaptation to our environmental conditions. Lines BQPM 9, 10 and 11 were selected for further work. On the other hand, from ZP QPM program three lines were chosen: GS-4, 5 and 6, that are derived from the same sources but in Serbian conditions. In winter nursery 2015/16 (Chile) this six lines were crossed as mothers as well as fathers with converted ZPL-5QPM line. The cross with line GS-5 as a father failed to produce seed. The hybrids were consecutively coded (Table 1).

Table 1. Codes of the experimental QPM hybrids

No.	Hybrid code	Hybrid combination
1	ZPQPM1	ZPL-5QPM × BQPM9
2	ZPQPM2	BQPM9 × ZPL-5QPM
3	ZPQPM3	BQPM10 × ZPL-5QPM
4	ZPQPM4	ZPL-5QPM × BQPM10
5	ZPQPM5	ZPL-5QPM × BQPM11
6	ZPQPM6	BQPM11 × ZPL-5QPM
7	ZPQPM9	GS-4 × ZPL-5QPM
8	ZPQPM10	ZPL-5QPM × GS-4
9	ZPQPM11	GS-5 × ZPL-5QPM
10	ZPQPM13	GS-6 × ZPL-5QPM
11	ZPQPM14	ZPL-5QPM × GS-6

In 2017 a test-trial in four locations, according to the Randomized Complete Block Design (RCBD) with three replications was conducted with obtained QPM hybrids and check hybrids: ZP 555, ZP 560, ZP 600, ZP 666 and ZP 606. The elementary plot consisted of two rows 0.75m apart with 20 hills per row 0.40m from each other. Sowing was done by hand, four plants per hill, and hills were thinned to two plants at 5-7 leaf stage. Plant density was 66,667 plants ha^{-1}. Harvesting was also done by hand. Standard agronomical practices were performed. Measured agronomic traits were plant height (PH) and ear height (EH; cm), lodged (LP) and broken plants (BP; %), grain moisture at harvest (GM; %) and grain yield (GY) adjusted to 14% grain moisture (t ha^{-1}). Two-way analysis of variance was performed in MSTAT-C program, and LSD test at 0.05 probability level between hybrid means was obtained.

Results and discussion

Replications were significant source of variation only for PH (data not shown). Differences between hybrids were significant for all traits: for PH, EH, GM and GY at $p<0.001$, for BP at $p<0.01$ and for LP at $p<0.05$. Locations were significant for all the traits ($p<0.001$). Hybrid × location interaction was significant at $p<0.001$ for PH, EH, GM and GY, while for BP at $p<0.05$. In Tab. 2 values of LSD test are presented. Three QPM hybrids had suitable agronomic performances, namely ZPQPM5, 6 and 13. All three hybrids had GY at the level of ZP 606, which is in fact late commercial hybrid of FAO 700, grown largely in Serbia and other countries. ZPQPM13 had higher PH than ZP 606, while other two hybrids were at the same level, while for EH ZPQPM5 and ZPQPM6 had significantly lower values than ZP 606. LP values were low for the three hybrids, bud BP had very high values for QPM hybrids (over 10%), showing this trait as a possible constraint in wide production of these hybrids. GM of ZPQPM5 and ZPQPM6 was at the level of ZP 606, while for ZPQPM13 it was higher. Considering variation of three chosen QPM hybrids over locations, ZPQPM5 had PH in the range of 181.5-227 cm, EH 70.5-90.5 cm, GM 18.50-29.55% and GY 4.44-10.60 t ha^{-1}. ZPQPM6 had 185.0-237.5 and 76.0-96.0 cm PH and EH, respectively, GM 19.45-29.00% and GY 3.79-10.46 t ha^{-1}, while ZPQPM13 had these values of 178.5-242.0 cm for PH, 74.0-103.0 cm for EH, 22.20-33.55% GM and GY 3.22-11.41 t ha^{-1}. These values point out to a large difference in the environmental conditions among test-locations. One of the main impediments to the commercial use of QPM hybrids is their frequently lower grain yield than that of standard hybrids (Scott et al., 2009). However, using MAS Babu et al. (2005) and Gupta et al. (2013) obtained higher grain yields of QPM over standard hybrids, and Jompuk et al. (2011) concluded the opposite.

Table 2. Average values of tested hybrids in 2017 with values of LSD test at 0.05 probability level

No.	Hybrid	PH	EH	LP	BP	GM	GY
1	ZPQPM1	219.4cdef1	80.88gh	4.804ab	5.969cde	25.15bc	4.522h
2	ZPQPM2	235.5ab	87.06ef	3.088abc	11.090abcde	26.88a	6.145def
3	ZPQPM3	223.1cd	82.64g	0.329c	8.586bcde	21.70g	5.722fg
4	ZPQPM4	219.5cdef	77.53h	1.005bc	13.260abc	21.07g	5.065gh
5	ZPQPM5	212.4g	81.00gh	1.024bc	11.180abcde	25.06bc	7.156c
6	ZPQPM6	217.4defg	87.50ef	1.266abc	16.130ab	25.16bc	7.030cd
7	ZPQPM9	223.6c	101.80a	4.774ab	8.630bcde	27.29a	5.349fgh
8	ZPQPM10	213.6fg	94.94bc	1.738abc	9.656bcde	24.35cd	5.122gh
9	ZPQPM11	218.5cdefg	97.94ab	5.025a	11.880abcd	22.24fg	5.958efg
10	ZPQPM13	221.5cde	91.88cd	0.313c	13.190abc	26.33ab	7.702bc
11	ZPQPM14	218.3cdefg	84.06fg	0.000c	18.470a	24.21cd	6.812cde
12	ZP 555	217.5cdefg	90.50de	0.000c	6.994cde	22.49efg	9.165a
13	ZP 560	238.5a	97.56b	0.000c	4.383de	21.52g	7.679bc
14	ZP 600	231.6b	94.69bc	3.125abc	5.360de	22.35fg	8.805a
15	ZP 666	221.0cde	89.94de	0.000c	6.665cde	23.39def	8.616ab
16	ZP 606	215.9efg	91.94cd	0.000c	4.135e	24.01cde	7.452c
$LSD_{0.05}$		6.097	4.089	3.872	7.551	2.418	0.998
Average		221.708	89.487	1.656	9.723	23.950	6.769
CV		2.75	4.57	234.09	77.73	6.49	14.76
SD		19.43	10.13	4.68	8.88	3.48	2.91

[1] - values in a column followed by all the different letters are significantly different at 0.05 probability level; CV - coefficient of variation (%); SD - standard deviation

Having the highest quantity of seed, hybrid ZPQPM5 was tested in the Pre-commission trials (from which hybrids suitable to be send into State Commission for releasing varieties are chosen), but it failed to fulfil required agronomic criteria. Since two remaining hybrids were of FAO 700-800, we have repeated the test-trial with them in 2018 at seven locations alongside with official commercial check hybrids for FAO 700: NS 6010 and AS 72 (repeated twice instead of one missing hybrid), and 800 group - ZP 735 and ZP 873, and also with ZP 606 as a check that was used in the first year of testing. The methodology of the trial was the same as in 2017, and only difference was that lodged and broken plants (LBP) were counted together before the harvest. Locations and hybrids differences for all the traits were very highly significant ($p<0.001$), as well as interaction for all traits but LBP (data not shown). In Table 3 are presented values for LSD test of this new trial.

Table 3. Average values of tested hybrids in 2018 with values of LSD test at 0.05 probability level

No.	Hybrid	PH	EH	LBP	GM	GY
1	AS 72	256.8f1	99.30d	0.5754d	21.60d	11.43b
2	ZPQPM6	271.9d	96.05e	3.413a	26.85ab	10.02de
3	ZPQPM13	277.4c	93.27f	1.956b	26.01bc	10.59cd
4	ZP 606	267.9e	94.95ef	0.762cd	22.87d	12.55a
5	NS 6010	275.2cd	108.30c	2.022b	27.26ab	9.57e
6	AS 72	258.2f	99.90d	0.905bcd	21.69d	11.47b
7	ZP 735	299.3a	116.90a	0.933bcd	28.38a	10.10de
8	ZP 873	284.2b	114.20b	1.749bc	24.91c	11.29bc
$LSD_{0.05}$		3.792	2.616	1.131	1.916	0.7944
Average		273.852	102.864	1.539	24.947	10.877
CV		2.26	4.16	120.08	12.56	11.94
SD		18.74	12.43	2.30	8.28	2.78

[1] - values in a column followed by all the different letters are significantly different at 0.05 probability level; CV - coefficient of variation (%); SD - standard deviation

The most prominent difference for two QPM hybrids tested in both years was the percentage of BP in 2017 and LBP in 2018. This was most probably due to the huge difference between meteorological conditions between the two years, namely in 2017 a few storms were recorded in the test-locations, causing high LB in QPM hybrids. Since ZP 606 is one of the best and most widely grown ZP hybrid, significance of t-test for the two QPM hybrids and this check is calculated for PH, EH, GM and GY (lodged and broken stalks were omitted due to difference in measurement in two years of the research). ZPQPM13 showed better performances over ZPQPM6. Its GY was at the level of ZP 606, although its GM was 3% higher. This is most probably due to the tropical origin of the mother of this hybrid. PH was higher, but what is more important EH was at the level of ZP 606, which is favourable due to the lesser lodging. This hybrid also had the best chemical kernel characteristics of all examined QPM hybrids. Namely, ZPQPM6 had average tryptophan content of 0.075% measured in two locations over two years, while ZPQPM13 had 0.081% tryptophan, in comparison with standard hybrids (0.069%; $p<0.01$). So ZPQPM13 was chosen and sawn on 0.5 ha in mercantile production in 2019 to produce seed for feeding trials for broilers and pigs. QPM was used on a large scale for food in undeveloped countries for improving the health of populations living there (Akuamoa-Boateng, 2002). QPM would be beneficial for developed countries as well, since soybean or artificial lysine should not be needed to add to the feed, thus lowering its cost (Scott et al., 2009). Due to a twofold growth and better usage of the meal made from QPM (Burgoon et al., 1992) a part of conventional maize could be used for some other purposes (bioethanol production). All of these results confirm the fact that QPM hybrids can be at the level of the best standard commercial hybrids regarding agronimic traits (Vivek et al., 2008). Also, temperate QPM inbred lines can have high combining abilities, which is in agreement with Ignjatović-Micić et al. (2013) and Kostadinović et al. (2016).

Conclusions

Based on the results presented herein we could draw the conclusion that it is possible to create QPM hybrids suitable for temperate conditions, both in the wiev of good agronomic traits, as well as grain quality. This task is not easy and it is time consuming, but it is attainable and worth trying.

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