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B73 AND RELATED INBRED LINES IN MAIZE BREEDING

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Inbred lines B73 and Mo17 or some versions thereof are the most commonly used parental pair in the development of medium late and late maize hybrids in Serbia and Montenegro. Because of the ever-increasing importance of line B73 in maize hybrid production, we chose several B73-type lines and a few unrelated lines and crossed them. Using the pedigree method, progenies were developed up to the S6 generation. The grain yield potential of test crosses with Mo17 inbred tester, as well as ear length, number of grain rows per ear and 1,000-grain mass of lines per-se were tested. Among the new inbred lines related to B73, line 260277/2 distinguished itself by a high potential for grain yield when crossed with Mo17. Inbred lines 260465/1, 260362/1, 260747/4, 260357/13, 260151/2 and 260156/2 had a significantly longer ear than the mean value of all progenies. Compared with progeny mean, lines 260341/7, 260317/4, 260277/2 and 260187/2 had significantly more grain rows per ear, while 260362/1, 260130/5, 260277/2, 260151/2 and 260187/2 had a significantly larger 1,000-grain mass.

Key words: inbred line, B73, grain yield, 1,000-grain mass, ear length, number of rows

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INTRODUCTION

The 1950s saw the beginning of a new phase in our country's maize breeding. The year 1953 is regarded as a turning point in the history of modern maize breeding, as it was then that the first areas were sown to seeds of hybrid maize, which was of US origin. Even more importantly for the future of domestic maize breeding and production, that same year a program for the development of domestic maize hybrids was started by the domestic research institutes. That year several hundred select plants from local open-pollinated maize populations (Vukovarski Zuban, Rumski Zuban and Šidski Zuban), which had been previously grown for years in domestic agroecological conditions and thus accumulated wide adaptability, were selfed to obtain progeny that was then used to develop the first self-pollinated lines to be used as parental components of hybrids (ŠARIĆ *et al*., 1980; TRIFUNOVIĆ, 1986). Domestic inbred lines and public lines of US origin were crossed to develop double-cross hybrids and then, soon after, single-cross ones. Among them was the hybrid NSSC70 (SAVIĆ and VIDOJEVIĆ, 1970), which was one of the most widely grown domestic maize hybrids at the time.

For hybrid development purposes, inbred lines regarded as potential parental components of hybrids were assorted into heterotic groups. Although a large number of heterotic groups have been discovered thus far in all climatic zones, only a few heterotic pairs are intensively used in inbred line development. The most frequently used pair in the US maize belt is Reid Yellow Dent x Lancaster Sure Crop (KAUFFMANN *et al*., 1982). Lines of Reid Yellow Dent origin were predominant in hybrids developed in the U.S between 1950 and 1980. Private companies made more use of non-BSSS germplasm as the source of lines, while public ones used BSSS germplasm more (SMITH *et al*., 1999). In addition to these two source, maize breeders in Serbia and Montenegro also have the wide variability of domestic germplasm at their disposal. The combination of local populations or inbred lines derived from them and B73 and Mo17 and lines related to them will produce heterotic hybrids (ŠARIĆ *et al*., 1980; RADOVIĆ and JELOVAC, 1995; STOJAKOVIĆ *et al*., 2000; IVANOVIĆ *et al*., 2002).

Given the breeders' ever-increasing interest in it, the B73/Mo17 heterotic pair will, in our opinion, continue to be a significant source of heterotic hybrid combinations in the future as well. In the present paper, we chose to focus on the improvement of traits of line B73. Germplasm recombinations within the BSSS group and between the BSSS group and the non-BSSS ones are expected to produce lines able to replace line B73, which, coupled with line Mo17, is being used the most for the development of medium late maize hybrids at present.

MATERIALS AND METHODS

The Stiff Stalk Synthetic (SSS) was developed in the early 1930s by George F. Sprague of the Iowa State University, who used recombination of 16 lines having above-average stalk sttrenght to obtain the SSS. Ten of the 16 lines had Reid Yellow Dent-type germplasm, while the rest were of partially or completely unknown origin (SPRAGUE, 1946). From its inception, the SSS has been the subject of intensive breeding using recurrent selection methods. A large number of lines have been developed as a result, including B73, obtained in the fifth cycle of SSS selection (RUSSELL, 1972).

Table 1. Name, pedigree and origin of inbred lines derived from B73 and related lines

Line	Pedigree	Origin	Type of germplasm
260341/7	796.20 x (B84)	796.20: Vukovarski zuti zuban B84: Iowa Stiff Stalk, Synthetic Cycle 7	BSSS
260465/1	B73 x A632	B73: Iowa Stiff Stalk, Synthetic Cycle 5 A632: Mt42xB14) x B14(3)	BSSS
260285/5	NS19 x NS544	NS19: B73(2) x H93, NS544: B73 Reselection	BSSS
260319/15	NS568 x NS19	NS568: B73 Reselection	BSSS
260322/1	NS568 x P3183	P3183: Hybrid (Unknown)	BSSS/Unknown
260362/1	NS19 x NS113	NS113: B84 x (B73)3	BSSS
260317/4	NS568 x NS20	NS20: B84 x (B73)2	BSSS
260130/5	NS32 x NS114	NS32: B73(2) x H93; H93: 37 x GE440)xB37(4), NS114: B73 Reselection	BSSS
260277/2	NS32 xP3183		BSSS/Unknown
260361/1	NS19 x NS2040B/92	NS2040B/92: Synthetic	BSSS
260747/4	NS796A/92	NS796A/92: Vukovarski Zuti zuban x B73, NS20, NS568	BSSS/Local
260743/9	NS2040B/92		BSSS
260357/13	NS19 x NS20	NS19: B73(2) x H93,	BSSS
260151/2	NS32		BSSS
260156/2	NS568 x P3183		BSSS/Unknown
260187/2	NS2040B/92 x ID1205.Z7	ID1205.Z7: Iodent	BSSS/Iodent
260512/1	NS20 x NS113		BSSS

As a public line, B73 has been used intensively in the maize breeding programs of the Institute of Field and Vegetable Crops in Novi Sad. Line B73 was crossed with several related lines (NS19, NS20, NS32, NS113, NS114, NS568, NS2040B/92), a line of unknown origin (P3183), an Iodent-type line (I205.Z7), and a domestic line, NS796/20, originating from the Vukovarski Žuti Zuban (Table 1). Progenies of the direct crosses or backcrosses were grown in a breeding field. Using pedigree selection, progenies with desirable traits were selected from the segregating generations up to S6. After several hundred S3 lines were tested for their combining abilities with the Mo17 tester, 17 inbreds were chosen and then tested again in the S6 generation for grain yield with Mo17 and ear characters per se.

The single-cross hybrids (17 hybrids and one standard) were tested for grain yield in trials set up in 1998 and 1999 in two locations, Rimski Šančevi and Srbobran, on a chernozem soil with 3.0-4.2% humus and neutral reaction. A randomized block design with three replicates was used. The basic plot was $10m^2$ in size and consisted of two rows. Sowing was done on April 10 and 12 in 1998 and April 10 in 1999. Harvesting was done with the two-row combine harvester HEGE 180. Grain yield (tha^{-1}) at 14% grain moisture was calculated according to the following formula: sample weight (kg/plot) x (100% grain moisture/86) x (10,000/plot area).

Used as the standard for grain yield assessment in the test crosses was a commercial hybrid between the lines B73 (the newer version) and Mo17.

During the 1998-2000 period, 17 inbred lines were grown in a breeding field at Rimski Šančevi in a trial with two replicates using a randomized block design and 20 plants per plot. Sowing was done individually on April 12, 15 and 17. At harvesting, two samples with five ears each were established out of the full stand in order to analyze the following characteristics: ear length, number of grain rows per ear, and 1,000-grain mass.

The results were processed using MSTAT (NISSEN, 1984).

RESULTS AND DISCUSSION

Mean square of error for grain yield of test crosses and ear length, number of grain rows per ear and grain mass of inbred lines (Table 2). All sources of variance were a significant source of variation of grain yield, ear length and 1,000-grain mass. Line and line x year interaction were a significant source of variation of grain row number per ear. Year had no major influence on grain number (Table 2).

Table 2. Mean square of grain yield of test crosses and ear length, number of grain rows and grain mass of inbred lines

Sources of variation	Grain yield of hybrids	Ear length of inbred lines	No. of grain rows of inbred lines	1,000-grain mass of inbred lines
A Hybrid/Line	4.65**	7.92**	13.76**	4506.88**
B Year	122.12**	0.63**	0.18	837.23**
C Location	508.85**	-	-	-
AxB	7.05**	3.22**	5.24**	952.61**
AxC	3.66**	-	-	-
BxC	146.47**	-	-	-
AxBxC	2.66**	-	-	-
error	0.56	0.12	0.47	75.76

*significant at 5%; ** significant at 1%

The grain yield of a hybrid and its parental components is the most important trait, as it has crucial influence on the economy of production of commercial and seed maize crops alike. Yield levels in the present study were affected by hybrid, year and location as well as by interactions among the three factors. On average, significantly higher yields were obtained in 1998 than in 1999 and at Rimski Šančevi compared with Srbobran. The average grain yield at the two sites over the two study years was 13.34 tha^{-1}, ranging from 12.02 tha^{-1} in 260465/1 x Mo17 to 14.29 tha^{-1} in 260277/2 x Mo17 (Table 3). Very high yields were also recorded in 260341/7 x Mo17, 260187/2 x Mo17 and 260357/13 x Mo17, while the lowest ones were observed in 260512/1xMo17 and 260747/4xMo17, in addition to the lowest–ranking hybrid 260465/1xMo17. The objective of this study was to develop hybrids with a higher potential for yield than that of the standard (B73xMo17), so the 260277/2 x Mo17 combination may be of commercial importance because of its significantly higher grain yield.

As a component of grain yield, ear length has a positive effect on it.. Among the inbred lines studied, the longest ear (16.7 cm) was found in 260465/1 (Table 3), followed by 260747/4 and 260156/2. Line 260512/1 had the shortest ear (13.3 cm).

Table 3. Mean value, LSD test and coefficient of variation (cv) of B73 family-like inbred

Line	Grain yield of hybrids (tha^{-1})	Ear length of inbre lines (cm)	No. of grain rows of inbre lines	1,000-grain mass of inbre lines (gr)
260341/7	13.98	14.8	19.7**	286.3
260465/1	12.02	16.7**	17.0	319.0*
260285/5	12.93	13.6	16.3	297.7
260319/15	13.52	14.9	16.7	317.7*
260322/1	13.11	14.2	16.7	302.7
260362/1	13.62	15.3**	16.7	322.0**
260317/4	13.65	14.2	18.7**	293.7
260130/5	13.57	14.2	17.3	355.3**
260277/2	14.29*	15.2*	17.7**	328.0**
260361/1	12.93	13.5	17.3	261.0
260747/4	12.61	16.1**	15.7	287.3
260743/9	13.68	14.3	15.7	306.3
260357/13	13.73	15.5**	16.3	302.0
260151/2	13.26	15.3**	16.3	338.7**
260156/2	13.49	15.9**	15.0	307.3
260187/2	14.08	14.6	18.3**	328.7**
260512/1	12.13	13.3	15.7	297.0
B73 x Mo17	13.53	-	-	-
Average	13.34	14.80	16.80	308.86
LSD 5%	0.60	0.32	0.64	8.14
LSD 1%	0.80	0.43	0.85	10.77
CV %	5.62	2.33	4.09	2.82

The inbreds differed in grain row number per ear as well. The largest and smallest values of this trait were found in lines 260341/7 (19.7) and 260156/2 (15.0), respectively (Table 3). Compared with the progeny average, a larger value of the trait by a highly significant margin was also found in 260317/4, 260187/2 and 260277/2.

The 1,000-grain mass, or absolute mass, is an indicator of grain size. In the present study, the average 1,000-grain mass for the 17 inbred lines was 308.86 grams, ranging from 261.0 to 355.3 grams in 260361/1 and 260130/5, respectively (Table 3). Above-average 1,000-grain masses were found in 260362/1, 260130/5, 260277/2, 260151/2 and 260187/2 at 1% significance level as well as in lines 260465/1 and 260319/15 at 5% significance level.

Inbred lines of BSSS origin, including B14, B37, B73 and B84, have been used on a massive scale in hybrid maize seed production in the U.S. In 1971, B37, the most popular of the BSSS lines, satisfied 26% of the total US demand for maize seed. Line B14 accounted for another 9% at the time. In 1980 (only eight years after its release), line B73 met 16% of the demand for maize seed in the U.S. (HALLAUER *et al*., 1983). Many of the hybrids widely used in 1992 had RFLP profiles similar to those of B73 and lines related to it (SMITH *et al*., 1997). The three most widespread BSSS inbreds (B14, B37 and B73) were used in the development of numerous private and public lines (GERDES *et al*., 1993). Soon after it was released, line B73 found application in the breeding of hybrid maize in our country. It was a parental component of the hybrids NSSC606, ZPSC704, Bc6661 and others, which were grown widely in the late 1980s and early 1990s but have since been replaced by the more recently developed hybrids NSSC640 and ZPSC677. At the same time, the role of B73 as a parental component of hybrids has been taken over by the newer versions of the line (IVANOVIĆ *et al*., 2002).

The dominance in commercial production of one hybrid or several hybrids of similar pedigree involves certain dangers, one of which is the possible narrowing of the genetic base. The Iowa Stiff Stalk Synthetic is found in the pedigrees of most maize hybrids developed in the U.S. between 1950 and 1990 by public and private companies (SMITH *et al*., 1999). Isozyme and zein profiles indicate a continued use of B73 and A632 and lines related to them (SMITH, 1988). Isozyme analysis of 21 loci in 15 original SSS lines revealed a high level of genetic variability in the distribution of alleles. The SSS inbred lines contain over 84% of alleles found in all Corn Belt lines as well as 77% of the total number of alleles found in all lines (Smith *et al*., 1985). The level of genetic variability found in SSS lines will continue to contribute for a long time to the synthetic's potential as a source of new elite inbreds. New B73 inbreds developed in the B73 improvement program have a high level of variability for most traits. Line 260277/2 is the the most promising one overall. The high positive effect on grain yield in the test crosses was brought to line B73 by a line of unknown origin present in the hybrid P3183. In addition to the high potential for grain yield in crosses with the Mo17 tester, line 260277/2 also has an above-average number of grains per ear and an above-average 1,000-grain mass.

Inbred lines obtained during the process of improving the BSSS line B73 could potentially be of great value for maize breeding in two ways. The first one is through crosses with inbred line Mo17 or its relatives in order to develop commercial hybrids. The second is through intercrossing among related B73 lines for trait recombination purposes in order to create a good initial breeding material for the derivation of new B73-type inbreds. The breeding value of the newly developed gene pool could be enhanced by the addition of elite germplasm from the same source (BSSS) or related sources belonging to the Reid Yellow Dent heterotic group as well as by adding unrelated sources such as exotic germplasm or some other non-BSSS source.

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B73 I SRODNE LINIJE U OPLEMENJIVANJU KUKURUZA

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Izvod

Inbred linije B73 i Mo17 ili njihove verzije su najviše korišćeni roditeljski par za stvaranje srednjekasnih i kasnih hibrida kukuruza kod nas. Zbog stalno rastućeg značaja linije B73 za proizvodnju hibrida kukuruza odabrali smo nekoliko linija tipa B73, kao i nekoliko ne srodnih linija i međusobno ih ukrstili. Pedigre metodom su razvijena potomstva do S6 generacije. Linije su ispitivane na prinos zrna u test ukrštanjima sa inbred testerom linijom Mo17, kao i na: dužinu klipa, broj redova zrna na klipu i masu 1000 zrna per-se. Među novim inbred linijama srodnim liniji B73 ističe se linija 260277/2 sa visokim potencijalom za prinos zrna u ukrštanju sa inbred linijom Mo17. Inbred linije 260465/1, 260362/1, 260747/4, 260357/13, 260151/2 i 260156/2 imaju značajno duži klip od proseka svih potomstava. Inbred linije 260341/7, 260317/4, 260277/2 i 260187/2 imaju značajno veći broj redova od proseka svih potomstava. Inbred linije 260362/1, 260130/5, 260277/2, 260151/2 i 260187/2 imaju značajno veću masu 1000 zrna od proseka svih potomstava.

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