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Qualities of monogerm male-sterile sugar beet lines

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Key words: Sugar beet, Male sterility, Monogerm, Productivity.

Abstract

The majority of the commercial varieties of sugar beet in Europe are hybrids, based on monogerm diploid male-sterile females and multigerm diploid and tetraploid pollinators. The aim of the present study is by testing the basic biological qualities of recently created male-sterile sugar beet lines (male sterility, monogermity, seeds germination), and the combination of productivity and technological qualities, to make an assessment of their breeding value. The diploid lines have high male sterility, combined with high laboratory seeds germination and practically full monogermity. The tetraploid lines show significantly lower levels of male sterility and germination. The diploid monogerm lines MS 0819, MS 0922 and MS 0926 combine good biological characteristics with high own productivity and technological indices. The tetraploid lines tested have better technological qualities, and the best combination of good biological and economic qualities is manifested by MS 142. The high heterosis effect levels registered for the white sugar yield from the triploid hybrids of the tested lines with multigerm pollinators are indication for the very good combining ability of the monogerm lines and a proof for their high breeding value.

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Introduction

The modern sugar beet varieties are hybrids between monogerm male-sterile lines and multigerm diploid and tetraploid pollinators (Bosemark, 2006). The use of lines with pollen sterility is forced by the hermaphrodite structure of the beet flowers and the impossibility of mass castration for the needs of seed production, and thus the hybridization process could be regulated (Antonov, 1997). Different schemes of breeding monogerm male-sterile lines in our country are applied, including assessment of the sterility, monogermity, habit of the bushes and the quantity of seeds formed, seeds germination, own productivity, technological qualities of the beet row material, combining ability. The objective is by individual combinations (Kikindonov and Kikindonov, 2004) and systematic selection to be created lines - practically fully sterile and monogerm, with good productivity and technological qualities. The manifestation of heterosis effect in hybridization is in direct dependence on the combining ability and the portion of the hybrids in the generation (Uchkunova, 2006). That is why the selection of lines with high combining ability in hybridization with multigerm pollinators is one of the most important parts of the sugar beet breeding program (Uchkunov and Uchkunova, 2012). The present report shows results of our tests with recently created by hybridization, individual combinations and systematic selection, monogerm MS lines of sugar beet. The aim is on the basis of the most important biological and economic characteristics of these lines and the manifested combining ability in the crosses with multigerm pollinators to assess their breeding value. The analysis of such study's results gives possibility for selection of the most eligible monogerm male-sterile lines for creation of new sugar beet varieties.

Material and methods

Breeding materials

The study is performed on the experimental fields of the Agricultural Institute – Shumen during the period 2010-2013. Six diploid and three tetraploid monogerm male-sterile lines have been studied for their basic for breeding biological indices – male sterility, monogermity and seeds germination (2010-2012).

Methods of pollen sterility determination, monogermity and germination assessment

The grouping of the plants for male sterility is made according the following method: sterile – fully male-sterile plants with white, colorless or pink stamens without pollen; half-sterile – plants with pale, non-bursting open anthers, not releasing pollen. The half-sterile plants which generate pollen, no matter its quality and quantity, fall into the group of fertile plants. This method is easily applied in the large scales of the practical breeding – for a three years period 600 plants of each line were given an account of. The degree of monogermity and the laboratory seeds germination are determined by standard for our Institute methods, in four repetitions for each year of study.

Hybridization

The diploid monogerm male-sterile (MS) lines were crossed with six tetraploid multigerm (MM) pollinators, and the tetraploid monogerm MS lines – with four diploid MM pollinators. The crosses between the parental components of the triploid hybrids are made in sunflower isolation, with a 6:2 ratio between the plants of the diploid MS line and the tetraploid MM pollinator, and with 4:2 ratio between tetraploid MS line and diploid MM pollinator.

Field tests design

The field tests for productivity and technological qualities of the monogerm MS lines and their crosses with MM pollinators, carried out during 2010-2013, are arranged in a randomized block design, each tested variant in 4 repetitions, 3 rows spaced 45 cm apart, experimental plot with 10.8 m^2 area, with a Group Standard of certified sugar beet varieties.

Statistical analysis

Dispersion analysis (Lidanski, 1988) was used for determination of the statistical significance of the differences between the test variants.

Results and discussion

An obligatory condition for full hybridization in the crosses between diploid monogerm lines and MM pollinators (the classic scheme for creation of monogerm hybrid varieties of sugar beet) is the high pollen sterility of the monogerm maternal component. In case of incomplete pollen sterility are obtained not only triploid hybrids, but also diploid seeds, formed as a result of pollination in the frames of the monogerm lines (Steinrucken, 2005). The percentage of the male sterile plants among the tested diploid monogerm lines varies from 95.08 to 100.0% (Table 1). Such a high degree of male sterility is a precondition for obtaining fully hybrid progeny after the crosses with MM pollinators. Significantly lower is the percentage of the fully male-sterile plants registered in the tetraploid monogerm lines (mean of 77.3%). But the lower male-sterility of the maternal component is not an obstacle in their hybridization with diploid MM pollinators, because of the much higher vitality of the diploid's pollen in comparison with that of the tetraploids and with such a degree of maternal component's male sterility the high percentage of obtained triploid hybrids is guaranteed. But yet, we would outline the high male-sterility and the lack of any fertile plants in the monogerm tetraploid MS 142 line.

Table 1. Male sterility, monogermity and seeds laboratory germination of male-sterile lines of sugar beet (2010-2012).

Line	Male Sterility- %			Mono-germity	Germi-nation
	Sterile	Half-sterile	Fertile		
	Diploid male-sterile lines				
MS 0819	98.4	1.5	0.1	99.1	86.0
MS 0908	95.8	4.0	0.2	99.4	86.5
MS 0910	96.3	2.5	1.2	95.1	85.5
MS 0915	97.3	1.9	0.8	96.6	90.0
MS 0922	100.0	-	-	100.0	87.5
MS 0926	99.2	0.8	-	100.0	88.0
	Tetraploid male-sterile lines				
MS 59	73.6	23.6	2.8	90.0	71.5
MS 78	67.9	30.8	1.3	92.4	77.0
MS 142	90.6	9.4	-	96.3	75.5

The monogermity of the tested lines varies from 92.4% (for the tetraploid MS78 line) to 100.0% (for the diploid lines MS0922 and MS0926). According to Antonov and Zakhariev (1994) over 40% of the polyploid seedballs germinate with a single seedling. This means that in field conditions all the tested lines would be practically fully monogerm (Kawakatsu and Tanaka, 1999).

The seeds germination is another biological trait of great importance for the parental components in the hybridization. The mean laboratory seeds germination of the diploid lines is over 87%, and is a good basis for reaching high percentage of hybrid seeds germination on the field. We would agree with Antonov (1997) and Bosemark (2006) that the significantly lower germination of seeds is the main disadvantage of the monogerm tetraploids, and the reason for their limited use in the breeding programs.

In general – the diploid monogerm male-sterile lines MS0922, MS0926, MS 0819, and the monogerm tetraploid line MS142, are the lines with the best biological characteristics.

On Table 2 are given the results of 3-years field test for productivity and technological qualities of the same monogerm lines. The root yield of the diploid MS lines is significantly higher than the yield of the monogerm tetraploid lines, with proved difference between the mean values of the two groups of lines. The highest yielding line is MS 0915 – with proved excess towards most of the remaining diploid lines. The same is valid for the monogerm line MS142, which exceeds the other studied tetraploid lines with proved differences. The sugar content of the tetraploid lines is higher than that of the diploid lines. But it should be noted that all of the diploid MS lines have sugar content at the level of the Standard varieties, which is really impressive. It is normal, that the MS line with the lowest yield of roots – MS78, is with the highest sugar content. But at the other hand – it is with quite high soluble ashes content.

Table 2. Productivity and technological qualities of monogerm male sterile lines of sugar beet (In percents to the Standard's values).

MS line	Root Yield	Sugar content	Soluble ashes	Output	White sugar yield
	Diploid male- sterile lines				
MS 0819	93.3	100.3	93.1	101.7	94.9
MS 0908	93.2	97.6	100.8	97.1	90.5
MS 0910	93.5	100.4	94.4	101.6	95.0
MS 0915	101.3	94.3	114.0	89.8	91.2
MS 0922	94.5	98.5	100.2	98.2	92.8
MS 0926	98.1	96.4	104.9	95.2	93.4
	Tetraploid male-sterile lines				
MS 59	88.3	100.7	93.4	101.9	90.3
MS 78	77.4	104.6	108.9	104.2	81.0
MS 142	97.1	102.1	96.0	103.4	100.7
Standard Abs.values	51.73 t/ha	16.32%	0.488%	13.32%	6.89 t/ha
P ≤ 0.05	6.9	5.2	9.8	6.5	9.5
P ≤ 0.01	9.2	6.9	13.0	8.5	12.6

The output is strongly dependent on the values of sugar and soluble ashes contents (Jansen and Stibbe, 2007). This index is higher for the tetraploid lines. Diploid lines with near to the tetraploids' values of output are MS0819 and MS0910. But we would say that the output values at the level of the output of the Group standard of hybrid varieties are indicative for the very good technological qualities of the diploid monogerm lines MS0908, MS0922 and MS0926 too.

The white sugar yield is the most important economic index (Biancardi *et al*., 2010). The tetraploid MS59 and MS78 lines and the diploid MS 0908 fall back the Standard. That is normal for the monogerm linear materials having in mind their allied propagation. All the other studied lines realize high white sugar yields - at the level of the yield from the Standard varieties. And this is a precondition for excellent performance of their hybrids.

It is obvious that the high values of the white sugar yield for the studied diploid MS lines are due to their comparatively high productivity while the very good technological qualities are determining for the white sugar yield of the tetraploid lines.

The best combination of high productivity and good technological qualities manifest the monogerm diploids MS0819, MS0910 and MS0922, and the tetraploid line MS142.

The results of white sugar yield tests of hybrids with multigerm pollinators are given on Table 3. And they are indicative for the high combining ability of the tested lines. The general combining ability expresses the mean value of the parents in the crosses, and it is conditioned by the additive action of genes (Uchkunova, 2006). As it is inherited in the generation, the materials with high general combining ability are with high breeding value. Data from the table show that all tested lines are with high potential in the hybrid breeding. The hybrids of the diploid monogerm lines MS0819 and MS0915 exceed the Standard's white sugar yield with proved differences and all the hybrids with the tetraploid multigerm pollinator M985 give proved higher white sugar yield (mean of 113.7% of the Standard white sugar yield value). The use of multigerm pollinators is determined by the fact that for a number of economic indices the multigerm forms significantly exceed the monogerm forms. After Rostel (1981) the multigerm tetraploid pollinator, having better productivity and technological qualities, participates with two genomes in the triploid hybrids, and its affect on the heredity of the hybrids is much stronger. In our case, this influence is especially strong in the crosses of MS0819 with the multigerm pollinators M18 (118.7%) and M985 (115.9%), and in the crosses of MS 0915 with M63 (118.5%) and with M985 (116.3%). The proved heterosis effect regarding the white sugar yield of the parents, and regarding the group standard, revealed in some of the crosses of the diploid monogerm MS lines is indication for high specific combining ability of the MS lines in the relevant hybrid combinations.

Table 3. White sugar yield from hybrids of the studied monogerm lines (In percents to Standard's values).

MS line/Pollinator	M17	M18	M41	M63	M69	M985	Average
	Diploid MS lines × Tetraploid Pollinators						
MS 0819	106.9	118.7	107.8	109.7	100.4	115.9	111.0
MS 0908	106.0	114.8	110.8	103.0	112.4	113.6	110.1
MS 0910	114.9	111.8	106.1	108.8	97.7	107.7	107.8
MS 0915	113.8	108.7	111.0	118.5	106.3	116.3	112.4
MS 0922	106.3	108.7	115.9	105.3	108.1	112.6	109.5
MS 0926	104.1	106.2	108.3	106.0	107.1	115.9	107.9
	Tetraploid MS lines × Diploid Pollinators						
			E	DH 52	DH 58	DH 63	Average
MS 59			106.4	105.8	107.8	105.4	106.4
MS 78			108.2	105.6	104.9	109.7	107.1
MS 142			106.8	106.0	108.2	107.5	107.1
Standard Abs.values				6.39 t/ha			
P ≤ 0.05				11.1			
P ≤ 0.01				14.7			

In the group of hybrids of the tetraploid MS lines there are no proved higher white sugar yield values. Probably the reason for that is the stronger negative reaction of this type of hybrids to the continuous summer droughts (Akeson, 1980), characteristic for the test period. But we would note the stable high white sugar yield from the hybrids of MS142.

Conclusion

The studied diploid lines have high degree of male sterility and practically full monogermity. The tetraploid lines have significantly lower seeds germination which limits their use in the hybridization schemes. The diploid monogerm lines MS0819 and MS0922, and the tetraploid line MS142 are good combinations of biological and economic qualities. The heterosis effect in the white sugar yield from the triploid hybrids with multigerm pollinators is an indication for good combining ability of the studied lines and a proof for their high breeding value.

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