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The generative propagation and quality of new male-sterile cauliflowers with the *Ogu-INRA* and *Brassica nigra* cytoplasm

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ABSTRACT

In the years of 2012-2013 male-sterile cauliflower genotypes with the *Brassica nigra* cytoplasm and their maintainers were tested with respect to their ability for generative propagation and the quality of agronomical traits in comparison to male-fertile inbreeds and sterile genotypes with the *Ogu-INRA* cytoplasm. The ability for the generative propagation for male-sterile genotypes with the *B. nigra* cytoplasm was diversified and lower than for the maintainer, fertile lines and lines with the *Ogu-INRA* cytoplasm.

Generative stalks of cauliflowers with the *B. nigra* cytoplasm usually had a higher number of buds and flowers in comparison to the fertile genotypes and to the sterile *Ogu-INRA* lines. The most desired commercial characteristics, such as circular shape, compactness of curd and intermediate or strong coverage by leaves, were noticed for sterile lines with the *Ogu-INRA* cytoplasm and their fertile complementary lines. Three experimental F_1 hybrids showed good quality in comparison to commercial F_1 cultivars.

Key words: *Brassica nigra CMS*, *Ogu-INRA CMS*, breeding, quality, seeds

INTRODUCTION

Cytoplasmic male sterility (*CMS)* is described as the inability of the plant to produce fertile pollen and was broadly investigated in order to introduce it as a low-cost, reliable and efficient means of directed pollination for the large-scale production of hybrid seeds in crops (Prakash et al. 2009). Male sterility usually manifests itself in floral development as an incompatibility of nuclear-mitochondrial interaction in alloplastic lines derived from wide hybridisation, which carry nuclear and mitochondrial genomes from different species. *CMS* may have a spontaneous character or may arise following intraspecific, interspecific or intergeneric crosses (Bannerot et al. 1974, Kaul 1988, Qiong et al. 2009). Maternally inherited cytoplasmic male sterility encoded in mitochondrial genes can be utilised more effectively by breeders than genic male sterility, as crosses between a male-sterile plant and a hermaphrodite plant homozygous for maintainer alleles give rise to 100% female plants. Another set of nuclear genes – restorers of fertility (*Rf*) – overcome the effect of the *CMS* genes, restoring the hermaphrodite condition. *CMS* arising in interspecific crosses is often linked to the interaction of the cytoplasm of one species with the nuclear genome of the other parent (Budar et al. 2006). The first report of male sterility in Japanese

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radish (Ogura 1968) started the most extensively investigated *CMS* system among *Brassica* plants. After the improvement of female fertility and cold tolerance via protoplast fusion (Pelletier et al. 1983) The *CMS*-Ogura system has become one of the most popular and broadly used for the breeding of F_1 hybrids. Generally, the cytoplasm donor species from which the sterility originates also provides the nuclear restorers (Kalia 2009). The *Ogura* sterility in all *B. oleracea* species does not have any fertility-restorer genes, while all fertile forms act as maintainers (Dickson 2007, Prakash et al. 2009).

Male-sterile genotypes with the *B. nigra* cytoplasm were developed by Pearson (1972) through sexual hybridisation with *B. oleracea* genotypes. The disadvantage of this *CMS*-system was associated with the lack of nectaries and abnormal flower development with low seed production (Hoser-Krauze 1987). Unimproved male-sterile cauliflower lines propagated by the use of their fertile maintainers had poor commercial value, with small, early curds, not suitable for the market. Cauliflower lines with the *B. nigra* cytoplasm had petaloid-type flowers without anthers. Instead of stamina, longitudinal thin and spoon-like structures similar to petals were present in the internal whorl. The investigated male-sterile lines with the *B. nigra* cytoplasm often had smaller petals, undeveloped nectaries and various types of style deformations that made the flowers less attractive for pollinating insects. Also disorders in the development of pistils leading to deformations of siliquae were the reason for poor seed sets (Kamiński and Dyki 2007). A lack of rigorous selection in the early generations following fusion or sexual hybridisation may cause problems with the failure of seed production among male-sterile plants (Dickson and Kyle 1987). The selection of *CMS* cauliflowers with the *B. nigra* cytoplasm performed in the former Research Institute of Vegetable Crops in Skierniewice resulted in obtaining genotypes with higher ability for generative propagation and better quality of commercial characteristics (Kamiński et al. 2012). The *B. nigra* system in contrast to *Ogu-INRA* allows for the development of fertile F_1 hybrids for *B. oleracea* genotypes, as all forms with fertile cabbage cytoplasm act as fertility restorers. A limited number of good maintainer genotypes seems to be the main problem for the breeders trying to use interspecific *CMS* (Delourme and Budar 1999). The commercial utilisation of *CMS* cauliflowers with the *B. nigra* cytoplasm could only be successful if an effective method of improvement of maintainer lines is applied. Maintainer genotypes for the propagation of sterile forms with the *B. nigra* cytoplasm were formerly obtained by Pearson (1972) and were constantly improved by breeders with the use of the test-cross method of segregating BC plants with the sterile cytoplasm. This procedure allowed the identification of desired *rf* genotypes. (Hoser-Krauze 1987, Kamiński et al. 2012).

The breeding of cauliflower F_1 hybrids requires a reliable, effective and inexpensive pollination control mechanism such as self-incompatibility or male sterility (Ramchiary et al. 2011). The diversified collection of *Brassica oleracea* genotypes with several male-sterility sources collected at the Department of Genetics, Breeding and Biotechnology at the Institute of Horticulture has unique characteristics and allows for the development of the modern cauliflower F_1 hybrids for the first time in Poland. Obtaining cauliflower F_1 hybrids with the *B. nigra* cytoplasm was never described in the available literature and for this reason should be of high scientific importance.

The aim of this study was the comparison of the male-sterile cauliflowers with the *B. nigra* cytoplasm and sterile genotypes with the *Ogu-INRA* cytoplasm, with respect to biological characteristics, commercial quality, ability for generative propagation and the creation of F_1 hybrids.

MATERIAL AND METHODS

Plant material

Male sterile lines of broccoli and broccoli-cauliflower with *B. nigra* cytoplasm and their maintainers were obtained from Dr Dickson and have been investigated at the Department of Genetics, Breeding and Biotechnology at the Institute of Horticulture in Skierniewice, Poland since 1976. Five male-sterile cauliflower lines with the *B. nigra* cytoplasm (AP8, AP81, AP4, AP51, AP61) of the BC_5 generation and their fertile maintainers (BP4, BP8, BP81, BP51, BP61) of the $F_5(BC_1)$ generation were selected as a result of the breeding program performed since 2002 (Kamiński et al. 2012). Three fertile inbred lines of the F_5 generation (FL, FA43, DT70) and two male-sterile lines after BC_5 with the *Ogu-INRA* cytoplasm (CFA43, CDT70) were also used. The source of *Ogu-INRA* male sterility was kindly supported by the Beijing Vegetable Research Centre, China in 1999. For the development of F_1 hybrids two

Table 1. Propagation of cauliflower lines and F_1 hybrids, Skierniewice 2012

No.	Sterile component	Type of sterility	Fertile component	Type of pollination
1	AP8	*B. nigra*	BP8	sterile × maintainer
2	AP81	*B. nigra*	BP81	sterile × maintainer
3	AP4	*B. nigra*	BP4	sterile × maintainer
4	AP51	*B. nigra*	BP51	sterile × maintainer
5	AP61	*B. nigra*	BP61	sterile × maintainer
6	CFA43	*Ogu-INRA*	FA43	sterile × maintainer
7	CDT70	*Ogu-INRA*	DT70	sterile × maintainer
8	AP44	*B. nigra*	FL	cross-pollination
9	AP411	*B. nigra*	FL	cross-pollination
10	CFA43	*Ogu-INRA*	FL	cross-pollination
11	CDT70	*Ogu-INRA*	FA43	cross-pollination

good quality sublines of BC_6 generation related to the AP4 line (AP44, AP411) with the *B. nigra* cytoplasm and two lines of BC_6 with the *Ogu-INRA* cytoplasm (CFA43, CDT70) were chosen to be crossed with fertile components (Tab. 1). Two commercial F_1 hybrids ('Vinson', 'Livingstone') were used as a control.

Evaluation of morphological traits and seed production effectiveness of cauliflower lines and F_1 hybrids

In 2012 the male-sterile cauliflower genotypes with the *B. nigra* cytoplasm and their maintainers were generatively propagated in the field. Plants were raised from seeds in the greenhouse at the beginning of February and cultivated in 1L plastic pods filled with Kronen substrate. All genotypes were fertilised and protected against pests and diseases according to the requirements and current recommendations for cauliflower. Plants in the stage of early curd formation were transplanted at the second ten-days of May to the field into 9 m^2 growth cages covered with transparent fabric to avoid undesired cross-pollination by insects. The soil type was a pseudopodsolic over loamy sand (1.5% organic matter, pH 6.5). Cauliflowers were planted in two rows, 100 cm between rows, and 50 cm between plants in one row, with five male-sterile plants and five fertile pollinators (maintainers or fertile lines) for each cage.

At the second ten-days of May, when plants started to bloom, about 90 hatched insects of Red Mason Bee (*Osmia rufa* L.) were placed into each cage to ensure appropriate cross-pollination between male-sterile and fertile components. Flowers and seed stalks were observed during their blooming with respect to their morphological traits, such as average size of flowers (mm), colour of petals, presence/absence of fertile pollen, average number of flowers/stack and percentage of deformed and atypical siliquae. For each plant, three branches 7 cm in length were independently observed. From the second ten-days of August until the beginning of September matured siliquae were gradually harvested from each male-sterile and fertile line separately. After the siliquae were dried, seeds were extracted, cleaned and weighted.

Evaluation of agronomical and commercial traits of male-sterile, fertile lines, experimental and commercial F_1 hybrids

In 2013 three male-sterile cauliflower lines with the *B. nigra* cytoplasm that developed a sufficient amount of seeds in the previous season (AP8, AP81, AP4), their fertile maintainers (BP8, BP81, BP4), three fertile genotypes (FL, FA43, DT70), two male-sterile lines with *Ogu-INRA* cytoplasm (CFA43, CDT70) and four experimental F_1 hybrids (AP44 × FL, AP411 × FL CFA43 × FL, CDT70 × FA43) were evaluated in the field in the Institute of Horticulture at Skierniewice with respect to commercial and agronomical characteristics. Plants were raised from seeds in the greenhouse at the beginning of May. One-month-old seedlings were planted in the field (50 × 50 cm spacing) in a completely randomised block design with three replications. Each plot consisted of 10 plants in one row. Fertilisation, pest and disease control followed the current recommendations for cauliflower. Plants were harvested gradually from the beginning of August to the end of September when curds reached maturity. The mass of curds was weighted and results were subjected to an analysis of variance (ANOVA) using Statistica 10 software (StatSoft). The significance of differences among means was evaluated by Tukey's test at $p = 0.05$. A correlation between the length of vegetation and yield was also analysed in this study. Other morphological characteristics of the cauliflower population such as internal uniformity, length of vegetation period from planting to harvest, foliage colour, leaf attitude, waxiness, shape, colour, pubescence, blistering and compactness of curd as well as coverage by leaves were classified separately for each plot according to a multi-grade UPOV scale.

RESULTS

Morphological traits and seed production effectiveness of cauliflower lines and F_1 hybrids

Differentiation of flower morphology and seed production effectiveness was observed between the tested male-fertile and male-sterile lines propagated in growth cages by the use of the Red Mason Bee as a pollinator (Tab. 2). The male-sterile cauliflowers with the *B. nigra* cytoplasm had a smaller average yield of seeds/plant (12.49 g) in comparison to the fertile maintainers (33.82 g) and in comparison to the male-sterile lines with the *Ogu-INRA* cytoplasm (38.14 g). The highest seed yield among the male-sterile lines with the *B. nigra* cytoplasm was observed for the AP8 and AP4 genotypes (27.35 and 21.90 g/plant, respectively); the AP81 line created more than 10 g of seeds/plant and two other lines (AP51, AP61) set the lowest seed yield (1.56 and 1.21 g/plant, respectively). The two lines with the *Ogu-INRA* cytoplasm were also diversified with respect to the ability for generative propagation and ranged from 24.08 g (CDT70) to 52.20 g (CFA43) of seeds/plant. The fertile inbred lines, used as maintainers for the cauliflowers with the *Ogu-INRA* cytoplasm, were also diversified in respect to this trait and developed from 29.9 (FA43) to 44.2 (DT70) g of seeds/plant, respectively. Fertile inbred line FL, used as the paternal component for the creation of experimental F_1 hybrids, created the highest average number of seeds when pollinated in the field (48.8 g/plant). The experimental F_1 hybrids created by the use of maternal lines with the *B. nigra* cytoplasm (AP44 × FL, AP411 × FL) developed a lower mass of seeds (20.8, 21.0 g/plant) in comparison to the other two hybrids (CFA43 × FL and CDT70 × FA43) with the *Ogu-INRA* cytoplasm (31.6 and 36.4g/plant, respectively). All cauliflower lines with the *B. nigra* cytoplasm were characterised by the petaloid-type sterility with the lack of stamina and longitudinal thin and spoon-shaped structures similar to petals. A diversified level of morphological abnormalities of flowers such as additional, opened carpels with ovules or cracked pistils were frequently observed in this group of lines. However, the AP8, AP4 and AP81 lines, which developed about 60% of normal flowers, had better ability for seed setting (27.35, 21.9 and 10.42 g/plant, respectively) in comparison to the lines with a higher number of flower deformations: AP51 and AP61 (1.56 and 1.21 g/plant, respectively). The range of variation of average mass of seed/plant (51.9-94.9) for the sterile *B. nigra* lines was higher than for the other tested genotypes (11.7-35.4). The five fertile maintainers used for the propagation of the male-sterile genotypes with the *B. nigra* cytoplasm had a diversified yield of seeds that ranged from 16.38 g (BP61) to 46.70 g (BP4). The male-sterile cauliflower lines with the *B. nigra* and *Ogu-INRA* cytoplasm had buds and flowers smaller in size in comparison to the fertile analogues. A higher number of buds and flowers at generative stacks was observed only for sterile lines with the *B. nigra* cytoplasm (Tab. 2). All of the tested genotypes were characterised by yellow flowers typical for most *B. oleracea* cultivars, with the exception of the DT70 and CDT70 lines with a white colour of petals.

Agronomical and commercial traits of male-sterile, fertile lines, experimental and commercial F_1 hybrids

The cauliflower lines and F_1 hybrids evaluated in the field in 2013 showed a high variability with respect to most of the evaluated morphological and agronomical traits. All of the genotypes were characterised by good internal uniformity of tested traits, with the exception of the AP81 male sterile line with the *B. nigra* cytoplasm and the CFA43 × FL experimental F_1 hybrid, which were partially not uniform (Tab. 3). The mean vegetation period from planting to harvest at curd maturity was 82 days (± 19 days SD) while the shortest vegetation period (55-77 days) was noted for the male-sterile lines with the *B. nigra* cytoplasm and their maintainers. The two fertile complementary lines (DT70, FL) had intermediate vegetation length – 77-80 days – after planting, while FA43 line was late (117 days). The male-sterile lines with the *Ogu-INRA* cytoplasm (CFA43, CDT70) had similar length of vegetation to their complementary fertile components (115 and 88 days after planting, respectively). The experimental F_1 hybrids with the *B. nigra* cytoplasm had a light green colour of leaves, while the other genotypes were green or dark green. All *B. nigra*

Table 2. Morphological traits and seed production effectiveness of male-sterile and male-fertile cauliflowers propagated by the use of Red Mason Bee (*Osmia rufa*). Skierniewice 2012

Genotype		Aver. size of flower (mm)	SD	Range of variation	Colour of flower	Fertility/ sterility	Aver. number of flowers /stalk	SD	Range of variation	Deformed and untypical siliquae (%)	Aver. mass of seeds /plant (g)	SD	Range of variation
Sterile lines with *Brassica nigra* cytoplasm	AP8	12	0.60	5.05	yellow	sterile	22	2.17	9.95	38	27.35	16.39	59.92
	AP81	11	0.43	3.94	yellow	sterile	25	3.04	12.17	42	10.42	5.53	53.13
	AP4	12	0.35	2.95	yellow	sterile	30	4.03	13.25	40	21.90	17.30	78.82
	AP51	12	0.25	2.08	yellow	sterile	28	3.04	10.99	55	1.56	1.47	94.91
	AP61	11	0.39	3.54	yellow	sterile	25	3.39	13.75	70	1.21	0.63	51.93
										Average	12.49		
Fertile maintainers for sterile lines with *B. nigra* cytoplasm	BP8	16	0.67	4.11	yellow	fertile	14	2.42	17.16	0	37.80	6.92	18.33
	BP81	17	0.42	2.47	yellow	fertile	15	1.41	9.64	0	47.54	6.20	13.06
	BP4	17	0.42	2.47	yellow	fertile	12	1.27	10.68	0	46.70	7.06	15.14
	BP51	17	0.33	1.95	yellow	fertile	13	1.22	9.42	0	20.70	7.31	35.40
	BP61	17	0.33	1.97	yellow	fertile	14	1.56	11.35	0	16.38	3.65	22.24
										Average	33.82		
Sterile lines with *Ogu-INRA* cytoplasm	CFA43	11	0.60	5.52	yellow	sterile	14	2.32	16.67	0	52.20	10.88	20.82
	CDT70	12	0.68	5.90	white	sterile	16	1.56	9.91	0	24.08	5.53	22.93
										Average	38.14		
Fertile maintainers for sterile lines with *Ogu-INRA* cytoplasm	FA43	15	0.44	2.90	yellow	fertile	12	1.45	12.22	0	29.90	3.85	12.87
	DT70	15	0.17	1.11	white	fertile	15	0.60	4.04	0	44.20	9.85	21.67
										Average	37.05		
Fertile inbred line	FL	16	0.33	2.10	yellow	fertile	14	1.05	7.59	0	48.80	5.72	11.72
Experimental F_1 hybrids	AP44 × FL	-			-	-	-			-	20.79		
	AP411 × FL	-			-	-	-			-	21.00		
	CFA43 × FL	-			-	-	-			-	31.57		
	CDT70 × FA43	-			-	-	-			-	36.40		
										Average	29.65		

Table 3. Morphological and commercial characters of selected cauliflower genotypes evaluated in the field. Skierniewice 2013

Genotype		Uniformity	Length of vegetation	Foliage colour	Leaf attitude	Wax	Average mass (g)	Shape	Compactness	Coverage by leaves	Pubescence	Blistering	Colour
Sterile lines with *Brassica nigra* cytoplasm	AP8	1	65	2	3	4	301 a	3	2	1	2	2	2
	AP81	2	77	2	3	4	425 ab	2-3	3	1	2	2	2
	AP4	1	65	2	3	4	385 a	3	2	1	2	1	2
Fertile maintainers for *B. nigra* cytoplasm	BP8	1	55	2	3	4	273 a	3	2	1	2	2	2
	BP81	1	63	2	3	4	426 ab	2	2	1	2	2	2
	BP4	1	55	2	3	4	373 a	3	2	1	2	2	2
Sterile lines with *Ogu-INRA* cytoplasm	CFA43	1	115	3	7	3	956 c	1	3	3	1	1	1
	CDT70	1	88	2	5	4	1030 c	1-2	3	2-3	1	1	1
Fertile maintainers for *Ogu-INRA* cytoplasm	FA43	1	117	3	7	3	993 c	1	3	3	1	1	1
	DT70	1	77	2	5	4	1003 c	1	3	3	1	1	2
Fertile inbred line	FL	1	80	2	5	3	851 c	2	3	2	1	1	2
Experimental F_1 hybrids	AP44 × FL	1	70	1	5	4	752 bc	2	3	2	1	1	2
	AP411 × FL	1	70	1	5	4	729 bc	2	3	2	1	1	2
	CFA43 × FL	2	80	2	5	3	867 c	2	3	2	1	1	2
	CDT70 × FA43	1	110	3	7	4	965 c	1	3	3	1	1	1
Commercial F_1 hybrids	Vinson F_1	1	95	3	5	4	994 c	2	3	2	1	1	2
	Livingstone F_1	1	90	3	5	4	815 c	2	3	3	1	1	1

Means followed by the same letter are not significantly different at $p = 0.05$

Internal uniformity:	1– entire,	2 – partial,	3 – lack of uniformity			
Foliage colour:	1 – light green,	2 – medium green,	3 – dark green,	4 – grey-green,	5 – blue-green,	6 – purple-green
Leaf attitude:	3 – horizontal,	5 – semi-erect,	7 – erect			
Wax presence:	1 – none,	2 – weak,	3 – intermediate,	4 – strong		
Shape of curd:	1 – circular,	2 – transverse broad elliptic,	3 – transverse elliptic,	4 – transverse narrow elliptic		
Compactness of curd:	1 – loose:	2 – medium,	3 – tight			
Coverage of curd by inner leaves:	1 – exposed,	2 – partly covered,	3 – covered			
Curd pubescence:	1 – none,	2 – slight,	3 – heavy			
Blistering:	1 – none,	2 – weak.	3 – intermediate,	4 – strong		
Colour of curd:	1 – white,	2 – cream/ivory,	3 – yellow,	4 – orange		

lines and their maintainers were characterised by a horizontal attitude of leaves, in contrast to other genotypes with a semi-erect or erect attitude of leaves. All cauliflowers had strong or intermediate waxiness of leaves. Significant differences with respect to the average mass of curd were observed among the evaluated populations of cauliflower. The head mass for CDT70 from the *Ogu-INRA* line had the highest value (1030 g). The mass of curd for the male sterile lines with the *B. nigra* cytoplasm and their maintainers (from 273 g – BP8 to 426 g – BP81) was lower than for the fertile inbreeds and *Ogu-INRA* sterile lines (Tab. 3). The mass of curd for the experimental F_1 hybrids ranged from 729 g (AP411 × FL) to 965 g (CDT70 × FA43) and did not differ significantly from the commercial F_1 cultivars used as the control. The overall mean curd mass was 722.6 g (± 293.8 g SD) and the curd mass also depended on the plant vegetation period as indicated by Pearson's linear correlation coefficient ($r = 0.76$; $p < 0.05$). Curds of the *B. nigra* genotypes and their maintainers were exposed with medium compactness, a transverse-elliptic shape with lower quality due to slight pubescence, weak blistering and creamier colour of curds. The most desired commercial characteristics such as circular shape, compactness of curd and intermediate or strong coverage by leaves was observed for the sterile lines with the *Ogu-INRA* cytoplasm and their fertile complementary components.

DISCUSSION

A comparison of the morphological traits, commercial characteristics and seed production effectiveness of male-sterile lines with the *B. nigra, Ogu-INRA* cytoplasm and their experimental F_1 hybrids are presented first for the first time in the available literature and for this reason should facilitate the development of modern commercial cultivars in the future. The obtained results confirmed that cauliflower lines with the *Ogu-INRA* cytoplasm had a high potential of generative propagation by seeds without negative influence on the quality and yield (Dickson 2007, Kamiński et al. 2012). A number of cultivars developed within oilseed *Brassica* based on an improved *Ogu-INRA CMS* system by various seed companies have been recently described (Prakash et al. 2009). Four experimental F_1 hybrids were not only comparable with commercial cultivars but also with the pollinator fertile parents used in the study with respect to the average mass of curd. These results confirm the low level of inbreeding depression and lack of heterosis effect for cauliflowers typical for an open-pollinated cultivar (Brown and Caligari, 2008). Three male-sterile lines with the *B. nigra* cytoplasm, presented in this paper, had reasonably good ability for sexual propagation, but lower in comparison to the fertile cauliflowers and to the *Ogu-INRA* lines. The high range of variation for the seed yield of the *B. nigra* lines suggest their low level of internal uniformity in respect to this trait. Lines with a low percentage of deformed flowers/siliquae and higher ability for the development of seeds were probably more attractive for pollinator insects, due to the presence of functional nectaries (Kamiński and Dyki 2007). A lower mass of seeds/plant for the AP51 and AP61 lines also corresponds to the about 50% lower seed yield of their fertile maintainers BP51 and BP61 in comparison to the other fertile maintainers for the *B. nigra* cytoplasm. Lower seed setting for the AP51 and AP61 lines with the *B. nigra* cytoplasm associated with the presence of undesired abnormalities of flowers, siliquae and lack of nectaries among the *B. nigra* genotypes probably makes *CMS* plants not attractive for pollinators (Kalia 2009, Kamiński et al. 2012). Generally, *CMS* genotypes with deleterious drawbacks for vegetative growth or seed production should not be used for breeding (Budar et al. 2006). However, the surplus of buds and flowers created by male-sterile lines with the *B. nigra* cytoplasm in comparison to other genotypes may compensate in some extent the lower ability of seed production. Further investigations of morphological and anatomical characteristics should help to elucidate the reason for different seed setting for the lines with the *B. nigra* cytoplasm. The improvement of cauliflower lines with the *B. nigra* cytoplasm with respect to the quality of curds and ability for generative propagation is an important step forward to obtaining new and alternative sources of male sterility for breeding.

CONCLUSION

1. The highest ability for generative propagation was noticed in the sterile *Ogu-INRA* lines and in the fertile inbred genotypes. Male-sterile lines with the *B. nigra* cytoplasm were diversified with respect the trait and developed a lower number of seeds.
2. The most desired commercial characteristics, such as high curd mass, circular shape, compactness and intermediate or strong coverage by leaves, were noticed for sterile

lines with the *Ogu-INRA* cytoplasm and their fertile components. Sterile lines with the *B. nigra* cytoplasm had curds smaller in size, more suitable for the development of early-type F_1 cultivars.

3. Experimental F_1 hybrids developed with the use of both types of male sterility were characterised by good quality comparable with commercial cultivars and with the pollinators used in this study.

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OCENA ZDOLNOŚCI DO ROZMNAŻANIA GENERATYWNEGO ORAZ CECH UŻYTKOWYCH NOWYCH LINII KALAFIORA Z CECHĄ CYTOPLAZMATYCZNEJ MĘSKIEJ STERYLNOŚCI TYPU *BRASSICA NIGRA* I *OGU-INRA*

Streszczenie: W latach 2012-2013 dokonano oceny zdolności do rozmnażania generatywnego oraz cech użytkowych dla nowych linii kalafiora z cechą cytoplazmatycznej męskiej sterylności typu *Brassica nigra*, *Ogu-INRA* oraz eksperymentalnych mieszańców F_1. Męskosterylne linie z cytoplazmą *B. nigra* były zróżnicowane pod względem wydajności tworzenia nasion i plonowały słabiej od linii z cytoplazmą *Ogu-INRA* oraz linii płodnych. Najkorzystniejsze cechy użytkowe takie jak kształt i zwartość róż oraz całkowite lub średnie okrycie liśćmi, obserwowano dla linii sterylnych typu *Ogu-INRA* oraz ich płodnych form dopełniających. Cztery eksperymentalne formy mieszańcowe charakteryzowały się wysoką jakością porównywalną do komercyjnych mieszańców F_1 kalafiora.

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