

INFLUENCE OF CYTOPLASMIC MALE-STERILITY SOURCE ON SOME
CHARACTERS OF CAULIFLOWER (*BRASSICA OLERACEA*
VAR. *BOTRITIS* L.)

J. HOSER-KRAUZE²

Institute of Vegetable Crops, Skierniewice

Summary. A cytomale-sterile cabbage line, a broccoli line having *B. nigra* CMS, and Bannerot's line having *R. sativus* CMS have been investigated for their suitability in breeding cytomale-sterile lines of cauliflower.

Regarding the quality of cauliflower curd the both investigated cytoplasmic male sterility sources can be successfully used in the breeding cytomale-sterile lines of cauliflower. However, in the case of breeding very early lines, a negative influence of CMS cytoplasm on the commercial quality of early curds cannot be ignored.

A chlorotic appearance of cauliflower seedlings and young leaves was determined by *R. sativus* cytoplasm; it had no negative influence on the commercial value of cauliflower curds, though it delayed their maturity.

The seed sets of petaloid lines having *R. sativus* CMS were very poor. The variation between lines and single plants in this character suggested some improvement through selection.

Male sterility is an alternative to the incompatibility system as a method of producing F_1 hybrid cultivars. It seems to be a promising method for the breeding of F_1 hybrids of cauliflower, because this botanical variety is largely self-compatible.

Cytoplasmic male-sterility seems to be the best for producing male-sterile lines.

Recently, several investigators succeeded in obtaining cytoplasmic male-sterile material in the cruciferous crops by crossing species. Pearson (1972) crossed *B. nigra* with *B. oleracea*. Dickson (1975) using cabbage stocks furnished in 1967 by Pearson, introduced this character into broccoli. Bannerot et al. (1974) crossed cytomale-sterile *R. sativus* with *B. oleracea* and introduced the nucleus of *B. oleracea* and *B. napus* into *S-Raphanus* cytoplasm. At our Institute, these sources of cytomale sterility were introduced into several summer cauliflower cultivars by the conventional method of successive backcrossing. The offspring of backcrossing was compared to determine which source of cytomale sterility is the most useful for breeding cauliflower lines.

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² Doc. Dr. hab. Present address: ul. 22 Lipca 1/3, Skierniewice, Poland.

MATERIAL AND METHODS

The maternal crossing components were the following cytomale-sterile lines of *B. oleracea*:

- line of cabbage No. 5255 (Pearson, Cornell, New York State)
- line of broccoli No. 1117 A (Dickson, N. Y. State Agricultural Exp. Sta., Geneva)
- F_1 from crossing Bannerot's line with cauliflower Snowball cv. (made by Pearson, Cornell, N. Y. State).

Recurrent paternal components were: self-compatible lines of the following summer cultivars: Rapid (Poland), Idol, Master (Ohlsen's Enke, Denmark) and Super Snowball (Stokes Seed, Canada).

Successive backcrossing with paternal cauliflower lines took place from 1977 till 1983 under greenhouse conditions (Figs 1, 2, 3). In 1984, comparative field trials were carried out. The layout followed the pattern of randomized blocks with three replications. The offspring of the successive backcrossing and corresponding paternal cauliflower lines were compared. Seeds for this trial were sown on March 5, and pricked out into soil pots 8 cm in diameter on March 14. They were then cultivated in a technically heated hot bed at 12° — 16°C. The plants were moved to the field on April 27 at the 5 — 6 leaf stage and planted at the space of 50 × 50 cm. Earliness of curd maturity, weight, size and quality were observed. Curds were harvested every third day. Their quality was divided into four classes — the 1st and 2nd conformed the Polish commercial standard, while the 3rd and 4th comprised to nonmarketable curds. Moreover, the percentage of commercial curds has been calculated. The data defining the characteristics under observation were compared by frequency distributions on the basis of which the arithmetic mean (\bar{x}) and standard deviation were calculated. Results were interpreted statistically with the application of the Hoavantz formula (1953). In the same field cytomale-sterile hybrids Bc_4 and Bc_5 having CMS of *R. sativus* were tested for their pod and seed setting ability. Cytomale-sterile plants were planted together with their recurrent paternal fertile lines at the space of 50 × 50 cm. Plants were pollinated under open field conditions by bees. Under observation were: pod setting per plant and seed number per pod. From these data, the effectiveness of seed setting was calculated.

RESULTS AND DISCUSSION

The commercial quality of cauliflower hybrids resulting from successive backcrossing proved that Pearson's source of cytomale sterility (cabbage line No. 5255 of Pearson and Dickson's broccoli line No. 1117 A) can be successfully used in breeding cytomale-sterile lines of cauliflower. Earliness and commercial quality of hybrids Bc_3 and Bc_4 (Tab. 1, Fig. 1) were as good as the value of the corresponding recurrent paternal cauliflower lines. Hybrids A, obtained by backcrossing

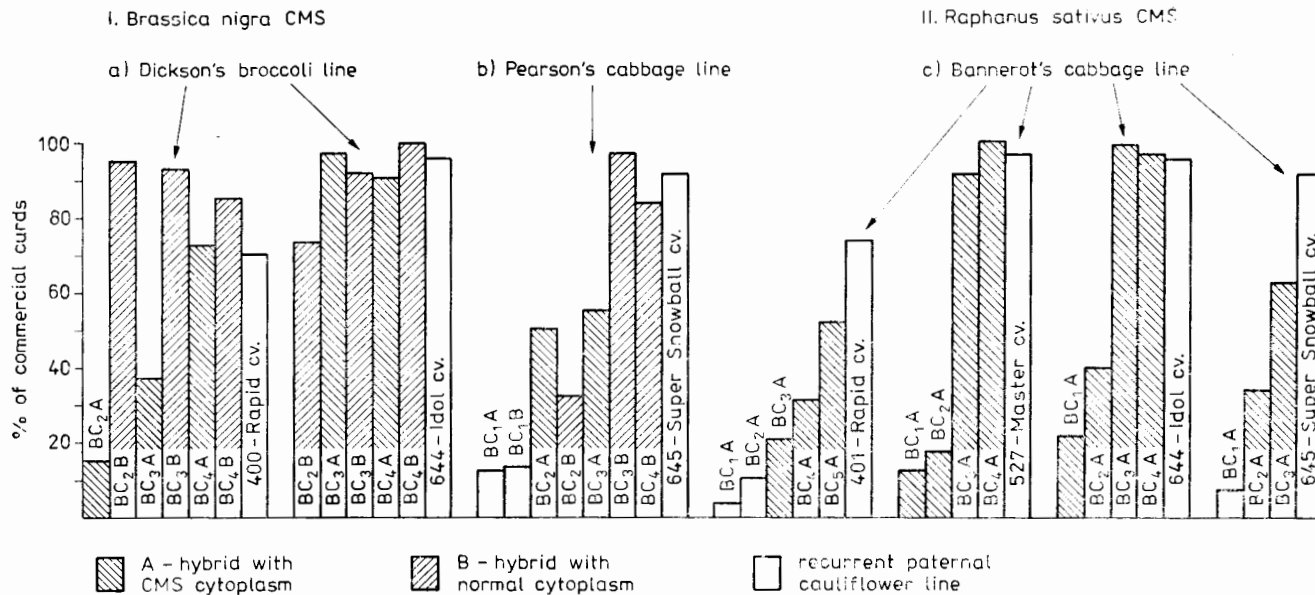
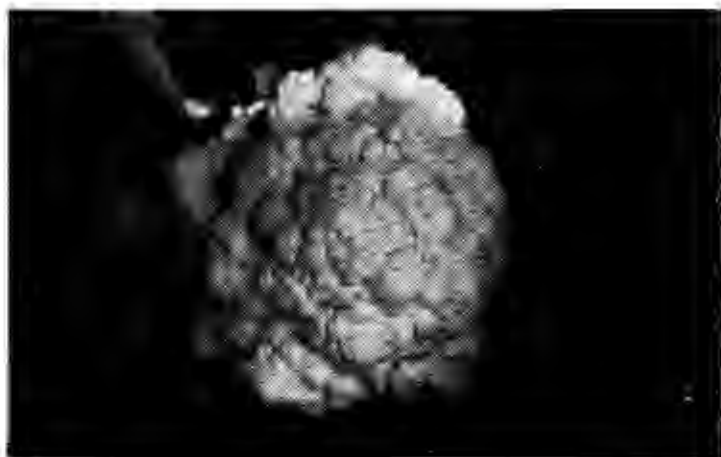
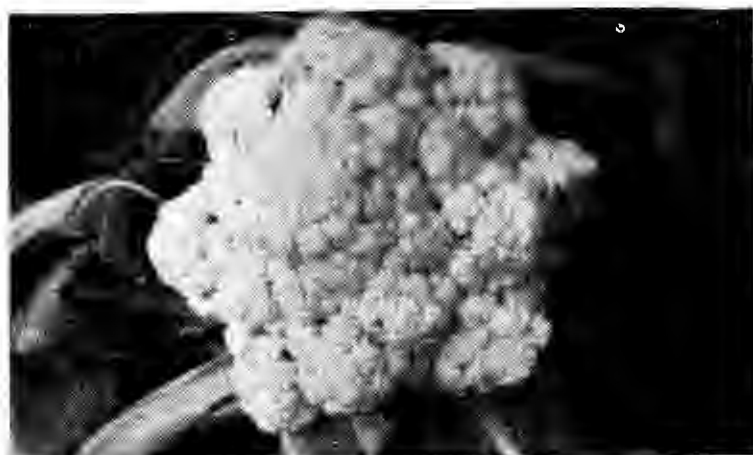


Fig. 1. Comparison of successive backcrossed hybrids and recurrent paternal cauliflower lines

Table 1. Mean values of some cauliflower characters of recurrent paternal lines and successive backcrossed hybrids

Hybrids Bc and recurrent paternal lines				Days to maturity from planting date in the field			Curd weight (g)			Curd diameter (cm)			Curd quality in classes		
				No. of plants	mean	standard deviation	No. of plants	mean	standard deviation	No. of plants	mean	standard deviation	No. of plants	mean	standard deviation
1117 A × 400 — Rapid cv.				<i>Brassica nigra</i> CMS — Dickson's broccoli line											
60/1/3	Bc ₂	— line A ¹	20	51.0	8.2	18	279	168.4	18	16.9	4.4	20	3.6	0.51	
62/12		B ²	15	57.5**	8.7	15	581**	206.3	15	24.7	5.0	15	1.5	0.64	
60/1/4/15	Bc ₃	A	23	39.5	7.9	13	155	114.9	13	15.1	3.4	23	2.6	0.66	
62/6/14		B	27	47.0	7.7	26	291	134.4	26	18.2	4.0	27	1.4	0.63	
60/8/3	Bc ₄	A	19	46.7	8.4	18	260	165.8	18	17.7	4.7	19	2.0	0.67	
62/6/11/8		B	28	38.5*	10.9	25	174	136.9	25	16.6	4.4	28	1.7	0.67	
400 — Rapid cv.			24	44.7	8.3	17	265	154.9	17	17.4	4.2	24	2.0	1.38	
1117 A × 644 (Idol cv.)				<i>Brassica nigra</i> CMS — Pearson's cabbage line											
76/12	Bc ₂	— line B	27	55.9	6.6	27	540**	296.7	27	24.3	7.1	27	1.8**	1.00	
78/7/24		A	28	53.3	7.0	27	450	186.8	27	22.7	7.0	28	1.1	0.45	
76/12/12		B	27	54.1	7.5	26	413	210.7	26	21.8	5.8	27	1.2	0.58	
78/7/24/11	Bc ₄	A	29	58.4	4.8	28	476	129.0	28	24.4*	4.2	29	1.1	0.44	
76/12/12/1		B	31	49.7**	7.0	31	326	152.6	31	20.7	4.4	31	1.1	0.24	
644 — Idol cv.			26	54.6	9.4	26	359	182.9	26	21.1	5.7	26	1.2	0.49	
5255 × 645 — Super Snowball cv.				<i>Brassica nigra</i> CMS — Bannerot's cabbage line											
P ₁₀ × 886/4/7	Bc ₁	— line A	25	72.0**	9.1	24	532**	251.4	24	23.2	5.4	25	3.2**	0.78	
P ₄ × 886/4/7		B	27	69.1**	10.2	25	610**	295.9	25	23.8	5.9	27	3.2**	0.75	
P ₁₀ × 886/4/4/10	Bc ₂	A	16	69.9**	14.8	16	518	151.2	16	24.7	4.6	16	2.1*	1.20	
P _{5/12}		B	27	51.9	8.4	25	456	277.7	25	20.8	5.9	27	2.4**	0.75	
P _{3/6}	Bc ₃	A	27	49.3**	11.9	26	218**	109.6	26	15.6**	3.9	27	2.2**	0.88	
P _{6/4}		B	26	52.6	6.0	26	388	193.8	26	20.5	4.3	26	1.2	0.49	
P _{6/2/4}	Bc ₄	B	13	46.8**	7.6	13	284*	166.8	13	16.7**	4.7	13	1.7	0.75	
645 — Super Snowball cv.			24	57.1	7.8	24	416	187.7	24	22.2	5.6	24	1.3	0.64	
RK × 401 — Rapid cv.				<i>Raphanus sativus</i> CMS — Bannerot's cabbage line											
RK — 1	Bc ₁	— line A	20	78.4**	8.1	19	514**	173.9	19	23.0**	4.9	20	3.7**	0.47	
RK — 1/1		A	20	76.4**	4.7	17	415**	195.9	17	22.3**	4.9	20	3.0**	0.46	
RK — 1/1/4	Bc ₂	A	21	68.4**	8.4	21	442**	205.8	21	22.4**	5.0	21	2.6**	0.75	
RK — 1/8/8		A	22	52.1*	11.0	18	313	210.1	18	17.6	6.0	22	2.5**	0.74	
RK — 1/8/8/1	Bc ₃	A	23	53.7**	12.4	21	281	176.8	21	16.9	4.9	23	2.3	0.76	
401 — Rapid cv.			22	44.5	7.1	18	229	159.6	18	15.3	5.6	22	1.8	0.85	



Phots 1 - 3. Successive backcrossed hybrids ♀ Bannerot's cabbage
line × cauliflower line ♂
1 -- Hybrid Be_1 , 2 -- Hybrid Be_2 , 3 -- Hybrid Be_3

RK × 527 — Master cv.

RK - 2/1	Bc ₁ line	A	23	83.1**	7.6	18	563	230.2	18	27.2	8.2	23	3.0**	0.56
RK - 2/9	Bc ₂	A	9	72.8**	10.8	9	470	183.3	9	26.1	3.8	9	2.6**	0.88
RK - 2/7/7	Bc ₃	A	14	67.1**	7.5	14	491	135.2	14	23.6	4.2	14	1.2	0.58
RK - 2/7/1/1	Bc ₄	A	14	72.7**	4.3	14	567	211.2	14	26.8	3.9	14	1.1	0.27
527 - Master cv.			22	56.5	7.3	21	484	174.3	21	24.2	5.7	22	1.1	0.43

RK × 644 — Idol cv.

RK - 3	Bc ₁ line	A	24	85.2**	7.1	21	476	264.4	21	24.9*	7.0	24	2.8**	0.70
RK - 3/8	Bc ₂	A	25	76.5**	8.5	22	469	179.4	22	22.7	4.8	25	2.4**	0.92
RK - 3/16/7	Bc ₃	A	24	62.2**	8.5	24	384	131.3	24	22.6	4.1	24	1.1	0.28
RK - 3/16/7/7	Bc ₄	A	24	67.2**	7.9	24	471	156.6	24	24.2*	4.5	24	1.2	0.48
644 - Idol cv.			26	54.6	9.4	26	359	182.9	26	21.1	5.7	26	1.2	0.49

RK × 645 — Super Snowball cv.

RK - 4	Bc ₁ line	A	22	86.8**	6.7	13	398	176.0	13	22.4	5.0	22	3.5**	1.53
RK - 4/13	Bc ₂	A	27	70.7**	6.2	27	523	164.8	27	25.0*	4.0	27	2.7**	0.54
RK - 4/13/14	Bc ₃	A	21	69.3**	4.9	21	426	148.6	21	22.5	4.0	21	2.0**	0.86
645 - Super Snowball cv.			24	57.1	7.8	24	416	187.7	24	22.2	5.6	24	1.3	0.64

** Significant difference at $\alpha=0.01$ — between backcrossed hybrid and corresponding recurrent paternal cauliflower line.

* Significant difference at $\alpha=0.05$.

¹ A — Hybrid with CMS cytoplasm.

² B — Hybrid with normal cytoplasm.

³ 1st class designates the best commercial quality of curd.

with the most early paternal 401 — Rapid line having CMS of *B. nigra* — Dickson's broccoli line (Tab. 1), were several days earlier and formed curds of the quality not as good as that of the corresponding hybrids B with normal cytoplasm. The influence of cytoplasm on the earliness and quality of curds was also observed in F_1 hybrids from Indian cultivars and the summer cauliflower cv. which are cultivated in temperate climates (Hoser-Krauze, Gabryl 1982).

Cytoplasmic male-sterile hybrids Bc_4 and Bc_5 having *R. sativus* CMS (Bannerot's line) formed curds 10 - 12 days later than the recurrent paternal lines. Chlorosis

Table 2. Effectiveness of seed setting of petaloid hybrids Bc_4 and Bc_5 with *Raphanus sativus* CMS (Bannerot's) and corresponding recurrent paternal pollinators-lines

No. of line	Percent of plants with seed sets	Average number of seeds per pod	Effectiveness of seed setting (in % check)
<i>Bc₄</i> -Rk-1 × 400			
Rk-1/3/1	44	3	13
1/1/11	50	3	15
1/3/12	39	4	16
1/4/3	23	1	2
1/8/1	27	5	14
1/8/4	47	5	24
1/8/5	64	4	26
1/8/7	44	2	9
1/8/8	30	4	12
1/8/9	31	2	6
1/8/11	44	3	13
1/8/15	15	1	2
1/8/16	28	5	14
° 400 check-pollinator	100	10	100
<i>Bc₄</i> -Rk-2 × 527			
Rk-2/7/1	7	3	2
2/7/3	23	9	23
2/7/4	11	3	4
2/15/2	16	4	7
2/15/4	15	5	8
2/12/3	14	4	6
2/16/6	8	1	1
2/12/10	15	5	8
527 check-pollinator	100	9	100
<i>Bc₄</i> -Rk-3 × 644			
Rk-3/16/1	29	3	7
3/16/3	25	5	10
3/16/7	18	5	7
3/16/8	22	3	5
3/16/9	19	2	3
3/16/10	7	6	3
3/16/18	25	6	12
3/16/20	8	4	3
644 check-pollinator	100	13	100
<i>Bc₄</i> -Rk-4 × 645			
Rk-4/13/8	40	4	13
4/13/9	25	6	13
645 check-pollinator	100	12	100

of seedlings and the leaves of young plants still existed in these hybrids but it disappeared at the time of curd maturity. This character had no a negative influence on curd quality (Tab. 1, Fig. 1, Phots 1-3). Alloplasmic plants obtained by McCollum (1981) after substituting the cytoplasm from Early Scarlet Globe radish (*R. sativus*) to *B. oleracea* had the same kind of chlorosis on the leaves. The chlorotic appearance of seedlings and transplants was determined by the cytoplasm of *R. sativus*. Seed and pod setting after open pollination of Bc_4 , Bc_5 cytomale-sterile petaloid cauliflower hybrids having CMS of *R. sativus*, compared with their recurrent paternal lines, was very poor (Tab. 2). The degree of fertility among petaloid sterile varied. The early hybrids (RK \times 400) were the most effective, but the results obtained suggest that the seed yield of petaloid sterile lines could be 70% smaller than those of normal self fertile lines.

CONCLUSIONS

1. Regarding the curd quality, both sources (Pearson's having CMS of *B. nigra* and Bannerot's having cytoplasm of *R. sativus*) can be successfully used in breeding cytomale-sterile lines of cauliflower.
2. A negative effect of CMS cytoplasm on a high commercial quality of curds cannot be ignored in breeding very early lines.
3. A chlorotic appearance of cauliflower seedlings and leaves in the young stage of plants is determined by *R. sativus* cytoplasm, but it has no a negative influence on the commercial quality of cauliflower curds, though it delayed their maturing.
4. Seed setting of petaloid lines having *R. sativus* cytoplasm was very poor. The variations between lines and single plants in this character suggest some improvement through selection.

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WPLYW ŹRÓDŁA CYTOPLAZMATYCZNEJ MĘSKIEJ STERYLNOŚCI NA NIEKTÓRE CECHY KALAFIORA (*BRASSICA OLERACEA* VAR. *BOTRITIS*)

Streszczenie

Badano przydatność linii kapusty i brokuła posiadających *Brassica nigra* CMS oraz linii Bannerota posiadających *Raphanus sativus* CMS do hodowli cytoplazmatycznie męskosterylnych linii kalafiora.

Z punktu widzenia cech decydujących o jakości róż kalafiora wymienione źródła cytoplazmatycznej męskiej sterylności mogą być z powodzeniem używane do hodowli cytoplazmatycznie męskosterylnych linii kalafiora, jednakże w przypadku hodowli bardzo wczesnych linii należy się liczyć z negatywnym wpływem CMS cytoplazmy na jakość handlową wczesnych róż.

Chłoroza liści siewek i młodych roślin jest determinowana cytoplazmą *R. sativus*, ale nie wywiera ona negatywnego wpływu na wartość handlową róż kalafiora, chociaż opóźnia ich dojrzewanie. Wiązanie nasion płatkowych (petaloid) u linii kalafiora posiadających *Raphanus sativus* CMS było bardzo słabe. Zmienność międzyliniowa i międzyosobnicza tej cechy sugeruje możliwość pewnej poprawy efektywności wiązania nasion na drodze selekcji.

ВЛИЯНИЕ ИСТОЧНИКА ЦИТОПЛАЗМАТИЧЕСКОЙ МУЖСКОЙ СТЕРИЛЬНОСТИ НА НЕКОТОРЫЕ ПРИЗНАКИ ЦВЕТНОЙ КАПУСТЫ (*BRASSICA OLERACEA* VAR. *BOTRITIS*)

Резюме

Исследовалась пригодность линии капусты и брокколи, имеющих *Brassica nigra* CMS, а также линий Баннерота, имеющих *Raphanus sativus* CMS для разведения цитоплазматически мужско-стерильных линий цветной капусты.

С точки зрения признаков, которые имеют решающее значение для качества розетки цветной капусты, представленные источники цитоплазматической мужской стерильности могут быть успешно использованы для разведения цитоплазматически мужско-стерильных линий цветной капусты. Однако, при разведении очень ранних линий следует считаться с отрицательным влиянием цитоплазмы CMS на высокое промышленное качество ранних розеток цветной капусты.

Хлороз листьев сеянцев и молодых растений обусловлен цитоплазмой *R. sativus*, но не оказывает он отрицательного влияния на промышленную ценность розеток цветной капусты, хотя вызывает их позднее созревание. Завязывание семян петалойдных линий цветной капусты, имеющих *Raphanus sativus* CMS, было очень слабым. Межлинейная и индивидуальная изменчивость этого признака указывает на возможность определённого улучшения завязывания семян путём селекции.