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Współzależność między plonem nasion a zawartością glukozynolanów u pokolenia F_1 mieszańców rzepaku ozimego podwójnie ulepszonego (*Brassica napus* L.)

Relationship between seed yield and glucosinolate content in F_1 hybrid generation of double low winter oilseed rape (*Brassica napus* L.)

Przeprowadzono badania pokolenia F_1 mieszańców diallelicznych uzyskanych z krzyżowań pomiędzy 10 liniami rzepaku ozimego podwójnie ulepszonego. Efekty specyficznej zdolności kombinacyjnej dla plonu nasion były istotne dla 9 kombinacji. Istotne dodatnie efekty heterozji liczonej w stosunku do lepszego rodzica zaobserwowano dla 18 kombinacji krzyżowań. Średni plon nasion mieszańców w porównaniu do średniej dla rodziców wyniósł 124,7%. Korelacje pomiędzy plonem nasion mieszańców pokolenia F_1 a plonem nasion ich linii rodzicielskich były nieistotne, natomiast bardzo istotne korelacje znaleziono pomiędzy plonem nasion mieszańców F_1 a efektami specyficznej zdolności kombinacyjnej oraz heterozją. Zawartość glukozynolanów oznaczono w nasionach zebranych z roślin pokolenia F_1. Efekty ogólnej zdolności kombinacyjnej dla glukozynolanów były niskie, ale istotne dla czterech linii. Istotne efekty specyficznej zdolności kombinacyjnej i dodatnie heterozji wystąpiły odpowiednio tylko u sześciu i trzech kombinacji z 45 badanych. Wydaje się, że badane linie rodzicielskie posiadały zbliżone, jeżeli nie identyczne, allele warunkujące zawartość glukozynolanów.

F_1 generation of diallel cross between 10 lines of double low winter oilseed rape was examined. Specific combining ability effects for seed yield were significant in 9 combinations. Significant positive heterosis effects as compared to better parent were observed for 18 cross combination. Average seed yield of hybrids as compared to parent mean was 124,7 per cent. Correlations between the seed yields of F_1 hybrids and yields of their parental lines were not significant but very significant correlations were found between seed yields and SCA effects or heterosis. Glucosinolate content was estimated in seeds collected from plants of F_1 generation. General combining ability effects for glucosinolate content were low but significant for four lines. Significant SCA effects and positive heterosis occurred only in six and three combinations from forty five examined. It seems that examined parental lines possessed almost the same alleles controlling glucosinolate content.

Introduction

Several CMS systems were established to produce hybrids of winter oilseed rape (Bartkowiak-Broda 1995, Delourme at al. 1995, Downey 1994). These hybrids should be of good double low quality. Erucic acid does not make the troubles (Krzymański, Downey 1969, Krzymański 1970), but it is necessary to examine the interactions between glucosinolate content and heterosis in seed yield. (Krzymański at al. 1993, 1994, 1995). Following studies were concerned conditions which are necessary to produce high yielding hybrids with low glucosinolate content.

Materials and methods

Diallel crosses were done among 10 S_1 inbred lines selected from experimental double low varieties of winter oilseed rape (*B. napus*). These varieties were bred by Oil Crop Department in Poznań. Lines were zeroerucic and of very low glucosinolate content (table 1).

Table 1

Glucosinolate content in parental lines of double low winter oilseed rape
Zawartość glukozynolanów w liniach rodzicielskich rzepaku ozimego podwójnie ulepszonego

1 — gluconapin — *glukonapina*, 2 — glucobrassicanapin — *glukobrassicanapina*
3 — progoitrin — *progoitryna*, 4 — napoleiferin— *napoleiferyna*
5 — total of aliphatic glucosinolates — *suma glukozynolanów alkenowych*
6 — 4-hydroxybrassicin — *hydroxybrassicyna*

Line *Linie*	Glucosinolates — *Glukozynolany* [μM/g suchej masy]					
	1	2	3	4	5	6
PN 2293/91	3.1 cd	0.8 c	4.0 cd	0.2 ab	8.1 de	2.8 a
PN 2306/91	3.4 d	1.2 d	4.9 e	0.1 ab	9.7 f	3.0 a
PN 2317/91	3.4 d	0.7 bc	4.5 de	0.1 ab	8.7 ef	1.9 a
PN 2337/91	2.5 ab	0.4 a	4.1 cde	0.3 b	7.3 bcd	2.6 a
PN 2348/91	2.8 bc	0.5 ab	4.2 cde	0.1 ab	7.6 cde	2.0 a
PN 2587/91	3.1 cd	0.9 c	4.5 de	0.1 ab	8.5 def	2.3 a
PN 2595/91	2.4 ad	0.7 bc	2.9 a	0.0 a	6.0 ab	2.3 a
PN 2600/91	2.1 a	0.5 ab	3.1 ab	0.1 ab	5.8 a	2.0 a
PN 2621/91	2.6 abc	0.7 bc	3.8 bcd	0.1 ab	7.3 bcd	2.5 a
PN 2870/91	2.6 abc	0.5 ab	3.5 abc	0.0 a	6.6 abc	2.9 a
$LSD_{0.05}$	0.48	0.20	0.80	0.24	1.28	1.12

a, b, c,... — grouping results according Duncan — *wyniki grupowania wg Duncana*

Seed yield was estimated in field trials conducted in Poznań in 1991/1992. Experiments were set up in the randomized complete block design, in four replications with systematically distributed standard plots. These plots were used to reduce intrablock variability by covariance analysis. Yield results were calculated in dt/ha.

Glucosinolate analyses were made by gas chromatography of silyl derivatives (Thies 1978, Sosulski, Dąbrowski 1984, Landerouin at al. 1987, Michalski at al. 1995). Detector was calibrated using CRM-366 Rapeseed Standard of European Community Bureau of Reference. Obtained results were fully comparable with results of high resolution liquid chromatography when the same standard was used for calibration. Glucosinolate contents were calculated in μM/g of seed.

Statistical analysis of obtained results was made according Griffings method (1956). Simple correlation coefficients for parental lines and hybrids were calculated for general combining ability effects (GCA), specific combining ability effects (SCA) and heterosis effects and also among them and seed yield.

Results

Glucosinolate content in seed of parental lines used for the study is characterized in table 1. Glucosinolate levels in these lines were very low but significant differences still existed among the lines. These differences were high enough to carry out research on inheritance of glucosinolate content in breeding materials of oilseed rape with very low glucosinolate level. Results of such research are very important on the way to hybrid varieties.

Tables 2–4 are giving results obtained for general combining ability (GCA), specific combining ability (SCA) and heterosis in F_1 generation of diallel cross.

Some significant GCA effects for seed yield were found but only at $\alpha = 0.05$ level. Many GCA effects for individual and total glucosinolate contents were significant at $\alpha = 0.01$ level. GCA effects for napoleiferin were not significant. GCA effects for glucosinolate contents were rather low and achieved practical values only few cases.

The GCA effects estimate the additive genetic correlations so the lines PN 2337, PN 2348, PN 2587 and PN 2595 should be the most valuable for breeding of double low varieties because positive values of GCA effects for seed yield and negative for glucosinolate content.

The most frequent significant SCA effects were found for glucobrassicanapin content. The best combinations for double low hybrid production should be PN 2600 x 2870, PN 2337 x 2600, PN 2595 x 2621 and PN 2293 x 2621, because the SCA effects estimate the nonadditive (dominant) correlations.

Table 2

General combining ability effects for glucosinolate contents and for seed yield in F_1 generation of diallel cross — *Efekty ogólnej zdolności kombinacyjnej dla zawartości glukozynolanów i dla plonu nasion w pokoleniu F_1 krzyżowań diallelicznych* (1–6 as in Table 1 — *jak w tabeli 1*)

Line *Linie*	Glucosinolates — *Glukozynolany*						Seed yield *Plon nasion* [dt/ha]
	1	2	3	4	5	6	
PN 2293/91	–0.03	–0.01	–0.33*	0.05	–0.33	0.12	–0.24
PN 2306/91	0.48**	0.46**	1.16**	0.05	2.18**	0.31*	–0.58
PN 2317/91	0.13	–0.07**	0.09	–0.02	0.15	–0.29*	–0.36
PN 2337/91	0.08	–0.11**	0.43*	0.03	0.42	0.04	1.15*
PN 2348/91	–0.05	–0.14**	–0.12	–0.02	–0.34	–0.16	1.16*
PN 2587/91	0.04	0.06**	0.06	–0.01	0.12	0.04	1.07*
PN 2595/91	–0.27**	–0.01	–0.57**	–0.03	–0.92**	–0.07	–0.65
PN 2600/91	0.02	–0.05*	0.08	–0.01	0.06	0.07	–0.31
PN 2621/91	0.10	0.03	0.10	–0.00	0.24	0.11	–0.06
PN 2870/91	–0.49**	–0.16**	–0.90**	–0.04	–1.58**	–0.18	–1.18*

* — effects significantly different from zero (negative or positive) at the level $\alpha = 0.05$
efekty istotnie różne od zera (ujemne lub dodatnie) na poziomie $\alpha = 0,05$
** — effects significantly different from zero (negative or positive) at the level $\alpha = 0,01$
efekty istotnie różne od zera (ujemne lub dodatnie) na poziomie $\alpha = 0,01$

Heterosis effects for seed yield were found to be significant for 19 cross combinations but one of them was negative.

Comparisons between general means for parents and for hybrids in F_1 generation of diallel cross were shown for different traits in table 5. Differences were significant only for seed yield (24.7 per cent) and for 4-hydroxybrassicin (12,5 per cent).

Tables 6 and 7 are presenting correlation coefficients between different glucosinolates and seed yield calculated for trait value, GCA effects, SCA effects and heterosis. The less significant were the correlation coefficients between trait values, the most significant correlation coefficients between SCA effects. There were not significant correlation coefficients for GCA effects, SCA effects and heterosis effects between seed yield and glucosinolate contents. Only correlation coefficient for GCA effects between seed yield and 4-hydroxybrassicin content was significant.

Table 3

Specific combining ability effects for glucosinolate contents and for seed yield in F_1 generation of diallel cross hybrids — only cross combinations showing effects significantly different from zero — *Efekty specyficznej zdolności kombinacyjnej dla zawartości glukozynolanów i dla plonu nasion w pokoleniu F_1 mieszańców krzyżowań diallelicznych — tylko kombinacje wykazujące efekty istotnie różne od zera*

(1–6 as in Table 1 — *jak w tabeli 1*)

Cross combination *Mieszańce*	Glucosinolates — *Glukozynolany*						Seed yield *Plon nasion* [dt/ha]
	1	2	3	4	5	6	
2293x2317	0.14	–0.19**	–0.21	0.04	–0.24	0.59	1.25
2293x2337	–0.21	0.15*	–0.45	–0.01	–0.52	0.07	–0.45
2293x2587	–0.18	–0.33**	–0.78	0.03	–1.32	–0.34	2.36
2293x2595	–0.06	–0.05	–0.65	0.05	–0.77	–0.03	–3.89*
2293x2600	–0.36	–0.02	–0.40	–0.07	–0.75	–0.17	–4.43*
2293x2621	–0.04	0.11	0.68	0.03	0.67	0.29	4.37*
2306x2337	2.47**	0.47**	4.26**	0.00	7.28**	–0.13	4.65*
2306x2348	–0.11	0.21**	0.51	0.15	0.63	–0.33	0.32
2306x2600	–0.48	0.01	–0.09	0.04	–0.56	0.34	–5.07**
2306x2621	0.74*	0.13*	0.48	0.14	1.36	2.00**	–1.82
2306x2870	–0.36	–0.18**	–0.82	0.07	–1.22	–0.01	1.92
2317x2587	1.06**	0.33**	2.10**	0.10	3.61**	–0.23	2.15
2317x2595	0.18	–0.19**	0.33	–0.07	0.25	1.08*	0.17
2337x2348	–0.40	–0.22**	–0.66	–0.03	–1.21	–0.06	–0.75
2337x2587	–0.39	–0.13*	–0.44	–0.05	–0.97	0.84	1.13
2337x2600	–0.67	–0.12	–1.06	–0.05	–1.90	–0.18	4.91**
2337x2621	0.75*	0.01	1.12*	–0.05	1.82	–0.33	0.93
2337x2870	–0.06	–0.00	–0.08	–0.01	–0.27	–0.23	–5.32**
2348x2595	–0.75*	–0.22**	–1.16*	0.03	–2.17*	0.05	2.33
2348x2600	2.65**	0.41**	3.29**	0.10	6.36**	1.61**	2.57
2348x2621	–0.62	–0.16*	–1.33*	–0.10	–2.22*	–0.24	0.66
2348x2870	–0.73*	–0.07	–1.23*	–0.06	–2.01	–0.14	1.21
2587x2600	0.26	0.01	0.31	–0.01	0.60	1.41**	1.96
2587x2621	–0.11	–0.17**	–0.52	–0.01	–0.78	–0.04	–1.74
2595x2600	0.78*	0.18**	1.04	0.11	2.04*	–0.48	–1.23
2595x2621	0.50	0.21**	1.22*	0.01	1.96	–0.32	4.46*
2600x2621	0.10	–0.16*	0.07	–0.01	0.09	–0.56	–2.66
2600x2870	–0.41	–0.07	–0.43	–0.08	–1.00	–0.17	5.74**
2621x2870	–0.08	0.16*	–0.36	0.02	–0.28	–0.01	1.72

* and ** as in Table 2 — *jak w tabeli 2*

Table 4

Heterosis for glucosinolate contents and for seed yield as compared to parent with higher value – only cross combination with effects for seed yield significantly different from zero — *Heterozja dla zawartości glukozynolanów i dla plonu nasion wyznaczona względem lepszego rodzica – tylko kombinacje wykazujące efekty dla plonu nasion istotnie różne od zera* (1–6 as in Table 1 — *jak w tabeli 1*)

Cross combination *Mieszańce*	Glucosinolates — *Glukozynolany*						Seed yield *Plon nasion*	
	1	2	3	4	5	6	[dt/ha]	[%]
2293x2348	–0.2	–0.3**	–0.2	–0.1	–0.5	–0.3	4.99*	32.0*
2293x2587	–0.5	–0.5**	–1.6**	0.0	–2.5*	–0.3	5.02*	32.1*
2293x2621	–0.3	0.0	0.4	0.0	0.0	0.4	5.89**	37.8**
2306x2337	2.4**	0.3**	4.9**	–0.1	7.7**	–0.1	5.99**	35.9**
2306x2600	–0.6	–0.1	0.2	0.1	–0.5	0.4	–5.20**	–31.2**
2317x2337	–1.0**	–0.3**	–1.0	–0.2	–2.3*	–0.4	4.75*	30.2*
2317x2348	–0.7	–0.3**	–0.9	–0.1	–1.9	0.1	6.74**	46.1**
2317x2587	0.6	0.1	1.7**	0.1	2.7*	–0.1	5.44**	36.6**
2337x2587	–0.6	–0.4**	–0.5	–0.2	–1.4	1.0	5.06*	32.2*
2337x2600	–0.3	–0.1	–0.7	–0.2	–1.2	0.0	7.46**	47.4**
2348x2595	–1.1**	–0.4**	–2.1**	0.0	–3.5**	0.2	5.66**	38.7**
2348x2600	2.6**	0.4**	3.0**	0.1	6.0**	2.2**	5.13**	32.6**
2348x2870	–1.3**	–0.2**	–2.5**	–0.1	–4.0**	–0.7	4.01*	27.4*
2587x2595	–1.0**	–0.1	–1.4*	0.0	–2.4*	0.4	5.40**	36.4**
2587x2600	0.0	–0.2**	–0.1	0.0	–0.2	1.9**	4.43*	28.2*
2587x2870	–1.1**	–0.3**	–1.8**	0.0	–3.2**	–0.7	5.95**	40.1**
2595x2621	0.5	0.2**	0.9	0.0	1.5	–0.1	5.65**	36.4**
2595x2870	–0.4	–0.3**	–0.5	0.1	–0.9	–0.5	6.67**	55.1**
2600x2870	–0.7	–0.1	–0.8	–0.1	–1.6	–0.5	5.96**	37.9**

Table 5

Comparison of parents and F_1 hybrids according to general means for glucosinolate contents and seed yield — *Porównanie rodziców i mieszańców F_1 pod względem średniej zawartości glukozynolanów i średniego plonu nasion*

(1–6 as in Table 1 — *jak w tabeli 1*)

General means *Średnia ogólna*	Glucosinolates — *Glukozynolany*						Seed yield *Plon nasion* [dt/ha]
	1	2	3	4	5	6	
— for parents — *dla rodziców*	2.80	0.69	3.95	0.11	7.56	2.43	14.50
— for hybrids — *dla mieszańców*	2.77	0.67	3.95	0.13	7.51	2.73	18.08
— difference — *różnica*	–0.03	–0.02	0.00	0.02	–0.05	0.30**	3.58**
— difference — *różnica* [%]	–1.2	–2.4	0.0	15.2	–0.6	12.5**	24.70**

* and ** as in Table 2 — *jak w tabeli 2*

Table 6

Matrix of correlation coefficients among glucosinolate contents and seed yield for hybrids of F_1 generation (above diagonal) and among GCA effects of these traits (below diagonal) — *Macierz współczynników korelacji pomiędzy zawartością glukozynolanów i plonem nasion dla mieszańców pokolenia F_1 (powyżej przekątnej) oraz pomiędzy efektami ogólnej zdolności kombinacyjnej (OZK) tych cech (poniżej przekątnej)*

1 — gluconapin — *glukonapina*, 2 — glucobrassicanapin — *glukobrassicanapina*
3 — progoitrin — *progoitryna*, 4 — napoleiferin— *napoleiferyna*
5 — total of aliphatic glucosinolates — *suma glukozynolanów alkenowych*
6 — 4-hydroxybrassicin — *hydroxybrassicyna*
7 — seed yield — *plon nasion*

		Trait — *Cecha*						
		1	2	3	4	5	6	7
	1	–	0.71*	0.87**	0.09	0.95**	0.19	0.27
	2	0.73*	–	0.55	–0.15	0.73*	0.38	0.36
GCA	3	0.96**	0.74*	–	0.37	0.96**	0.17	0.50
	4	0.64*	0.55	0.61	–	0.26	0.12	0.66*
OZK	5	0.97**	0.82**	0.99**	0.66*	–	0.26	0.48
	6	0.60	0.76*	0.63	0.78**	0.68*	–	–0.08
	7	0.26	–0.19	0.28	0.16	0.19	0.03	–

* and ** as in Table 2 — *jak w tabeli 2*

Table 7

Matrix of correlation coefficients among specific combining abilities (SCA) for glucosinolate contents and seed yield for hybrids of F1 generation (below diagonal) and among heterosis for these traits (above diagonal) — *Macierz współczynników korelacji między wartościami specyficznej zdolności kombinacyjnej (SZK) dla zawartości glukozynolanów i plonu nasion mieszańców pokolenia F_1 (poniżej przekątnej) oraz pomiędzy efektami heterozji dla tych cech (powyżej przekątnej)*

(1–7 — as in Table 6 — *jak w tabeli 6*)

		Heterosis — *Heterozja*						
		1	2	3	4	5	6	7
	1	–	0.72**	0.92**	0.13	0.97**	0.40**	0.13
	2	0.70**	–	0.76**	0.26	0.78**	0.22	–0.05
SCA	3	0.95**	0.78**	–	0.17	0.99**	0.30*	0.08
	4	0.41**	0.41**	0.39**	–	0.18	0.17	–0.24
SZK	5	0.98**	0.79**	0.99**	0.42**	–	0.34*	0.10
	6	0.34*	0.13	0.23	0.25	0.26	–	0.06
	7	0.19	0.15	0.23	–0.07	0.22	0.00	–

* and ** as in Table 2 — *jak w tabeli 2*

Table 8 shows correlations between seed yield of F_1 hybrid generation and GCA effects, SCA effects and heterosis for different examined traits. This table was made in search for effects significantly correlated with seed yield of F_1 hybrid generation in diallel cross. This seed yield was highly correlated with SCA effects and heterosis for seed yield but not with its GCA effects. It is very interesting that seed yield of F_1 hybrid generation was also highly significantly correlated with GCA effects for contents of gluconapin, progoitrin, 4-hydroxybrassicin and total of aliphatic glucosinolates.

Table 8

Correlation coefficients between seed yield of F_1 hybrid generation and GCA effects or SCA effects or heterosis for different traits. — *Współczynniki korelacji między plonem nasion mieszańców pokolenia F_1, efektami ogólnej zdolności kombinacyjnej, specyficznej zdolności kombinacyjnej oraz heterozji dla różnych cech*

Trait — *Cecha*	Correlation coefficients *Współczynniki korelacji*		
	GCA *OZK*	SCA *SZK*	heterosis *heterozja*
Seed yield — *Plon nasion*	0.46	0.93**	0.97**
Gluconapin — *Glukonapina*	0.89**	0.19	0.20
Glucobrassicanapin — *Glukobrassicanapina*	0.49	0.13	0.06
Progoitrin — *Progoitryna*	0.82**	0.22	0.18
Napoleiferin — *Napoleiferyna*	0.73*	–0.14	–0.24
Total of aliphatic glucosinolates *Suma glukozynolanów alkenowych*	0.82**	0.20	0.19
4-hydroxybrassicin — *4-hydroxybrassicyna*	0.64*	0.03	0.10

* and ** as in Table 2 — *jak w tabeli 2*

Conclusions

- Significant heterosis effects for seed yield occurred in 19 combinations of 45 examined.
- Heterosis and combining ability effects for glucosinolate contents were not correlated with heterosis or combining ability effects for seed yield.
- Seed yield of F_1 generation was correlated:
  - — with SCA effect and heterosis calculated for seed yield but not with GCA effect,

— with GCA effects for all glucosinolate contents except of glucobrassicanapin.

- It was shown that it should be possible to produce high yielding winter oilseed rape hybrids with low glucosinolate content.

Wnioski

- Znaleziono istotne efekty heterozji w plonie nasion dla 19 kombinacji z 45 badanych.
- Heterozja i efekty zdolności kombinacyjnej dla zawartości glukozynolanów nie były skorelowane z heterozją lub efektami kombinacyjnymi dla plonu nasion.
- Plon nasion pokolenia F_1 był skorelowany:
  — z efektem specyficznej zdolności kombinacyjnej i heterozją dla plonu nasion, ale nie był skorelowany z efektem ogólnej zdolności kombinacyjnej dla plonu nasion.
  — z efektami ogólnej zdolności kombinacyjnej dla zawartości wszystkich glukozynolanów z wyjątkiem glukobrassicanapiny.
- Wykazano, że powinno być możliwe otrzymanie wysoko plonujących odmian mieszańcowych rzepaku ozimego z niską zawartością glukozynolanów.

References

Bartkowiak-Broda I. 1995. CMS polima. Proceedings of 9th International Rapeseed Congress, Cambridge, UK, 4-7.07.1995, 1: 24-27.

Delourme R., Eber F., Renard M. 1995. Breeding double low restorer lines in radish cytoplasmic male sterility of rapeseed (*Brassica napus* L.). Rapeseed today and tomorrow. Proceedings of 9th International Rapeseed Congress, Cambridge, UK, 4-7.07.1995, 1: 6-8.

Downey R. K. 1994. The status of hybrid systems and biotechnology applications in Canada. Bulletin GCIRC. 10: 45-47.

Griffing B. 1956. Concept of general and specific combining ability in relation to diallel crossing systems. Aust. J. Biol. Sci. 9: 463-492

Krzymański J., Downey R. K. 1969. Inheritance of fatty acid composition in winter forms of rapeseed, *Brassica napus*. Can. J. Plant Sci. 49: 313-319.

Krzymański J. 1970. Genetyczne możliwości ulepszania składu chemicznego nasion rzepaku ozimego. (Genetic possibilities of improvement of chemical composition of winter oilseed rape (Brassica napus) seeds.). Hodowla Roślin Aklim. Nas. 14: 95-133.

Krzymański J., Piętka T., Krótka K. 1993. Zdolność kombinacyjna i heterozja mieszańców diallelicznych rzepaku ozimego podwójnie ulepszonego. I. Pokolenie F_1. (Combining ability and heterosis in diallel crosses of double low winter oilseed rape. I. F_1 generation.). Post. Nauk Rol. 5: 41-52.

Krzymański J., Piętka T., Krótka K. 1994. Zdolność kombinacyjna i heterozja mieszańców diallelicznych rzepaku ozimego podwójnie ulepszonego. II. Pokolenia F_1 i F_2. (Combining ability and heterosis in diallel crosses of double low winter oilseed rape. II. F_1 and F_2 generations) Rośliny Oleiste XV (1): 21-32.

Krzymański J., Piętka T., Krótka K., Michalski K. 1995. Zawartość glukozynolanów u mieszańców F_1 polskiego rzepaku ozimego podwójnie ulepszonego. (Glucosinolate content in F_1 hybrids of Polish double low winter oilseed rape). Rośliny Oleiste XVI (1): 13-24.

Landerouin A., Quinsac A., Ribaillier D. 1987. Optimization of silylation reactions of desulphoglucosinolates before gas chromatography. World Crops 13: 26-37.

Michalski K., Kołodziej K., Krzymański J. 1995. Quantitative analysis of glucosinolates in seeds of oilseed rape. Effect of sample preparation on analytical results. Proceedings of 9th International Rapeseed Congress, Cambridge, UK, 4-7.07.1995, 3: 911-913.

Sosulski F. W., Dąbrowski K. J. 1984. Determination of glucosinolates in canola meal and protein products by desulfatation and capillary gas-liquid chromatography. J. Agri. Food Chem. 32: 1172-1175.

Thies W. 1978. Quantitative analysis of glucosinolates after their enzymatic desulfatation on ion exchange columns. Proceedings of 5th Int. Rapeseed Conf., Malmo, 1: 136-139.