Study on General Combining Ability in F_1 and F_2 Generations of Winter Oilseed Rape Hybrids in Respect of Glucosinolate Content

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Introduction

It is expected that qualitative requirements for double low oilseed rape will become more rigorous in the future. This will be important especially in reference, to glucosinolate content. Glucosinolates are the main antinutritive component of oilseed rape (*Brassica napus* L.) (Krzymański 1970).

In consequence of research and breeding works double low varieties of oilseed rape (Canola type) were obtained. Glucosinolate in rapeseed meal produced from seed of these varieties is low enough to obtain good body weight in animal production. Nevertheless enlarged thyroid gland and changes in its metabolism is usually observed. Therefore breeding for further elimination of glucosinolates from rapeseed is desired and purposeful. Quality requirements concerning antinutritive components by licensing new varieties are increasing around the world. It concerns not only traditional cultivars but also hybrids (Bartkowiak-Broda 1998; Heiman1999; Friedt 1999).

Presented study is the continuation of research on glucosinolate inheritance in low glucosinolate winter oilseed rape. Earlier works concerning this matter used crossings between inbred lines in diallel design (Krzymański *et al.* 1993; 1994; 1995). This study showed, that it should be possible to produce high yielding winter oilseed rape varieties and hybrids with low glucosinolate content (Krzymański *et al.* 1995; 1998).

Recent study was undertaken in order to establish general combining abilities in

respect to glucosinolate content in seeds of F_1 and F_2 generation of hybrids between winter double low varieties and inbred lines with extremely low glucosinolate content. Crossings were performed in factor design.

Materials and methods

Hybrids were produced by crossing of double low varieties: Mar, Polo, Silvia, Lirajet and Wotan with inbred lines of extremely low glucosinolate content. Hybrids were grown in field trials. Harvested seeds were analysed for glucosinolate content and composition. Analyses were conducted using gasliquid chromatography of sililated desulfoglucosinolates (Michalski *et al*. 1995). Results were expressed in μmol/g seeds. Calculations of general and specific combining abilities were performed in North Caroline II (NC II) design (Garretsen, Keuls 1978; Ubysz-Borucka 1985). GCA values and statistical tests of their significance were calculated separately for F_1 and F_2 generations and compared afterwards.

Discussion of results

Results shown in Table 1 were obtained in field trials with hybrids combinations inbred lines × cultivars. Calculated F coefficients were extremely significant for maternal plants (inbred lines) and for pollinators (cultivars) as concerns contents of gluconapin, progoitrin and total alkenyl glucosinolates in F_1 and F_2 generations of hybrids. Differentiation of genotypes in respect to 4-hydroxybrassicin content was observed only for pollinator plants in F_2 generation of hybrids.

Table 1

Values of general combining ability for inbred lines and for varieties examined in F_1 and F_2 generations in respect of glucosinolates content

Line /variety/	Gluconapin		Glucobrassicanapin		Progoitrin		4-hydroxybrassicin		Total of glucosinolates		Total of aliphatic glucosinolates	
	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2
Maternal plants												
PN-3181	-0,14	0,03	-0,04**	-0,06	-0,60**	-0,40	-0,44	0,17	-1,20**	-0,24	-0,79**	-0,39
PN-3451	0,22**	0,06	-0,02	0,01	0,04	-0,67**	0,27	0,04	0,49	-0,64	0,24	-0,65
PN-3455	-0,20**	-0,24**	0,03	-0,04	0,05	-0,39	0,05	-0,09	-0,08	-0,86	-0,11	-0,75
PN-3462	0,06	-0,14	0,00	0,02	0,55**	0,21	0,01	-0,18	0,64	0,01	0,62**	0,15
PN-3707	-0,11	0,21	-0,08**	-0,01	0,10	0,85**	0,07	-0,20	-0,07	0,85	-0,11	1,06*
PN-3710	0,08	-0,22	0,05**	-0,02	-0,04	-0,36	-0,68*	0,13	-0,60	-0,57	0,09	-0,68
PN-3734	-0,37**	-0,26**	-0,02	-0,03	-0,85**	-0,63**	0,33	-0,21	-0,90**	-0,98	-1,25**	-0,80
PN-3999	-0,23**	0,12	-0,04**	0,04	-0,34**	0,30	0,06	0,36	-0,55	0,79	-0,61**	0,41
PN-4043	0,13	-0,05	0,16**	0,14**	-0,02	0,00	0,32	0,46	0,63	0,59	0,30	0,13
PN-4272	0,49**	0,35**	0,00	-0,03	1,15**	0,86**	0,41	-0,30	2,09**	0,88	1,68**	1,19**
PN-4287	0,09	0,14	-0,05	0,00	-0,08	0,23	-0,44	-0,22	-0,46	0,16	-0,07	0,32
F	6,52**	2,56**	10,28**	1,39	16,85**	3,80**	1,74	0,72	4,38**	1,15	11,04**	2,69**

	Pollinators											
Lirajet	-0,23**	-0,26**	-0,02*	-0,05	-0,24**	-0,44*	-0,11	-0,17	-0,61*	-1,00*	-0,49**	-0,80**
Silvia	0,05	0,28**	0,05**	0,13**	0,13	0,55**	0,20	-0,21	0,46	0,82*	0,23	1,02**
Wotan	-0,12*	-0,40**	0,07**	-0,06*	-0,03	-0,59**	-0,41*	-0,44*	-0,52	-1,45**	-0,10	-1,01**
Mar	-0,01	0,07	-0,06**	-0,02	-0,24**	-0,18	0,14	0,62**	-0,13	0,51	-0,28*	-0,13
Polo	0,32**	0,31**	-0,04**	0,00	0,38**	0,66**	0,18	0,19	0,81**	1,12**	0,64**	0,92**
F	10,51**	14,42**	16,72**	6,24**	9,02**	9,38**	1,98	4,13**	4,29**	6,70**	8,14**	10,38**

* — significant at the level $\alpha = 0.05$
** — significant at the level $\alpha = 0.01$

Results obtained for reciprocal crossings: cultivars × inbred lines are shown in Table 2. For maternal plants in F_1 generation calculated F coefficients were significant for glucobrassicanapin contents. In F_2 generation for this group of plants GCA effects were extremely significant in respect to gluconapin, glucobrassicanapin, progoitrin, total of glucosinolates and total of alkenyl glucosinolates and significant for 4-hydroxybrassicin. For pollinators extremely significant GCA effects were observed for gluconapin, progoitrin, total of glucosinolates and total of alkenyl glucosinolates in F_1 and F_2 generations of hybrids.

Table 2

Values of general combining ability for cultivars and for inbred lines examined in F_1 and F_2 generations in respect of glucosinolates content

Line /variety/	Gluconapin		Glucobrassicanapin		Progoitrin		4-hydroxybrassicin		Total of glucosinolates		Total of aliphatic glucosinolates	
	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2
Maternal plants												
Lirajet	0,06	-0,11**	0,04**	-0,02	0,10	-0,20	0,03	-0,25	0,18	-0,55	0,20	-0,28
Silvia	0,07	0,23**	0,05**	0,13**	-0,02	0,41**	0,07	0,25	0,23	1,06**	0,10	0,79**
Wotan	-0,19**	-0,29**	0,00	-0,05**	0,01	-0,43**	-0,29*	-0,53**	-0,49*	-1,35**	-0,16	-0,80**
Mar	0,10	0,10	-0,01	0,00	-0,01	0,17	0,02	0,26	0,12	0,59	0,09	0,28
Polo	-0,04	0,07	-0,09**	-0,06**	0,09	0,04	0,18	0,27	-0,04	0,26	-0,22	0,01
F	2,14	10,21**	10,66**	16,75**	0,26	5,72**	2,01	3,15*	1,30	8,33**	0,78	7,50**
Pollinators												
PN-3181	0,17	0,18*	0,02	0,00	-0,05	0,03	0,04	-0,23	0,20	-0,05	0,15	0,19
PN-3451	0,07	0,11	-0,02	0,04	-0,37*	-0,27	0,03	-0,02	-0,28	-0,18	-0,35	-0,18
PN-3455	-0,19	0,15	-0,01	0,02	-0,07	0,38	-0,41*	-0,01	-0,74*	0,50	-0,27	0,55
PN-3462	0,13	0,19*	-0,01	0,01	0,47*	0,68**	0,18	0,59*	0,77*	1,45**	0,57	0,84**
PN-3707	-0,26*	-0,27**	-0,05	-0,06*	0,25	0,16	-0,02	-0,04	-0,16	-0,26	-0,07	-0,18
PN-3710	-0,01	0,06	0,02	0,02	0,15	-0,16	0,00	0,06	0,13	-0,12	0,14	-0,15
PN-3734	-0,19	-0,29**	0,02	-0,01	-0,42*	-0,61**	-0,01	-0,04	-0,62	-0,99*	-0,61*	-0,95**

PN-3999	-0,27**	-0,04	-0,02	0,02	-0,57**	-0,25	-0,38*	-0,38	-1,24**	-0,61	-0,86**	-0,23
PN-4043	-0,26*	-0,37**	0,02	0,00	-0,56**	-0,93**	0,13	0,29	-0,63	-0,95*	-0,79**	-1,27**
PN-4272	0,82**	0,48**	0,06	-0,01	1,44**	1,18**	0,70**	-0,28	3,07**	1,53**	2,37**	1,78**
PN-4287	-0,03	-0,18*	0,01	-0,04	-0,26	-0,17	-0,27	0,03	-0,54	-0,34	-0,26	-0,36
F	6,93**	7,36**	1,40	1,14	9,07**	8,35**	2,75**	0,75	9,18**	2,96**	8,35**	6,78**

* — significant at the level $\alpha = 0.05$
** — significant at the level $\alpha = 0.01$

Results of SCA calculations for both series of crosses showed, that some combinations which had positive SCA could change to negative values in F_2 generation (Table 3).

Coefficients of correlation calculated among GCA for investigated glucosinolates were compared separately for cultivars and inbred lines in F_1 and F_2 generations independently of the direction of crossing (Table 4). GCA values for total of alkenyl glucosinolates were significantly positively correlated with GCA for gluconapin, progoitrin and total glucosinolates for inbred line in F_1 and F_2 generation. Also GCA values for total glucosinolates were strongly positively correlated with GCA of gluconapin and progoitrin in both generations.

Correlation for general combining abilities of cultivars was less significant in F_1 generation. More significant correlations were observed in F_2 generation of hybrids.

Table 3

Values of specific combining abilities in F_1 and F_2 generations of hybrids in respect to glucosinolates content

Trait	Field trial	Range		F calculated		$LSD_{0,05}$	
		F_1	F_2	F_1	F_2	F_1	F_2
Gluconapin	I	-0,63-0,91	-0,80-1,38	2,60**	2,67**	0,36	0,48
	II	-0,55-0,64	-0,64-0,92	1,60	4,11**	0,46	0,36
Glucobrassicanapin	I	-0,18-0,43	-0,18-0,35	4,68**	1,59	0,08	0,17
	II	-0,10-0,16	-0,15-0,28	1,83*	3,53**	0,10	0,10
Progoitrin	I	-1,10-1,99	-2,28-1,93	4,44**	2,43**	0,16	1,06
	II	-0,91-1,02	-1,51-1,71	1,50	2,94**	0,74	0,78
4-hydroxybrassicin	I	-1,30-1,93	-1,00-1,26	1,20	0,84	1,05	1,15
	II	-1,18-1,06	-1,06-1,51	2,23**	0,66	0,70	1,18
Total of glucosinolates	I	-2,04-3,17	-3,75-4,95	1,80*	1,72*	1,69	2,52
	II	-2,16-2,73	-2,53-3,18	1,96*	1,84*	1,46	1,88
Total of aliphatic glucosinolates	I	-1,69-3,39	-3,31-3,76	3,74**	2,50**	0,89	1,66
	II	-1,24-1,66	-2,29-2,37	1,60	3,00**	1,18	1,23

* — significant at the level a = 0.05
** — significant at the level a = 0.01
Field trail I — inbred lines × varieties
Field trail II — reciprocal crossing

Table 4

Matrix of correlation coefficients between GCA of inbred lines (below diagonal) and varieties (over diagonal)

		1	2	3	4	5	6
Generation F_1							
1.	Gluconapin	1	-0,066	0,723*	0,657*	0,949**	0,895**
2.	Glucobrassicanapin	0,358	1	0,041	-0,438	-0,022	0,245
3.	Progoitrin	0,821**	0,204	1	0,335	0,762*	0,877**
4.	4-hydroxybrassicin	0,469*	0,271	0,491*	1	0,767**	0,395
5.	Total of glucosinolates	0,892**	0,355	0,928**	0,733**	1	0,890**
6.	Total of aliphatic glucosinolates	0,924**	0,333	0,974**	0,515*	0,960**	1
Generation F_2							
1.	Gluconapin	1	0,700*	0,961**	0,652*	0,984**	0,976**
2.	Glucobrassicanapin	0,171	1	0,733*	0,179	0,671*	0,794**
3.	Progoitrin	0,782**	0,057	1	0,457	0,921**	0,990**
4.	4-hydroxybrassicin	-0,179	0,383	-0,165	1	0,754*	0,495
5.	Total of glucosinolates	0,821**	0,280	0,923**	0,160	1	0,944**
6.	Total of aliphatic glucosinolates	0,881**	0,145	0,978**	-0,174	0,943**	1

Conclusions

- Calculated GCA values showed that both inbred lines and cultivars were highly and significantly differentiated in reference glucosinolate content and composition. So it makes possible further effective selection for still lower glucosinolate content.
- It is possible that obtained highly significant GCA for inbred lines are the result of intensive selection performed during several years for extremely low glucosinolate content and inbreeding connected with it. Cultivars were not so homozygous. They fulfill only the conditions necessary for double low standard and were more

differentiated internally.

- Possibilities of SCA use for improvement in glucosinolate content were much smaller. Only few combinations had SCA values significantly different from zero. For many hybrids positive SCA values in F_1 generation became changed to negative values in generation F_2 or inversely.
- Distinct effects of domination of higher glucosinolate content were not found in examined hybrids between lines and cultivars.
- It was ascertained, that the use of crossing between lines and cultivars could be profitable for larger genetical differentiation of breeding materials and is not accompanied by difficulties in selection for extremely low glucosinolates content in seeds.

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