Genetic Variation, Genotype x Environment Interactions and Heritabilities of Tocopherol Content in Winter Oilseed Rape (Brassica napus L.)

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Abstract

Tocopherols as natural antioxidants in vegetable oils are found in all oil crops as major sources. They are important dietary nutrients and thus enhanced tocopherol contents in seeds appear favourable and breeding for tocopherol has become an increasingly important objective in winter oilseed rape. In the seedoil of oilseed rape, α- and γ-tocopherol are predominantly contributing to total tocopherol content. In this study, genetic variation of α- and γ-tocopherol in oilseed rape as well as heritability of tocopherol traits were evaluated. As a result of this study, total tocopherol contents as plot mean values showed a broad range from about 350 – 1000 ppm in oil and the α/γ tocopherol ratio varied from 0.53 to 1.70 yielding a good potential for breeding purposes. Inheritance of tocopherol traits was analysed in three doubled haploid populations. Large genotype x environment interactions were identified as major source of variation, resulting in a heritability from 0.23 for α-tocopherol to 0.50 for γ-tocopherol, which is low compared to other seed components like oil (0.56-0.90), protein (0.43-0.76) or glucosinolate content (0.91-0.95). No correlation between α- and γ-tocopherol was observed. Tocopherol content was not correlated with the contents of oil, protein and glucosinolates. In conclusion, tocopherol content in oilseed rape can be increased without negative effects on other quality traits, but response to selection will be reduced by large genotype x environment interactions.

Key words. Tocopherols - oil quality - genotype x environment interactions – heritability – vitamin E

Introduction

Synthesized by plants only, α–,β–,γ- and δ-tocopherol are important natural antioxidants as Vitamin E (α-tocopherol) and inhibit fatty acid oxidation in food oil products (γ-tocopherol) (Kamal-Eldin et al. 1996). In winter oilseed rape tocopherol proportions of 65% γ- tocopherol and 35% α-tocopherol are commonly found in the seedoil (Dolde et al. 1999). Very low amounts of δ-tocopherol (< 1%) and generally no β-tocopherol are present. Genetic variation of tocopherol contents in winter oilseed rape was investigated in material of different genetical origin. Three doubled haploid populations were tested in three to four environments in northern Germany to analyse heritability of α-, γ- and total tocopherol content as well as correlations with other quality traits.

Plant material

Selection for tocopherol content in winter oilseed rape was done in field grown material at Göttingen, Germany, from 1999-2002. Genotypes were originating from nine different crosses between very diverse breeding material. Moreover, genotypes were derived from two lines subjected to mutagenesis, which were Skrzeszowicki ("++"-quality cultivar) and DH 0-120, a "00"-quality DH-line (Jan Olejniczak, pers. communication). In 2002, results were obtained from F5-seeds derived from the nine crosses and from the progeny of the mutagenically treated lines (M6 = 5th generation of selfing after treatment). Plots in a year were originating from seeds of single plants of the previous year. In a plot 3-4 single plants were selfed. To study tocopherol heritability three doubled haploid (DH) populations were tested:

Population 1: 144 DH-lines from a cross between two DH-lines of the winter rapeseed cultivars "Mansholts Hamburger Raps"(++) and "Samourai"(00) grown at two locations in Göttingen with different soils in 1999 and 2000.
Population 2: 49 DH-lines derived from a cross between a high oleic acid mutant line and a low linolenic acid line grown at the locations Göttingen, Thüle and Hohenlieth in Northern Germany in 2000.
Population 3: 46 DH-lines from a cross between the winter rapeseed cultivar "Samourai" and the winter rapeseed line "Sva 0565" (00) grown at Göttingen and Hohenlieth in 2001 and 2002.
Tocopherol analysis was performed by HPLC (Thies 1997). Total tocopherol content was calculated as the sum of α-, γ- and δ-tocopherol, tocopherol composition is described as ratio of α- to γ-tocopherol content. NIRS was used for analysis of oil, protein and glucosinolate contents in whole seeds.

Results and Discussion

Tab. 1 shows tocopherol content and composition in the seedoil of ten single plants of harvest 2001 and the corresponding ten plots with extreme tocopherol content and composition of harvest 2002 out of 195 plots. Total tocopherol contents in oil ranges between about 350 and 1000 ppm, while α/γ-tocopherol ratio shows a variation of 0.53-1.70.

Tab. 1: Tocopherol contents in seed oil, α/γ-tocopherol ratios and oil content of 10 extreme winter oilseed rape genotypes of harvest 2002 as plot mean values and the corresponding single plants of harvest 2001

Total tocopherol content		**Harvest 2002** (plot mean values)			**Harvest 2001** (single plant values)		
	Genotype no.	**Total tocopherol in oil (ppm)**	**α/γ**	**oil content** (% DM)	**Total tocopherol in oil (ppm)**	**α/γ**	**oil content** (% DM)
low	1	409	1.43	35	437	0.88	37
	2	446	1.20	35	348	0.87	40
	3	352	1.70	44	507	0.83	45
	4	428	1.50	47	489	0.89	49
	5	533	0.92	40	488	0.27	47
high	6	897	0.60	43	893	0.38	47
	7	857	0.53	45	904	0.37	42
	8	900	0.57	44	713	0.40	51
	9	1003	0.63	40	894	0.39	48
	10	974	0.63	42	821	0.39	49
cv. Express		669	0.84	47	698	0.69	48

Tab. 2 shows the results obtained from the DH-populations by analysis of variance. Highly significant genotype x environment interaction effects were the major sources for variation of tocopherol traits, resulting in low heritability of tocopherol traits.

Tab.2: Components of variance and heritability of α- ,γ-, total tocopherol contents and α/γ-tocopherol ratio in three doubled haploid winter rapeseed populations

	Components of variance and heritability											
	α-tocopherol			**γ-tocopherol**			**total tocopherol**			**α/γ tocopherol ratio**		
	Population no.											
	1	2	3	1	2	3	1	2	3	1	2	3
σ^2_G [1]	3.6*	8.8**	11.2*	37.9**	65.2*	49.7**	38.9**	75.3*	62.1**	7.1**	6.8**	10.9**
σ^2_{GE} [2]	23.8**	14.7**	3.6	66.2**	215.7**	58.5**	102.9**	288.9**	-20.6	21.2**	10.4**	25.9**
σ^2_ε [3]	47.4	48.3	135.1	166.3	397.8	324.1	234.1	443.3	572.7	35.4	41.4	68.8
h^2	0.23	0.46	0.39	0.50	0.36	0.47	0.41	0.34	0.48	0.42	0.46	0.42

** significant at p = 0.01, * significant at p = 0.05

[1] σ^2_G = genotypic variance, [2] σ^2_{GE} = variance of genotype x environment interaction, [3] σ^2_ε = residual error, [4] h^2 = heritability

Tab.3 reveals that α-tocopherol content is not correlated with γ-tocopherol. No correlation was found between tocopherols and other quality traits in agreement with Dolde et al. (1999) and Goffman and Becker (2001).

Tab.4: Coefficients of correlation of α- and γ-tocopherol content, α/γ-tocopherol ratio and other quality traits in three doubled haploid winter rapeseed populations

	Correlations											
	α-toc[1]			γ-toc[1]			total toc[1]			α/γ ratio[1]		
	Population no.											
	1	2	3	1	2	3	1	2	3	1	2	3
α-toc				-0.002	0.11	-0.06	0.39**	0.39**	0.42**	0.62**	0.54**	0.71**
γ-toc							0.91**	0.96**	0.88**	-0.77**	-0.76**	-0.72**
total toc										-0.46**	-0.54**	-0.32*
oil content	-0.13	-0.30*	-0.18	-0.35**	0.23	-0.06	-0.35**	0.13	-0.14	0.25**	-0.41**	-0.07
protein content	0.05	0.09	-0.12	0.17	-0.18	0.05	0.17	-0.14	-0.002	-0,14	0.24	-0.10
glucosinolates	-0.08	-0.11	-0.21	0.05	-0.30*	-0.10	0.02	-0.30*	-0.182	-0.09	0.19	-0.03

[1]α-toc=α-tocopherol content, γ-toc=γ-tocopherol content, total toc=total tocopherol content, α/γ ratio= α/γ-tocopherol ratio

(** significant at p = 0.01, * significant at p = 0.05)

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