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Chemotaxonomic value of tocopherols in Brassicaceae

Fernando D. Goffman*, Werner Thies, Leonardo Velasco

Institut für Pflanzenbau und Pflanzenzüchtung, Georg-August-Universität Göttingen, Von-Siebold-Str. 8, D-37075 Göttingen, Germany

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Abstract

The significance of tocopherols as chemotaxonomic markers and their relationship with oil content and fatty acid profile was investigated in a collection of 91 species of the family Brassicaceae. Total tocopherols content ranged from 68 mg kg^{-1} oil in *Diplotaxis viminea* to 2479 mg kg^{-1} oil in *Schivereckia doerfleri*. The collection also showed wide variability for tocopherol composition. The average tocopherol profile consisted of 65.4% γ-, 28.7% α-, 5.1% δ- and 0.8% β-tocopherol. Individual tocopherols were found to have great taxonomic value in the Brassicaceae.

Keywords: Brassicaceae; Chemotaxonomy; Tocopherols; Vitamin E

1. Introduction

Tocopherols are a group of closely related derivatives of the phenolic tocol marked by an extensive ring alkylation (Larson, 1988). They occur in four forms of derivatives (α-, β-, γ- and δ-tocopherol; the a-derivative is also know as vitamin E), differing in the methylation of the tocol head group (**1**). The relative content of individual tocopherols is known to be characteristic of the seed oil of different cultivated plants. The germ oil of wheat (*Triticum aestivum*), for example, contains 60% of *a*-tocopherol and 23% of *b*-tocopherol and the oil of linseed (*Linum usitatissimum*) oil contains 76% of *g*-tocopherol and 24% of plastochromanol-8, an unusual tocol derivative in plant oils (Balz, Schulte, & Thier, 1992). In the oil of soybean (*Glycine max* L.), *d*-tocopherol represents ca. 30% of the total tocopherols (Van Niekerk, & Burger, 1985; Yoshida, Hirooka, & Kajimoto, 1990). Conversely, α-tocopherol is the main fraction in the seed oil of sunflower (*Helianthus annus*) (>95%) (Gustafsson, Haglund, & Johansson, 1993). *Brassica napus* contains ca. 65% of γ-tocopherol and 35% of α-tocopherol (Appelqvist, 1972; Goffman, & Becker, 1998).

Individual glucosinolates and fatty acids are widely recognized as constituents of systematic interest in Brassicaceae (Seigler, 1981). No information about the significance of tocopherols as chemotaxonomic markers is available. The objective of this study was to determine the chemotaxonomic value of tocopherols in Brassicaceae.

* Corresponding author. Fax: +49-551-39-4601; e-mail: fgoffma@gwdg.de.

2. Results and discussion

Oil content, fatty acid composition and tocopherol contents in the seeds of the 91 Brassicaceae accessions are listed in Table 1. Variation for total tocopherol content was extremely wide, ranging from 68 mg kg^{-1} oil in *Diplotaxis viminea* to 2479 mg kg^{-1} oil in *Schivereckia doerfleri*. The average content was 995 mg kg^{-1} oil. The collection also showed large variation for the relative presence of individual tocopherols, γ-tocopherol being the most abundant. The average tocopherol profile con-

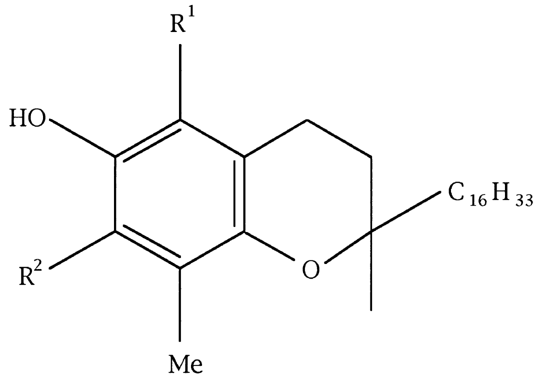

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Fig. 1. Chemical formulae of tocopherols: α-tocopherol (R^1 = Me, R^2 = Me); β-tocopherol (R^1 = Me, R^2 = H); γ-tocopherol (R^1 = H, R^2 = Me); δ-tocopherol (R^1 = H, R^2 = H).

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Table 1
Oil content[a], fatty acid composition[b], total tocopherols content[c], and concentration of individual tocopherols[d] in 91 accessions of Brassicaceae

	Oil[a]	Fatty acids[b]								Tocopherols				
		16:0	18:0	18:1	18:2	18:3	20:1	22:1	24:1	TTC[c]	α-T[d]	β-T[d]	δ-T[d]	γ-T[d]
Tribe Brassiceae: subtribe Brassicinae														
Brassica elongata	17.5	3.8	1.1	8.9	21.3	33.3	3.7	20.2	1.3	1017	4.5	0.0	1.7	93.8
B. juncea	27.7	4.2	1.4	13.8	23.5	21.5	9.5	19.8	1.4	508	22.7	0.0	0.0	77.3
B. napus	40.6	3.7	1.0	45.6	18.5	10.3	3.5	14.7	0.4	581	42.0	0.0	0.9	57.2
B. nigra	26.3	4.0	1.1	10.4	17.9	19.2	5.0	32.6	1.7	430	7.1	0.0	2.7	90.3
B. rapa	31.4	2.6	1.4	18.4	13.6	10.7	10.1	37.6	1.1	606	46.3	0.0	2.1	51.6
Diplotaxis muralis	22.6	8.1	2.1	11.3	25.2	26.4	3.6	17.2	0.0	770	14.4	0.0	10.9	74.7
D. tenuifolia	25.4	6.0	1.7	11.3	18.7	33.8	4.0	18.8	0.5	746	5.8	0.0	3.2	91.0
D. viminea	22.1	8.3	2.4	8.9	20.6	27.7	3.3	20.8	0.6	68	0.0	0.0	0.0	99.9
Eruca sativa	19.0	5.7	0.8	10.8	15.4	19.5	4.4	37.3	1.3	813	13.0	0.0	2.6	84.4
Erucastrum nasturtifolium	25.9	4.3	1.2	12.8	22.2	32.7	5.6	16.8	0.9	672	15.5	0.0	2.3	82.2
Hirschfeldia incana	25.2	6.6	1.3	7.9	12.6	35.4	2.1	26.4	1.4	739	3.8	0.0	4.8	91.4
Sinapis alba	19.4	4.3	0.8	18.2	15.9	13.8	8.9	33.0	2.1	774	16.0	0.0	3.3	80.7
S. arvensis	24.3	3.9	0.9	9.2	16.0	19.3	10.8	34.2	1.2	679	4.2	0.0	3.6	92.1
Tribe Brassiceae: subtribe Raphaninae														
Calepina irregularis	13.0	7.2	1.7	11.2	13.5	32.2	20.9	6.3	0.3	795	3.9	0.0	2.9	93.2
Crambe maritima	32.2	4.1	0.6	26.7	25.3	4.8	14.5	21.6	0.4	1331	11.4	0.0	0.9	87.7
Rapistrum perenne	11.5	4.6	2.6	14.2	25.6	32.6	5.2	11.4	0.5	486	28.6	0.0	0.0	71.4
R. rugosum	12.7	5.0	1.3	7.6	13.7	28.9	3.2	31.4	1.9	506	12.5	0.0	0.0	87.5
Tribe Brassiceae: subtribe Moricandiinae														
Conringia orientalis	26.7	2.6	0.3	6.7	29.2	2.8	22.0	24.5	4.4	718	98.4	0.0	0.0	1.6
Moricandia arvensis	24.5	10.4	1.7	11.5	19.6	32.6	5.3	14.8	0.5	1054	0.8	0.0	6.6	92.6
Tribe Heliophileae														
Heliophila longifolia	21.6	4.4	0.5	30.4	7.4	8.7	0.8	27.1	15.2	1424	1.0	0.0	3.9	95.1
Tribe Lepidieae: subtribe Lepidiinae														
Coronopus didymus	14.7	7.4	3.1	16.0	18.1	39.6	8.7	1.8	0.5	871	14.8	0.0	4.7	80.5
C. squamatus	15.0	11.9	3.0	23.1	9.9	39.2	9.0	0.5	0.3	848	1.6	0.0	3.2	95.3
Lepidium campestre	13.9	4.3	1.0	12.4	11.1	44.1	4.3	18.0	1.5	1289	6.7	0.0	0.0	93.3
L. graminifolium	27.4	8.3	2.3	15.0	11.5	51.0	6.3	0.6	0.0	736	4.0	0.0	1.0	95.1
L. heterophyllum	19.0	5.6	1.8	21.8	10.7	35.6	5.9	15.0	0.8	885	1.8	0.0	1.8	96.4
L. sativum	19.0	8.8	2.0	25.7	10.5	37.6	8.6	3.0	0.6	1492	0.0	0.0	3.2	96.8
Biscutella auriculata	33.9	6.4	1.0	31.9	8.1	13.3	36.1	1.6	0.0	602	5.9	0.0	1.5	92.7
Tribe Lepidieae: subtribe Iberidinae														
Iberis amara	19.4	4.4	0.3	19.8	17.6	17.9	4.6	29.1	3.9	618	88.3	0.0	0.0	11.7
I. umbellata	22.6	3.9	0.2	9.2	25.7	10.1	2.8	39.5	4.4	527	92.4	1.7	2.5	3.4
Tribe Lepidieae: subtribe Thlaspidinae														
Aethionema grandiflora	13.7	7.5	1.4	10.9	11.8	63.6	0.7	0.8	0.0	2649	0.6	0.0	4.4	95.1
A. saxatile	21.5	8.2	3.4	14.9	8.7	56.4	2.6	0.2	0.0	825	0.0	0.0	2.3	97.7
Thlaspi alliaceum	26.6	3.6	0.8	15.4	21.2	5.3	5.9	42.6	2.8	568	72.2	0.0	0.0	27.8
T. alpestre	31.7	2.9	0.4	8.2	26.3	12.0	9.4	33.9	2.5	621	77.2	14.2	3.6	5.1
T. alpinum	21.6	2.9	0.3	10.1	21.1	14.3	12.7	29.5	3.8	626	70.4	2.2	2.2	25.2
T. arvense	31.1	2.9	0.4	13.5	24.3	18.2	10.5	23.6	2.6	557	79.8	0.0	0.0	20.2
Tribe Lepidieae: subtribe Capsellinae														
Hornungia petraea	24.7	6.8	1.7	7.3	18.7	35.8	12.9	11.4	0.4	576	86.6	0.0	3.5	9.9
Tribe Lepidieae: subtribe Cochleariinae														
Cochlearia officinalis	21.1	3.9	1.7	14.0	37.7	22.5	4.9	9.9	1.6	2009	9.7	4.3	44.1	42.0
Tribe Euclidieae														
Bunias erucago	12.8	10.1	2.1	27.0	11.3	45.1	0.8	2.3	0.0	870	15.3	0.0	5.4	79.3
B. orientalis	11.1	4.7	1.6	12.7	21.5	57.3	0.4	0.9	0.2	696	2.6	0.0	7.8	89.6
Myagrum perfoliatum	10.9	6.1	1.3	10.7	16.2	29.8	5.6	23.0	1.9	470	0.0	0.0	5.9	94.1
Neslia paniculata	17.1	5.1	1.4	14.6	17.3	37.9	13.1	6.1	0.3	987	0.0	0.0	1.8	98.2

Table 1 (*continued*)
Oil content[a], fatty acid composition[b], total tocopherols content[c], and concentration of individual tocopherols[d] in 91 accessions of Brassicaceae

	Oil[a]	Fatty acids[b]								Tocopherols				
		16:0	18:0	18:1	18:2	18:3	20:1	22:1	24:1	TTC[c]	α-T[d]	β-T[d]	δ-T[d]	γ-T[d]
Tribe Lunarieae														
Lunaria annua	30.1	2.1	0.3	29.4	6.7	1.5	1.9	37.5	20.0	821	30.4	6.5	2.4	60.7
L. rediviva	27.0	2.2	0.0	20.1	14.9	4.0	12.3	37.7	6.8	946	14.5	2.0	8.2	75.3
Peltaria turkmena	37.7	4.3	0.6	21.4	21.1	12.4	9.2	28.2	2.0	764	33.7	0.0	1.4	64.9
Tribe Alysseae														
Alyssoides utriculata	13.0	6.9	1.4	13.5	16.7	55.5	0.6	2.7	0.4	734	77.9	0.0	1.1	21.1
Alyssum alyssoides	18.2	7.7	1.3	9.2	10.1	69.8	0.0	0.6	0.0	341	95.2	0.0	0.0	4.8
A. corymbosum	17.3	6.6	1.9	14.1	15.9	58.7	0.2	0.2	0.0	1123	20.6	0.0	1.0	78.4
A. granatense	12.2	5.9	1.3	15.9	14.6	59.4	0.4	0.9	0.0	703	97.7	0.0	0.0	2.3
A. murale	19.1	6.0	1.2	15.9	19.6	54.7	0.0	0.0	0.0	640	96.7	0.0	0.0	3.3
A. repens	16.4	6.8	0.9	10.1	14.4	65.3	0.0	0.0	0.0	1309	31.6	0.0	0.9	67.4
A. saxatile	14.2	5.7	1.1	12.0	20.3	56.5	0.0	0.0	0.0	981	85.6	0.0	0.0	14.4
Berteroa incana	21.6	4.7	1.6	15.1	19.4	55.4	0.6	1.5	0.2	906	82.1	1.0	1.5	15.3
Clypeola jouthlaspi	12.1	10.7	2.3	21.6	13.4	48.5	0.5	0.9	0.2	537	69.2	3.1	9.2	18.5
Fibigia clypeata	18.8	7.2	1.9	16.5	22.0	47.7	0.4	1.6	0.3	696	94.7	0.0	0.0	5.3
Lobularia maritima	28.9	4.1	4.3	31.8	9.2	11.6	35.6	0.4	0.2	582	20.8	0.0	3.6	75.6
Tribe Drabeae														
Draba aurea	24.7	5.6	1.9	12.2	27.4	51.2	0.2	0.4	0.0	1533	2.1	0.0	4.8	93.1
D. incana	18.0	4.2	1.1	8.1	32.3	52.5	0.0	0.2	0.0	1763	3.8	0.0	4.7	91.5
D. magellanica	22.6	4.3	1.0	10.2	30.5	52.6	0.2	0.0	0.0	1963	3.4	0.0	2.7	93.9
Kernera saxatilis	28.3	4.0	0.7	10.4	41.9	15.5	5.7	13.6	1.0	802	98.7	1.3	0.0	0.0
Schivereckia doerfleri	16.4	6.6	1.2	7.5	27.9	51.6	0.3	0.8	0.0	2749	15.6	0.0	1.8	82.7
Tribe Arabideae														
Arabis alpina	23.5	6.2	1.8	14.3	28.3	46.8	0.0	0.0	0.0	1091	10.6	0.4	24.2	64.8
A. caucasica	20.8	6.2	1.7	13.0	28.3	48.5	0.3	0.0	0.0	721	7.3	0.0	14.7	78.0
A. corymbiflora	20.9	9.4	2.7	14.2	24.1	46.9	0.0	0.0	0.0	703	27.9	0.0	2.7	69.4
A. glabra	30.3	5.3	1.0	6.8	30.6	31.4	9.3	8.9	0.3	1223	5.7	0.0	1.4	93.0
A. procurrens	25.0	5.7	2.3	16.4	33.3	40.1	0.3	0.0	0.0	1550	28.6	0.0	3.1	68.3
A. rosea	25.2	9.6	2.5	10.8	32.9	42.7	0.0	0.0	0.0	955	3.3	0.0	3.7	93.0
A. soyeri	20.1	8.1	1.9	11.9	35.0	41.4	0.0	0.0	0.0	1681	6.8	0.0	12.7	80.5
A. virginica	19.1	9.1	1.5	6.5	36.1	45.3	0.0	0.0	0.0	1804	20.4	0.0	16.0	63.7
Barbarea stricta	30.5	2.0	0.3	20.0	26.8	14.4	10.5	21.1	1.3	414	98.4	0.8	0.0	0.8
B. verna	31.0	3.4	0.4	10.7	20.2	9.0	4.7	44.7	1.6	394	93.4	2.5	1.6	2.5
B. vulgaris	27.5	2.6	0.6	25.1	23.1	8.4	10.4	24.7	2.1	382	98.1	0.0	0.0	1.9
Cardaminopsis neglecta	32.4	3.8	1.6	13.2	31.4	29.5	5.8	10.0	0.6	1059	12.2	0.0	4.1	83.7
Dentaria bulbifera	11.5	15.3	1.1	15.4	31.6	23.5	4.3	5.8	0.3	462	77.4	17.0	0.0	5.7
Tribe Matthioleae														
Aubrieta gracilis	15.9	9.7	1.8	13.4	24.4	49.1	0.0	0.0	0.0	1823	4.2	0.0	2.4	93.4
Matthiola incana	20.8	8.0	2.5	13.6	9.0	65.3	0.5	0.8	0.0	2078	0.9	0.0	73.4	25.6
Tribe Hesperideae														
Cheiranthus cheiri	20.7	4.2	0.6	10.7	21.4	25.2	5.9	23.6	1.4	914	1.6	0.0	8.5	90.0
Erysimum hieraciifolium	36.7	3.3	0.8	10.8	26.3	23.9	4.1	22.3	2.5	1147	20.7	0.0	3.6	75.8
E. marschallianum	33.1	4.1	1.2	6.1	32.2	26.1	2.5	17.7	2.1	1327	2.5	0.0	3.2	94.3
E. odoratum	29.4	4.2	1.5	9.7	28.3	30.5	3.9	14.3	1.1	1050	23.6	0.0	1.0	75.4
E. repandum	22.2	7.2	2.0	6.8	19.8	38.7	4.3	13.9	0.8	2012	1.4	0.0	3.8	94.8
E. wittmannii	32.0	5.0	0.9	7.0	28.9	27.1	2.1	18.6	1.4	1199	26.9	0.0	1.3	71.8
Hesperis laciniata	19.3	6.8	2.0	11.6	12.6	64.1	0.0	0.2	0.0	2031	9.2	0.0	27.6	63.3
H. matronalis	25.7	7.2	2.1	14.3	24.2	50.5	0.0	0.0	0.0	1865	4.2	0.0	34.8	61.0
Tribe Sisymbrieae: subtribe Alliariinae														
Alliaria petiolata	26.2	2.5	0.2	10.8	19.1	6.0	6.2	45.8	6.4	880	15.2	0.0	1.3	83.5

(*Continued on next page*)

Table 1 (*continued*)
Oil content[a], fatty acid composition[b], total tocopherols content[c], and concentration of individual tocopherols[d] in 91 accessions of Brassicaceae

	Oil[a]	Fatty acids[b]								Tocopherols				
		16:0	18:0	18:1	18:2	18:3	20:1	22:1	24:1	TTC[c]	α-T[d]	*β*-T[d]	δ-T[d]	γ-T[d]
Tribe Sisymbrieae: subtribe Sisymbriinae														
Sisymbrium austriacum	30.8	6.1	1.3	10.0	14.6	37.2	8.0	13.9	0.6	1200	2.4	0.0	5.1	92.4
S. loeselii	29.7	7.3	1.1	11.1	16.2	36.3	8.4	13.8	0.3	1244	2.7	0.0	3.8	93.5
S. orientale	22.2	9.4	0.9	6.4	13.3	41.4	3.6	17.3	0.6	913	4.4	0.0	2.0	93.6
S. strictissimum	35.6	3.9	0.8	8.1	19.8	36.2	6.4	15.6	0.8	960	42.1	12.9	9.4	35.7
Tribe Sisymbrieae: subtribe Camelininae														
Camelina pilosa	25.1	7.5	2.3	12.7	22.7	36.0	11.5	1.9	0.5	846	0.9	0.0	0.9	98.1
Tribe Sisymbrieae: subtribe Descuriinae														
Descurainia sophia	30.3	5.9	1.4	9.5	17.3	44.9	8.2	7.1	0.6	1585	1.3	0.0	2.9	95.8
Hugueninia tanacetifolia	24.9	6.8	1.2	9.1	20.1	30.6	11.6	15.2	0.9	1076	1.9	0.0	1.5	96.6

[a] Expressed as % wt/wt.
[b] Expressed as % of total fatty acids.
[c] Tocopherols: TTC = total tocopherols content, expressed as mg kg^{-1} oil.
[d] α-T = α-tocopherol, *β*-T = *β*-tocopherol, δ-T = δ-tocopherol, γ-T = γ-tocopherol, all individual tocopherols expressed as % of total tocopherols.

sisted of 65.4% γ-, 28.7% α-, 5.1% δ- and 0.8% *β*-tocopherol. α-Tocopherol was not detected (< 1%) in ten accessions (*Diplotaxis viminea*, *Moricandia arvensis*, *Heliophila longifolia*, *Lepidium sativum*, *Aethionema grandiflora*, *A. saxatile*, *Myagrum perfoliatum*, *Neslia paniculata*, *Matthiola incana* and *Camelina pilosa*), but it was the predominant tocopherol (> 50%) in 21 accessions. γ-Tocopherol was absent in only two accessions (*Kernera saxatilis* and *Barbarea stricta*), being predominant in 67 accessions. The highest levels of δ-tocopherol were found in *Matthiola incana* (73.4%), *Cochlearia officinalis* (44.1%), *Hesperis matronalis* (34.8%), *H. laciniata* (27.6), *Arabis alpina* (24.2%), *A. virginica* (16,0%) and *A. soyeri* (12.7); in 66 of the 91 accessions, this tocopherol derivative was present as a secondary constituent (> 1%) only. *β*-Tocopherol was found in no more than 11 of the accessions, the highest values occurring in seed oils of *Dentaria bulbifera* (17.0%), *Thlaspi alpestre* (14.2%) and *Sisymbrium strictissimum* (12.9%).

The average oil content was 23.0%, ranging from 10.9% in *Myagrum perfoliatum* to 40.6% in *Brassica napus*. Kumar and Tsunoda (1980) reported a variation for oil content in Brassicaceae between 6 and 49% after reviewing published results from different sources. Since our results were obtained from plants grown under the same environment, they provide reliable information on the relative oil content values of the different species. The variability for the fatty acid composition of the seed oil altogether was found within the limits determined in previous studies and reviewed by Kumar and Tsunoda (1978).

2.1. Study of correlations

Correlation coefficients between oil content, fatty acids and tocopherols are shown in Table 2. Total tocopherols content was positively correlated with linolenic and negatively correlated with eicosenoic and erucic acid. A positive correlation between tocopherols content and linolenic acid also had been revealed in rapeseed mutants (Röbbelen, & Thies, 1980). Moreover, Kamal-Eldin and Andersson (1997) analysed data of oil samples from 14 botanical species and reported a positive correlation between tocopherols content and linoleic and linolenic acid. Oil content in the present study was negatively correlated with the main saturated fatty acids (palmitic and stearic) and with linolenic acid and positively correlated with eicosenoic and erucic acid. After grouping all fatty acids by their level of unsaturation (data not shown), the oil content was negatively correlated with the sum of saturated ($r = -0.43$) and with the sum of polyunsaturated fatty acids ($r = -0.43$), but it was positively correlated with the sum of monounsaturated fatty acids ($r = 0.44$). These results suggest that the species accumulating the highest amounts of oil in their seeds show preference for synthesizing monounsaturated fatty acids. None of these correlations were found in the above mentioned study of Kumar and Tsunoda (1978) on 159 species of Brassicaceae. The present correlations involving fatty acids were basically similar to those reported by Kumar and Tsunoda (1978). A strong negative correlation ($r = -0.80$) was found between linolenic and erucic acid, which is easily explained taking into account that the accessions exhibited basically two main patterns,

Table 2
Correlation coefficients between oil content (%), individual fatty acids (% of the total fatty acids), total tocopherols content (mg kg^{-1} oil) and concentration of individual tocopherols (% of the total tocopherols) in a set of 91 accessions of Brassicaceae. Significance limits: $r = \pm 0.21$ (5%), $r = \pm 0.27$ (1%)

	C16:0	C18:0	C18:1	C18:2	C18:3	C20:1	C22:1	C24:1	TTC[a]	α-T	β-T	δ-T	γ-T
Oil	−0.47	−0.30	0.16	0.20	−0.53	0.33	0.37	0.18	−0.10	0.03	0.08	−0.06	−0.02
C16:0		0.56	−0.05	−0.12	0.54	−0.24	−0.59	−0.41	0.15	−0.22	0.08	0.13	0.17
C18:0			0.10	−0.14	0.49	−0.02	−0.65	−0.45	0.11	−0.36	−0.21	0.24	0.30
C18:1				−0.37	−0.30	0.29	−0.03	0.27	−0.19	0.06	−0.02	−0.05	−0.04
C18:2					−0.10	−0.20	−0.09	−0.22	0.17	0.15	0.13	0.03	−0.17
C18:3						−0.54	−0.80	−0.52	0.42	−0.17	−0.20	0.25	0.11
C20:1							0.19	0.02	−0.30	0.00	0.01	−0.19	0.05
C22:1								0.55	−0.40	0.17	0.14	−0.22	−0.11
C24:1									−0.11	0.07	0.18	−0.09	−0.06
TTC										−0.45	−0.13	0.44	0.33
α-T											0.27	−0.25	−0.95
β-T												0.03	−0.36
δ-T													−0.05

[a] Abbreviations of tocopherols as for Table 1.

characterized by high linolenic and high erucic acid content, respectively. Palmitic and stearic acids were positively correlated with linolenic acid and negatively correlated with erucic acid.

2.2. *Taxonomic potential of tocopherols*

The investigated collection of Brassicaceae displayed great variability for total tocopherols content and tocopherol profile. Based on the classification of Schulz (1936), it is possible to conclude that the tocopherols have a significant taxonomic meaning, at least as important as that of the fatty acids have. Some clear lines can be observed: for example, the tribe Brassiceae was characterized by a high concentration of γ-tocopherol. The only exception was *Conringia orientalis*, but this accession was marked by a fatty acid profile (low linolenic acid and high nervonic acid, Table 1) atypical for this taxonomic group. Likewise, a high number of the accessions with the highest α-tocopherol percentage belonged to the tribe Alysseae. In some of the species an interesting similarity occurred from fatty acids and tocopherols for the informations. For example, two genera of the subtribe Thlaspidinae (tribe Lepidieae), were analysed. The accessions of *Aethionema* had a high linolenic acid and practically no erucic acid contents, while the accessions of *Thlaspi* showed considerably lower linolenic and higher erucic acid contents. Such differences were paralleled by a completely different profile of tocopherols, with γ-tocopherol being the predominant in *Aethionema* and of α-tocopherol in *Thlaspi*. A similar case was observed in the subtribe Iberidinae (tribe Lepidieae) and in the tribe Drabeae. The accessions of the tribe Arabideae are another excellent example of the taxonomic potential of tocopherols and of the unsatisfactory taxonomic assignments within this family (Warwick, & Black, 1993). According to the tocopherols information, the genera *Arabis* and *Cardaminopsis*, with high γ-tocopherol content, are clearly different from the genera *Barbarea* and *Dentaria*, characterized by high α-tocopherol content. Schulz (1936) assigned all these genera to the same tribe, while Janchen (1942) divided the tribe into the subtribe Cardamininae (including *Barbarea* and *Dentaria*) and the subtribe Arabidinae (including *Cardaminopsis* and *Arabis*). Tocopherols composition clearly supports the latter subtribe division. In conclusion, this study demonstrates that tocopherols possess an important chemotaxonomic value in Brassicaceae and may play a major role in taxonomic studies on this family.

3. Experimental

3.1. *Plant materials*

This study included 91 germplasm accessions from 91 species (48 genera) of the family Brassicaceae. The samples belonged to the Brassicaceae collection were kindly provided by the Botanical Garden of the University of Göttingen, Germany. The accessions had been multiplied in 1996/97 in the Botanical Garden. The complete list of the germplasm collection can be found in the Index Seminum (1997). Taxonomic classification was based on Schulz (1936).

3.2. *Analysis of seed oil content*

Oil content was determined nondestructively by near-infrared reflectance spectroscopy (NIRS). Ca. 300 mg of intact-seed samples were analysed on a NIRS instrument.

Oil content was calculated from NIRS spectral information by using a calibration equation developed from a wide range of genera of Brassicaceae (Velasco, Goffman, & Becker, 1998).

3.3. Analysis of fatty acid composition

Fatty acid composition of seed oil was determined by the GLC method described by Thies (1971), using a FFAP capillary column, 25 m × 0.25 mm and a FID detector. The temperatures of oven, detector and injector were 200°C, 250°C and 250°C, respectively. The carrier gas was hydrogen, at a pressure of 100 kPa. Two ml of sample were injected, at a split rate of 1:70.

3.4. Analysis of tocopherols

Tocopherols content was determined by HPLC as described by Thies (1997), with a fluorescence detector (l_{ex} = 295 nm and l_{em} = 330 nm), a C-18 diol column (250 × 3 mm), and isooctane/tert-buthyl–methylether (94/6) as eluent at a flow rate of 0.7 ml/min. β-Tocopherol was used as internal standard. The samples were first analysed without the internal standard to check the presence of β-tocopherol. A calibration curve of β-tocopherol was used as external standard for the quantification of samples containing this tocopherol derivative.

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