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Seed fatty acid compositions and chemotaxonomy of wild *Crambe* (Brassicaceae) taxa in Turkey

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Abstract: Wild *Crambe* species have greater potential than *Crambe hispanica* in industry, medicine, as a vegetable, etc. A total of 53 germplasm accessions, belonging to 7 taxa, were collected from the natural flora of Turkey. The accessions consisted of *C. orientalis* var. *orientalis* (18 accessions), *C. orientalis* var. *dasycarpa* (1 accession), *C. orientalis* var. *sulphurea* (2 accessions), *C.tataria* var. *aspera* (3 accessions), *C. tataria* var. *tataria* (26 accessions), *C. grandiflora* (1 accession), *C. orientalis* var. *sulphurea*, and *C. maritima* (2 accessions). In this study, the seed fatty acid compositions and oil contents were determined, and the data were used for taxonomic cluster, correlation, and principal component analyses. Important correlations were determined among the fatty acids; however, the oil contents were not correlated. Altitude was positively correlated with linolenic acid, while negatively correlated with oleic and linoleic acid. For the principal component and correlation analyses, 7 major fatty acids (>1%) were used, including palmitic (C16:0), oleic (C18:1), linoleic (C18:2), cis-11 eicosenoic (20:1), linolenic (C18:3), erucic (C22:1), and nervonic acid (C24:1). A total of 17 fatty acids were used for the cluster analyses. Two major clusters were formed, where the first consisted of *C. orientalis*, *C. tataria*, and *C. grandiflora* taxa, while the second consisted of only *C. maritima* taxa. The dendrogram based on the fatty acid values clearly discriminated the species groups; however, *C. tataria* was not located close to *C. maritima*, contrary to previous molecular cluster studies.

Key words: Chemotaxonomy, fatty acid composition, seed oil content, wild *Crambe*

1. Introduction

Indigenous plants form the bedrock of diversity in industrial systems. Deficiently used industrial crop genetic resources have great potential as an alternative to worldwide known species or varieties that are commonly produced and consumed. With climate uncertainty, there is an urgent need to diversify plant resources to a wider range of crops for greater system resistance (Zia-Ul-Haq et al., 2013; Colak et al., 2019).

The genus *Crambe* comprises annual, biennial, and perennial species (Comlekcioglu et al., 2008). It has potential in terms of use in the oleochemical industry; however, currently, *C. abyssinica* Hochst. is the only species of *Crambe* that is used in industry (Warwick and Black, 1997). Due to its high amount of erucic acid, which provides high boiling and evaporating points, it is widely used in industrial applications, such as the production of plastic film, nylon, coatings, and lubricants (Warwick and Black, 1997; Piovan et al., 2011).

There are 6 species and 4 intraspecific taxa in the natural flora of Turkey, while there are 35 taxa worldwide (Prina, 2009; Mutlu, 2012; Bassegio et al., 2016; Tarıkahya-Hacıoğlu, 2016).

The oil content of cultivated *C. abyssinica* species has been reported to have a wide range of variation, from 24% to 46% (Warwick and Black, 1997; Gastaldi et al., 1998; Comlekcioglu et al., 2008; Rudloff and Wang, 2011; Uyaroğlu, 2018). The total fatty acid composition comprised 53.9%–63.1% erucic acid (Vollmann and Ruckenbauer, 1993). Little information on the oil content of other wild *Crambe* species has been reported. The whole-seed oil content was reported as 11% and 15% in *C. orientalis* and *C. tataria*, respectively (Comlekcioglu et al., 2008). However, although the reported oil and erucic acid rates of wild *Crambe* species have been low, they are a significant source of genetic variation for fatty acid composition. Wild *Crambe* seed oil mainly contains palmitic, oleic, cis-11 eicosenoic, erucic, linoleic, and linolenic acid.

Understanding the genetic potential and characteristics of wild relatives of the different plant species is important for long-term breeding programs (Ersoy et al., 2018; Gecer et al., 2020). In addition, many wild species have the potential to become new valuable crop plants. As an industrial oil source, wild relatives of *Crambe* may possess many important agronomical properties, such

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as cytoplasmic and nuclear male infertility, disease and pest resistance, C3-C4 photosynthetic activity, and cold, drought, and salinity resistance; therefore, they could be used in breeding programs (Warwick et al., 2009).

In this study, it was aimed to determine the seed oil properties of some wild *Crambe* accessions and investigate whether the seed oil compositions could be used as a taxonomical character for different *Crambe* species and taxa.

2. Materials and methods

2.1. Material

Crambe seeds were obtained from multiple flora collection expeditions in 2014 in Turkey. Among these, 53 germplasm accessions were chosen to represent 7 *Crambe* taxa collected from different regions of Turkey, comprising18 of *C. orientalis* var. *orientalis*, 1 of *C. orientalis* var. *dasycarpa*, 2 of *C.orientalis* var. *sulphurea*, 3 of *C. tataria* var. *aspera*, 1 of *C. grandiflora*, 21 of *C. tataria* var. *tataria*, and 2 of *C. maritima*. Each taxon is listed in Table 1. The distribution of the species in Turkey is given in Figure 1.*C. orientalis* was collected at an altitude of 800–1897 m, *C. tataria* at 744–1347 m, and *C. maritima* at 0–4 m.

2.2. Extraction and gas chromatography

The oil contents and compositions were determined in the laboratories of the Central Research Institute for Field Crops of the Ministry of Agriculture and Forestry, in Ankara, Turkey. Determination of the oil contents was performed following the method of Matthäus and Brühl (2001), with some modifications. First, 5 grams of whole seeds were milled in a Foss KN 195 Knifetec laboratory mill (Hillerød, Denmark). Afterwards, the extraction was performed for 3 h using a Soxhlet extractor (Soxtherm 2000 automatic, C. Gerhardt GmbH & Co. KG, Königswinter, Germany) with hexane. After extraction, the solvent was evaporated at 103 °C for 2.5 h, cooled for 30 min in a desiccator, and weighed. The seed oil content was reported as the mass percent [crude oil weight (g)/ground seeds weight (g) × 100].

For determination of the fatty acid compositions, the method given by Sampaio et al. (2012) was followed, with some modifications. First, 0.1 g of oil was dissolved in 10 mL of n-hexane, to which 0.5 mL of 2 N potassium hydroxide/methanol solution was added, and then incubated for 30 min at room temperature. The fatty acids were esterified as methyl esters and placed into a Shimadzu AOC-20i automatic injector (Shimadzu Corp., Kyoto, Japan) (split ratio 1:100). The methyl ester phase was analyzed using a Shimadzu GC-2010 system equipped with a Teknokroma capillary column (Teknokroma Anlítica, SA, Barcelona, Spain) (100 m × 0.25 mm and 0.2 µm) and flame ionization detector. Helium was used as the carrier gas at a flow rate of 0.94 mL/min. The injector and detector temperatures were set at 250 °C. The column was programmed with the following temperature regime: hold at 140 °C for 5 min, ramp to 240 °C at 4 °C/min, and hold at 240 °C for 20 min. Fatty acid methyl esters (FAMEs) were identified by comparison of their retention times with those of the reference standards (Restek FAME Mix 37). The fatty acid content was calculated based on the peak area ratio and expressed as grams of fatty acid/100 g of oil.

2.3. Statistical analysis

All statistical analyses were performed using JMP Pro 11 (SAS Institute Inc., Cary, NC, USA, 2013). Correlation among the studied traits was calculated using the Pearson correlation procedure implemented in the mentioned statistical program. Principal component analysis (PCA) was performed using the fatty acid (palmitic, oleic, linoleic, linolenic, cis-11 eicosenoic, and erucic acids) values of each of the 7 accessions. For chemotaxonomic evaluation of the 7 *Crambe* taxa, the mean values of the 17 fatty acids were used to perform the cluster analyses.

3. Results

Within the wild relative species of *Crambe*, 17 fatty acids were determined, of which the 7 main fatty acids (>1%) were palmitic (C16:0), oleic (C18:1), linoleic (C18:2), cis-11 eicosenoic (20:1), linolenic (C18:3), erucic (C22:1), and nervonic (C24:1) (Table 2). Acids identified with <1% of the total fatty acid content were myristic (C14:0), palmitoleic (C16:1), stearic (C18:0), arashidic (C20:0), heneicosanoic (C21:0), cis-11,14-eicosadienoic (C20:2), behenic (C22:0), cis-11,14-eicosadienoic (C20:2), cis-13,16-docosadienoic (C22:2), and lignoceric (C24:0) (Table 3).

The maximum and minimum oil contents for palmitic (C16:0), oleic (C18:1), linoleic (C18:2), cis-11 eicosenoic (C20:1), linolenic (C18:3), erucic (C22:1), and nervonic (C24:1) acid were determined as 4.70%–20.50%, 0.17%–5.78%, 15.02%–32.49%, 3.94%–17.45%, 10.76%–21.79%, 2.18%–9.57%, 22.59%–49.68%, and 0.79%–2.86% in all of the *Crambe* accessions, respectively (Table 2). *C. orientalis* accessions were identified as possessing higher mean values of erucic acid than the other *Crambe* species accessions.

According to the biplot diagram, 71% of the total variation was explained (Figure 2). The first 4 eigenvalues were 3.57, 1.47, 0.72, and 0.59. For taxonomic evaluation, the mean values of all of the determined seed fatty acids were used. As in the cluster analyses, all accessions belonging to the same species revealed close associations. There were 4 species groups, comprising *C. orientalis*, *C. grandiflora*, *C. tataria*, and *C. maritima*. *C. grandiflora* was located in the *C. orientalis* accession group, while the *C. maritima* accessions were placed close to the *C. tataria* group.

Table 4 shows the major fatty acid compositions (>1%) of all of the germplasm accessions. The total variation and

Table 1. List of investigated *Crambe* germplasm accessions and localities.

Taxon	No	Accession code	Locality.	Altitude	Taxon	No.	Accession code	Locality	Altitude
C. orientalis var. *orientalis*	1	1C.o_o	Ankara	800	*C. tataria* var. *tataria*	28	28C.t_t	Kırıkkale	892
	2	2C.o_o	Malatya	918		29	29C.t_t	Eskişehir	895
	3	3C.o_o	Malatya	924		30	30C.t_t	Afyon	903
	4	4C.o_o	Nevşehir	935		31	31C.t_t	Eskişehir	940
	5	5C.o_o	K.Maraş	943		32	32C.t_t	Ankara	950
	6	6C.o_o	Nevşehir	964		33	33C.t_t	Ankara	950
	7	7C.o_o	Aksaray	976		34	34C.t_t	Aksaray	970
	8	8C.o_o	Elbistan	1050		35	35C.t_t	Ankara	1000
	9	9C.o_o	Elazığ	1118		36	36C.t_t	Eskişehir	1009
	10	10C.o_o	Elbistan	1143		37	37C.t_t	Elbistan	1039
	11	11C.o_o	Kayseri	1191		38	38C.t_t	Ankara	1078
	12	12C.o_o	Adıyaman	1222		39	39C.t_t	Kırşehir	1080
	13	13C.o_o	Kayseri	1400		40	40C.t_t	Kırşehir	1096
	14	14C.o_o	Erzincan	1431		41	41C.t_t	Afyon	1115
	15	15C.o_o	Kars	1677		42	42C.t_t	Kırşehir	1150
	16	16C.o_o	Van	1725		43	43C.t_t	Kırşehir	1138
	17	17C.o_o	Kars	1793		44	44C.t_t	Kayseri	1162
	18	18C.o_o	Erzurum	1897		45	45C.t_t	Kayseri	1197
C. orientalis var. *dasycarpa*	19	19C.o_d	Adana	1076		46	46C.t_t	Kırşehir	1200
C. tataria var. *aspera*	20	20C.t_a	Ankara	1059		47	47C.t_t	Afyon	1249
	21	21C.t_a	Ankara	1127		48	48C.t_t	Nevşehir	1347
	22	22C.t_a	Ankara	1135	*C. grandiflora*	49	49C.g	Şanlıurfa	777
C. tataria var. *tataria*	23	23C.t_t	Ankara	744	*C. maritima*	50	50C.m	Sinop	0
	24	24C.t_t	Ankara	791		51	51C.m	Kastamonu	4
	25	25C.t_t	Eskişehir	855	*C. orientalis* var. *sulphurea*	52	52C.o_s	K.Maraş	1456
	26	26C.t_t	Bilecik	878		53	53C.o_s	K.Maraş	1122
	27	27C.t_t	Kırıkkale	892					

mean of each major fatty acid in the genus *Crambe* were compared to the intraspecies averages and variations of the fatty acids of the *C. orientalis* and *C. tataria* species (Figure 3).

The highest variations were observed in palmitic (16:0), linolenic (18:3), linoleic (18:2), and nervonic (24:1) acid, respectively, while the lowest variations were observed in cis-11-eicosenoic (20:1), erucic (22:1), and oleic (18:1) acid.

Intraspecific fatty acid variations of the *C. tataria* species (coefficient of variation (CV) C.t) were lower than those of all of the other *Crambe* accessions (total CV) and those of the *C. orientalis* accessions (CV C.o). This showed that the fatty acids in *C. tataria* were more stable than those of the other *Crambe* species.

Despite having different climatic and environmental factors, the *Crambe* species collected from different locations in the natural flora exhibited intraspecific

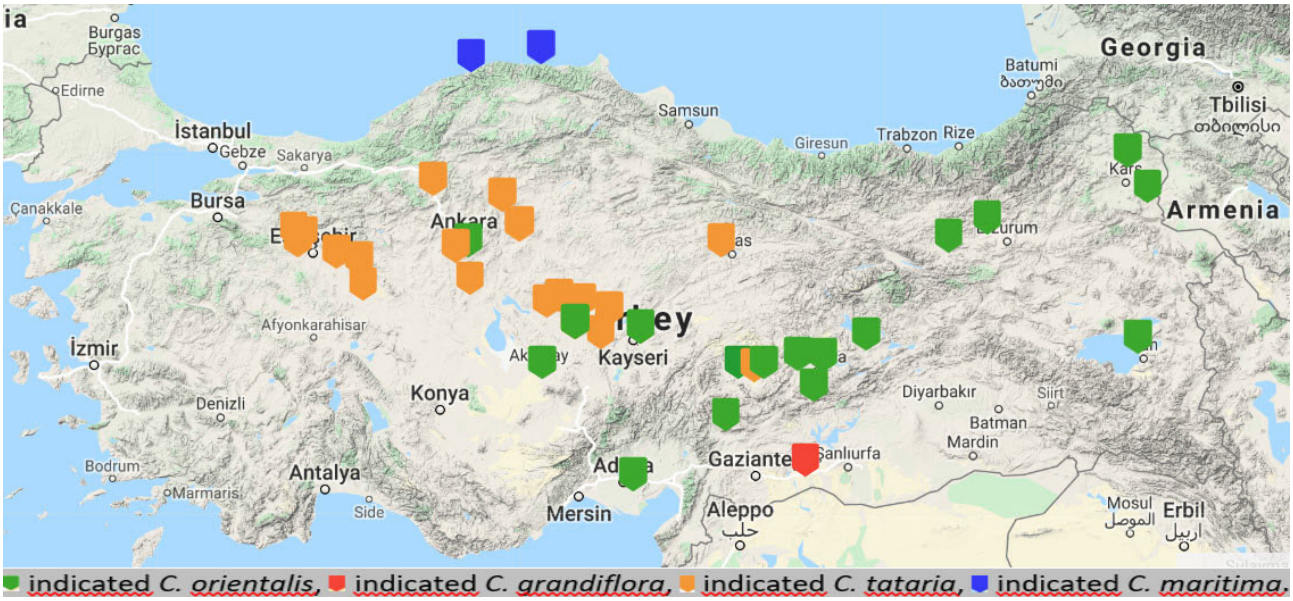

Figure 1. Distribution map of the investigated *Crambe* species.

genotypic stability in terms of their fatty acids. In this respect, cis-11-eicosenoic, erucic, and oleic acid, which had relatively lower variations in the genus *Crambe*, played a more decisive role in the species separations.

Correlations between the altitude, oil ratio, and 7 major fatty acid values were investigated. There was a positive correlation between altitude and linolenic acid and a negative correlation between altitude and the oleic and linoleic acid contents.

A high positive correlation was found among the oleic, linoleic, and cis-11-eicosenoic acid contents. However, this group was negatively correlated with the palmitic and erucic acid contents. A negative correlation was also found between linolenic acid and the oleic and nervonic fatty acid contents (Table 4 and Figure 2). The possible positive correlation between linoleic and linolenic acid can be explained by the synthesis pathway of these fatty acids (Saastamoinen et al., 1989).

4. Discussion

Cultivated *Crambe* (*Crambe abyssinica* Hochst.) comprises industrial properties because its oil (30%–45% of the seed weight) has a high content (55%–62.5%) of erucic acid (Wang et al., 1995, Lalas et al., 2012, Tarıkahya-Hacıoğlu, 2016). *C. hispanica* is quite similar to *C. abyssinica* (Mikolajczak et al., 1961), which has been grown successfully (Miller et al., 1965). According to the current results, the oil content of the wild *Crambe* species was lower (4.7%–20.5%) than that of the cultivated *Crambe*. The difference in the oil contents between the whole and dehulled seeds was 11%, 15%, and 8.5% in *C. orientalis*, *C. tataria*, and *C. abyssinica*, respectively. The pericarp content in *C. orientalis* and *C. tataria* was reported as 45% and 25%, respectively (Lazzeri et al., 1994; Comlekcioglu et al., 2008).

In previous studies conducted on *C. orientalis*, *C. tataria*, and *C. maritima*, the main fatty acid contents were determined as follows: erucic: 34.69%–39.39%, 27.0%–29.87%, and 21.60%–32.60%; cis-11-eicosenoic: 11.34%–20.00%, 7.70%–21.00%, and 14.50%–18.50%; linolenic: 7.55%–21.21, 11.00%–15.01%, and 4.80%–8.60%; linoleic: 9.76%–13.07%, 9.00%–15.00%, and 21.2%–25.3%; oleic: 1.61%–25.05%, 14.00%–21.00%, and 18.80%–26.70%; and palmitic: 2.00%–3.27%, 2.00%–2.3%, and 1.80%–4.10% (Miller et al., 1965; Dolya et al., 1973; Goffman et al., 1999; Comlekcioglu et al., 2008).

In the current study, the erucic acid content was higher in *C. tataria* and *C. maritima* when compared to previous reports, and was consistent with that of *C. orientalis*. However, the findings for linoleic acid were lower in *C. orientalis* and *C. maritima*. Moreover, the oleic acid content was slightly higher and that of linolenic acid was lower than that mentioned in studies of *C. orientalis* and *C. tataria*. The palmitic acid content was similar to that of all reported studies on all of the investigated *Crambe* species. *C. Orientalis* var. *orientalis*, accession 12 (12Co_o) (listed in Table 1), had the highest erucic acid rate (49.68%) among the accessions, while *C. orientalis* var. *orientalis*, accession 9 (9Co_o), had the highest oil content (20.50%).

As in many plant families, the family Brassica has a large number of wild relatives and can be used for breeding. However, in long-term breeding programs, the superior characteristics and phylogenic relationships among these wild relatives can also be used. Although

Table 2. Oil and major fatty acid contents of the investigated *Crambe* taxa (%).

Accession code	Oil rate	C16:0	C18:1	C18:2	C20:1	C18:3	C22:1	C24:1
1C.o_o	9.20	2.51	20.45	10.56	16.10	7.95	37.57	1.23
2C.o_o	6.81	4.65	23.66	3.94	15.28	2.18	41.96	2.86
3C.o_o	4.84	5.78	18.57	5.75	14.65	3.84	43.25	1.30
4C.o_o	11.30	2.87	21.05	11.24	16.74	7.98	35.41	1.17
5C.o_o	4.70	0.41	17.17	4.13	14.55	2.87	47.66	1.29
6C.o_o	12.20	2.78	23.94	10.63	18.23	7.00	33.31	1.11
7C.o_o	7.90	2.92	22.24	11.05	16.93	7.63	34.16	1.41
8C.o_o	13.90	2.66	15.16	10.40	12.81	8.61	45.49	1.48
9C.o_o	20.50	3.08	15.02	10.59	12.66	8.91	44.25	1.41
10C.o_o	7.62	3.12	17.94	7.70	13.95	5.02	46.64	1.47
11C.o_o	14.20	2.53	19.38	8.07	17.30	6.84	41.14	1.40
12C.o_o	8.87	3.65	16.60	8.05	10.76	4.14	49.68	2.28
13C.o_o	9.80	2.53	23.89	9.83	17.65	8.08	33.79	1.03
14C.o_o	12.00	3.23	23.34	11.12	17.51	7.50	31.83	1.61
15C.o_o	10.44	2.72	25.11	11.21	14.88	8.42	33.14	1.36
16C.o_o	7.71	2.68	17.64	11.68	15.16	9.09	38.21	1.51
17C.o_o	10.42	2.33	21.27	11.45	17.03	9.57	33.83	1.32
18C.o_o	12.54	2.77	24.94	10.66	17.34	8.15	31.50	1.46
19C.o_d	9.60	2.79	25.05	9.63	17.48	7.55	32.95	1.03
20C.t_a	10.50	2.64	24.84	11.34	21.20	4.06	30.52	1.54
21C.t_a	9.20	2.01	27.04	13.03	19.73	6.95	26.87	1.15
22C.t_a	7.60	2.20	25.06	12.64	17.31	4.55	32.77	1.60
23C.t_t	10.70	1.85	19.34	13.82	18.05	9.15	32.90	1.37
24C.t_t	10.50	2.08	22.62	12.89	18.53	6.28	32.81	1.53
25C.t_t	8.70	2.47	24.15	13.71	19.01	4.55	30.50	1.63
26C.t_t	8.80	2.23	26.32	10.36	20.38	4.85	31.33	1.24
27C.t_t	6.60	2.21	24.68	13.89	18.80	6.79	28.57	1.25
28C.t_t	7.00	2.18	28.56	9.91	21.04	4.24	29.53	1.40
29C.t_t	10.40	1.79	20.14	15.48	17.83	9.22	31.05	1.36
30C.t_t	12.40	2.03	27.82	11.41	21.74	5.82	27.55	1.05
31C.t_t	8.70	2.18	23.09	13.03	19.94	5.73	31.07	1.33
32C.t_t	10.50	2.17	24.92	13.63	20.17	6.38	28.47	1.17
33C.t_t	8.58	0.21	28.13	9.48	20.74	3.39	30.59	1.32
34C.t_t	11.40	1.98	26.00	9.93	21.35	7.96	28.49	1.06
35C.t_t	11.50	1.90	18.46	14.21	17.51	8.32	34.36	1.51
36C.t_t	7.00	2.37	21.71	16.24	17.68	7.56	29.14	1.28
37C.t_t	12.40	2.32	25.62	10.59	20.97	5.53	30.48	1.26
38C.t_t	9.50	2.54	25.28	12.66	20.00	5.37	29.27	1.37

Table 2. (Continued).

39C.t_t	9.70	2.19	25.8	13.67	20.28	6.95	26.84	1.09
40C.t_t	7.60	2.24	24.56	13.47	19.04	7.70	28.27	1.23
41C.t_t	5.10	2.37	21.71	14.59	17.22	8.02	30.66	1.38
42C.t_t	11.60	1.86	23.11	11.09	19.86	8.52	30.89	1.33
43C.t_t	9.26	0.17	25.09	13.29	20.39	7.12	27.41	1.43
44C.t_t	9.10	2.23	23.21	15.39	18.88	7.56	28.25	1.21
45C.t_t	11.20	2.01	25.33	12.96	19.42	7.08	28.67	1.21
46C.t_t	8.00	2.42	20.95	12.69	18.95	6.24	33.37	1.62
47C.t_t	9.60	2.37	24.39	14.11	18.28	7.50	28.87	1.21
48C.t_t	9.50	2.02	22.78	11.16	21.79	6.93	30.69	1.35
49C.g	7.40	3.07	17.13	10.68	11.26	7.65	30.89	1.96
50C.m	14.05	1.81	31.30	17.34	17.14	3.37	25.17	1.27
51C.m	12.63	1.84	32.49	17.45	17.26	3.32	22.59	0.79
52C.o_s	13.74	2.59	22.63	11.42	18.70	5.20	32.32	1.81
53C.o_s	10.58	2.96	23.81	8.10	18.15	4.04	37.76	1.68
$\bar{x}$ (total)	9.92	2.41	23.03	11.57	17.84	6.51	33.11	1.39
$\bar{x}$ (C.o)	10.24	2.95	20.65	9.35	15.63	6.91	38.72	1.46
$\bar{x}$ (C.t)	9.4	2.04	24.16	12.78	19.52	6.56	30.01	1.33
CV (total)	27.5	35.83	16.23	24.24	14.47	29.02	17.97	22.9
CV (C.o)	35.79	35.03	16.58	25.97	13.05	31.77	15.53	29.69
CV (C.t)	19.01	27.12	10.41	13.72	6.99	23.52	6.63	12.15

Table 3. Mean values of the oil and fatty acid contents of the 7 *Crambe* taxa (%).

Taxon	Oil rate (%)	Myristic acid (C14:0)	Palmitic acid (C16:0)	Palmitoleic acid (C16:1)	Stearic acid (C18:0)	Oleic acid (C18:1)	Linoleic acid (C18:2)	Arașidic acid (C20:0)	Cis-11-eicosenoic acid (20:1)	Linolenic acid (C18:3)	Heneicosanoic acid (C21:0)	Cis-11,14-eicosadienoic acid C20:2	Behenic acid (C22:0)	Erusic acid (C22:1)	Cis-11,14-eicosadienoic acid (C20:2)	Cis-13,16-docosadienoic acid (C22:2)	Lignoseric acid (C24:0)	Nervonic acid (C24:1)
C. *grandiflora*	7.43	0.14	3.07	0.26	0.66	17.13	10.68	1.49	11.26	7.65	0.55	0.39	0.89	42.97	0.42	0.20	0.00	1.96
C. *maritima*	13.34	0.00	1.83	0.00	0.59	31.90	17.40	0.35	17.20	3.35	0.64	0.76	0.19	23.88	0.00	0.18	0.00	1.03
C. *orientalis_dasycarpa*	9.65	0.00	2.79	0.19	0.84	25.05	9.63	0.54	17.48	7.55	0.22	0.50	0.37	32.95	0.49	0.22	0.15	1.03
C. *orientalis_orientalis*	11.24	0.07	3.09	0.23	0.80	21.74	9.38	0.49	15.98	6.69	0.15	0.57	0.38	37.85	0.60	0.30	0.12	1.46
C. *orientalis_sulphurea*	12.16	0.10	2.78	0.19	0.92	23.22	9.76	0.92	18.43	4.62	0.44	0.52	0.39	35.04	0.29	0.26	0.19	1.75
C. *tataria_aspera*	9.63	0.08	2.42	0.20	0.70	24.14	11.98	0.36	18.61	5.62	0.44	0.64	0.26	32.23	0.55	0.25	0.11	1.38
C. *tataria_tataria*	9.61	0.08	2.20	0.18	0.69	23.82	12.44	0.36	19.44	6.50	0.41	0.69	0.25	30.78	0.45	0.23	0.10	1.33

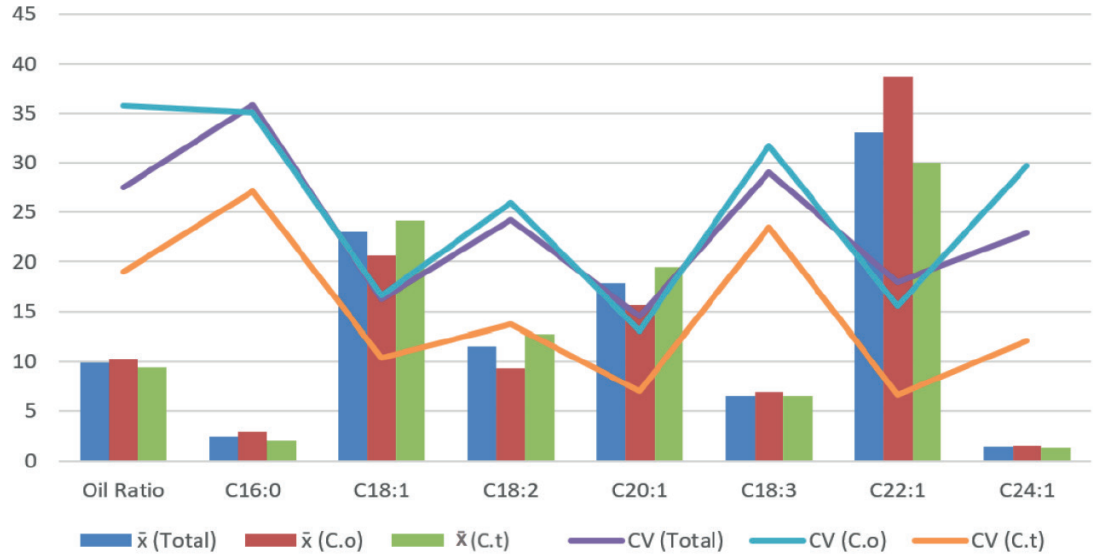

Figure 2. 2D PCA of the major fatty acid data of the 7 *Crambe* taxa with 53 accessions.

Table 4. Coefficients of correlation between the oil and major fatty acid contents of the 53 *Crambe* accessions (%).

	Altitude	Oil rate	C16:0	C18:1	C18:2	C20:1	C18:3	C22:1	C24:1
Altitude	1								
Oil rate	–0.01	1							
C16:0	0.146	–0.059	1						
C18:1	–0.312*	0.026	–0.321*	1					
C18:2	–0.274*	0.172	–0.393**	0.368**	1				
C20:1	–0.055	0.004	-0.47**	0.683**	0.333*	1			
C18:3	0.442**	0.263	–0.075	–0.358**	0.322*	–0.077	1		
C22:1	0.227	–0.034	0.435**	–0.779**	–0.737**	–0.722**	–0.105	1	
C24:1	0.164	–0.162	0.421**	–0.369**	–0.416**	–0.427**	–0.298*	0.465**	1

*P < 0.05, **P < 0.01.

molecular phylogenetic relationships among the taxa have been investigated, no chemotaxonomic studies have been conducted on their fatty acids. In the species belonging to *Crambe* and other Brassicaceae family members, fatty acids, and especially, the erusic acid content, are important in chemotaxonomic classification (Appelqvist, 1971; Umarov, 1975). In this study, it was investigated whether fatty acids can be a chemotaxonomic criterion. According to the dendrogram (Figure 4), based on the fatty acid compositions, *C. maritima* was separated from all of the other taxa and later, *C. grandiflora* was located on a separate branch than *C. orientalis* and *C. tataria*. In the subbranches, *C. orientalis* taxa were clustered together and *C. tataria* taxa were clustered together. When compared with the molecular analyses of previous studies (Tarıkahya-Hacıoğlu, 2016), it was seen that *C. maritima* and *C. tataria* were located on a separate branch than all of the other taxa. *C. grandiflora* and *C. orientalis* taxa formed a cluster together.

5. Conclusion

Crambe is a plant that may have significant potential in the future with regards to use in industry, medicine, and as vegetable. For breeding programs, genotypes that have a wide variation are required. Determination of the genetic affinities among the taxa is facilitative for breeders. This study showed the *Crambe* species in Turkey were divided into 2 major groups, with *C. maritima* in the first and the other *Crambe* species in the second .

Herein, it was seen that the seed fatty acids supported the current taxonomic classification. Hence, seed fatty acids can be used as a taxonomic character and can distinguish *Crambe* taxa at the species and subspecies level.

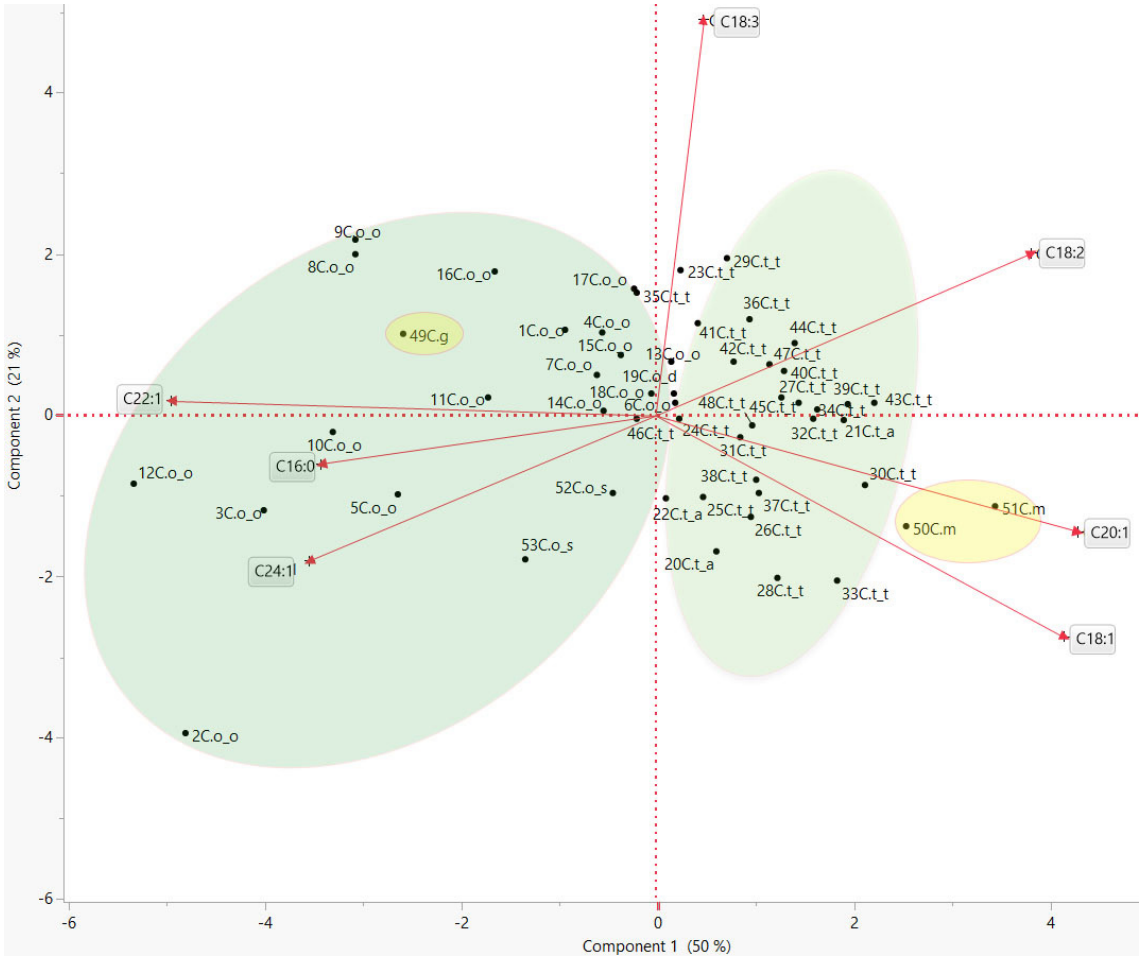

Figure 3. Means and CV of the oil ratio and major fatty acid values of *C. orientalis*, *C. tataria*, and all of the other *Crambe* accessions.

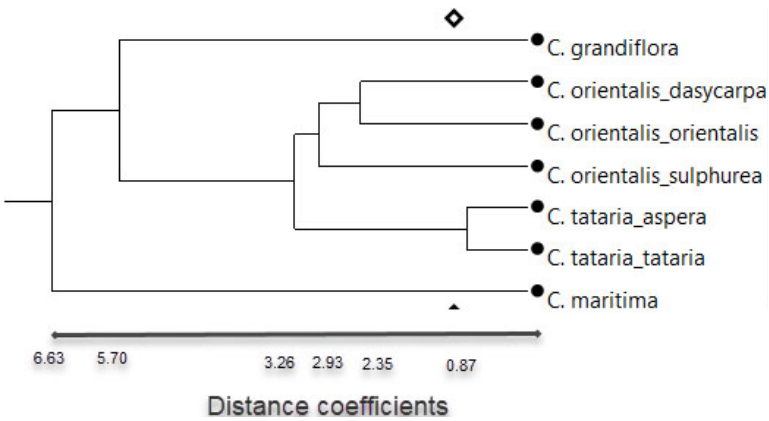

Figure 4. Dendrogram created with mean values of the 17 fatty acids of the wild *Crambe* taxa.

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