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Evaluation of fatty acid compositions and some seed characters of common wild plant species of Turkey

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Abstract: Seeds of 14 commonly found plant species from 3 different families (Brassicaceae, Dipsacaceae, and Asteraceae) were investigated for 1000-seed weights (g), total oil (%), total protein (%), total soluble sugar contents (TSS; mg g^{-1}), and fatty acid compositions (%). Correlation coefficients of fatty acids from different families were investigated, as well. Palmitic, stearic, oleic, linoleic, linolenic, eicosenoic, and erucic acids were present in varying amounts. Within the family Brassicaceae, only *Cardaria draba* did not contain eicosenoic and erucic acids, while species of the Asteraceae and Dipsacaceae did not contain linolenic, eicosenoic, or erucic acids. The 1000-seed weights ranged between 0.17 and 32.71 g among the examined species. Species from Brassicaceae generally had high oil content, with the exception of C. draba. The highest oil content was found in *Boreava orientalis* (36.87%). Total protein content was higher in members of families Brassicaceae and Dipsacaceae than in Asteraceae, and total protein content was found to be between 9.4% and 32.6%. TSS contents of seeds varied widely, ranging from 4.98 to 26.65 mg g^{-1}. Palmitic and stearic acid contents of the species showed significant positive correlations, but erucic acid content negatively correlated with both linoleic and linolenic acids in Brassicaceae. Significant negative correlations were found between linolenic acid to both palmitic and oleic acids in Asteraceae and Dipsacaceae. Further studies are needed for a better understanding of seed quality parameters, as well as oil and seed yield, to detect promising genotypes of selected species.

Key words: Asteraceae, Brassicaceae, Dipsacaceae, fatty acid composition, oil content

Introduction

Plant oils are important macromolecules for both human consumption and for industrial applications. The majority of world oil production is based on a few annual and perennial plant species, such as soybean, oil palm, cotton, canola, and sunflower. Human consumption accounts for 80% of oil consumption in the world. Six percent is used as animal feed, and the remaining is used in industrial applications (Lühs and Friedt 1994).

In order to meet the necessary demand for oils, different plant species have been domesticated and cultivated for centuries, and more recently, have been bred specifically for edible and industrial end products. *Brassica* species are cultivated extensively to produce edible and industrial oils throughout the world. *Brassica* species usually contain high amounts of undesirable fatty acids for human consumption, such as erucic acid (Snowdon et al. 2007). Even though the family Asteraceae is the largest family of the plant kingdom, only sunflower and safflower are used as oilseed crops. Sunflower is the main source of plant oils in Turkey, followed by cotton and canola. Even though Turkey is self-sufficient for many

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agricultural commodities, it is a net importer of plant oils. One billion US dollars was spent to import 2 billion tons of oil in 2010 (TÜİK 2011).

Plants are good sources for both common and uncommon fatty acids. Many uncommon fatty acid types have been isolated from different species (Jaworski and Cahoon 2003). Uncommon fatty acids are usually produced by nonagronomic crops. There is a growing interest in finding new alternative crops for oil production (Kumar and Tsunoda 1978; Luo et al. 1997).

Turkey has a rich flora; more than 9000 flowering plant species have been recorded. Asteraceae is the largest plant family in Turkey, comprising 133 genera and more than 1100 species. The family Brassicaceae contains 84 genera with 441 species, and the family Dipsacaceae is represented by 8 genera and 80 species (Davis 1965-1985).

Relatives of some agronomic crops, such as *Eruca sativa*, *Camelina rumelica*, and *Carthamus dentatus*, grow wild and are regarded as weeds in Turkish flora. Therefore, there is a possibility to utilize these species for agricultural production. The purpose of the present preliminary study was to evaluate seed fatty acid compositions, 1000-seed weight, oil, protein, and TSS contents of these species commonly found in Turkish flora.

Materials and methods

Plant material

Fourteen commonly found species from families Brassicaceae, Asteraceae, and Dipsacaceae were evaluated (Table 1). All seeds were collected from the Süleyman Demirel University (SDU) research farm (37°45′N, 30°33′E; altitude: 1035 m) between June and August of 2010, and the seeds were stored at room temperature. Identification of the species was performed at the Biology Department of the Arts and Sciences Faculty. Seeds of *B. orientalis* and *Rapistrum rugosum* were dehulled before the analyses, and all observations of Brassicaceae members were done using naked seeds. For the species of Asteraceae and Dipsacaceae, hulls were not removed and the results were based on whole seeds (hull + kernel). In order to calculate 1000-seed weight, 4 replicates of 100 seeds from each species were counted and weighed. Average seed weight was calculated for each species and then multiplied by 10.

Table 1. The 1000-seed weight, oil, protein, and TSS contents of the studied species.

Species	Family	1000-seed weight (g)	Oil content (%)	Protein content (%)	TSS content (mg g^{-1})
Camelina rumelica	Brassicaceae	0.31	24.31 ± 0.32	28.1 ± 1.32	4.98 ± 0.62
Sisymbrium loeselii	Brassicaceae	0.19	29.84 ± 0.58	26.5 ± 0.45	15.09 ± 1.55
Descurainia sophia	Brassicaceae	0.17	28.14 ± 0.19	29.3 ± 0.67	16.16 ± 1.96
Eruca sativa	Brassicaceae	0.85	24.18 ± 0.53	28.4 ± 0.06	11.17 ± 0.85
Sinapis arvensis	Brassicaceae	0.28	25.72 ± 0.74	32.6 ± 0.96	9.42 ± 1.91
Diplotaxis tenuifolia	Brassicaceae	0.21	23.40 ± 0.87	25.2 ± 0.10	21.66 ± 1.71
Cardaria draba	Brassicaceae	1.33	6.97 ± 0.43	23.5 ± 1.95	26.65 ± 1.47
Boreava orientalis	Brassicaceae	10.29	36.87 ± 0.59	31.8 ± 0.61	9.99 ± 0.47
Rapistrum rugosum	Brassicaceae	1.11	27.98 ± 1.25	30.2 ± 1.18	-
Knautia integrifolia	Dipsacaceae	1.38	25.31 ± 0.45	26.8 ± 0.60	26.44 ± 1.18
Centaurea depressa	Asteraceae	8.26	19.68 ± 0.27	11.7 ± 0.57	7.09 ± 0.65
Acroptilon repens	Asteraceae	5.61	8.91 ± 0.08	13.7 ± 1.01	12.24 ± 0.90
Onopordum acanthium	Asteraceae	9.86	14.36 ± 0.56	14.9 ± 0.51	10.35 ± 0.54
Carthamus dentatus	Asteraceae	32.71	15.39 ± 1.59	9.4 ± 0.66	6.24 ± 0.72

- = not measured.

Determination of oil and protein contents

Oil contents of seeds (%) were determined as described by Folch et al. (1957). Seeds were ground to powder using a mortar and a pestle. The oil extraction was done using n-hexane, and oil content was determined by the difference before and after Soxhlet extraction. Protein content of samples was determined using the Kjeldahl method (Kaçar and İnal 2008).

Determination of total soluble sugars

For the determination of total soluble sugars (TSS), the phenol sulfuric acid assay was used (Dubois et al. 1956). Glucose was used to obtain standard curve. Five aqueous solutions of glucose at 20, 40, 60, 80, and 100 μg mL^{-1} were prepared and read at 490 nm with a spectrophotometer, and results were expressed as mg g^{-1} dry weight.

Fatty acid analysis

Fatty acid compositions of seeds were determined with a gas chromatography and mass spectrophotometry (GC–MS) device. Analyses were performed at the central laboratories of SDU. The samples (4 g) were ground, the oil was extracted with hexane/isopropanol (3:2 v/v), and the solvent was evaporated in a rotary evaporator (Laborota 4001, Heidolph, Germany). Fatty acids were transformed to their methyl esters by the method of Marquard (1987). The GC–MS device (PerkinElmer Auto System XL, USA) was equipped with a flame ionization detector and Cp WAX 52 CB (50 m × 0.32 mm i.d.; 1.2 μm) column. Helium was used as the carrier gas, and the flow rate was adjusted to 40 mL min^{-1}. Detector temperature was set to 260 °C and oven temperature was raised from 60 °C to 240 °C at a rate of 4 °C min^{-1}. Palmitic, stearic, oleic, linoleic, linolenic, eicosenoic, and erucic acid contents of samples (%) were determined.

Statistical analysis

All analyses, except fatty acid compositions and 1000-seed weights, were performed in triplicate. Correlation coefficients between individual fatty acids were calculated separately for species of different families using SAS software (SAS 1998).

Results

Nine species from Brassicaceae, 4 species from Asteraceae, and 1 species from Dipsacaceae were evaluated in the study. Eleven of the 14 species were annuals, whereas *Diplotaxis tenuifolia*, *C. draba*, and *Acroptilon repens* were perennial species. In order to calculate the 1000-seed weight, oil and protein contents, total soluble sugars, and fatty acid compositions reported in Tables 1 and 2 for *B. orientalis* and *R. rugosum*, a large number of seeds were dehulled before the analyses. No such treatment was performed on seeds of other species.

Species exhibited large variation for their 1000-seed weights (Table 1). The 1000-seed weights of Brassicaceae species were around 1 g with the exception of *B. orientalis*, which had a 1000-seed weight of 10.29 g. The heaviest seeds were found from members of the family Asteraceae, with *C. dentatus* having the highest 1000-seed weight among the 14 studied species (32.71 g). The seed weights of Asteraceae and Dipsacaceae members ranged between 1.38 and 32.71 g.

Oil content of Brassicaceae members varied between 6.97% and 36.87%, and Brassicaceae members generally had higher oil contents than other species. The highest and the lowest oil contents were found in *B. orientalis* and *C. draba*, respectively. Oil contents of Asteraceae members were less than 20%, and *A. repens* had considerably less oil in its seeds compared to the other Asteraceae species (8.91%). Even though *K. integrifolia* is not regarded as an oilseed crop, its seeds contained 25.31% oil (Table 2).

Brassicaceae members had higher protein contents than the other species, ranging from 23.5% to 32.6%. The lowest protein content observed in the study was obtained from *C. dentatus* (9.4%), and *Onopordum acanthium* (14.9%) had the highest protein content among Asteraceae members.

TSS contents of seeds were also determined in the study. There were not enough seeds for *R. rugosum* for analysis, and therefore it was not possible to determine the TSS content of this species. TSS content varied widely among the species. *C. rumelica* (4.98 mg g^{-1}) and *C. dentatus* (6.24 mg g^{-1}) had the lowest TSS contents among the studied species. The highest amount of TSS in seeds was observed in *K. integrifolia* (26.44 mg g^{-1}) and *C. draba* (26.65 mg g^{-1}).

In order to determine the fatty acid compositions of the species, GC–MS analysis was performed.

Table 2. Seed fatty acid compositions of the species (%) examined in the study.

Species	Palmitic (C16:0)	Stearic (C18:0)	Oleic (C18:1)	Linoleic (C18:2)	Linolenic (C18:3)	Eicosenoic (C20:1)	Erucic (C22:1)
Camelina rumelica	0.65	3.41	9.02	11.73	31.72	10.50	24.47
Sisymbrium loeselii	9.82	4.13	13.67	14.61	34.37	21.01	2.12
Descurainia sophia	7.50	2.45	10.90	20.15	40.52	10.66	7.77
Eruca sativa	5.28	2.07	10.34	7.04	8.33	10.10	56.63
Sinapis arvensis	6.92	3.64	10.70	12.05	20.06	7.64	38.24
Diplotaxis tenuifolia	8.20	3.60	22.23	16.70	19.60	9.68	18.79
Cardaria draba	17.90	9.24	12.29	18.93	38.93	-	-
Boreava orientalis	4.98	2.65	16.74	22.39	26.43	10.98	14.01
Rapistrum rugosum	6.87	3.72	13.28	13.56	13.56	8.89	38.62
Knautia integrifolia	16.30	7.22	18.36	58.12	-	-	-
Centaurea depressa	12.29	6.79	32.66	48.25	-	-	-
Acroptilon repens	24.43	9.18	51.15	15.24	-	-	-
Onopordum acanthium	8.81	4.43	28.79	57.65	-	-	-
Carthamus dentatus	9.82	3.95	19.92	66.22	-	-	-

- = not detected.

Palmitic, stearic, oleic, linoleic, linolenic, eicosenoic, and erucic acids were detected in the seed samples (Table 2). Fatty acid compositions of the species differed among the plant families. Palmitic, stearic, oleic, and linoleic acids were common among the 3 families. Large ranges for these fatty acids were observed. Variation was found to be greater for palmitic (0.65%–24.43%) and linoleic (7.04%–66.22%) acids than for stearic (2.07%–9.24%) and oleic (9.02%–51.05%) acids. Linolenic, eicosenoic, and erucic acids were found only in members of the family Brassicaceae. However, *C. draba* did not contain eicosenoic or erucic acids. The eicosenoic acid content of Brassicaceae members showed a smaller variation (7.64%–21.01%) than the linolenic (8.33%–40.52%) and erucic (2.12%–56.63%) acids. In general, Asteraceae members and *Knautia integrifolia* contained the highest levels of palmitic, oleic, and linoleic acids found in the study (Table 2).

Correlation coefficients between fatty acids were calculated separately for species belonging to Brassicaceae, Dipsacaceae, and Asteraceae because of the different fatty acid compositions of these families (Table 3). Within the family Brassicaceae, a positive correlation was detected for palmitic and stearic acids, whereas negative correlations were detected between erucic acid and both linoleic and linolenic acids. Similarly, for the species belonging to Asteraceae and Dipsacaceae, a positive correlation was detected between palmitic and stearic acids. Negative correlations between palmitic and linoleic acids and between palmitic and oleic acids were detected.

Discussion

For breeding new crops and improvement of existing cultivars, it is necessary to have diverse germplasms. In order to broaden the genetic base of crop species, different approaches could be employed. Species of Brassicaceae are especially amenable to genetic manipulations to improve oil types or to transfer other desired characters (Cardoza and Stewart 2004; Scarth and Tang 2006). Characterization is the first step to using available germplasm resources (McFerson 1998). In the present study, 14 species were studied for their fatty acid compositions, correlations between fatty acids, 1000-seed weights and oil, protein, and TSS contents, all of which are important agronomic and quality characters. Species examined in this

Table 3. Correlation coefficients between fatty acids of the species from different families.

	Palmitic acid	Stearic acid	Oleic acid	Linoleic acid	Linolenic acid	Eicosenoic acid	Erucic acid
Family Brassicaceae							
Palmitic acid	-						
Stearic acid	0.845**	-					
Oleic acid	0.168	–0.009	-				
Linoleic acid	0.365	0.257	0.446	-			
Linolenic acid	0.380	0.441	–0.155	0.627	-		
Eicosenoic acid	-0.415	–0.578	0.096	–0.133	0.008	-	
Erucic acid	-0.524	–0.502	–0.263	–0.784*	–0.894**	–0.082	-
Families Dipsacaceae and Asteraceae							
Palmitic acid	-						
Stearic acid	0.934*	-					
Oleic acid	0.711	0.686	-				
Linoleic acid	–0.882*	–0.852	–0.957*	-			

*, **: $P < 0.05$ and $P < 0.01$, respectively.

study currently do not have economic importance at present; they are considered to be weeds and may cause important crop losses (Taştan and Erciş 1991). Among the examined species, only *E. sativa* and *O. acanthium* have uses as food and medicine.

Seed weight and oil content are quantitatively inherited characters and they are influenced greatly by environmental and genetic factors. Hence, reported 1000-seed weights were close to values reported for some species in this paper (Miller et al. 1965; Luo et al. 1997), while in some other species 1000-seed weights were quite different (Miller et al. 1965). Oil content of cultivated *Brassica* species is higher than 30% and could reach up to 45% (Mandal et al. 2002). In the present study, oil content of Brassicaceae members varied between 6.97% and 36.87%. As was observed for 1000-seed weights, the oil contents of the same studied species usually varied among the previous studies. Oil content of *R. rugosum* was reported to be between 6% and 38%, while for *S. arvensis* it was 26%–31% and for *Descurainia sophia* it was 32%–44% (Kumar and Tsunoda 1978; Luo et al. 1997). Our results for oil contents of *R. rugosum* and *S. arvensis* were within the range of reported values; however, for *D. sophia* it was less than that of the reported value (Luo et al. 1997). Even though *K. integrifolia* is not considered to be an oil crop, its oil content was comparable to Brassicaceae members, and it had higher oil content than the Asteraceae species. Seeds with high oil content have negative effects on the milling and baking qualities of flour (Leonova et al. 2010). Conversations with local milling companies in Isparta revealed that seed contamination of *K. integrifolia* is a major problem for flour production because of the high oil content of *K. integrifolia* seeds.

Beside human nutrition and industrial uses, by-products of oilseeds could also be used as a protein source for animal feed. The families Asteraceae and Brassicaceae are good sources of seed proteins (Betschart 1975; Snowdon et al. 2007). However, the species studied from Asteraceae did not exhibit high amounts of protein in their seeds as compared to *K. integrifolia*, and the protein contents of Brassicaceae members were lower than those of safflower and sunflower seeds (Betschart 1975; Parrado et al. 1991). Screening 102 species from the family Brassicaceae revealed that the protein content of the species ranged from 15% to 40%, and our results were within the reported ranges for Brassicaceae members (Miller et al. 1965).

Seeds contain carbohydrates as reserve molecules, along with fatty acids. There is little known about the

TSS content of seeds. Among the studied species, *K. integrifolia* and *C. draba* had the highest levels of TSS, the latter of which is known to accumulate high levels of sugars as reserves in its root system (Barr 1942). It was reported that the TSS contents of 2 safflower cultivars were 8.81 mg g^{-1} and 17.35 mg g^{-1} (Tonguç et al. 2012). In the present study, *C. dentatus*, a wild relative of cultivated safflower, had lower levels of TSS content than safflower cultivars.

The most commonly cultivated oilseed crops of Asteraceae, sunflower and safflower, do not produce linolenic, eicosenoic, and erucic acids, unlike traditionally cultivated oilseed *Brassica* species (Knowles 1972; Weiss 1997). Accordingly, fatty acid compositions of species differed among the studied plant families. There was only one species among the family Brassicaceae not containing eicosenoic and erucic acids (Table 2). Screening of many wild species within Brassicaceae indicated that high levels of eicosenoic and erucic acids were very common among the Brassicaceae species (Kumar and Tsunoda 1978; Miller et al. 1965; Mandal et al. 2002). However, it was noted that some species within Brassicaceae did not produce these fatty acids. Different fatty acids for *B. orientalis*, *R. rugosum*, *E. sativa*, and *Sinapis arvensis* that were not detected in this study were reported earlier (Miller et al. 1965), showing that infraspecific variations for fatty acid composition within the same species exist, which could be used to isolate variants of fatty acid synthesis genes within a species.

Short-chain fatty acids such as lauric and myristic acids and long-chain eicosenoic and erucic acids are not desired in edible oils due to their negative effects on health and in other applications (Gurr 1992; Snowdon et al. 2007). Breeding efforts have resulted in alterations of fatty acid composition and yields of oilseed crops. Fatty acid compositions of oilseed species have been altered both in Brassicaceae and Asteraceae (Knowles 1972; Snowdon et al. 2007). There was no suitable species for possible selection for edible oilseed crops in this study due to high levels of palmitic, stearic, linolenic, eicosenoic, and erucic acid contents. The studied species, except *A. repens*, did not have high levels of oleic acid; however, the oil content of *A. repens* was very low. Fourteen percent of world oil production is used in industrial applications (Lühs and Friedt 1994). High erucic acid-type oilseed crops have been developed for industrial applications (Yaniv et al. 1994). The highest level of erucic acid content was found in *E. sativa* (56.63%), and this species could be considered a candidate species for breeding material for high erucic acid-type crops (Lazzeri et al. 2004).

Correlation studies revealed positive and negative associations among fatty acids. Significant positive correlations between palmitic and stearic acids and oleic and linoleic acids have been reported for safflower (Fernandez-Martinez et al. 1993; Johnson et al. 1999), and our results are in agreement with the previous reports. Although a positive correlation was reported between linoleic and palmitic acids for safflower, a negative correlation was found for these 2 fatty acids in our study.

Correlations among fatty acids within Brassicaceae members were investigated in previous studies. Positive correlations between linolenic acid and both palmitic and stearic acids, and negative correlations between erucic acid and palmitic, stearic, oleic, linoleic, and linolenic acids, have been reported (Kumar and Tsunoda 1978). In the present study, correlations between palmitic and stearic acids were positive, but correlations between erucic acid and linoleic and linolenic acids were negative (Table 3). Based on our results, selection against erucic acid in the studied species will increase linoleic and linolenic acids, as was witnessed in *Sisymbrium loeselii, D. sophia*, and *C. draba*.

In the present study, seed quality characters, fatty acid compositions, and correlations between the fatty acids of 14 common species belonging to different families were evaluated. In order to have a better understanding regarding oil quantity, yield, and other important agronomic character, replicated trials with different populations of the selected species are necessary.

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