



Wild almond (*Prunus scoparia* L.) as potential oilseed resource for the future: Studies on the variability of its oil content and composition



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ABSTRACT

Wild almond genetic resources have still not received considerable attention for oil chemical compositions and uses. The aim of this study was to assess the levels of variation in oil content and fatty acid composition in forty Iranian accessions of *Prunus scoparia* L. (Spach) to identify genotypes with desirable traits in terms of oil quantity, quality and industrial utilization. Oil parameters and indices were measured, and fatty acid methyl ester analysis was carried out by gas liquid chromatography. Oleic and linoleic fatty acids showed high variability among accessions, ranging from 232.4 to 359.6 g/kg oil and from 190.7 to 348.8 g/kg oil, respectively. Total unsaturated fatty acid fraction was higher than total saturated fatty acid. The ranges of saponification number (199.2–202.1), iodine value (104.8–125.7 kg I₂/kg) and cetane number (43.8–48.8), confirmed that the oils have industrial potentialities. Results could contribute to select wild almond genotypes as genetic sources for oil production.

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1. Introduction

Almonds (*Prunus amygdalus* L.) are native to the Western and Central Asia, including eastern China, Kurdistan, Turkestan, Afghanistan and Iran (Martínez-Gómez et al., 2007; Sathe, Teuber, Gradziel, & Roux, 2001; Zeinalabedini et al., 2008). Wild almond species commonly grow in areas between 28° and 38°N and 41° and 54°E and from 1100 to 2700 m.a.s.l. (Browicz, 1969), in regions characterized by a subtropical Mediterranean climate, with mild wet winters and warm, dry summers. Nearly 20 almond wild species have been reported in Iran (Sorkheh et al., 2009), indicating that this country is within the center of origin of almond. Indeed, Iran has primarily a subtropical climate in the south of the country, temperate in the north part, with mostly desert in the middle, and the resultant variability in environment and climate made possible an extensive diversity of almond germplasm (Sorkheh et al., 2009). In 2004, world production of cultivated almond was approximately 2,917,894 tonnes, of which Iran produced 87,281 tonnes (FAO STAT, 2013). Iranian almond production is mainly based on locally adapted clones, with minimum to no inputs, and traditional management (Sorkheh et al., 2009).

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The almond is considered a pleasant nut throughout the world with applications in food, pharmaceutical and cosmetic industries. It is used as an ingredient in many snacks and other processed foods (Zhang et al., 2009). As is the case with other nuts, an almond-based diet reduces the risk of cardiovascular diseases (Chen, Lapsley, & Blumberg, 2006). This is attributed to the hypocholesterolemic effect of high levels of fiber, sterols, ratio of total unsaturated fatty acids (TUSFA) to total saturated fatty acids (TSFA), and also to the antioxidant capacity of vitamin E and sphingolipids present in almonds (Chen et al., 2006; Maguire, O'Sullivan, Galvin, O'Connor, & O'Brien, 2004).

At present, a few crop species such as soybean (*Glycine max*), oilseed rape (*Brassica napus*) and sunflower (*Helianthus annuus*) dominate the international edible oilseed market. However, with a continuous increase in population, the demand for high-quality seed oils is also increasing. To meet the demand, there is a need not only to increase the production of the major oilseed crops but also to diversify the sources by popularizing and increasing the production of minor crops. Although numerous studies have been reported on the characteristics of the oil and other components of almond species (Farhoosh & Tavakoli, 2008; Kiani, Rajabpoor, Sorkheh, & Ercisli, 2015), a complete investigation on the nutritional and chemical compositions of wild almond species is not currently provided in the literature. The wide adaptation of wild almond indicates its potential as sources for resistance to abiotic and biotic stresses, as well as for advantageous nut traits.

Efforts have been made to evaluate and utilize the available germplasm, particularly in terms of fat and fatty acid profiles (Kiani et al., 2015). Despite the wide distribution of wild almond species having high nutritional values, they have not been fully utilized for industrial applications. Therefore, a thorough investigation on the chemical compositions of the oils extracted from wild almond species could significantly contribute to the current limited data available for their potential use as raw materials in food industry.

Particularly, *Prunus scoparia* L. (Spach) is a wild almond species of the taxonomic section 'Spartoids' and it is distributed as an oil-seed crop in Iran. *P. scoparia* seeds are used in human food mainly as a spice in the frying of pulses, vegetables and also in pickles (Kiani et al., 2015). Its seed oil is used for various industrial products, such as soaps, paints, and biodiesel. In addition, this crop is an important source of seed protein that significantly contributes to the human dietary protein intake. Despite its great advantages in comparison with other wild almond germplasm, including low bitterness, evergreen habitus, high values of net photosynthesis, and high yields of seed and oil, *P. scoparia* suffers from a lack of improvement program through modern breeding efforts (Sorkheh et al., 2009).

On this basis, the aim of this study was to assess the levels of variation in oil content and fatty acid composition among accessions of *P. scoparia* in order to identify genotypes with desirable oil quality for consumption, industrial use or biodiesel production. This information could be used for increasing oil content and diversifying oil quality in wild almond.

2. Materials and methods

2.1. Plant materials

Forty accessions from seven populations of *Prunus scoparia* L. (Spach) were collected in seven different parts of Chaharmahal-e Bakhtiari province (Iran; 32°19'32" N, 50°51'52" E; average rainfall 321.5 mm) (Table 1 and Supplementary Fig. 1) for two consecutive years (2012 and 2013) and used for this study. Field expeditions were carried out according to Sorkheh et al. (2009). Sites were selected based on previous literature, indigenous information, or conspicuous presence. Collections were made from both wild and cultivated habitats from trees at the same physiological stage. The detailed procedure is available in Sorkheh et al. (2009). Mature plants were harvested by cutting plants at 15–20 cm above ground level and placing them in plastic bags before taking them to the laboratory. Most of these accessions were previously morphologically, genetically and biochemically characterized (Sorkheh et al., 2009). All the samples were stored under refrigerated conditions (4 °C) until used in the experiments.

2.2. Oil extraction and analysis

Seeds were manually separated from the rest of the plant and cleaned of impurities. The seeds were oven-dried at 60 °C, and then stored in desiccators until analysis. Seeds were ground in a laboratory rotor mill (model Pulverisette 14; Fritsch GmbH, Markt Eisenheim, Germany) to particle size <200 µm. Seed moisture content was determined before oil extraction by weighing about 5 g of ground seed in pre-calibrated porcelain capsules and placing in thermostated oven at 105 °C until constant weight was reached. Oil extraction was performed using a Soxhlet apparatus with about 20 g of ground seeds and *n*-hexane as solvent applying the method reported by Zhang et al. (2009). The solvent was then removed under vacuum rotary evaporation at 40 °C and the percentage of recovery was meanly 80–85% for all the samples; the flask containing the extracted oil was placed in an oven at 70 °C

Table 1

Prunus scoparia accessions with the respective codes and collection site characteristics.

Code	Number of accessions	Collection site	Latitude N	Longitude E	Elevation (m)	Annual rainfall (mm)
PSA	7	Ardal	32.01	49.50	1850.0	320.2
PSB	8	Broojen	31.57	51.18	2197.0	254.3
PSFA	6	Farsan	32.15	50.35	2250.0	275.4
PSFE	4	Felard	31.17	51.22	1970.0	456.8
PSKB	4	Kareh-e-Base	31.30	45.54	2700.0	283.2
PSKO	5	Kohreng	32.26	50.70	2285.0	1441.8
PSLO	6	Lordegan	31.30	50.59	2085.0	280.3

for 4 min and weighed after cooling in a dryer. The oil content was determined using the following relation:

$$\text{Oil content} = [(P_1 - P_2)/P]100$$

where P is the weight of the dry seed, P₁ the weight of the flask containing the oil, and P₂ the weight of the empty flask.

The pure oil was transferred into a small glass vial, flushed with nitrogen and maintained at –20 °C until analyzed for, iodine value (IV), saponification number (SN) and cetane number (CN). The values of IV and SN were determined according to the methods 920.158 and 920.160, respectively, both from the official methods of analysis of AOAC International (2005). CN was determined according to Krisnangkura (1986).

2.3. Fatty acid methyl ester (FAME) analysis by gas liquid chromatography

Kernels were freshly ground with a hand homogenizer (model 400010; Bioreba AG, Reinach, Switzerland) and weighed to obtain 40 mg oil when extracted with 10 mL solvent mixture consisting of chloroform:hexane:methanol (8:5:2, v/v/v). The extracts obtained were dried at 60 °C in nitrogen gas for 30 min. Methyl esters of oil samples were prepared according to the method of Sarin, Sharma, and Khan (2009). An aliquot of the hexane extract (1 mL) was injected into a highly polar HP Innovax capillary column of 30 m length (inner diameter: 0.32 mm, film thickness: 0.5 µm, split: 1:80). A gas chromatograph with flame ionization detector (FID) was used (Agilent 6890 GC Gas Chromatograph Series; Varian Inc., Walnut Creek, CA, USA). The injector and detector temperatures were 260 °C and 275 °C, respectively. Oven temperature was held at 150 °C for 1 min, ramped to 210 °C at 15 °C/min and then to 250 °C at the rate of 5 °C/min, with a final hold at 250 °C for 12 min. Peaks of fatty acid methyl esters were identified by comparing their retention time with that of the known standards, were run under the same conditions. Peak integration was performed applying instrument software.

2.4. Oil indices

Stability index was defined as the ratio of oleic to linoleic acid (O/L). Correlation coefficients were calculated for the various traits studied (Yadav et al., 2010). Degree of unsaturation (DU) among various oil samples was derived taking into account the amount of monounsaturated and polyunsaturated fatty acids present in the oil (Ramos, Fernández, Casas, Rodríguez, & Pérez, 2009.).

2.5. Statistical analysis

The experiments were organized in a randomized block design. Data are the average of two crop years and, for each crop year

(2012 and 2013), five kernel samples were taken from each accession (each containing 50 individual kernels) per year ($n = 10$ over the two experimental years). Data were analyzed using SAS version 9.2 (SAS Institute Inc., Cary, NC, USA). Analysis of variance (ANOVA) was performed using the PROC GLM procedure of the software, that uses the method of least squares to fit general linear models. PROC GLM enables to specify any degree of interaction (crossed effects) and nested effects, and also provides for polynomial, continuous-by-class, and continuous-nesting-class effects. Correlation analysis was performed to determine the relationship between the traits using the CORR procedure, computing Pearson correlation coefficients as parametric measure of the linear relationship between the variables. Significant differences among means were determined at $P \leq 0.01$ and $P \leq 0.001$, according to Fisher's LSD test.

3. Results and discussion

3.1. Statistics

Results of the analysis of variance for most of the studied characteristics showed significant differences among almond genotypes (Table 2). In particular, accessions differ significantly for oil ($P < 0.01$), palmitic acid ($P < 0.01$), stearic acid ($P < 0.001$), oleic acid ($P < 0.001$) and linoleic acid ($P < 0.001$) content.

3.2. Oil content

Data concerning moisture content and oil content in *P. scoparia* accessions are reported in Table 3. On average, moisture content in PSA, PSB, PSFA, PSFE, PSKB, PSKO and PSLO (for more details on codes and collection site characteristics, see Table 1) was 69.4, 81.3, 79.4, 73.4, 86.0, 88.6 and 85.5 g/kg respectively, and it was not statistically different among accessions within the same group (Table 3). The average oil content of PSA, PSB, PSFA, PSFE, PSKB, PSKO and PSLO was 205.6, 183.4, 235.5, 210.1, 270.1, 203.8 and 214.5 g/kg DM, with appreciable variability among the six populations. These values are low in comparison to the cultivated almond species but in line with previous findings on various wild almond species (Kiani et al., 2015). The highest oil content in the studied germplasm was recorded for the accessions PSKB2 and PSKB3, with 271.5 and 270.6 g/kg DM, respectively, whereas PSB6 presented the lowest (180.6 g/kg DM). Six populations (PSA, PSFA, PSFE, PSKB, PSKO, and PSLO) showed mean values of oil content higher than 200 g/kg DM.

Plant seeds are an important source of oils of nutritional, industrial and pharmaceutical importance. No oil from any single source has been found to be suitable for all purposes because oils from different sources generally differ in their fatty acid composition (Vaughan, 1970). This necessitates the search for new sources of novel oils. The oil from *P. scoparia* is edible and it can also be used in the manufacture of soap and paints, or as a lubricant or illuminant. The meal after oil extraction is protein rich and is used as a feed, manure or fuel (Vaughan, 1970). In this experiment, the seed oil content of the *P. scoparia* accessions varied within a mass fraction of 180.6–271.5 g/kg DM (Table 4).

3.3. Fatty acid profile

Seed oil quality and utility is determined mainly by its fatty acid composition (Harrington, 1986). The range and mean of fatty acid composition along with oil content and biodiesel traits of *P. scoparia* are shown in Table 4. The results on fatty acid composition show that the oils contain palmitic (PA), stearic (SA), oleic (OL) and linoleic (LA) acids as the major fatty acids. Vegetable fats with

high concentrations of saturated fatty acids are desired by the food industry, especially to avoid the need for hydrogenation and transesterification processes in the production of margarine and related products. Indeed, there are currently breeding programs focusing on the development of accessions of the major oilseed crops with a high concentration of saturated fatty acids in the seed oil (Hartmann et al., 1996).

Saturated fatty acids are present in high-fat dairy foods, meat and some plant-based oils, such as palm, palm kernel and coconut oils. Palmitic and stearic acids constitute the total saturated fatty acids (TSFA). Among wild almond accessions, palmitic and stearic acids ranged from 106.2 to 206.3 g/kg oil and 194.3–276.5 g/kg oil, respectively (Table 4). Oleic acid, a monounsaturated fatty acid (MUFA), was reported as the major fatty acid present in the wild almond oils, ranging from 232.4 to 359.6 g/kg oil (Table 4). The accessions PSLO2 and PSKB1 exhibited the least variation in oleic content during the two years. The Iranian almond germplasm is reported to have on average 66.7–69.7% (w/w) oil oleic acid content of the total fatty acid (Kiani et al., 2015) but the range found here is higher. Compared with other minor oilseed crops like linseed, sesame and sunflower, *P. scoparia* oil has a comparable oleic and linoleic acid content (Supplementary Table 1). Thus, these accessions may be used in breeding programmes for enhanced oleic acid content. Indeed, vegetable oils with high C18:1 content is increasingly appreciated both for food and industrial applications due to its hypocholesterolemic effect and has a much greater oxidative stability than polyunsaturated fatty acids. Moreover, the oils with high oleic acid can be used for cooking and frying, as they tolerate high temperature (Arslan, 2007). Linoleic acid, a polyunsaturated fatty acid, is nutritionally an essential compound which needs to be supplemented only through diet in humans. Linoleic acid in *P. scoparia* germplasm ranged from 190.7 to 348.8 g/kg oil, with a mean value of 269.8 g/kg oil. Moreover, the linoleic content in wild almond was higher than linseed and comparable to sesame and sunflower oil (Supplementary Table 1). The oils of the almond cultivars with high linoleic acid could be used for producing medicines aimed at reducing the risk of chronic pathologies, such as cancer and cardiovascular diseases. Indeed, many authors demonstrated the antioxidant, cardioprotective, anti-cancer, anti-inflammation, anti-ageing and anti-microbial properties of linoleic acid in almonds (Arslan, 2007; Chen et al., 2006; Maguire et al., 2004). Finally, germplasm accessions yielding higher concentrations of oleic and linoleic acids are required by the industry for cooking oils with acceptable shelf life. In general, the accessions of wild almond species exhibited slight variations in oleic and linoleic acid content between the two experimental years (Fig. 1).

The results showed that *P. scoparia* oil contains high values of TUSFA (range = 457.2–681.5 g/kg oil) as compared with total TSFA (range = 318.5–542.8 g/kg oil) (Table 4). The saturated fats were found to be higher than the concentrations present in other minor oilseed crops (Supplementary Table 1). Considering all the 40 accessions, the mean value of oleic and linoleic acid as TUSFA was 569.4 g/kg oil. The high level of unsaturation in oil increases the value of oil for nutritional purposes (Kiani et al., 2015). The stability index, an indicator of oil stability, ranged from 0.4 to 1.7 (Table 4). The oil stability is inversely related to linoleic acid and positively related to oleic acid content. For this reason, the accession PSA6, with a high stability index of 1.71 could be utilized for the production of cooking oil. The ratio of saturated fatty acid/monounsaturated fatty acids/polyunsaturated fatty acids (SFA/MUFA/PUFA) is essential for oil quality, especially for edible purposes, with the recommended range for SFA/MUFA/PUFA being 1/1–3/1 (Kale, 2007). Thus, PUFA in wild almond oil (in this case, linoleic acid) should be reduced to appropriate level to make the cooking oil more stable and desirable for edible purposes, compared to other oil crops (Supplementary Table 1).

Table 2
ANOVA analyses of oil chemical parameters of *Prunus scoparia* accessions.

	Moisture (g/kg)	Oil content (g/kg DM)	Palmitic acid (g/kg oil)	Stearic acid	Oleic acid	Linoleic acid	Unsaturated/saturated (%)	Linoleic/oleic
Genotype effect								
Minimum value	69.4	180.6	106.2	194.3	232.4	190.7	1.44	0.82
Maximum value	90.2	271.5	266.3	276.5	359.6	348.8	1.26	0.97
CV (%)	6.01	12.7	20.8	19.4	29.6	38.4	2.59	1.5
<i>P</i>	ns							

Means from 2012 CE 2013 experiments ($n = 10$). CV = coefficient of variation.

* Significant difference at $P < 0.01$.

** Significant difference at $P < 0.001$.

Table 3
Moisture content and oil content of *Prunus scoparia* accessions. Values represent means ($n = 10$) \pm SD. Means from 2012 CE 2013 experiments.

Code	Moisture content (g/kg)	Oil content (g/kg DM)
PSA1	80.3 \pm 9.2	205.8 \pm 21.3
PSA2	78.6 \pm 8.1	204.9 \pm 32.2
PSA3	77.6 \pm 8.2	204.8 \pm 23.5
PSA4	80.2 \pm 8.9	206.7 \pm 11.6
PSA5	79.6 \pm 5.0	207.8 \pm 32.3
PSA6	80.3 \pm 11.3	203.8 \pm 27.4
PSA7	78.9 \pm 20.4	206.5 \pm 19.1
Mean	79.3	205.7
PSB1	82.9 \pm 20.1	184.5 \pm 27.4
PSB2	83.1 \pm 10.3	183.7 \pm 18.2
PSB3	79.8 \pm 9.7	182.6 \pm 28.6
PSB4	78.6 \pm 12.5	185.0 \pm 22.8
PSB5	80.2 \pm 11.3	186.3 \pm 15.3
PSB6	81.3 \pm 11.2	180.6 \pm 10.9
PSB7	82.6 \pm 7.1	182.7 \pm 15.2
PSB8	82.1 \pm 5.3	181.9 \pm 15.3
Mean	81.3	183.4
PSFA1	79.6 \pm 12.0	253.4 \pm 21.6
PSFA2	78.4 \pm 11.3	254.0 \pm 22.1
PSFA3	77.6 \pm 15.7	254.9 \pm 22.1
PSFA4	78.5 \pm 15.3	253.8 \pm 22.2
PSFA5	77.2 \pm 6.2	250.4 \pm 18.2
PSFA6	79.2 \pm 12.2	252.6 \pm 19.3
Mean	78.4	235.1
PSFE1	73.6 \pm 10.9	209.8 \pm 14.6
PSFE2	72.8 \pm 9.5	210.4 \pm 11.2
PSFE3	72.6 \pm 7.5	211.7 \pm 21.3
PSFE4	74.5 \pm 3.9	208.6 \pm 15.2
Mean	73.4	210.1
PSKB1	87.2 \pm 17.1	269.8 \pm 19.2
PSKB2	87.0 \pm 13.4	271.5 \pm 26.1
PSKB3	85.6 \pm 12.1	270.6 \pm 16.6
PSKB4	84.3 \pm 21.2	268.6 \pm 16.5
Mean	86.0	270.1
PSKO1	89.9 \pm 10.7	202.6 \pm 24.3
PSKO2	90.2 \pm 21.5	204.7 \pm 19.7
PSKO3	88.6 \pm 14.6	203.1 \pm 15.6
PSKO4	87.4 \pm 13.5	202.9 \pm 18.8
PSKO5	86.9 \pm 11.2	205.7 \pm 28.7
Mean	88.6	203.8
PSLO1	85.6 \pm 12.58	215.9 \pm 12.6
PSLO2	86.1 \pm 11.30	214.2 \pm 19.2
PSLO3	84.5 \pm 7.85	215.2 \pm 10.1
PSLO4	85.4 \pm 10.92	216.8 \pm 25.6
PSLO5	84.9 \pm 10.30	213.8 \pm 15.3
PSLO6	86.4 \pm 15.34	211.4 \pm 17.4
Mean	85.4	214.5

3.4. Wild almond as biodiesel and industrial crop

Fatty acid methyl esters (FAMES) of seed oils have been found suitable for use as fuel in diesel engines (Harrington, 1986). Indeed, FAMES as biodiesel are environmentally safe, non-toxic and

Table 4

Ranges in oil chemical parameters of *Prunus scoparia* accessions. Average values represent means ($n = 10$) \pm SD. Means from 2012 CE 2013 experiments. TSFA = total saturated fatty acids; TUSFA = total unsaturated fatty acids.

Parameter	Range		Average \pm SD
	Min	Max	
Oil content (g/kgDM)	180.6	271.5	226.1 \pm 21.4
Palmitic acid (g/kg oil)	106.2	266.3	186.3 \pm 14.3
Stearic acid (g/kg oil)	194.3	276.5	235.4 \pm 12.8
Oleic acid (g/kg oil)	232.4	359.6	296.2 \pm 19.2
Linoleic acid (g/kg oil)	190.7	348.8	269.8 \pm 17.4
Stability index	0.42	1.71	0.79 \pm 0.07
TSFA (g/kg oil)	318.5	542.8	430.6 \pm 10.5
TUSFA (g/kg oil)	457.2	681.5	569.4 \pm 16.2
Saturation ratio	0.54	0.96	0.78 \pm 0.08
Saponification number	199.2	202.1	200.3 \pm 28.1
Iodine value (kgI ₂ /kg)	104.8	125.7	113.6 \pm 19.7
Cetane number	43.8	48.8	47.7 \pm 7.2
Degree of unsaturation	116.1	139.1	129.5 \pm 10.3

biodegradable. Saponification value (SV), iodine value (IV) and cetane number (CN) were used to predict the utility of *P. scoparia* oil as biodiesel source. The SV represents the number of milligrams of KOH required to saponify 1 g of oil; it is a measure of the average molecular weight of all the fatty acids present in an oil. This parameter depends on the molecular weight and the percentage concentration of fatty acid components. The IV, the mass of iodine in grams that is consumed by 100 g of oil, are used to determine the amount of unsaturation in fatty acids, as the higher the iodine number, the more C=C bonds are present in the oil. This value depends on percentage concentrations of unsaturated fatty acid components, their molecular weight and the number of double bonds present in them. Finally, CN is an indicator of the combustion speed and ignition quality of the fuel, as a higher value indicates better quality of fuel. Generally, diesel engines operate efficiently with values of SV, IV and CN in the range of 190–220, 70–160, and 40–55, respectively (Azam, Waris, & Nahar, 2005).

Higher IV indicates higher unsaturation of fats and oils and the potential for the oil to polymerize. The mean IV of almond species oil was 104.8–125.7 kg I₂/kg (Table 4). The oils with such IV are placed in the semi-drying oil group. The IV of wild almond oilseed suggests its use in production of alkyne resin, shoe polish, and varnishes. Saponification value of the studied oils was 199.2–202.1 (Table 4). High saponification value indicated that the oil can be useful in the production of liquid soap and shampoo. Noteworthy, biodiesel USA standards (ASTM, 2016) have set CN value as 47, while lowest limit of IV is 115, set by the standard BS EN 14214:2012 + A1:2014 (BSI, 2014).

3.5. Correlation among traits

The correlation among the various oils from *P. scoparia* accessions is reported in Table 5. The oil content did not show any sig-

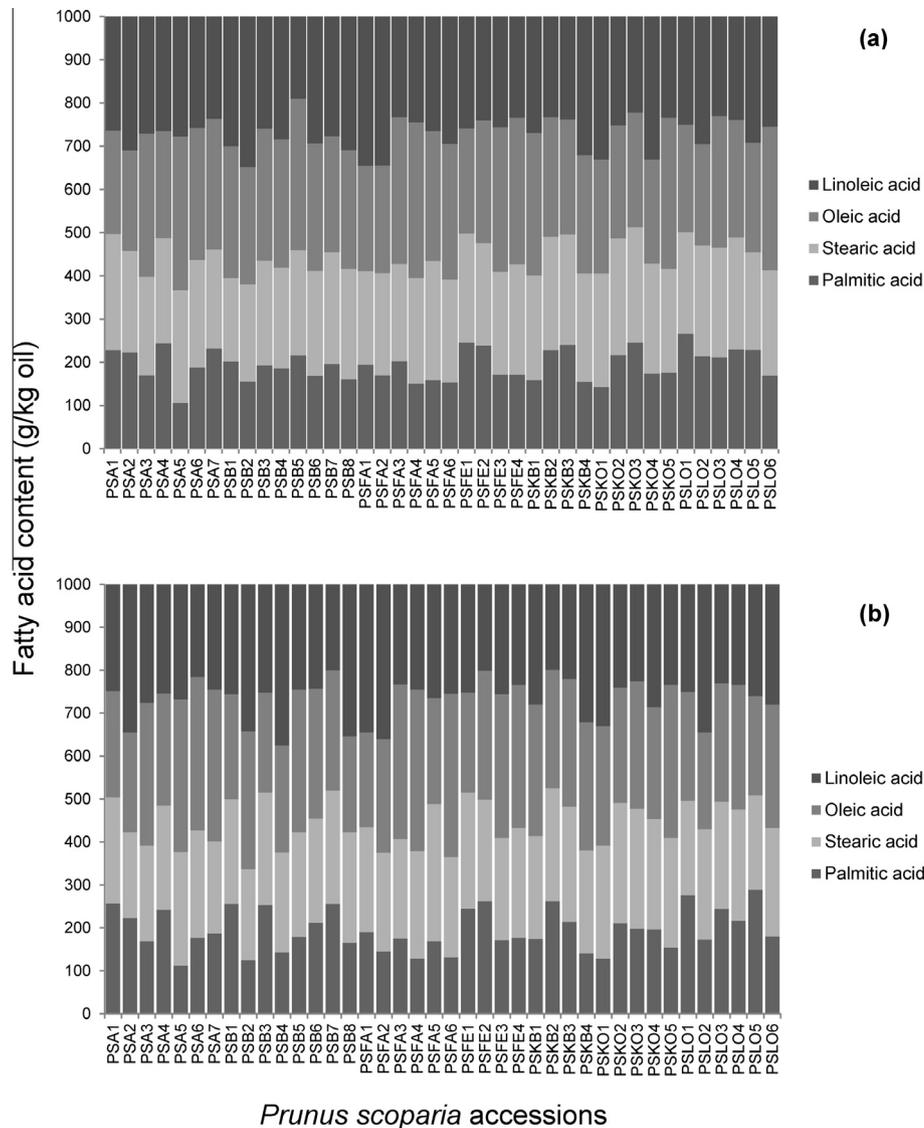


Fig. 1. Variations in fatty acid composition of the *Prunus scoparia* accessions from the experiments of (a) 2012 and (b) 2013 ($n = 5$).

nificant correlation with any of the traits studied, excepting for TUSFA, that showed a significant correlation at $P < 0.01$. Palmitic acid was inversely associated with oleic acid. This association is well documented and reported in other oil crops like soybean (Rebetzke, Pantalone, Burton, Carver, & Wilson, 1996.), peanut (Andersen & Gorbet, 2002), winter oilseed rape (Mollers & Schierholt, 2002) and sesame (Were, Onkware, Gudu, Welander, & Carlsson, 2006.). The 16-carbon acyl chains are elongated followed by desaturation for the synthesis of 18-carbon fatty acids and this elongation step plays a key role in regulating the relative amounts of palmitic acid and the 18-carbon fatty acids (Brar, 1982). A deficiency in this step leads to a decrease in the amount of the 18-carbon fatty acids and an increase in the palmitic acid content. This can explain the observed correlations (Table 5).

Linoleic acid had a significant negative correlation with oleic acid (Table 5). This observation agrees with various reports on oil composition available in sesame (Were et al., 2006), crucifer species (Knowles & Hill, 1964), soybean (Patil, Taware, Oak, Tamhankar, & Rao, 2007) and safflower (Fernandez-Martinez, Rio, & Haro, 1993). It is known that species with no linolenic acid in their seed, as in this case, fatty acids composition show inverse relationship between oleic and linolenic acid because they are the last products in the

biosynthetic pathway and linked by the activity of the enzyme FAD2. It is also true that the environment where the accessions were grown could be another reason for the inverse relationship between these two fatty acids, as demonstrated by Maestri, Labuckas, Guzman, and Giorda (1998) in soybean.

4. Conclusions

This study indicated that oil quantity and quality in wild almond (*P. scoparia*) is comparable to that of other minor oilseed like sunflower, safflower and linseed. The oils from *P. scoparia* were generally rich in both oleic and linoleic acid, even though a wide range of variability for fatty acid composition was found among accessions. The high oleic acid accessions make wild almond oil suitable for cooking purposes while the high linoleic acid content makes the oil of wild species nutritionally valuable. *P. scoparia* could be nutritionally considered as a new potential source of edible seed oils. It also has potential for industrial uses as in paint industries and soap making factories and it could be used as alternative fuel options for biodiesel. *P. scoparia* seeds are valuable not only in meeting demands for food and food supplements with functional, health-promoting properties, but also for industrial uses.

Table 5
Correlation coefficients among oil chemical parameters of *Prunus scoparia* accessions.

	Oil content	Palmitic acid	Stearic acid	Oleic acid	Linoleic acid	O/L	TSFA	TUSFA	SN	IV	CN	DU
Oil content	1.00											
Palmitic acid	−0.07	1.00										
Stearic acid	−0.01	0.62 [*]	1.00									
Oleic acid	−0.09	−0.84 [*]	−0.80 [*]	1.00								
Linoleic acid	0.09	0.79 [*]	0.79 [*]	−1.00 [*]	1.00							
O/L	−0.06	−0.78 [*]	−0.74 [*]	0.98 [*]	−0.99 [*]	1.00						
TSFA	0.03	0.85 [*]	0.95 [*]	0.87 [*]	0.87 [*]	0.85 [*]	1.00					
TUSFA	−0.38 [*]	0.49 [*]	0.50 [*]	0.86 [*]	0.48 [*]	−0.47 [*]	0.51 [*]	1.00				
SN	0.10	0.78 [*]	0.75 [*]	−0.52 [*]	1.00 [*]	−0.99 [*]	0.83 [*]	−0.53 [*]	1.00			
IV	0.05	0.79 [*]	−0.76 [*]	−0.99 [*]	−1.00 [*]	0.97 [*]	−0.82 [*]	0.54 [*]	−0.40 [*]	1.00		
CN	0.10	0.70 [*]	0.71 [*]	0.98 [*]	0.98 [*]	−0.98 [*]	0.81 [*]	0.49 [*]	0.82 [*]	0.99 [*]	1.00	
DU	0.04	0.69 [*]	0.69 [*]	0.97 [*]	0.89 [*]	0.86 [*]	0.79 [*]	0.55 [*]	−0.84 [*]	1.00 [*]	−0.98 [*]	1.00

Means from 2012 CE 2013 experiments ($n = 10$). O/L = oleic/linoleic ratio; TSFA = total saturated fatty acids; TUSFA = total unsaturated fatty acids; SN = saponification number; IV = iodine value; CN = cetane number; DU = degree of unsaturation.

^{*} Significant difference at $P < 0.01$.

This study adds new oil compositional data that could be of interest for almond breeding, focused to improve oil content and ameliorate oil composition. Results could also contribute to establish quality criteria to select wild almond genotypes as genetic sources for oil production.

Competing interests

The authors declare that they have no competing of interests.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at <http://dx.doi.org/10.1016/j.foodchem.2016.05.160>.

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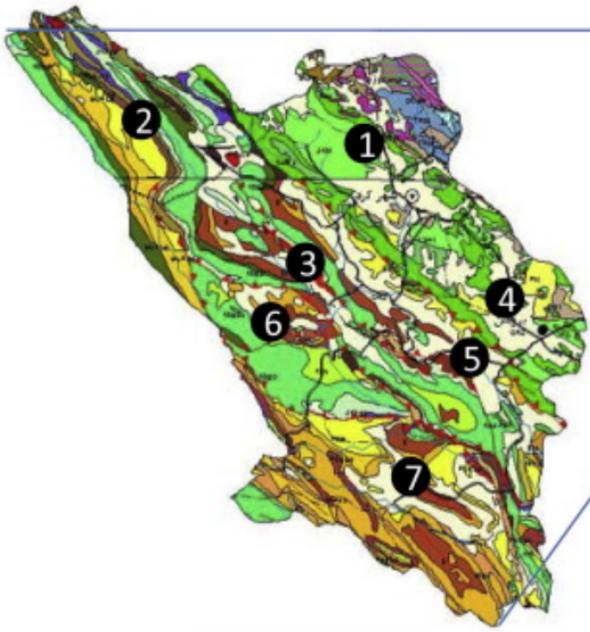
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Chaharmahl-e Bakhtiari Province

32° 19' 32" N , 50° 51' 52" E



- 1: Farsan
- 2: Kohrang
- 3: Ardal
- 4: Broojn
- 5: Kareh-e Base
- 6: Felard
- 7: Lordegan

Supplementary Table 1. Comparison between oil chemical parameters of *Prunus scoparia* accessions and oils from other oilseeds. nd = not detected. For *P. scoparia* only, the values are means from 2012 ad 2013 experiments ($n = 10$).

Parameter	<i>P. scoparia</i>	Safflower ^a	Linseed ^b	Sesame ^c	Sunflower ^d
Oil content (% DM)	18.1-27.2	13-5	36-4	40.4-59.8	19.8-26.7
Myristic acid (% oil)	nd	nd	0.5-0.2	0.5-1.8	nd
Palmitic acid (% oil)	10.6-26.6	3.4-10.2	5.6-7.7	4.0-9.6	9.9-12.7
Stearic acid (% oil)	19.4-27.7	0.8-9.9	3.1-4.4	3.9-9.6	3.2-5.1
Oleic acid (% oil)	23.2-36.0	5.6-86.9	20.9-24.4	31.8-37.6	16.9-27.4
Linoleic acid (% oil)	19.1-34.9	7.1-88.7	17.4-19.2	42.2-51.6	56.2-58.9
Linolenic acid (% oil)	nd	nd	46.1-50.7	3.8-9.4	6.8-10.0

^a Johnson, Bergman, & Flynn, 1999; Velasco & Fernandez, 2001; ^b El-Beltagi, Salama, & El-Hariri, 2007; ^c Azeez & Morakinyo, 2009.; ^d Maestri, Labuckas, Guzman, & Giorda, 1998.