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Original Article

Seed Oil Content and Fatty Acids Profile in Populations of Iranian Caper (*Capparis spinosa* L.)

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Abstract

Caper (*Capparis spinose* L.) from Capparaceae is a multipurpose plant that is well adapted to semi-arid and nutrient-poor soils. This research was conducted to investigate the oil content and fatty acids composition in some populations of Iranian caper seeds. According to the results, the seed oil content ranged from 31.59 to 35 % in different caper populations. The highest unsaturated fatty acid (UFA) content of approximately 91.25% and saturated fatty acid (SFA) with 11.14% was related to Germi (GE), and Kelid Daghi (KD) population, respectively. The highest content of linoleic acid and oleic acid was observed in populations of Dasht Moghan (53.33%) and Mahalat (46.57%). A Principal Component Analysis (PCA) was performed with the main fatty acids. The first component (PC1) was contributed by the content of linoleic acid, oleic acid, linolenic acid, palmitoleic acid, margaric acid, and stearic acid content. Cluster analysis based on all biochemical properties showed three separated clusters including (1) Damavand (DA), Booinzahra (BO) and Kelid Daghi (KD), (2) Germi (GE) population, and (3) Mahalat (MA), Tafresh (TA) and Delijan (DL). Furthermore, clusters of (1) DA and TA, (2) KD and GE, and (3) BO, MA, and DL were found based on climatic characteristics. The fatty acid profile of *C. spinosa* seed oil highlights its potential as a future alternative for the edible oilseed, especially in subtropical regions.

Keywords: *Capparis spinosa* L., Linoleic acid, Oleic acid, Edible oilseed, Caper populations

Introduction

Capparis spinosa L. from Capparaceae is grown in the subtropical and tropical regions of the world [1]. The genus *Capparis* entails more than 250 species. Among these, *C. spinosa* L. and its buds and fruits are economically important and they are used in different meals, especially in the Mediterranean region [2,3]. *C. spinosa* L. adapts strongly to the regions with changing climates and subject to hyper-aridity and is a proper alternative for domestication to improve agriculture in the mentioned regions [4]. *C. spinosa* chemical compounds and health benefits are in high value as well as its potential for sustainability [4,5]. Caper extract has extensive therapeutic benefits such as anti-oxidant [6], anti-diabetic [7-9], bronchorelaxant [10], antibiotic properties [11]. Also, it has rheumatoid arthritis [12] and cardioprotective effect [13]. Caper seeds are a rich source of unsaturated lipids [14], tocopherols, sterols, and carotenoids [15]. The oil in caper seeds with a high content of oleic and linoleic acids have variable composition between regions [15]. In Turkey, the seed oil content and composition of *C. spinosa* were previously reported in some cases for native populations. The oil content of the seeds ranged from 27.3 to 37.6 g/100 g oil, with a high content of unsaturated fatty acids [14].

Vegetable oils have attracted attention in recent decades due to their economic value. Oil crops have been creating extensive benefits for food and pharmacological purposes. However, the selection of species for the considered purposes depends on factors such as high productivity of fruits and seeds (oil weight per hectare), low demand on soil fertility, noncompetition for food production lands or with food-grade oils, and the physical-chemical properties of the seed oil [16]. According to researches, factors such as temperature,

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rainfall, light, drought, ozone exposure, nitrogen deprivation, fertilizers may affect the nutritional value of oilseeds [17-22]. Reports showed that temperature influenced the profile of saturated [23] and polyunsaturated fatty acids [24]. Furthermore, environmental conditions by the time of the developing stage have a key role in seed oil content and fatty acids in plants. The concentration of oleic acid in sunflower has been significantly influenced by minimum temperature and sunlight (solar radiation), while the effect of maximum temperature is less than that mentioned temperature. The linoleic acid content of sunflower is affected negatively by minimum temperature and sunlight [25].

Now, *C. spinosa* is emerging as an important source of vegetable oil, praised for its health benefit. Despite the importance of *C. spinosa* seed oil, the study about its seed oil quality and quantity isn't well documented. The present study was carried out to determine the variation in the oil content and fatty acid composition of *C. spinosa* seeds from seven geographical areas in Iran.

Material and Methods

Sampling and Environmental Condition

C. spinosa seeds were collected from seven populations of Iran in the year 2017. They were identified according to Flora Iranica [26] and Flora of Iran [27] by authors. The voucher samples were deposited in the seed bank and herbarium of Medicinal Plants Institute (MPI), ACECR, Karaj, Iran. The seeds were transferred to the laboratory in polypropylene bags and dried at room temperature. Then, the seeds were cleaned in an air screen cleaner to remove all exterior materials. All samples were stored at refrigerated conditions (4˚C) until used in the experiments. The temperature, precipitation, and average annual rainfall were recorded during the harvesting year. Geographic coordinates including latitude, longitude, and altitude of each region were recorded using Global Positioning System (GPS) (Table 1 & Fig. 1). In all habitats, samples were taken by a random-systematic method along with the located transects.

Oil Extraction and Determination of Fatty Acids

The seeds were dried to constant weight at 40˚C using an oven then were grounded with a blender. Oil extraction from the seeds was carried out using the Soxhlet oil extraction technique with n-hexane [28]. The oil was then recovered by evaporating the solvent to constant weight in a rotary evaporator. The total oil content of each sample was expressed as a percentage of the oil.

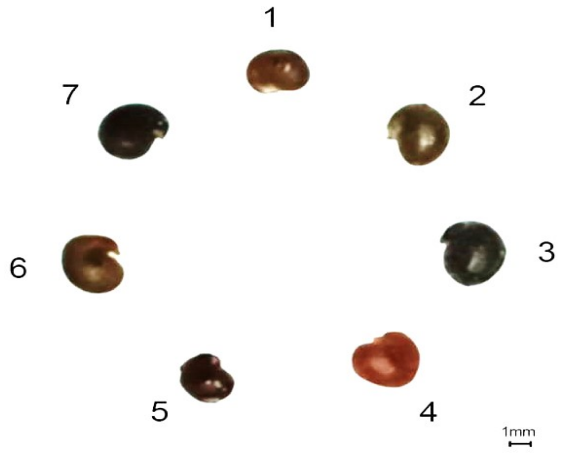

Fig. 1 Populations of Iranian caper seeds: (1) Tafresh (TA: 3.1×2.2×1.7 mm); (2) Mahalat (MA: 3.7×2.4×1.6 mm); (3) Delijan (DL: 3.1×2.3×1.9 mm); (4) Damavand (DA: 2.8×1.9×1.7 mm); (5) Booinzahra (BO: 3.1×2.2×1.6 mm); (6) Kelid Daghi (KD: 3.5×2.5×1.6 mm); (7) Germi (GE: 3.4×2.7×1.7 mm)

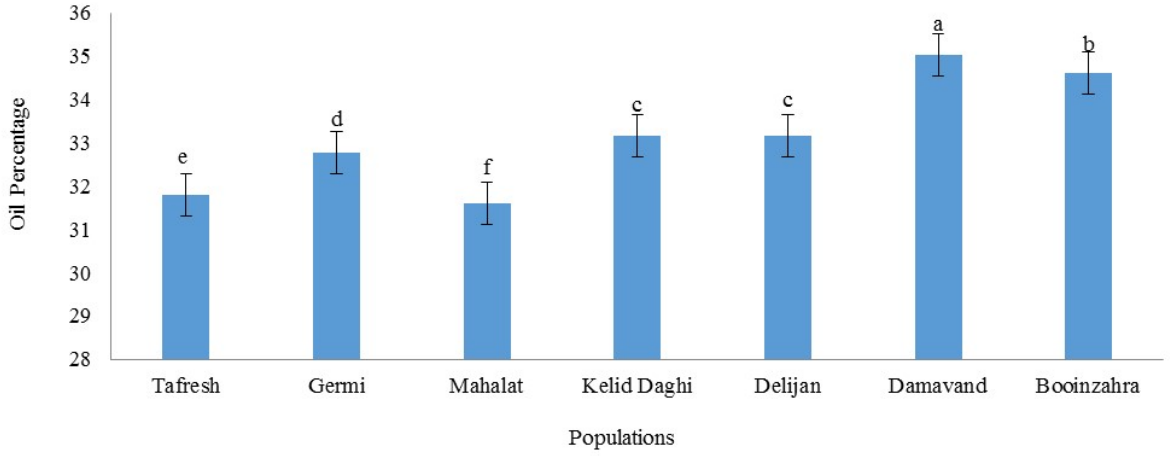

Fig. 2 Oil percentage of different populations of *C. spinosa* L

Table 1 Geographical origins and climatic condition of *C. spinosa* L. populations

Population No.	Seed bank and herbarium No.	Region originated	Latitude (N)	Longitude (E)	Altitude (m)	Average annual rainfall (mm)	T (˚C) (mean)	T(˚C) (max)	T(˚C) (min)	Precipitation (mm)	Annual Irradiation (h)
1	479Cs020-MPISB	TA	34˚42 46.2″	50˚01'01.6″	1872	6	13.3	18.9	7.7	37.3	3115.5
2	475Cs020-MPISB	MA	34˚1′36.24″	50 ˚31'39.7″	1788	189	16.2	22.4	10	38	3212.4
3	476Cs020- MPISB	DL	34˚70′24.3″	50˚35'05.04″	1406	170.6	16.4	23.6	9.2	37	3267
4	478Cs020 -MPISB	DA	35˚44′13.7″	51˚38'07.34″	1648	288.6	12.3	18	6.5	52	2919.4
5	474Cs020-MPISB	BO	35˚46′3.75″	50˚3'31.14″	1410	199.4	15.3	22.6	8	49	3079
6	437Cs020-MPISB	KD	38˚55′26.1078″	45˚34 38.6544″	1480	234.3	13.57	25.7	1.6	61.3	2569.8
7	477Cs020-MPISB	GE	39˚16′23.99″	48˚7'59.3″	278	284.9	13.7	18.1	9.3	64	2274.1

Temperature and precipitation data are average (±SD) values taken monthly during harvesting year

TA: Tafresh; MA: Mahalat; DL: Delijan; DA: Damavand; BO: Booinzahra; KD: Kelid Daghi; GE: Germi

Table 2 Analysis of variance of biochemical properties of *C. spinosa* L.

Variables	C16:0	C16:1	C17:0	C18:0	C18:1c	C18:2c	C20:0	C18:3 (6,9,12)	C18:3 (9,12,15)	C20:2 (11,14)	O/L	UFA	SFA	Oil percentage
Mean of squares	2.83	0.268	0.012	0.164	56.39	72.04	0.078	0.054	0.093	0.072	0.108	2.41	2.41	5.01
F value	18006.01**	92.69**	867**	1107.7**	13322.1**	27759.98**	1169.4**	13.509**	112.58**	104.49**	7550.4**	406.79**	6952.58**	376.04**
R2	1	0.975	0.997	0.998	1	1	0.998	0.853	0.980	0.978	1	0.994	1	0.994

The fatty acid methyl ester (FAME) was prepared from oil using the methanolic sodium hydroxide and buron trifluoride (BF3) for esterifying the FAs [29]. Then, FAME was analyzed for its FA composition on a gas chromatograph (GC) (Unicam model 4600, UK), equipped with a flame-ionization detector (FID), and a BPX70 capillary column (0.25 mm ID × 30 m long × 0.22 µm film thickness). The temperature program consisted of first from 160 °C for 6.0 min ramp at 20 °C/min to 180°C, hold for 10 min, ramp at 20 °C/min to 210 °C, for a total run time of 40 min. The injector and detector were regulated at 250°C. The carrier gas was Helium and the split ratio was 40:1. Peak identification was performed by comparing relative retention times with those of a commercial standard mixture. Concentrations of fatty acids were determined using an integrator and expressed as a percentage [%(w/w)] of the total oil content.

Statistical Analysis

Analysis of variance was performed for all traits by SPSS statistics (ver. 22) software. ANOVA analysis and mean comparison of the seed oil content and fatty acid composition were done by using Duncan multiple range tests at $p\leq0.05$ significant level. A Principal Component Analysis (PCA) was performed with the ten major fatty acids as well as saturated and unsaturated fatty acid and oil percent which found in the oil of *C. spinosa* The quantitative distribution of the major fatty acids, and climatic characteristics from seven different populations of *C. spinosa* submitted to cluster analysis with Euclidean Distance and UPGMA to examine the relationships within different localities. All statistical analysis was performed using XLSTAT (XLSTAT, 2013, Addinsoft, New York, NY, USA).

Results

Analysis of variance showed a significant difference among trial cultivars for all fatty acids, saturated and unsaturated fatty acids and oil percent ($p\leq0.01$) (Table 2). The means for seed oil content, and fatty acid of *C. spinosa* seeds from each population are shown in Table 3. The total oil content of *C. spinosa* varied significantly among the populations. The highest content of seed oil was observed in DA (35.03%), while the lowest of that (31.59%) was obtained in seeds from the MA population (Table 3 & Fig. 2). In the seven populations studied, the seed oil of *C. spinosa* was characterized by a high unsaturated fatty acid (UFA) content of approximately 91.25%, which was observed in the GE population. The least content of that (88.85%) was attained in the KD population. The highest and the lowest level of SFA (11.14% and 8.75%) was observed in KD and GE population, respectively. The seeds of *C. spinosa* consisted of 10 main fatty acids which all of them varied among the populations (Table 3). According to the results, for two populations (TA and MA), oleic acid was the main fatty acid of caper seed oils, accompanied by linoleic acid and lesser amounts of palmitic acid. According to the results, the highest content of linoleic acid was observed in GE (53.33%) and KD population (48.98%), while the lowest content of that (39.6%) has resulted in the Mahalat population.

Table 3 Mean comparison of fatty acids of *C. spinosa* L. based on Duncan Multiple Range Test's.

Population	Mahalat	Tafresh	Damavand	Delijan	Booinzahra	Germi	Kelid Daghi
C16:0	7.3±0.006 e	8.26±0.006 b	7.51±0.006 c	7.27±0.006 d	6.25±0.003 f	6.17±0.009 g	8.82±0.012 a
C16:1	2.3±0.021 a	1.87±0.012 b	1.77±0.012 c	1.66±0.006 d	1.53±0.015 e	1.5±0.075ef	1.42±0.009 f
C17:0	0±0.0 b	0±0.0 b	0±0.0 b	0±0.0 b	0±0.0 b	0.17±0.006 a	0±0.0 b
C18:0	2.38±0.006 b	2.51±0.009 a	2.36±0.006 b	2.52±0.003 a	2.17±0.009 c	2.02±0.009 d	1.93±0.006 e
C18:1c	46.57±0.058 a	45.02±0.012 b	39.59±0.006 d	42.31±0.006 c	39.47±0.009 d	34.33±0.079 f	36.97±0.006 e
C18:2c	39.6±0.006 g	40.53±0.015 f	46.86±0.012 d	43.9±0.006 e	48.32±0.009 c	53.33±0.074 a	48.98±0.003 b
C18:3 (6,9,12)	0.58±0.006 d	1.01±0.009 a	0.67±0.007 cd	0.77±0.010bc	0.78±0.006bc	0.82±0.095 b	0.76±0.006bc
C18:3 (9,12,15)	0.57±0.038 c	0.36±0.006 d	0.58±0.012 c	0.72±0.012 b	0.57±0.012 c	0.93±0.006 a	0.72±0.012 b
C20:0	0.44±0.006b	0±0.0 e	0.36±0.006 d	0.46±0.003 a	0.45±0.003 ab	0.38±0.006 c	0.38±0.006 c
C20:2(11,14)	0.42±0.009 ab	0.42±0.015 ab	0.27±0.012 c	0.38±0.003 ab	0.42±0.009 a	0.37±0.009 b	0±0.0 d
O/L	1.17±0.001 a	1.1±0.002 b	0.84±0.003 d	0.96±0.001 c	0.81±0.003 e	0.64±0.002 g	0.75±0.003 f
UFA	90±0.006 c	89.23±0.115 e	89.77±0.006 d	89.74±0.003 d	91.11±0.013 b	91.25±0.015 a	88.85±0.003 f
SFA	9.95±0.006 d	10.77±0.018 b	10.23±0.006 c	10.25±0.003 c	8.88±0.013 e	8.75±0.015 f	11.14±0.003 a
Oil percentage	31.59±0.003 f	31.8±0.058 e	35.03±0.033 a	33.16±0.033 c	34.6±0.115 b	32.76±0.088 d	33.16±0.067 c

In each column, the means with similar letter had no significant difference according to Duncan Multiple Range Tests (P<0.05). Data are averages showing standard deviations (n = 5) ± SD. Different lower case letters show significant differences between populations (P\0.05) O/L oleic/linoleic ratio, SFA saturated fatty acids, UFA unsaturated fatty acids. C16:0 palmitic acid, C16:1 palmitoleic acid, C17:0 Margaric acid, C18:0 stearic acid, C18:1 oleic acid, C18:2 linoleic acid, C18:3(6,9,12): γ-Linolenic acid, C18:3(9.12.15): α-Linolenic acid, C20:0 Arachidic acid, C20:2Eicosadienoic acid, SFA saturated fatty acids, UFA unsaturated fatty acids.

The maximum content of oleic acid was attained in the MA population (46.57%), while the minimum of that was related to the GE population (34.33%). GE and Tafresh showed the greatest and the lowest content (0.93 and 0.36%) of linolenic acid (9, 12, 15), respectively. The highest and the least value of linolenic acid (1.01 and 0.58%) was observed in TA and MA populations, respectively. KD and GE populations had the highest and the lowest value of Palmitic acid (8.82 and 6.17%), respectively. MA and KD populations accounted for the greatest and the lowest value of Palmitoleic acid (2.3 and 1.42%), respectively. Interestingly, margaric acid was seen just in the GE population. The maximum and minimum O/L (1.17 and 0.64%) was obtained in MA and GE populations, respectively (Table 3).

Principal Components Analysis (PCA)

Factor analysis was used based on principal components to provide a reduced dimension model indicating differences measured among groups. Principal components analysis (PCA) allows to evaluation of multicollinear data and to determine the traits most suitable for classification [30]. A Principal Component Analysis (PCA) was performed with the ten major fatty acids as well as saturated and unsaturated fatty acid and oil percent in *C. spinosa* seeds. Table 4 showed scores of PCA analysis. The first four components (PC1–PC4) explained 93.67% of the total variation. In the first PC (PC1), some characters such as linoleic acid, oleic acid, linolenic acid, palmitoleic acid, margaric acid and stearic acid content showed the highest variance. Also, in PC2 palmitic acid and eicosadienoic acid, UFA, SFA and O/L of seed oil showed the highest variance. While, the highest variance was observed for arachidic acid and γ-Linolenic acid seed oil in PC3. The PC4 with an explanation of just 9.4% of variance mainly correlated with oil percent (Table 4). The score plot PC1 vs PC2 distinguished three groups of populations of *C. spinosa*. The first group was GE which distinguished more with vectors palmitoleic acid, stearic acid and oleic acid, eicosadienoic acid and UFA. The second group contained BO, DA and KD. BO and DA with lower distance was distinguished with palmitoleic acid, stearic acid and oleic acid, eicosadienoic acid, UFA and O/L. KD was distinguished with palmitic acid and SFA. The third group included MA, TA and DL. This group more distinguished with margaric acid, linoleic acid and α-Linolenic acid (Fig. 3).

Cluster Analysis

Cluster analysis based on all biochemical properties indicated three separated classes. The first class contained DA, BO, and KD. The second class just included GE. Finally, the third class contained MA, TA, and DL (Fig. 4). The results of cluster analysis of populations showed three separated classes. The first class included DA, and TA. The second contained KD and DA and the third included BU, MA and DL (Fig. 5).

Table 4 Eigen analysis of the correlation matrix loadings of the significant principal components (PCA)

	PC1	PC2	PC3	PC4
C16:0	-0.564	-0.810	-0.055	-0.144
C16:1	-0.814	0.465	-0.295	-0.109
C17:0	0.707	0.236	0.372	-0.484
C18:0	-0.727	0.352	0.165	0.353
C18:1c	-0.921	0.351	-0,093	0.059
C18:2c	0.959	-0.236	0.079	-0.016
C18:3 (6,9,12)	-0.277	-0.316	0.868	0.155
C18:3 (9,12,15)	0.878	-0.073	-0.080	-0.248
C20:0	0.527	0.244	-0.733	0.149
C20:2 (11,14)	-0.167	0.844	0.463	0.177
UFA	0.651	0.728	0.123	0.075
SFA	-0.651	-0.728	-0.123	-0.075
OilP	0.498	-0.156	-0.220	0.773
O/L	-0.548	0.584	-0,270	-0.418
Eigenvalue	6.328	3.533	1.934	1.318
Variability (%)	45.199	25.235	13.814	9.416
Cumulative %	45.199	70.434	84.248	93.665

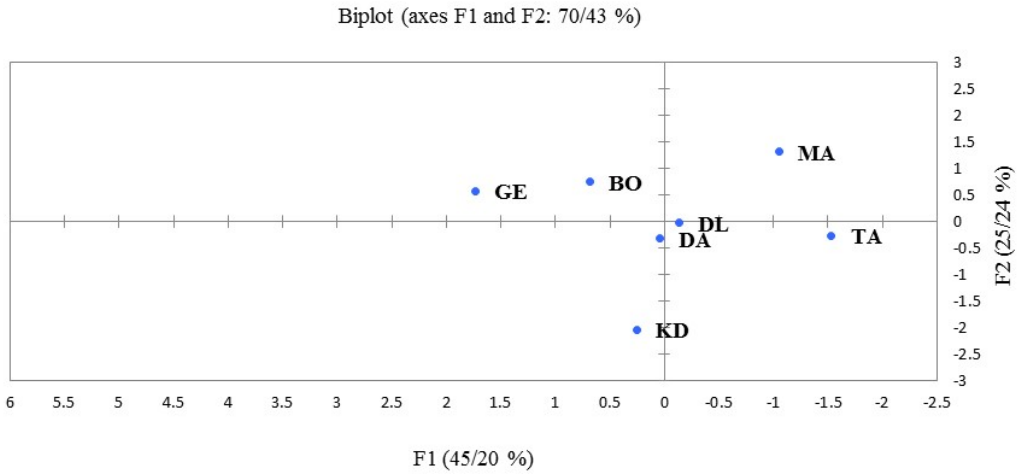

Fig. 3 Principal component analysis (PCA) based on biochemical properties of seven *C. spinosa* L. populations: PC1 vs PC2 score plot. TA Tafresh, BO Booin Zahra, MA Mahalat, DA Damavand, GE Germi, DL Delijan, KD Kelid Daghi

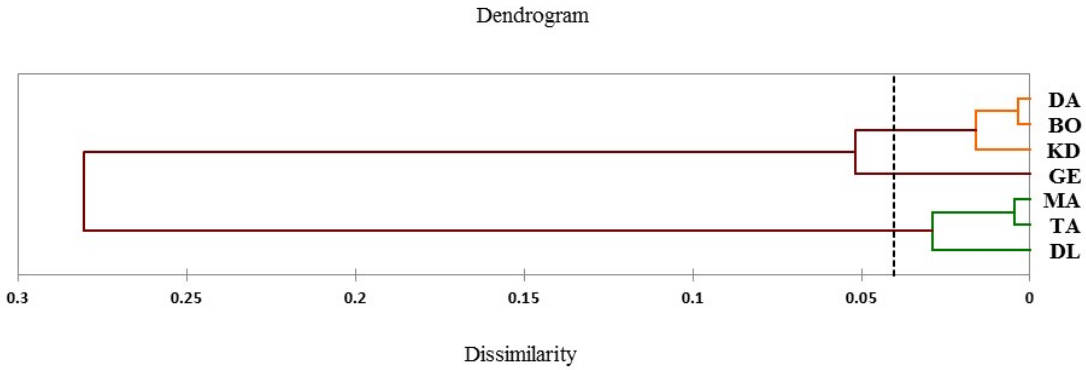

Fig. 4 Cluster analysis (Ward method) based on fatty acid distributions, saturated and unsaturated fatty acid from seed oils of seven different populations of *C. spinosa* L.. TA Tafresh, BO Booin Zahra, MA Mahalat, DA Damavand, GE Germi, DL Delijan, KD Kelid Daghi

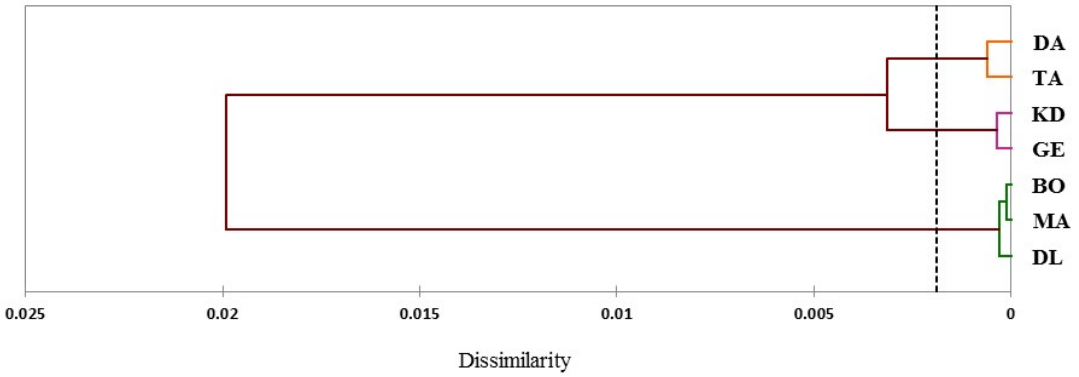

Fig. 5 Cluster analysis (Ward method) based on climatic characteristics of seven different populations of *C. spinosa* L. TA Tafresh, BO Booin Zahra, MA Mahalat, DA Damavand, GE Germi, DL Delijan, KD Kelid Daghi.

Table 5 Pearson correlation coefficients (r) between the seven geo-climatic conditions and the seed oil content and fatty acid composition of *C. spinosa* L.

Variables	O/L	Oil P	SFA	UFA	C20:2(11,14)	C18:3(9,12,15)	C18:3(6,9,12)	C20:0	C18:2c	C18:1c	C18:0	C17:0	C16:1	C16:0	Radiation	Annualr ainfall	Precipitation	Tmean	Tmin	Tmax
O/L	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Oil P	-0.558	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
SFA	-0.052	-0.259	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
UFA	0.052	0.259	-1.000	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C20:2(11,14)	0.347	-0.202	-0.558	0.558	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C18:3(9,12,15)	-0.530	0.190	-0.434	0.434	-0.244	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C20:0	-0.313	-0.187	0.270	-0.270	0.200	-0.348	1	-	-	-	-	-	-	-	-	-	-	-	-	-
C18:2c	-0.094	0.410	-0.419	0.419	-0.168	0.568	-0.809	1	-	-	-	-	-	-	-	-	-	-	-	-
C18:1c	-0.637	0.523	-0.475	0.475	-0.339	0.808	-0.131	0.344	1	-	-	-	-	-	-	-	-	-	-	-
C18:0	0.682	-0.484	0.357	-0.357	0.426	-0.808	0.088	-0.282	-0.990	1	-	-	-	-	-	-	-	-	-	-
C17:0	0.277	-0.234	0.242	-0.242	0.607	-0.608	0.230	-0.298	-0.812	0.816	1	-	-	-	-	-	-	-	-	-
C16:1	-0.191	-0.123	-0.607	0.607	0.185	0.742	-0.078	0.070	0.658	-0.644	-0.448	1	-	-	-	-	-	-	-	-
C16:0	0.855	-0.462	0.241	-0.241	0.370	-0.715	-0.222	-0.153	-0.898	0.917	0.679	-0.494	1	-	-	-	-	-	-	-
C18:3(6,9,12)	-0.085	-0.244	0.975	-0.975	-0.642	-0.401	0.335	-0.487	-0.348	0.227	0.067	-0.532	0.121	1	-	-	-	-	-	-
Radiation	0.382	-0.080	0.227	-0.227	0.433	-0.716	0.079	-0.031	-0.838	0.874	0.823	-0.775	0.707	0.072	1	-	-	-	-	-
Annual rainfall	-0.077	-0.126	0.191	-0.191	0.077	-0.263	0.593	-0.858	0.050	-0.107	0.043	0.258	-0.089	0.291	-0.341	1	-	-	-	-
Precipitation	-0.451	0.363	-0.252	0.252	-0.562	0.698	-0.207	0.220	0.918	-0.938	-0.915	0.603	-0.762	-0.094	-0.939	0.181	1	-	-	-
Tmean	0.319	-0.289	-0.236	0.236	0.358	0.039	-0.281	0.523	-0.369	0.435	0.287	-0.195	0.331	-0.359	0.546	-0.833	-0.537	1	-	-
Tmin	0.406	-0.252	-0.604	0.604	0.924	-0.026	-0.131	0.118	-0.302	0.390	0.556	0.284	0.421	-0.726	0.374	-0.155	-0.507	0,517	1	-
Tmax	-0.053	-0.072	0.333	-0.333	-0.515	0.071	-0.167	0.435	-0.096	0.081	-0.240	-0.473	-0.061	0.323	0.209	-0.729	-0.074	0,560	-0.420	1

Values in BUld are different from 0 with a significance level alpha=0.05

Correlation Between Characters

Simple correlation coefficient analysis showed the existence of significant positive and negative correlations among seed oil characteristics and environmental condition. According to the results, precipitation is one of the most important factors which affected annual radiation (r=0.93**), C 16:1 (r=-0.76**), C 18:0 (r= -0.91**), C 18:1c (r= -0.93**) and C 18:2c (r= 0.91**). Also annual radiation correlated with C 17:0 (r=-0,775**), C 18:0 (r=0,823**), C 18:1c (r=0,874**), C 18:2c (r= -0,838**). Also significant correlation was observed between minimum of temperature and C20:2(**11**, 14) (r=0.924**). In our study, annual rainfall inversely correlated with C 20:0 (r=- 0.85*) (Table 5).

Discussion

According to variance analysis in table 2 significant difference was observed for all fatty acids, saturated and unsaturated fatty acids and oil percent among trial cultivars ($p \leq 0.01$). The highest amount of seed oil was observed in the DA population that was in agreement with previous reports [14,31-33]. According to researches by El-Waseif & Saed [34], the oil content of caper seed oil ranged between 27.3 to 37.6%. The total oil content of Egyptian *C. spinosa* seeds was reported at 30.47%. The maximum percentage of UFA in this research was higher compared to conducted studies with proportion varied between 66.5 to 79.55% [35] and 86.91% [33]. Furthermore, the highest value of SFA was related to the KD population. The fatty acid compositions of oleic, linoleic and palmitic acids showed the highest amount in populations of MA, DA, and KD, respectively. The results for the mentioned populations are in agreement with those previously reported. They found that the most abundant fatty acids were oleic acid (46.21%), linoleic acid (21.79%) and palmitic acid (16%) [35]. In accordance with results of Akgul & Ozcan [32], the highest content of fatty acid composition was in relevance to oleic acid (49.9%), linoleic acid (25.2%), and palmitic acid (13.2%). Gupta & Chakrabarty [31] similarly reported the highest content of oleic acid (57%), linoleic acid (11%) and palmitic acid (21%) of the total fatty acids. These results are also in agreement with that attained in Uzbekistan, which reported the content of linoleic (59.3%) and oleic acids (28. 9%) are higher in seeds of *C. spinosa* [36]. The mean content of fatty acid composition proved that Iranian caper seed oil shows higher content of linoleic and oleic acid and the lower amount of palmitic acid in comparison with other researches. Variation in caper fatty acid composition between populations was reported previously as well as oil and fatty acid contents [15, 37, 38]. Palmitic acid (51.95%), stearic (15.72%) and linoleic acids (10.08%) were reported as the majority of fatty acid composition in the oil of *C. spinosa* by Mollica *et al.* [39]. In accordance with these results, the content of oil and chemical components depends on species, plant part, growth season, environmental conditions, and genetic factors [40]. It was reported that a wide range of differences was observed in earliness, plant height, thousand seed weight and fatty acid composition. Besides the mentioned factors with high effectiveness from environmental factors, the planting years had a high correlation with seed yield and oil content [41]. According to PCA, The first and the most impressible fatty acid composition was related to linoleic acid, oleic acid, linolenic acid, palmitoleic acid, margaric acid and stearic acid content. The positive and negative correlations illustrated that in different populations the content of fatty acid compositions of linolenic acid and margaric acid raised while the palmitoleic acid, stearic acid and oleic acid decreased in different climates. In PC2 the fatty acids of eicosadienoic acid, palmitic acid, UFA, SFA and O/L showed the highest susceptibility and the content of eicosadienoic acid, UFA and O/L improved in different populations when the palmitic acid and SFA declined. The most influence was related to arachidic acid and γ-Linolenic acid seed oil in PC3. Same to our results, fatty acid composition and total oil in soybean seeds were affected by precipitation during the grain-filling period [42]. In another study, in soybean, seasonal precipitation had a significant effect on oleic acid and linoleic acid contents [43]. Precipitation and humid spring significantly affected oil synthesis and accumulation in canola [44, 45]. Higher precipitation positively correlated with oleic acid concentration [46]. According to previous studies, irradiation had significant effect on oil fatty acid composition in oilseed plants [47, 48]. Oleic acid content was positively increased by high irradiation which happened in longer period of exposure to sunlight [49]. Different mechanism would explain the effect of irradiation on fatty acid composition. Variations in the carbon supply to the grains can adapt the influence of irradiation on fatty acid composition and these changes influence the key enzymes saturation in lipid synthesis and the fatty acid composition. High radiation enhanced the carbon accumulation to the grain and total lipid synthesis [50,51]. According to The score plot, the fatty acids of palmitoleic acid, stearic acid and oleic acid, eicosadienoic acid and UFA were found in the DA population with most variation as well as BO and DA with O/L in addition to mentioned fatty acids. Regarding to Dendrogram of Wards Cluster analysis (CA), three main populations 1) DA, BO and KD, 2) GE, and 3) MA, TA and DL were resulted on the basis of fatty acid distributions, saturated and unsaturated fatty acid from seed oils of mentioned populations. Also, the CA showed the three main populations 1) DA and TA, 2) KD and GE

and 3) BO, MA and DL based on climatic characteristics. In this study, UFA, SFA and oil percentage did not differ through populations. It is proven that location and genotype contributed significantly to the difference of oil concentration [52]. This could be explained that in *C. spinosa* populations, some characters might be more resistant to environmental changes or genetic. Furthermore, some environmental factors such as air temperature during the flowering stage [53], water availability during seed filling period [54], light quality and so on might affect the fatty acid composition. It is possible that studied factors are not the key factor for affecting the mentioned traits.

Conclusion

In our study, oil content and fatty acid composition from caper populations in several regions of Iran were investigated. Based on the present study and available literature, it can be concluded that caper seeds are rich in oil especially unsaturated fatty acids. The population of GE showed the maximum amount of UFA (91.25%) and the while the highest content of SFA (11.14%) was related to the population of KD. From the FA profile point of view, wide variability was observed among populations. The highest value of seed oil content was observed in the DA (35.03%) population. All populations showed high oleic-linoleic rich oil which draws attention as an alternative source of edible oil. The maximum content of oleic acid and linoleic existed in MA (46.57%) and GE (53.33%), respectively. Factor analysis indicated four components explaining 93.67% of the total variance. In the first PC, some traits such as palmitoleic acid, stearic acid, and oleic acid contents showed the highest variance. Hierarchical cluster analysis divided populations into three separate classes. A wide range of variation among *C. Spinosa* populations can be used for the selection of suitable genotypes to improvement and correlation between seed oil traits among populations can be used for breeding programs.

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Conflict of Interest

The authors declare that there is no conflict of interest. The authors alone are responsible for the content of the paper.

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