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Fatty acid composition of canola (*Brassica napus* L.), as affected by agronomical, genotypic and environmental parameters

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ABSTRACT

Vegetable oils with a high relative amount of unsaturated fatty acids are of great significance for human health. There is not any data on the effects of tillage practices on fatty acid composition of canola (*Brassica napus* L.). Hence, in a 2-year split plot experiment, the effects of different tillage systems (no (NT), minimum (MT) and conventional tillage (CT)), canola genotypes (Hyola 401 (V1) and PF (V2)) and sowing dates (including Sep. 8, 23 and Oct. 7) on the fatty acid composition of canola were evaluated. Tillage practices and the combination of canola genotypes and sowing dates were randomized to the main and sub-plots, respectively. The highest oleic acid content was the result of combining NT, V1 and Sep. 23, and the lowest was related to the combination of CT, V2 and Oct. 7. While the combination of NT, V1 and D1 resulted in the highest amount of unsaturated fatty acids, this amount was the lowest for the combination of CT, V2 and Sep. 23. For the selection of an appropriate canola producing strategy, all these parameters must be taken into account. The combination of NT, V1 and Sep. 23 may be the most favorable cropping strategy for canola production under a Mediterranean climate.

1. Introduction

Canola is one of the most important oil seeds growing in many parts of the world. It is very important to grow canola with high oil levels for agronomical benefits. A large part of vegetable oil for human consumption in Iran is imported to the country, and hence cultivation and appropriate management of oil seeds to increase yield is very important. In recent years, due to the adaptation of canola to different climatic conditions, its production has been the center of attention and its cultivation area has increased from 19 000 ha in 2000 to 280 000 ha in 2006 [1]. With an average of 40% oil (on the basis of seed dry weight), *Brassica* oil seeds are used for oil and meal consumption (Kimber and McGregor [2]). Also, there is a growing interest for the use of oil seeds for nutritional, industrial and pharmaceutical usages [3]. The world production of canola oil is higher than soybean and sunflower [4].

The ratio of unsaturated and saturated fatty acids in canola, with a density of 0.91 g/cm^3 [5], are 93 and 7%, respectively. The latter in canola is the lowest, compared with other vegetable oils. The combinations of unsaturated fatty acids contain 61% monounsaturated oleic acid, 11% acid α-linolenic and 21% acid linoleic [6]. The monounsaturated fatty acid, oleate is found in plants at the highest frequency and has an 18 C chain and a double bond exactly in the middle. With the help of desaturase, oelate is converted to linoleate [7].

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There is no data in the literature on the effects of different tillage practices on fatty acid composition. However, different tillage practices may affect fatty acid composition through influencing the physiological parameters, related to the effects of fatty acid production in the seeds. For example, different patterns of nutrient uptake under different tillage practices [8] may affect the co-enzyme functioning of micronutrients and hence oil production in the plant.

Both genotypic and environmental parameters determine the amount and quality of canola oil [9]. Among the environmental parameters affecting the concentration of canola oil, temperature (sowing date) is one of the most important ones, decreasing the seed oil content if it increases [10]. Canola is a cool-season crop and the duration of flowering period determines very much the amount of seed yield [11] and hence oil content.

The effect of soil moisture on canola oil is also significant and while increased soil water, including irrigation, increases oil concentration (Johnston et al. [11]), water stress (i.e., drought and water lodging) reduces it [10]. They also stated that water stress increased the ratio of oleic to linoleic acid. Some researchers have reported that there is a correlation between the oleic acid content and water consumption at the vegetative period. Water stress at the grain filling stage of standard cultivars and genotypes with high level of oleic acid increased the ratio of oleic to linoleic acid [12].

There should be at least 127 mm of water for the production of canola yield. After achievement of such amount of water for each millimeter of rain, 6.9 to 7.2 kg/ha canola seed is produced [11]. Canola root can grow deeply to a depth of 1.1 to 1.7 m, and hence absorb water from deep soils [13,11]. Using different sowing dates can change the time of plant growth and development, helping the plant to better survive under the stress of heat and drought [14,15].

The sowing date may influence the fatty acid composition through improving ontogenesis. It has been found that a late sowing date partially decreases the oleic acid and increases the linoleic acid content of seed. The amount of unsaturated fatty acids including linoleic and linolenic is very much under the influence of environmental parameters during the period of oil accumulation and seed maturity [4,9].

It is very important to indicate the aim of canola production before planting. For example, if canola were produced for oil extraction, strategies used to increase seed oil content, would reduce seed protein and vice-versa. This kind of interaction is also under the influence of environmental parameters [16]. This also indicates the significance of applying the proper rates of fertilizer, particularly N and S, which increase the ratio of seed protein and seed oil, respectively. For an optimum level of canola seed yield and oil, 20 and 200 kg/ha of S and N is required, respectively [17].

To produce good quality canola seeds with a high amount of oil, it is necessary to manage both the genotypic (including the breeding and selection of good varieties) and environmental parameters (including tillage practices and planting date), properly. It is also worth mentioning that the interaction of genotypic and environmental parameters also affects the quality of canola seed oil [16,18].

The main constituents of vegetable oils are fatty acids, including saturated (sum of palmitic, $C_{16:0}$, and stearic acid $C_{18:0}$) and unsaturated (sum of oleic, $C_{18:1}$, linoleic, $C_{18:2}$ and linolenic acid, $C_{18:3}$) acids, and triglycerides (about 3% of grain weight), which are very nutritious [19,3]. The minor ones include sterols and tocopherols, detected by the chromatographic analysis [20]. Linoleic and linolenic acid are among the most important components, because they are dietary essential fatty acids, preventing nutritional deficiency symptoms, and are not produced by humans [3]. Heating canola oil, resulting in the oxidation of fatty acids, produces oxidized stable oleic acid, while, the oxidized linoleic and linolenic acid are not stable and are converted to other products [21].

Canola seed fatty acids are high in linoleic acid ($C_{18:2}$). Also the presence of other fatty acids including linolenic, palmitic, oleic ($C_{18:1}$) and stearic acid in canola seeds has been proved [22].

There is very little known about the effects of agronomical, including different tillage practices, genotypic, including different canola genotypes, and environmental parameters, including different sowing dates reflecting the combined effects of temperature and soil moisture. Also since there is not any data on the effects of different tillage practices on the fatty acid composition of canola (*Brassica napus* L.), these experiments were conducted. Due to the significance of canola as a crop with nutritional values, it is very important to suggest the most suitable tillage practices, canola genotypes and sowing dates for canola production, with regard to the climatic conditions.

2. Materials and methods

2.1. Experimental design

The experiments were carried out at the Sari Agricultural Experimental Station, 25 km, East of Sari, Iran in 2001–2002 and 2002–2003. The experimental design was a split plot with three replications. The three tillage practices, including no- (NT), minimum (MT) (residue return with two disk) and conventional tillage (CT) (residue return with plow and one disk) were allocated to main plots, and the combination of canola autumn genotypes (Hyola 401 (V1), PF (V2)) and sowing dates (including Sep. 8 and 23, and Oct. 7) were factorially randomized to sub-plots.

2.2. Experimental procedure

The 10 rows in each subplot were 7 m long, with 16 cm interspacing. The plots were 3 m apart and seeds planted at a 5 cm distance on the rows. Hence, the required area for each plot was 11.2 m^2. There were 18 plots in each replicate producing a 2000 m^2 experimental area.

Soil physical and chemical properties were determined. Soil texture (silty clay loam) was determined by the hydrometry method [23]. Acidity (7.7) of a saturated paste and electrical conductivity (0.6 dS/m) of a saturated extract were also measured [24]. Organic carbon (C) (0.63%) and total nitrogen (N) (0.055%) were measured

Table 1
Climate data.

Month / Parameter	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
Temperature (°C)	7.0	7.3	9.5	14.9	19.5	23.5	25.5	25.7	22.8	18.1	13.0	8.6	16.3
Humidity (%)	84.0	83.0	84.0	81.0	78.0	79.0	81.0	82.0	83.0	84.0	85.0	86.0	82.0
Precipitation (mm)	66.2	62.6	63.6	36.4	31.2	31.1	31.4	48.2	80.4	103.6	99.9	77.0	731.6
Wind (m/s)	2.9	3.0	3.3	3.4	3.1	2.7	2.4	2.4	2.3	2.4	2.4	2.5	2.8
Degree-days	135.2	120.7	125.1	161	205.7	215.8	210.8	171.5	157.7	170.3	145.4	130.4	1949.6

using wet oxidation [25], and the Kjeldahl method [26], respectively. Phosphorous (P) (31 ppm) and potassium (K) (400 ppm) were determined by sodium bicarbonate extraction [27] and flame photometer (emission spectrophotometry), respectively [28]. Climate data, including temperature, humidity, precipitation, wind and degree-days, for the complete year are presented in Table 1.

Fertilization was performed according to the soil testing analyses. P, at 59 kg P_2O_5, and K, at 100 kg K_2O, fertilizers were completely applied at seeding according to canola fertilization requirements, while 30% (of the total of 150 kg) of N was applied at seeding and the remaining parts were applied at the stem and flowering producing stages.

Plants were thinned at the six-leaf stage. The field preparation, fertilization and chemical weeding were conducted in the August of each year. Surface irrigation was performed twice at seeding, with a 7–9-day interval, to let the seeds grow at their highest germination. The field was also irrigated at stemming and flowering along with N fertilization, and twice at the pod producing and grain filling stages.

2.3. Measurement of oil content and determination of fatty acid composition

Plants were harvested, when 40–50% of the seeds in the main pods and primary branches turned brown. After harvesting, the oil content and the fatty acid composition were determined. Oil content was determined by nuclear magnetic resonance analyser (Newport of North America, 1986). Fatty acid composition, including saturated (sum of palmitic ($C_{16:0}$), and stearic acid ($C_{18:0}$)) and unsaturated (sum of oleic ($C_{18:1}$), linoleic ($C_{18:2}$) and linolenic acid ($C_{18:3}$)) acids, was analysed using gas chromatography of methyl esters [29,20] by the following procedure.

Fifty milligram of extracted oil was saponified with 5 ml of methanolic NaOH (2%) solution by refluxing for 10 min at 90 °C. After addition of 2.2 ml BF_3-methanolic, the sample was boiled for 5 min. The FAMEs were extracted from a salt-saturated mixture with hexane. The FAMEs were then analyzed using a gas chromatograph (UNICAM model 4600, UK) coupled with a FID detector. The column used for fatty acid separation was a fused silica BPX70 column, 30 m × 0.22 mm i.d. × 25 μm film thickness (from SGE, UK). The oven temperature was held at 180 °C during separation; the injector and detector temperatures were 240 and 280 °C, respectively. The carrier gas (helium) flow ratio was 1 ml/min. One microliter of methyl esters of free fatty acids was injected into the split injector. The split ratio was adjusted to 1:10. The compounds were identified by comparison of their retention times with authentic compounds. The internal standard $C_{15:0}$ was used in the quantitative analysis of the separated fatty acids. Each fatty acid was expressed as a percent of the total fatty acids.

2.4. Statistical analysis

Data were analysed using the general linear model (GLM) procedure of the statistical analysis system, SAS [30]. When analysis of variance showed significant treatment effects, Duncan's multiple range test was applied to compare the means at $P = 0.05$. Bartlett's test determined the homogeneity of variance in all traits [31].

3. Results

According to Table 2, genotype significantly affected the amount of saturated fatty acid, palmitic acid. However, the saturated fatty acid, stearic acid was not affected by genotypic or other parameters. The unsaturated oleic acid was significantly affected by sowing date (Tables 3 and 4) and the interaction effect of tillage, sowing date and genotype (Table 3). The interaction effect of year and tillage

Table 2
Analysis of variance for the effects of different parameters on the saturated fatty acids of canola oil.

Mean of squares			
$C_{18:0}$	$C_{16:0}$	D.F.	S.O.V.
0.0009	0.0093	2	Repetition(R)
0.0001	0.0001	1	Year
0.0005	0.03	4	R(Y)
0.0034	0.0045	2	Tilage (T)
0.0042	0.0069	2	Y*T
0.0031	0.0048	8	R*T(Y)
0.0007	0.0045	2	Sowing date (D)
0.0006	**0.030***	1	Genotype (V)
0.0012	0.0052	2	Y*D
0.0024	0.00014	1	Y*V
0.0017	0.00078	4	T*D
0.0038	0.01027	2	T*V
0.0006	0.0052	2	D*V
0.0027	0.0012	4	Y*D*V
0.0008	0.0009	2	Y*T*V
0.0025	0.0009	2	Y*D*V
0.0015	0.0043	4	Y*T*D*V
0.0019	0.0034	4	V*D*T
0.0023	0.0062	60	Error

$C_{16:0}$, Palmitic acid; $C_{18:0}$, Stearic acid; *: Significant at 5% of probability.

Table 3
Analysis of variance for different parameters affecting the saturated and unsaturated fatty acid contents of canola oil.

Mean of squares										
TU/TS	UAP	TUSFA	18:3	18:2	18:1	16:1	TSFA	$C_{20:0}$	D.F.	S.O.V.
0.0227	0.1022	0.098	0.5998	0.150	0.0007	0.0146	0.0089	0.0001	2	Repetition(R)
0.0001	0.0198	0.0149	0.2205	0.024	0.00003	0.0004	0.0003	0.00001	1	Year
0.0786	0.0359	0.0043	0.0998	0.1908	0.00002	0.0043	0.0352	0.0007	4	R(Y)
0.0142	0.0148	0.0342	0.0449	0.0605	0.00003	0.0057	0.0042	0.0017	2	Tilage
0.01405	0.0212	0.0193	0.2046	**0.744***	0.0001	0.0051	0.0067	0.0003	2	Y*T
0.0264	0.07583	0.0821	0.3609	0.613	0.0001	0.0030	0.009	0.0009	8	R*T(Y)
0.0134	0.01452	0.0326	0.5121	0.0407	**0.0004***	0.0045	0.0042	0.00067	2	Sowing date (D)
0.0431	0.05917	0.1233	0.0844	0.0060	0.00006	0.0009	0.0116	0.0003	1	Genotype
0.0017	0.02040	0.0237	0.0799	0.1360	0.00004	0.0018	0.0002	0.00084	2	Y*D
0.0083	0.05512	0.0252	0.1760	0.0211	0.00009	0.0018	0.0057	0.00006	1	Y*V
0.00578	0.07725	0.08388	0.6804	**0.6445***	0.00007	0.0036	0.0013	0.0015	4	T*D
0.0052	0.0049	0.00051	0.07206	0.347	0.00004	0.0026	0.0025	0.00025	2	T*V
0.0035	0.0873	0.0933	**1.234***	0.1711	0.00005	0.0078	0.00038	0.0003	2	D*V
0.01806	0.0517	0.0223	0.1135	0.2311	0.0001	0.0003	0.0095	0.00049	4	Y*D*V
0.0061	0.0244	0.02417	0.09786	0.1356	0.000034	0.0004	0.0024	0.00087	2	Y*T*V
0.03073	0.15255	**0.20081***	0.09014	0.1439	0.00034	0.0020	0.0074	0.0012	2	Y*D*V
0.01559	0.1844	**0.2213***	0.4690	0.1204	0.0004	0.0024	0.0019	0.00033	4	Y*T*D*V
0.03073	0.15255	**0.20081***	0.09014	0.1439	**0.00034***	0.0020	0.0074	0.0012	4	V*D*T
0.02098	0.0739	0.0830	0.3645	0.2417	0.0001	0.0028	0.0073	0.0011	60	Error

*: Significant at 5% level of probability; $C_{16:0}$, Palmitic acid; $C_{18:0}$, Stearic acid; $C_{20:0}$ Arachidic acid; TSFA, Total saturated fatty acid; 16:1, Palmitolic acid; 18:1, Oleic acid; $C_{18:2}$, Linoleic acid; $C_{18:3}$, Linolenic acids; TUSFA, Total unsaturated fatty acid; UAP, Unknown acids; TU/TS, Ratio of total unsaturated to total saturated fatty acids; S.O.V.: source of variation.

Table 4
The effects of different sowing dates and canola varieties on the oleic and palmitic acid content of canola oil, respectively.

Palmitic acid (%) (16:0)	Genotype	Oleic acid (18:1)	Sowing date
4.65b	Hyola 401	0.642b	8 Sep.
4.69a	PF	0.648a	23 Sep.
		0.644ab	7 Oct.

Mean values, followed by the same letters in each column are not significantly different (Duncan multiple range test at 5%).

and also tillage and sowing date on unsaturated linoleic acid was significant. It is also clear from Table 4 that the interaction effect of sowing date and genotype significantly influenced the unsaturated linolenic acid content. In addition to the significant interaction effects of year, sowing date and genotype, the interaction effects of year, tillage, sowing date and genotype and also the interaction effects of genotype, sowing date and tillage on the total amount of unsaturated fatty acids (including palmitolic, oleic, linoleic and linolenic acid) was significant (Table 3).

The amount of oleic acid in the seeds, planted on Sep. 23 was significantly higher than that of Sep. 8. In addition, the higher and significantly different palmitic acid content was found in V2, compared with V1 (Table 4). The combination of NT and CT with Sep. 8 resulted in the highest and lowest amount of linoleic acid content, respectively (Table 5). The highest linolenic acid was related to the combination of Sep. 23 and V1 and also the combination of Oct. 7 and V1, and the lowest was related to the combination of Sep. 23 and V2 (Table 6).

The highest oleic acid content was the result of combining NT, Sep. 23 and V1, and the lowest was related to the combination of CT, Oct. 7 and V2. While the combination of NT, Sep. 8 and V1 resulted in the highest amount of unsaturated fatty acids, it was the lowest for the combination of CT, Sep. 23 and V2 (Table 7).

Table 5
The combined effects of different tillage practices and sowing dates on the linoleic acid content of canola oil.

Linoleic acid (%) (18:2)	Sowing date	Tillage
21.22a	8 Sep.	No- tillage
20.96ab	23 Sep.	
20.95ab	7 Oct.	
21.09ab	8 Sep.	Minimum tillage
21.03ab	23 Sep.	
20.76ab	7 Oct.	
20.72b	8 Sep.	Conventional tillage
21.08ab	23 Sep.	
21.17ab	7 Oct.	

Mean followed by the same letters in each column are not significantly different (Duncan multiple range test at 5%).

Table 6
The interaction effects of sowing date and genotype on the linolenic acid content.

Linolenic acid (18:3) (%)	Genotype	Sowing date
11.17ab	Hyola 401	8 Sep.
11.25ab	PF	
11.53a	Hyola 401	23 Sep.
11.05b	PF	
11.33ab	Hyola 401	7 Oct.
11.56a	PF	

Mean followed by the same letters in each column are not significantly different (Duncan multiple range test at 5%).

Table 7
The interaction effects of tillage practices, sowing dates and varieties on the oleic acid content and total unsaturated fatty acids.

TUSFA (%)	18: 1	Genotype	Sowing date	Tillage
91.91a	0.643ab	Hyola 401	8 Sep.	
91.76 ab	0.638b	PF		
91.69ab	0.656a	Hyola 401	23 Sep.	NT
91.54ab	0.645ab	PF		
91.63ab	0.641b	Hyola 401	7 Oct.	
91.70ab	0.648ab	PF		
91.53ab	0.652ab	Hyola 401	8 Sep.	
91.74ab	0.638b	PF		
91.77ab	0.643ab	Hyola 401	23 Sep.	MT
91.71ab	0.648ab	PF		
91.83ab	0.643ab	Hyola 401	7 Oct.	
91.51ab	0.645ab	PF		
91.71ab	0.638b	Hyola 401	8 Sep.	
91.63ab	0.643ab	PF		
91.78ab	0.645ab	Hyola 401	23 Sep.	CT
91.45b	0.652ab	PF		
91.54ab	0.647ab	Hyola 401	7 Oct.	
91.75ab	0.637b	PF		

Mean followed by the same letters in each column are not significantly different (Duncan multiple range test at 5%).

4. Discussion

4.1. Effects of tillage practices

It is clear from our data that different tillage practices influenced the composition of fatty acids differently. The most appropriate method for the production of high quality canola oil, having the highest ratio of oleic acid and other unsaturated fatty acids, seems to be NT. The amounts of unsaturated acids under NT are significantly different from those of other tillage practices. This can also be another important advantage for using the NT method and can be very advantageous for the agronomical and pharmaceutical industries. According to Carvalho et al. [3], agronomical practices affect the quality of oil seeds.

Any situations resulting in the enhanced activity of enzymes, particularly at the flowering and seed-filing stage, can improve the amount and quality of seed oil. NT and MT can enhance soil productivity and properties through reducing soil erosion [11]. They may also increase seed yield by increasing plant available water [32,11] and also water use efficiency, due to creating a suitable microclimate, as a result of plant residues presence on the soil surface [33]. In addition, due to the presence of plant residues, the efficiency of plant uptake increases [34]. It also influences the distribution, and availability of nutrient to the plant, and hence plant growth [35]. Soil structure is a very important factor affecting the availability of nutrients in the soil [36–39]. Accordingly, tillage practices can also influence canola growth and oil production by affecting soil structure and hence nutrients uptake.

Plant residues extend the availability of N to the plant by immobilizing N, and then mineralizing it gradually [11]. NT is especially more efficient for plant growth in soils where the amount of organic matter is low and there is not a good soil structure, compared with soils with high amount of organic matter and good structure [40]. This is also of great significance under NT, since the change in nutrient availability to plant can alter seed yield and seed oil and fatty acid composition.

4.2. Effects of genotypic parameters

The two genotypes behaved differently under the different conditions of the experiments. The ratio of unsaturated fatty acid in V1 is significantly higher than V2, indicating that under the climatic conditions of the experiment this genotype can perform more efficiently. This enhanced performance may be attributed to the genotypic and physiological properties of V1, which is an early-mature genotype and can grow more efficiently in a shorter growth period. This can help the plant to reach the physiological maturity faster, compared with V2 and, hence would increase the plant efficiency. However, genotypes with a faster growth rate are more sensitive to the suboptimal air temperatures [15].

Genotypes with a higher rate of oleic acid are more resistant to oxidative changes and are of higher dietary values [21]. Fatty acid composition is very much affected by year, genotype, sowing date (earlier and standard) and irrigation. The amount of seed oil is a function to genotypic parameters [9]. Hence, significant amount of effort has been made to produce genetically modified canola genotypes with high amount of oil [16]. In addition to the significance of agronomical practices, which affect the quality of oil seeds, producing canola genotypes with high quality, which make them profitable like cereals, is also important [3].

4.3. Effects of environmental parameters

The amount of unsaturated fatty acids in Sep. 23 is significantly different from other sowing dates. This can be attributed to the favorable climatic conditions (rain and temperature) at this time (Table 1). Long periods of high temperature during the seed-fill stage result in the production of seeds with a low quality, reducing the amount of seed oil content [9,41,42]. At maturity, high temperature significantly increased oleic acid and decreased linoleic acid content. This is in agreement with the results of Lagravere et al. [43] and Izquierdo et al. [6]. The reverse situation also takes place at low temperatures. Under high temperatures, the synthesis of linoleic acid from oleic acid, during the seed development is interrupted, due to the inhibition of oleate desaturase activity [44,45]. Heat stress alters the growth of embryo and hence the ratio of pericarp:embryo, resulting in the reduction of oil content. Also the oleic acid content is very much correlated with the temperature at the period of 21 to 70 days after flowering [46].

Heat stress considerably reduces the number of flowers. The optimum daily temperature for canola flowering is 20 °C (Chen et al., [15]). A daily temperature rise of 21 to 24 °C during flowering substantially reduced canola yield [47,15]. However, in areas with a temperate or even cold climate, seeds contain a high amount of oil. The optimum temperature for the germination of canola seed is in the

range of 10 to 30 °C and the base germination temperature is between 0.4 to 5 °C [48,15].

Drought and high temperature reduces seed oil amount [10,16]. Hence, a 1-mm increase in rain and 1-°C reduction in daily mean temperature increased oil concentration by 0.04 and 0.27%, respectively, for all environments and canola genotypes. The effect of genotype, environment and their interaction on the amount of seed oil was very significant [16]. Salinity, high temperature and drought stress may increase the oleic/linoleic ratio due to a faster accumulation of lipid and, hence less available time duration for the activity of enzymes including $\Delta 12$ desaturase [49].

Canola is a good source of oleic or monounsaturated fatty acid and linoleic and linolenic acid or polyunsaturated fatty acid [5,3]. The desaturases change the saturated fatty acid into unsaturated ones, which is of great significance for the production of vegetable oils.

Climate and growing conditions are effective on the fatty acid composition, for example on the balance between n-6 and n-3 fatty acids. Canola is high in linolenic acid including 95 g/kg [3], which is very important for the pharmaceutical industry [50,11].

Increased water resulted in higher linoleic acid and lower oleic acid, which is reverse, compared with the effects of sowing date. Sowing date with regard to influencing soil moisture conditions and also temperature are very important and decisive parameters for canola production [9]. Early sowing (cooler temperature) decreased oleic and increased linoleic acid content. When the temperature was higher at the seed filing stage the oleic acid content was the highest and vice-versa. Irrigation resulted in higher and lower linoleic and oleic acid, respectively. Water stress at seed-filling stage increased oleic/linoleic ratio in high oleic acid genotypes [49].

According to 'in vivo' experiments for growing sun flower seeds, subjected to low and high temperature, the activity of oleate desaturase was stimulated and inhibited, respectively, and was re-stimulated when the temperature reduced once more [44,53]. Also, under lower moisture, the decreased cell water and also the nutritional situation may influence the synthesis and activity of oleate desaturase [9]. In addition, the synthesis of fatty acids takes place in different parts of the cell, up to 18:1 are synthesized in proplastids and from 18:1 to 18:2 and 18:3 are synthesized in cytosol [51]. Hence, the effect of environmental parameters on the ratio of fatty acids is through both affecting the activity of enzymes and their transporting to different parts of the cell [52]. The likely interaction effects between different parameters may also have significant effects on the fatty acid composition of seeds.

We can conclude that the agronomical, genotypic and environmental parameters, tested in these experiments substantially influenced the fatty acid composition of canola oil and must be taken into account when planning strategies for canola production for agronomical and pharmaceutical industries. The combination of NT, genotype Hyola 401 and second sowing date may be the most favorable cropping strategy for canola production under Mediterranean climatic conditions.

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