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IMPACT OF CLIMATE CHANGES AND CORRELATIONS ON OIL FATTY ACIDS IN SUNFLOWER

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Sunflower oil is a major important vegetable oil because it is widely used in human nutrition and in many industrial productions depends on fatty acid composition. Field studies were conducted during in two years on the same soil to investigate changes of climate induced oil fatty acid composition of a traditional sunflower, and to obtain correlations among oil fatty acids. Seed oil content and twelve fatty acid percentages of sunflower oil were analyzed. Variations for years were significant for seed oil content and palmitic acid (C16:0), oleic (C18:1), linoleic (C18:2), linolenic (C18:3), miristic (C14:0) and eicosenoic acids (C20:1). Higher temperatures during seed development in 2010 resulted with 68.38 % increasing in oleic content of the traditional sunflower hybrid. The highest negative correlations (r= -0.99) were noted between oleic and linoleic acids.
Keywords: *Helianthus annuus* L., climate change, fatty acids, oil quality

INTRODUCTION

Sunflower (*Helianthus annuus* L.) is one of the most important oil crops in the world. Sunflower oil is economically important because it is widely used in human nutrition and in many industrial applications. Traditional sunflower oil is rich for essential fatty acids according to high oleic and NuSun types, and it is preferred by humans as cooking and salad oil, and by industries for oil hydrogenation (Miquel and Browse, 1994; Baydar and Erbas, 2005; Pereyra-irujo and Aguirrezabal, 2007).

Oil quality of vegetable oil is associated with fatty acid composition, mainly with percentage of oleic and linoleic acids, and saturated fatty acids. The unsaturated fatty acids, oleic and linoleic acid, comprise 85-90% of the total fatty acids in the oil of sunflower seeds. It has been widely reported that the environment affects fatty acid composition of sunflower seed. Variations in fatty acid composition have been mainly related to temperature and drought (Harris *et al*., 1978; Nagao and Yamazaki, 1984; Lajara *et al*., 1990; Izquierdo *et al*., 2002; Tahmasebi-enferadi *et al*., 2004; Izquierdo *et al.,* 2006).

Linear relationships between oleic (or linoleic) acid concentration and climate have been established. However, in recent years, the increasing demand for plant-oils has led to renewed interest in oil quality of sunflower. In addition, it is necessary to study this response under a wide range of climate since sunflower is cultivated at different latitudes. The aim of this study was to investigate changes of climate on the same soil induced fatty acid composition of traditional sunflower oil, and to obtain correlations among oil fatty acids.

MATERIALS AND METHODS

A traditional sunflower (*Helianthus annuus* L.) hybrid, P4223, developed by Pioneer Hi-Bred was used as plant material in this study. Field experiments were conducted at a farmer field in Kesan, Turkey located in 40^0 51'N, 26^0 38'E, elevation 185 m on a sandy clay loam soil during 2009-11 growing seasons. Planting dates were kept on April 20 for both years. Experimental units consisted of 50 m^2 plot area with four replications, and with a 0.70 m spacing between rows and a 0.30 m spacing among plants for a density of 47 610 plants/ha. The recommended dose of fertilization of 60 kg nitrogen and 60 kg P_2O_5 per hectare was applied at the time of seed planting in both years. Weed control included a preplant incorporation of Trifluralin, supplemented with hand weeding. Plants were harvested just after physiological maturity (reproductive stage-R9). Monthly climate values, rainfall, rainy days number, relative humidity, maximum, minimum and means of temperature were recorded throughout the growing period (Table 1). Table 1 is also included the mean values for the last 35 years from 1975 to 2010.

Seed oil and fatty acid analysis was conducted at the laboratory of Trakya Birlik, a Turkish Agricultural Cooperative. Seed oil content was determined with a pulsed NMR instrument (Bruker Minispec-Bruker Analytische Messtechnic, Karlsruhe, Germany). Oil contents are expressed as a percentage of dry seed weight.

Gas chromatography (GC) of fatty acid methyl esters (FAME) was performed with an Agilent 6890 N gas chromatography equipped with a flame ionization detector (FID). Analyses were conducted on an Agilent capillary column with 100 m x 0.25 mm x 20 m according to ISO

Table 1. Monthly climate values during sunflower development in experimental area

	Rainfall (mm)			Rainy day (No.)			Relative humidity (%)			Temperature (^{0}C)								
										Means			Maximum			Minimum		
	L.T.	2009	2010	L.T.	2009	2010	L.T.	2009	2010	L.T.	2009	2010	L.T.	2009	2010	L.T.	2009	2010
April	47.3	15.8	17.8	10.5	8	12	67.6	68.8	76.0	12.9	12.3	12.7	19.3	25.9	24.9	7.1	-0.4	0.9
May	53.9	27.7	16.0	10.0	8	9	64.6	66.1	68.6	18.0	19.1	18.1	24.7	32.1	33.6	11.4	7.5	3.3
June	40.2	25.9	30.8	8.1	7	12	62.0	62.5	72.3	22.4	22.6	22.5	29.3	36.4	38.7	15.4	9.3	12.0
July	34.2	89.4	72.3	6.0	5	8	56.9	55.3	66.4	24.6	24.5	24.7	31.7	39.7	35.5	17.3	15.4	14.6
August	26.5	17.0	0	4.9	1	0	58.3	51.9	56.9	24.2	25.0	28.1	31.5	37.0	39.6	17.1	14.2	15.8
September	39.1	74.1	31.4	4.9	6	4	62.9	67.7	64.8	19.7	19.9	21.2	27.1	36.9	33.8	13.3	6.6	9.0

L.T.: Long term means of climate values for 35 years from 1975 to 2010 in experimental area

5508. The column temperature was programmed from 120 to 230°C, and injector and detector temperature was set at 250°C using helium, air and hydrogen. Twelve fatty acids were identified as percentage of total fatty acids. These were miristic (C14:0), palmitic (C16:0), palmitoleic (C16:1), margaric (C17:0), stearic (C18:0), oleic (C18:1), linoleic (C18:2), linolenic (C18:3), arachidic (C20:0), eicosenoic (C20:1), behenic (C22:0), lignoseric (C24:0

Statistical analyses were conducted by using Standard procedures using year factor. The least significant difference (LSD) at 5% probability was used to compare the factors. Collected data were analyzed using the SAS statistical computer package (SAS Institute, 1997).

RESULTS AND DISCUSSION

The results of variance analyses of oil and fatty acid contents are presented in Table 2. Variations of year were significant for seed oil content and palmitic acid (C16:0) at 5%, probability, and miristic (C14:0), oleic (C18:1), linoleic (C18:2), linolenic (C18:3) and eicosenoic acids (C20:1) at 1%, probability.

It was observed a decrease (6.74%) for oil content of seeds in 2010 growing season compared to 2009. No precipitation had received during the final seed accumulation stages in the second year (reproductive stages R8 and R9), and temperature values in 2010 were higher than that of 2009. This increase caused a stress in plants resulting negatively effect on oil synthesis during second year, and showed an early maturing depends on stress. It has been reported that oil content is negatively affected by water stress and higher temperatures (Harris *et al*., 1978; Quadir *et al.,* 2006; Pejic *et al.,* 2009; Kaya and Kolsarici, 2011; Oraki *et al*., 2011). However, there is limited report that ceasing of final oil synthesis depend on stress by early maturity (Baydar and Erbas, 2005; Baud and Lepinec, 2010).

The percentage of oleic acid in 2010 was higher than 2009. The higher temperatures and lower day/nigh temperature differences during seed development resulted in an increase in oleic content of the sunflower. Oleic acid percentage of seed oil (68.38%) increased in first year, and reached to 45.75%, close to content of NuSUN types. Generally, it has

Table 2. Analysis of variance and LSD groups of the oil content and fatty acid percentages of sunflower

Oil fatty acids (%)	Mean square	F value	LSD	Years		Change (%)
				2009	2010	
Oil	15.876613	15.31*	2.29	41.82a[+]	39.00b	-6.74
Miristic (C14:0)	0.000595	102.76**	0.01	0.06a	0.04b	-33.33
Palmitic (C16:0)	2.305878	20.88*	0.75	6.06a	4.99b	-17.66
Palmitioleic (C16:1)	0.002211	2.11ns	ns	0.11	0.08	-27.27
Margaric (C17:0)	0.000006	0.24ns	ns	0.04	0.04	0.00
Stearic (C18:0)	0.080802	1.46ns	ns	4.07	3.87	-4.91
Oleic (C18:1)	690.358482	26963.27**	0.36	27.17b	45.75a	68.38
Linoleic (C18:2)	596.281311	1994.40**	1.23	61.06a	43.79b	-28.28
Linolenic (C18:3)	0.027730	1425.10**	0.01	0.04b	0.16a	300.00
Arachidic (C20:0)	0.000378	2.81ns	ns	0.27	0.26	-3.70
Eicosenoic (C20:1)	0.030628	188.53**	0.03	0.15a	0.03b	-80.00
Behenic (C22:0)	0.000325	1.08ns	ns	0.68	0.69	1.47
Lignoseric (C24:0)	0.000015	0.24ns	ns	0.25	0.25	0.00

ns: non significant, * and ** means statistical significance at the at P<0.05 and P<0.01, respectively;

[+]: Within each column, means followed by same small letters are not significantly different by the least significant difference (LSD) test at P<0.05.

Table 3. Correlations among oil fatty acid percentages in sunflower

	C14:0	C16:0	C16:1	C17:0	C18:0	C18:1	C18:2	C18:3	C20:0	C20:1	C22:0	C24:0
Oil	0.88**	0.93**	0.46ns	0.05ns	0.10ns	-0.84**	0.84**	-0.85**	0.36ns	0.81**	-0.50ns	0.08ns
C14:0		0.93**	0.38ns	0.11ns	0.34ns	-0.98**	0.98**	-0.98**	0.60ns	0.95**	-0.37ns	0.32ns
C16:0			0.34ns	0.07ns	0.31ns	-0.87**	0.86**	-0.88**	0.58ns	0.85**	-0.23ns	0.40ns
C16:1				0.43ns	0.44ns	-0.48ns	0.48ns	-0.48ns	0.25ns	0.52ns	-0.43ns	-0.40ns
C17:0					0.56ns	-0.22ns	0.21ns	-0.26ns	0.48ns	0.11ns	-0.46ns	-0.45ns
C18:0						-0.46ns	0.44ns	-0.47ns	0.86**	0.45ns	0.21ns	0.24ns
C18:1							-0.99**	0.99**	-0.66ns	-0.98**	0.40ns	-0.22ns
C18:2								-0.99**	0.65ns	0.98**	-0.41ns	0.20ns
C18:3									-0.67ns	-0.96**	0.41ns	-0.20ns
C20:0										0.65ns	0.09ns	0.40ns
C20:1											-0.32ns	0.26ns
C22:0												0.71*

ns: non significant, * and ** means statistical significance at the $P < 0.05$ and $P < 0.01$, respectively

been reported that higher temperature affect positively on oleic content (Lajara *et al*., 1990; Izquierdo *et al.,* 2002; Rondanini *et al.,* 2003; Izquierdo *et al.,* 2006).

Inversely to oleic acid concentration, linoleic acid percentage showed a decrease in 2010. The higher temperature had negative effect on linoleic acid synthesis during seed development. Similar results were also reported by Izquierdo *et al.* (2002). A higher percentage of palmitic, miristic and eicosenoic acids was observed in 2009 while the second year (2010) had higher linolenic acid content.

The oil content of seed correlated positively with linoleic, palmitic, miristic and eicosenoic acids, and negatively with oleic and linolenic acids (Table 3). The highest negative correlations (r= -0.99) were noted between oleic and linoleic acids, and linoleic and linolenic acids. Percentage of linoleic acid was shown to be correlated positively with palmitic acid, whereas it had no significant correlation with stearic acid. The other some positive correlations were observed for arachidic and stearic, palmitic and eicosenoic, miristic and palmitic acids. An inverse correlation was found between palmitic and oleic, and palmitic and linolenic. Similar correlations have been reported in previous studies (Lajara *et al*., 1990; Tahmasebi-enferadi *et al.,* 2004; Izquierdo *et al.,* 2006; Quadir *et al.,* 2006; Kalem *et al.,* 2011).

These results indicate that oil content and percentage of fatty acids, especially oleic and linoleic acids are largely affected by climatic changes depending on years. Extreme climatic values in 2010 compared to 2009 and means of long period in research area provide an opportunity to understand the effects of climatic values on changes of oil fatty acid composition in traditional sunflower hybrids. The significant differences exhibited by years for oil content and fatty acids in this study could be attributed to be useful in reaching high oil quality. Knowing better the effects of climatic fluctuations on fatty acid composition would be useful to predict oil quality of production.

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