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Increased Temperature and Shortened Grain Filling Duration Due to Sowing Dates Significantly Affect Fatty Acids Composition of Corn (*Zea mays* L. indentata Sturt.)

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ABSTRACT

Due to global climate change, environmental conditions change and cause alteration on the factors that affect the plants during their growth and development. For this reason, it becomes important to determine the reactions of plants, which are evaluated in different ways in many areas and are a large source of raw materials, to these changing conditions. One of these plants is corn (*Zea mays L. indentata* Sturt.), which is used extensively in both human and animal nutrition. Therefore, besides the starch and protein content and quality of corn grain, oil content and the composition of fatty acids are important. This study was conducted to determine the effect of temperature parameters and grain filling duration, which varies depending on sowing dates, on the fatty acid composition of corn. Field experiments were conducted in the growing season of 2019 and 2020 in Hatay/Turkey ecological conditions. The experiment was designed as split plot on randomized complete block design with three replications. Three varieties of corn were cultivated in four sowing dates. The content of fatty acids was determined by chromatographic method. Variance analysis revealed that fatty acid composition was significantly affected by sowing dates and crop variety. It was determined that total fatty acid content decreased due to the increasing temperature by the delay in sowing dates.

Keywords: Climate change, High temperature, Linoleic acid, Maize, Oleic acid.

INTRODUCTION

Global changes in climate and environmental conditions in recent years have constantly provoked international discussions and research on this topic. Studies, predictions and simulations are frequently carried out on how plant production, which forms the basis of a large part of the essential needs of people in sustaining their lives and provides its raw materials, is affected by these changing climate and environmental conditions. Studies on climate change predict that temperatures will increase in the future and significant differences will occur in annual rainfall regimes. The agricultural sector and, therefore, food production will be greatly affected by changing climatic conditions (Senthilkumar *et al.*, 2015). Depending on the changing climatic conditions, the effect of environmental factors that the cultivated plants are exposed to during their growth also changes. Therefore, the quality and yield values derived from agricultural production can be very different from those targeted.

Without limiting nutrients, the main factors affecting the growth and development of corn are temperature, radiation, photoperiod and water availability. Temperature has the greatest impact on the development of modern corn hybrids, as it determines the rate and duration of development stages (Tsimba *et al.,* 2013). High temperatures cause a decrease in yield and yield components of

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maize (Abebe *et al.*, 2016) and it has been suggested that the optimum temperature for corn should be 27-32°C during grain filling (Zhou *et al.*, 2017). Delaying sowing date reduces cumulative photosynthetic active radiation, because higher temperatures shorten the development period of the plants (Otegui *et al.*, 1995; Bonelli *et al*., 2016). The difference in yield between early and late sowing occurs due to the decrease in grain weight with the decrease in dry matter accumulated in the grain (Law-Ogbomo and Remison, 2009).

Research on seeds of plants shows that seeds are potential sources of oil that can be used for nutritional, medicinal and industrial purposes (Sabudak, 2007). Corn is widely used in both human and animal nutrition. Since the quality of the products obtained from corn is proportional to the quality of the corn grain, increasing the grain quality becomes important. Grain quality in corn is mainly associated with protein and oil concentration. While protein quality is related to amino acid composition, oil quality is determined in part by the composition of fatty acids (Egesel *et al.*, 2011). Nutritional value of oil is limited by the energy content of triglycerides, essential fatty acids and the fat-soluble vitamins they contain (Asiedu *et al.*, 1993). The fatty acid composition of corn oil is important for determining the nutritional quality characteristics and the use of the oil in industrial applications (Jellum and Widstrom, 1983). Linoleic acid, oleic acid, palmitic acid, linoleic acid and stearic acid are the major fatty acids that constitute the composition of corn oil (Egesel *et al.*, 2011; Savva and Kafatos, 2016; Carrillo *et al.*, 2017; Koca *et al*., 2017). Linoleic acid, the primary dietary omega-6 fatty acid (Mori and Hodgson, 2013), is considered the only essential fatty acid for humans, constitute more than 50% of corn fatty acids (Preciado-Ortiz *et al.*, 2013). Oleic acid is a mono-unsaturated omega-9 fatty acid found in various animal and vegetable sources and is used as an excipient in pharmaceuticals and as an emulsifying or solubilizing agent in aerosol products (Choulis, 2014). Palmitic acid forms a large proportion of total dietary saturated fatty acid intake and can be found in palm oil, meat, and butter (Chowdhury *et al.*, 2016). Linolenic acid belongs to the group of omega-3 fatty acids, which are essential fatty acids for animal nutrition (Gilman and Bilyeu, 2012). Stearic acid is a saturated fatty acid found in solid-liquid oils derived from most animals and plants and is used in many industrial areas (Uçurum and Malgır, 2017).

Previous studies revealed that the distribution of fatty acids in plants are determined by genotypic characteristics rather than the physical environment of plants (Poneleit and Davis, 1972; Goffman and Böhme, 2001; Koca *et al*., 2017). However, there are also studies indicating that factors such as intercepted solar radiation, sowing date and environmental conditions such as temperature **(**Jellum and Marion, 1966, Thompson *et al.*, 1973; Zuil *et al.*, 2012) significantly affect the fatty acid component of corn.

In this study, it was aimed to determine the effects of changes in temperature and grain filling duration, depending on sowing dates, on the fatty acid content of maize.

MATERIALS AND METHODS

Field Trials

Field trials were conducted at Hatay Mustafa Kemal University Research and Application Area located in Turkey (36° 15' 17.0" N, 36° 30' 09.1" E; 96 m) in 2019 and 2020 crop growing seasons. The soil structure is loam, slightly alkaline (pH 8.22) and calcareous (23.42%) and has low organic matter (1.39%), nitrogen (0.036%) and phosphorus (6.40 ppm) content. In the study, three different varieties of hybrid corn from the same maturity group (FAO 700); 77MAY35 (H1), DKC6630 (H2) and P2088 (H3), were cultivated on four different sowing dates. Sowing Dates (SD) were March 1, and 20; April 3, and 15 in 2019 and March 3, and 15; April 6, and 20 in 2020.

Sowing was carried out manually in plots with 11 m length in 4 rows, 70 cm between intra-rows and 6 cm row, and then thinned to 18 cm per row. Soil was fertilized with 100 kg ha^{-1} N, P_2O_5 and K_2O before sowing. When the plants reached V6-V7 stages, 150 kg ha^{-1} N was applied as urea form. Irrigation was made as drip irrigation. During the experiment, weed, disease and pest control were carried out, and cultural and chemical managements (40 g L^{-1} Nicosulfuron, 50 g L^{-1} Lambda-Cyhalothrin active ingredients) were applied when necessary. Corn grains were obtained by harvesting two central rows in each plot, two weeks after physiological maturity. Fatty acid composition of the grain products obtained at harvest was determined by gas chromatographic method.

Oil Extraction and Determination of Fatty Acids

The grains obtained at harvest were milled in an electric grain grinder and passed through a sieve with a hole diameter of 1 mm. Milled material was dried at 65°C to constant weight and was used for oil extraction. Oil extraction was carried out with a classical soxhlet mechanism for 3 hours using n-Hexane as solvent. The Fatty Acids Methyl Esters (FAME) were prepared for determination of the fatty acids composition. Esterification was carried out using 100 µL of oil sample, 3 mL of n-Heptane and 400 µL of 2N KOH solution. The samples were analyzed under the conditions explained below.

The FAME were analyzed in Thermo Scientific ISQ Single Quadrupole gas chromatography device. The components were separated in an TR-Fame MS capillary column (With: 0.25 mm, Internal diameter: 60 m and Film thickness: 0.25 µm). Helium (99.9%) was used as the carrier gas with linear speed of 1 mL min^{-1}. Scan Mode was used for data collection. The structure of each compound was identified using mass spectra with the Xcalibur program (Wiley 9). The following chromatographic conditions were observed: column temperature program was 120°C for 1 minute, 120–170°C at 10°C min^{-1}, 175°C for 10 minutes, 175–210°C at 5°C min^{-1}, 210°C for 5 minutes, 210–230°C at 5°C min^{-1}, 230°C for 6 minutes. Total analyze duration was 38.5 min. Fatty acids identified in the study were defined on the basis of pure fatty acid methyl esters and expressed as a percentage of total fatty acids, including minor fatty acids. Saturated, monounsaturated, polyunsaturated and total fatty acids contents were determined according to the proportions of linoleic, oleic, palmitic, linolenic and steraic acids, which are the five major fatty acids included in corn oil.

The data obtained were analyzed using MSTAT-C statistical software and the differences were grouped according to the Duncan multiple range test ($P< 0.05$).

RESULTS AND DISCUSSION

Temperature Data and Grain Filling Duration

Considering the course of weather conditions during the trial years, it is seen that the mean temperature increased in the second year of the experiment, and there was a decrease in the total precipitation. In the first year of the study, relative humidity was lower than the second year in May, June, and July, while it was higher in August (Table 1).

During the grain-filling period, the lowest minimum mean temperature in the first year of the study was 22.0°C, and the highest minimum mean temperature was 23.4°C. The lowest and highest maximum mean temperatures were determined as 34.1°C and 34.6°C, respectively. In the second year of the study, the lowest minimum mean temperature was determined as 21.1°C and the highest minimum mean temperature was 23.1°C. The lowest and highest maximum mean temperatures were determined as 34.3 and 35.8°C, respectively. Minimum mean temperatures were lower than the previous year, while maximum mean temperatures were higher (Table 2).

Table 1. Weather conditions during the research, according to Hatay Provincial Department of Meteorology.

	Mean temperature (°C)		Total precipitation (mm)		Relative humidity (%)	
	2019	2020	2019	2020	2019	2020
March	13.0	14.9	80.0	49.4	80.4	82.1
April	16.4	18.1	81.6	32.2	76.8	75.0
May	23.9	23.2	0.4	13.8	55.9	63.4
June	27.7	25.2	0.0	0.4	60.6	67.4
July	28.4	29.5	0.4	0.0	63.9	68.3
August	29.1	29.6	0.0	0.0	68.1	64.7

Table 2. Mean daily minimum and maximum temperatures (°C) occurred during grain filling period according to Sowing Dates (SD), according to Hatay Provincial Department of Meteorology.[a]

	2019							
	SD1		SD2		SD3		SD4	
	Min	Max	Min	Max	Min	Max	Min	Max
VT-R3	20.5	33.4	22.0	33.6	22.2	34.0	22.4	34.8
R3-R5	22.2	34.9	22.5	34.3	23.2	34.0	23.4	34.2
R5-R6	23.2	34.2	23.6	34.4	24.0	34.7	24.2	34.7
Mean	**22.0**	**34.2**	**22.7**	**34.1**	**23.1**	**34.3**	**23.4**	**34.6**
	2020							
VT-R3	17.8	32.0	19.5	31.6	21.3	34.2	22.7	35.1
R3-R5	22.1	35.3	23.0	36.1	23.3	35.2	23.3	36.4
R5-R6	23.4	35.7	23.8	36.1	23.6	36.3	23.3	36.0
Mean	**21.1**	**34.3**	**22.1**	**34.6**	**22.8**	**35.2**	**23.1**	**35.8**

[a] SD: Sowing Date, VT: Tassel emergence, R3: Milk stage, R5: Dent stage, R6: Physiological maturity.

In the second year of the study, daily minimum temperatures at the beginning of the grain filling period were lower than the previous year, while the daily maximum temperatures were higher in the following days. In the second year of the study, daily maximum temperatures were above 35°C for a long time, which could negatively affect the grain filling process of corn (Figure 1).

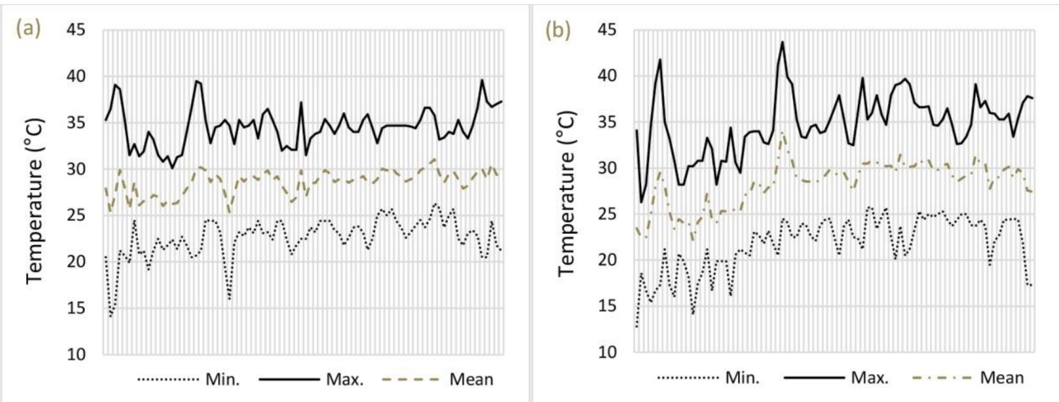

Figure 1. Daily minimum and daily maximum temperatures during grain filling period in 2019 (a) and 2020 (b) at the experimental site (according to Hatay Provincial Department of Meteorology).

In the first year of the study, tasseling dates were determined as May 27, June 4, June 10 and June 12, respectively, according to the sowing dates. Physiological maturity dates were determined as August 2, 8, 19 and 28, respectively. In the second year, tasseling dates were determined as May 19 and 27, June 10 and 16 and physiological maturity dates as July 28, August 10, 17 and 25 (Figure 2). In 2019, time from tasseling to physiological maturity was established as 57, 57, 64, and 65 days respectively, while in the second year, it was 56, 63, 60 and 62 days (Figure 3). In the second year, due to the higher daily maximum temperatures, grain filling durations were shortened compared to the previous year, especially on the last two sowing dates.

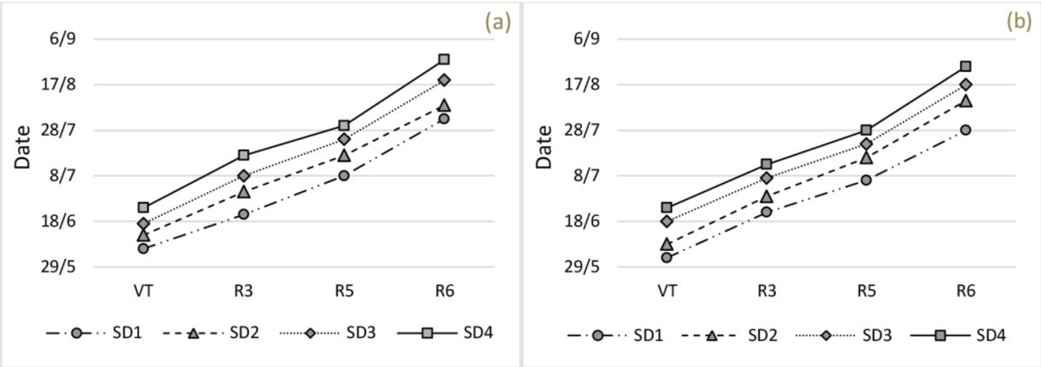

Figure 2. Dates of development stages of corn according to sowing dates in 2019 (a) and 2020 (b). (SD: Sowing Date, VT: Tassel emergence, R3: Milk stage, R5: Dent stage, R6: Physiological maturity)

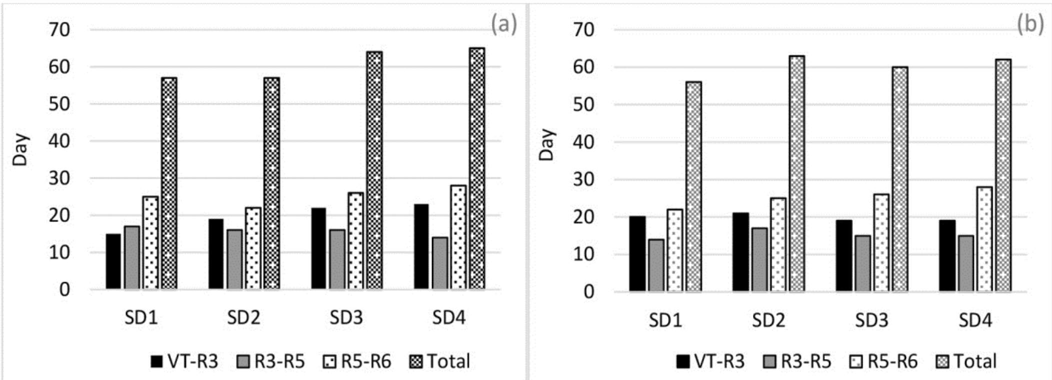

Figure 3. Total number of days between development stages according to sowing dates in 2019 (a) and 2020 (b). (SD: Sowing Date, VT: Tassel emergence, R3: Milk stage, R5: Dent stage, R6: Physiological maturity)

Fatty Acids Content

As a result of the study, it was determined that the fatty acids, except stearic acid, were statistically significantly affected by sowing dates, although the differences between them were not great (Table 3). Linoleic acid content ranged from 48.34 to 51.08% and tended to decrease as the sowing date was delayed. On the average, the highest value was determined at SD1 (50.49%), which is in the group different from other applications. In the first year of the study, the difference between sowing dates in terms of oleic acid content was found to be significant, while it was insignificant in the second year. Oleic acid content ranged between 27.74 and 29.04%. According to the two-year averages, the highest oleic acid contents (28.51 and 28.77%) were determined in the first two sowing dates, while the difference between years was found to be insignificant. Palmitic acid content was found to be higher in the first year of the study compared to the second year. Content of palmitic acid ranged from 11.84 to 13.26%. The highest palmitic acid contents (13.26 and 12.89%) were determined in SD2 in both years, with mean of 13.08%. The content of linolenic acid ranged from 2.71 to 3.85% and varied significantly between years, and a higher proportion of linolenic acid was detected in the second year (3.64%) of the study. Linolenic acid content showed also significant differences according to the years and sowing dates. In both years, the highest linolenic acid contents (3.64 and 3.85%) were determined at the last sowing date. Although the rate of stearic acid was not affected by the applications, there was significant differences between years. The amount of stearic acid increased in the second year of the study.

In the studies about the effect of sowing date on other species, Canvin (1964) reported that various temperature regimes did not affect the fatty acid composition of castor bean and safflower. However, lowest temperature increased linoleic acid and decreased oleic acid content of sunflower. Öztürk (2018) stated that sowing date significantly affected fatty acid composition of sunflower due to the temperature differences in grain production period. As the sowing date was delayed, it was determined that the oleic, palmitic and linoleic acid contents decreased while linoleic and stearic acid contents increased. Arıoğlu *et al.* (2020) reported that linoleic, oleic and palmitic acid content of peanut were significantly affected by sowing dates.

Table 3. Fatty acids content (%) determined in corn oil according to Sowing Dates (SD).[a]

		SD1		SD2		SD3		SD4		SL	CV	LSD	**Mean**		SL
Linoleic	2019	51.08	a	49.53	b	50.96	a	50.29	ab	*	1.57	1.04	**50.47**	**A**	***
	2020	49.89	a	49.74	a	48.43	b	48.34	b	*	1.27	1.10	**49.10**	**B**	
	Mean	50.49	a	49.64	b	49.69	b	49.31	b	*	1.43	0.67	**49.78**		
Oleic	2019	28.56	ab	29.04	a	28.01	b	27.95	b	*	2.72	0.62	**28.39**	-	ns
	2020	28.45	-	28.50	-	28.07	-	27.74	-	ns	2.12	-	**28.19**	-	
	Mean	28.51	a	28.77	a	28.04	b	27.85	b	**	2.44	0.45	**28.29**		
Palmitic	2019	13.10	-	13.26	-	12.66	-	12.31	-	ns	3.50	-	**12.83**	**A**	**
	2020	11.94	b	12.89	a	12.47	ab	11.84	b	*	4.61	0.71	**12.29**	**B**	
	Mean	12.52	bc	13.08	a	12.57	b	12.08	c	**	4.07	0.46	**12.56**		
Linolenic	2019	2.71	c	3.03	b	3.24	b	3.64	a	***	4.35	0.24	**3.16**	**B**	***
	2020	3.83	a	3.31	c	3.56	b	3.85	a	***	6.12	0.15	**3.64**	**A**	
	Mean	3.27	bc	3.17	c	3.40	b	3.75	a	***	5.45	0.13	**3.40**		
Stearic	2019	2.00	-	2.20	-	2.12	-	2.19	-	ns	11.46	-	**2.13**	**B**	***
	2020	2.48	-	2.51	-	2.23	-	2.46	-	ns	9.04	-	**2.42**	**A**	
	Mean	2.24	-	2.36	-	2.18	-	2.33	-	ns	10.19	-	**2.27**		

[a] SD: Sowing Date, SL: Significant Level, CV: Coefficient of Variation, LSD: Least Significant Difference, ns: Not significant, * P< 0.5, ** P< 0.01, *** P< 0.001. [a, b,] and [c] show differences between sowing dates; A, B between years.

Differences between all fatty acid contents were found to be significant when compared in terms of varieties. All varieties were in different groups for linoleic acid content according to the average of the two years (Table 4). The highest linoleic acid was detected in H1 (50.73%), followed by H3 (49.61%) and H2 (49.02%), respectively. The highest oleic acid content was determined in H3 (29.26%), followed by H2 (28.35%) and H1 (27.26%), respectively. Different varieties were in different groups. The variety with the highest palmitic acid content was H2 (13.00%), which was in a different group from other varieties, followed by H1 (12.43%) and H3 (12.26%) varieties in the same group. All varieties were in different groups in terms of linolenic acid content and the highest content was determined in H2 (3.63%), followed by H1 (3.41%) and H3 (3.16%), respectively. The least stearic acid content was established in H2 variety. According to the average of the two years, the stearic acid content of H2 dropped below 2%. H1 (2.65%) variety was the highest variety in terms of stearic acid, followed by H3 (2.29%) variety.

Jellum and Marion (1966) stated that corn hybrids had a significant effect on palmitic acid (12.3-15.3%), stearic acid (2.0-2.8%), oleic acid (33.0-38.5%) and linoleic acid (43.1-50.0%), except for linolenic acid (1.0-

1.2%). Asiedu *et al*. (1993) determined that fatty acids content of corn was in the range of 29.4-48.8% for linoleic acid, 32.9-40.2% for oleic acid, 13.9-18.8% for palmitic acid, 0.7-1.3% for linolenic acid and 2.2-3.1% for stearic acid. Koca *et al.* (2017) stated that fatty acids contents ranged between 17.8%-25.9% for oleic acid, 53.2-67.6% for linoleic acid and 0.5-3.2% for linolenic acid between four maize cultivars. Egesel *et al.* (2011) determined that fatty acids contents were in the range of 50.8-61.8% for linoleic acid, 23.3-35.4% for oleic acid, 9.2-12.7% for palmitic acid, 0.81-1.44% for linolenic acid and 1.46-2.14% for stearic acid. In a study conducted with eight different genotypes, it is indicated that fatty acids content varied depending on years and genotype and had a significant effect on fatty acids content. Saini *et al.* (2020) in the study conducted with 21 maize hybrids, revealed that genotype has a significant effect on fatty acids content and the highest variability was recorded for linoleic and oleic acid.

Table 4. Fatty acids content (%) determined in maize Hybrids (H).[a]

		H1		H2		H3		SL	LSD
Linoleic	2019	51.40	a	49.94	b	50.05	b	***	0.69
	2020	50.05	a	48.10	c	49.16	b	***	0.54
	Mean	50.73	a	49.02	c	49.61	b	***	0.42
Oleic	2019	27.23	c	28.62	b	29.31	a	***	0.67
	2020	27.29	c	28.07	b	29.20	a	***	0.52
	Mean	27.26	c	28.35	b	29.26	a	***	0.41
Palmitic	2019	12.91	a	13.08	a	12.50	b	*	0.39
	2020	11.94	b	12.91	a	12.01	b	***	0.49
	Mean	12.43	b	13.00	a	12.26	b	***	0.30
Linolenic	2019	2.98	b	3.50	a	2.97	b	***	0.12
	2020	3.83	a	3.75	a	3.34	b	***	0.19
	Mean	3.41	b	3.63	a	3.16	c	***	0.11
Stearic	2019	2.35	a	1.77	b	2.27	a	***	0.21
	2020	2.95	a	2.00	c	2.31	b	***	0.19
	Mean	2.65	a	1.89	c	2.29	b	***	0.14

[a] H1: 77MAY35, H2: DKC630, H3: P2088, SL: Significant Level, LSD: Least Significant Difference, ns: Not Significant, * P< 0.5, ** P<0.01, *** P<0.001.

When compared in terms of Saturated Fatty Acids (SFA), although the differences between sowing dates in years 2019 and 2020 were insignificant, they were significant in the two years average (Table 5). SFA contents ranged from 14.42 to 15.46%. The highest SFA content was determined in SD2 (15.43%), which was in a different group. Differences between Monounsaturated Fatty Acids (MUFA) content were significant in the first year, but not significant in the second year. MUFA contents ranged between 27.74 and 29.04%. According to the average of the two years, SD1 (28.50%) and SD2 (28.77%) treatments were in one group, while both SD3 (28.04%) and SD4 (27.84%) were in another group. In terms of polyunsaturated fatty acids (PUFA), the difference between sowing dates compared to the average of two years was insignificant. PUFA contents changed between 51.99 and 54.19%. Total amount of fatty acids examined in the study decreased with the delay of sowing dates. Total fatty acid content ranged from 94.23 to 97.45% according to the sowing dates. The highest average value was in SD1 (97.02%) and the lowest value was in SD4 (95.30%).

Significant differences were found between the varieties in terms of SFA content compared to the average of the two years (Table 6). H1 (15.07%) and H2 (14.88%) varieties in the same group were the varieties with the highest SFA content, while H3 (14.54%) was the variety with the lowest SFA content and was in a different group. According to the proportion of MUFA, each variety was in different groups. MUFA content was determined as 27.26, 28.35 and 29.26% in H1, H2 and H3, respectively. In terms of PUFA, H1 was in different group from the other varieties with a rate of 54.13% and had the highest PUFA content. H1 was followed by H3 (52.76%) and H2 (52.64%) that were in the same group. When evaluated in terms of the content of total fatty acids, H1 and H3 in the same group were the varieties with the highest fatty acid content with 96.46 and 96.56%, respectively, while H2 was in a different group with a value of 95.87%.

Table 5. SFA, MUFA, PUFA and total fatty acids content (%) determined in corn oil according to sowing dates (SD).[a]

		SD1		SD2		SD3		SD4		SL	CV	LSD	**Mean**		SL
SFA	2019	15.11	-	15.46	-	14.78	-	14.49	-	ns	3.36	-	**14.96**	-	ns
	2020	14.42	-	15.40	-	14.70	-	14.30	-	ns	3.57	-	**14.71**	-	
	Mean	14.76	b	15.43	a	14.74	b	14.40	b	*	3.47	0.18	**14.83**		
MUFA	2019	28.56	ab	29.04	a	28.00	b	27.95	b	*	2.72	0.62	**28.39**	-	ns
	2020	28.45	-	28.50	-	28.07	-	27.74	-	ns	2.12	-	**28.19**	-	
	Mean	28.50	a	28.77	a	28.04	b	27.84	b	**	2.44	0.45	**28.29**		
PUFA	2019	53.79	a	52.56	b	54.19	a	53.93	a	*	1.49	1.08	**53.62**	**A**	**
	2020	53.73	a	53.05	ab	51.99	b	52.19	b	*	1.23	1.15	**52.74**	**B**	
	Mean	53.76	-	52.81	-	53.09	-	53.06	-	ns	1.37	-	**53.18**		
Total	2019	97.45	a	97.05	a	96.98	a	96.37	b	*	0.29	0.50	**96.96**	**A**	***
	2020	96.59	a	96.95	a	94.76	b	94.23	b	**	0.79	1.47	**95.63**	**B**	
	Mean	97.02	a	97.00	a	95.87	b	95.30	b	***	0.59	0.23	**96.30**		

[a] SFA: Saturated Fatty Acids, MUFA: Monounsaturated Fatty Acids, PUFA: Polyunsaturated Fatty Acids, SD: Sowing Date, SL: Significant Level, CV: Coefficient of Variation, LSD: Least Significant Difference, ns: Not Significant, * P< 0.5, ** P<0.01, *** P< 0.001. [a, b,] and [c] show differences between sowing dates; A, B between years.

Table 6. SFA, MUFA, PUFA and total fatty acids content (%) determined in maize Hybrids (H).[a]

		H1		H2		H3		SL	LSD
SFA	2019	15.27	-	14.85	-	14.76	-	ns	-
	2020	14.88	a	14.91	a	14.32	b	*	0.45
	Mean	15.07	a	14.88	a	14.54	b	**	0.10
MUFA	2019	27.23	c	28.62	b	29.31	a	***	0.67
	2020	27.29	c	28.07	b	29.20	a	***	0.52
	Mean	27.26	c	28.35	b	29.26	a	***	0.14
PUFA	2019	54.39	a	53.44	b	53.02	b	**	0.69
	2020	53.87	a	51.84	c	52.50	b	***	0.56
	Mean	54.13	a	52.64	b	52.76	b	***	0.15
Total	2019	96.88	-	96.91	-	97.10	-	ns	-
	2020	96.05	a	94.83	b	96.03	a	**	0.65
	Mean	96.46	a	95.87	b	96.56	a	***	0.34

[a] SFA: Saturated Fatty Acids, MUFA: Monounsaturated Fatty Acids, PUFA: Polyunsaturated Fatty Acids; H1: 77MAY35, H2: DKC6630, H3: P2088, SL: Significant Level, LSD: Least Significant Difference, ns: Not Significant, * P< 0.5, ** P< 0.01, *** P< 0.001.

Correlation Analysis

Sowing date showed a significant, positive, and moderate correlation with mean temperature (Table 7, and 8). It is observed that as the mean temperature increases, oleic acid, linoleic acid and palmitic acid decrease, while linolenic acid increases. It is seen that the effect of sowing dates on oleic acid is significant and negative. Palmitic acid had a negative relationship with sowing dates, while linoleic, linolenic and stearic acid had a low level positive relationship (Table 7). While SFA, MUFA, PUFA and total fatty acids showed negative correlation with mean temperature, the relationship between the other properties investigated, except for saturated fatty acids, with the mean temperature was significant. A significant, negative, and low-level correlation was determined between sowing date and monounsaturated fatty acids. Total fatty acids showed a significant, negative, and moderate correlation with mean temperature, while it showed a negative and low-level correlation with sowing date (Table 8).

Table 7. Correlation analysis for mean temperature, sowing dates and fatty acids.[a]

	MT	SD	Oleic	Linoleic	Linolenic	Palmitic	Stearic
MT	1						
SD	0.664**	1					
Oleic	-0.250*	-o.232*	1				
Linoleic	-0.348**	0.015	-0.388**	1			
Linolenic	0.270*	0.198	-0.346**	-0.267*	1		
Palmitic	-0.184	-0.110	0.198	-0.087	-0.594**	1	
Stearic	0.011	0.022	-0.341**	0.150	0.174	-0.440**	1

[a] MT: Mean Temperature, SD: Sowing Date, ** Correlation is significant at the 0.01 level, * Correlation is significant at the 0.05 level.

Table 8. Correlation analysis for mean temperature, sowing dates, SFA, MUFA, PUFA and total fatty acids.[a]

	MT	SD	SFA	MUFA	PUFA	TOTAL
MT	1					
SD	0.664**	1				
SFA	-0.198	-0.111	1			
MUFA	-0.250*	-0.232*	0.035	1		
PUFA	-0.262*	0.087	-0.220	-0.527**	1	
TOTAL	-0.606**	-0.168	0.381**	0.304**	0.489**	1

[a] MT: Mean Temperature, SD: Sowing Date, SFA: Saturated Fatty Acids, MUFA: Monounsaturated Fatty Acids, PUFA: Polyunsaturated Fatty Acids, ** Correlation is significant at the 0.01 level, * Correlation is significant at the 0.05 level.

COCLUSIONS

As a result of the study, it was determined that the fatty acid content of corn varied significantly according to the environmental conditions occurring during the growing period. Because linoleic acid is an essential fatty acid that cannot be synthesized in human body, it should be taken via food products. When evaluated for linoleic acid, oleic acid (MUFA) and PUFA, it can be concluded that the first sowing date was the optimum sowing date. Besides that, even though they were from the same maturation group, the varieties could show significant differences in terms of fatty acids content. Among corn varieties, 77MAY35 could be the favorable one, with the highest linoleic acid and PUFA content.

In addition to the negative effect on the final product yield as determined in previous studies, this study shows that the limitations in agricultural production caused by the global climate change may negatively affect the chemical components and, therefore, the nutritional properties of corn. It has been concluded that agricultural management systems that have been modified and/or newly developed in order to adapt to changing environmental conditions, should be evaluated not only in terms of yield, but also for the intended use of the plants. Additionally, studies should be carried out to improve the chemical properties of the crop suitable for that purpose.

REFERENCES

1. Abebe, A., Pathak, H., Singh, S. D., Bhatia, A., Harit, R. C. and Kumar, V. 2016. Growth, Yield and Quality of Maize with Elevated Atmospheric Carbon Dioxide and Temperature in North–West India. *Agric. Ecosyst. Environ.*, **218:** 66-72.
2. Arıoğlu, H, Bakal, H. and Onat, B. 2020. The Effect of Planting Dates on Some Agronomic and Quality Characteristics of Peanut Varieties in Mediterranean Region (Turkey). *Turkey 13th National, 1st International Field Crops Conference,* Special Issue, PP. 159-165.
3. Asiedu, M., Nilsen, R., Lie, O. and Lied, E. 1993. Effect of Processing (Sprouting and/or

Fermentation) on Sorghum and Maize. I: Proximate Composition, Minerals and Fatty Acids. *Food Chem.,* **46:** 351-353.

4. Bonelli, L. E., Monzon, J.P., Cerrudo, A., Rizzalli, R. H. and Anrade, F. H. 2016. Maize Grain Yield Components and Source-Sink Relationship as Affected by the Delay in Sowing Time. *Field Crop. Res.,* **198:** 215-225.
5. Canvin, D. 2011. The Effect of Temperature on the Oil Content and Fatty Acid Composition of the Oils from Several Oil Seed Crops. *Can. J. Bot.,* **43:** 63-69.
6. Carrillo, W., Carpio, C., Morales, D., Vilcacundo, E., Alvarez, M. and Silva, M. **2017.** Content of Fatty Acids in Corn (*Zea mays* L.) Oil from Ecuador. *Asian J. Pharm. Clin. Res.,* **10(8):** 150-153.
7. Choulis, N. H. 2014. Miscellaneous Drugs, Materials, Medical Devices, and Techniques. In: *"Side Effects of Drugs Annual*", (Eds.): Aronson, J. K. Elsevier, **33:** 1009-1029.
8. Chowdhury, R., Steur, M., Patel, P. S. and Franco, O. H. 2016. Individual Fatty Acids in Cardiometabolic Disease, In: "*Handbook of Lipids in Human Function"*, (Eds.): Watson, R. R. and De Meester, F. AOCS Press, PP. 207-318.
9. Egesel, C. Ö., Kahrıman, F. and Gül, MK. 2011. Discrimination of Maize Inbreds for Kernel Quality Traits and Fatty Acid Composition by a Multivariate Technique. *Acta Sci., Agron.,* **33(4):** 613-620.
10. Gilman, J. D. and Bilyeu, K. D. 2012. Genes and Alleles for Quality Traits on the Soybean Genetic/Physical Map, In: "*Designing Soybeans for 21st Century Markets"*, (Ed.): Wilson, R. F. AOCS Press, PP. 67-96.
11. Goffman, F. D. and Böhme, T. 2001. Relationship between Fatty Acid Profile and Vitamin E Content in Maize Hybrids (*Zea mays* L.). *J. Agric. Food Chem.,* **49:** 4990-4994.
12. Jellum, M.D. and Marion, J.E. 1966. Factors Affecting Oil Content and Oil Composition of Corn (*Zea mays* L.) Grain. *Crop Sci.,* **6:** 41-42.
13. Jellum, M. D. and Widstrom, N. W. 1983. Inheritance of Stearic Acid in Germ Oil of the Maize Kernel. *J. Hered.,* **74(5):** 383-384.
14. Koca, Y. O., Yorulmaz, A., Yavas, I. and Unay, A. 2017. The Effects of Plant Density on Yield and Fatty Acid Composition of Corn Oil. *Fresenius Environ. Bull.,* **26(12):** 7264-7270.
15. Law-Ogbomo, K. E. and Remison, S. U. 2009. Growth and Yield of Maize as Influenced by Sowing Date and Poultry Manure Application. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca,* **37(1):** 199-203.
16. Mori, T. A. and Hodgson, J. M. 2013. Fatty Acids: Health Effects of Omega-6 Polyunsaturated Fatty Acids. In: "*Encyclopedia of Human Nutrition",* (Ed.): Caballero, B. Third Edition, Academic Press, PP. 209-214.
17. Otegui, M. E., Nicolini, M. G., Ruiz, R. A. and Dodds, P. A. 1995. Sowing Date Effects on Grain Yield Components for Different Maize Genotypes. *Agron. J.,* **87:** 29-33.
18. Öztürk, F. 2018. Effetcts of Different Sowing Dates on The Oil Quality of Some Sunflower (*Helianthus annuus* L.) Genotypes. *JIST,* **8(4):** 337-349.
19. Poneleit, C. G. and Davis, D. L. 1972. Fatty Acid Composition of Oil during Maize Kernel Development. *Phytochemistry,* **11(12):** 3421-3426.
20. Preciado-Ortiz, R. E., García-Lara, S., Ortiz-Islas, S., Ortega-Corona, A. and Serna-Saldivar, S. O. 2013. Response of Recurrent Selection on Yield, Kernel Oil Content and Fatty Acid Composition of Subtropical Maize Populations, *Field Crop. Res.,* **142:** 27-35.
21. Sabudak, T. 2007. Fatty Acid Composition of Seed and Leaf Oils of Pumpkin, Walnut, Almond, Maize, Sunflower and Melon. *Chem. Nat. Compd.,* **43(4):** 465-467.
22. Saini, R. K., Rengasamy, K. R. R., Ko, E. Y., Kim, J. T. and Keum, Y. S. 2020. Korean Maize Hybrids Present Significant Diversity in Fatty Acid Composition: An Investigation to Identify PUFA-Rich Hybrids for a Healthy Diet. *Front. Nutr.,* **7**: 223-231.
23. Savva, S.C. and Kafatos, A. 2016. Vegetable Oils: Dietary Importance. In: "*Encyclopedia of Food and Health"*, (Eds.): Caballero, B., Paul, M. and Finglas, F, T. Academic Press, PP. 365-372.
24. Senthilkumar, K., Bergeza, J. E. and Leenhardt, D. 2015. Can Farmers Use Maize Earliness Choice and Sowing Dates to Cope Withfuture Water Scarcity? A Modelling Approach Applied Tosouth-Western France. *Agric. Water Manag.,* **152:** 125-134.

25. Thompson, D. L., Jellum, M. D. and Young, C. T. 1973. Effect of Controlled Temperature Environments on Oil Content and On Fatty Acid Composition of Corn Oil. *J. Am. Oil Chem. Soc.*, **50:** 540-542.
26. Tsimba, R., Edmeades, G. O., Millner, J. P. and Kemp, P. D. 2013. The Effect of Planting Date on Maize: Phenology, Thermal Time Durations and Growth Rates in a Cool Temperate Climate. *Field Crop. Res.*, **150:** 145-155.
27. Uçurum, M. and Malgır, E. 2017. Effect of Stearic Acid Type on Calcite Coating Yield. *Ç. U. J. Fac. Eng. Arch.*, **32(2):** 137-144.
28. Zhou, B., Yue, Y., Sun, X., Ding, Z., Ma, W. and Zhao, W. 2017. Maize Kernel Weight Responses to Sowing Date-Associated Variation in Weather Conditions. *Crop J.*, **5(1):** 43-51.
29. Zuil, S.G., Izquierdo, N.G., Lujáni J., Cantarero, M. and Aguirrezábal, L.A.N. 2012. Oil Quality of Maize and Soybean Genotypes with Increased Oleic Acid Percentage as Affected by Intercepted Solar Radiation and Temperature. *Field Crop. Res.*, **127:** 203-214.

افزایش دما و کوتاه شدن دوره پرشدن دانه به علت تاریخ کاشت، تاثیر معناداری بر ترکیب اسیدهای چرب ذرت (*Zea mays* L. indentata Sturt.) دارد

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چکیده

با توجه به تغییرات آب و هوایی جهانی، شرایط محیطی تغییر می کند و منجر به تغییر در عوامل موثر بر گیاهان در طول رشد و نمو آنها می شود. به این دلیل، تعیین واکنش گیاهانی که در بسیاری از مناطق به روش های مختلف ارزیابی می شوند و منبع بزرگی از مواد خام هستند، به این شرایط متغیر مهم می شود. یکی از این گیاهان ذرت (*Zea mays* L. indentata Sturt) است که در تغذیه انسان و حیوان بسیار استفاده می شود. بنابراین، علاوه بر محتوای نشاسته و پروتئین و کیفیت دانه ذرت، محتوای روغن و ترکیب اسیدهای چرب مهم است. هدف این پژوهش تعیین تأثیر پارامترهای دما و مدت زمان پر شدن دانه، که به تاریخ کاشت بستگی دارد، بر ترکیب اسیدهای چرب ذرت بود. آزمایش‌های مزرعه ای در فصل رشد ۲۰۱۹ و ۲۰۲۰ در شرایط اکولوژیک منطقه هاتای Hatay /ترکیه انجام شد. طراحی آزمایش به صورت کرت های خرد شده در قالب طرح بلوک های کامل تصادفی با سه تکرار بود. سه رقم ذرت در چهار تاریخ کشت شد. محتوای اسیدهای چرب با روش کروماتوگرافی تعیین شد. تجزیه واریانس نشان داد که ترکیب اسیدهای چرب به طور معنی داری تحت تأثیر تاریخ کاشت و رقم محصول قرارگرفت. برمبنای نتایج، با تاخیردر تاریخ کاشت، کل محتوای اسیدهای چرب به دلیل افزایش دما کاهش یافت.