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EFFECT OF EXTRA POTASSIUM SUPPLY ON FATTY ACID COMPOSITION OF CORN OIL IN DEFICIT IRRIGATION CONDITIONS: (SECTION B)

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Abstract

The study investigates the influence of extra potassium application and deficit irrigation on fatty acid composition of corn oils. The field experiment was conducted with split plot design with three replications in Aydın location of Turkey in 2013. 31G98, 31D24 and NK-Arma corn varieties were grown with three different supplies as non-fertilization, standard fertilization [210 kg.ha^{-1} pure N, 60 kg.ha^{-1} pure P, 60 kg.ha^{-1} pure K 60 kg.ha^{-1} (NH_4NO_3, P_2O_5 and K_2O with 15-15-15 composite before planting and H_2NCONH_2 – 150 kg.ha^{-1} with urea before first water)] and extra potassium (standard fertilization +60 kg.ha^{-1} K_2SO_4) and three irrigation doses (500 mm, 400 mm and 300 mm) during development stages [(8 leaf stage (V8), before Tasselling (VT), after blister, milk stage and dough stage)]. Corn oil samples were obtained from corn seeds by soxhelet extraction using n-hexane and assessed for their fatty acid composition with a gas chromatograph. The data obtained from studies has shown that extra potassium application and deficit irrigation have significantly effected to fatty acid rates of corn oil of all varieties. Main fatty acids were linoleic, oleic and palmitic and ranged between 52.56-63.60%, 20.56-28.06%, 9.32-14.01% respectively. Besides heptadecanoic, linolenic, arachidic, stearic and eicosenoic acids were determined in small amounts. Extra potassium application increased linoleic (18:2), linolenic (18:3) and eicosenoic (20:1) but decreased palmitic (16:0), heptadecanoic (17:0), stearic (18:0) and oleic (18:1) fatty acid ratios. Deficit irrigation increased palmitic, linoleic and eicosenoic fatty acids, but decreased stearic, oleic, linolenic and arachidic acids.

Key words*: corn oil, deficit irrigation, palmitic acid, oleic acid, linoleic acid.*

INTRODUCTION

Fat intake can promote immune system and reply against disease, injury, and infection. Nowadays diet programs are taking adequate fat every day for numerous metabolic activities. For example A, D, and E vitamins require fat for proper absorption (Rodriguez et al., 2009) and fat provided energy and endurance of body (Mastaloudis and Traber, 2006).
Fats remain an effective regulator of many physiological functions (Lowery, 2004). Moreover many researchers have referred to the potency of several lipids as pharmaceutical in nature (Fauconnot and Buist, 2001; Watkins et al., 2001). Monounsaturated fatty acids may reduce cardiovascular risks (Perez-Jimenez et al., 2002). Besides polyunsaturated fatty acids help to reduce inflammation (Browning, 2003). Similarly polyunsaturated fatty acids increase E vitamin requirement (Hodwitt, 1974). So E vitamin content of vegetable oils are parallel with the polyunsaturated fat content of the oils (Lukaski, 2004).
Current dietary guidelines advise that 10% of fat intake should be obtained from monounsaturated sources, 10% from polyunsaturated and no more than 10% from saturated (Walter and Satai, 2009). Conversely fatty acid composition of vegetable oil can be influenced by many factors, such as temperature, cultivars, and fertilization period (Scollan et al., 2001; Karaca and Aytaç, 2007). Similarly saturated or unsaturated fatty acid ratio of oil are also effected by environmental factors such as temperature, location, water dose, geography, planting year and fertilizer

nutrient (Ahmad and Abdin 2000; Reynolds et al., 2005).

The current study investigates the influence of standard fertilization and extra potassium supply (60 kg.ha^{-1} K_2SO_4) on fatty acid composition of oil under deficit irrigation conditions.

MATERIALS AND METHODS

The research was carried out in Aydin province with typical Mediterranean climate (hot summer and mild winter), located in west Turkey at 37º44' N 27º44' E at 65 m above sea level; and was conducted in 2013. General characteristics of soil is given Table 1.

Table 1. Soil texture and chemical analysis

Soil texture[1] (%)			pH[2]	Organic mater[3]
Sand	Silt	Clay		(%)
72.0	16.7	11.3	8.4	1.2

Method of; [1]Bouyoucos; [2]1:2.5 Saturasyon; [3]Walkley-Black
(Bouyoucos G.J. 1962; Ayers and Westcot 1989; Walkley and Black 1934)

The experimental soil in the experiment has a sandy loamy structure with alkaline characteristic and it contains quite low organic matters.

Monthly temperature, total precipitation and long-term (1975–2013) temperature and precipitation values of Aydin is shown in Table 2. The temperature of 2013 was higher than long term means except for June and July. Rainfall data showed that May, July and August had lower values than long term means.

Table 2. Monthly temperature and total rainfall during corn growth period and long-term mean (1975–2013) in Aydin

Months	Temperature (°C)		Precipitation (mm)	
	2013	Long term	2013	Long term
April	16.1	15.7	42.6	45.5
May	23.2	20.9	1.0	33.5
June	25.3	25.9	18.4	14.0
July	27.9	28.4	2.4	3.5
August	27.8	27.2	0.0	2.2
September	22.6	23.2	22.8	14.4

Experimental design

The experiment was set up as split block experimental design with 3 replications. All parcels were sowed at April 26, 2013 and the first seed emergence observation was conducted at May 13, 2013. Each plot area was 28 m^2 (5 m x 5.6 m) and consisted of 8 rows. Distance between rows was 70 cm and intra row spaces were 18 cm. NK-Arma, P31G98 and 31D24 varieties were used as the crop material. All varieties were hybrid (F1) and had single cross corn (*Zea mays* L.) variety. NK-Arma was produced by Syngenta Turkey Co. Ltd., and the others were produced by Pioneer Turkey Seed Distribution and Marketing Co. Ltd.

Treatments

Treatment factors were created out with non-fertilizer, standard fertilizer and extra potassium application. Standard fertilizer application from soil was applied as 210 kg.ha^{-1} pure nitrogen (NH_4NO_3) (60 kg.ha^{-1} with 15-15-15 composite was applied immediately at the beginning of cultivation - 150 kg.ha^{-1} with urea (H_2NCONH_2) before first water), 60 kg.ha^{-1} phosphor (P_2O_5) and 60 kg.ha^{-1} potassium (K_2O). Extra potassium was applied by adding 60 kg.ha^{-1} K_2SO_4 onto the standard fertilizer application.

Irrigation doses

Soil from the field experiment [(0-30 cm, 30-60 cm and 60-90 cm depth (Rd)] was put into pots. The water content of the soil after being saturated by irrigation and allowed to drain is called field capacity (FC). Crop can no longer take up water from the soil is referred wilting point (WP). The water held by the soil between field capacity and the permanent wilting point is considered as available water (AW). Corn is capable of using 50% of the available water. Irrigation water requirement (100 mm) was calculated with the following formulas (Martin and Gilley, 1993; Lamm et al., 1994).

AW = Rd (FC-WP)/100

Table 3. Irrigation periods and doses in corn growing

Irrigation time	Irrigation rate per parsel		
	300 mm	400 mm	500 mm
20th June 2013	X	X	X
04th July 2013	X	X	X
12th July 2013	X	X	X
25th July 2013	-	X	X
06th August 2013	-	-	X
10th September 2013	Harvest time		
X: Applied 100 mm water			

Irrigation doses was applied as follows: standard (5X100 mm) during 5 times (V8, before VT, after blister, milk stage and dough stage), as deficit irrigation (4X100 mm) during 4 times (V8, before VT, after blister and milk stage) and as more deficit irrigation (3X100) during 3 times V8, before VT and after blister) at corn growth period. Irrigation periods and doses were given in Table 3.

The analysis of fatty acid composition of corn oil

Corn oil samples were obtained by solvent extraction using n-hexane. Fatty acid methyl esters were prepared according to International Union of Pure and Applied Chemistry (IUPAC) method and analysed by gas chromatography (Agilent 7890A, Santa Clara, CA). DB-23 fused silica capillary column (60 m, 0.25 mm i.d. and 0.25 µm film thickness) (J&W Scientific) was employed for separating individual fatty acids. Carrier gas was helium with a flow rate of 1 ml/min. Injector, column and detector temperatures were 230, 195 and 240°C, respectively. The split ratio was 80:1 and injection volume was 0.5 µl.

Statistical analysis

All the plant data collected from all treatments were statistically analysed using the TARIST package software (Açıkgöz et al., 1994) as a split plot design with three replications using analysis of variance to evaluate the effect of different fertilization doses (non-fertilization, standard fertilization and extra potassium) and deficit irrigation levels (500 mm, 400 mm, 300 mm) on the corn. Means among treatments were compared using Least Significant Difference (LSD) at $P \leq 0.05$ probability.

RESULTS AND DISCUSSIONS

The results of variance analysis for treatment factors (different fertilization) water doses (deficit irrigations) variety and their interactions are presented in terms of saturated and unsaturated fatty acids in Table 4. Irrigation dose x treatment factor x variety interaction was found to be significant in all parameters except for arachidic acid. Moreover, irrigation dose x treatment factor interaction was significant for arachidic acid. Table 5 and Table 6 tabulate the saturated and unsaturated fatty acids values.

Palmitic acid (C16:0), heptadecanoic acid (C17:0), stearic acid (C18:0), arachidic acid (C20:0) and their total values were shown as saturated fatty acids in Table 5. Palmitic and stearic decreased with increasing fertilization. Heptadecanoic acid ratios didn’t change and arachidic acid averages moved erratically with standard and extra potassium fertilizations compared to control treatment. Increasing water doses decreased palmitic acid percentages and didn’t affect heptadecanoic acid ratios.

Table 4. The result of variance analyses and mean squares values for saturated and unsaturated fatty acids of corn oil

Variance Source	Pal.	Hep.	Ste.	Ara.	Ole.	Lin.	Lino.	Eic.
Irrigation dose (A)	3.9**	0.0ns	0.3ns	0.3ns	21.6**	5.9*	0.0ns	0.0ns
Treatment (B)	3.1**	0.0ns	0.2*	0.0ns	0.9ns	10.5**	0.1**	0.0**
Variety (C)	26.4**	0.0**	1.4**	0.0ns	31.6**	8.72**	0.2**	0.0**
A x B	1.0ns	0.0**	0.0ns	0.1**	3.1**	5.5*	0.0ns	0.0**
A x C	0.8ns	0.0**	0.1ns	0.0ns	3.0**	2.4ns	0.1**	0.0**
B x C	0.8ns	0.0ns	0.2**	0.0ns	3.7**	2.0ns	0.0ns	0.0ns
A x B x C	1.2*	0.0*	0.1**	0.0ns	3.2**	10.9**	1.0**	0.0**
Error 1	0.2	0.0	0.1	0.0	0.2	0.7	0.0	0.0
Error	0.6	0.0	0.0	0.0	0.8	1.6	0.0	0.0

** $P<0.01$; * $P<0.05$, ns: non-significant

Pal.: Palmitic acid, **Hep.:** Heptadecanoic acid, **Ste.:** Stearic acid, **Ara.:** Arachidic acid, **Ole.:** Oleic acid, **Lin.:** Linoleic acid, **Lino.:** Linolenic acid, **Eic.:** Eicosenoic acid

Table 5. Effect of fertilization on saturated fatty acid rates of corn oil under deficit irrigation conditions

Treatment	Irrigation Dose	Cultivar	Palmitic Acid (C16:0)	Heptadecanoic Acid (C17:0)	Stearic Acid (C18:0)	Arachidic Acid (C20:0)	Total (%)
Non -fertilization	300 mm	31G98	13.01	0.06	1.92	0.41	15.40
		31D24	13.47	0.05	1.60	0.22	15.34
		NK-Arma	12.14	0.07	1.87	0.35	14.43
		Average	12.87	0.06	1.80	0.33	15.06
	400 mm	31G98	12.85	0.07	1.98	0.87	15.77
		31D24	12.67	0.06	1.59	0.47	14.79
		NK-Arma	11.50	0.07	2.16	0.37	14.10
		Average	12.34	0.07	1.91	0.57	14.89
	500 mm	31G98	12.28	0.07	1.80	0.35	14.50
		31D24	13.19	0.08	1.79	0.38	15.44
		NK-Arma	9.89	0.07	2.07	0.39	12.42
		Average	11.79	0.07	1.89	0.37	14.12
Average of non-fertilization			**12.33**	**0.07**	**1.86**	**0.42**	**14.68**
Standard fertilization	300 mm	31G98	12.73	0.07	1.55	0.32	14.67
		31D24	12.02	0.06	1.47	0.42	13.97
		NK-Arma	12.17	0.07	1.86	0.38	14.48
		Average	12.31	0.07	1.63	0.37	14.38
	400 mm	31G98	11.70	0.07	1.61	0.39	13.77
		31D24	12.16	0.07	1.65	0.35	14.23
		NK-Arma	9.85	0.06	2.22	0.38	12.51
		Average	11.24	0.07	1.83	0.37	13.51
	500 mm	31G98	12.71	0.05	1.52	0.53	14.81
		31D24	11.83	0.07	1.72	0.33	13.95
		NK-Arma	10.53	0.07	2.25	0.39	13.24
		Average	11.69	0.06	1.83	0.42	14.00
Average of standard fertilization			**11.74**	**0.07**	**1.76**	**0.39**	**13.96**
Extra Potassium supply	300 mm	31G98	12.82	0.07	0.97	0.45	14.31
		31D24	12.75	0.08	1.73	0.43	14.99
		NK-Arma	10.19	0.07	1.98	0.44	12.68
		Average	11.92	0.07	1.56	0.44	13.99
	400 mm	31G98	12.35	0.07	1.78	0.37	14.57
		31D24	12.35	0.08	1.57	0.40	14.40
		NK-Arma	10.87	0.07	1.85	0.39	13.18
		Average	11.86	0.07	1.73	0.39	14.05
	500 mm	31G98	11.47	0.04	1.66	0.29	13.46
		31D24	12.76	0.07	1.67	0.39	14.89
		NK-Arma	10.04	0.09	2.03	0.43	12.59
		Average	11.42	0.07	1.79	0.37	13.65
Extra potassium supply			**11.73**	**0.07**	**1.69**	**0.40**	**13.89**
Average of irrigation doses							
300 mm			12.37	0.07	1.66	0.38	14.48
400 mm			11.81	0.07	1.82	0.44	14.15
500 mm			11.64	0.07	1.84	0.39	13.93
LSD irrigation*potassium*cultivar (0.05)			1.24	0.02	0.33	-	-
LSD irrigation*potassium (0.05)			-	-	-	0.13	-

Table 6. Effect of fertilization on unsaturated fatty acid rates of corn oil under deficit irrigation conditions

Treatment	Irrigation Dose	Cultivar	Oleic acid (C18:1)	Linoleic acid (C18:2)	Linolenic acid (C18:3)	Eicosenoic acid (C20:1)	Total (%)
Non-fertilization	300 mm	31G98	24.91	58.09	1.23	0.15	84.38
		31D24	23.61	59.40	1.07	0.12	84.20
		NK-Arma	21.88	59.49	1.23	0.21	82.81
		Average	23.47	58.99	1.18	0.16	83.80
	400 mm	31G98	25.23	58.10	0.71	0.16	84.20
		31D24	23.32	61.07	1.57	0.24	85.20
		NK-Arma	26.72	55.77	1.31	0.20	84.00
		Average	25.23	58.38	1.20	0.20	85.01
	500 mm	31G98	24.90	59.16	1.22	0.17	85.45
		31D24	23.90	59.07	1.31	0.20	84.48
		NK-Arma	26.01	59.90	1.41	0.19	87.51
		Average	24.94	59.38	1.31	0.19	85.82
Average of non-fertilization			**24.55**	**58.92**	**1.23**	**0.18**	**84.48**
Standard fertilization	300 mm	31G98	23.24	60.55	1.19	0.18	85.16
		31D24	20.91	63.59	1.22	0.25	85.97
		NK-Arma	24.23	59.58	1.37	0.20	85.38
		Average	22.79	61.24	1.26	0.21	85.50
	400 mm	31G98	23.21	61.32	1.41	0.23	86.17
		31D24	23.63	56.96	1.32	0.17	82.08
		NK-Arma	26.91	59.04	1.29	0.20	87.44
		Average	24.58	59.11	1.34	0.20	85.23
	500 mm	31G98	25.32	58.65	1.07	0.12	85.16
		31D24	24.11	60.40	1.31	0.18	86.00
		NK-Arma	27.10	58.13	1.23	0.22	86.68
		Average	25.51	59.06	1.20	0.17	85.94
Average of standard fertilization			**24.30**	**59.80**	**1.27**	**0.19**	**85.56**
Extra potassium supply	300 mm	31G98	23.07	59.93	1.33	0.22	84.55
		31D24	23.34	59.97	1.35	0.25	84.91
		NK-Arma	24.95	60.72	1.33	0.22	87.22
		Average	23.79	60.21	1.34	0.23	85.57
	400 mm	31G98	24.23	59.64	1.28	0.20	85.35
		31D24	22.51	61.38	1.41	0.28	85.58
		NK-Arma	25.15	59.90	1.36	0.26	86.67
		Average	23.96	60.35	1.35	0.25	85.91
	500 mm	31G98	25.02	60.08	1.27	0.13	86.50
		31D24	23.54	59.85	1.43	0.20	85.02
		NK-Arma	25.64	59.38	1.50	0.26	86.78
		Average	24.80	59.80	1.40	0.20	86.20
Extra potassium supply			**24.18**	**60.12**	**1.36**	**0.22**	**85.88**
Average of irrigation doses							
300 mm			23.35	60.15	1.26	0.20	84.96
400 mm			24.59	59.28	1.30	0.22	85.38
500 mm			25.08	59.41	1.30	0.19	85.99
LSD irrigation*potassium*cultivar (0.05)			1.47	2.06	0.22	0.04	-

Steraic acid contents increased and arachidic acid averages moved erratically with increased water supply. The total saturated fatty acid value decreased with standard fertilization and extra potassium application. Similarly the same value decreased with increasing water doses. These results have shown that saturated fatty acid rates increased in deficit irrigation conditions. Therefore the standard fertilization and extra potassium reduced the deficit irrigation effects on the fatty acid rate of corn oil.

Oleic acid, linoleic acid, linolenic acid and eicosenoic acid and unsaturated fatty acid contents were shown in Table 6. Oleic acid rate of corn oil decreased with standard fertilization and extra fertilization, whereas linoleic acid, linolenic acid and eicosenoic acid averages increased with the treatments. Increasing water doses increased oleic and linolenic acid averages. Additionally linoleic and eicosenoic acid averages moved erratically with increased water doses. Total unsaturated fatty acid values increased with standard fertilization and extra potassium. The same value also raised with increasing water doses, however standard fertilization and extra potassium supply reduced the deficit irrigation effect on the unsaturated fatty acid content of corn oil.

Our results have shown that standard fertilization and extra potassium application decreased the total saturated fatty acids compared to non-fertilizer control. Similar results regarding to potassium effects of fatty acid composition of oil have also been reported by some studies (Mekki et al., 1999; Sawan et al., 2006). Froment et al., (2000) have stated that oleic acid and linoleic acid rates increased by extra potassium treatment. The other report has shown that application of nitrogen, phosphorus and potassium (standard fertilization) have the most beneficial effects among the treatments examined, affecting the oil seed quality (as indicated by better fatty acid profile in the oil) (Sawan et al., 2007). These results are compatible with the ones obtained in our study.

Water stress causes a significant reduction about 15% in the concentration of oleic acid. Baldini et al (2000) stated that, from the 8th days after flowering, with the increase in the biosynthesis of the oil, the enzyme D–9 desaturase starts to be active (Baldini et al., 2000). This enzyme has been proposed as being responsible for the accumulation of oleic acid (18:1) by unsaturated stearic acid (18:0), (Mckeon and Stumpf, 1982). Another enzyme leading to the oleic acid accumulation is D–12 desaturase, which catalyses the desaturation of oleic acid into linoleic acid (Stymme and Appelqvist, 1980). It could be considered that as seed maturity progressed, the oil yield of corn seed were affected by decreasing seed filling period after bilister stage under water deficit condition during seed filling.

When water was supplied, a major enhancement of oleic acid content was associated with a concomitant reduction of linoleic acid content and a decrease in saturated fatty acid content. Higher temperature increased the oleic acid content in seed. Oil content was enhanced under colder temperature and irrigation. The content of minor oil components was also enhanced when seed development occurred under high temperature and severe water stress (Roche et al., 2006).

Monounsaturated fatty acids may reduce cardiovascular risks (Perez-Jimenez et al., 2002). Besides, unsaturated fatty acids reduce inflammation and positively effect coronary heart disease (Browning, 2003). Similarly, polyunsaturated fatty acids increase the vitamin E requirement (Lukaski, 2004). Therefore, it may be said that standard fertilization and extra potassium affect human health positively in deficit irrigation condition.

CONCLUSIONS

Based on the results of our study, we can conclude that water shortage had a positive effect on saturated fatty acid rate and negative effect on unsaturated fatty acid rate of corn oil during milk stage and dough stage. Furthermore, fatty acid composition can be affected by standard fertilization and extra potassium supply in deficit irrigation condition.

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