Effects of different soil types and varieties on oil quality of sunflower in the Thrace Region§

Ferruh Feza YILMAZ [1]
Duygu BOYRAZ ERDEM [2*]

[1] The Union of Agricultural Sales
Cooperation for Oil Seeds
Tekirdag, Turkey

[2] Tekirdag Namık Kemal University
Agricultural Faculty
Dep. of Soil Science and Plant Nutrition
Tekirdağ, Turkey

(*) CORRESPONDING AUTHOR:
E-mail: dboyraz@nku.edu.tr

§ *Produced from the PhD thesis*

Received: July 17, 2019
Accepted: November 26, 2019

This study was carried out to determine the influence of different soil types and varieties on seed yield and oil quality of sunflower in the Thrace Region, Turkey conditions in 2013, 2014 and 2015. Four sunflower varieties (LG 5580, P64 LL05, MAXTOR and BOSFORA) were grown under three different soil orders as Typic Xerorthent (Entisol), Typic Haploxerept (Inceptisol) and Typic Haploxerert (Vertisol). The plots were arranged in a randomised split design replicated three times and varieties were the main plot factor whereas soil types were the sub-plot. Grain yield, moisture content, oil content, saturated and unsaturated fatty acids obtained from experimental plots were evaluated in the study. The seed yield for treatments ranged from 1.64 t ha^{-1} to 2.53 t ha^{-1} in 2013, 1.60 t ha^{-1} to 2.41 t ha^{-1} in 2014 and 1.77 t ha^{-1} to 2.55 t ha^{-1} in 2015. Treatment differences for seed yield were statistically significant at 0.01 confidence level according to an analysis of variance. The highest average yield of sunflower was obtained from Vertisol soils with 2.26 t ha^{-1} while the lowest yield was obtained from Inceptisol soils with 2.03 t ha^{-1}. The highest average seed yield among the varieties was obtained from P64 LL05 with the value of 2.17 t ha^{-1} and the lowest yield was obtained from MAXTOR with 2.03 t ha^{-1}. The harvest moisture content of the treatments varied between 4.50 and 8.56%. Treatment differences for oil contents were statistically significant at 0.01 confidence level according to an analysis of variance and oil contents obtained from treatments varied between 31.79% and 43.69%. The Vertisol soil had higher results than other soils for oil content. Unsaturated fatty acid (oleic, linoleic, linolenic and the other unsaturated fatty acids (UFA)) and saturated fatty acid (palmitic, stearic, lineolenic and other saturated fatty acids (SFA)) were evaluated in the research. As a result, sunflower seeds should be grown primarily in Vertisol soils for region and national economy.

Keywords: Seed yield, fatty acid, soil orders, oil content.

INTRODUCTION

Vegetable crude oil production in the world was 171.82 million tons in 2013, 177.26 million tons in 2014 and 176.82 million tons in 2015. It was mostly obtained from palm oil, soybean, rapeseed, sunflower and cotton products [1]. The annual vegetable oil consumption of 20 kg per capita in Turkey is at a low level than the amount of consumption in developed countries of 30-40 kg per capita [2]. Turkey annual vegetable oil consumption per capita consists of 26.8% sunflower, 16.6% cotton, 15.4% soybean, 10.8% corn and 2.3% olive [3]. Although the total oil requirement of Turkey is between 1.200-1.500 thousand tons with a sufficient nutrition condition, sunflower oil production was 691.000 tons in 2013, 792.000 tons in 2014 and 650.000 tons in 2015 [4]. Since the crude oil produced does not meet the requirements in domestic consumption, thousands of tons of oilseeds crude oil is imported to Turkey from abroad every year. According to the latest data from the Ministry of Economy [5], the amount paid for oilseed, crude oil and pulp imports exceeds 4 billion dollars. It can be contributed to closing the crude oil deficit in Turkey, preventing foreign exchange loss through importation, gaining foreign currency by exporting finished product oil and increasing the income level of Turkish farmers with the increase of sunflower production [6].

An important part of Turkey's sunflower cultivation area is located in the Thrace Region. According to the data of the last decade, 55% of the country sunflower cultivation area is located in the Thrace Region and provides 53% of its production. The sunflower, cultivated in all kinds of soil under the regional conditions, is generally grown alternatively with the wheat. Due to the cultivation of sunflower from hybrid seeds under regional conditions, it has an important place for seed companies. For this reason, sunflower genotypes with very different characteristics are grown in the region conditions under non-irrigation conditions. Determination of the yield and quality characteristics of different sunflower varieties grown in different soil conditions are important for the region's farmers and the country. It is stated that environmental, soil conditions and crop genotypes are the most important features affecting sunflower yield and quality in many studies carried out in the world and in Turkey [7-14]. (Especially previous studies carried out have shown that the sunflower variety significantly affects the oil content and quality [15-17]. For this reason, it is important to reveal the varieties that can be grown in different soil conditions and the yield and quality characteristics that can be obtained in the Thrace Region that is an important sunflower production centre in Turkey.

This study was planned to determine oil quality characteristics of different sunflower varieties (*Helianthus annuus* L.) under different soil order groups under rainfed cultivation in the Thrace Region of Turkey. In the research, the sunflower was grown under three different soil subgroups: Typic Xerorthent, Typic Haploxerept and Typic Haploxerert and four different varieties (P64 LL05, Maxtor, LG 5580 and Bosfora) during the years in 2013, 2014 and 2015. The idea is that the results will be beneficial for the producers of the region and country and important in the closure of the vegetable oil deficit.

MATERIALS AND METHODS

The experiment was carried out during the sunflower growing seasons of 2013, 2014 and 2015 years, between May and September. The research fields are situated in a semi-arid climatic region. The averages of annual temperature, relative humidity, wind speed, sunshine duration per day, total annual precipitation is 14.0°C, 77%, 2.90 m/s, 6.5 h and 580.8 mm, respectively [18]. Additionally, some climatic data during the growing season in 2013, 2014 and 2015 is listed in Table I.

In the research, three different soil subgroups, Typic Xerorthent (A1), Typic Haploxerept (A2) and Typic Haploxerert (A3), were selected [19]. Some physical and chemical characteristics at A1, A2 and A3 profiles are presented in Tables II-VII.

The soil texture of the horizons up to a depth of 0-92 cm is clay and Ck horizon is silty-clay texture in A1 profile. Soil reaction (pH) is slightly alkaline in all horizons in the A1 profile. There was no salinity problem and the organic matter ratios show a regular decrease in the

Table I - Some climatic data for Tekirdag in 2013 - 2015.

Month	T_{max} (°C)	T_{min} (°C)	T_{avg} (°C)	RH_{avg} (%)	W (m/s)	P (mm)
2013						
May	23.9	15.5	19.5	69.7	2.4	8.0
June	26.7	18.1	22.4	65.2	2.6	34.8
July	28.7	20.1	24.7	61.4	3.2	0.2
August	30.1	21.9	25.9	62.7	3.5	-
September	25.6	17.2	21.6	61.3	2.6	10.2
2014						
May	21.6	13.6	17.4	80.7	2.4	64.2
June	26.2	17.7	21.7	76.3	2.5	60.0
July	29.2	20.2	24.7	73.7	2.5	52.8
August	30.1	20.9	25.3	74.6	2.7	6.1
September	25.2	16.9	20.7	77.8	2.6	0.8
2015						
May	22.9	14.7	18.5	74.9	2.5	32.2
June	25.8	17.3	21.4	72.3	2.8	62.8
July	29.5	19.9	24.9	70.5	3.0	0.5
August	30.5	21.8	26.1	68.8	3.4	-
September	27.4	19.1	22.8	77.3	2.8	34.9

T_{max}: Maximum temperature T_{min}: Minimum temperature. T_{avg}: Average temperature RH_{avg}: Average relative humidity, W: Average wind speed at 2 m. P: Precipitation.

profile depth [20]. In all horizons within the depth of the A1 profile, there is very little useful phosphorus, an excess of useful calcium, enough useful magnesium, enough useful copper and available iron is at the intermediate level [21]. According to all horizons in the profile [22]; the useful manganese is very small, the useful zinc is low in Ap horizon located in 0-17 cm and very low in all other horizons in the profile depth of 17-92+ cm. Useful potassium is low in Ap and Ad horizons at a depth of 0- 37 cm and low in other horizons at a depth of 37-92+ cm [23].

The whole profile of the horizons of soil texture for the A2 profile is clay. The soil reaction (pH) is neutral in Ap and Bw1 horizons in the profile between 0 and 52 cm, slightly alkaline in the horizons of Bw2, BC and C1 at a depth of 52-127 cm, and a moderate alkaline reaction in the C2 horizon of 127+ cm depth. Salinity problems were not found in the Typic Haploxerept soils. The organic matter ratios show a regular decrease in the profile depth and are very low in the Ap horizon and in the other horizons at a depth of 25-127+ cm. The Ap horizon, which is located between 0 and 25 cm in profile, has very low limy, Bw1 and Bw2 horizons between 25-82 cm depth is low limy, BC and C1 horizons at 82-127 cm depth are limy and the C2 horizon at 127+ cm depth is very limy. In the all horizons, very little phosphorus, excess useful calcium, enough useful copper, medium useful iron was determined. The useful magnesium is high in Ap and Bw1 horizons located at a depth of 0-52 cm and is very high in all other horizons at 52-127+ cm [21]. The available zinc in all profiles is very low while the usable manganese is very low in the Ap horizon at 0-25 cm, less in all other horizons in the profile depth of 25-127+ cm [22]. Useful potassium is sufficient in the Ap horizon at a depth of 0-25 cm, is low in the Bw1 horizon at a depth of 25-52 cm, is sufficient in the Bw2 horizon at a depth of 52-82 cm [23].

The soil texture of the A3 horizons in the whole profile is clay. Soil reaction (pH) in the profile between 0 and 39 cm in the Ap and Ad horizons are neutral, 39-97 cm depth Ass1 and Ass2 horizons in slightly alkaline, 97-116+ cm depth AC and Ck horizons in the moderate alkaline reaction. There was no salinity problem in the Vertisol order. The level of organic matter is low between 0 and 39 cm and very low between 39 and 116+ cm. The Ap, Ad and Ass1 horizons of the profile between 0 and 76 cm are low limy while the horizons of Ass2 and AC horizons between 76 and 116 cm are limy. The useful phosphor was observed as high in the Ap horizon, less in the Ad horizon between 15-39 cm,

Table II - Some physical and chemical analysis results of the soil for A1 profile

Depth (cm)	pH	EC (µs/cm)	Organic Material (%)	$CaCO_3$ (%)	Sand (%)	Clay (%)	Silt (%)	Texture Class
Ap 0-17	7.57	233	1.04	6.18	25.28	48.72	26.00	Clay (C)
Ad 17-37	7.58	166	1.03	5.87	25.28	48.72	26.00	Clay (C)
A 37-60	7.59	158	0.76	10.88	21.28	48.72	30.00	Clay (C)
ACk 60-76	7.62	157	0.66	17.75	22.92	46.72	30.36	Clay (C)
CAk 76-92	7.61	147	0.35	23.93	18.92	44.72	36.36	Clay (C)
Ck 92+	7.72	148	0.21	32.73	14.92	43.08	42.00	Silty clay (SiC)

Table III - Some physical and chemical analysis results of the soil for A2 profile

Depth (cm)	pH	EC (µs/cm)	Organic Material (%)	$CaCO_3$ (%)	Sand (%)	Clay (%)	Silt (%)	Texture Class
Ap 0-25	7.35	267	1.07	0.96	26.92	47.08	26.00	Clay (C)
Bw1 25-52	7.11	107	0.65	1.13	26.92	49.04	23.64	Clay (C)
Bw2 52-82	7.51	177	0.43	2.44	26.92	47.44	25.64	Clay (C)
BC 82-101	7.71	202	0.35	8.19	24.20	49.80	26.00	Clay (C)
C1 101-127	7.83	217	0.31	9.75	22.20	51.80	26.00	Clay (C)
C2 127 +	8.03	280	0.08	13.28	26.20	45.80	28.00	Clay (C)

Table IV - Some physical and chemical analysis results of the soil for A3 profile

Depth (cm)	pH	EC (µs/cm)	Organic Material (%)	$CaCO_3$ (%)	Sand (%)	Clay (%)	Silt (%)	Texture Class
Ap 0-15	7.33	186	1.18	1.22	32.20	47.44	20.36	Clay (C)
Ad 15-39	7.30	141	1.07	1.04	32.20	47.44	20.36	Clay (C)
Ass1 39-76	7.55	144	0.48	2.96	34.20	49.44	16.36	Clay (C)
Ass2 76-97	7.72	173	0.54	5.39	33.28	48.72	18.00	Clay (C)
AC 97-116	8.20	213	0.32	6.10	34.92	50.72	14.36	Clay (C)
Ck 116 +	8.48	280	0.30	10.97	31.28	48.72	20.00	Clay (C)

very small in the other horizons located within the profile depth of 39- 116+ cm. The excess calcium, enough useful copper, useful iron medium was determined in all horizons in the profile. The useful magnesium in all horizons located at a depth of 0 to 116 cm is high [21]. The useful zinc in the Ap horizon located at 0-15 cm is low while it is very low in all other horizons in the profile depth of 15- 116+ cm [22]. The usable manganese is very little in all horizons. Useful potassium is sufficient in all horizons between 0 and 97 cm depth and low in AC and Ck horizons between 97 and 116+ cm depth [23].

Four different sunflower varieties; LG 5580 (V1), P64 LL05 (V2), MAXTOR (V3), and BOSFORA (V4) cultivated intensively in the region were grown. Sunflower seeds were planted in May and harvested in early September during the three years. The plots were arranged in a randomised split design replicated three times. The sunflower varieties were the main plot factor. Each experiment plot took up an area of 3000 m^2 with 0.7 × 0.3 m^2 planting spacing. Before planting, the experimental area was formed with a disk bedder and trifluralin was applied to control the weeds. A basal fertilizer of 200 kg ha^{-1} (20% N, 20% P_2O_5) was mixed into it with planting time. Urea (46%) and ammonium nitrate (33%) were applied at the rates of 60 kg ha^{-1} and 100 kg ha^{-1}.

After physiological maturity, head samples for yield and quality analyses were harvested from three centre rows in each plot. Twenty plants were selected randomly from each treatment for the measurement of yield and quality analyses. Seed oil content and moisture content of it was determined by Anonymous [24]. The oil was obtained by cold pressing at 24°C without using any chemical/solvent. Agilent 7890 A gas chromatography was used for the measurement of fatty acid compositions [25]. Analyses of variance (ANOVA) and multiple comparisons of means performed using the least significant test (LSD) were used to carry out a statistical evaluation [26].

RESULTS AND DISCUSSION

The seed yield and oil quality parameters for all treatments during the three years are presented in Tables VIII-X. The results of the statistical analysis according to these values are summarised in Table XI.

The seed yield for treatments ranged from 1.64 t ha^{-1} to 2.53 t ha^{-1} in 2013, 1.60 t ha^{-1} to 2.41 t ha^{-1} in 2014 and

Table V - Nutrient analysis results of the soil for A1 profile

Depth (cm)	Ca (ppm)	K (ppm)	Mg (ppm)	Cu (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)	P_2O_5 (kg da^{-1})
Ap 0-17	8072	189.6	287.2	0.869	0.923	2.262	0.267	2.93
Ad 17-37	8018	164.1	273.8	0.898	1.102	2.159	0.120	2.24
A 37-60	8035	130.1	317.1	0.809	1.375	2.406	0.053	0.77
ACk 60-76	7512	106.8	270.4	0.591	1.578	3.153	0.040	0.70
CAk 76-92	7180	83.77	322.7	0.452	1.355	2.329	0.032	0.56
Ck 92+	6774	60.30	389.0	0.219	1.608	0.976	0.037	0.49

Table VI - Nutrient analysis results of the soil for A2 profile

Depth (cm)	Ca (ppm)	K (ppm)	Mg (ppm)	Cu (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)	P_2O_5 (kg da^{-1})
Ap 0- 25	5499	153.8	867.8	1.271	1.759	5.916	0.113	4.40
Bw1 25- 52	4549	137.4	1315	1.211	1.435	2.583	0.050	0.63
Bw2 52- 82	6084	145.9	1799	1.069	1.268	1.533	0.047	0.49
BC 82- 101	5488	131.9	2189	0.942	1.118	0.824	0.041	0.77
C1 101-127	5373	130.5	2449	0.972	0.939	0.678	0.028	0.28
C2 127 +	4973	108.3	2678	0.653	0.640	0.248	0.030	0.14

Table VII - Nutrient analysis results of the soil for A3 profile

Depth (cm)	Ca (ppm)	K (ppm)	Mg (ppm)	Cu (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)	P_2O_5 (kg da^{-1})
Ap 0-15	6573	233.8	687.3	0.918	1.248	3.779	0.318	11.04
Ad 15-39	6418	169.2	699.4	0.850	1.066	1.876	0.112	5.66
Ass1 39-76	7428	149.3	1091	0.876	1.139	1.095	0.038	1.19
Ass2 76-97	6871	168.7	1323	0.973	1.315	1.274	0.037	0.91
AC 97-116	6368	125.8	1471	0.945	1.054	1.163	0.038	0.84
Ck 116 +	6255	132.7	1520	1.016	1.224	1.709	0.035	0.77

Table VIII - Yield and oil quality parameters for sunflower in 2013

Soil Types	Variety	Yield (t ha^{-1})	Moisture content (%)	Oil content (%)	Oleic acid (C18:1) (%)	Linoleic acid (C18:2) (%)	Palmitic acid (C16:0) (%)	Stearic acid (C18:0) (%)	Linolenic acid (C18:3) (%)	UFA (%)	SFA (%)
A1	V1	2.04±0.02	6.06±0.17	35.61±0.20	39.64±0.05	49.43±0.05	5.65±0.01	3.41±0.01	0.05±0.01	0.37±0.04	1.47±0.01
	V2	2.11±0.02	6.07±0.30	34.80±0.32	39.27±0.02	49.66±0.03	5.76±0.01	3.51±0.01	0.03±0.01	0.30±0.01	1.47±0.01
	V3	1.93±0.02	6.00±0.19	37.12±0.31	49.33±0.40	41.00±0.07	5.19±0.01	2.95±0.26	0.03±0.01	0.43±0.04	1.40±0.05
	V4	2.22±0.02	5.97±0.15	38.61±0.08	39.36±0.38	49.81±0.49	5.71±0.05	3.31±0.03	0.05±0.01	0.40±0.01	1.37±0.01
A2	V1	2.29±0.02	5.99±0.15	40.72±0.35	39.26±0.68	50.28±0.47	5.65±0.05	2.91±0.03	0.001±0.01	0.54±0.02	1.36±0.01
	V2	1.93±0.04	5.39±0.17	37.37±0.15	43.46±0.07	45.93±0.08	5.40±0.01	3.42±0.01	0.03±0.01	0.36±0.01	1.40±0.01
	V3	1.64±0.03	5.83±0.41	37.01±0.43	51.77±0.03	37.36±0.02	5.58±0.01	3.34±0.01	0.07±0.01	0.43±0.01	1.44±0.02
	V4	2.22±0.02	6.52±0.33	38.36±0.27	45.15±0.33	44.24±0.26	5.34±0.03	3.42±0.02	0.05±0.01	0.33±0.01	1.46±0.01
A3	V1	2.18±0.02	5.77±0.24	42.47±0.16	39.51±0.36	50.13±0.30	5.70±0.03	2.97±0.02	0.001±0.01	0,37±0.01	1.32±0.01
	V2	2.27±0.02	5.95±0.32	41.08±0.26	43.75±0.63	45.88±0.51	5.38±0.06	3.30±0.04	0.001±0.01	0.33±0.01	1.37±0.02
	V3	2.10±0.03	6.41±0.09	42.54±0.13	55.46±0.38	34.84±0.30	4.98±0.05	3.03±0.03	0.001±0.01	0.34±0.01	1.35±0.02
	V4	2.53±0.03	5.80±0.17	43.69±0.14	44.61±0.01	45.53±0.02	5.27±0.01	3.04±0.01	0.03±0.01	0.34±0.02	1.19±0.01

±: standard deviation of three blocks

1.77 t ha^{-1} to 2.55 t ha^{-1} in 2015. Treatment differences for seed yield were statistically significant at 0.01 confidence level according to an analysis of variance. For these years, the highest average seed yields were obtained with 2.12 t ha^{-1} in 2013 and the lowest yields were obtained with 2.01 t ha^{-1} in 2014. This can be explained by the fact that the differences in seed yield between the years are due to the rainfall difference in the region during the sunflower growing period. The highest yield of sunflower was obtained from Typic Haploxerert (A3) soils with 2.26 t ha^{-1} while the lowest yield was obtained from Typic Haploxerept (A2) soils with 2.03 t ha^{-1}. This result can be explained by the fact that due to the high-water holding capacity of the Typic Haploxerert (A3) soils and the plant can supply the moisture it needs during the development periods. The highest average yield of sunflower among the varieties was obtained from P64 LL05 (V2) with the value of 2.17 t ha^{-1} and the lowest yield was obtained from MAXTOR (V3) with 2.03 t ha^{-1}. Also, 2.16 t ha^{-1}and 2.14 t ha^{-1}average seed yield was obtained from BOSFORA (V4) and LG 5580 (V1) varieties, respectively. When the year-soil-variety interaction is examined, it can be seen that the highest yield was obtained in BOSFORA (V4) grown in Typic Xerorthent (A1) soils in 2015 as 2.55 t ha^{-1}. When the seed yield obtained from the experimental subjects is evaluated in general; significant differences were obtained between the years, soil types and varieties. Due to the cultivation of sunflower under rainfed conditions in the Thrace Region, the amount of water held in soil varies according to the year and soil structure. This amount of change affects the sunflower yield to be obtained. It has been stated that similar results were obtained for sunflower seed yield in the studies carried out in the world and country conditions [10, 11, 14, 16].

The harvest moisture content of sunflower seeds is important in terms of storage and processing of crude oil. It is recommended that moisture content for sunflower seeds should be below 10% for proper storage [27]. The moisture content of the treatments varied between 4.50% and 8.56%. On the other hand, statistically significant differences were obtained in all variation sources for moisture contents, except for varieties (Table XI).

The main parameter in the vegetable oil industry is the production of seeds with a high oil content. The high oil content of sunflower seeds increases the income of producers.

The oil contents obtained from treatments varied between 31.79% and 43.69%. The oil content obtained from the experimental subjects were found to be in parallel with the values obtained from previous studies [16, 17, 28]. Treatment differences for oil contents were statistically significant at 0.01 confidence level according to an analysis of variance. As averages of experimental subjects, oil contents were 39.11%,

Table IX - Yield and oil quality parameters for sunflower in 2014

Soil Types	Variety	Yield (t ha^{-1})	Moisture content (%)	Oil content (%)	Oleic acid (C18:1) (%)	Linoleic acid (C18:2) (%)	Palmitic acid (C16:0) (%)	Stearic acid (C18:0) (%)	Linolenic acid (C18:3) (%)	UFA (%)	SFA (%)
A1	V1	1.90±0.02	8.04±0.11	40.53±0.15	46.91±0.31	42.62±0.16	5.12±0.10	3.28±0.05	0.08±0.02	0.61±0.02	1.39±0.01
	V2	2.00±0.03	7.71±0.86	41.33±0.24	42.95±0.27	46.29±0.14	5.20±0.09	3.71±0.05	0.01±0.01	0.31±0.01	1.53±0.01
	V3	1.60±0.01	6.98±0.24	41.01±0.29	45.54±0.25	43.99±0.13	5.19±0.08	3.56±0.03	0.02±0.01	0.29±0.01	1.41±0.01
	V4	1.85±0.03	8.56±0.59	40.88±0.50	51.69±0.30	38.25±0.09	4.71±0.15	3.28±0.06	0.05±0.01	0.45±0.01	1.57±0.02
A2	V1	2.00±0.02	7.24±0.47	39.46±0.23	39.53±0.14	49.87±0.07	5.29±0.04	3.27±0.02	0.03±0.01	0.50±0.01	1.51±0.01
	V2	2.10±0.02	7.14±0.36	40.33±0.31	41.15±0.23	48.27±0.06	5.24±0.13	3.36±0.05	0.06±0.01	0.43±0.01	1.49±0.01
	V3	1.75±0.01	7.83±0.21	40.42±0.12	49.82±0.22	39.92±0.13	4.93±0.07	3.62±0.02	0.04±0.01	0.30±0.01	1.37±0.01
	V4	1.90±0.02	8.22±0.85	41.01±0.44	44.99±0.17	45.33±0.09	5.02±0.07	3.01±0.05	0.08±0.01	0.33±0.01	1.23±0.01
A3	V1	2.18±0.02	5.11±0.44	31.79±0.26	31.44±0.27	56.08±0.20	6.22±0.14	4.32±0.07	0.07±0.01	0.31±0.01	1.56±0.01
	V2	2.41±0.03	5.50±0.37	39.66±0.14	41.28±0.24	47.66±0.23	5.27±0.05	4.00±0.03	0.04±0.01	0.31±0.01	1.44±0.02
	V3	2.04±0.02	5.46±0.14	35.53±0.60	54.13±0.19	35.55±0.07	5.11±0.08	3.48±0.04	0.06±0.01	0.34±0.01	1.33±0.01
	V4	2.41±0.04	4.50±0.51	36.84±0.52	41.31±0.25	48.00±0.11	5.44±0.10	3.74±0.04	0.05±0.01	0.23±0.01	1.21±0.01

±: standard deviation of three blocks

Table X - Yield and oil quality parameters for sunflower in 2015

Soil Types	Variety	Yield (t ha^{-1})	Moisture content (%)	Oil content (%)	Oleic acid (C18:1) (%)	Linoleic acid (C18:2) (%)	Palmitic acid (C16:0) (%)	Stearic acid (C18:0) (%)	Linolenic acid (C18:3) (%)	UFA (%)	SFA (%)
A1	V1	2.18±0.03	6.60±0.61	35.92±0.28	45.26±1.10	45.19±0.99	5.12±0.17	3.00±0.08	0.03±0.01	0.30±0.05	1.12±0.16
	V2	2.53±0.02	7.65±0.03	38.80±0.16	51.14±1.22	38.01±1.04	4.92±0.08	3.75±0.06	0.10±0.02	0.12±0.02	0.96±0.29
	V3	2.18±0.04	7.46±0.31	37.89±0.99	56.40±0.33	34.03±0.40	4.81±0.05	3.22±0.07	0.01±0.02	0.21±0.07	1.32±0.05
	V4	2.55±0.06	6.25±0.34	40.07±0.38	63.51±0.61	27.34±0.54	4.42±0.13	2.89±0.32	0.09±0.02	0.37±0.02	1.39±0.04
A2	V1	2.13±0.02	6.59±0.10	33.43±0.19	44.38±2.11	45.43±2.11	5.38±0.27	3.51±0.16	0.01±0.01	0.24±0.01	1.05±0.30
	V2	2.10±0.03	6.50±0.20	34.87±0.40	46.15±0.88	43.12±0.79	5.45±0.18	3.71±0.08	0.03±0.01	0.19±0.02	1.30±0.27
	V3	2.51±0.03	7.78±0.07	33.91±0.38	56.26±0.72	33.41±0.64	5.05±0.05	3.68±0.04	0.05±0.01	0.10±0.02	1.45±0.04
	V4	1.77±0.05	6.15±0.23	40.05±0.18	54.83±0.80	36.25±1.10	4.54±0.09	2.98±0.08	0.03±0.01	0.28±0.03	1.09±0.59
A3	V1	2.34±0.02	6.04±0.51	34.40±0.75	40.15±0.56	49.41±0.22	5.42±0.07	3.29±0.09	0.05±0.02	0.30±0.02	1.37±0.19
	V2	2.11±0.02	5.37±0.59	40.11±0.27	44.84±0.77	44.77±0.57	5.45±0.08	3.71±0.09	0.00±0.01	0.22±0.02	1.01±0.23
	V3	2.54±0.01	6.17±0.52	39.44±0.66	62.72±1.48	27.74±1.27	4.87±0.05	3.33±0.02	0.08±0.01	0.14±0.02	1.29±0.10
	V4	1.97±0.02	5.66±0.56	42.26±0.56	52.89±0.37	38.27±0.38	4.81±0.08	2.89±0.01	0.10±0.01	0.20±0.03	0.85±0.21

±: standard deviation of three blocks

Table XI - The statistical analyses summary of treatments

Variations	Yield (t ha^{-1})	Moisture content (%)	Oil content (%)	Oleic acid (C18:1) (%)	Linoleic acid (C18:2) (%)	Palmitic acid (C16:0) (%)	Stearic acid (C18:0) (%)	Linolenic acid (C18:3) (%)	UFA (%)	SFA (%)
Replacement	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Years	**	*	**	**	**	**	**	ns	**	*
Soil types	**	**	**	**	**	**	**	ns	*	**
Years × soil types	**	**	**	**	**	**	**	ns	ns	ns
Varieties	**	ns	**	**	**	**	**	ns	**	ns
Years × varieties	**	**	**	**	**	**	**	ns	ns	ns
Soil types × varieties	**	**	**	**	**	**	**	ns	ns	*
Years × soil types × varieties	**	**	**	**	**	**	**	ns	ns	ns

ns: not statistical significance. * : statistical significance at P<0.05. ** : statistical significance at P<0.01.

39.07% and 37.60%. Among the soil types, these values are 38.55% for Typic Xerorthent soils (A1), 38.08% for Typic Haploxerept soils (A2) and 39.15 for Typic Haploxerert soils (A3). When the oil contents obtained from varieties are examined, it is seen that the highest average values are taken from BOSFORA (V4) with 40.20%. This was followed by P64 LL05 (V2) with 38.71%, MAXTOR (V3) with 38.32% and LG 5580 (V1) with 37.15%, respectively. The highest oil content was obtained in BOSFORA (V4) grown in Typic Haploxerert (A3) soils in 2013 as 43.69% for year-soil-variety interaction. When the oil content results were evaluated in general, it was observed that the Vertisol soil structure (Typic Haploxerert (A3)) had higher results than other soil structures. This result can be explained as the high-water retention capacities due to the high amount of smectite clay minerals in this type of soil.

Sunflower seeds usually contain 90% unsaturated fatty acid (oleic, linoleic, linolenic and the other unsaturated fatty acids (UFA)) and 10% saturated fatty acid (palmitic, stearic, lineolenic and other saturated fatty acids (SFA)) [29].

Oleic acid values, one of the important acids in determining sunflower oil quality. Oils with high oleic acid are very light in their specific gravity, thus particularly preferred as cooking or frying oil. Many advantages of oleic acid-rich oils such as high oleic acid oils have higher shelf life and stability compared to high linoleic acid oils, better oxidation resistance, better frying oil properties, higher number of uses and lower sedimentation degree and increased demand [30]. The oleic acid values for treatments ranged from 31.44% to 63.51% among the experimental subjects for three years. The oleic acid values obtained were found to be statistically significant at the level of 0.01 in all variation sources. Among the years, 2015 was the highest with an average oleic acid ratio of 51.63%. This was followed by 44.23% in 2014 and the lowest average oleic acid ratio was 44.22% in 2013. The Entisol soil structure (Typic Xerorthent (A1)) was the highest with an average oleic acid ratio of 47.68% for the soils. While the average oleic acid ratio of MAXTOR (V3) among varieties was highest with 53.49%, the lowest average oleic acid ratio of LG 5580 (V1) was 40.68%. Linoleic acid which is the other important unsaturated fatty acid is one of omega-6 fatty acids. Statistical analyses for linoleic acid values showed significant differences between years, soil structures, varieties and all variations. The highest linoleic acid value was obtained in LG 5580 (V1) grown in Typic Haploxerert (A3) soils in 2014 as 56.08%. The linoleic acid values obtained from the experimental subjects were in parallel with the values obtained from previous studies [16, 31].The other unsaturated fatty acid (UFA) values ranged from 10% to 61% among the experimental subjects and the statistical differences were only observed between years, soil structures and varieties. It was determined that unsaturated fatty acid values obtained as a result of the research were within the limits given in Anonymous [32]. The reason for the difference between the unsaturated fatty acid values for treatments is that the fatty acid compositions of the oil plants are not constant and vary according to physiological, ecological and cultural factors.

Palmitic acid, a saturated fatty acid, is the first fatty acid synthesized by living things and ranged from 4.42% to 6.22% among the experimental subjects for three years. The palmitic acid values obtained were found to be statistically significant at the level of 0.01 in all variation sources. In terms of palmitic acid values, it is seen that 2013, Vertisol soils (Typic Haploxerert (A3)) and LG5580 (V1) varieties have come to the fore. The values of stearic acid, which is saturated fatty acid, ranged from 2.89% to 4.32%. The highest stearic acid value was obtained in LG 5580 (V1) grown in Typic Haploxerert (A3) soils in 2014 as 4.32% and these values were found to be statistically significant at the level of 0.01 in all variation sources. Linolenic acid values were between 0.01% and 0.10%, while statistical differences were not between the obtained values. The linolenic acid values from the experimental subjects were found to be in parallel with the values obtained from previous study [33]. The other saturated fatty acid (SFA) values ranged from 1.09% to 1.47% among the experimental subjects and the statistical differences were only observed between years, soil structures and varieties. It was determined that saturated fatty acid values obtained as a result of the research were within the limits given in Anonymous [32].

CONCLUSIONS

The most important factors affecting the yield and oil quality parameters of sunflower are the genotype, ecological conditions and soil characteristics. In the study carried out in the Thrace ecological conditions in 2013, 2014 and 2015 production years, four different sunflower varieties were grown in three different soil classes. The highest average seed yield of four different sunflower seed varieties in Entisol, Inceptisol and Vertisol orders was 2.26 t ha^{-1} in Vertisol order. Likewise, the highest oil content in three different soil classes was obtained in Vertisol soils with 39.15%. Seed varieties grown in Entisol, Inceptisol and Vertisol orders were the highest significant seed yield in 2.17 t ha^{-1} in P64 LL05 variety. This variety was followed by Bosfora 2.16 t ha^{-1}, LG 5580 2.14 t ha^{-1} and the lowest Maxtor 2.03 t ha^{-1} seed yield. The saturated and unsaturated fat ratios obtained from the research subjects showed statistical differences in terms of year, soil and variety.

As a result; for product design, detailed soil classification is required in the region and country. Because, as seen in our research, there are significant differences between yield and quality parameters obtained from sunflower seeds grown in different soil orders, which directly affect the national economy. It is suggested that seed varieties P64 LL05 and Bosfora should be preferred as the first priority in the soil orders used in the research. According to the seed yield and oil content values, which are the most important economic parameters for sunflower cultivation; it is concluded that sunflower seeds should be grown primarily in Vertisol soil in terms of positive contribution to farmers, region and national economy. The fact that sunflower is cultivated in Entisol and Inceptisol orders should not be ignored. In order to obtain the best crops from these soils, it should be guided by sustainable land management based on the natural qualities and capabilities according to the correct land management theories.

REFERENCES

[1] Oilseed: World Markets and The Trade Reports (United States Department of Agriculture, USDA, 2017).

[2] H. Buyuksahin, Oilseeds and vegetable oil industry advice in Turkey. Turkey Seed Growers Association Journal (TURKTOB) 2(7), 44-47 (2014). in Turkish.

[3] B.T. Top, I. Ucum, Vegetable oil gap in Turkey. TEPGE 14(2), 1-8 (2012). in Turkish.

[4] Sunflower Crop Production Statistics, (Turkish Statistical Institute, Turkey, 2016). in Turkish.

[5] I. Senel, Economic perspective on vegetable oil industry in Turkey. Oilseed Plants and Vegetable Oils Conference, Istanbul, Turkey, (2014). in Turkish.

[6] H. Arioglu, Breeding of Oil Crops. University of Cukurova, Press Number: 220, Adana, Turkey, (1999). in Turkish.

[7] E. Oral, K. Kara, A trial of some oil sunflower varieties under the ecological conditions of Erzurum, Doğa. Turkish Journal of Agriculture and Forestry 13(2), 342-345 (1989).

[8] L. Denis, F. Vear, Variation of hullability and other seed characteristics among sunflower lines and hybrids. Euphytica 87, 177-187 (1996).

[9] O. Botella Miralles, J.A. de Juan Valero, F. Martin de Santa Ollalla, Growth, development and yield of sunflower hybrids. European Journal of Agronomy 6, 47-59 (1997).

[10] A.T. Goksoy, Z.M. Turan, Evaluation of Biometrical Variations in the Hybrid Genotypes of Sunflower II. Correlation and Path Analysis, Journal of Uludag University Agricultural Faculty 17(1), 1-11 (2003).

[11] T. Erdem, L. Delibas, Yield response of sunflower to water stress under Tekirdag conditions. Helia 26(38), 149-158 (2003)

[12] K.K. Uttam, R.K. Sheoran, R.C. Punia, R. Kumar, Correlation studies of seed yield and seed quality traits in sunflower (Helianthus annuus L.). Natnl. J. Pl. Improv. 8(1), 47-49 (2006).

[13] W.S. Porto, C.G. Portela de Carvalho, R.J. Barth Pinto, M.C. Fernandes de Oliveira, A.C. Barneche de Oliveira, Evaluation of sunflower cultivars for Central Brazil. Sci. Agric. (Piracicaba, Braz) 65(2), 139-144 (2008).

[14] A.J. Hall, C. Feoli, J. Ingaramo, M. Balzarini, Gaps between farmer and attainable yields across rainfed sunflower growing regions of Argentina. Field Crops Research 143, 119-129 (2013).

[15] E. Petcu, A. Arsintesscu, D. Stanciu, The effect of drought stress on fatty acids composition in some Romanian sunflower hybrids. Romanian Agricultural Research 15, 39-43 (2001).

[16] S.M. Sezen, A. Yazar, S. Tekin, Effects of partial root zone drying and deficit irrigation on yield and oil quality of sunflower in a Mediterranean environment. Irrig. and Drain 60, 499-508 (2011).

[17] A. Del Gatto, C. Mengarelli, E.F. Pedretti, D. Duca, S. Pieri, L. Mangoni, S.A. Raccuia, M.G. Melilli, Adaptability of sunflower (Helianthus annuus L.) high oleic hybrids to different Italian areas for biodiesel production. Industrial Crops and Products 75, 108-117, (2015).

[18] Meteorological Statistics, (Turkish State Meteorological Service, Turkey, 2016). in Turkish.

[19] Key to Soil Taxonomy by Soil Staff, (United States Department of Agriculture Natural Resources Conservation Service, USA, 2014)

[20] C. Cangir, "Soil Science" University of Thrace, Tekirdag Agricultural Faculty Press Number: 5, Tekirdag, Turkey, (1991). in Turkish.

[21] I.H. Gucdemir, M. Kececi, M. Usul, H. Ozcan, H. Polat, Fertilizers, Fertilization Manual Based on Soil Analysis. Directorate of Agricultural Production and Development, (2008). in Turkish.

[22] Micronutrient Assessment at the Country Level: An International Study, (Food and Agriculture Organization of the United Nations (FAO), Soil Bulletin No: 63, (1990).

[23] M. Alparslan, A. Gunes, A. Inal, Experimental Technique. University of Ankara, Agricultural Faculty Press Number 1501, Ankara, Turkey, (1998). in Turkish.

[24] TS 12302, TS 886, TS 9059 EN ISO 5511 Standards, (Turkish Standards Institution, 2000). in Turkish.

[25] TS 4664 EN ISO 5508 Standard, (Turkish Standards Institution, 1996). in Turkish.

[26] K.A. Gomez, A.A. Gomez, Statistical Procedures for Agricultural Research. John Wiley & Sons, New York.

[27] Y. Kaya, Sunflower: the most important oil crop for Turkey. Turkey Seed Growers Association Journal (TURKTOB) 2(7), 20-23 (2013). in Turkish.

[28] V. Gul, K. Kara, Effects of different nitrogen doses on yield and quality traits of common sunflower (Helianthus annuus L.). Turkish Journal of Field Crops. 2, 159-165, (2015).

[29] B.T. Steer, G.L. Seiler, Changes in fatty acid composition of sunflower (Helianthus annuus L.), seeds in response to time of nitrogen application, supply rates and defoliation. J. Sci. Food Agric. 51, 11-26, (1990).

[30] H. Baydar, Improvements in oleic acid rich cultivars in oil Crops. Turkey Seed Growers Association Journal (TURKTOB) 5(20), 34-39 (2016). in Turkish.

[31] S. Yasumoto, Y. Yamaguchi, H. Yoshida, M. Matsuzaki, K. Okada, Growth, yield and quality of bird-resistant sunflower cultivars found in genetic resources. Plant Prod. Sci. 15(1), 23-31 (2012).

[32] Regulations on oil crop: (Turkey Ministry of Agriculture and Forestry), Number 2012/29, (2012).

[33] R. Lopez Garrido, E. Madejon, M. Leon Camacho, I. Giron, F. Moreno, J. M. Murillo, Reduced tillage as an alternative to no-tillage under Mediterranean conditions: A case study. Soil and Tillage Research. 140, 40-47 (2014).