

Effects of irrigation intervals and irrigation levels on oil content and fatty acid composition of peanut cultivars

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Abstract

Oil content and fatty acid composition are the most significant quality criteria of peanuts (*Arachis hypogaea* L.), and these parameters is greatly influenced by irrigation and fertilization practices. A study was conducted to investigate the effects of irrigation intervals and irrigation levels on oil content and fatty acid composition of peanuts, under sandy soil conditions in two consecutive years, using ‘Halisbey’, ‘NC-7’, and ‘Sultan’ peanut cultivars, commonly grown in Turkey. Irrigation levels were arranged based on total evaporation from Class-A pan, and irrigations were applied through drip lines. Irrigation intervals were set as two and four days, and irrigation levels were set as 50% (I₅₀), 75% (I₇₅), 100% (I₁₀₀) and 125% (I₁₂₅) of Class-A pan evaporations. Oil content, unsaturated fatty acids (oleic and linoleic acids), and saturated fatty acids (palmitic, myristic, arachidic, behenic and lignoceric acids) were determined. For oil content, treatments were identified as the most appropriate irrigation for a two-day irrigation interval of all cultivars, I₁₀₀ for four-day irrigation interval of ‘Halisbey’ and ‘Sultan’ cultivars and I₇₅ for four-day irrigation interval of ‘NC-7’ cultivar. Oleic, linoleic, and palmitic acids were the major fatty acids of peanuts. Cultivars exhibited different variations in these fatty acids based on irrigation intervals and irrigation levels. In general, oleic acid contents decreased, but linoleic and palmitic acid contents increased with increasing irrigation levels. The greatest oleic acid contents were obtained from two and four-day irrigation intervals of I₅₀ treatments in ‘Halisbey’ and ‘NC-7’ cultivars and from two and four-day irrigation intervals of I₇₅ treatments of the second year in ‘Sultan’ cultivar. Present findings revealed that for quality peanut production, both irrigation intervals and irrigation levels should be taken into consideration.

Keywords: *Arachis hypogaea* L.; fatty acid composition; irrigation interval; irrigation level; oil content; peanut

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Introduction

Irrigation is an essential component of plant production. Proper irrigation programs play a key role not only in improving both the yield and the quality. Irrigation programs play a significant role also in the preservation and efficient use of water resources (Kaplan *et al.*, 2019). Increasing water demands are not sufficiently met with deficit water resources, and existing droughts generate crisis not only in agricultural productions but also in several other sectors. These cases will probably get worse in the future. Therefore, deficit water resources should be properly and efficiently be used, especially in agriculture and the other sectors. The proper and efficient application of irrigation water at the right time and the right quantity to root zone of the plants without generating any environmental problems will improve yield and quality. Plants exhibit quite different responses against water deficits (Tas, 2017). Therefore, the plant responds to water deficits that should be determined for sustainable agricultural production. Plant responses should especially be determined in peanut-like plants mostly used as industrial raw material.

Peanut is an annual leguminous plant either used for oil production in the industry or consumed as an appetizer. Peanut is an important oil crop cultivated worldwide in different continents, and world annual production is about 43.9 million tons (Sezen *et al.*, 2019). Turkey, with available climate conditions, is among the leading peanut producer countries of Europe (Florkowski, 2012). Peanut is cultivated as the main and second crop in some regions of Turkey (Çukurova and Southeast Anatolia region) but cultivated as only the main crop in Aegean, Mediterranean, and Marmora regions. Peanut is a legume crop able to fixate 150 kg/ha nitrogen into soils through symbiotic rhizobium bacteria in a single growing season (Arioğlu, 2014). With such an attribute, the peanut is a significant crop rotation and green fertilizer plant (Langat *et al.*, 2006). Harvest residues could also be used as roughage, thus generate a significant feed source for animals (Kokten *et al.*, 2014).

Peanut seeds are rich in proteins, essential fatty acids, minerals, and bioactive compounds (Akram *et al.*, 2018). Oil is the major component of peanut seeds (36 - 54%), and seeds also contain high quantities of proteins (16 - 36%) and carbohydrates (10 - 20%) (Davis *et al.*, 2016). Peanut seeds also contain coenzyme Q10, arginine, and polysterols (Akhtar *et al.*, 2014). However, the majority of world peanuts are produced for cooking oil just because of light and soft taste and some advantages of peanut oil over the other vegetable oils (Toomer, 2018). Following the oil extraction, the remaining peanut meal is quite rich in protein (50%), thus constitutes an important source of nutrients (Zhao *et al.*, 2012). Since peanut is an oil crop, characteristics of peanut oil should be known (Abbas *et al.*, 2018). Peanut oil contains major saturated fatty acids of palmitic (C16: 0), unsaturated fatty acids of oleic (C18: 1) and linoleic acids (C18: 2) (Toomer, 2018). Besides these fatty acids, peanut oil also contains slight quantities of stearic acid (C18: 0), arachidonic (C20: 0), eicosenoic (C29: 1), behenic (C22: 0) and lignoceric (C24: 0) acids (Casini *et al.*, 2003; Carrin and Carelli, 2010).

The taste and quality of peanuts and peanut products largely depend on the chemical composition of peanut oil. With a high oleic acid content, peanut oil has a well oxidative and frying stability. Peanut oil does not provide solidity when exposed to air, but become solid between 0-3 °C (O'Brien, 2004). Lipid and fatty acid composition of peanut oil-primarily depend on the cultivar, seed maturity, environmental conditions, agronomic practices, and geographical location (Young, 1996). Low temperatures at the seed ripening stage influence the unsaturated fatty acid composition of peanuts (Casini *et al.*, 2003). Oleic acid content increases, and linoleic and palmitic acid contents decrease toward the harvest maturity (Hinds, 1995). Andersen and Gorbet (2002) indicated that the fatty acid profile of peanuts did not effect varied with the sowing times and the years. It was indicated in another study that the fatty acid profile of peanut may vary with the soil texture (Hinds, 1995). However, it was indicated in studies conducted in the USA that genetics significantly influenced the fatty acid composition of peanuts, and greater genetic-dependent variations were observed in major components (palmitic, oleic, and linoleic acid) than the other minor fatty acids (Zhu *et al.*, 2004).

'NC-7', 'Halisbey', and 'Sultan' are the most commonly cultivated peanut cultivars in Turkey, and they belong to the Virginia group (Arioğlu *et al.*, 2016). Oil contents of peanut cultivars grown in different environments of Turkey were reported as between 35.3-45.4% (Özcan, 2010). In a previous experiment

conducted in a single location, the oil content was reported as 48.94% for ‘Halisbey’ cultivar, 47.55% for ‘NC-7’ cultivar, and 48.62% for ‘Sultan’ cultivar (Arioğlu *et al.*, 2016). Yol *et al.* (2017) reported the oil content of peanut genetic materials as between 31.7 - 57.0%, oleic acid contents as between 35.3 - 60.9% and linoleic acid contents as between 16.1 - 43.6%. Greater adaptation to certain environmental conditions may contribute to high seed yield and quality of peanuts (Yol and Uzun, 2018). Growing techniques greatly influence oil content and fatty acid composition. Isleib *et al.* (2008) indicated that the chemical composition of peanut seeds significantly influenced by environmental factors, genetic factors, and interactions of these factors. Researchers also investigated the effects of drought, water deficit and air temperature on fatty acid composition of peanuts at different locations (Young *et al.*, 1974; Dwivedi *et al.*, 1996; Yao *et al.*, 2003; Reddy *et al.*, 2003; Patel *et al.*, 2008; Shinde and Laware, 2010). A limited number of researchers investigated the effects of irrigation water levels on quality parameters of peanuts (Zhu *et al.*, 2004; Amir *et al.*, 2005; Boydak *et al.*, 2010; Aydinsakir *et al.*, 2018). However, a comprehensive study investigating the effects of cultivars, irrigation intervals, and irrigation levels on oil content and fatty acid composition of peanuts hasn’t been conducted yet.

This study was conducted to assess the variations in oil contents and fatty acid composition of ‘Halisbey’, ‘NC-7’, and ‘Sultan’ peanut cultivars grown under sandy soil conditions, two different irrigation intervals, and different irrigation levels for two growing seasons. Effects of irrigation interval x irrigation level interactions on oil content and fatty acid compositions were also investigated, and proper irrigation practices for quality peanut production under sandy soil conditions were tried to be identified.

Materials and Methods

Study area, the conditions in which the research was carried out and analyzed material

This study was conducted for two years between May and October of 2017 and 2018 under Balıkesir Burhaniye conditions over the experimental fields of Farmer’s Training and Extension Center of Balıkesir Greater City Municipality, Turkey. Irrigation-related soil parameters of the experimental site are provided in Table 1. Soil texture is mostly sandy, and sandy-loam and sand contents varied between 58.7-95.0%, silt contents varied between 2.4-30.1%, and clay contents varied between 2.6-21.4%. Field capacity (FC) values varied between 10.87-17.78%, and permanent wilting point (PWP) values varied between 4.83-8.67%. Soil bulk density (BD) values varied between 1.36-1.59 g/cm³.

‘Halisbey’, ‘NC-7’, and ‘Sultan’ cultivars with Virginia-type seeds and commonly grown in Turkey were used as the plant material of the study. Two different irrigation intervals (2 and 4 days) and four irrigation levels (I₅₀, I₇₅, I₁₀₀, and I₁₂₅) were applied. The amount of irrigation water was calculated based upon cumulative evaporation from Class-A-Pan (CAP). There different irrigation intervals (2 and 4 days) and level of cumulative evaporation (I₅₀, I₇₅, I₁₀₀ and I₁₂₅) were used in the experiment. Experiments were conducted in split-split plots experimental design with three replications. The main plots included cultivars, sub-plots included irrigation intervals, and sub-sub-plots included irrigation levels. A 4 m spacing was provided between sub-plots, and 2 m spacing was provided between sub-sub-plots to prevent transitions between the treatments. Plots were 5 m long and composed of 4 rows. Row spacing was 70 cm, and on-row plant spacing was 20 cm.

Sowing was performed on 20 April 2017 in the first year and 23 April 2018 in the second year. Two seeds were sown manually into each seedbed, and following the emergence, the number of plants was thinned to one in each seedbed. Before sowing, 250 kg/ha DAP (45 kg/ha N, 115 kg/ha P₂O₅) fertilizer was provided, and 50 kg/ha ammonium nitrate was applied twice through 3rd and 4th irrigations. Befuraline active-ingredient herbicide (60% w/w) was applied before sowing, and hoeing was practiced after emergence for weed control.

Harvest was performed through manual pull-out on 15 October 2017 and 20 October 2018. For oil content and fatty acid analyses, 100 g seeds were sampled from 10 plants of each plot. Seeds were dried to constant moisture before the analyses.

Table 1. Soil physical characteristics

Soil depth	Sand (%)	Silt (%)	Clay (%)	Texture	FC (%)	PWP (%)	BD (g/cm ³)
0-30	60.7	24.0	15.3	SL	16.87	7.98	1.54
30-60	95.0	2.4	2.6	S	10.87	4.83	1.59
60-90	58.7	30.1	11.2	SL	17.78	8.21	1.56

Oil extraction and preparation of fatty acid methyl esters (FAME)

Impurities were removed from the seeds, and the cleaned seeds were ground using a ball mill into powder. Lipids were extracted with hexane/isopropanol (2 v/v) solution overnight in a laboratory-type shaker. The lipid extracts were centrifuged at 10000 g for 5 min and filtered after that solvent was removed on a rotary evaporator at 40 °C. After the extraction procedure, fatty acids in the lipid extracts were converted into methyl esters employing 2% sulphuric acid (v/v) in methanol (Christie, 1990).

Determination of fatty acid composition by GC system

Lipid fatty acid methyl esters (FAME) in seed samples were prepared using 1-step extraction-trans esterification. The FAME profile for a 0.6- μ L sample at a split ratio of 1:50 was generated using a gas chromatograph (Schimadzu, GC 2010 plus) equipped with a flame ionization detector (Shimadzu, Kyoto, Japan), a 100-m fused silica capillary column (i.d. 0.25 mm) and H₂ as the carrier and fuel gas. The FAME was separated using a temperature gradient program (Chilliard *et al.*, 2013), and the peaks were identified based on comparing retention times with authentic standard (Supelco #37, Supelco Inc., Bellefonte, PA, USA; L8404 and O5632; Sigma).

Resultant data were subjected to variance analysis. Then, regression analyses were conducted for each fatty acid to assess years, cultivars, irrigation intervals, and irrigation levels visually. In regression analysis, the cubic model was used to see the effects, especially of irrigation levels. Variance analysis and regression graphs were generated with the use of JMP software (SAS Institute, 2014). Finally, biplot graphs were generated with the aid of GGE biplot software to see the effects of different irrigation interval x irrigation level combinations on the fatty acid composition of different cultivars (Yan, 2001).

Results and Discussion

Initially, oil contents were determined, then unsaturated fatty acids (oleic and linoleic) and saturated fatty acids (palmitic, myristic, arachidic, behenic, and lignoceric) were calculated. Oil contents and fatty acid compositions of peanut cultivars varied with the years, cultivars, irrigation intervals, irrigation levels, and interactions of these factors (Table 2).

Effects of years on total oil, saturated and unsaturated fatty acid contents and fatty acids, except for linoleic acid; effects of cultivars on total oil, saturated and unsaturated fatty acid contents and fatty acids, except for arachidic and behenic acid; effects of irrigation levels on total oil, saturated and unsaturated fatty acid contents and fatty acids, except for arachidic acid; effects of irrigation intervals on total oil, saturated and unsaturated fatty acid contents and fatty acids, except for palmitic, arachidic and behenic acids were found to be highly significant ($P < 0.01$).

Of double interactions, year x irrigation interval and year x irrigation level interactions were found to be significant for total oil content, but insignificant for all fatty acids. Irrigation interval x cultivar interactions were found to be significant for total oil, saturated and unsaturated fatty acid contents, myristic, arachidic and lignoceric acids; cultivar x irrigation level interactions were found to be significant for total oil, saturated and unsaturated fatty acid contents, myristic, palmitic, behenic, oleic and linoleic acids; irrigation interval x irrigation level interactions were found to be significant for total oil, saturated and unsaturated fatty acid contents, myristic, oleic and linoleic acids ($P < 0.01$).

Of triple interactions, irrigation interval x cultivar x irrigation level interactions were found to be significant for total oil, saturated and unsaturated fatty acid contents and all fatty acids, except for linoleic acid; year x irrigation interval x irrigation level interactions were found to be significant for total oil contents and myristic acid ($P < 0.01$).

Table 2. Variance analysis for oil content and fatty acid composition (mean square)

Source	DF	Mean Square									
		Oil content	Oleic	Linoleic	TUSFA	Myristic	Palmitic	Arachidic	Behenic	Lignoceric	TSFA
Year (Y)	1	37.990*	137.910**	0.535	121.2605**	0.1257**	10.2022**	5.3272**	9.2959**	4.7724**	122.9899**
Block (Year)	4	4.400	3.036	2.223	0.0744	0.0002	0.0264	0.0672	0.0096	0.0063	0.0426
Cultivar (V)	2	25.460*	429.468**	287.703**	14.1843**	0.0021*	4.3060**	0.0864	0.0804	1.8875**	13.6875**
Y*C	2	33.920*	122.414**	116.555**	0.3316	0.0051**	2.1222*	0.0112	0.3704*	0.1742**	0.4941
Error-1	8	5.920	0.996	0.818	0.3138	0.0004	0.3392	0.0318	0.0507	0.0092	0.3155
Day (D)	1	6.550**	10.741*	21.243*	1.7738*	0.0028**	0.2605	0.0249	0.0831	0.1491*	1.6656*
Y*D	1	83.260**	4.063	2.375	0.2253	0.0001	0.0248	0.0003	0.0284	0.0312	0.2741
D*C	2	13.540**	1.797	3.456	0.2734	0.0026**	0.5492	0.3438**	0.0110	0.1079*	0.3311
Y*D*C	2	8.090**	0.141	0.056	0.1235	0.0001	0.0405	0.0106	0.0003	0.0195	0.0933
Error-2	12	0.320	2.083	2.753	0.3535	0.0003	0.2079	0.0253	0.0453	0.0269	0.2944
Irrigation (I)	3	297.240**	34.922**	24.199**	3.3907**	0.0014**	1.7928**	0.0413	0.4529**	0.1515*	3.3826**
Y*I	3	16.400**	1.764	3.095	0.3534	0.0005	0.1075	0.0057	0.0199	0.0097	0.2997
V*I	6	23.130**	11.163**	9.635**	0.7552	0.0044**	0.7752*	0.0259	0.1418*	0.0559	0.8141
Y*C*I	6	11.510**	2.440	2.185	0.1388	0.0009	0.0471	0.0125	0.0231	0.0113	0.0954
D*I	3	16.430**	12.666**	11.392*	0.3241	0.0066**	0.3732	0.0704	0.0326	0.0261	0.3832
Y*D*I	3	32.330**	1.325	1.551	0.0417	0.0016**	0.0531	0.0322	0.0086	0.0052	0.0420
D*C*I	6	9.340**	9.888**	4.357	4.1174**	0.0044**	0.9680**	0.1173*	0.3788**	0.2034**	4.2432**
Y*D*C*I	6	30.770**	0.534	0.312	0.3118	0.0009*	0.0843	0.0264	0.0256	0.0163	0.2288
Error-3	72	1.908	3.652	3.584	0.5388	0.0004	0.2933	0.0432	0.0655	0.0468	0.5277
Coefficient of variation		3.23	3.94	5.91	0.91	11.70	5.00	6.36	7.28	13.13	3.74
R-Square		0.96	0.86	0.81	0.84	0.90	0.69	0.73	0.78	0.78	0.84

DF: Degrees of freedom, TUSFA: Total unsaturated fatty acid, TSFA: Total saturated fatty acid**: $P < 0.01$, *: $P < 0.05$

Since the effects of the years on oil content and fatty acid compositions were found to be significant, assessments were made separately for fatty acids through distributing the effects of cultivars, irrigation intervals over the year. Resultant averages are provided in Tables 3 and 4; regression graphs are presented in Figures 1, 2, and 3; biplot graphs are presented in Figure 4.

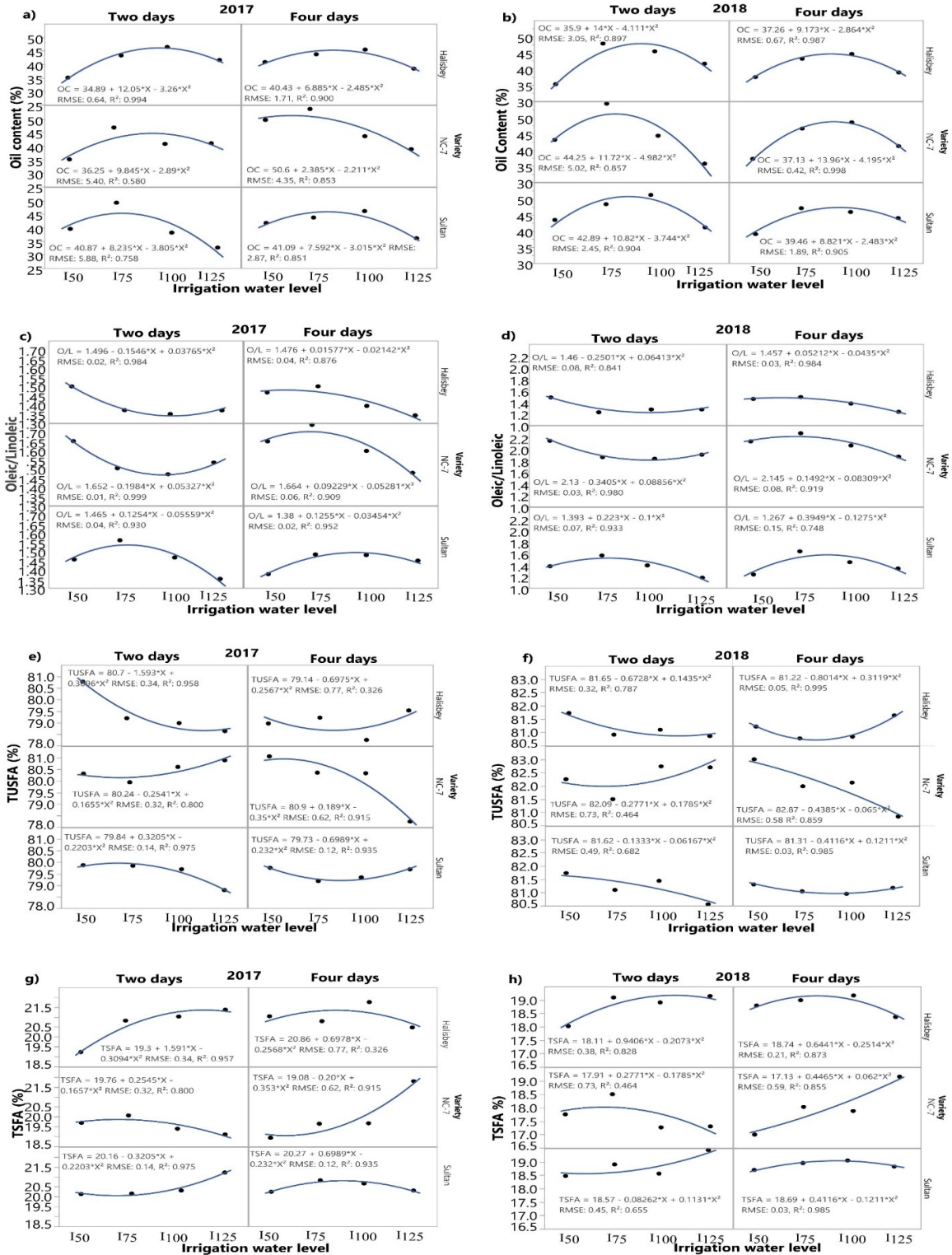


Figure 1. Change in a-b) oil content, c-d) oleic/linoleic acid ratio, e-f) total unsaturated fatty acids, g-h) total saturated fatty acids based on year, cultivar, irrigation interval, and irrigation level

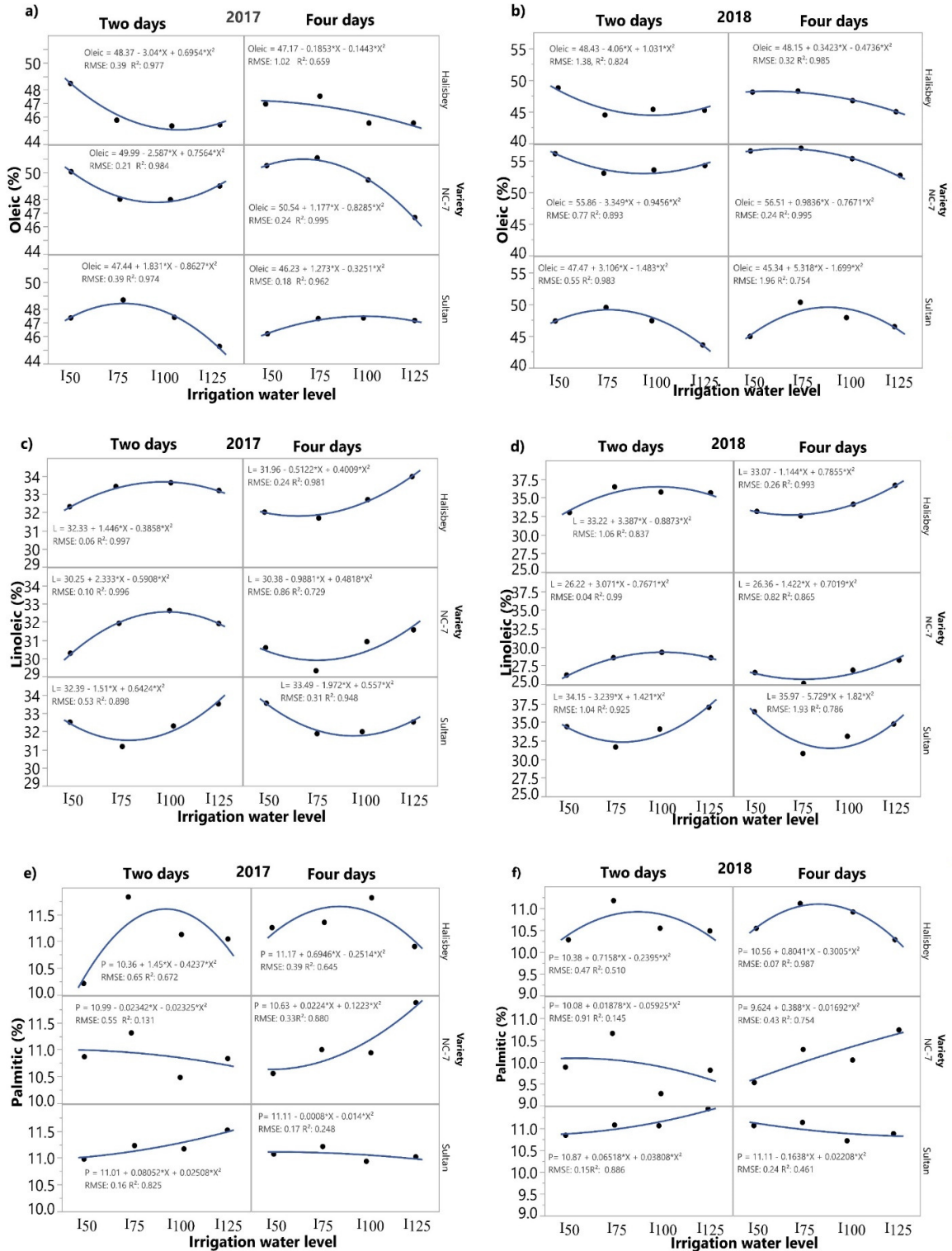


Figure 2. Change in a-b) oleic, c-d) linoleic and e-f) palmitic acid contents based on year, cultivar, irrigation interval, and irrigation level

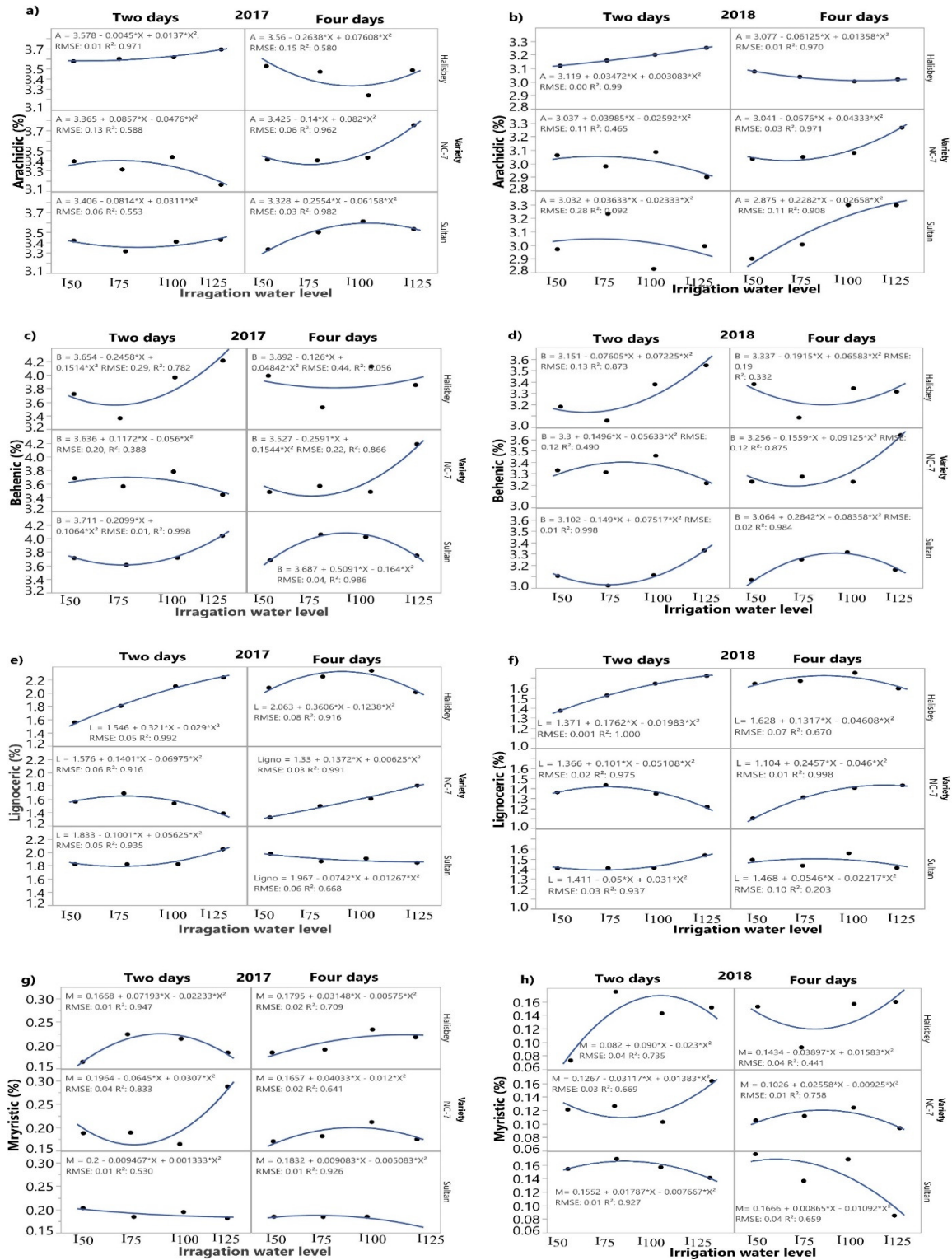


Figure 3. Change in a-b) arachidic, c-d) behenic, e-f) lignoceric, g-h) myristic acid contents based on year, cultivar, irrigation interval, and irrigation level

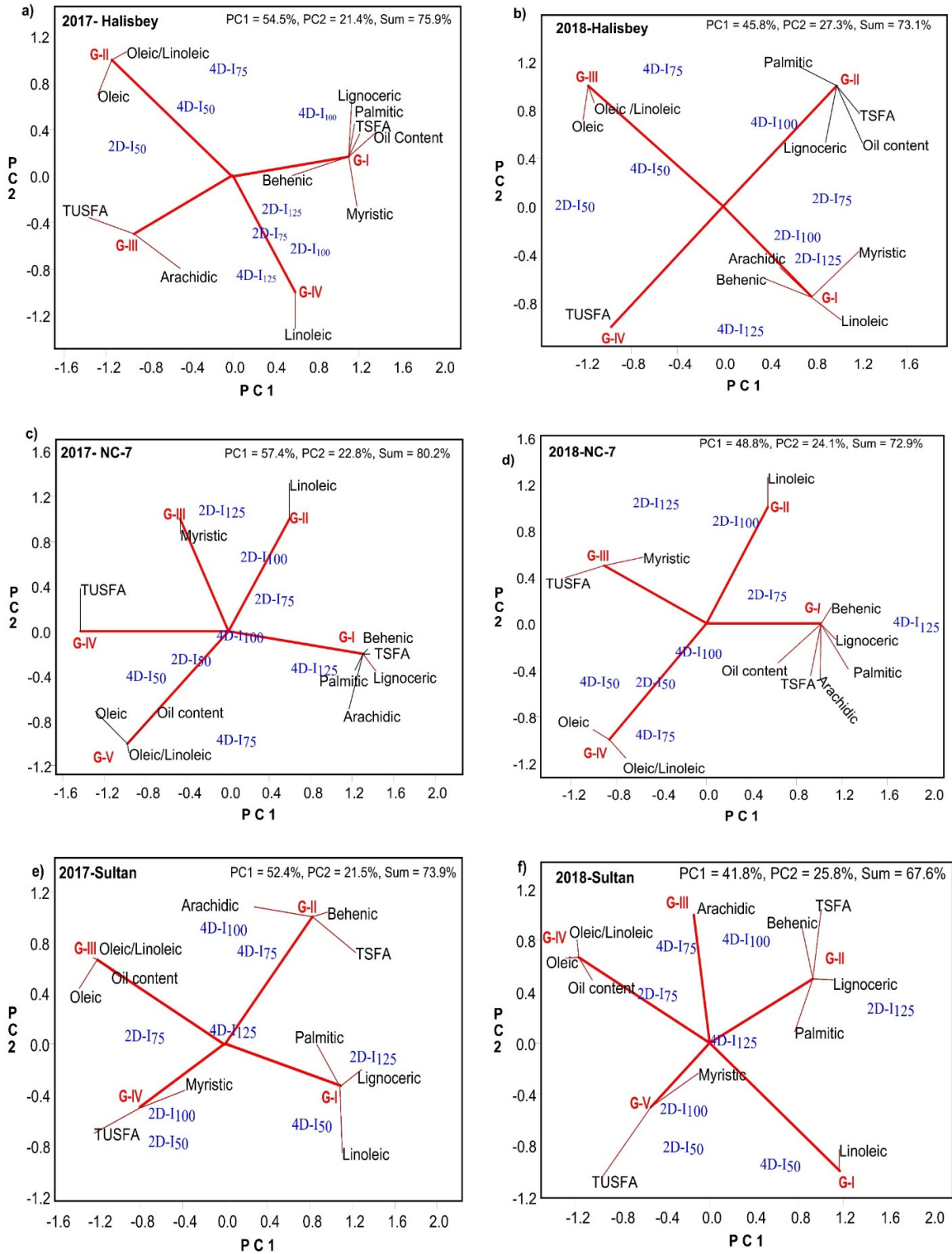


Figure 4. Relationships between investigated parameters of the years and attribute groups

Total oil, saturated, and unsaturated fatty acid contents of peanut cultivars were significantly influenced by the years and irrigation treatments. Effects of irrigation intervals and irrigation levels on total saturated and unsaturated fatty acid contents significantly varied with the cultivars. Generally, the saturated fatty acid ratio increased, and the unsaturated fatty acid ratio decreased (Figure 1e-h). In general, the total oil ratio at a two-day irrigation interval was lower in the first year (40.8%) than in the second year (43.6%). In the four-day irrigation interval, the oil ratio of the second year (42.8%) was lower than the oil ratio of the first year (43.5%). As can be seen in regression analyses, peak levels were determined for the greatest oil ratios at two and four-day irrigations of both years (Figure 1a and b). The lowest oil ratios of all cultivars were obtained from I₅₀ and I₁₂₅ irrigation levels. Since the soil texture of the experimental site was sandy, plants were highly influenced by water stress in deficit irrigation treatment and negatively influenced by excessive water in I₁₂₅ treatments. The greatest oil ratios were obtained from the I₇₅ irrigation level. In general, at both irrigation intervals, oil ratios significantly increased from I₅₀ to I₇₅ level, but a significant change was observed at the I₁₀₀ level in 'Halisbey' and 'Sultan' cultivars. On the other hand, 'NC-7' exhibited a different response to I₁₀₀ treatment from the other two cultivars (Figure 1a and b). Aydınşakir *et al.* (2019) reported the greatest crude oil ratio of 'NC-7' cultivar under clay-loam soil conditions at I₁₀₀ and I₁₂₅ irrigation levels.

Considering the entire factors of the years together, it was observed that the values of oleic acid and total unsaturated fatty acids were greater in the first year than the second year and a reverse case was valid for the total oil ratio, saturated fatty acid ratio and the other fatty acids (Tables 3 and 4).

Table 3. Averages for total oil content and fatty acid contents based on irrigation interval, irrigation level and cultivar in 2017

Irrigation	Oil Content	Unsaturated fatty acids			Saturated fatty acids					
		Oleic	Linoleic	TUSFA	Palmitic	Myristic	Arachidic	Behenic	Lignoceric	TSFA
Two days										
'Halisbey'										
I ₅₀	35.0 ± 1.7	48.74 ± 1.1	32.99 ± 1.1	81.72 ± 0.6	10.28 ± 0.4	0.07 ± 0.01	3.12 ± 0.05	3.18 ± 0.18	1.37 ± 0.09	18.02 ± 0.44
I ₇₅	43.3 ± 1.0	44.48 ± 0.7	36.43 ± 0.7	80.91 ± 0.1	11.17 ± 0.4	0.17 ± 0.03	3.16 ± 0.13	3.06 ± 0.05	1.53 ± 0.22	19.09 ± 0.10
I ₁₀₀	46.4 ± 1.8	45.36 ± 2.2	35.74 ± 2.1	81.09 ± 0.2	10.54 ± 0.6	0.14 ± 0.02	3.2 ± 0.13	3.38 ± 0.25	1.64 ± 0.12	18.91 ± 0.17
I ₁₂₅	41.5 ± 0.9	45.22 ± 3.5	35.63 ± 3.8	80.85 ± 0.6	10.48 ± 0.6	0.15 ± 0.03	3.25 ± 0.09	3.54 ± 0.05	1.72 ± 0.05	19.15 ± 0.61
Mean	41.6	45.95	35.2	81.15	10.62	0.14	3.18	3.29	1.57	18.79
'NC-7'										
I ₅₀	35.0 ± 0.9	56.03 ± 1.1	26.22 ± 1.7	82.25 ± 1.0	9.88 ± 0.7	0.12 ± 0.01	3.06 ± 0.18	3.33 ± 0.22	1.36 ± 0.19	17.75 ± 0.96
I ₇₅	46.8 ± 0.6	52.95 ± 1.5	28.55 ± 0.5	81.50 ± 1.4	10.65 ± 0.7	0.13 ± 0.01	2.98 ± 0.16	3.31 ± 0.28	1.43 ± 0.25	18.5 ± 1.36
I ₁₀₀	40.8 ± 1.0	53.46 ± 0.5	29.27 ± 0.3	82.74 ± 0.2	9.27 ± 0.5	0.10 ± 0.02	3.08 ± 0.18	3.46 ± 0.21	1.35 ± 0.09	17.26 ± 0.23
I ₁₂₅	41.0 ± 0.3	54.16 ± 1.3	28.54 ± 0.6	82.70 ± 0.8	9.81 ± 0.6	0.16 ± 0.01	2.9 ± 0.09	3.21 ± 0.14	1.21 ± 0.04	17.3 ± 0.77
Mean	40.9	54.15	28.15	82.3	9.9	0.13	3.01	3.33	1.34	17.7
'Sultan'										
I ₅₀	39.6 ± 0.7	47.35 ± 1.2	34.39 ± 1.0	81.73 ± 0.5	10.84 ± 0.4	0.15 ± 0.04	2.97 ± 0.05	3.1 ± 0.27	1.4 ± 0.19	18.47 ± 0.55
I ₇₅	49.2 ± 1.6	49.46 ± 3.0	31.64 ± 2.8	81.10 ± 0.2	11.07 ± 0.3	0.17 ± 0.01	3.23 ± 0.10	3.02 ± 0.21	1.41 ± 0.10	18.90 ± 0.16
I ₁₀₀	38.2 ± 2.1	47.38 ± 0.7	34.06 ± 0.5	81.44 ± 0.8	11.06 ± 0.4	0.16 ± 0.03	2.82 ± 0.38	3.11 ± 0.06	1.41 ± 0.08	18.56 ± 0.79
I ₁₂₅	32.6 ± 0.3	43.56 ± 1.1	36.99 ± 1.6	80.56 ± 0.6	11.44 ± 0.3	0.14 ± 0.01	2.99 ± 0.06	3.33 ± 0.10	1.54 ± 0.11	19.44 ± 0.58
Mean	39.9	46.94	34.27	81.21	11.1	0.16	3.01	3.14	1.44	18.84
D mean	40.8	49.01	32.54	81.55	10.54	0.14	3.07	3.25	1.45	18.44
Four days										
'Halisbey'										
I ₅₀	40.8 ± 0.2	48.08 ± 1.7	33.13 ± 1.5	81.21 ± 0.6	10.54 ± 0.4	0.15 ± 0.02	3.08 ± 0.12	3.38 ± 0.16	1.64 ± 0.15	18.79 ± 0.63
I ₇₅	43.7 ± 1.3	48.23 ± 0.6	32.53 ± 1.4	80.77 ± 1.2	11.11 ± 0.5	0.09 ± 0.01	3.04 ± 0.28	3.09 ± 0.15	1.67 ± 0.16	18.99 ± 0.79
I ₁₀₀	45.4 ± 1.7	46.73 ± 2.5	34.10 ± 3.4	80.83 ± 1.1	10.91 ± 0.9	0.16 ± 0.03	3.00 ± 0.29	3.34 ± 0.24	1.75 ± 0.24	19.17 ± 1.06
I ₁₂₅	38.3 ± 2.4	44.99 ± 2.1	36.65 ± 2.9	81.64 ± 0.8	10.28 ± 0.7	0.16 ± 0.01	3.02 ± 0.03	3.31 ± 0.13	1.59 ± 0.02	18.36 ± 0.82
Mean	42.1	47.01	34.1	81.11	10.71	0.14	3.03	3.28	1.66	18.83
'NC-7'										
I ₅₀	49.6 ± 1.7	56.46 ± 2.2	26.55 ± 2.5	83.00 ± 0.6	9.53 ± 0.5	0.11 ± 0.02	3.03 ± 0.18	3.23 ± 0.18	1.10 ± 0.26	17.00 ± 0.61
I ₇₅	53.7 ± 0.7	56.89 ± 0.9	25.10 ± 0.4	81.98 ± 0.5	10.28 ± 0.7	0.11 ± 0.02	3.05 ± 0.11	3.27 ± 0.17	1.31 ± 0.13	18.03 ± 0.5
I ₁₀₀	43.6 ± 0.5	55.25 ± 3.5	26.88 ± 3.0	82.12 ± 0.7	10.04 ± 0.7	0.12 ± 0.01	3.08 ± 0.17	3.23 ± 0.22	1.40 ± 0.13	17.88 ± 0.65
I ₁₂₅	38.8 ± 0.3	52.61 ± 2.3	28.23 ± 2.8	80.84 ± 0.8	10.73 ± 0.5	0.09 ± 0.01	3.27 ± 0.18	3.64 ± 0.09	1.43 ± 0.1	19.16 ± 0.83
Mean	46.4	55.3	26.69	81.99	10.15	0.11	3.11	3.34	1.31	18.01
'Sultan'										
I ₅₀	41.7 ± 1.3	44.90 ± 4.8	36.40 ± 4.4	81.30 ± 0.4	11.06 ± 0.9	0.18 ± 0.01	2.90 ± 0.32	3.07 ± 0.21	1.49 ± 0.04	18.70 ± 0.43
I ₇₅	43.7 ± 0.5	50.28 ± 1.0	30.77 ± 0.8	81.04 ± 0.2	11.13 ± 0.3	0.14 ± 0.03	3.01 ± 0.08	3.25 ± 0.21	1.43 ± 0.10	18.96 ± 0.21
I ₁₀₀	46.1 ± 0.8	47.87 ± 2.9	33.09 ± 3.0	80.95 ± 0.5	10.71 ± 0.7	0.17 ± 0.01	3.30 ± 0.31	3.31 ± 0.05	1.56 ± 0.34	19.05 ± 0.54
I ₁₂₅	36.1 ± 2.3	46.44 ± 3.6	34.73 ± 3.4	81.17 ± 0.8	10.88 ± 0.4	0.09 ± 0.02	3.30 ± 0.21	3.16 ± 0.1	1.41 ± 0.13	18.83 ± 0.78
Mean	41.9	47.37	33.75	81.12	10.95	0.14	3.12	3.2	1.47	18.88
D.mean	43.5	49.89	31.51	81.41	10.6	0.13	3.27	1.48	1.48	18.57
G. Mean	42.2	49.45	32.03	81.48	10.57	0.14	3.08	3.26	1.47	18.51

Table 4. Averages for total oil content and fatty acid contents based on irrigation interval, irrigation level and cultivar in 2018

Irrigation	Oil Content	Unsaturated fatty acids				Saturated fatty acids					
		Oleic	Linoleic	TUSFA		Palmitic	Myristic	Arachidic	Behenic	Lignoceric	TSFA
Two days											
'Halisbey'											
I ₅₀	35.2 ± 1.8	48.74 ± 1.1	32.99 ± 1.1	81.72 ± 0.6	10.28 ± 0.4	0.07 ± 0.01	3.12 ± 0.05	3.18 ± 0.18	1.37 ± 0.09	18.02 ± 0.44	
I ₇₅	47.8 ± 1.5	44.48 ± 0.7	36.43 ± 0.7	80.91 ± 0.1	11.17 ± 0.4	0.17 ± 0.03	3.16 ± 0.13	3.06 ± 0.05	1.53 ± 0.22	19.09 ± 0.10	
I ₁₀₀	45.4 ± 1.0	45.36 ± 2.2	35.74 ± 2.1	81.09 ± 0.2	10.54 ± 0.6	0.14 ± 0.02	3.2 ± 0.13	3.38 ± 0.25	1.64 ± 0.12	18.91 ± 0.17	
I ₁₂₅	41.6 ± 1.2	45.22 ± 3.5	35.63 ± 3.8	80.85 ± 0.6	10.48 ± 0.6	0.15 ± 0.03	3.25 ± 0.09	3.54 ± 0.05	1.72 ± 0.05	19.15 ± 0.61	
Mean	42.5	45.95	35.2	81.15	10.62	0.14	3.18	3.29	1.57	18.79	
'NC-7'											
I ₅₀	43.1 ± 1.9	56.03 ± 1.1	26.22 ± 1.7	82.25 ± 1.0	9.88 ± 0.7	0.12 ± 0.01	3.06 ± 0.18	3.33 ± 0.22	1.36 ± 0.19	17.75 ± 0.96	
I ₇₅	54.4 ± 1.4	52.95 ± 1.5	28.55 ± 0.5	81.50 ± 1.4	10.65 ± 0.7	0.13 ± 0.01	2.98 ± 0.16	3.31 ± 0.28	1.43 ± 0.25	18.5 ± 1.36	
I ₁₀₀	44.4 ± 1.6	53.46 ± 0.5	29.27 ± 0.3	82.74 ± 0.2	9.27 ± 0.5	0.10 ± 0.02	3.08 ± 0.18	3.46 ± 0.21	1.35 ± 0.09	17.26 ± 0.23	
I ₁₂₅	35.7 ± 1.4	54.16 ± 1.3	28.54 ± 0.6	82.70 ± 0.8	9.81 ± 0.6	0.16 ± 0.01	2.9 ± 0.09	3.21 ± 0.14	1.21 ± 0.04	17.3 ± 0.77	
Mean	44.4	54.15	28.15	82.3	9.9	0.13	3.01	3.33	1.34	17.7	
'Sultan'											
I ₅₀	43.4 ± 3.3	47.35 ± 1.2	34.39 ± 1.0	81.73 ± 0.5	10.84 ± 0.4	0.15 ± 0.04	2.97 ± 0.05	3.1 ± 0.27	1.4 ± 0.19	18.47 ± 0.55	
I ₇₅	48.3 ± 1.9	49.46 ± 3.0	31.64 ± 2.8	81.10 ± 0.2	11.07 ± 0.3	0.17 ± 0.01	3.23 ± 0.10	3.02 ± 0.21	1.41 ± 0.10	18.90 ± 0.16	
I ₁₀₀	51.2 ± 0.4	47.38 ± 0.7	34.06 ± 0.5	81.44 ± 0.8	11.06 ± 0.4	0.16 ± 0.03	2.82 ± 0.38	3.11 ± 0.06	1.41 ± 0.08	18.56 ± 0.79	
I ₁₂₅	41.1 ± 1.3	43.56 ± 1.1	36.99 ± 1.6	80.56 ± 0.6	11.44 ± 0.3	0.14 ± 0.01	2.99 ± 0.06	3.33 ± 0.10	1.54 ± 0.11	19.44 ± 0.58	
Mean	46.0	46.94	34.27	81.21	11.1	0.16	3.01	3.14	1.44	18.84	
D. mean	44.3	49.01	32.54	81.55	10.54	0.14	3.07	3.25	1.45	18.44	
Four days											
'Halisbey'											
I ₅₀	37.4 ± 1.9	48.08 ± 1.7	33.13 ± 1.5	81.21 ± 0.6	10.54 ± 0.4	0.15 ± 0.02	3.08 ± 0.12	3.38 ± 0.16	1.64 ± 0.15	18.79 ± 0.63	
I ₇₅	43.1 ± 1.1	48.23 ± 0.6	32.53 ± 1.4	80.77 ± 1.2	11.11 ± 0.5	0.09 ± 0.01	3.04 ± 0.28	3.09 ± 0.15	1.67 ± 0.16	18.99 ± 0.79	
I ₁₀₀	44.6 ± 1.1	46.73 ± 2.5	34.10 ± 3.4	80.83 ± 1.1	10.91 ± 0.9	0.16 ± 0.03	3.00 ± 0.29	3.34 ± 0.24	1.75 ± 0.24	19.17 ± 1.06	
I ₁₂₅	38.9 ± 2.2	44.99 ± 2.1	36.65 ± 2.9	81.64 ± 0.8	10.28 ± 0.7	0.16 ± 0.01	3.02 ± 0.03	3.31 ± 0.13	1.59 ± 0.02	18.36 ± 0.82	
Mean	41.0	47.01	34.1	81.11	10.71	0.14	3.03	3.28	1.66	18.83	
'NC-7'											
I ₅₀	37.2 ± 2.1	56.46 ± 2.2	26.55 ± 2.5	83.00 ± 0.6	9.53 ± 0.5	0.11 ± 0.02	3.03 ± 0.18	3.23 ± 0.18	1.10 ± 0.26	17.00 ± 0.61	
I ₇₅	46.6 ± 4.4	56.89 ± 0.9	25.10 ± 0.4	81.98 ± 0.5	10.28 ± 0.7	0.11 ± 0.02	3.05 ± 0.11	3.27 ± 0.17	1.31 ± 0.13	18.03 ± 0.5	
I ₁₀₀	48.5 ± 3.0	55.25 ± 3.5	26.88 ± 3.0	82.12 ± 0.7	10.04 ± 0.7	0.12 ± 0.01	3.08 ± 0.17	3.23 ± 0.22	1.40 ± 0.13	17.88 ± 0.65	
I ₁₂₅	41.1 ± 1.1	52.61 ± 2.3	28.23 ± 2.8	80.84 ± 0.8	10.73 ± 0.5	0.09 ± 0.01	3.27 ± 0.18	3.64 ± 0.09	1.43 ± 0.1	19.16 ± 0.83	
Mean	43.4	55.3	26.69	81.99	10.15	0.11	3.11	3.34	1.31	18.01	
'Sultan'											
I ₅₀	39.0 ± 0.7	44.90 ± 4.8	36.40 ± 4.4	81.30 ± 0.4	11.06 ± 0.9	0.18 ± 0.01	2.90 ± 0.32	3.07 ± 0.21	1.49 ± 0.04	18.70 ± 0.43	
I ₇₅	47.1 ± 1.4	50.28 ± 1.0	30.77 ± 0.8	81.04 ± 0.2	11.13 ± 0.3	0.14 ± 0.03	3.01 ± 0.08	3.25 ± 0.21	1.43 ± 0.10	18.96 ± 0.21	
I ₁₀₀	45.9 ± 1.5	47.87 ± 2.9	33.09 ± 3.0	80.95 ± 0.5	10.71 ± 0.7	0.17 ± 0.01	3.30 ± 0.31	3.31 ± 0.05	1.56 ± 0.34	19.05 ± 0.54	
I ₁₂₅	44.0 ± 3.1	46.44 ± 3.6	34.73 ± 3.4	81.17 ± 0.8	10.88 ± 0.4	0.09 ± 0.02	3.30 ± 0.21	3.16 ± 0.1	1.41 ± 0.13	18.83 ± 0.78	
Mean	44	47.37	33.75	81.12	10.95	0.14	3.12	3.2	1.47	18.88	
D.mean	42.8	49.89	31.51	81.41	10.6	0.13	3.27	1.48	1.48	18.57	
G.Mean	43.6	49.45	32.03	81.48	10.57	0.14	3.08	3.26	1.47	18.51	

The major unsaturated fatty acids of peanuts were reported as oleic and linoleic acids, and the major saturated fatty acid was reported as palmitic acid (Janila *et al.*, 2016). Therefore, these fatty acids were separately assessed from the others, and regression graphs, including years, irrigation intervals, cultivars, and irrigation levels, are presented in Figure 2.

As can be seen in Figure 2, while regression curves of oleic acid concentrations were similar for the years and irrigation intervals, they were significantly different for cultivars and irrigation levels.

In 'Halisbey' cultivar, the greatest oleic acid content was obtained from the two-day interval of I₅₀ irrigation level (48.74% in 2017 and 48.46% in 2018), and the lowest value was obtained from I₁₂₅ irrigation level (45.42% in 2017 and 45.22% in 2018). In the two-day irrigation interval of 'Halisbey' cultivar, changes in oleic acid contents were similar in I₇₅ and I₁₀₀ treatments (Figure 2a). In the four-day irrigation interval of 'Halisbey' cultivar, oleic acid content was 46.39% in 2017 and 47.01% in 2018. As it was in the two-day irrigation interval, the greatest oleic acid content was observed in I₅₀ treatment, and the lowest oleic acid content was observed in I₁₂₅ treatments of both years (Figure 2a and b).

In a two-day irrigation interval of NC-7 cultivar, the greatest oleic acid content was measured as 50.04% in 2017 and 56.03% in 2018. Despite this difference, regression curves were quite similar in both years (Figure 2 a and b). The lowest oleic contents were observed in I₇₅ and I₁₀₀ irrigation levels of both years, and slightly greater oleic acid contents were observed in the I₁₂₅ irrigation level than the previous two doses. In the four-day irrigation interval of NC-7 cultivar, the greatest oleic acid contents were observed in I₇₅ and I₅₀ irrigation levels (51.05 and 50.49% in 2017 and 56.89 and 56.46% in 2018). The lowest oleic acid contents in this irrigation interval were observed in the I₁₂₅ irrigation level (46.67% in 2016 and 52.61% in 2018) (Tables 3 and 4).

In a two-day irrigation interval of 'Sultan' cultivar, the greatest oleic acid contents were obtained from the I₇₅ irrigation level (48.68% in 2017 and 49.46% in 2018), and the lowest oleic acid contents were obtained

from I₁₂₅ treatments (45.26% in 2017 and 43.56% in 2018). In a two-day irrigation interval of 'Sultan' cultivar, years had slight effects on oleic acid contents. Consequently, resultant regression curves were quite similar to each other (Figure 2 a and b). In a four-day irrigation interval of 'Sultan' cultivar, oleic acid contents of 2017 varied between 46.19 - 47.35% based on irrigation levels. In 2018, the greatest oleic content was obtained from I₇₅ (50.28%), and the lowest oleic acid content was obtained from I₅₀ (44.90%) treatment (Table 3 and 4). The regression curves generated based on irrigation intervals, and irrigation levels of 'Sultan' cultivar were significantly different in 2017 and 2018 (Figure 2a and b).

In previous studies, oleic acid contents of peanuts were reported as between 35 - 72% and such differences were attributed to cultivars and environmental factors (Liu *et al.*, 2008; Abbas *et al.*, 2018). Significant effects of irrigation levels and drought treatments on oleic acid contents were also reported (Dwivedi *et al.*, 1996).

For linoleic acid contents, in a two-day irrigation interval, 'Halisbey' and 'NC-7' cultivars exhibited similar responses to irrigation levels in 2017 and 2018 (Figure 2c and d). In two-day irrigation interval of 2017, the lowest linoleic acid contents of these two cultivars were obtained from I₅₀ irrigation level (32.32% for 'Halisbey' and 30.17% for 'NC-7'), and the greatest linoleic acid contents were obtained from I₁₀₀ irrigation level (33.60% for 'Halisbey' and 32.62% for NC-7) (Table 3). In 2018, 'Halisbey' and NC-7 cultivars also exhibited the same responses. The lowest linoleic acid content was observed in the lowest irrigation level (I₅₀). The greatest linoleic acid content was observed in I₇₅ treatment of 'Halisbey' (36.43%) and I₁₀₀ treatment of 'NC-7' (29.37%). In the four-day irrigation interval, linoleic acid contents of these two cultivars had similar variations based on irrigation levels. The lowest linoleic acid content was obtained from I₇₅ treatment (Figure 2c and d).

In Sultan cultivar, similar regression curves were obtained for linoleic acid contents in both years and irrigation intervals. The lowest linoleic acid contents at a two-day irrigation interval of 2017 and both two and four-day irrigation intervals of 2018 were observed in the I₇₅ irrigation level (Figure 2c and d).

The total saturated fatty acid content of the cultivars was greater in 2018 than in 2017. Among the present cultivars, 'NC-7' had the greatest total saturated fatty acid content. Considering the year x cultivar x irrigation interval x irrigation level interactions, the greatest total saturated fatty acid ratio (82.74%) was obtained from the I₁₀₀ irrigation level of the second year at a two-day irrigation interval of NC-7 cultivar (Table 3).

Oleic acid is the second unsaturated fatty acid of peanuts, and oleic acid contents of peanuts were reported as between 20 - 45% by Liu *et al.* (2008) and between 20.9 - 43.2% by Carrin and Carelli (2010). The change in linoleic acid content based on genetics and environmental factors (drought stress) directly reflects on oleic acid content. In other words, decreasing oleic acid contents were observed with increasing linoleic acid contents (Akram *et al.*, 2018). Just because of significant correlations between these fatty acids, some researchers indicated oleic/linoleic acid ratio (O/L) as a significant quality parameter. It was reported in previous studies that plants under drought stress and plants grown in cool regions generally had low O/L ratios (Hashim *et al.*, 1993; Dwivedi *et al.*, 1993).

Palmitic acid was the major saturated fatty acid of peanut cultivars. For palmitic acid contents, 'Halisbey' cultivar exhibited similar reactions against different irrigation levels in two and four-day irrigation intervals of 2017 and 2018 (Figure 2 and f). In a two-day irrigation interval of 'Halisbey' cultivar, the lowest palmitic acid content was obtained from the I₅₀ irrigation level (10.28% in 2017 and 10.21% in 2018) (Table 3 and 4). The greatest palmitic acid ratios of the same cultivar were obtained from I₇₅ treatment in a two-day irrigation interval and I₁₀₀ treatment in a four-day irrigation interval. For palmitic acid content, the most extreme reactions to entire experimental factors were presented by 'NC-7' and 'Sultan' cultivars. In regression analysis, the lowest coefficient of determination values was identified in two and four-day irrigation intervals of these two cultivars (Figure 2e and f).

In both years, in a two-day irrigation interval, the palmitic acid content of 'NC-7' cultivar initially increased, then decreased with increasing irrigation levels. In the four-day irrigation interval, palmitic acid

contents increased in both years with increasing irrigation levels. The lowest palmitic acid content in this irrigation interval was obtained from I₅₀ and the greatest from I₁₂₅ treatments. In ‘Sultan’ cultivar, in a two-day irrigation interval, palmitic acid contents increased in both years with increasing irrigation levels, however, in four-day irrigation interval, palmitic acid contents decreased with increasing irrigation levels (Figure 2 e and f).

The other unsaturated fatty acids of peanut seeds included arachidic, behenic, lignoceric, and myristic acids. The averages for these fatty acids based on experimental factors are provided in Tables 3, and 4 and regression curves are presented in Figure 2.

For arachidic acid, regression curves were similar to each other (Figures 3a and b). In both years of the experiments, in two-day irrigation interval, arachidic acid contents decreased in ‘NC-7’ cultivar and increased in ‘Halisbey’ and ‘Sultan’ cultivars with increasing irrigation levels. In the four-day irrigation interval, arachidic acid contents increased in ‘NC-7’ and ‘Sultan’ cultivars with increasing irrigation levels in both years. In ‘Halisbey’ cultivar, in the first year, arachidic acid contents decreased with I₇₅ and I₁₀₀ treatments, but increased with I₁₂₅ irrigation level; in the second year, arachidic acid contents decreased with increasing irrigation levels.

In the first year, the lowest behenic acid contents of two-day irrigation intervals were obtained from I₇₅ treatments of ‘Halisbey’ and ‘Sultan’ cultivars, and the lowest behenic acid contents of four-day irrigation intervals were obtained from I₅₀ and I₁₂₅ treatments. In 2018, in a two-day irrigation interval, the lowest behenic acid contents were observed in ‘Halisbey’ and ‘Sultan’; in a four-day irrigation interval, the lowest values were obtained from the I₇₅ irrigation level of ‘Halisbey’ and ‘NC-7’ cultivars. In both years, the greatest behenic acid contents of two-day irrigation intervals were obtained from I₁₂₅ treatment of ‘Halisbey’ cultivar, and the greatest behenic acid contents of four-day irrigation intervals were obtained from I₁₂₅ treatment of ‘NC-7’ cultivar (Figure 3c and d).

For lignoceric acid contents, ‘Halisbey’ and ‘Sultan’ cultivars had similar reactions in 2017 and 2018 against irrigation intervals and irrigation levels. In both years, the lignoceric acid content of both cultivars increased in two-day irrigation intervals and decreased in four-day irrigation intervals with increasing irrigation levels. In ‘NC-7’ cultivar, lignoceric acid contents decreased in two-day irrigation intervals and increased in four-day irrigation intervals with increasing irrigation levels in both years (Figure 3e and f).

Myristic acid was the least common unsaturated fatty acid in present experiments. ‘NC-7’ and ‘Sultan’ cultivar and similar changes in myristic acid contents with the years and irrigation intervals. In ‘NC-7’ cultivar, in a two-day irrigation interval of both years, myristic acid contents initially decreased with irrigation levels but reached the maximum in I₁₂₅ treatment. In four-day irrigation intervals of the same cultivar, a reverse case was evident, there was an increase in I₅₀, I₇₅, and I₁₀₀ treatments, but a decrease in I₁₂₅ treatment (Table 3 and 4). In two-day irrigation intervals of ‘Halisbey’ cultivar, myristic acid contents increased in I₅₀, I₇₅, and I₁₀₀ treatments and decreased in I₁₂₅ treatment in both years (Figure 3g and h). In ‘Sultan’ cultivar, myristic acid contents did not change significantly with irrigation levels in two and four-day irrigation intervals of the first year; significant decreases were observed in myristic acid content, especially in four-day irrigation intervals of the second year with increasing irrigation levels.

The biplot graphs generated for visual assessment of the relationships between the fatty acids of the cultivars based on irrigation intervals and irrigation levels are presented in Figure 4. Each one of the present biplots explained over 60% of total variations. Since Singkham *et al.* (2010) used the oleic/linoleic acid ratio as a quality criterion for peanuts, O/L ratio is presented in Figure 4.

As can be seen in Figure 4a, investigated fatty acids formed four groups in ‘Halisbey’ cultivar in the first year. There were significant negative correlations between G-IV (linoleic acid) and G-II (oleic acid and oleic/linoleic acid ratio); between G-III (arachidic acid, TUSFA) and G-I (the other saturated fatty acids, TSFA, and oil ratio) (Figure 4a). In the second year, TUSFA alone formed Group-IV and had negative correlations with Group-II (lignoceric, palmitic acid, oil ratio, and TSFA). Group-III was composed of oleic acid and oleic/linoleic acid ratio and had negative correlations with Group-I (Figure 4b). In both years of ‘Halisbey’ cultivar, the group including oleic acid (G-II in the first year and G-III in the second year) negatively correlated with the group, including oil ratio (G-I in the first year and G-II in the second year). Such a finding

indicated that the treatments to increase the oil ratio of this cultivar would reduce the oleic/linoleic acid ratio. Like this, in both years, 2D-I₅₀, 4D-I₅₀, and 4D-I₇₅ treatments increased oleic acid contents, and 4D-I₁₀₀ treatment increased oil content in both years (Table 3 and 4).

In NC-7 cultivar, the interactions between oil ratio and fatty acids were similar in both years. In the first year, TUSFA and myristic acid alone formed single groups. In the second year, myristic acid and TUSFA were placed in the same group. In the first year, there were significant negative correlations between Group-V (oleic acid, oil content, oleic/linoleic acid ratio) with the greatest vector length and Group-II (linoleic acid). There were significant negative correlations between Group-IV (TUSFA) and Group-I (arachidic, palmitic, lignoceric, behenic acids, and TSFA) (Figure 4c). In the second year, there were significant negative correlations between Group-V (oleic and oleic/linoleic acid ratio) and Group-II (linoleic acid) and between Group-III (TUSFA and Myristic) and Group-I (oil content, arachidic, palmitic, lignoceric, behenic acids, and TSFA) (Figure 4d). In 'NC-7' cultivar, the oil ratio had significant positive correlations with oleic acid and oleic/linoleic acid ratios. Thus, they were placed into the same attribute group (G-V) in the first year. In the second year, the level of correlation of oil ratio with oleic acid and oleic/linoleic ratios was lower. Thus, oil ratio was placed into a different group. In NC-7 cultivar, 4D-I₅₀, 2D-I₅₀, and 4D-I₇₅ treatments were prominent for high oil and oleic acid content in the first year, and besides these treatments, 4D-I₁₀₀ was also prominent for both oil ratio and oleic acid content in the second year (Figure 4c and d).

In 'Sultan' cultivar, there were significant negative correlations between Group-IV (TUSFA and myristic) and Group-II (behenic, TSFA, and arachidic) and between Group-III (oleic, oil content, oleic/linoleic acid ratio) and Group-I (linoleic, lignoceric, and palmitic) in the first year (Figure 4e). In the second year, arachidic acid alone formed a group (Group-3), and this group had significant negative correlations with Group-V (TUSFA, myristic) and Group-I (linoleic). The greatest negative correlation was observed between Group-I (linoleic) and Group-IV (oil content, oleic acid, and oleic/linoleic acid ratio) (Figure 4f). The most stable and positive correlations between oil content and oleic acid were observed in the 'Sultan' cultivar. In this cultivar, oil content, oleic acid, and oleic/linoleic acid ratio were placed in the same attribute group. The 2D-I₇₅ treatment had positive correlations with this attribute group and placed in the closest position. Such a case indicated that 2D-I₇₅ was the best irrigation combination for high oil content and thus high oleic acid content in Sultan cultivar (Figure 4e and f).

High oleic acid content is the primary quality attribute in peanuts, as can be inferred from the present findings that oleic acid contents varied with the cultivars and environmental conditions. When an appropriate irrigation program was applied, high oleic acid contents could be achieved based on the genetic potential of the cultivar. As can be seen in Figure 4, the greatest oleic contents in 'Halisbey' and 'NC-7' cultivars were obtained from I₅₀ treatment of two and four-day irrigation intervals. In 'Sultan' cultivar, the greatest oleic acid content was obtained from I₇₅ treatment of two and four-day irrigation intervals of the second year.

Three peanut cultivars used in the present experiments were the most common cultivars of Turkey. As a general average, the greatest oleic acid content (51.90%) was obtained from 'NC-7' cultivar, and it was followed by 'Sultan' (47.12%) and 'Halisbey' (46.40%) cultivars. Similarly, in peanut samples taken from common peanut-cultivated regions, 'NC-7' cultivar had greater oleic acid content than 'Sultan' and 'Halisbey' cultivars (Kalefetoğlu *et al.*, 2018).

Nutritional quality, taste, and shelf life of peanut products and seeds largely depend on relative quantities of saturated fatty acids (SFA), mono-unsaturated fatty acids (MUFA) and poly-unsaturated fatty acids (PUFA). High oleic acid contents play a significant role both in human health and thermo-oxidative stability of peanuts for industrial purposes (Nawade *et al.*, 2018). Singkham *et al.* (2010) indicated that genetics was the most significant factor affecting the fatty acid composition of peanuts, genotype x environment interactions were also significant for oleic, linoleic acids and O/L ratio and genetic effects especially on oleic acid contents may decrease based on (GxE) interactions. Climate, irrigation, and soil conditions are effective primary factors in peanut cultivation. During the seed ripening stage, environmental factors generally increase oleic acid contents and decrease the other fatty acid quantities (Sanders, 1980). In the present study, significant

variations were observed in the oleic contents of three peanut cultivars with irrigation intervals and irrigation levels. In the two-day irrigation interval, oleic acid contents decreased in 'NC-7', and 'Halisbey' cultivars with increasing irrigation levels and the greatest oleic acid content in Sultan cultivar were achieved in the I₇₅ irrigation level. In a four-day irrigation interval, the response of cultivars for oleic acid content varied with the years and irrigation levels. In this irrigation interval, the greatest oleic acid content was obtained from I₇₅ treatment of 'NC-7' cultivar. The oleic acid contents were generally greater in 2018 than in 2017. Such a case was mostly attributed to climate factors. It was reported in a previous study that high temperatures during the seed development phase reduced linoleic acid content and increased oleic acid content of peanut oil (Casini *et al.*, 2003). Plant tolerance of high temperatures largely depends on soil moisture, thus irrigation treatments. The oleic and stearic acid content of peanuts grown in rainy seasons was greater than the peanuts grown in dry seasons and linoleic, and palmitic acid contents also increased in rainy seasons (Singkham *et al.*, 2010). Chaiyadee *et al.* (2013) reported that droughts improved the oil quality of peanuts, increased oleic acid contents, genotype x environment interactions influenced fatty acid composition, resistant and sensitive genotypes exhibited similar response to droughts and recommended further research about the effects of droughts on oleic acid content.

Since irrigations have quite significant effects on peanut oil quality, effects of irrigation intervals and irrigation levels on oil content and fatty acid composition of three commonly cultivated peanut cultivars of Turkey were put forth in this study. Especially the effects of irrigation interval x irrigation level interactions on fatty acid composition were investigated. In previous studies conducted on peanuts, either irrigation intervals or irrigation levels, were investigated alone. Together with different peanut cultivars, two factors were not considered together in previous studies. Previous studies mostly focused on a single cultivar with different irrigation intervals or with different irrigation levels. Aydınşakir *et al.* (2019) applied different water-deficit levels to 'NC-7' peanut cultivar under Mediterranean conditions and reported that oleic acid contents decreased with increasing irrigation levels, linoleic acid contents increased until I₇₅ treatment and decreased in I₁₀₀ and I₁₂₅ treatments. In another study, decreasing oleic contents were reported with increasing irrigation levels, and the greatest linoleic acid contents were reported for I₇₅ and I₁₀₀ treatments (Boydak *et al.*, 2010).

Conclusions

Regression graphs facilitated visual assessment of oil content, and fatty acid composition of peanut cultivars and biplot graphs facilitated the assessment of cultivar x years x irrigation interval x irrigation level interactions. With the aid of biplot graphs, the best irrigation interval x irrigation level combination for each attribute group was tried to be identified. In two and four-day irrigation intervals, the greatest oil contents were generally achieved in I₇₅ and I₁₀₀ irrigation levels. Recommendations of cultivar, irrigation interval, and irrigation level were provided for high oleic acid contents. It was concluded based on present findings that high oleic acid contents could be achieved based on genetic potential of the cultivars with a proper irrigation program; I₅₀ treatment could be used at two or four-day irrigation intervals in 'Halisbey', and 'NC-7' cultivars and I₇₅ treatment could be used in four-day irrigation interval in 'Sultan' cultivar to get high oleic acid contents under sandy soil conditions.

Authors' Contributions

Conceptualization: SA and IT; Methodology: IT; Validation: SA, MK and IT; Formal analysis: SA and MK; Investigation: SA, IT and MK; Data curation: MK, KK and ASB; Funding acquisition: IT; Writing: SA; Review and editing: SA, MK and IT. All authors read and approved the final manuscript.

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Conflict of Interests

The authors declare that there are no conflicts of interest related to this article.

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