Effect of Row Space and Irrigation on Seed Composition of Turkish Sesame (*Sesamum indicum* L.)

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ABSTRACT: The effect of row space (RS) and irrigation (IR) on total protein, total oil, and fatty acid composition of Harran-grown sesame seed was studied. Total oil content of sesame varied from 46.4 to 51.5%. The oil and protein contents were significantly different among treatments ($P < 0.01$) in 1998 and 1999. IR affected oil content significantly ($P < 0.01$) in both years, and RS had no significant effect. The protein content was significantly influenced by RS and IR at $P < 0.05$ and $P < 0.01$, respectively. RS 70 cm had the highest protein content followed by RS 60, 50, and 40 cm, respectively. IR every 24th day resulted in the highest level of protein, followed by 18th-, 12th-, and 6th-day irrigation, respectively. Correlation coefficients between protein and oil content were –0.34 in 1998 and –0.59 in 1999. RS ($P < 0.05$) and IR ($P < 0.01$) influenced oleic and linoleic acid contents significantly. Interactions of RS and IR were also found to be significant ($P < 0.05$) over the oleic and linoleic acid levels.

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Sesame (*Sesamum indicum* L.) is probably the most ancient oilseed known and used by humans as a food source. This important annual oilseed crop has been cultivated for centuries, particularly in the developing countries of Asia and Africa, for its high content of both excellent quality edible oil (42–54%) and protein (22 to 25%) (1).

Sesame seeds typically give a greater yield of oil than many other oilseeds. However, wide ranges of oil contents, from 37 to 63%, have been reported for sesame seed (2–4). The composition is markedly influenced by genetic, climatic, and agronomic factors and varies considerably within variety. Shorter-season varieties tend to have higher oil content than longer-season varieties (5). The dark-colored seeds generally have higher oil content (6). High rates of nitrogen fertilizer reduce oil content (7–9). Irrigation (IR) raises yield in arid and desert areas (9). Dry periods during germination and fruit formation are detrimental to the crop (10).

Sesame production in Turkey is mostly in an area influenced by the Mediterranean climate. Turkish sesame has a great range of variation in genetic, morphological, and quality characteristics (5). The realization of Turkey's South Anatolian IR project (GAP) could possibly make sesame an important plant as a second crop in the region.

Although papers have been published on protein and oil contents of sesame seed (2,11–14), information on how IR influences seed composition is quite limited. The aims of this research were to investigate the effect of row space (RS) and IR on oil, protein, and fatty acid (FA) composition of a Harran-grown sesame variety.

MATERIALS AND METHODS

In this study, a local dark-colored sesame cultivar was grown as a second crop behind soybeans in 1998 and 1999 by the Faculty of Agriculture, Department of Crop Science, Harran University (Sanliurfa, Turkey). The experimental design for IR and RS trials was a randomized block with three replicates. Trials were conducted on a silty-clay soil at pH 7.5 and lime content of 9.9% without a salinity problem, which was low in organic matter (1.12%). All treatments were fertilized with 5 kg nitrogen and 6 kg phosphorus per decare. Sowing was performed on nonirrigated seedbeds. Four sprinkle-type IR treatments were applied at 6-d intervals, up to the 24th day after germination. The space between rows was 40, 50, 60, or 70 cm. Each row was 4 m long with a 20-cm distance between seeds. IR was terminated 15 to 20 d before harvest. The length of growing period varied from 130 to 145 d; IR every 6th day produced the longest growth period, and every 24th day produced the shortest. The meteorological data were recorded from planting date to the harvest of each treatment (Table 1).

Composition analyses. Sesame seed was ground in a lab mill, and crude oil was extracted at 70°C for 1 h using *n*-hexane (15). Oil samples were stored in brown bottles at –30°C until analysis. Protein content (N × 6.25) of sesame seed was determined by a

TABLE 1
Meteorological Data for Sesame-Growing Area in 1998 and 1999[a]

	Average temperature (°C)		Relative humidity (%)		Rainfall (mm)	
Months	1998	1999	1998	1999	1998	1999
June	29.4	28.8	22.3	43.6	0.6	1.6
July	33.0	32.5	43.8	39.7	NR	NR
August	33.4	31.2	41.4	44.7	NR	26.0
September	27.0	26.2	53.3	46.8	NR	NR
October	21.5	21.0	49.5	51.2	0.1	8.4
November	16.7	13.5	66.4	50.9	22.7	0.8

[a]NR, no rainfall.

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Kjeldahl procedure (16) using the Tecator Kjeltec Auto Analyzer, Model 1030 (Hoganas, Sweden) (16). The FA composition of seed was determined with a Hewlett-Packard 6890 Series II gas chromatograph (Palo Alto, CA) equipped with a 15% OV-275 on Chromosorb PAW11/120 stainless steel column (6.1 m × 2 mm i.d.). Fatty acid methyl esters were prepared according to AOAC Method No. 963.33 (17). The column temperature was 215°C; injector and detector temperatures were 250°C. The carrier gas was nitrogen, with a flow rate of 9.5 mL/min. FA were identified by retention time relative to authentic standard. Heptadecanoic acid was used as an internal standard.

Statistical analysis. Statistical evaluation was carried out using the Statistical Analysis System (18), with a general linear model and analysis of variance. Significant differences between means were determined using Duncan's multiple range test at $P < 0.05$ and $P < 0.01$.

RESULTS AND DISCUSSION

The effect of changes of RS on oil, protein, and FA contents averaged over 1998 and 1999 is presented in Table 2. Total oil content of sesame samples varied from 46.4 to 51.5%. The RS 70-cm treatment in 1999 resulted in a maximal oil value. RS of sesame also affected protein content ($P < 0.05$), where the protein content of the RS 70-cm treatment was the highest among RS treatments. While RS 70 cm had the highest oleic acid, the highest linoleic acid was obtained from RS 40 cm.

The effect of IR on oil, protein, and FA contents averaged over 1998 and 1999 is shown in Table 3. IR affected oil content significantly ($P < 0.01$) for both years. In a similar study, Majumdar and Pal (9) found that the delay of IR from flowering to capsule development when two irrigation treatments were applied did not affect oil content. A study by Kumar *et al.* (10) reported that two IR resulted in the maximum oil and that moisture stress caused a significant reduction in oil content in the sesame seed. The protein content of sesame seed varied from 19.8% in 1998 (RS 60 cm and a 6-d IR interval) to 24.1% in 1999 (RS 50 cm and a 24-d IR interval). Bahkali and Hussain (6) reported similar levels of protein content for Gizan-grown sesame samples. The protein content was also influenced ($P < 0.01$) by IR. IR every 24th day produced the highest level of protein followed by 18th-, 12th-, and 6th-day IR, respectively (Table 3).

TABLE 2
Effect of Row Space on Oil, Protein, and Fatty Acid Contents Averaged During 1998 and 1999[a]

	Row space			
Parameter (%)	40 cm	50 cm	60 cm	70 cm
Protein	22.3b	22.9a,b	22.3b	23.0a
Oil	49.5a	49.2a	49.3a	49.8a
Oleic acid	42.0b	42.8b	42.8b	44.2a
Linoleic acid	41.7a	40.9b	40.7b	38.5c

[a]The different letters following mean values in rows indicate significant differences at $P < 0.05$.

TABLE 3
Effect of Irrigation on Oil, Protein, Fatty Acid Contents Averaged During 1998 and 1999[a]

	Irrigation every			
Parameter (%)	6 d	12 d	18 d	24 d (control)
Protein	21.5b	22.5b	23.2a	23.3a
Oil	49.0b	49.0b	49.6a	50.2a
Oleic acid	43.7a	43.4a,b	42.7b,c	42.0c
Linoleic acid	39.5c	40.0b,c	40.8a,b	41.4a

[a]The different letters following mean values in rows indicate significant differences at $P < 0.05$.

Statistical evaluation revealed that RS had no significant effect on the oil content of sesame for both years (Table 4). The oil content varied significantly ($P < 0.01$) between 1998 and 1999. Interactions of RS × Year, RS × IR, IR × Year, and RS × IR × Year were found to have a significant effect over oil content of sesame. Many studies have found that ecological condition, maturity, variety, and location affect the oil content of sesame (11,19,20). Bahkali and Hussain (6) reported that dark sesame seed has significantly higher oil but lower protein content than white seeds. These results agree with the results of the current study. Similar results were also reported by Al-Kahtani (2) and Baydar *et al.* (5), who investigated sesame seed from the South Anatolian region of Turkey.

Significant differences ($P < 0.01$) were found in protein contents of sesame samples between 1998 and 1999 (Table 4). This can be explained by the fact that annual climatic conditions were not identical. The literature indicates that the protein concentration increases at higher temperatures (21). Interactions of RS × Year and IR × Year were found to have a significant effect ($P < 0.01$) over protein content of sesame. The correlation coefficient (r) between protein and oil content was –0.34 and –0.59 in 1998 and 1999, respectively. A negative correlation between total oil and total protein due mainly to environment and genotype-related variations has been reported (21).

The FA compositions of sesame oils in 1998 are illustrated in Table 5. Palmitic (16:0), stearic (18:0), oleic (18:1), and linoleic (18:2) acids were the principal FA. The proportion of linoleic acid (18:3) varied between 37.7 and 43.4%, while

TABLE 4
Analysis of Variance (mean square values) for Sesame Seed Composition and Agronomic Factors[a]

				Fatty acids	
SV	DF	Oil (%)	Protein (%)	Oleic (%)	Linoleic (%)
RS	3	1.73	3.38*	9.57*	22.04*
Year	1	11.48**	8.05**	—	—
IR	3	7.83**	16.22**	6.88**	2.13**
RS × Year	3	3.63**	4.89**	—	—
RS × IR	9	3.87**	0.46	2.82*	3.53**
IR × Year	3	4.87**	6.84**	—	—
RS × IR × Year	9	3.54**	1.47	—	—
Error	64	0.98	0.98	1.00	1.00

[a]SV, source of variation; DF, degree of freedom; RS, row space; IR, irrigation.
*Significant at $P < 0.05$; **significant at $P < 0.01$.

TABLE 5
The Effect of Row Space and Irrigation on Fatty Acid Composition (1998)[a]

RS (cm)	R (day)	C16	C16:1	C18	C18:1	C18:2	C18:3	C20	C20:1	C22
40	6th	9.4	0.3	5.5	43.6	39.9	0.4	0.6	0.2	ND
	12th	9.1	0.3	5.4	42.6	41.1	0.4	0.6	0.2	0.0
	18th	9.7	0.3	4.8	41.4	42.5	ND	0.6	0.4	0.2
	24th	9.5	0.4	5.0	40.4	43.4	ND	0.4	0.5	0.3
50	6th	9.5	0.3	5.7	44.6	38.7	ND	0.4	0.6	0.2
	12th	9.0	0.3	5.4	43.4	40.7	ND	0.4	0.6	0.2
	18th	9.6	0.3	3.3	42.8	41.6	ND	0.4	0.6	0.4
	24th	9.3	0.3	5.7	41.3	42.4	ND	0.4	0.5	0.1
60	6th	9.5	0.3	5.8	43.4	39.8	ND	0.4	0.6	0.2
	12th	9.4	0.3	5.4	42.9	40.6	ND	0.4	0.6	0.4
	18th	9.3	0.3	5.5	42.5	41.2	ND	0.4	0.6	0.2
	24th	9.6	0.3	5.7	42.4	41.1	ND	0.4	0.3	0.2
70	6th	9.6	0.3	6.0	43.1	39.8	ND	0.4	0.5	0.3
	12th	9.7	0.3	6.1	44.7	37.7	ND	0.4	0.7	0.4
	18th	9.5	0.3	6.0	44.9	37.9	ND	0.4	0.6	0.4
	24th	9.8	0.3	5.7	43.9	38.8	ND	0.4	0.6	0.5

[a]RS, row space; IR, irrigation; ND, not detected.

oleic acid ranged from 40.4 to 44.9%. These findings are comparable with the results of Bahkali and Hussain (6). As indicated by many researchers (12,22,23), the variation in FA composition of vegetable oils depends on agronomic and climatic factors during the growing season. IR, on the other hand, has been reported to have no significant effect on free FA acid level in canola (23). In this investigation oleic and linoleic acid contents were affected by RS ($P < 0.05$) and IR ($P < 0.01$) significantly. Interaction of RS and IR was also found to have a significant effect at $P < 0.05$ and $P < 0.01$ over the oleic and linoleic acids, respectively (Table 4).

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