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# Seed Composition of Soybeans Grown in the Harran Region of Turkey As Affected by Row Spacing and Irrigation

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This study was conducted to determine the effects of row spacing (RS) and irrigation (IR) on protein content, oil content, and fatty acid composition of soybeans grown in the Harran region of Turkey. Oil content of the seed varied from 20.9 to 22.3%. Oil and protein contents were both affected by year. RS and IR affected protein and oil contents significantly ($P < 0.01$) in both years. RS of 70 cm had the highest protein content, followed by RS of 60, 40, and 50 cm, respectively. IR every 3rd day resulted in the highest level of protein, followed by 6th, 9th, and 12th day irrigation, respectively. The correlation coefficient ($r$) between protein and oil content was −0.791 in 1998 and −0.721 in 1999. RS ($P < 0.01$) and IR ($P < 0.01$) influenced oleic and linoleic acid contents significantly. Interactions of RS and IR were also found to be significant ($P < 0.05$) for the oleic and linoleic acid contents of soybeans.

**KEYWORDS: Soybean; irrigation; row space; oil and protein; fatty acid**

## INTRODUCTION

Soybeans are an economical and valuable agricultural commodity because of their unique chemical composition. Among cereal and other legume species, soybean seeds contain the highest amount of protein (35−45%) and a relatively high level of oil (20−25%) (*1*).

The actual composition of soybeans depends on many factors, including genotype, growing season, geographic location, and agronomic practices (*2*−*5*). The effect of row spacing (RS) on the protein and oil contents of soybean (*6*, *7*), sesame (*8*, *11*), lupin (*9*), corn (*10*), alfalfa (*12*), wheat (*13*), and oat (*14*) has been reported. Irrigation (IR) has also been known to affect oil and protein contents in soybean (*15*) and sesame (*16*, *17*). It is well-known that climate has a great influence on the ripeness and chemical composition of vegetable oils (*18*). Climate and cultivar both affect the linolenic acid content of soybean oil (*19*). The negative correlation between oil and protein contents has been well documented (*20*−*22*).

In Turkey, soybean adaptation trials started in 1980, and soybeans have been grown since 1982 in various regions including Harran (*23*). When the Southeastern Anatolia Project (GAP), which is the largest irrigation project in terms of acreage in the world, is complete, the irrigated land will amount to 141000 ha. Soybeans are expected to be a second crop in terms of planting date in the region. The effects of agronomic factors on the seed protein and oil of soybeans have not been quantified under the growing conditions of the Harran region. Information regarding the effect of irrigation on seed composition may be valuable for soybean growers. Effects of cultivar and climate on seed composition are also of interest to the soybean industry. This study was conducted to determine the effect of row spacing and irrigation on oil and protein contents and fatty acid composition of soybeans.

## MATERIALS AND METHODS

Soybeans [*Glycine max* (L.) Merr. cv. Asgrow 3935] were grown as a second crop behind corn (*Zea mays* L.) in 1998 and 1999 in Harran, Turkey. The experimental design was a randomized block of split block with three replications. Field tests were conducted on the silty-clay soil with a pH of 7.5 and a lime content of 9.9%. All treatments were fertilized with 5 kg of nitrogen and 6 kg of phosphorus per da. Sowing was performed on nonirrigated seedbeds. Sprinkle-type irrigation was applied every 3rd, 6th, 9th, and 12th day after emergence. The spaces between rows were 40, 50, 60, and 70 cm. Each row was 4 m long with a 3 cm distance between seeds. Irrigation was terminated 15−20 days before harvest. The length of the growing period varied from 115 to 125 days, with every 3rd day irrigation being the longest growth period and irrigation every 12th day the shortest growth period. Meteorological data were recorded from planting to harvest of each treatment (**Table 1**).

**Composition Analyses.** Soybeans were ground with a laboratory mill (Braun, type 4-041), and the oil content of seeds was determined by a Soxhlet extraction method using *n*-hexane as solvent at 70 °C for 6 h (*24*). Protein content (N × 6.25) of soybean samples was determined acccording to the Kjeldahl procedure (*25*) using a Tecator Kjeltec Auto Analyzer, model 1030. The fatty acid composition of seed was determined with a Hewlett-Packard 6890 series II gas chromatograph

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**Table 1.** Meteorological Data for Soybean Growing Area in 1998 and 1999

| | av temp (°C) | | relative humidity (%) | | rainfall (mm) | |
|---|---|---|---|---|---|---|
| month | 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[a] | NR |
| Aug | 33.4 | 31.2 | 41.4 | 44.7 | NR | 26.0 |
| Sept | 27.0 | 26.2 | 53.3 | 46.8 | NR | NR |
| Oct | 21.5 | 21.0 | 49.5 | 51.2 | 0.1 | 8.4 |
| Nov | 16.7 | 13.5 | 66.4 | 50.9 | 22.7 | 0.8 |

[a] NR, no rainfall.

**Table 2.** Effect of Row Spacing on Oil, Protein, and Fatty Acid Contents Averaged over 1998 and 1999[a]

| | row spacing | | | |
|---|---|---|---|---|
| parameter | 40 cm | 50 cm | 60 cm | 70 cm |
| protein (%) | 38.05bc | 37.65c | 38.48b | 39.05a |
| oil (%) | 21.80ab | 22.05a | 21.35b | 21.55ab |
| oleic acid (%) | 27.16a | 26.10b | 27.23a | 27.10a |
| linoleic acid (%) | 50.05b | 51.25a | 49.78bc | 49.56c |

[a] Different letters following mean values in a row indicate significant differences at $P < 0.05$. Values are the average of three replications.

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 an AOAC (*25*) method. 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 $min^{-1}$. Fatty acids were identified by retention time relative to that of an authentic standard. Heptadecanoic acid was used as internal standard.

**Statistical Evaluation.** Statistical evaluation was carried out using SPSS package version 7.50 with general linear model (GLM) analysis of variance (ANOVA). Duncan's multiple-range test was used to determine significant differences between means.

## RESULTS AND DISCUSSION

Oil content varied from 21.35 to 22.05% (**Table 2**). A row spacing of 50 cm produced maximum oil value. Row spacing had a significant effect ($P < 0.05$) on soybean oil content averaged over 1998 and 1999. Protein content was significantly affected by row spacing (**Table 2**). The row spacing of 70 cm produced the highest protein value (39.05%), whereas a row spacing of 50 cm yielded the lowest value (37.65%). These results slightly differ from those of Dwivedi et al. (*26*), who reported protein content was moisture sensitive. These differences can be explained by the fact that climatic conditions were not identical in the 1998 and 1999 growing seasons. The literature indicates that the protein concentration should increase at higher temperature (*26*) similar to climatic condition of Harran.

The effects of irrigation on oil, protein, and fatty acid contents averaged over 1998 and 1999 are shown in **Table 3**. The oil content of soybean irrigated on the 6th day was significantly ($P < 0.05$) different from that of other treatments. In contrast, 12th day irrigation produced a significantly different protein value compared to other treatments. A similar trend was observed for oleic and linoleic acid contents, respectively.

Analysis of variance for chemical composition and agronomic properties of soybean is presented in **Table 4**. Interactions of row spacing × year ($P < 0.01$), row spacing × irrigation, irrigation × year, and row spacing × irrigation × year were significant at either $P < 0.05$ or $P < 0.01$ for protein and oil contents except for the interaction between row spacing and year for oil content.

**Table 3.** Effect of Irrigation on Oil, Protein, and Fatty Acid Contents Averaged over 1998 and 1999[a]

| parameter | 3rd day | 6th day | 9th day | 12th day (control) |
|---|---|---|---|---|
| protein (%) | 38.60a | 38.58a | 38.45a | 37.60b |
| oil (%) | 21.45a | 20.91b | 22.10a | 22.28a |
| oleic acid (%) | 26.80b | 26.51b | 26.65b | 27.63a |
| linoleic acid (%) | 50.51a | 50.58a | 50.35a | 49.20b |

[a] Different letters following mean values in a row indicate significant differences at $P < 0.05$. Values are the average of three replications.

**Table 4.** Analysis of Variance (Mean Square Values) for Soybean Seed Composition and Agronomic Factors

| | | | | fatty acids | |
|---|---|---|---|---|---|
| source | DF[a] | oil (%) | protein (%) | oleic (%) | linoleic (%) |
| RS[b] | 3 | 1.11*[c] | 4.31** | 3.41** | 6.84** |
| year | 1 | 1.73* | 51.77** | | |
| IR[d] | 3 | 4.61** | 2.71** | 3.01** | 5.01** |
| RS × year | 3 | 0.32 | 2.64** | | |
| RS × IR | 9 | 3.71** | 2.38* | 4.66** | 3.85** |
| IR × year | 3 | 31.81** | 40.19** | | |
| RS × IR × year | 9 | 9.35** | 10.14** | | |
| error | 64 | 0.38 | 0.32 | | |
| error | 32 | | | 0.31 | 0.16 |

[a] DF, degree of freedom. [b] RS, row spacing. [c] *, significant at $P < 0.05$; **, significant at $P < 0.01$. [d] IR, irrigation.

**Table 5.** Effect of Row Spacing and Irrigation on Fatty Acid Composition (1998)

| RS[b] | IR[c] | fatty acid composition[a] (%) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| (cm) | (day) | 16:0 | 16:1 | 18:0 | 18:1 | 18:2 | 18:3 | 20:0 | 20:1 | 22:0 |
| 40 | 3 | 10.9 | 0.2 | 4.5 | 27.4 | 50.0 | 6.0 | 0.4 | 0.1 | 0.4 |
| | 6 | 11.0 | 0.1 | 4.4 | 25.7 | 51.5 | 6.1 | 0.3 | 0.1 | 0.4 |
| | 9 | 11.0 | 0.2 | 4.8 | 26.7 | 50.4 | 5.8 | 0.4 | 0.2 | 0.4 |
| | 12 | 10.9 | 0.2 | 5.3 | 28.9 | 48.3 | 5.1 | 0.4 | 0.2 | 0.5 |
| 50 | 3 | 10.9 | 0.3 | 4.9 | 25.8 | 51.3 | 6.0 | 0.4 | nd[d] | 0.3 |
| | 6 | 11.0 | 0.3 | 4.7 | 25.4 | 51.9 | 5.8 | 0.4 | nd | 0.4 |
| | 9 | 10.9 | 0.3 | 4.9 | 25.9 | 51.8 | 5.3 | 0.4 | nd | 0.3 |
| | 12 | 11.1 | 0.2 | 4.6 | 27.3 | 50.0 | 5.9 | 0.4 | nd | 0.3 |
| 60 | 3 | 10.6 | 0.3 | 4.8 | 25.4 | 52.0 | 6.0 | 0.4 | nd | 0.4 |
| | 6 | 10.8 | 0.2 | 4.9 | 28.7 | 48.6 | 5.5 | 0.4 | 0.2 | 0.4 |
| | 9 | 11.2 | 0.2 | 5.5 | 27.7 | 49.0 | 5.4 | 0.4 | 0.2 | 0.3 |
| | 12 | 11.1 | 0.2 | 5.3 | 27.1 | 49.5 | 5.4 | 0.4 | 0.2 | 0.5 |
| 70 | 3 | 11.0 | 0.2 | 5.0 | 28.6 | 48.6 | 5.4 | 0.4 | 0.2 | 0.4 |
| | 6 | 11.2 | 0.2 | 4.8 | 26.3 | 50.3 | 6.0 | 0.4 | 0.2 | 0.4 |
| | 9 | 10.8 | 0.2 | 5.4 | 26.3 | 50.2 | 5.9 | 0.4 | 0.2 | 0.2 |
| | 12 | 11.2 | 0.2 | 5.6 | 27.2 | 49.0 | 5.6 | 0.4 | 0.2 | 0.4 |

[a] 16:0, palmitic acid, 16:1, palmitoleic acid, 18:0, stearic acid, 18:1, oleic acid, 18:2, linoleic acid, 18:3, linolenic acid, 20:0, arachidic acid, 20:1, eicosaenoic acid and 22:0, behenic acid. [b] RS, row spacing. [c] IR, irrigation. [d] nd, not detected.

The fatty acid compositions in 1998 are shown in **Table 5**. Linoleic, oleic, palmitic, linolenic, and stearic acids are the principal fatty acids. The proportion of linoleic acid varied between 48.3 and 52.0%, whereas oleic acid ranged from 25.4 to 28.9% and linolenic acid ranged from 5.1 to 6.1%. As indicated in previous publications (*27*, *28*), the fatty acid composition of vegetable oils varies depending on seed genealogy, planting date, and meteorological factors during the growing season. Irrigation, on the other hand, has been reported to have no significant effect on free fatty acid level in canola (*28*). Oleic and linoleic acid contents were significantly ($P < 0.01$) affected by row spacing and irrigation. Interaction between

row spacing and irrigation was also found to be significant at $P < 0.01$ for the oleic and linoleic acid contents.

The correlation coefficients ($r$) between protein and oil content were −0.791 and -0.721 for soybeans grown in 1998 and 1999, respectively. Negative correlation between oil and protein has been reported (*20*, *21*).

In general, row spacing and irrigation appeared to have an influence on seed composition of soybeans grown in the southeastern region (Harran) of Turkey.

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