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Comparison of Determinate and Indeterminate Types of Sesame for Oil Content and Fatty Acid Composition

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Abstract: Determinate growth habit in sesame is not available in nature originally. The character was a mutant induced by gamma rays and has the potential to make possible mechanised harvesting in sesame by enabling synchronous flowering. Though no detailed study on fatty acids of determinate types has been recently performed, much material is available on the genotypes of indeterminates. Therefore, the present study aimed to compare determinate and indeterminate types of sesame with regard to oil content and fatty acid composition. A total of 10 genotypes, six determinate and four indeterminate types, were grown in a randomised complete blocks design with three replications at Antalya in the growing seasons of 1998 and 1999. The seeds from each plot in the two years were subjected to oil extraction and subsequent fatty acid analysis using gas chromatography. The oil contents of the determinate genotypes were found to be close to their wild types and sibs. However, the low seed yield of these genotypes resulted in lower oil yields compared to indeterminate types. In addition, it was seen that the determinate genotypes were found to be of higher oleic acid content and lower linoleic acid content. In conclusion, the fatty acid composition of determinate types was found to be satisfactory. However, the oil yield of these genotypes has to be improved by increasing their seed yield.

Key Words: Sesame, *Sesamum indicum* L., Determinate growth habit, Oil content, Fatty acids

Determinant ve İndeterminant Susam Tiplerinin Yağ Oranı ve Yağ Asitleri Kompozisyonu Bakımından Karşılaştırılması

Özet: Susamda determinant büyüme özelliği, doğada kendiliğinden bulunan bir özellik değildir. Bu özellik Gama ışınları muamelesiyle yapay olarak elde edilmiş olup, eş zamanlı çiçeklenme sağlaması nedeniyle, susamın makinalı hasatının yapılabilmesinde önemli role sahiptir. Doğal indeterminant tiplerde yağ asitleri araştırmalarına çokca rastlanırken, uzun bir geçmişi bulunmayan determinant genotiplerde bu konuda ayrıntılı çalışmalar mevcut değildir. Bu nedenle sunulan çalışma determinant ve indeterminant susam tiplerini, yağ miktarı ve yağ asitleri bakımından karşılaştırmak için planlanmıştır. Bu amaçla altı determinant ve dört indeterminant tipten oluşan on ayrı susam genotipi, üç tekerrürlü Tesadüf Blokları Deneme Deseninde Antalya'da 1998 ve 1999 yıllarında yetiştirilmiştir. Her iki yılda elde edilen tohumlar ayrı ayrı yağ ekstraksiyonuna tabi tutulmuşlar ve takiben yağ asitleri kompozisyonu gaz kromotografi cihazında belirlenmiştir. Determinant genotiplerin yağ oranları indeterminantlarla yaklaşık olarak aynı bulunurken, düşük tohum verimleri nedeniyle yağ verimleri de düşük bulunmuştur. Bununla birlikte determinant genotiplerin, yüksek oleik ve düşük linoleik asit içeriğine sahip oldukları görülmüştür. Sonuç olarak, determinant genotiplerin yağ asitleri kompozisyonu bu haliyle iyi görünmektedir. Ancak yağ verimlerinin, tohum verimlerinin artırılarak geliştirilmesi gerekmektedir.

Anahtar Sözcükler: Susam, *Sesamum indicum* L., Determinant büyüme, Yağ oranı, Yağ asitleri

Introduction

Sesame (*Sesamum indicum* L.) is an important annual oilseed crop grown especially in developing countries as a rich source of oil, protein, calcium and phosphorus. Among oilseed crops, sesame is the most ancient oilseed known and grown by humans according to archaeological records (Nayar, 1984; Salunkhe et al., 1991). There are no definite findings on the origin of sesame, though Ethiopia is considered to be the centre of cultivated sesame (Weiss, 1983). Despite its long history, sesame has recently attracted increasing interest as a source of good quality oil that is resistant to oxidative rancidity due to the presence of endogenous antioxidants such as sesamol, sesamolinol and sesaminol (Isshiki and Umezaki, 1997; Fukuda et al., 1994).

In general, sesame oil contains about 47% oleic acid (C18:1), 39% linoleic acid (C18:2), 9.0% palmitic acid (C16:0), 4.1% stearic acid (C18:0), and 0.7% arachidic acid (C20:0) (Weiss, 1983). However, fatty acid composition as well as oil content is influenced by various physiological, ecological and cultural factors. Thus, Mosjidis and Yermanos (1984) reported that seed samples from central and lateral capsules affected the fatty acid composition in sesame. Sowing date also influenced fatty acid composition of sesame by decreasing linoleic and increasing oleic and stearic acid content as sowing was delayed (Gupta et al., 1998; Baydar and Turgut, 1994). Unsaturated fatty acid contents in sesame are higher in cultivars from temperate regions than in those from tropical regions (Lee and Kang, 1980). Moreover, the maturity of sesame seeds also causes fatty acid changes (Sekhon and Bhatia, 1972). Not only these conditions affect fatty acid composition but also genotypic factors play an important role in the process, resulting in the fact that each genotype shows different fatty acid composition. The determinate growth habit, which is a very useful character enabling the possibility of mechanised harvesting by providing synchronous flowering in sesame, should also influence genotypic factors as well as environment with respect to fatty acid composition. However, there is no detailed study about the fatty acid composition of determinacy character even though it was induced first as early as the 1980s (Ashri, 1981). In this study, the oil content and fatty acid composition of the new ideotype, determinates, were compared with those of traditional indeterminate types of sesame in order to provide insights into the practical value of these mutants in breeding programmes.

Materials and Methods

Plant material: Six determinate and four indeterminate types of sesame were used in the study. The six determinates were selected from the mutagenised population of Muganli and Camdibi, as described by Cagirgan (1997). The dt-1, dt-2, and dt-3, selected from Muganli were similar to dt-45, which was the first determinate growth habit of sesame reported (Ashri, 1981; 1995). The mutant of Camdibi, dt-6, has no similarity to the previously known types which have many leaves on a compact stem stopping flowering earlier than in the wild type. The other two determinate types (6157 and 6158) were obtained from an F3 family of a cross between dt-45 and Muganli. Of the four indeterminate types, two (6159 and 6160) were isolated from the same F3 family in order to compare them with a genetically similar background. The other two indeterminate types were the wild types of the determinate mutants Muganli and Camdibi.

Plant cultivation and field trials: A total of 10 genotypes containing determinate and indeterminate growth habit lines were grown in the 1998 and 1999 seasons in Antalya province in a randomised complete blocks design with three replications. The field is located 5 km from the Mediterranean Sea at an elevation of 40 m above sea level. The soil type is clay-loam with a pH of 8.5 and low organic matter. The experimental plots consisted of two rows 2 m in length 70 cm apart and were sown by hand. Sprinkler irrigation was maintained immediately after sowing and thereafter used when necessary based on soil and plants conditions. Nitrogen, phosphorus and potassium were applied at a rate of 60 kg per hectare at sowing. Five plants were randomly chosen from each plot in the two seasons, on which seed yield per plant was assessed.

Oil content and fatty acid composition: Seed samples of each genotype in the two years were subjected to oil extraction using Soxholet apparatus (Gerhardt) and their oil content was determined (Lee, 1981). Sesame oil was esterified according to the method of Marguard (1987). A 1 ml sample of oil was placed into a tube and 1 ml of Na-methylate was added to the mixture. The sample was left at room temperature overnight, and then 0.25 ml of isooctane added. A 0.5 µl sample of the mixture was injected into the gas chromatographer. The composition of fatty acid was determined by gas liquid chromatography (GC) performed on a Fison GC equipped with a flame ionisation detector (FID), and fitted with a fused capillary column FFAP-DF (25 m x 0.25 mm ID). The detector was operated at 260 ºC and the injector at 250 ºC. The column was ballistically heated from 150 to 200 ºC at rate of 5 ºC min-1. The carrier gas (helium) inlet pressure was 0.15 MPa and flow rate was 1 ml/min.

Statistical analyses: The data obtained from seed yield, oil content, oil yield, arachidic acid, oleic acid, linoleic acid, palmitic acid, and stearic acid were analysed using the MSTAT-C software package (Freed et al., 1989). Four different orthogonal contrasts were also described; i.e., (i) determinates vs. indeterminates, (ii) determinates of Muganli vs. Muganli, (iii) the determinate dt-6 of Camdibi vs. Camdibi, and (iv) dt-45 vs. Dt-45 for the measured characters.

Results and Discussion

The values for seed and oil yield, oil, arachidic, oleic, linoleic, palmitic and stearic acid content of determinate and indeterminate types of sesame and the test results of contrasts between determinates vs. indeterminates, determinates of Muganli vs. Muganli, determinate of Camdibi vs. Camdibi, and dt-45 vs. Dt-45 are given in Tables 1 and 2, respectively. Data in Table 1 shows significant differences between determinate and indeterminate types concerning seed yield. The determinate genotypes generally had lower seed yield capacity than the indeterminates even though dt-1 and dt-3 exhibited close means to their control, Muganli, in 1998. Muganli had very high seed yields in the 1999 season when compared to 1998 since the sampled plants in the 1999 season for Muganli had more branches and, thus, a higher seed yield. The direct effect of the number of fruiting branches on seed yield in sesame was considerable, as shown by Uzun and Cagirgan (2001). Therefore, determinate genotypes including dt-1 and dt-3 did not equal Muganli with regard to seed yield in the 1999 season. There was a clear difference between determinate and indeterminate genotypes for seed yield. The described contrast between determinate vs. indeterminate genotypes supported the result (Table 1). However, there was no difference between the two types regarding oil content based on the data obtained by orthogonal contrast between determinates and indeterminates. It was concluded that determinate genotypes had close means to their controls for oil content even though the contrasts between dt-6 vs. Camdibi and dt-45 vs. Dt-45 were significant statistically only in the growing season of 1999. It should be noted that the oil contents of the genotypes in 1999 were higher than those in 1998. Although environmental factors influenced the oil content of all the genotypes by

Table 1. Mean values of seed and oil yield, oil and arachidic acid content of sesame genotypes in 1998 and 1999.

Genotype	Seed yield g/plant		Oil content (%)		Oil yield g/plant		Arachidic acid (% in oil)	
	1998	1999	1998	1999	1998	1999	1998	1999
dt-1	6.3	5.4	41.5	74.7	2.6	4.1	0.19	0.1
dt-2	4.0	1.4	51.2	71.0	2.1	1.0	0.12	0.1
dt-3	6.9	4.3	51.1	75.2	3.5	3.3	0.30	0.2
Muganli	5.3	27.9	49.3	63.3	2.7	16.2	0.32	0.2
dt-6	1.8	1.6	43.7	77.3	0.8	1.3	0.28	0.2
Camdibi	8.8	11.9	40.0	78.0	3.5	9.1	0.30	0.4
6157 (dt-45)	3.9	5.5	43.8	67.7	1.7	3.7	0.26	0.2
6158 (dt-45)	2.5	5.1	49.3	66.3	1.3	3.5	0.20	0.2
6159 (Dt-45)	7.6	4.6	46.9	66.1	3.6	3.1	0.20	0.4
6160 (Dt-45)	6.1	6.7	49.3	67.3	3.0	4.6	0.23	0.3
LSD (0.05)	3.5	ns	7.1	ns	ns	6.8	ns	ns
Orthogonal Contrasts								
dt vs. indt	**	*	ns	ns	*	**	ns	ns
dt-1,2,3 vs. Mug	ns	**	ns	ns	ns	**	*	ns
dt-6 vs. Cam	**	ns	ns	*	*	*	ns	ns
dt-45 vs. Dt-45	**	ns	ns	**	*	*	ns	ns

*, **: Statistically significant at 0.05 and 0.01 significance level, respectively.
ns: Statistically non-significant

Table 2. Mean values of oleic, linoleic, palmitic, and stearic acid content of sesame genotypes in 1998 and 1999.

Genotype	Oleic acid (% in oil)		Linoleic acid (% in oil)		Palmitic acid (% in oil)		Stearic acid (% in oil)	
	1998	1999	1998	1999	1998	1999	1998	1999
dt-1	44.2	39.7	40.8	47.2	9.7	9.5	4.6	2.7
dt-2	44.2	42.0	38.5	41.7	10.0	10.3	5.4	3.3
dt-3	43.4	37.6	40.0	43.5	9.7	11.8	4.7	2.9
Muganli	41.7	36.1	41.5	47.3	9.7	11.8	4.6	2.1
dt-6	42.3	35.9	41.3	45.3	9.7	13.8	4.9	3.2
Camdibi	41.0	38.4	42.5	47.6	10.1	10.2	4.7	2.9
6157 (dt-45)	43.6	38.9	39.7	42.1	9.0	10.4	6.2	3.4
6158 (dt-45)	46.7	39.1	38.0	42.7	8.7	9.1	5.3	3.7
6159 (Dt-45)	43.2	39.3	40.1	41.3	9.7	11.6	4.6	3.3
6160 (Dt-45)	44.5	37.1	39.7	43.3	9.7	11.2	4.6	3.5
LSD (0.05)	2.0	ns	1.5	ns	ns	1.6	0.4	0.8
Orthogonal Contrasts								
dt vs. indt	**	ns	**	ns	ns	ns	**	ns
dt-1,2,3 vs. Mug	*	*	*	ns	ns	ns	ns	*
dt-6 vs. Cam	ns	ns	ns	ns	ns	**	ns	ns
dt-45 vs. Dt-45	ns	ns	ns	**	ns	*	**	ns

*, **: Statistically significant at 0.05 and 0.01 significance level, respectively.
ns: Statistically non-significant

increasing their values, as it has been reported by many that oil content was greatly affected by environmental factors (Gupta et al., 1998; Baydar and Turgut, 1994), the extraction procedure followed in this study also affected the oil content of the sesame genotypes. The extracted products from all genotypes were dried for three days. The moisture in the products possibly did not properly evaporate in the given time resulting in the higher oil content values in 1999.

With regard to oil yields, great variations were observed among the genotypes. The determinate genotypes generally had lower means for oil yield than the indeterminates. The orthogonal contrast between determinate vs. indeterminate based on the data in Table 1 supported this phenomenon. The other contrasts also showed that the controls as indeterminates had higher oil yield than the determinates over the two years. However, this superiority was due to higher seed yield of indeterminate types rather than the higher oil content. Therefore, when the seed yield improvement of determinate genotypes is accomplished, the oil yield obtained from the determinate genotypes will automatically be increased as much as desired.

It is of great importance to obtain high oleic/low linoleic and high linoleic/low oleic acid genotypes for different needs since the percentages of oleic and linoleic acids are very close to each other in sesame oil (Baydar et al., 1999). Considering the means of oleic and linoleic acids in 1998 and 1999 (Table 2), the oleic acid content of almost all the genotypes was higher than the linoleic acid content in 1998 but lower in 1999. This revealed that the oleic/linoleic balance was strongly affected by the environment, as reported by Baydar and Turgut (1994), Sekhon and Bhatia (1972), and Turgut et al. (1996). In fact, the temperature of the 1999 growing season was higher than in 1998. This increased the oleic acid synthesis while reducing that of linoleic acid. Comparing the genotypes for oleic acid, determinate types had slightly higher means than the indeterminates based on the variance analysis data in Table 2. The contrast between determinates vs. indeterminates was also found to be significant in 1998. However, the major advantage over indeterminates for oleic acid content was observed in the determinates of Muganli, dt-1, dt-2 and dt-3 as is shown in the orthogonal contrast in Table 2. However, the linoleic acid content of dt-1, dt-2 and dt-3 was significantly lower than their control, Muganli. This suggests that the determinates of Muganli were of relatively high oleic/low linoleic acid content.

There was no statistically significant difference among the genotypes for arachidic acid in the growing seasons of both years and for palmitic acid only in 1998. However, dt-6 had a higher mean for palmitic acid in the 1999 season compared to the other genotypes. In particular, the contrast between dt-6 and Camdibi was found to be statistically significant at the level of 1%. A large variation was observed for stearic acid content among the genotypes. The determinate genotypes were superior to the indeterminate genotypes with respect to stearic acid; the determinate genotypes 6157 and 6158 were the highest means in both years. The three groups of determinate genotypes were all found to be superior to their controls with respect to stearic acid.

Conclusions

The major obstacles to the extension of sesame are its low yield and the absence of non-shattering cultivars suitable for machine harvest. In addition, the indeterminate growth habit with its subsequent uneven ripening of the capsules creates difficulties for mechanical harvesting. Because of this, determinate growth habit is an important mutant trait in sesame for mechanised harvesting by providing synchronous flowering. Genotypes reflecting this important character were compared with their wild types and indeterminate sibs. As a result of this comparison, determinate genotypes had almost as much oil content as indeterminates even if they were behind indeterminates with respect to oil yield because the yields of determinates were low. The determinate genotypes of Muganli, dt-1, dt-2 and dt-3, were found to have slightly higher oleic acid content than their wild type, Muganli, though lower linoleic acid content. This suggested that these genotypes had high oleic/low linoleic acid content. In conclusion, the fatty acids of determinate types were found to be of good composition, whereas their oil yields need to be improved by increasing their seed yield.

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