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ORIGINAL PAPER

# Determination of Oil Content and Fatty Acid Composition of Sesame Mutants Suited for Intensive Management Conditions

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**Abstract** Sesame mutants with closed capsules, determinate growth habit and wilt resistance, have been proposed to be suitable for intensive management conditions facilitating mechanized harvesting. The objective of our experiment was to determine the oil content and fatty acid composition of these mutants before they are placed on the market. Oil content and fatty acids were studied in 19 mutants, 6 breeding lines and 4 control source genotypes. The oil contents of the seeds ranged from 46.4 to 62.7%. The mutants had generally a lower oil content than the control genotypes except the wilting tolerant group. For unsaturated fatty acids, oleic acid was higher in the mutants and breeding lines while linoleic acid was lower in the seed oil. However, no mutants or breeding lines were found with radically different composition or with any undesirable lipid component. The closed capsule and determinate growth habit mutants need to be improved for oil content while their fatty acid composition is fine.

**Keywords** Fatty acids · Gas chromatography · Mutants · Oil content · Sesame · *Sesamum indicum* L.

## Introduction

Sesame (*Sesamum indicum* L.) is an ancient oilseed crop whose seeds contain 50–60% oil. The seed bearing capsules dehisce when mature. It is possible to see different developmental stages of capsules in a plant because plant growth is originally indeterminate. Plants may flower as long as conditions permit [1]. The two unwanted characteristics, capsule shattering and indeterminate growth habit of sesame prevent determining of the optimum harvest time to maximize yield. In addition, they are the major obstacles to mechanized harvesting in sesame. In the absence of high yielding varieties with closed capsules and determinate growth habit, sesame is harvested by hand. There is almost no mechanized harvesting worldwide at the moment [2]. For this reason, closed capsule and determinate mutants may have an important role for sesame cultivation throughout the world.

Turkey has a great interest in growing sesame after wheat in the same year in the areas of the cotton belt. The intensive management conditions are valid for these areas where cultivation practices require supplementary irrigation. With irrigation, the fungal disease *Fusarium* wilt has the potential to attack the crop. *Fusarium* wilt becomes a major problem when sesame is grown under intensive management conditions. The most effective method of controlling the disease in sesame is through the use of resistant cultivars.

Closed capsules, determinate growth habit and tolerance to wilting are therefore prerequisites for adapting sesame to modern farming systems with intensive management. However, their oil content and fatty acid compositions should be also taken into consideration since sesame is grown as an oilseed crop. Before these valuable sources for intensive management conditions have been released, the quality criteria should be determined in the mutants. This study was therefore undertaken to determine oil content and fatty acid compositions of the mutants comparatively.

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## Materials and Methods

Twenty-nine genotypes including closed capsule (cc), determinate growth habit (dt), resistance to Fusarium blight (wt) and source varieties of the mutants, Muganlı, Özberk, Çamdibi, and Gölmarmara were used in the study. The mutants were obtained by gamma ray irradiation as described by Çağırgan [3, 4]. Their usefulness and agronomic characteristics were presented in the previous studies [5–8]. The breeding lines other than the mutants, dt-6157, dt-6158, Dt-6159, Dt-6160, were obtained from an $F_3$ family of a cross between dt-45 and Muganlı as determinate and indeterminate sibs originating from the first induced determinate mutant of dt-45 [9]. The main characteristics of the entries are given in Table 1.

The experimental materials were grown in 2002 and 2004 growing seasons at Antalya province Turkey (30°44′E, 36°52′N, and 51 m above sea level). A total of 29 genotypes were sown by hand in the second week of June in each year. Thinning was carried out 20 days after sowing to secure one plant at 10 cm. Sprinkler irrigation was established immediately after sowing and thereafter used when necessary based on soil and plant conditions. Nitrogen, phosphorus and potassium were applied at a rate of 60 kg per hectare at sowing as a complete fertilizer. Weeds were controlled by hand and no herbicides were applied during the growing seasons. All the agronomical treatments were the same each year. Temperature, rainfall and relative humidity of the experimental site during the crop growing period are presented in Table 2.

For every accession, seeds from a given year were bulked and 5-g clean and mature seed samples taken for oil content and fatty acid analysis. Two replicates comprising healthy looking seeds were analyzed. The obtained seeds from 2 years for each genotype were used for oil extraction by using Soxholet apparatus and their oil content was determined. Sesame oil was then esterified according to the method of Marquard [10]. 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 isooctane added. A 0.5-μL sample of the isooctane extract mixture was injected into the gas chromatography. The fatty acid composition was determined by gas liquid chromatography (GC) performed on a Fison GC equipped with a flame ionization detector (FID), and fitted with a fused capillary column FFAP-DF (25 m × 0.25 mm ID). The detector was operated 260 °C and the injector at 250 °C. The column was ballistically heated from 150 to 200 °C at rate of 5 °C/min. The carrier gas (helium) inlet pressure was 0.15 MPa and flow rate was 1 mL/min.

The data were statistically analyzed using MSTAT-C statistical program [11]. Four different orthogonal contrasts were also described in order to further classification; i.e. (1) closed capsules versus controls, (2) determinates versus controls (3) wilt resistants versus control and (4) mutants versus controls for the measured characters.

**Table 1** Genetic material and their characteristics used in the study

| Genotypes | Characteristics of the mutants or improved lines |
|---|---|
| cc1 | Closed capsule mutant in Çamdibi |
| cc2 | Closed capsule in Muganlı |
| cc3 | Closed capsule mutant in Özberk |
| Dur4–1/5 bicarpellatum | Closed capsule mutant in Özberk |
| Dur4–1/5 quadricarpellatum | Closed capsule and *quadricarpellatum* mutant in Özberk |
| cc6 | Closed capsule mutant in Muganlı |
| cc7 | Closed capsule in Çamdibi |
| cc8 | Closed capsule mutant |
| cc9 | Closed capsule and *quadricarpellatum* segregation in M3 with slightly opening from the tip in Muganlı |
| cc10 | Closed capsule improved line from the *id* gene |
| dt1 | True determinate mutant in Muganlı |
| dt2 | True determinate mutant in Muganlı |
| dt3 | True determinate mutant in Muganlı |
| dt4 | Short flowering determinate leafy mutant in Çamdibi |
| dt5 | Short flowering determinate leafy mutant in Çamdibi |
| dt6 | Short flowering determinate leafy mutant in Çamdibi |
| dt45–6157 | Determinate improved line from *dt-45* |
| dt45–6158 | Determinate improved line from *dt-45* |
| Dt45–6159 single plant | Indeterminate improved sib |
| Dt45–6159 bulk | Indeterminate improved sib in bulk |
| Dt45–6160 single plant | Indeterminate improved sib |
| Dt45–6160 bulk | Indeterminate improved sib in bulk |
| wt-2 | Wilting tolerant mutant in Muganlı |
| wt-6 | Wilting tolerant mutant in Muganlı |
| wt-7 | Wilting tolerant mutant in Çamdibi |
| Muganlı | *Bicarpellatum*, source cultivar |
| Özberk | *Bicarpellatum*, source cultivar |
| Çamdibi | *Bicarpellatum*, source pure line, unregistered. |
| Gölmarmara | Bicarpellatum, white seed |

Based on Çağırgan [4]

## Results and Discussion

The ranges of variation in oil content and fatty acid compositions of the entries are shown in Table 3. Total oil content of sesame samples in the 2 years varied from 46.4 to 62.7%. The magnitude and range of the values obtained

**Table 2** Meteorological data for the field site during sesame growth in 2002 and 2004

| Months | Min. temperature (°C) | | Mean temperature (°C) | | Max. temperature (°C) | | Rainfall (mm) | | Relative humidity (%) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2002 | 2004 | 2002 | 2004 | 2002 | 2004 | 2002 | 2004 | 2002 | 2004 |
| June | 21.2 | 19.9 | 26.6 | 25.5 | 32.3 | 31.0 | 0.1 | 8.7 | 62.8 | 58.8 |
| July | 24.5 | 23.6 | 29.3 | 29.7 | 34.6 | 36.3 | 20.4 | 0.3 | 63.2 | 49.0 |
| August | 23.9 | 23.1 | 28.7 | 28.1 | 34.8 | 33.6 | 1.3 | 0.0 | 63.1 | 60.5 |
| September | 19.3 | 19.8 | 24.2 | 25.5 | 30.1 | 32.6 | 5.5 | 0.1 | 69.9 | 53.1 |

for the oil content were more than those reported by Yermanos et al. [12], Tashiro et al. [13]. The highest value for oil content was for a sample from the white seeded cultivar, Gölmarmara in 2002, and from the cc3 mutant in 2004. The described contrasts for oil content showed that there was a significant difference between mutants and their counterparts in the 2 years except for wilting tolerant mutants (Table 3). This difference was much higher for samples obtained from 2002.

The mutants and breeding lines had generally lower means for oil content than the controls except wt-2, wt-6 and wt-7 mutants as wilting tolerant group (Table 3). Although closed capsule and determinate mutants have many advantages and are suitable for mechanized harvesting, their oil contents are low. Therefore, these mutants should be improved for oil content before they are evaluated in intensive farming conditions. They can serve as parents in crosses.

Oleic and linoleic acids are the major fatty acids of sesame. The high amount of unsaturated fatty acid with a value of 80% of total fatty acids increases the quality of sesame oil [14]. There are significant differences among the genotypes for oleic acid ($p < 0.01$). Oleic acid percentage in seed oil in the 2 years ranged from 31.7 to 47.1. Means of the genotypes for the character are similar to those reported by Bahkali and Hussain [15], and Yermanos et al. [12].

All the samples obtained from 2002 showed generally lower oleic acid contents than those of 2004. For linoleic acid, the trend was reversed as expected. This demonstrated that the oleic/linoleic balance was strongly affected by the environment as reported by Uzun et al. [16], Sekhan and Bhatia [17] and Brar [18]. As several investigators

**Table 3** Range of variation in oil content (%) and fatty acid composition (% in oil) of 29 accessions and orthogonal comparisons

| Entries | Oil content | | Oleic acid | | Linoleic acid | | Palmitic acid | | Stearic acid | |
|---|---|---|---|---|---|---|---|---|---|---|
| Description | 2002 | 2004 | 2002 | 2004 | 2002 | 2004 | 2002 | 2004 | 2002 | 2004 |
| Mutants | | | | | | | | | | |
| Closed capsule (cc) | 47.3–59.5 | 46.4–60.4 | 36.2–43.2 | 40.1–47.1 | 32.2–40.3 | 34.9–41.0 | 9.3–11.7 | 9.0–11.1 | 3.7–4.7 | 4.1–6.0 |
| Determinates (dt) | 48.1–59.4 | 50.0–57.3 | 35.4–42.4 | 36.8–45.9 | 37.0–44.1 | 36.4–43.6 | 8.8–10.8 | 8.8–10.9 | 3.4–4.4 | 3.2–5.8 |
| Indeterminate (indt) | 51.4–59.8 | 56.9–60.0 | 37.3–40.3 | 38.7–41.6 | 41.2–42.4 | 41.0–42.1 | 9.0–10.9 | 10.2–11.3 | 3.6–4.5 | 3.6–4.7 |
| Wilt tolerant (wt) | 57.3–61.2 | 49.1–58.7 | 35.6–38.0 | 37.9–40.3 | 43.4–45.1 | 37.8–40.7 | 9.8–11.8 | 10.3–10.6 | 3.3–3.5 | 4.2–4.6 |
| Varieties | | | | | | | | | | |
| Muganlı | 60.3 | 54.5 | 35.2 | 44.3 | 43.3 | 37.9 | 9.6 | 9.6 | 3.0 | 4.8 |
| Özberk | 59.8 | 55.7 | 34.3 | 41.7 | 43.4 | 39.1 | 10.1 | 10.3 | 3.2 | 4.3 |
| Çamdibi | 56.8 | 59.1 | 36.0 | 39.9 | 44.7 | 43.2 | 10.3 | 10.2 | 3.6 | 4.5 |
| Gölmarmara | 62.7 | 59.7 | 31.7 | 39.9 | 47.1 | 42.6 | 10.0 | 10.5 | 3.0 | 4.5 |
| LSD (0.05) | 5.5 | 6.1 | 3.7 | 3.3 | 3.6 | NS | NS | NS | 1.0 | NS |
| CV (%) | 4.8 | 6.7 | 4.8 | 4.8 | 4.3 | 7.4 | 8.0 | 8.7 | 12.7 | 19.6 |
| Orthogonal contrasts | | | | | | | | | | |
| cc versus control | –** | –* | +** | NS | –** | –* | +** | NS | +** | NS |
| dt versus control | –** | –* | +** | NS | –** | NS | +** | NS | +** | NS |
| wt versus control | NS | NS | +* | –* | NS | NS | +* | NS | NS | NS |
| Mutants versus control | –** | –* | +** | NS | –** | NS | NS | NS | +** | NS |

See Table 1 for descriptions of the mutants

*NS* Not significant

*, ** Statistically significant at 0.05 and 0.01 significance level, respectively

–, + Direction of effect

have demonstrated, sesame oil content and composition are influenced by many internal and external factors [19–22].

All the mutants and breeding lines generally had higher oleic acid than their controls (Table 3). Orthogonal contrasts in 2002 support this result. However, the control genotypes had a higher oleic acid content in 2004 unlike in 2002. This caused no differences between closed capsule mutants to controls, determinates to controls and mutants to controls based on the data of orthogonal comparisons in Table 3. For linoleic acid, this situation is reverse. As a result, the mutants and breeding lines suitable for intensive management conditions had higher oleic and lower linoleic acid content in their seed oil.

Palmitic acid is the predominant saturated fatty acid of sesame oil. There was no significant difference among the genotypes in the 2 years for palmitic acid (Table 3). However, orthogonal contrasts in 2002 showed that some mutants had higher palmitic acid content. Similarly, closed capsule and determinate mutants had higher stearic acid content than the control group in 2002 ($p < 0.01$) while there were no significant differences among the genotypes for the saturated fatty acids in 2004. When 2-years data obtained from saturated fatty acids were evaluated, there were no radical changes for these fatty acids. However, several mutants such as cc3, cc8, wt-6 and wt-7 had individually higher means compared to the control genotypes for saturated fatty acids (data not shown).

In conclusion, there is considerable variation in the oil content and fatty acid compositions of the mutants suited for intensive management conditions. However, no mutants or breeding lines were found with a radically different composition or with any undesirable lipid component. On the other hand, the mutants have considerably higher amounts of oleic acid while having low linoleic acid contents. This oleic and linoleic acid balance in the mutants increases the oil stability. Our study of oil content and fatty acid composition shows that the mutants, except for the wilting tolerant group, had lower oil contents than the control genotypes while fatty acid composition of the investigated types were found to be of good composition. In fact, the closed capsule and determinate mutants can serve as parents using suitable breeding strategies to produce desirable genotypes, combining habit and oil contents and quality.

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