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Oil Contents of Seeds and Minor Components in the Oil of Sesame, *Sesamum indicum* L., as Affected by Capsule Position*

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Abstract : Field trials were conducted at the Experimental Station of Nagoya University from May to September 1986 to study within-plant variations in seed weight, hull percentage and the seed oil content and its minor components as affected by different capsule locations on individual sesame plants. Seven capsule positions, five on the main stem and two on the branches, were selected.

Seed weight and hull percentage decreased with capsule position from the bottom to the top of the main stem and branches. The oil content of the seed was greatest at positions on the top part of the branches and smallest at the position on the lower bottom part of the main stem. The capsules on the lower bottom part of the main stem had the lowest sesamin and sesamolin contents, but the capsules on the upper central part had the highest sesamin content and those on the lower central part had the highest sesamolin content.

The difference in sesamin and sesamolin contents from the time when the lower bottom part capsules turned light yellow to the time of rupture showed a marked decrease at the central position. The evidence suggests that conversion of sesamin and sesamolin to other substances takes place prior to full maturity.
Key words : Capsule position, Hull percentage, Oil, Seed, Sesame (*Sesamum indicum* L.), Sesamin, Sesamolin.

ゴマ種子中の油脂含量及び油脂中微量成分含量に及ぼすさく果着生位置の影響：田代　亨・福田靖子**・大澤俊彦（名古屋大学農学部・**市邨学園短期大学）

要　旨：ゴマ（*Sesamum indicum* L.）の開花は基部から上部に求頂的に順次進み，開花期間は8から10週間におよぶ．さく果の着生位置を異にするゴマ種子の油脂及びその微量成分含量（セサミン，セサモリン）の差異を明らかにするために，植物体を主茎では5区分（基部下位，基部上位，中央部下位，中央部上位，上部），分枝では2区分（基部，上部）した．

種子重及び種皮割合は主茎・分枝ともにさく果着生基部から上部に向かって減少した．油脂含量は，主茎の基部下位から得た種子が最も低く（51.7%），分枝の上部から得たものが最も高かった（56.6%）．油脂含量のさく果着生位置間での変動は小さかった．一方セサミン及びセサモリンの含量は，それぞれ主茎の中央部上位及び中央部下位の種子で最高値（油脂100 g 当りそれぞれ452.1 mg，332.0 mg）を示し，また両物質ともに主茎の基部下位の種子で最低値（油脂100 g当りそれぞれ187.3 mg，278.6 mg）を示した．セサミン及びセサモリン含量のさく果着生位置間での変動は大きく，とくにセサモリンはこの傾向が強かった．

収穫時期と種子中の油脂含量及び油脂中の微量成分含量との関係を明らかにするために，基部下位さく果の黄緑色期と裂開始期に主茎の中央部着生さく果を採取し，比較した．油脂含量には両期で差異が認められなかったが，セサミン及びセサモリンの含量は裂開始期で減少した．種子の成熟過程でセサミン及びセサモリンは他の物質に転換することが示唆された．
キーワード：ゴマ，さく果着生位置，種子，種皮割合，セサミン，セサモリン，油脂．

Sesame (*Sesamum indicum* L.) is one of the world's important oil crops. Its primary marketable products are the whole seed, seed oil and meal. Expansion of use of sesame seed nowadays has stimulated research on the composition of the seed, particularly the oil and protein content of the seed and the contents of minor components, sesamin and sesamolin, in oil[3,8,14,16].

Sesame is a plant with indefinite inflorescence. Capsules ripen irregularly from the base of the stem upward, the topmost often being only half-mature at harvest. Harvested seed is always of variable quality because of this uneven ripening. The growing time and location of a capsule on a plant is, therefore, important for sesame seed produc-

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tion.

Within-plant variations in the chemical composition of the seed have been reported. Collins and Catter[2] showed that soybean seeds from the lower half of the plant were higher in oil and lower in protein than those from the upper half. Fergason et al[4]. found a significant linear decrease in the amylose content of maize from the base to the tip of the ear and Jellum[10] reported that whereas the contents of linoleic and palmitic acids increased, the content of oleic acid decreased linearly from the base to the tip of the maize ear. Mosjidis and Yermanos[11] studied within -and among-plant variations in seed weight, oil content and the fatty acid composition of the oil of individual genotypes of sesame.

Our knowledge of the systematic variations in the seed composition attributes within the sesame plant, however, is still inadequate. Our objective, therefore, was to determine the extent of variation in seed weight and hull percentage and in the contents of the oil and its minor components, sesamin and sesamolin, from seeds located at different capsule positions on individual plants. This information would be highly valuable for making improvements in the quality of the seed and its oil.

Materials and Methods

Growing conditions

Seeds from two domestic strains of different seed color type, white and black, grown in 1986 at the Experimental Station of Nagoya University were used. These strains, both being dehiscent, have one capsule per leaf axil.

Seeds were sown in three-row plots, 5m long and 50cm between rows, in May. Thinning was done to maintain a plant to plant distance of 15cm, when the plants attainted a height of 10 to 15cm. Fertilizers were applied basally at the rate of 25 kg/ha of N and K_2O, and at the rate of 50 kg/ha of P_2O_5. In addition, top-dressing of N and K_2O at the rate of 25 kg/ha each was done during mid-July. Growing conditions were considered favorable. No important pest or disease was seen.

Sampling capsules

A schematic diagram of the sampling location of sesame capsules on the plant is shown in Fig.1. The main stem of each plant used was divided into quarters according to the number of nodes that produced capsules. The four divisions used were the top part, upper central part, lower central part and bottom part. The bottom part was further divided in half, into the upper and lower bottom parts. The two branches were divided in halves according to the number of nodes that produced capsules, into the top and bottom parts.

Analyses

Seeds were carefully cleaned, immature seeds being discarded by hand picking. The oil content of the seed was measured twice comparing the weights of approximately 5g samples before and after oil removal by soxhlet extraction with petroleum ether for 8 hours.

The sesamin and sesamolin contents of the oil were analyzed with a Shimazu Model 190 HPLC equipped with a stainless steel column (4.6mm id×25cm) packed with Develosil ODS-5. The chromatograph was operated with a mobile phase (70% methanol) at a flow rate of 1mL/min. The amount of each compound present was determined from the peak height at 290nm. Sesamin and sesamolin were purified as reported elsewhere[5]. Their purities were confirmed by mass spectrometry and proton nuclear magnetic resonance (^{1}H-NMR).

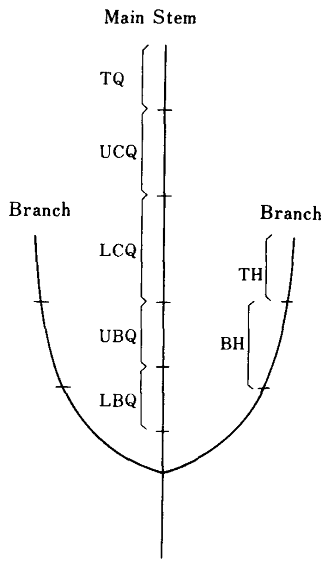

Fig. 1. Diagram of the sampling location of sesame capsule on the main stem and branches. LBQ: lower bottom part, UBQ: upper bottom part, LCQ: lower central part, UCQ: upper central part, TQ: top part, BH: bottom part, TH: top part.

Removal of the hull

Good quality sesame seeds were soaked in water for 5 minutes at room temperature with occasional shaking. The wet seeds were drained on gauze and then rubbed mildly with it to remove the loosened hulls. Seed weight was the average weight of 3 samples of 100 seeds each.

Results

To study variation in the seed characteristics at different capsule positions on the plant, 15 plant samples for white-seeded strains were harvested at random from each of the 2 replications in early-September, when the capsules on the lower bottom part had turned light yellow. Plants that had a main stem with 2 branches were selected. The number of nodes that produced capsules on the main stem and branches varied from plant to plant, ranging from 20 to 24 in the main stem and 8 to 10 in the branches. Data on the seed weight, hull percentage and contents of oil and the minor components are presented as mean values in Table 1. Flowering began on the main stem at the lowest capsule on mid-July and it progressed upward, the branches flowering some days later. The flowering period lasted for one month.

Capsule position along the plant showed similar effects on the seed weight and hull percentage. On the main stem and its branches, seed weight and hull percentage decreased progressively from bottom to top. Seeds in the lower bottom part capsules had an average weight of 298.1 mg and a hull percentage of 8.9%, whereas the values for those in the top part capsules were 228.5mg and 7.5%, respectively. The differences in seed weight and hull percentage between the lower bottom part capsules and top part capsules was significant at the 1% level.

The oil content of the seeds varied from 51.7% to 56.6% for different capsules on a plant. Seeds with the highest oil content came from capsules located on the top part of the branches and those with the lowest oil content came from capsules located on the lower bottom part of the main stem. The seeds in the capsules on the lower bottom part of the main stem had significantly lower oil contents than seeds from other parts.

The distribution of the sesamin and sesamolin contents of the within-plant seeds showed similar trends ; for sesamin, the upper central part capsules of the main stem and for sesamolin, the lower central part capules had the highest contents, with the lower bottom part capsules having the lowest. Moreover, the sesamin and sesamolin contents were greater in seeds from the bottom part capsules of the branches than for those from the top part.

Simple correlation coefficients for the values of all the seed characteristics based on the data for Table 1 are shown in Table 2. The positive correlation between seed weight and hull percentage was highly significant. Oil content was correlated negatively with seed weight and hull percentage. In addition, the correlation between sesamin and sesamolin was positive and significant.

To study the change of seed characteristics at the following 2 different maturity stages, 10 plant samples for black-seeded strains were harvested at random from each of the 3 replications of late-August, when capsules on the lower bottom part had turned light yellow (Stage I) and early-September, when capsules on the lower bottom part had just ruptured (Stage II). Flowering occurred on mid-July. Capsules of the central part of the main stem were used. The number of nodes that produced capsules on the main stem varied from plant to plant, ranging from 16 to 20.

Seed weight, hull percentage and the seed oil content and its minor components at 2 different maturity stages are shown in Table 3. Seed weight, hull percentage and oil content showed no significant differences between the 2 maturity stages. The sesamin and sesamolin contents in the oil of the seeds, however, decreased significantly after stage I.

Discussion

The sesame plants showed within-plant variations that followed a particular pattern. The relative magnitude of each variation clearly depended on the position of the capsule on the plant. The magnitude of the within-plant variation for oil content (coefficient of variation=2.9%) was much smaller than that for the other seed characteristics. The coefficient of variation for sesamin was 30.7% ; but that of sesamolin was only 8.8%. Unlike sesamin, the sesamolin contents were about the same at

Table 1. Effect of capsule position on seed characteristics of the white-seeded strain of sesame.

Capsule postion	Seed weight	Hull[a]	Oil	Sesamin	Sesamolin	Flowering time
	mg/100 seed	%	%	mg/100g oil		
Main stem						
Lower botton part	298.1	8.9	51.7	187.3	278.6	Mid-July
Upper bottom part	289.6	8.7	54.4	270.3	314.6	Mid-July to late July
Lower central part	267.3	8.3	54.4	371.7	332.0	Late-July to early-August
Upper central part	250.1	7.6	55.3	452.1	326.5	Early-August to mid-August
Top part	228.5	7.5	54.7	268.1	308.6	Mid-August to late-August
Branch						
Bottom part	260.9	8.5	56.1	457.1	355.2	Late-July to early-August
Top part	232.7	6.8	56.6	300.0	281.1	Early-August to mid-August
Mean	261.0	8.0	54.7	329.5	313.8	
CV, %	10.2	9.5	2.9	30.7	8.8	
LSD (0.05)	12.5	0.9	2.5	48.7	35.0	
(0.01)	16.9	1.2	3.4	72.1	58.7	

[a] Weight of the hull in proportion to that of the whole seeds.

Table 2. Simple correlation coefficients among seed characteristics of the sesame based on the data as presented in Table 1.

	Seed weight	Hull percentage[a]	Oil content	Sesamin content	Sesamolin content
Seed weight	——	0.908**	−0.723*	−0.325	−0.050
Hull percentage		——	−0.667*	−0.164	0.253
Oil content			——	−0.652	0.395
Sesamin content				——	0.829*
Sesamolin content					——

[a] Weight of the hull in proportion to that of the whole seed.
* Significant at the 5% level.
** Significant at the 1% level.

Table 3. Characteristics of seed[a] harvested at 2 different maturing stages of black-seeded strain of sesame.

Maturity stage[b]	Seed weight	Hull[c]	Oil	Sesamin	Sesamolin
	mg/100 seed	%	%	mg/100g oil	
Stage I	283.2	18.8	47.5	202.5	282.0
Stage II	294.7	18.4	48.1	167.0*	254.8*

[a] Seeds in the capsules of the central part on the main stem.
[b] Stage I : When the lower bottom part capsules turned light yellow.
Stage II : When the lower bottom part capsules had just ruptured.
[c] Weight of the hull in proportion to that of the whole seed.
* Significant at the 5% level.

all the capsule positions.

Three possible factors, (I) differences in assimilate partitioning, (II) differences in climatic conditions during seed maturation, and (III) uneven ripening of individual capsules harvested, might have accounted for the observed variations in the development of seeds and its chemical composition according to the position on a plant.

The differences in seed weight and hull percentage between the seeds from the top part and those from the bottom part of the main stem are probably associated with assimilate availability. According to the observation in this experiment, leaf area, which would control the supply of assimilate for capsule development, generally is maximum in the leaves at the bottom of the plant, decreasing from the bottom to the top of the main stems and branches. Also, the number of seeds per capsule along the main stem and branches increased from bottom to top, except the topmost capsules, which had slightly less developed seeds. This may be because the assimilate availability was greater for the bottom capsules of the main stem than for the upper capsules, resulting in good seed development for the bottom capsules.

Differences in climatic conditions during seed maturation have been given as the explanation for the differences in quantity and quality of oil in the seed of oil crops[9,17]. Climatic conditions during seed maturation at each the seven capsule positions differed considerably. During the seed maturation period, mean air temperature increased sharply from mid-July (first flowering) to late-July together with rainfall; up to the end of August the temperature increased gradually while rainfall stopped; and, at the end of maturation, the temperature decreased very sharply (Fig.2). Seed produced on the lower bottom part of the sesame plants had lower oil contents than seed produced on the other parts. These differences in oil synthesis may have been caused by differences in temperatures that existed when the oil was being synthesized in the seeds on different parts of the plant. However, the possibility of the influence of others environmental factors such as daylength, light intensity, humidity, wind speed, etc. and their interactions in producing such differences in oil synthesis can not be ruled out. Therefore, further research is needed to determine the relationship between temperature and the oil synthesis under controlled conditions. Capsules along the top part of the main stem contained more under-developed seeds having less oil than the other capsules, producing relatively a small amount of sesamin and sesamolin in the seed oil.

The distributions of the sesamin and sesamolin contents in seed oil for capsule position were very similar. Generally, oil from seed from the upper and lower central part capsules that had a high oil content tended to have higher sesamin and sesamolin contents. Because neither the biosynthetic pathway for sesamolin nor sesamin is known in sesame seed, we can not, at this point, explain this relationship.

The marked reduction in sesamin and sesamolin contents in seed produced by the central part capsules, when the lower bottom

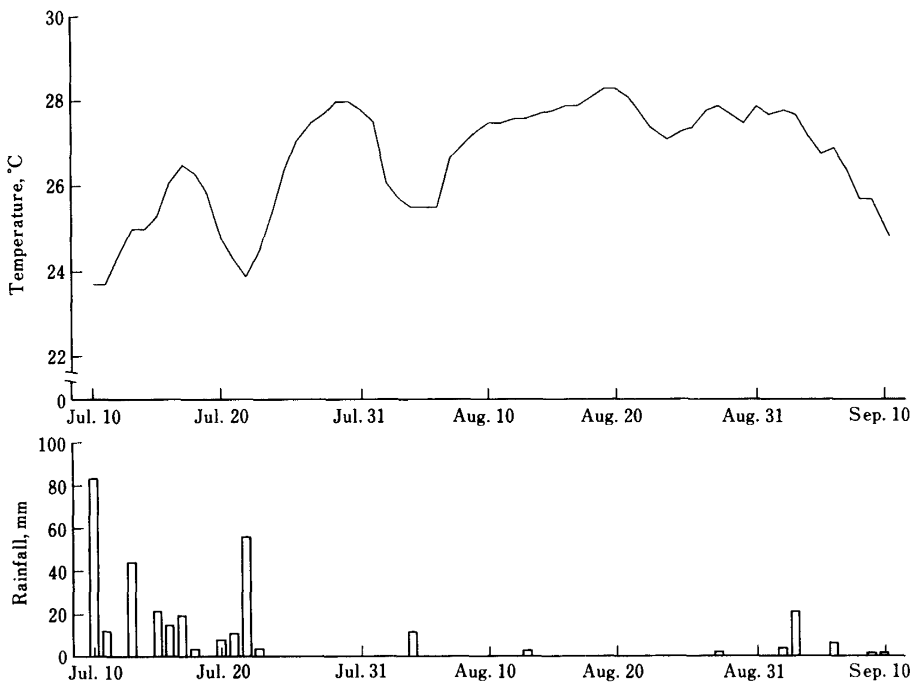

Fig. 2. Change in mean air temperature[a] and rainfall at Nagoya during the growing period of the sesame plants in 1986. Data were obtained from the nearby Nagoya Meteorological Station[15].
[a] Shown for a moving average.

part capsules have just ruptured, was not accompanied by a significant decrease in oil. The time at which the lower bottom part capsules ruptured appeared to be the time of full maturity for the seed produced in the central part capsules. The reduction in amount of sesamolin in oil concurrent with that of sesamin may mean that sesamin and sesamolin were converted to other substances prior to full maturity. Further research is needed to determine the reasons for the fluctuation in the contents of sesamin and sesamolin in sesame seed oil because a substantial amount of the sesamolin, precursor of an antioxidant[1], in seed oil appears to be related to the remarkable stability of sesame oil[6,7] and because sesamin is a major factor in dihomo-γ-linolenic acid biosynthesis in both lower and higher organisms[12,13].

Our study has demonstrated that the quality of sesame oil depends not only on capsule position but on the time of seed maturation as well. It may be possible to take advantage of these phenomena by selecting the optimum time for harvesting seed that has the maximum contents of its minor oil components.

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