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# INFLUENCE OF CULTIVATION PERIOD, CULTIVAR AND USABLE PART ON CONTENT OF CHLOROPHYLLS AND VOLATILE OILS IN DILL (*ANETHUM GRAVEOLENS* L.)

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## ABSTRACT

The investigation was carried out on the usable parts of dill plants, cultivars Amat, Ambrozja, and Lukullus, grown from spring to autumn. Dill seeds were sown on 10$^{th}$ April, 10$^{th}$ May, 10$^{th}$ June, 10$^{th}$ July, and 10$^{th}$ August 2000. Harvesting was conducted when the dill plants reached the height of 25-cm i.e. after 36-45 days, depending on the cultivar and period of cultivation. The content of chlorophyll a, chlorophyll b, total chlorophylls, and volatile oils was determined in the leafy part and in leaves with petioles of dill.

In expressing the results in fresh matter, the leafy part of dill plants when compared with leaves with petioles contained 33% more chlorophylls and 21% more volatile oils. In dry matter the respective differences were 8-9% and 2%. The content of total chlorophylls ranged from 130–163 mg in 100 g fresh matter of the leafy part, with

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extreme percentage deviations from the average of –6 to + 13%. In leaves with petioles those values were 77–133 mg and –22 to +18%, respectively. The average chlorophyll a to chlorophyll b ratio was 1:0.34. The extreme deviations being considered, the content of volatile oils in fresh matter reached the level of 31–148 $mm^3 \cdot 100\ g^{-1}$ (-61 to +0.85%) in the leafy part and 23–125 $mm^3 \cdot 100\ g^{-1}$ (-65 to +89%) in leaves with petioles.

The average data for five growing periods show that the compared dill cultivars differed in the level of chlorophylls and volatile oils to a small degree, Amat showing the greatest content of these components. In June and August harvests a high content of the analysed constituents, particularly of volatile oils, was recorded. The lowest content, especially of oils, was found in the September harvest.

**Key words:** dill, cultivar, usable part, growing period, chlorophyll, volatile oil

## INTRODUCTION

Dill, like such spice vegetables as parsley leaves and chive, is a valuable source of vitamin C, carotenoids, and mineral compounds [7, 12, 13, 16]. Until recently this species was a fairly unimportant component of our diet. In the vegetation period young plants were used to flavour soups and dishes or in preparing soups and sauces. The development of industrial production of food concentrates and ready dishes considerably increased the demand for dried and frozen dill. The countries of Western Europe import dried vegetables from Morocco, Turkey, Egypt, and Chile [15].

In Poland the conditions for growing this type of vegetable are fairly good, as was demonstrated in the investigation on the yields of parsley leaves [11]. In an experiment on dill yielding (the data still not published) in one growing cycle of about 40 days the harvest of the green mass exceeded 20 $t \cdot ha^{-1}$. Thus, Poland could potentially compete with the exporters mentioned above if the offered dried or possibly frozen products were characterized by good and uniform quality of all merchandised lots. The visual quality of frozen and dried dill, especially its colour and flavour, decisively depend on the technology of preservation and also on the content of chlorophyll pigments and volatile oils in the usable parts of the vegetable.

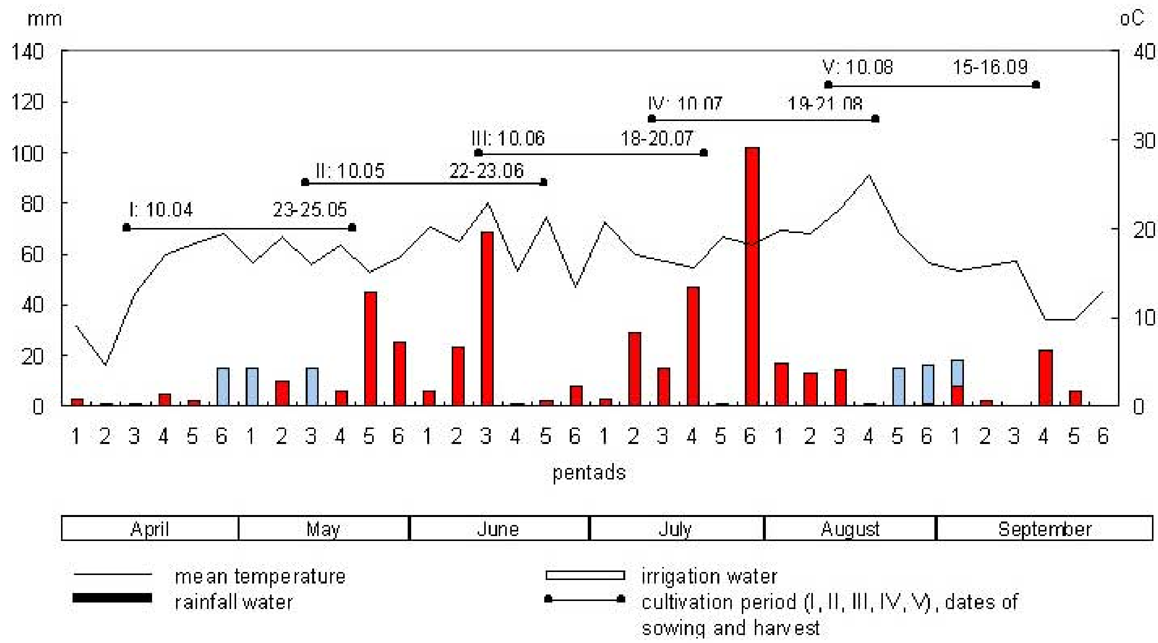
The aim of this work was to determine the level of chlorophyll and volatile oils in three cultivars of dill grown for the fresh market in five cycles from spring to autumn.

## MATERIALS AND METHODS

The investigated material was composed of usable parts of young plants of dill harvested in five production cycles conducted from spring to autumn (Fig.1). Three original cultivars of dill bred in Poland were evaluated, i.e Amat, Ambrozja, and Lukullus. The dill was grown on an experimental field in the Krakow region, on brown soil developed from loess formations, of the mechanical composition of silt loam. The soil was in good horticultural culture, having a high content of humus and basic macroconstituents. The production was conducted in the second year after manureing and with pulse crops as the fore-crop for all the successive growing cycles. The fertility of the soil and the nutritive requirements of the species being taken into consideration, the following doses of mineral fertilizers were applied: N – 30 $kg \cdot ha^{-1}$, $P_2O_5$ – 15 $kg \cdot ha^{-1}$, $K_2O$ – 30 $kg \cdot ha^{-1}$. Owing to the great similarity of soil resources in the successive growing cycles, the fertilization was not differentiated and all fertilizers were applied before sowing.

Dill was sown at a row spacing of 20 cm at the density of 400 seeds per 1 m, calculated per 100% capacity of germination. Cultural practices were limited to mechanical weeding, chemical protection against insects (aphids), and sprinkling irrigation if necessary. The pattern of weather conditions in the year 2000 and the dates of sowing and harvest of dill in the separate growing cycles are given in Fig.1.

**Fig. 1. Mean air temperatures and total rainfall during the vegetation season (in pentads) and cultivation periods of dill**




Harvesting was conducted when the plants were about 25 cm in height. Directly after harvest non-marketable plants were discarded and the usable parts of dill were evaluated. The usable parts of the vegetable included leaves or the leafy part with petioles. The authors assumed that in some directions of the technological processing (pastes for soups and dried and ground dill) young delicate petioles of the dill could be used, the usable yield thereby being considerably increased. It should be stressed that, depending on the cultivar and the period of growth, the leafy part constituted only 36.4 – 43.7% of commercial yield. Leaves with petioles reached 57.4 – 86.5% of this yield.

The level of physico-chemical indices analysed in the work was determined on the basis of the following analytical methods: dry matter using gravimetric method AOAC [2], chlorophyll a and b using the method given by Wettstein [18], and volatile oils according to AOAC [2]. All determinations were conducted in four replications. The results were presented after their calculation per 100-g fresh matter. If it was necessary for interpretation, they were also expressed in dry matter. In order to show the differentiation in the content of the investigated constituents with respect to fresh matter, analysis of variance for two variables was carried out.

## RESULTS AND DISCUSSION

Horticultural crops should be characterized on the one hand by high yields and good sensorial quality and on the other with a high content of nutrients. If these crops are used in food processing they should also contain compounds of technological importance, particularly affecting the quality of the final products. If no once-over harvest is used, the crop being obtained throughout the vegetation season, it is advisable to maintain its chemical composition at a uniform level. Within species the chemical composition of plants depends on the cultivar, the kind of usable parts, its size or maturity, and also on soil conditions, fertilization, and the pattern of weather conditions [7, 9, 12]. In the present work the soil, fertilization, and the size of harvested plants were the same. Particular care was also paid to ensure sufficient water content in the soil at each stage of plant growth. It can therefore be assumed that the differentiation in the level of the investigated components was above all brought about by the cultivar, the kind of the usable part evaluated, and variable climatic factors. The last element applied to the dates of harvest since the cultivation of the plants was carried out from spring to autumn. It should be stressed that, according to Pijanowski et al. [17], the variation in the chemical composition depending on the pattern of weather conditions, measured by the deviation from the average content, may reach values from –50% to + 175%.

No investigation concerning the content of chlorophylls and volatile oils in young dill has covered such a wide spectrum of problems as the present work. Therefore in the discussion the results concerning chlorophylls will be referred to other vegetables of the same or similar utility. Different parts of the plant can considerably differ in their chemical composition, this chiefly concerning –especially in the case of leafy vegetables – differences between the leaves and petioles or stems. The above observations were fully confirmed with respect to the investigated components. The averages for the compared plants and the entire growing period show that the leafy part of dill in relation to leaves with petioles contained more chlorophylls a and b, more total chlorophylls by 33%, and more volatile oils by 21% (Tables 1-4). If the results were referred to dry matter, the differentiation was distinctly smaller, amounting to 8-9% for chlorophylls and 2% for volatile oils (Fig. 2). These data may be taken into consideration in using leaves with petioles for drying, especially if the dried dill used as a component of various food concentrates is ground prior to blending.

Dill proved to be a rich source of chlorophylls. The data for all the growing periods show that in the leafy part the content of chlorophylls varied over the range of 97-122 mg of chlorophyll a, 33-43 mg of chlorophyll b, and 130-163 mg·100 $g^{-1}$ fresh matter of total chlorophylls. The respective values for leaves with petioles were 57-101 mg, 20-32 mg, and 77-133 mg·100 $g^{-1}$ (Tables 1-3). The data in the literature concerning the content of chlorophylls give the values from 55 to 100 mg·100 $g^{-1}$ fresh matter [1, 3]. The quoted authors do not precisely determine either the size of the plants or what parts were evaluated. With respect to the content of chlorophylls (a + b) in 100 g fresh matter of leaves of both leafy and Hamburg parsley, the determined level was 203 mg and 182 mg [14]. In chive the respective values were 121 mg [13], in leafy type of red beet 45 mg [5], in common spinach 89 mg, and in New Zealand spinach 46 mg [10].

**Table 1. Content of chlorophyll a depending on cultivation period and cultivar of dill (mg·100$g^{-1}$ fresh matter)**

| Cultivation period | Cultivar | | | | | | Mean | |
|---|---|---|---|---|---|---|---|---|
| | Amat | | Ambrozja | | Lukullus | | | |
| | Leaves | Leaves and petioles | Leaves | Leaves and petioles | Leaves | Leaves and petioles | Leaves | Leaves and petioles |
| I | 104 | 80 | 104 | 78 | 104 | 69 | 104 | 76 |
| II | 122 | 101 | 120 | 91 | 119 | 90 | 120 | 94 |

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|---|---|---|---|---|---|---|---|---|
| III | 103 | 88 | 97 | 78 | 102 | 79 | 101 | 82 |
| IV | 112 | 89 | 101 | 82 | 107 | 90 | 107 | 87 |
| V | 106 | 64 | 100 | 65 | 98 | 57 | 101 | 62 |
| Mean | 109 | 84 | 104 | 79 | 106 | 77 | 106 | 80 |
| LSD (P=0.99) | For:<br>cultivars<br>cultivation period<br>interaction | | Leaves<br>2.8<br>3.6<br>ns | | Leaves and petioles<br>2.6<br>3.4<br>5.9 | | | |

**Table 2. Content of chlorophyll b depending on cultivation period and cultivar of dill ($mg \cdot 100g^{-1}$ fresh matter)**

| Cultivation period | Cultivar | | | | | | Mean | |
|---|---|---|---|---|---|---|---|---|
| | Amat | | Ambrozja | | Lukullus | | | |
| | Leaves | Leaves and petioles | Leaves | Leaves and petioles | Leaves | Leaves and petioles | Leaves | Leaves and petioles |
| I | 34 | 26 | 38 | 29 | 36 | 24 | 36 | 26 |
| II | 40 | 32 | 43 | 32 | 40 | 32 | 41 | 32 |
| III | 33 | 29 | 33 | 28 | 34 | 26 | 33 | 28 |
| IV | 35 | 28 | 35 | 26 | 35 | 30 | 35 | 28 |
| V | 40 | 23 | 35 | 21 | 34 | 20 | 36 | 21 |
| Mean | 36 | 28 | 37 | 27 | 36 | 26 | 36 | 27 |
| LSD (P=0.99) | For:<br>cultivars<br>cultivation period<br>interaction | | Leaves<br>ns<br>3.8<br>ns | | Leaves and petioles<br>ns<br>2.1<br>3.7 | | | |

**Table 3. Content of total chlorophyll depending on cultivation period and cultivar of dill ($mg \cdot 100\ g^{-1}$ fresh matter)**

| Cultivation period | Cultivar | | | | | | Mean | |
|---|---|---|---|---|---|---|---|---|
| | Amat | | Ambrozja | | Lukullus | | | |
| | Leaves | Leaves and petioles | Leaves | Leaves and petioles | Leaves | Leaves and petioles | Leaves | Leaves and petioles |
| I | 138 | 106 | 142 | 107 | 140 | 93 | 140 | 102 |
| II | 162 | 133 | 163 | 123 | 159 | 122 | 161 | 126 |
| III | 136 | 117 | 130 | 106 | 136 | 105 | 134 | 109 |
| IV | 147 | 117 | 136 | 108 | 142 | 120 | 142 | 115 |
| V | 146 | 87 | 135 | 86 | 132 | 77 | 138 | 83 |

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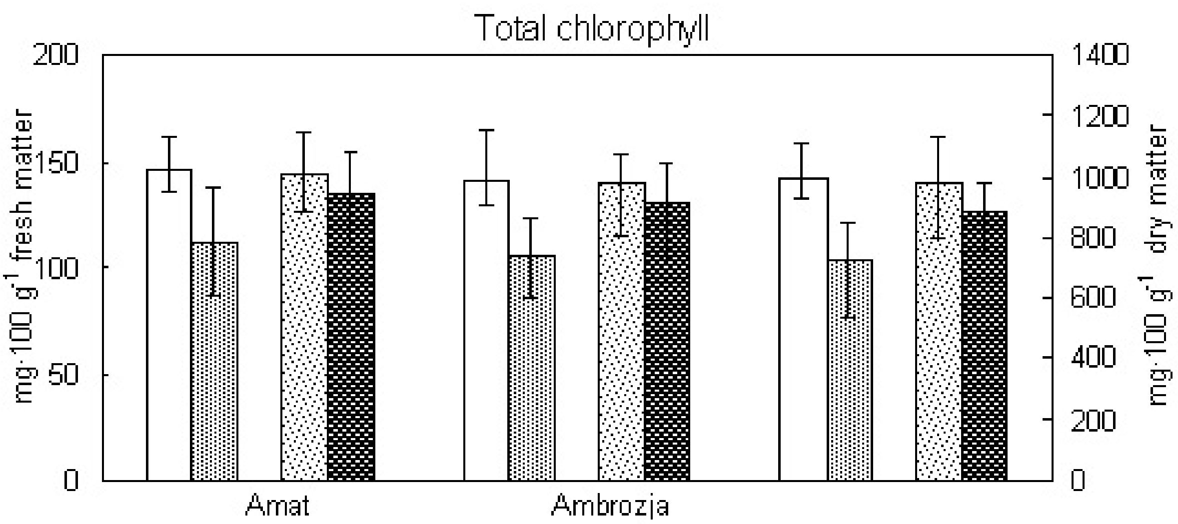
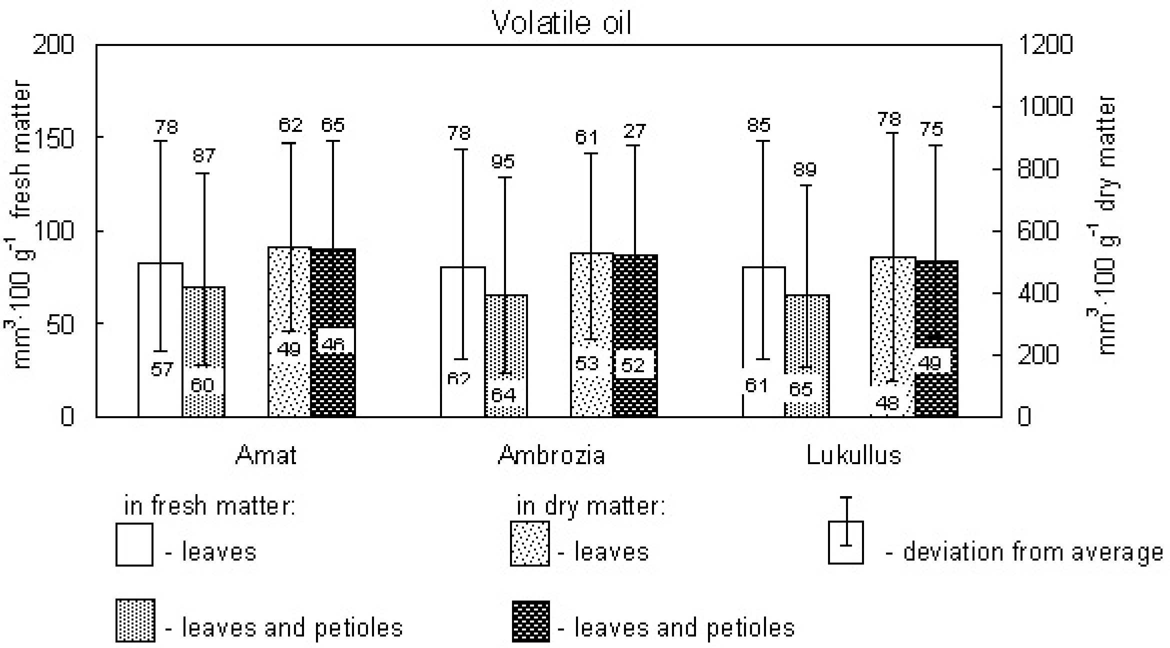
|---|---|---|---|---|---|---|---|---|
| Mean | 146 | 112 | 141 | 106 | 142 | 103 | 143 | 107 |
| LSD (P=0.99) | For:<br>cultivars<br>cultivation period<br>interaction | | Leaves<br>ns<br>6.6<br>ns | | Leaves and petioles<br>3.6<br>4.7<br>8.1 | | | |

**Table 4. Content of volatile oil depending on cultivation period and cultivar of dill ($mm^3 \cdot 100\ g^{-1}$ fresh matter)**

| Cultivation period | Cultivar | | | | | | Mean | |
|---|---|---|---|---|---|---|---|---|
| | Amat | | Ambrozja | | Lukullus | | | |
| | Leaves | Leaves and petioles | Leaves | Leaves and petioles | Leaves | Leaves and petioles | Leaves | Leaves and petioles |
| I | 50 | 38 | 51 | 39 | 41 | 30 | 47 | 36 |
| II | 140 | 116 | 136 | 104 | 148 | 119 | 141 | 113 |
| III | 41 | 35 | 44 | 34 | 40 | 31 | 42 | 33 |
| IV | 148 | 131 | 144 | 129 | 141 | 125 | 144 | 128 |
| V | 36 | 28 | 31 | 24 | 31 | 23 | 33 | 25 |
| Mean | 83 | 70 | 81 | 66 | 80 | 66 | 81 | 67 |
| LSD (P=0.99) | For:<br>cultivars<br>cultivation period<br>interaction | | Leaves<br>ns<br>5.8<br>ns | | Leaves and petioles<br>ns<br>4.8<br>8.2 | | | |

**Fig. 2. Mean level of total chlorophyll and volatile oil for five cultivation periods and greatest deviation from average**






All the analyses being taken into consideration, the average ratio of chlorophyll a and b was similar in the leafy part and in leaves with petioles of dill. It reached 1:0.34 with the maximum differentiation for cultivars and periods of plant growth not exceeding –5 to +5%. The data given by Bąkowski and Michalik [3] and Michalik and Dobrzański [16] show higher values of the chlorophyll a and b ratio, i.e 1:0.52 and 1:0.51, respectively.

The difference between the cultivars with respect to the chlorophyll content was fairly small and in most cases statistically non-significant. However, a slightly greater sum of chlorophylls was determined in Amat than in the remaining cultivars.

A greater differentiation in the content of chlorophylls concerned the growing periods. In this case the differences were significant. If the results referred to fresh matter, a significantly greater content of chlorophyll a and of total chlorophylls was found in the June (growing period II) and August (growing period IV) harvests. It should be stressed that on these two dates of the dill harvest very high average air temperatures accompanied a lack of rain during the five preceding days (Fig.1). Maximum deviations of total chlorophylls, chlorophyll a and chlorophyll b were fairly small, reaching –6 to +13% fresh matter in the leafy part and –22 to +18% in leaves with petioles in relation to the average content in the cultivars and in the different growing periods. In referring the results to dry matter the respective values were –17 to +11% and –17 to +12%.

Investigations concerning volatile oils in dill are fairly numerous. The material compared in the studies varied with respect to its biological condition, the degree of plant development, and dates of harvesting plants for analyses [7, 8, 9]. It is therefore, difficult to compare the results reported in the literature with those obtained in the present experiment.

The content of volatile oils in the investigated dill varied over a wide range. For the leafy part its value was 31–148 $mm^3 \cdot 100\ g^{-1}$ fresh matter and for leaves with petioles 23–125 $mm^3 \cdot 100\ g^{-1}$. In many publications the level of oils is calculated in dry matter. Therefore to compare the data obtained the extreme values we converted to 100-g dry matter, they amounted to

0.25–0.91 $cm^3$ and 0.25–0.87 $cm^3$, respectively. Bomme and Regenhardt [4] determine the content of volatile oils in volumetric percentages as 0.05–0.33% fresh matter, taking into consideration various experimental factors. Houpalahti and Linko [9] give the value of 24–94 $mg \cdot 100\ g^{-1}$ fresh matter, and Hälvä [6] 0.24 – 1.14% dry matter.

Differences between the cultivars in the average values were statistically non-significant and in extreme cases reached only 4%, suggesting Amat as the cultivar of the greatest resources. The differentiation between the growing periods was very distinct and – as in the case of chlorophylls – the highest content of oils was recorded in the June and August harvests, when the highest air temperatures accompanied the lack of rain. Differences between the remaining harvest dates were frequently non-significant. It should be noted that the statistically lowest level of volatile oils was found in the last, September, harvest. The differentiation in the level of volatile oils in dill, depending on the place of cultivation and dates of sowing, is discussed by Hälvä et al. [8]. Hälvä et al. [7] and Hälvä et al. [8] claim that the temperature affects the yield of volatile oils to a greater degree than the photoperiod.

The maximum deviations in the level of volatile oils with respect to the average content in fresh matter of all samples were –61 to +85% in the leafy part and –65 to +89% in leaves with petioles. In dry matter they were slightly smaller, reaching –48 to + 78% and –49 to +75%, respectively.

## CONCLUSIONS

1. In referring the results to fresh matter, the analysed parts of dill differed considerable in the level of chlorophylls and volatile oils in favour of the leafy part. In the dry matter differences between the leafy part and leaves with petioles can be regarded as distinctly less important from the practical point of view.
2. The data from the five growing periods show that the compared cultivars of dill differed in the level of chlorophylls and volatile oils to a very small degree, suggesting Amat as the cultivar with the richest content.
3. The period of growing significantly affected the content of chlorophylls and volatile oils. Differences resulting from the time of harvest were distinctly more pronounced in volatile oils than in chlorophylls.
4. The high content of the analysed discriminants of chemical composition, particularly of volatile oils, was recorded in the June and August harvests which were preceded by a period of high air temperatures and lack of rain. The decisively poorest content especially of volatile oils was found in the September harvest.

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