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RESEARCH ARTICLE

Composition of fatty acids, essential oils and morphological characteristics of some medial plants growing in permafrost ecosystems

Vasiliy V. Nokhsorov[1], Fedor F. Protopopov[2]

1 *Institute for Biological Problems of Cryolithozone Siberian Branch of the Russian Academy of Sciences, Yakutsk, Russia*
2 *North-Eastern Federal University, Yakutsk, Russia*

Corresponding author: Vasiliy V. Nokhsorov (vv.nokhsorov@mail.ru)

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Abstract

Using chromatographic (TLC, GC-FID), spectrophotometric methods (3D fluorescence spectroscopy), and scanning electron microscopy (SEM), the composition and content of fatty acids (FA), essential oils (EO) and morphological features were investigated in five plant species (*Alnus alnobetula* subsp. *fruticosa* (Rupr.) Raus, *Equisetum arvense* L., *Tanacetum vulgare* L., *Thymus serpyllum* L. subsp. *mongolicus* Ronniger, *Juniperus sibirica* Burgsd.) from different taxonomic groups (angiosperms, gymnosperms, and cryptogams) growing in the conditions of cryolithozone of Yakutia. Differences in the magnitude and variability of FA composition in the studied species were revealed. The main components of total lipids were found to be polyunsaturated fatty acids (PUFA) of the acid families omega-3 (n-3) and omega-6 (n-6), such as linoleic [18:2(n-6)], (LA) and alpha-linolenic [18:3(n-3)], (ALA), the content of which reached up to 47.4% of the sum of FA. Comparative analysis of the component composition of the components of EO of essential oils revealed that two species were characterized by a high content from polyphenolic compounds of *T. serpyllum* and *J. sibirica*, compared to other species studied. When plants were examined using SEM, morphological features such as the presence of well-formed trichomes, megasporophylls, and microphylls were identified. The identification of features such as high PUFA content in total lipids, polyphenolic components in essential oils, and well-formed trichomes, megasporophylls, and microphylls contribute to the survival and subsequent vegetation of perennial plants in cold climate permafrost ecosystems.

Keywords
Fatty acids, essential oil, lipids, saturated fatty acids, unsaturated fatty acids, gas-liquid chromatography, tocopherols, phenolic compounds, electron microscopy

Introduction

Plant organisms are constantly exposed to stressors caused by the conditions in which they grow. Due to the attached lifestyle of plants (poikilothermic organisms), they have to adapt to external environmental changes such as humidity, soil salinity, high and low air temperatures, and their fluctuations. To maintain normal physiological function and survive under unfavorable environmental conditions, plants have evolved defense mechanisms. Among the defense mechanisms are changes in the content of lipids and their fatty acid composition, proteins, or other biomolecules. For example, some plants are very sensitive to changes in ambient temperature, such as *Avena sativa* L. (Nokhsorov et al. 2024), while the others are less sensitive to temperature fluctuations, e.g., *Pinus sylvestris* L. (Sofronova et al. 2016) or *Picea obovata* Ledeb. These differences can be partially explained by quantitative and qualitative changes in lipid composition, which in turn, causes membrane fluidity and function. In this connection, the issues related to lipids of valuable medicinal plants from different taxonomic groups are of particular relevance to explain the differences in the composition and content of their fatty acid profile, as well as the specific role of these compounds for plants growing in permafrost ecosystems. Approximately 400 different fatty acids are currently known to be incorporated into plants (Li et al. 2017). All of them possess different functions, so some of them are necessary for the proper functioning of plant cells, and some of them have positive effects on human health (e.g., anti-inflammatory (Larsen et al. 2003; Larsen and Christensen 2007; Cateni et al. 2004), anticancer (Kuriyama et al. 2005; Maeda et al. 2008), antibacterial (Cateni et al. 2008) and antiparasitic effect (Mishra et al. 2005) or are in demand in various industries such as food, pharmaceuticals, and cosmetics (Konda et al. 2020; Leutou et al. 2020).

In the conditions of the cryolithozone of Yakutia, there are about 2000 species of vascular plants, of which 230 species are medicinal (Chirikova et al. 2021). The combination of different factors in one region has affected not only the character of the vegetation in Yakutia, but also the chemical composition of local plants. Yakutia plants, adapted to extreme growing conditions, are characterized by a higher content of biologically active substances (BAS) than the same species growing under milder conditions (Nokhsorov and Chirikova 2022). In summer, under conditions of high air temperatures and soil aridity, volatile terpenoid components of plants act as the main protective barriers of the photosynthetic apparatus. Monoterpenes and volatile sesquiterpenes react rapidly with reactive oxygen species (Vickers et al. 2009), thus protecting the cell membranes of plant cells from oxidative damage (Zhigzhitzhapova et al. 2023). Plants secrete huge amounts of terpenoids each year, reaching enormous amounts (Zwenger and Basu 2008). Climate change has been found to affect terpenoid emissions, which, in turn, affects the functioning of the biosphere (Peñuelas and Staudt 2010). Terpenoid compounds are obtained from plant material in the form of complex mixtures known as essential oils (EO). EOs have found widespread use in the pharmaceutical, food, agricultural, cosmetic, and medical industries because of their antibacterial, antifungal, herbicidal, and other beneficial properties (Bolouri et al. 2022; Gupta et al. 2023).

EOs contain tocopherols and polyphenolic compounds, the presence of fluorophores in them allows their quantitative and qualitative detection by fluorescence spectroscopy (Galeano et al. 2006). Tocopherols and polyphenols are considered to have antioxidant protection and can counteract oxidation of oils and increase their shelf life (Martín-Tornero et al. 2022).

The purpose of the present research is to undertake a comparative analysis of the fatty acids profiles and essential oil composition of five medicinal plants from different taxonomic groups (*Alnus alnobetula* subsp. *fruticosa* (Rupr.) Raus, *Equisetum arvense* L., *Tanacetum vulgare* L., *Thymus serpyllum* L. subsp. *mongolicus* Ronniger, and *Juniperus sibirica* Burgsd.) growing in permafrost ecosystems.

Materials and methods

As the objects of our study the following 5 species of medicinal plants from the flora of Central Yakutia were selected: leaves and buds of *A. alnobetula*, shoots of *E. arvense*, herb of *T. serpyllum*, herb of *T. vulgare* and needles of *J. sibirica*. The plants were sampled during the flowering phase, except *A. alnobetula*, which was in the area during the growing season. For each species, seven to 15 individuals (10-25 g) of leaves, flowers, or shoots were sampled. The plants were collected in the vicinity of Chapaevo village, Khangalassky District, Republic of Sakha (Central Yakutia) in the first half of the day (10:00–11:00 am). For FA analysis, plants were extracted with Folch's mixture immediately after collection, then plant extracts were stored until analysis in a freezer at -20 °C. Total lipids (TL) were isolated using a modified extraction method (Imbs 2012). The amount of TLs in the lyophilized samples was determined by the average mass of the extract. In addition to this procedure, the samples were purified from pigment impurities by thin layer chromatography (TLC). The hexane extract was evaporated on a rotor and dissolved in 100 μL of chloroform, then applied to the TLC plate in a thin longitudinal strip (silica gel served as adsorbent) with an indentation of 1.0-1.5 cm from the bottom edge. After complete drying of the solvent, the plate was immersed in a beaker for TLC filled with benzene, which served as an eluent. After the eluent reached the top edge of the plate, it was removed and dried. To determine the exact location of the fatty acid methyl esters (FAME), we sprayed with 10 % sulfuric acid solution at the edge of the plate and heated it on a hotplate. The FAMEs were taken from the part of the plate that had not been sprayed or preheated. They were placed in a funnel with a pre-cleaned cotton filter to remove 10-20 ml of chloroform. The chloroform extract was placed in a flask, evaporated on a rotor, and dissolved in 1 ml of hexane for subsequent chromatography. To analyze the FAMEs obtained, the Clarus 590 GC gas chromatograph and the flame ionization detector (Perkin Elmer, USA) were used (Christie, 1993). The experiment was carried out three times.

The collected plant material was dried to an air-dry condition for EO extraction. A total of ~100-120 g of dry plant material was subjected to hydrodistillation for 6 h using a Sosklet extractor. EO was obtained from the above-ground parts of the plants. The component composition of the EO was determined by fluorescence spectroscopy. A three-dimensional excitation-emission matrix (3D-EEM) was acquired on a fluorescence spectrophotometer (Perkin Elmer Instruments, Norwalk, USA). Emission (Em) spectra were scanned from 200 to 800 nm at 1 nm increments and excitation (Ex) spectra were scanned from 200 to 500 nm with 5 nm increments, at a scan rate of 60 nm per min. A total of 60 spectra were taken to obtain one 3D-EEM. The slits for excitation and emission were 5 nm. We used Tabletop SEM TM 4000 (Hitachi, Japan) to reveal the morphological features. The dried leaves fragments of 1 cm^2 were placed on the table of freezing attachment and studied in high vacuum mode at 5 kV.

Descriptive statistics were calculated using standard methodologies, with data analysis conducted through Statistica v.10 software (StatSoft, USA). Results are presented as means accompanied by standard deviations. Following a one-way ANOVA to evaluate differences among groups, a post-hoc Duncan test was employed to determine specific group differences. A significance threshold of $P < 0.05$ was established to denote statistical significance across all analyses.

Results

The plants studied were growing in natural habitats. *T. serpyllum* (Fig. 1D) and *T. vulgare* (Fig. 1C) were in the flowering phase during the sample collection (mid-July), observations of *J. sibirica* (Fig. 1F) showed that the plants were in the fruiting phase (beginning of cone berry formation), the shrub species *A. alnobetula* (Fig. 1A) was in the stage of completion of shoot growth and formation of new vegetative buds. In *E. arvense*, the stage of the vegetative growth of shoots was recorded during this period of the season (Fig. 1B).

GC analysis of 5 medicinal plants identified 26 FAs with different numbers of double bonds: monoenes (C14:1, C16:1, C18:1, C18:1n-7, C18:1n-9, C20:1), dienoic (C18:2n-6, linoleic acid (LA), trienoic (C18:3n-3, alpha-linolenic (ALA), tetraenoic (C20:4), pentaenoic (C20:5n-3), eicosapentaenoic (EPA) and hexaenoic (C22:6n-3), docosahexaenoic acid (DHA) (Fig. 2). FAs with the configuration trans-C16:1 and trans-18:2 were also detected. A 60 m gradient temperature column was used for the separation of the FAME, which allowed the separation of some trans/cis FAs.

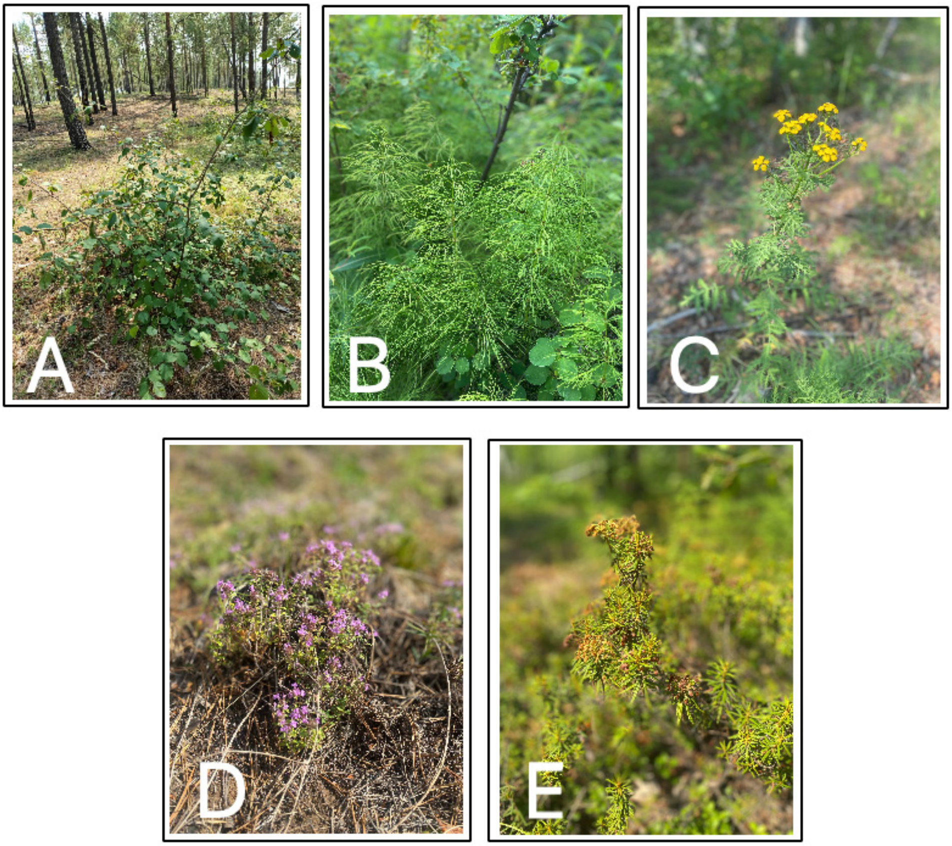

Figure 1. Wild plants in their natural habitat. **A** – *Alnus alnobetula* subsp. *fruticosa* (Rupr.) Raus, **B** – *Equisetum arvense* L., **C** – *Tanacetum vulgare* L., **D** – *Thymus serpyllum* L. subsp. *mongolicus* Ronniger, **E** – *Juniperus sibirica* Burgsd. (The photos were made by Nokhsorov, 16.07.2024).

Comparative analysis of the major groups of FAs (Fig. 3) revealed that significantly higher monoene content was found in leaves of *A. alnobetula* (13.61 ± 1.3 of the sum) and in above-ground parts of *T. serpyllum* (11.01 ± 1.5 of the sum%) than other studied medicinal plants studied. *T. vulgare* was characterized by a high level of FA of diene (18.46 ± 2.1 of sum %) than the other species. The trienoic fatty acid (ALA) was dominant in the shoots of *E. arvense* and *T. serpyllum* than the rest of the plant species. In the needles of *J. sibirica*, we found the highest content of physiologically important long-chain FAs such as EPA and DHA, whose content was 2-4 times higher than that of the other plants. In general, unsaturated FAs dominated over saturated ones in the aboveground parts of *T. vulgare*, *E. arvense*, and *T. serpyllum*.

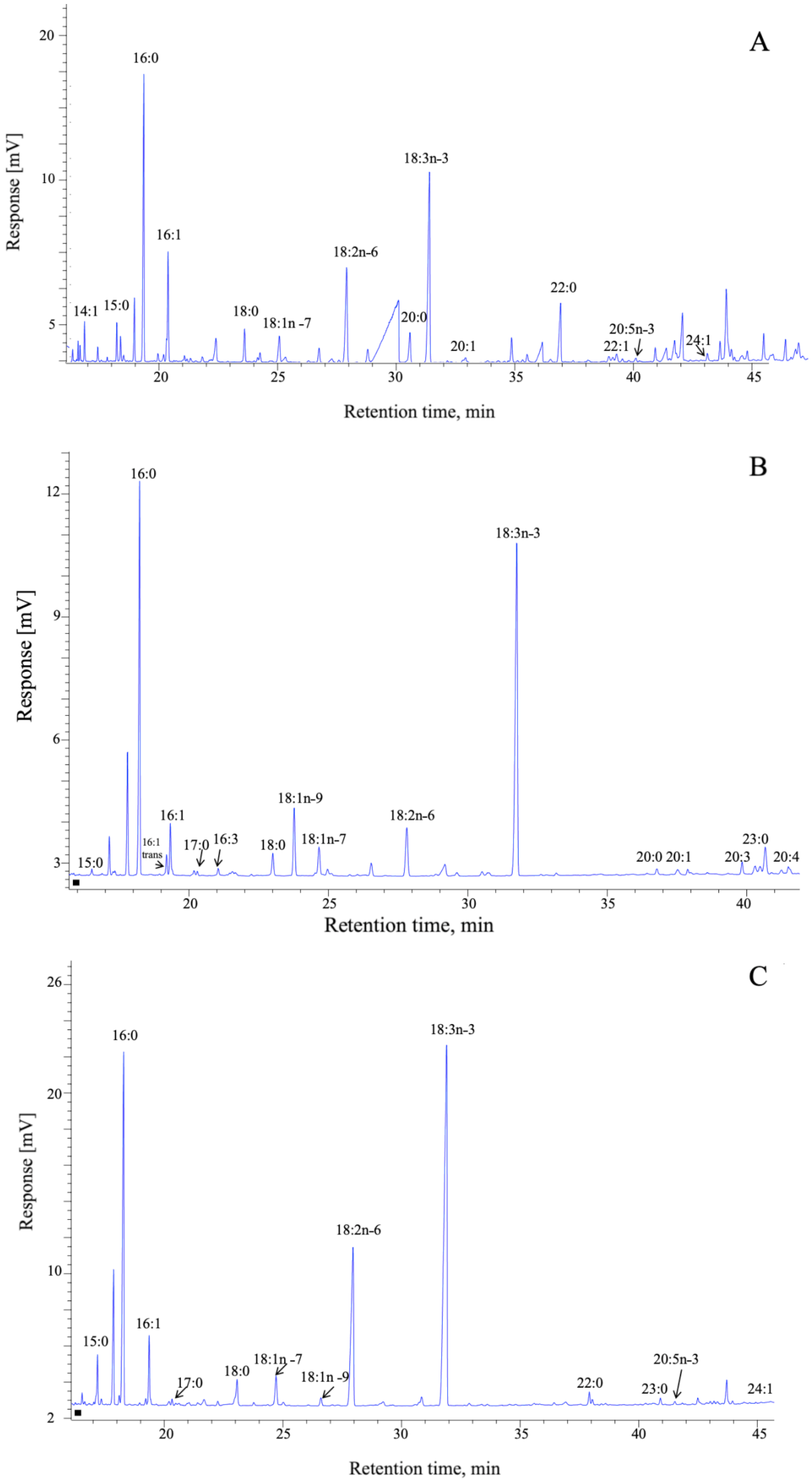

Figure 2. Continuation on the next page.

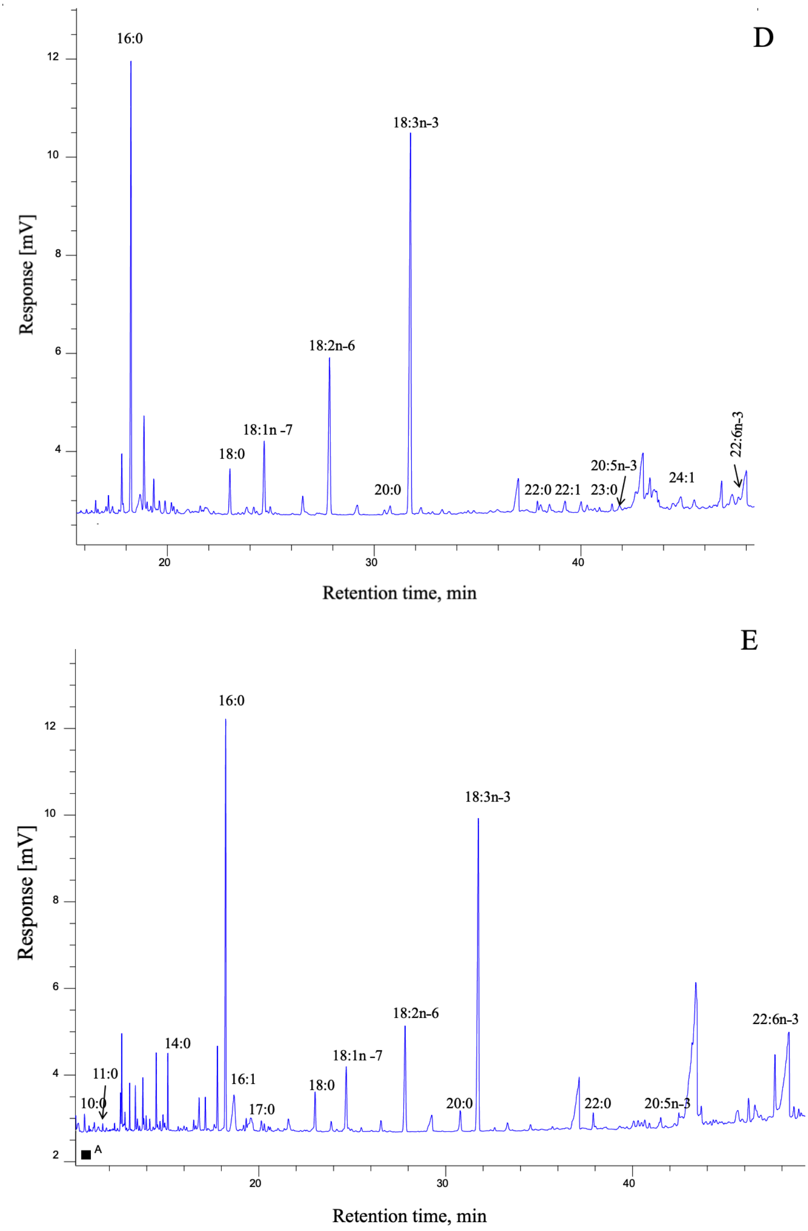

Figure 2. Continuation from the previous page. GC chromatograms of methyl esters of fatty acids of the upper part of five medicinal plants: *Alnus alnobetula* subsp. *fruticosa* (Rupr.) Raus (a), *Thymus serpyllum* L. subsp. *mongolicus* Ronniger (b), *Juniperus sibirica* Burgsd (c), *Equisetum arvense* L. (d), *Tanacetum vulgare* L. (e).

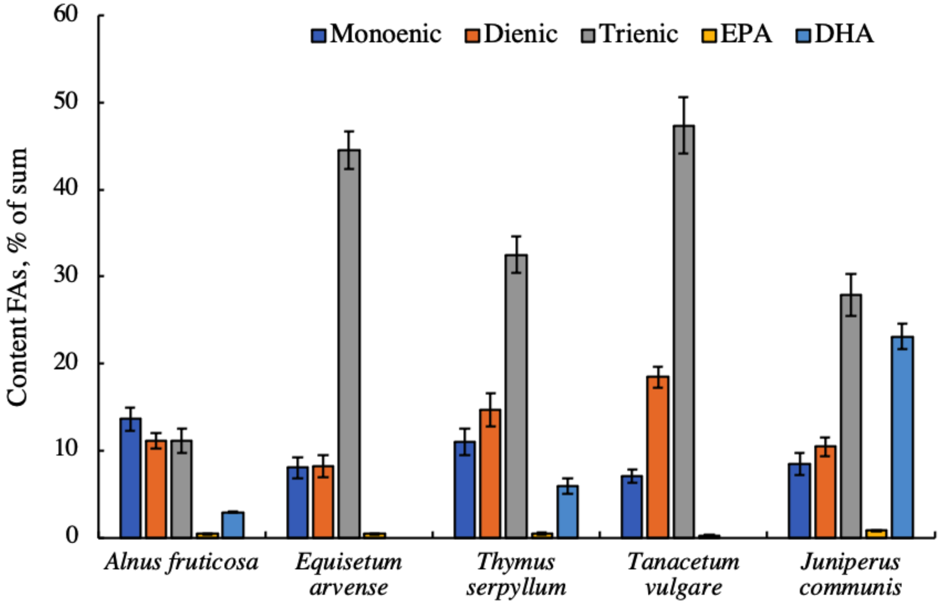

Figure 3. Content (% of total FA) of mono-, di-, trienoic Fas, EPA, and DHA in five medicinal plants.

In the subsequent series of experiments, a more detailed study of the FA composition of different taxonomic groups of medicinal plants was conducted. The data obtained was used in the construction of Table 1, which displays the content of FAs in five different plants. The analysis revealed that the percentage of FAs with the number of atoms in the acyl chain C20 (C20:0, C24:0, and C22:0) as well as C14:1, C18:0, and C16:1 was significantly higher in the leaves of *A. alnobetula* than in the other plants studied. Approximately 5% C18:1n–7 was detected in the shoots of the essential oil plant *T. serpyllum* and in the needles of *J. sibirica*. In these plants, the amount of minor C17:0 was found to be dominant in total lipids compared to the other species. In particular, the needles of J. sibirica exhibited the highest concentrations of short-chain FA, such as C10:0, C12:0, and C14:0, in addition to the presence of physiologically significant EPA and DHA, compared to other medicinal plants. On the contrary, the shoots of *T. serpyllum* contained between 0.2 and 7.8% of the sum FAs, including C6:0, C8:0, C11:0, C24:1, C22:1, and C18:1(n–9). The highest content of PUFAs such as LA and ALA was found in the leaves of *T. vulgare*, whose content was 17.8 and 47.4% of the total of FAs, respectively. In the shoots of *E. arvense*, it was found that the lowest LA content (6.6% of the sum of FA) and the lowest ALA content was inherent in the leaves of *A. alnobetula* (11.2% of the sum of FAs) than in the rest of the plant species studied.

Table 1. FA profile in 5 medicinal plants

Fatty acids	*A. alnobetula*	*E. arvense*	*T. serpyllum*	*T. vulgare*	*J. sibirica*
C6:0	-	-	0.20 ± 0.05^{a}	-	-
C8:0	-	0.33 ± 0.07^{b}	0.85 ± 0.08^{a}	-	-
C10:0	-	-	0.25 ± 0.02^{b}	0.10 ± 0.02^{c}	0.81 ± 0.09^{a}
C11:0	0.33 ± 0.02^{b}	-	7.88 ± 1.09^{a}	0.09 ± 0.01^{c}	0.24 ± 0.06^{b}
C12:0	0.31 ± 0.09^{b}	-	-	-	0.63 ± 0.16^{a}
C13:0	0.63 ± 0.10^{a}	-	0.60 ± 0.19^{a}	0.12 ± 0.02^{b}	0.5 ± 0.11^{ab}
C14:0	0.77 ± 0.08^{b}	0.62 ± 0.12^{b}	0.63 ± 0.06^{b}	1.09 ± 0.25^{ab}	2.36 ± 1.39^{a}
C14:1	1.03 ± 0.22^{a}	-	0.22 ± 0.08^{b}	0.10 ± 0.03^{b}	0.22 ± 0.05^{b}
C15:0	-	0.49 ± 0.10^{a}	0.52 ± 0.11^{a}	0.47 ± 0.06^{a}	0.5 ± 0.19^{a}
C16:0	18.16 ± 1.21^{b}	29.21 ± 1.57^{a}	19.46 ± 1.89^{b}	22.01 ± 1.01^{b}	19.73 ± 1.66^{b}
C16:1	7.68 ± 1.90^{a}	4.09 ± 0.96^{b}	1.31 ± 0.89^{c}	3.42 ± 1.12^{b}	0.65 ± 0.10^{c}
C17:0	0.22 ± 0.09^{b}	0.31 ± 0.07^{ab}	0.44 ± 0.06^{a}	0.34 ± 0.06^{ab}	0.44 ± 0.04^{a}
C18:0	4.24 ± 0.05^{a}	2.28 ± 0.09^{b}	2.81 ± 0.75^{b}	2.24 ± 1.45^{b}	2.53 ± 0.49^{b}
C18:1n-7	2.77 ± 0.67^{b}	3.34 ± 0.23^{b}	5.02 ± 1.02^{a}	2.43 ± 0.94^{b}	4.81 ± 1.79^{ab}
C18:1n-9	trace	trace	0.57 ± 0.19^{a}	-	0.2 ± 0.07^{b}
C18:2n-6, LA	6.97 ± 0.95^{cd}	6.64 ± 0.62^{d}	13.34 ± 1.37^{b}	17.82 ± 1.24^{a}	9.54 ± 1.45^{c}
C18:2trans	4.2 ± 0.62^{a}	1.58 ± 0.45^{b}	1.32 ± 0.45^{b}	0.64 ± 0.09^{c}	0.91 ± 0.21^{bc}
C18:3n-3, ALA	11.16 ± 1.29^{c}	44.53 ± 2.26^{a}	32.51 ± 2.52^{b}	47.37 ± 3.21^{a}	27.89 ± 2.96^{b}
C20:0	8.73 ± 0.09^{a}	0.65 ± 0.18^{c}	0.85 ± 0.09^{c}	0.26 ± 0.08^{bc}	1.79 ± 0.97^{b}
C20:1	0.25 ± 0.07^{a}	-	-	-	0.24 ± 0.09^{a}
C22:0	17.17 ± 1.52^{a}	0.43 ± 0.09^{c}	0.70 ± 0.10^{b}	0.86 ± 0.10^{b}	0.99 ± 0.35^{b}
C22:1	-	-	1.01 ± 0.18^{a}	-	-
C23:0	0.85 ± 0.05^{b}	3.89 ± 0.92^{a}	0.27 ± 0.06^{c}	0.43 ± 0.08^{c}	0.38 ± 0.12^{c}
C20:5, EPA	0.43 ± 0.09^{ab}	0.45 ± 0.16^{ab}	0.48 ± 0.03^{ab}	0.22 ± 0.04^{b}	0.82 ± 0.09^{a}
C24:0	9.82 ± 1.23^{a}	1.17 ± 0.35^{b}	0.55 ± 0.03^{c}	-	0.72 ± 0.03^{bc}
C24:1	1.11 ± 0.07^{b}	-	2.25 ± 0.79^{a}	-	-
C22:6, DHA	2.93 ± 0.48^{c}	-	5.96 ± 1.27^{b}	-	23.11 ± 2.97^{a}

Note: Values in the rows marked with the same letters were not significantly different at $p < 0.05$.

As a result of the present study, scanning electron microscopy was performed to identify the morphological features of medicinal plants growing in permafrost ecosystems. The leaves and buds of *A. alnobetula* (Fig. 4, images 1 and 4) were characterized by the presence of trichomes. Trichomes are epidermal cells and form outgrowths forming pubescence in the surface organs of the plant. The shoots of *E. arvense* (Fig. 4, images 2, 3, and 5) had small-scale-like leaves called microphylls. Microphylls are not photosynthetic tissues, their main role is to protect them. The leaves of *T. serpyllum* (Fig. 4, image 9) are serrated, a permanent feature of Far Eastern species, and their flowers are hairy, indicating the presence of trichomes. The flowers of *T. vulgare* are multirowed, shingled, hemispherical and collected in baskets (Fig. 4, image 7). Almost all species studied showed well-formed trichomes. Trichomes have different functions in plants and their physiological significance is not completely clear. Trichomas are generally believed to protect chlorenchyma from overheating plants during the summer season, when hot and dry weather is established. The shoots of *J. sibirica* are characterized by high mechanical properties and contain megasporophylls (Fig. 4, image 8).

The 3D-EEM analysis showed the presence of the following compounds in the extract solution: pheophytin *a*, oxidation products, tocopherols and phenolic compounds, according to Table 2.

All 3D-EEM EO fluorescence spectra (Fig. 5) clearly show the fluorescence maxima of pheophytin a 395/678 nm (Ex/Em). In *A. alnobetula*, only a weak peak of oxidation products is observed 335/431 nm (Ex/Em). Essential oils from *E. arvense* and *T. serpyllum* were characterized by strong and moderate peaks of oxidation products 305/416 nm and 245/412 nm (Ex/Em), while in *T. vulgare* and *J. sibirica* these peaks are relatively weak. In the UV region, *T. serpyllum* and *J. sibirica* showed relatively weakly shaped peaks responsible for the content of polyphenols and tocopherols (vitamin E) of 275/318 nm and 245/316 nm (Ex/Em), possibly with a predominance of polyphenols.

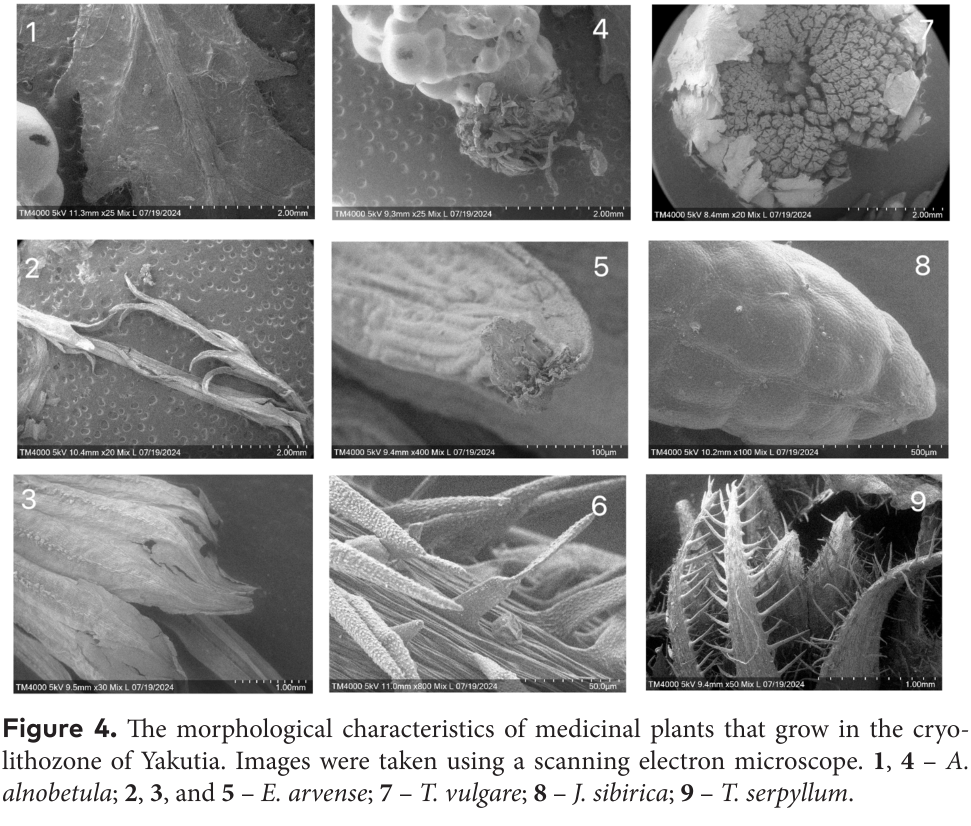

Figure 4. The morphological characteristics of medicinal plants that grow in the cryolithozone of Yakutia. Images were taken using a scanning electron microscope. **1**, **4** – *A. alnobetula*; **2**, **3**, and **5** – *E. arvense*; **7** – *T. vulgare*; **8** – *J. sibirica*; **9** – *T. serpyllum*.

Table 2. Main types of substances in EO detected by fluorescence spectroscopy (Ríos-Reina et al. 2024; Sikorska et al. 2012; Saini and Keum 2016; Lia et al. 2020)

Chemical class	λ_{max} Excitation	λ_{max} Emission
Pheophytin *a*, Chlorophylls	355–400, 408, 480, 510, 596, 640, 680	676–678
Oxidation products	300, 325, 340	450, 434–550
Tocopherols	295	330
Phenolic compounds	293, 270–280	330, 310–457

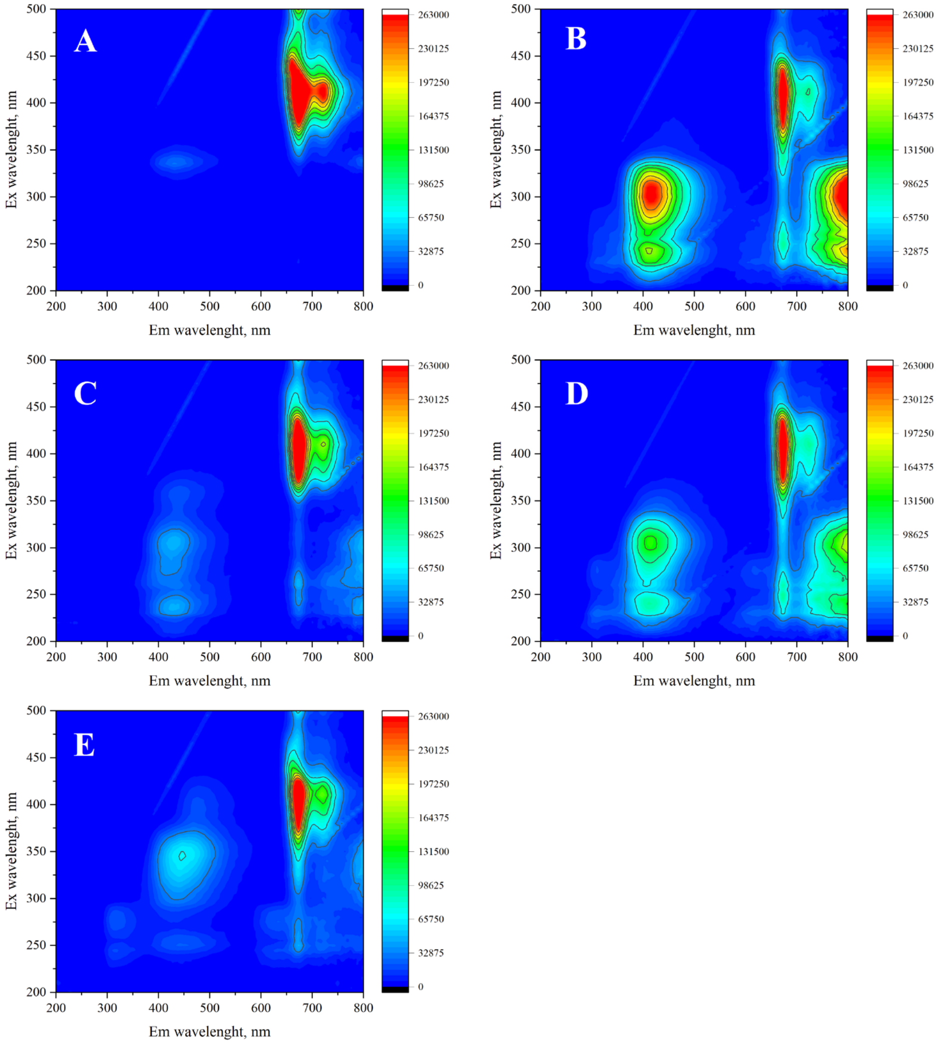

Figure 5. Colourmap shows 3D-EEM of EO obtained from different plants: **A** – *A. alnobetula*; **B** – *E. arvense*; **C** – *T. vulgare*; **D** – *T. serpyllum*; E – *J. sibirica*.

Discussion

The present-day natural environment of central Yakutia has a late-glacial character and is regarded a paleogeographic relic preserved due to severe natural and climatic conditions. Up to the present time, the climate, landscapes, vegetation, and soil cover here have late glacial features. This is evident both in the nature of the current cold and sharp continental climate and in the existence of conditions of plant life adapted to harsh conditions (Petrov 2016). The sharp continental climate of permafrost ecosystems probably contributed to the fact that, in the process of long-term evolution process, higher plants have developed complex biochemical adaptation to diurnal fluctuations in air temperatures, as well as to extremely low temperatures during the winter period, among which lipid metabolism plays a significant role. In this regard, the composition of FAs of lipids and the composition of essential oils of five different medicinal plants was established during the summer period, when very hot and dry weather was established in the cryolithozone of Yakutia, and the morphological features of these plants were revealed.

Under conditions of cryolithozone, the period of intensive shoot growth of *A. alnobetula*, as well as in other tree and shrub species, begins with the opening of the spring buds and ends mainly by the first half of the vegetation period (summer). During this period, leaves on shoots reach their maximum development and buds laid in their axils undergo a phase of preliminary (correlative) rest as the drying stress of environmental factors increases, vegetative growth of shoots fades, and apical bud closure on them (Nokhsorov et al. 2020). Specifically during this period, it was revealed that the leaves of *A. alnobetula* contain a high monoenolic FA content (13.61 ± 1.3 of sum %), PUFA content during this period was at the same level.

The presence and dominance of long chain FA in the buds of *A. alnobetula* (C20:0, C22:0, and C24:0) and in *J. sibirica* (C20:1, EPA, and DHA) can be explained by the presence of sticky plaque in the needles and leaves of these plants, as FA with a very long chain are components of these lipids (Morozova et al. 2019). In the summer period in the composition of the lipids of the cell membranes of *A. alnobetula* leaves, an increased content of saturated FAs over unsaturated FA, which, in all probability, is associated with a decrease in the activity of desaturases. The studies revealed the highest content of physiologically important EPA and DHA in *J. sibirica* needle extracts, the content of which was 2-4 times higher than in other plants. During the last decades, long-chain PUFAs of the omega-3 (n-3) family, namely EPA and DHA, have been recognized as substances of high physiological value for animals of different taxonomic groups, including humans (Lauritzen et al. 2001; Kris-Etherton et al. 2002; Wall et al. 2010). In the leaves of *T. vulgare*, we detected up to 17.8% LA and up to 47.4% ALA, it should be noted that these acids are obligatory compounds of photosynthetic membranes of eukaryotes.

In addition to LA and ALA, long-chain saturated FAs with an even number of carbon atoms, namely C20:0, C22:0, C24:0, which are compounds of constituent waxes of the cuticle, are present in the tissues of medicinal plants. These FAs are widely used as markers of flowering plants and allochthonous organic matter in the food webs of aquatic ecosystems (Makhutova et al. 2022).

In addition to determining the FA profile of five different medicinal plant species, we isolated essential oils containing biologically active compounds from the aboveground parts of these plants. Comparative analysis of the composition of the components of the EO revealed that *T. serpyllum* and *J. sibirica* have a high content of polyphenolic compounds compared to other species of medicinal plant species. This can be attributed to the fact that *T. serpyllum* is an essential oil plant. Thyme was previously found to form essential oils in glandular hairs, which is carried out by peltate glandular trichomes, which are responsible for the biosynthesis and accumulation of monoterpenes (Yamaura et al. 1992). It was also revealed that the flowers and leaves of *T. serpyllum* are mainly represented by trichomes (Fig. 5, image 9).

Thymol and carvacrol are generally considered the main bioactive components of thyme essential oil. However, thyme oil contains a complex mixture of other compounds that contribute to its overall aroma, flavor, and therapeutic effects (Etri and Pluhár 2024). Dumitrescu et al. (2022) investigated the chemical composition and antibacterial efficacy of EO *J. sibirica* from the western Romanian Carpathians and concluded that the main four volatile compounds were β-pinene, 1α-pinene, p-cymene and β-myrcene. It is possible that these components also accumulated in *J. sibirica* growing in the cryolithozone of Yakutia. The primary distinguishing feature of the lipid composition between horsetails and covered plants is that, as representatives of cryptogamous plants, horsetails have the ability to synthesise the betaine lipid O-(1,2-diacylglycero)-4’-(N,N,N-trimethyl)homoserine (DGTS) as part of polar lipids (Rozentsvet 2004). It is widely accepted that betaine lipids are evolutionarily ancient classes of lipids and are characteristic of cryptogamous plants. The influence of various types of stress, including osmotic, water stress, and phosphorus deficiency, on BL is a subject of ongoing research. It has been demonstrated that the amount of DGTS can increase in response to such conditions (Senik et al. 2015). The increase in DGTS content in the composition of membrane lipids is considered to be one of the ancient mechanisms of biochemical adaptation of plants with the participation of lipid molecules (Rozentsvet et al. 2011). The chemical structure of DGTS is closely related to that of the most common phospholipid. For instance, the authors of (Rozentsvet 2004) emphasise that DGTS is an evolutionarily ancient lipid and performs the same role in the cells of lower plants as phosphatidylcholine in higher plants.

Conclusion

As a result of the studies conducted on the fatty acid composition of lipids of five different medicinal plants that grow in permafrost ecosystems, it was found that the main ones were ALA and LA, which are polyunsaturated omega-3 and omega-6 fatty acids, respectively. In the current study, an attempt was made to obtain new and reliable data on the content of bioactive compounds derived from the essential oils of five medicinal plants. Comparative analysis of the composition of the EO components revealed that *T. serpyllum* and *J. sibirica* had a high content of polyphenolic compounds compared to other medicinal plant species. Almost all studied species were revealed by SEM to have well-formed peltate glandular trichomes in which biosynthesis and accumulation of monoterpenes and other BAS occurs. The high content of PUFA (LA and ALA) in lipids, essential oils containing polyphenols, as well as anatomomorphological characteristics, in our opinion, contribute to the survival and subsequent successful vegetation of perennial medicinal plants in the cold climate of Yakutia. It is evident that the established phylogenetic variability of the qualitative and quantitative composition of the FA profile of the studied groups of plants at the taxon level indicates that evolutionary processes initially took place at the level of individual molecules, in particular lipids, which determine the structural and functional features of the membranes of all cells. The selection of cell structural elements was aimed at adapting to constantly changing environmental conditions, resulting in the realization of different phenotypes of organisms with inherent morphofunctional properties, as demonstrated in this work.

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