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Anatomical Structure and Phytochemical Composition of a Rare Species *Fraxinus sogdiana* Bunge (Oleaceae) Growing in Different Soils in Kazakhstan

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Abstract: *Fraxinus sogdiana* Bunge (family Oleaceae) is a rare, relict species, with a disjunctive distribution range. The species is listed in the Red Book of Kazakhstan. The aim of this study was to determine anatomical features and identify the phytochemical composition of *F. sogdiana* growing in different soils in Kazakhstan. The research objects were vegetative organs collected in the Temirlik River Valley of the Almaty region (the State National Nature Park "Sharyn") and the Boralday River Valley of the Turkestan region (the Syrdarya–Turkestan Regional Nature Park) in 2020–2022. A comparative anatomical analysis of the vegetative organs of *F. sogdiana* revealed similarities and differences between the specimens studied. The level of significance was taken at 5%. The main feature identified in the anatomical structure of the *F. sogdiana* leaves was the presence of large special motor cells in the upper and lower epidermis. A study of the phytochemical composition identified the ten most important biologically active substances with antimicrobial, antitumor, diuretic, and antioxidative properties. In the study areas, soils were different in terms of conditions and time of soil formation. The soil profile of the floodplain terrace of the Temirlik River was found to be stratified with alternating interlayers of light loamy and sandy loam granulometric composition with inclusions of pebbles; differentiation of the soil profile into genetic horizons was poorly pronounced. The soil profile of the floodplain terrace of the Boralday River had a clear differentiation into genetic horizons.

Keywords: Sogdian ash; relict; morphometry; phytochemistry

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1. Introduction

With 58 species, the genus *Fraxinus* L. is one of the largest of the genera in the family Oleaceae [1]. This family contains 27 genera and 687 species. Most of the *Fraxinus* species are deciduous trees and shrubs. They are mainly found growing in temperate forests and forests of the northern hemisphere, from North America to Europe and from the Middle East to China and Japan. Several species can be found in tropical locations in Central America, India, and parts of Indochina, and two species occur in North Africa [2].

Only four *Fraxinus* species grow in Kazakhstan: *F. angustifolia* subsp. *syriaca* (Boiss.) Yalt., *F. sogdiana* Bunge, *F. pennsylvanica* Marshall, and *F. americana* L. [3]. Only *F. sogdiana* is native to Kazakhstan.

Modern land use and climate change pose a threat to the continued provision of ecosystem services expected from land cover. Studies of past land cover responses to such changes provide valuable information for future decision making. Precipitation is the main meteorological factor affecting tree growth, while temperature and atmospheric pressure also correlate significantly with tree growth [4].

Fraxinus species are of great interest for forest resilience as they can survive fire or drought by activating dormant vegetative buds for renewed growth [5].

Ash species were found to be the most resistant to environmental pollution, as other species' anatomical–morphological indicators decreased in polluted growing areas [6]. Under pollution conditions, the anatomical xeromorphic characteristics of tree leaf structures increased were enhanced and adaptability to stressful environmental conditions was observed [7].

Root traits, nitrogen concentration in tissues, and the ratio of stele diameter to root diameter explained up to 81–94% of the variation in intensity of root respiration in larch and up to 83–93% in ash [8]. The effect of soil compaction on the proportion of xylem vessels and the diameter of xylem vessels affected plant area and plant biomass in *Fraxinus*. In addition, soil compaction had an important effect on root anatomy and morphology at the seedling stage, with implications for plant physiology and growth [9]. Morphological and anatomical changes in leaf blades of ash under the influence of anthropogenic pollution have been studied. In a polluted environment, the anatomical xeromorphic characteristics of leaf structures were enhanced; the observed reactions were regarded as adaptive and compensating for the adverse effects of air pollution [7,10].

The three-dimensional arrangement of vessels and vessel connections in the secondary xylem of tree trunks of deciduous *Fraxinus* species with annular pores were studied in a series of thick cross-sections using a microscope and laser. Tracheids can facilitate the passage of water from the apoplast through the ring membrane of the terminal cells in tree rings [11]. The wood anatomy was studied for eight taxa (four species) of the genus *Fraxinus* L. indigenous to Turkey. There was a negative correlation between vascular height and radial and tangential diameter, vascular element length, fiber length and width, fiber lumen diameters, and ray width and height. The size of these elements decreased with height; in contrast, the number of vessels per mm^2 and the number of rays per mm increased with height [12].

Fraxinus bark has a long history of use in traditional Chinese medicine. However, it is difficult to differentiate and assess the quality of bark of different origins by using traditional chemical analysis methods, due to similar morphological features as well as the general chemical composition [13]. Fraxetin is a natural compound extracted from *Fraxinus* species and has antibacterial, antioxidant, neuroprotective, and antifibrotic properties. Although studies have reported its anti-cancer properties in lung and breast cancer, little is known about colorectal cancer, the most common type of cancer. The results suggest that fraxetin may be effective as a therapeutic agent against colorectal cancer, although further elucidation of the relationship between the distinctive abilities of fraxetin and the intracellular regulatory mechanism is needed [14]. Phytochemicals from *Fraxinus* species have a broad-spectrum antiviral activity [15].

It was determined that an average amount of soil nitrogen has a positive effect on the anatomy and physiology of ash leaves, while a high amount of nitrogen weakens the positive effect [16].

The main aim of the present study was to determine anatomical structure and identify the phytochemical composition of *F. sogdiana* growing in different soils in Kazakhstan.

2. Materials and Methods

2.1. Plant Material

The plant material of *F. sogdiana* was collected from 2–3-year-old individuals in June and July of 2020–2022 in the Temirlik River Valley of the Almaty region (in the area of SNNP "Sharyn") and in the Boralday River Valley of the Turkestan region (in the area of Syrdarya–Turkestan RNP), Figure 1.

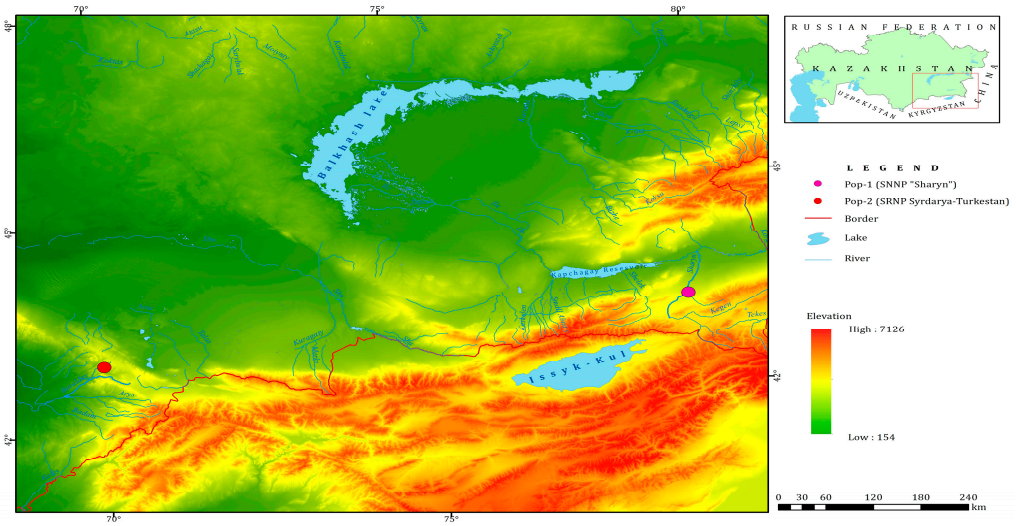


Figure 1. Map of the study areas. Population 1: Floodplain of the Temirlik River, coordinates 43°21′31.4″ N 79°09′56.5″ E, height above sea level 955 m. Population 2: Valley of the Boralday River, coordinates 43°00°10.7″ N 70°00°01.9″ E, height above sea level 824 m.

Sixty leaf samples were taken from two populations. Leaves were ovate-lanceolate, acuminate, pointed at the edges. The average leaf length was 10.25 ± 1.4 cm, and the leaf width averaged 4.4 ± 0.6 cm. Sixty stem and root samples were also taken from the same two populations.

For the phytochemical study, the leaves were first dried in the shade. All stages of the harvesting process were aimed at preserving the complex of biologically active substances in the raw material [17].

2.1.1. Soils of the Temirlik River Valley

The soils of the valleys of the Temirlik and Boralday Rivers, as one of the main factors determining the growing conditions of *Fraxinus sogdiana*, were studied. The bases of the study were edaphic (soil) conditions of tree species in habitats characterized by valley landscape, position in the relief represented by floodplain terraces, hydromorphic and semihydromorphic moisture regime with formation of floodplain meadow–forest soils, affecting the anatomo-morphological characteristics of plant vegetative organs. According to the natural zoning of Kazakhstan [18,19], the Temirlik River Valley belongs to the Ili River basin and the Ili-Balkhash-Alakol desert depression of the Ili semi-desert region with gray earth and gray-brown soils [20]. According to botanical–geographical zoning [21,22], the territory is part of the Dzungarian province of the Iran–Turan subregion, Sahara–Gobi Desert region, with a riparian floodplain forest and the meadow vegetation of the Ili and Sharyn River Valleys.

The study area belongs to the desert zone with light gray soils [23]. The valley of the Temirlik River is situated in the basin of the Ili River, which occupies the intermountain Ili represented by a lowland plain. The river is snow–glacial fed; its source is located on the southern slopes of the Ketmen mountain ridge and flows into the Sharyn River. The floodplain terrace of the river is characterized by the development of floodplain meadow–forest layered soils. The herbaceous layer under the tree canopy is represented by single individuals of *Asparagus angulofractus* Iljin, *Rubus caesius* L., *Elymus repens* (L.) Gould, *Poa bulbosa* L., *Sophora alopecuroides* L., *Cynanchum acutum* subsp. *sibiricum* (Willd.) Rech.f., *Clematis orientalis* L., and other species. At the periphery of plantations and in the lightened areas of the groves there are shrubs formed by Caragana halodendron (Pall.) Dum. Cours., Nitraria schoberi L., Lonicera nummulariifolia Jaub. and Spach, and Rosa laxa Retz. In the Temirlik River Valley, floodplain meadow–forest soils develop under a hydromorphic moisture regime, occupying areas of wide floodplain terraces. The weakly saline groundwater

occurs at a depth of 1–3 m and has a chloride–sulfate bicarbonate composition, contributing to soil salinization. The soil-forming rocks are river alluvial deposits.

2.1.2. Section of the Middle Reaches of the Boralday River

Soils of the Turkestan region are grayish brown, dark, dry, loose, dusty-grained, medium load, with inclusions of plant roots. Soil studies were carried out within the desert foothill zone, foothill belt, and the middle tier of the hilly wall foothill plains of Southern Karatau [24]. The Boralday River Valley belongs to the Syrdarya River basin. It is part of the Western Tien Shan province of the Chimkent-Pritashkent semi-desert and steppe piedmont area with sierozem and chestnut soils, and occupies the piedmont upland plain formed by loess. The river is mixed snow–rain fed and flows into the Arys River. The source is located on the slopes of the Boraldaytau Ridge, which is the southeastern spur of the Karatau Ridge. The floodplain forest–meadow granular soils of the semi-hydromorphic moisture regime have developed under the conditions of the floodplain terrace of the river, within the floodplain regime. Botanically and geographically, the valley belongs to the mountainous Middle Asian province, specifically the Karatau mountain sub-province and the piedmont plains of the Karatau Ridge. Foothill sagebrush deserts are characterized by the presence of grasses and ephemeroids in the vegetation cover.

Phytocoenose is represented by barberry ashberry (*Berberis* sp., *Fraxinus sogdiana* Bunge) with *Malus sieversii* (Ledeb.) M. Roem.) (synonym of *Malus domestica* (Suckow) Borkh. according to POWO) [25], *Salix karelinii* Turcz. ex Stschegl., *S. niedzwieckii* Goerz, *S. tenuijulis* Ledeb., *Rosa majalis* Herrm., *R. laxa* Retz., *R. kokanica* (Regel) Jus., mixed grasses (*Elymus repens*, *Poa bulbosa*, *Carex pseudocyperus* L., *C. riparia* Curtis, *Achillea filipendulina* Lam., *Cirsium vulgare* (Savi) Ten., *Mentha longifolia* var. *asiatica* (Boriss.) Rech.f., *Plantago lanceolata* L., *Salvia virgata* Jacq., *Eremurus tianschanicus* Pazij and Vved. ex Pavlov, *Allium turkestanicum* Regel, *Leonurus glaucescens* Bunge) and forb–grass–sagebrush (*Artemisia sublessingiana* Krasch. ex Poljak, *Lepidium draba* L., *Verbascum songaricum* Schrenk ex Fisch. and C.A.Mey., *Anthriscus silvestris* (L.) Hoffm. with *Rubus caesius* L.).

The river valleys are occupied by ash groves, riparian forests, reed beds, and in some places salt marshes and swamps. Soils of river valleys are represented by intrazonal soil types, the formation of which is associated with additional seasonal surface moisture and constant groundwater recharge with moisture, alluvial river deposits, and the influence of trees, shrubs, and meadow vegetation. The peculiarity of soil formation in the desert zone involves the emergence of salinization processes and an increase in carbonate content in the absence of precipitation in the summer. Floodplain meadow–forest soils that occupy positions above the floodplain terraces of different levels at different depths of groundwater occurrence have developed under woody vegetation.

2.2. Methods

2.2.1. Anatomical Analysis

For anatomical studies, fixation of materials was performed according to the Strasburger–Flemming method, with an alcohol, glycerin, and water ratio of 1:1:1 [26]. Anatomical studies were performed using fixed material. Transverse sections of roots, stems, and leaves were prepared using a microtome in a TOS-2 freezer. Thirty specimens from each organ from each population were used for the slices. Sections were made from the middle parts of leaves and stems. Roots were cut in their basal part along their entire length at 2–3 cm intervals. In a temporary preparation, the anatomical slices were fixed in glycerol. The object was covered with a coverslip and examined under a microscope, first at low magnification (×70, ×100) and then at high magnification (×200).

For anatomical studies, sectioning and staining methods were carried out according to Johansen (1940) with modifications. The plant materials were 3 mm sections of roots, stems, and leaves fixed in ethanol 70% for 48 h and then passed through 70, 90, and 96% ethyl alcohol series and xylol series, respectively. After that, plant parts were embedded in paraffin. Then, they were sectioned at 10–15 μm thicknesses using a sliding microtome.

The samples were kept in an oven at 65 °C in order to remove the paraffin from the slides. The samples taken from the oven were passed through the xylol and ethyl alcohol series and kept in safranin overnight, and then stained with Fast Green for 20 s. Following that, measurements and photographs were taken with the help of a camera-equipped light microscope (Leica DM750) [27].

For quantitative analysis, morphometric features were measured using an ocular micrometer MOV-1-15 (at objective × 9, × ocular 10). Microphotographs of anatomical sections were taken on an MC 300 microscope (Micros, Vienna, Austria) with a CAM V400/1.3 M video camera (jProbe, Tokyo, Japan). Microscopic examination of medicinal raw plant materials was carried out at the Laboratory of Plant Anatomy and Morphology at al-Farabi Kazakh National University [26,28,29].

The obtained data were analyzed using the Statistical Package for the Social Sciences (SPSS, version 20) computer program and the independent sample *t*-test. The level of significance was taken at 5%.

Statistical processing was used to analyze the data obtained, using a Microsoft Office software package. The correlation analysis was calculated using Rstudio software (Rstudio Team, 2015) [30].

The description of the external features was made in accordance with GF XI [31,32].

2.2.2. Determination of Organic Compounds in Plant Extracts

Ten grams of crushed (up to 5 µm) plant material was extracted for 48 h with 50 mL ethyl alcohol (96%); 1 mL was taken from these extracts and analyzed by gas chromatography with mass spectrometric detection (7890A/5975C).

Analysis conditions: Sample volume 3.0 µL, sample insertion temperature 250 °C, no flow division. Separation was carried out using a DB-35MS chromatographic capillary column with a length of 30 m, an inner diameter of 0.25 mm, and a film thickness of 0.25 µm at a constant carrier gas rate (helium) of 1 mL/min. The chromatography temperature was programmed from 40 °C (holding time 0 min.) at a heating rate of 10 °C/min until 150 °C (holding time 3 min.), then at a heating rate of 5 °C/min until 280 °C (holding time 10 min.). Detection was carried out in SCAN mode m/z 34-750. Agilent MSD ChemStation software (version 1701EA) was used to control the gas chromatography system and record and process the results and data. Data processing included determination of retention times and peak areas as well as spectral information from the mass spectrometric detector. The Wiley 7th edition and NIST'02 libraries were used to decipher the obtained mass spectra (the total number of spectra in the libraries is over 550 thousand).

2.2.3. Soil Analysis

Field surveys of soil cover were conducted at key sites in the valleys of the Temirlik and Boralday Rivers. Traditional methods were used in the studies [33]. The chemical analyses were carried out in the laboratory of the U.U. Uspanov Kazakh Research Institute of Soil Science and Agrochemistry in Almaty, in three replications. The study was based on the comparative geographical method [34,35], which consists of comparing the factors of soil formation and soil properties that determine the genesis and patterns of spatial distribution, and the formation of the soil cover structure in these conditions. To diagnose and characterize soil features and properties, three transects were laid within the study areas. The transect depth was determined by the level of soil-forming rocks or the groundwater level. The features were described using morphological methods [36], which determined the main processes of soil formation and the genetic soil type. Taxonomic determination of soil types, subtypes, and varieties was carried out according to the accepted classifications [37–39]. To obtain reliable data on the qualitative condition of soils in the river valleys, samples were taken to conduct analytical studies of the main indicators of the physical and chemical properties of the soils. Samples were taken from genetic horizons or layers. The number of soil samples was 36. Analysis of the indicators of physicochemical composition included determination of humus content, % (ST RK 34477-2019); gross nitrogen, % (GOST 26107-84); mobile nitrogen, mg/kg according to the Tyurin–Kononova

method [40]; mobile phosphorus (P_2O_5), mg/kg; mobile potassium (K_2O), mg/kg (GOST 26205-91); pH of aqueous solution (GOST 26423-85), absorbed bases (Ca, Mg, Na, K), mg-eq per 100 g of soil (GOST 26487-85-26950-86-26210-91); aqueous extract analysis, % (GOST 26423-85-26428-85); granulometric composition, % (GOST 12536-2014).

The results of studies [41,42] obtained by studying the soil cover and soils of the Syrdarya and Ili River Valleys, related to the presented regions, showed the formation of floodplain forest–meadow soils in uniform conditions, the uniformity of their genesis, their profile structure, and the limits of physical and chemical composition indicators. Five transects were laid on the floodplain terraces of the rivers. The number of soil samples taken for physical and chemical analysis was 52.

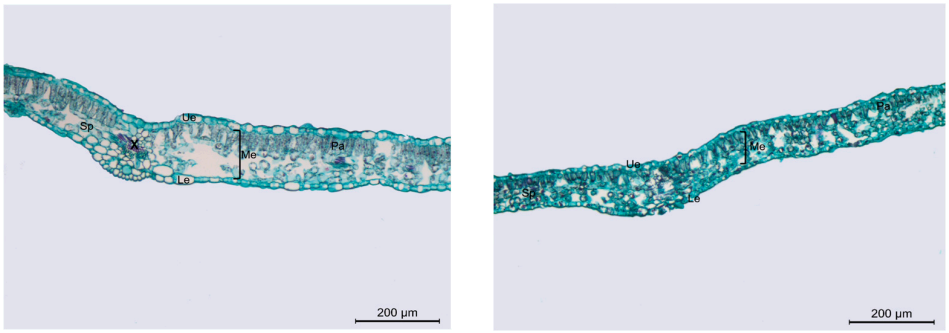
2.2.4. Plant Species Identification

The identification of plant species was carried out on the basis of identification keys in the *Flora of Kazakhstan* [43] and the *Illustrated Guide for Identification of the Plants of Kazakhstan* [44]. The names of plant species and genera were in accordance with the Plants of the World Online [25].

3. Results

3.1. Comparative Analysis of the Anatomical–Morphological Structure of the Leaf of F. sogdiana

When examining a cross-section of the leaf blade (Figure 2) of *F. sogdiana*, we observed thickened outer cell walls of the upper and lower epidermis (ue, le), and a thin cuticle layer. Depending on the growing conditions, the thickness of the upper epidermis (ue) and the thickness of lower epidermis (le) varied. The greatest development of stomata was observed in plants from the Boralday River area, and rather large air-bearing cavities were found under the stomata (ue).



(**a**) (**b**)

Figure 2. Anatomical structure of leaves of *F. sogdiana*: (**a**) Temirlik River; (**b**) Boralday River.

The columnar mesophyll parenchyma of plants from the Temirlik area consisted of two rows of oblong cells, with many chloroplasts, and the transition to the spongy parenchyma was clear (97.63 µm). The spongy parenchyma consisted of 3–4 rows of cells. (Table 1). In plants from the Boralday area, the mesophyll was looser (78.53 µm), consisting of two rows of columnar mesophyll cells and spongy mesophyll cells with large intercellular spaces (me, sp) filled with air. The statistical methods used in this work showed a significant difference between the regions, Figure 3. The thickness of the mesophyll of the Temirlik plants was significantly greater than that of the Boralday plants.

The conductive bundles located directly in the mesophyll were surrounded by single sclerenchyma cells (Temirlik), the cells which extend along the bundle. However, in plants from the Boralday area, the conductive bundles were smaller in size and had a well-developed sclerenchymal lining surrounding the conductive bundles; the conductive bundle endoderm consisting of alternating large and small rounded cells was clearly traceable. We found that the bioactive substances were concentrated around the xylem.

Table 1. Comparative leaf morphometrics of *F. sogdiana*. Significant differences are marked with an asterisk.

			Turkestan Region			Almaty Region		
Cell Types			**Mean (µm)**	**STD**	***n***	**Mean (µm)**	**STD**	***n***
Leaf	Epidermis	Width	18.20	5231	15	20.77	7.87	15
		Length	13.24	3708	15	12.37	2.36	15
	Mesophyll	Length	78.53 *	8095	15	97.63 *	10.50	15
	Trachea	Diameter	8.46 *	3027	15	4.58 *	1.67	15

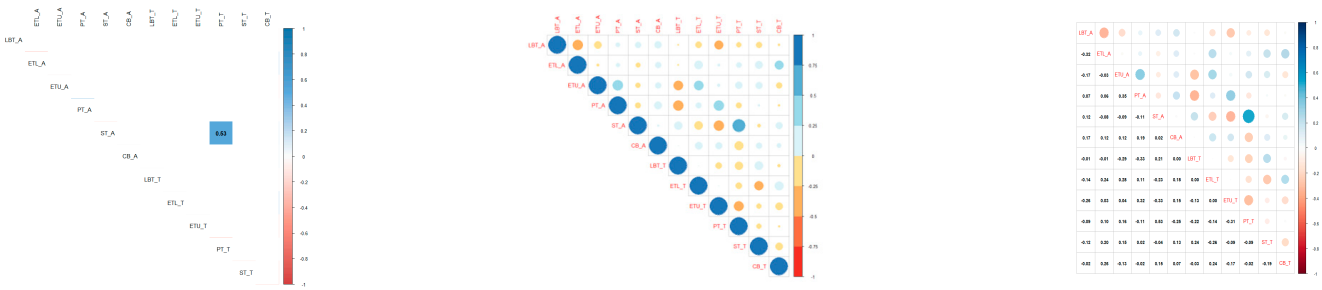
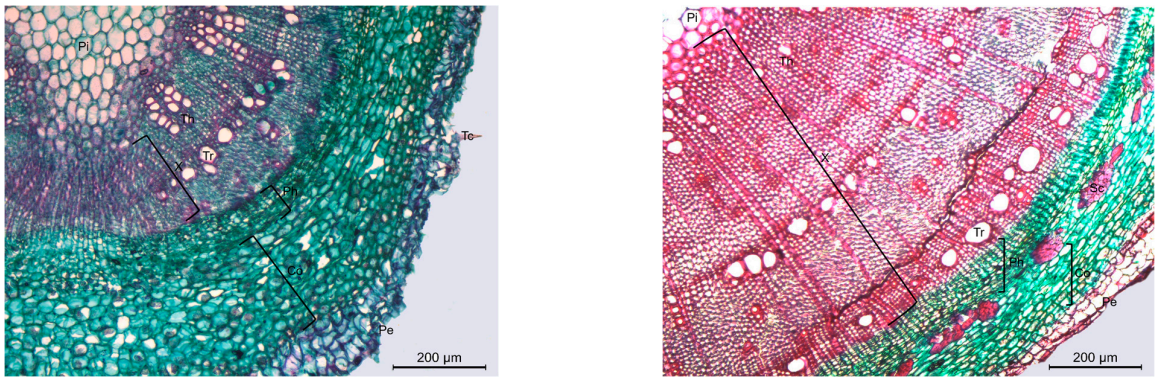


Figure 3. Correlation analysis of leaves from two regions. Correlations with $p < 0.05$ are highlighted in color. The color indicates either positive (blue) or negative (orange) correlation. (Leaf blade thickness-LBT_A,T; epidermis thickness lower-ETL_A,T; epidermis thickness upper-ETU_A,T; palisade tissue thickness-PT_A,T; sponge tissue thickness-ST_A,T; conductive bundle area-CB_A,T).

The collaterally closed conductive bundles were represented by the phloem sieve tubes (ph) and xylem vessels (x).

3.2. Comparative Analysis of the Anatomo-Morphological Structure of the Stem of F. sogdiana

The anatomical and morphological structures of the stems of *F. sogdiana* from the Temirlik area differ significantly from those of the plants growing in the Boralday area. The cross-section of the stems from the Temirlik River area (Figure 4) has a rounded outline. A cross-section from the Boralday River area (Figure 4) shows the stem with an even surface. The periderm (pe) is much more distinct, consisting of phellogen and its derivatives, phelloderm (deposited inwards) and phellema, or plug (secondary covering tissue, deposited outwards). For the first time, it was found that glycosides were localized between the vessels of the xylem.



(**a**) (**b**)

Figure 4. Anatomical structure of the stems of *F. sogdiana* (**a**) Temirlik River; (**b**) Boralday River.

The comparative morphometric parameters of the stems are shown in Table 2. The diameter of the pith of a stem from Temirlik was 36.84 µm, and from Boralday, 44.90 µm. The trachea diameter of a stem from Boralday was 37.15 µm, and from Temirlik, 18.90 µm, Figure 5. The width of the phloem from Boralday was 8.45 µm, and from Temirlik, 6.82 µm. The length of the cortex of a stem from Boralday was 33.42µm, and from Temirlik, 32.62 µm. These anatomical features are indicative of the growth pattern of a species under specific conditions.

Table 2. Comparative stem morphometrics of *F. sogdiana*. Significant differences are marked with an asterisk.

			Turkestan Region			Almaty Region		
	Cell Types		**Mean (µm)**	**STD**	***n***	**Mean (µm)**	**STD**	***n***
Stem	Pith	Diameter	45	14	15	37	8	15
	Trachea	Diameter	37 *	9	15	19 *	6	15
	Tracheid	Diameter	10 *	3	15	7 *	1	15
	Phloem	Width	8 *	1	15	7 *	2	15
		Length	17 *	2	15	14 *	2	15
	Cortex	Width	17	3	15	18	3	15
		Length	3	5	15	33	4	15

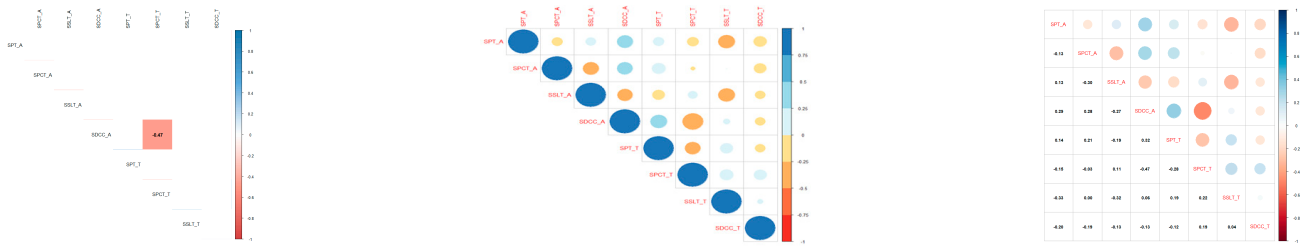
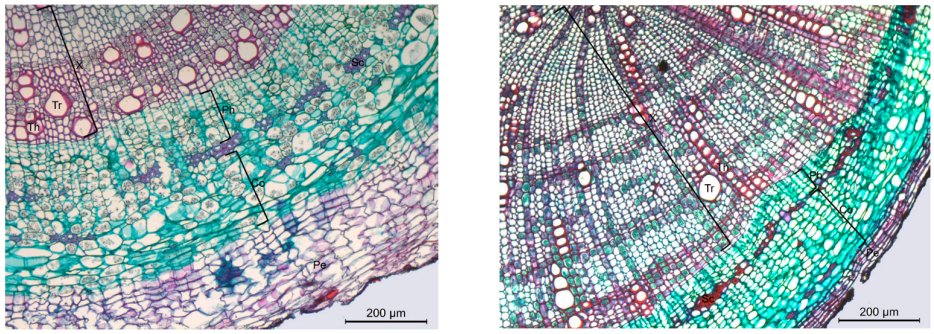


Figure 5. Correlation analysis of stems from two regions. Correlations with $p < 0.05$ are highlighted in color. The color indicates either positive (blue) or negative (orange) correlation. (Peridermal thickness-SPT_A,T; primary cortex thickness-SPCT_A,T; sclerenchymal layer thickness in the central cylinder-SSLT_A,T; diameter of central cylinder-SDCC_A,T).

3.3. Comparative Analysis of the Anatomo-Morphological Structure of F. sogdiana Roots

When a cross-section of the root of *F. sogdiana* from the Temirlik River area was examined, sloughing layers of periderm (pe) (dark green cell layer) forming rows of peripheral cells were visible on the root surface (Figure 6). There were 2–3 more or less concentric layers of secondary cortical parenchyma cells (pa). The cells were round with slightly thickened walls, without intercellular space. The secondary phloem (ph) was represented either by a continuous concentric layer of cells or by discontinuous areas around the cambial cell layer. The secondary phloem consisted mainly of heavy and radial parenchyma; it had relatively few sieve tubes. The cambial layer was represented by densely packed cells, which bordered the central cylinder. The tracheid diameter of roots from Boralday was 14.71 µm, and from Temirlik, 10.79 µm, Figure 7. The width of the phloem of roots from Boralday was 14.63 µm, and from Temirlik, 9.75 µm. The comparative morphometric indices of the roots are presented in Table 3.

As a result of a comparative anatomical and morphological analysis of vegetative organs (root, stem, leaf) of *F. sogdiana* collected from the areas of the Temirlik and Boralday Rivers, similarities and differences between the studied samples were both revealed. The results of a statistical analysis of the observed correlations between stem, leaf, and root traits are presented in Figure 8.



(**a**) (**b**)

Figure 6. Anatomical structure of the root of *F. sogdiana* (Temirlik (**a**) and Boralday (**b**) Rivers).

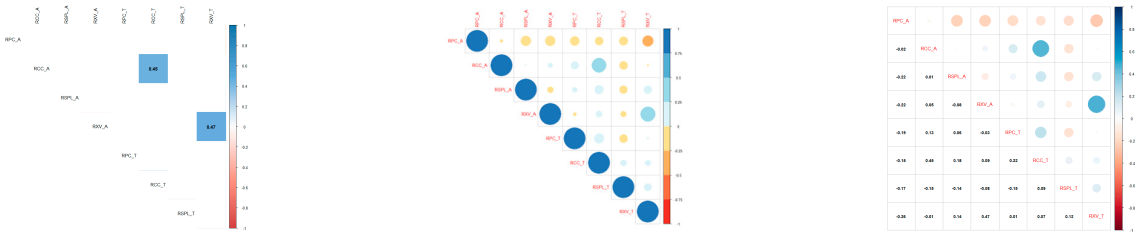


Figure 7. Correlation analysis of roots from two regions. Correlations with $p < 0.05$ are highlighted in color. The color indicates either positive (blue) or negative (orange) correlation. (Primary cortex thickness-RPC_A,T; central cylinder diameter-RCC_A,T; secondary phloem layer thickness-RSPL_A,T; xylem vessel area-RXV_A,T).

Table 3. Comparative morphometric indices of the root of *F. sogdiana*. Significant differences are marked with an asterisk.

			Fraxinus sogdiana B. Turkestan Region			*Fraxinus sogdiana* B. Almaty Region		
	Cell Types		**Mean (µm)**	**STD**	***n***	**Mean (µm)**	**STD**	***n***
Root	Trachea	Diameter	39	12	15	40	15	15
	Tracheid	Diameter	15 *	2	15	11 *	3	15
	Phloem	Width	15 *	2	15	10 *	2	15
		Length	22	4	15	19	5	15
	Schlerencyma	Diameter	15	3	15	15	4	15
	Cortex	Width	23	4	15	25	7	15
		Length	43	10	15	48	14	15

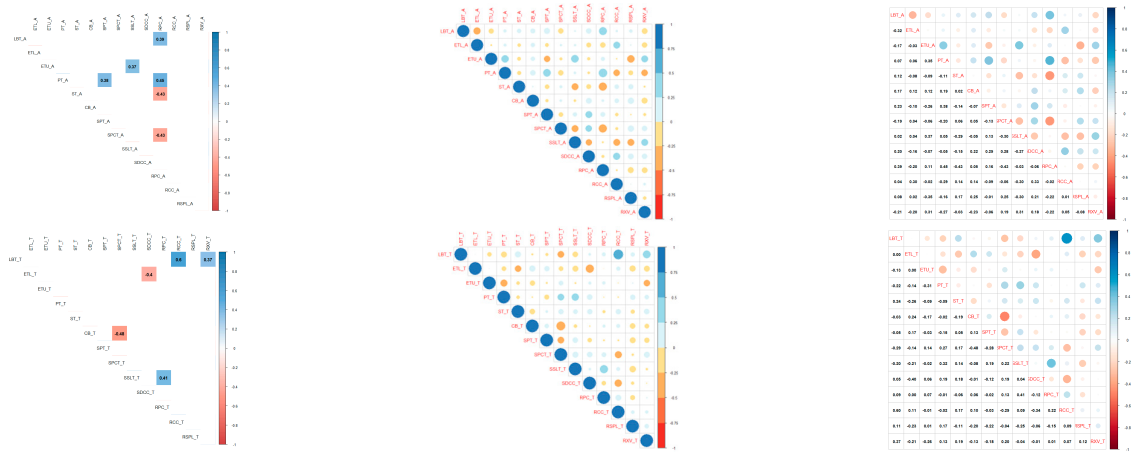


Figure 8. Correlation analysis of traits for leaf, stem, and root.

Distinctive features of the leaves include:

(1) The main feature identified in the anatomical structure of leaves of *F. sogdiana* from the area of the Temirlik River is the presence of large and frequent special motor cells in the upper and lower epidermis.
(2) In the Temirlik River area, the leaf mesophyll is looser, consisting of two rows of columnar mesophyll cells and two rows of spongy mesophyll cells with large intercellular spaces filled with air. The conductive bundles are smaller and have a well-developed sclerenchyma surrounding them; the conductive bundle of endoderm consisting of alternating large and small round-shaped cells is clearly visible.

Distinctive features of stems:

(1) Primary and secondary rays alternate among the cells of the central cylinder in plants from the Boralday region;
(2) The peripheral part of the pith is very well delineated, representing a perimedullary zone composed of smaller and thicker-walled cells;
(3) The pith is represented by a pronounced small-cell-hoarding parenchyma.

Thus, the anatomo-morphological study reveals that there are several features suggesting that the development of the conductive tissue of *F. sogdiana* is related to the moisture gradient in its habitat conditions. In the leaf blade, the large number of air-bearing cavities, the cutication of the stem walls, and the pronounced primary bark of the stem indicate the xerophytic features of plants from the Boralday River area, whereas mesophytic features can be observed in plants from the Temirlik River area. Therefore, the anatomical parameters of plants from the two study areas are substantially different.

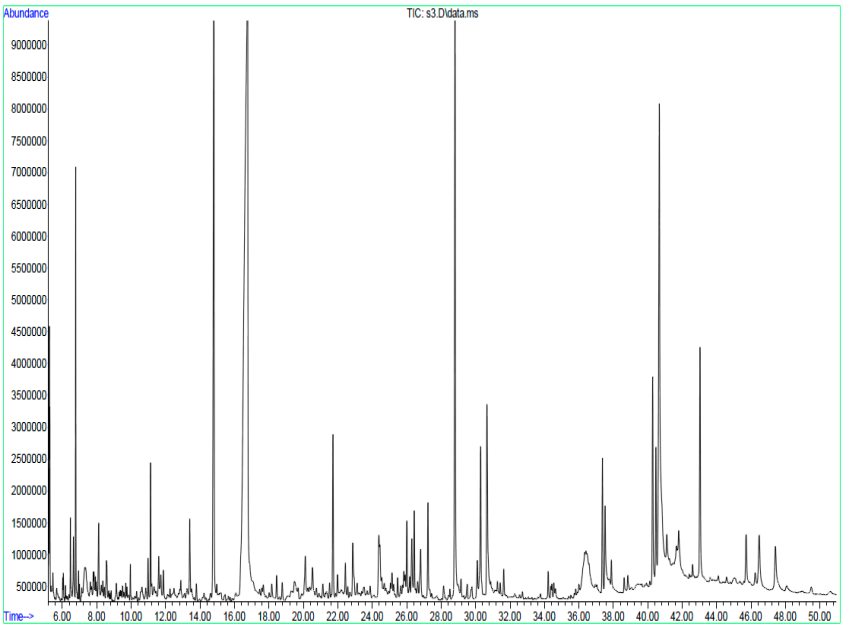
3.4. Organic Compounds in Plant Extracts

GC differentiation showed that there was a significant difference between *F. sogdiana* from Almaty and Turkestan regions and *F. pennsylvanica* from the Turkestan region. In the leaves of *F. sogdiana* from the Almaty region, 71 components were detected. In the Turkestan region, 60 components were detected in the leaves of *F. sogdiana* and only 54 components were detected in *F. pennsylvanica,* Figure 9. The results of the chromatographic analysis of *F. sogdiana* and *F. pennsylvanica* extracts are given in Appendices A–C . The phytochemical composition was analyzed and the most significant components are shown in Table 4, with the identified components of *F. pennsylvanica* for comparison.

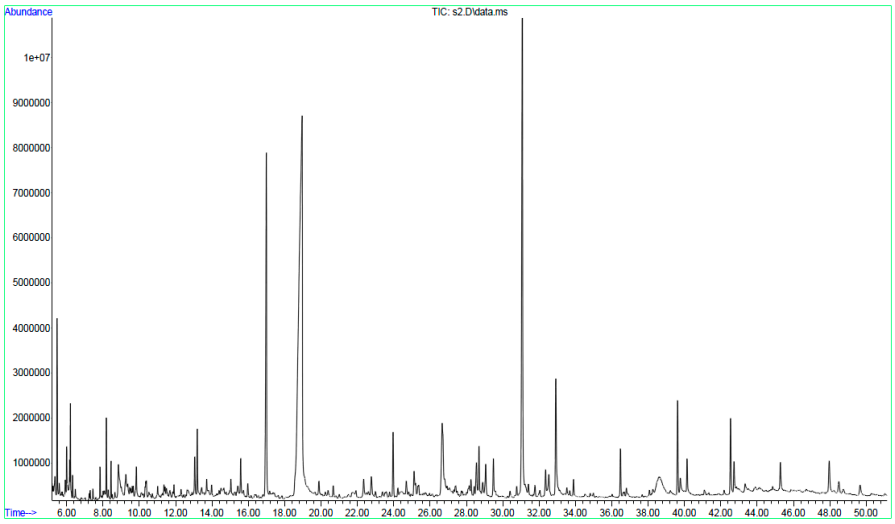
Soil Conditions in the Valleys of the Temirlik and Boralday Rivers

Edaphic ecotypes of forest species with characteristic genetic features and traits that develop under different growing conditions have significant variability in all their aspects. The edaphic form of Sogdian ash emerged under the influence of specific environmental conditions associated with the regime of rivers and groundwater, and the floodplain processes of soil formation. The root system of ash is superficial, growing horizontally with the predominance of the main mass of suction root endings in the upper soil layer, which has favorable physical properties, aeration, and the presence of nutrients. The taproot reaches the level of the capillary border and ground water with the formation of another branching.

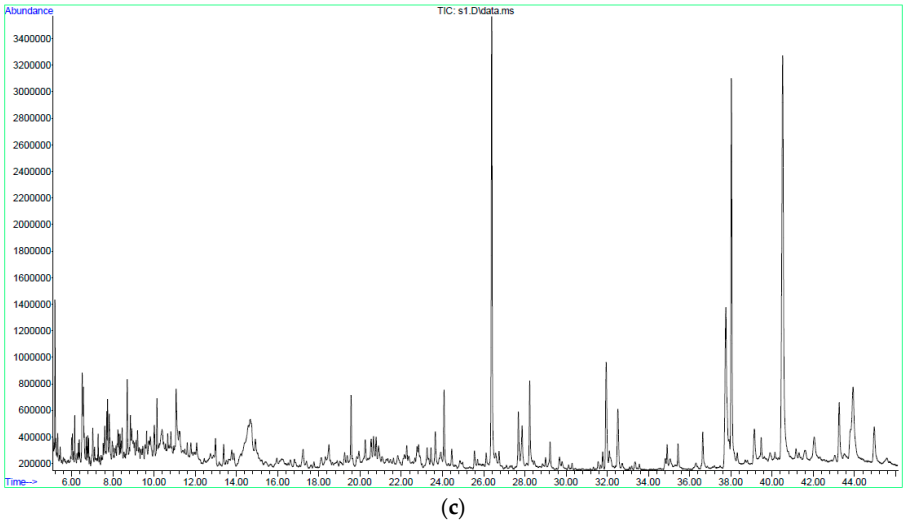
The river valleys are canyon-shaped, have a narrow floodplain terrace and a wide over-floodplain terrace of different levels with flat or convex tops; the levee floodplain is poorly expressed. Groundwater is fresh or slightly mineralized, the groundwater table depth is 2–5 m, and the supply is due to infiltration of atmospheric precipitation, inflow through riverbeds, and periodic flood waters.



(**a**)



(**b**)



(**c**)

Figure 9. Chromatogram of (**a**) *F. sogdiana* (Almaty region), (**b**) (Turkestan region), and (**c**) *F. pennsylvanica* (Turkestan region).

Table 4. Comparative GC differentiation: *F. sogdiana* and *F. pennsylvanica*.

Fraxinus sogdiana										*Fraxinus pennsylvanica*
№	Organic Compounds	RT, Area Percentage, (%)						Formula	Pharmacological Properties	References
		Almaty Region			Turkestan Region		Turkestan Region			
1	Phytol	28.81	6.70 (%)	31.08	14.20 (%)	26.40	12.45 (%)	$C_{20}H_{40}O$	Phytol is a constituent that exhibits several pharmacological effects, such as anticancer, antioxidant, and antimicrobial.	[45]
2	Squalene	40.47	1.40 (%)	42.73	0.83 (%)	38.03	10.34 (%)	$C_{30}H_{50}$	Squalene has nutritional, medicinal, and pharmaceutical health benefits, hence possessing antioxidant and cytoprotective effects.	[46]
3	Benzoic acid, 4-formyl-, methyl ester	14.80	6.30 (%)	16.99	7.95 (%)	13.38	0.46 (%)	$C_9H_8O_3$	Benzoic acid possesses anti-bacterial and anti-fungal properties. At a concentration of 0.1%, benzoic acid is a moderately effective preservative providing that the pH of the formulation (medicines, cosmetics, or foods) does not exceed 5.0. As ointment, benzoic acid is used for the treatment of fungal infections. Methyl ester is an anti-inflammatory agent	[47,48]
4	Benzeneethanol, 4-hydroxy-	16.75	27.59 (%)	18.96	35.54 (%)	14.92	1.01 (%)	$C_8H_{10}O_2$	Antibiotic and antimicrobial activity	[49]
5	9,12,15-Octadecatrienoic acid	30.67	3.17 (%)	31.78	0.33 (%)	-	-	$C_{18}H_{30}O_2$	Antioxidant, antimicrobial (antiviral, antibacterial and antifungal)	[48]
6	γ-Sitosterol	36.41	3.72 (%)	38.59	2.74 (%)	-	-	$C_{29}H_{50}O$	γ-sitosterol, an epimer of β-sitosterol, has antihyperglycemic activity by increasing insulin secretion in response to glucose, as confirmed by immunohistochemical studies of the pancreas.	[50]
7	Octadecanoic acid, 2-hydroxy-1-(hydroxymethyl)ethyl ester	40.67	9.97 (%)	-	-	-	-	$C_{21}H_{42}O_4$	Antioxidant and antibacterial activity	[48,51]
8	Tetratriacontane	43.04	2.99 (%)	-	-	40.52	19.76 (%)	$C_{34}H_{70}$	Antioxidant and antibacterial activity	[52]
9	Ethyl 9,12,15-octadecatrienoate	-	-	32.92	3.11 (%)	28.24	2.11 (%)	$C_{20}H_{34}O_2$	Anti-inflammatory activity	[53]
10	Tetratetracontane	35.82	0.15 (%)	45.28	0.81 (%)	43.93	6.42 (%)	$C_{44}H_{90}$	Antibacterial activity	[54]

In the Temirlik River Valley, floodplain meadow–forest soils develop under a hydromorphic moisture regime, occupying areas of wide floodplain terraces. The weakly saline groundwater occurs at a depth of 1–3 m and has a chloride–sulfate bicarbonate composition, contributing to soil salinization. River alluvial deposits serve as soil-forming rocks. Soils are characterized by a weakly formed profile and a humus horizon with a fragile dusty compound structure, indicating low intensity of biogenic-accumulative processes in combination with low capacity of silt fraction in the solid phase. On the surface, there is a thin (3–5 cm) turf horizon formed by turf grasses. The humus content in the upper horizon varies from 1.4 to 3.5%, drops sharply with depth, and depends on the granulometric composition. Soils have low or average content of mobile forms of nitrogen (30–60 mg/kg), low to high content of mobile phosphorus (15–60 mg/kg), and increased and high content of mobile potassium (220–490 mg/kg). Soils are carbonate (up to 3.0–5.0% carbonates in the upper part of the profile) with decreasing values with depth. Soil solution reaction is alkaline or strongly alkaline, pH = 8.2–9.3. Capacity of absorption (on the sum of the absorbed bases) is average, reaching 18.0–22.5 mg-eq per 100 g of soil in the surface horizon with a predominance of cations of calcium and magnesium. Soils are salinized by readily soluble salts; the sum of salts varies from 0.7 to 0.9% in the upper part and is comparatively desalinized (0.17–0.24%) in the lower part of the profile (deeper 60–80 cm). The salinity type is chloride–sulfate. Light loam horizons have a medium degree of salinity, and sandy loam horizons are slightly saline or non-saline. According to the salt depth, soils are of the solonchak type. According to the granulometric composition, light loamy varieties with predominant fractions of fine (39–42%) and medium (25–29%) sand are widespread. The distribution of silty fractions in the profile reveals maximum (26–28%) content in light loam sediments. The sandy loam varieties contain a large number of sand fractions (up to 70–80%), and small number (12–16%) of silt–silt fractions.

In the valley of the Boralday River, floodplain meadow–forest soils of semi-hydromorphic moisture regime are developing, occupying areas of over-floodplain terraces, that do not currently experience flooding, but with preserved signs of floodplain soil formation. Soils are formed under natural forest stands on medium-deep (4–6 m) groundwater. Soil-forming rocks are loams underlain by river sand–gravel sediments, preventing intensive groundwatering of soils due to the prevailing number of non-capillary pores of large diameter, which determines their xeromorphism. The soils are characterized by features of textural differentiation of profile with development of a granular structure 5–10 cm thick in the upper part of the sod and humus-accumulative horizon. Its content is 3.5–6.0% humus, which is an

indicator of biogenic-accumulative and eluvial processes in conditions long influenced by meadow and woody vegetation. In the illuvial–carbonate horizon of compacted formation and granular–crustal structure, signs are expressed of the modern process of accumulation of new carbonate formations (4.0–8.0%) with increasing depth. In the transition to the soil-forming horizon, residual signs of oxidation-reduction processes of the past hydromorphic stage of soil formation are prominent in the form of rusty spots of iron oxides. The soils have a low to average supply of mobile forms of nitrogen (30–50 mg/kg), an average and increased supply of mobile phosphorus (20–35 mg/kg), and an average to high supply of mobile potassium (120–400 mg/kg). The reaction of the soil solution is alkaline, pH = 8.4–8.9, which is characteristic of the desert type of soil formation. Absorption capacity is within the limits of 14–25 mg per 100 g of soil, with predominance in the absorbed calcium and magnesium cations, which determines the process of structure formation. Soils are not saline, the sum of salts does not exceed 0.05–0.10% up to depth of sandy–gravel deposits. According to the granulometric composition, the soils are medium loamy with predominance of coarse (40–45%) and fine (21–23%) dust fractions. In the profile, there is a redistribution of silt and dust fractions with some increase in values (39–43%) in the middle part, characterizing the formation of illuvial horizon. The low content of silt fractions (6–12%) determines the low absorptive capacity. The correlation between the content and distribution of physical clay particles (34–40%) and hygroscopic water (2.0–2.7%) in the 0–60 cm layer was revealed, characterizing the index of the total surface of fine particles possessing absorption energy and the possibility of water adsorption. In the underlying stratum, with the reduction of physical clay particles to 30% and increase of fine sand fraction up to 60%, the water-holding capacity of soil horizons decreases and their filtration capacity increases.

4. Discussion

Under global climate change, warming and drought are becoming increasingly serious. Most anatomical parameters were significantly positively correlated with daily accumulated temperature, although there were some differences between them. Climate warming and drying reduces the area and number of vessels in ash trees, but does not affect the distribution of vessels; current climate warming and drying does not limit the radial growth of ash trees, but promotes it. It was found that the upper slope position has a positive effect on the total area of ash wood vessels, and humidity, also effects changes in the anatomical structure of the wood [55]. The influence of environmental changes can also be observed; for example, where there is moderate humidity, ash leaves show signs characteristic of mesophytic plants, while plants in warmer areas show signs characteristic of xerophytic plants.

However, little is known about the response of xylem to the recent abrupt warming in many regions. The plasticity of the response and adaptation strategies of radial growth, early wood vessels, and hydraulic characteristics of Fraxinus have been studied in relation to climate change. Compared to the cold wet zone, trees in the warm dry zone were found to have wider rings, larger vessel area, more vessels, larger hydraulic diameters, and higher theoretical hydraulic conductivity in their tree rings. This provides a potential physiological explanation for the increased growth and range expansion of the main broadleaf tree species in the temperate zone: In the warm arid zone, trees benefit greatly from a continuously warming climate, but the risk of hydraulic deficiency may increase [56]. It has been noted that ash trees are recollective; sometimes populations are flooded, and changes in the anatomical structure of tree rings in periodically flooded trees have allowed the reconstruction of historical floods in unregulated hydrological systems. In regulated rivers, the study of flood rings can reconstruct the history of past floods, suggesting that hydrological regulation may have an impact. Study indicates that the xylem size is larger in ash plants growing near the Boralday River where weather conditions are more favorable, compared with plants growing near the Temirlik River where weather conditions are colder.

Xylem anatomy can provide valuable information on tree allometry and ecophysiological characteristics. It has unique advantages in the study of global climate change

and forest adaptation compared with traditional ring width or density proxies. The development of appropriate detrended sequences of xylem characteristics is necessary for a number of further studies. Tree growth in height depends on sufficient mechanical trunk support and an efficient hydraulic system. On unstable slopes, tree growth is affected by soil pressure from above and potential soil erosion from below the position of the tree. The necessary stabilization is provided by the production of mechanically stronger wood with reduced hydraulic conductivity. Unfortunately, the interaction between tree growth (both radial and axial) and stabilization in the soil is still poorly understood. Therefore, in this study, we sought to quantify the effects of slope dynamics on tree growth and hydraulic limitation, as well as the potential effects on tree height and growth plasticity. It was found that tree stabilization on unstable soil is accompanied by a failure to establish a sufficiently efficient hydraulic system, resulting in severe limitation of growth in height. This affects above-ground biomass accumulation and carbon sequestration, i.e., soil sequestration [57].

Drought is a critical and increasingly common abiotic factor that affects plant structure and function and is a problem for successful management of forest ecosystems. Changes in the morpho-anatomical or hydraulic characteristics of leaves and the growth of plants above ground were detected. Drought-induced changes in ash trees were found. The thickness of the palisade mesophyll, spongy mesophyll, and abaxial and adaxial epidermis increased under the influence of drought. Correlation analysis of ash tree traits indicates drought tolerance. The relationship between leaf morpho-anatomical traits was similarly affected by drought in all species studied, suggesting a lack of clear evidence to differentiate taxa on the basis of drought tolerance [58]. Correlations were found between functional traits of plants that are known to be related to drought tolerance. Thus, it has been determined that anatomical traits that indicate the ability of seedlings to cope with drought can be used + when selecting drought-tolerant species.

The results we obtained show that anatomical features are constantly adapting to changing environmental conditions and are directly linked to key functions and physiological processes of trees.

The Fraxinus plant is known to be a valuable medicinal candidate with its potential anticancer, anti-inflammatory, antioxidant, and neuroprotective properties. The phytochemical components of this plant have not been sufficiently studied in Kazakhstan, therefore it is necessary to determine the phytochemical composition of *F. sogdiana* growing in different soil conditions.

Medicinal plants are promising sources of biologically active phytochemicals. Phytochemical screening of plants reveals medicines, allowing development of new therapeutic agents and interpretation of the medicinal effects of different plant species [59,60]. Over recent decades, studies have shown that phytochemicals play an important role in ecosystem management and in the prevention of chronic diseases such as cancer [61]. Chemical analyses point to the effective role played by plant extracts and their mechanism of action, whether at environmental or therapeutic levels [62].

When several tree species were evaluated, including a preliminary assessment of the anticancer, anti-inflammatory and antidiabetic effects of tree sprout extracts, the most effective was ash. It should be noted that the beneficial activity of ash tree sprout extracts is due to their high phenolic acid content [63]. The results of various in vitro and in vivo studies have demonstrated the versatile use of ash in biological systems. The trunk bark, root bark, and leaf extract of the plant have been widely used in traditional folk medicine since ancient times. Extracts of the Fraxinus plant can serve as a model for the development of new medicines and the synthesis of new compounds for the treatment of various human tumors. Data on the chemical components of *F. sogdiana* extracts have been unavailable, so our research identified for the first time and characterized some components of the phytochemical composition. Various pharmacological perspectives relating to the Fraxinus plant, such as proper dosage and clinical efficacy, remain to be determined in the future.

The correlation between species in terms of drought tolerance and other morphological, physiological, and biochemical traits was assessed, establishing that ash trees are highly

susceptible to prolonged drought. The data can be used in the selection of species for afforestation programmes and the establishment of resilient forests, especially with drought-resistant species, under conditions of increasing frequency and intensity of spring and summer droughts [64]. Statistical processing of our own research also found correlation by traits and by regions.

Many varied chemical components including coumarins, secoiridoids, phenylethanoids, flavonoids, and lignans have been isolated from *Fraxinus* species. Extracts and metabolites have been found to possess anti-inflammatory, immunomodulatory, antimicrobial, antioxidative, skin regenerating, photodynamic damage prevention, liver protecting, diuretic, and antiallergic properties. Some species find applications in contemporary medicine [45–54].

The interaction of several factors shows that phenolic compounds cause many ecological and economic problems as they affect soil content. In this context, soil properties in the river valleys were studied.

The soils are layered, with alternating interlayers of light loam and sandy loam granulometric composition, and have high porosity, which provides aeration for plant roots in the intermittent period. Layers of different composition are characterized by capillary and non-capillary porosity (with prevalence of capillary porosity in light loam layers and equal porosity in sandy loam layers), determining the water-holding capacity of soils and the presence of soil moisture of different degrees of availability to plants [65]. They are underlain by loose sandy sediments with inclusions of pebbles, saturated with moisture from groundwater, having active circulation and significant outflow.

The humus and nitrogen content in the surface humus-accumulative horizon of meadow–sierozem non-saline soils of the floodplain terrace with ash stands is relatively high, gradually decreasing with depth and an average humus nitrogen supply. The soils are characterized by a low to very low supply of hydrolysable nitrogen and mobile phosphorus, but a high to medium supply of mobile potassium. The soils are low-carbonate; the amount of carbonate tends to increase with depth to a maximum in the transition zone between the soil and the soil-forming horizon. The soil solution reaction is alkaline with alkalinity increasing with depth. The increased content of humus and average loamy granulometric composition have caused an average absorption capacity (on the sum of the absorbed bases) in the top humus-accumulative horizon. The soils are not saline, and do not have easily soluble salts in composition down to the depth of the sandy–pebble deposits. According to the granulometric composition, the soils are medium loamy with some redistribution of silty–dusty fractions in the middle part of the profile.

Comparative analysis of the data obtained showed that the studied soils belong to different genetic types, differing in terms of conditions and time of soil formation and their morphogenetic properties, causing changes in the anatomical features of the study species.

5. Conclusions

As a result of the study, it was found that in Almaty region there are preserved natural relict ash groves in the Sharyn SNNP and the Turkestan region. A comparative anatomical and morphological analysis of the vegetative organs of *F. sogdiana* revealed similarities and differences between the specimens studied. In the leaf blade, a large number of air cavities, cutinization of the stem walls, and pronounced primary bark of the stem indicate the xerophytic features of plants from the area of the Boralday River, while mesophytic features prevail in plants from the region of the Temirlik River. It was found that bioactive substances concentrated around the xylem vessels of the leaves and stems.

GC differentiation showed the presence of glycosides and alkaloids. The medicinal properties are due to the presence of antioxidant, antitumor, and antibacterial substances. The presence of phytol suggests several pharmacological effects, such as anticancer, antioxidant, and antimicrobial. Squalene has nutritional and medicinal benefits, due to antioxidant and cytoprotective effects. Benzoic acid has antibacterial and antifungal properties. The results of chromatographic analysis of the leaf extract of *F. sogdiana* from the Almaty region

showed 71 chemical compounds, while in the extract taken from the Turkestan region 60 components were detected.

Comparative analysis of the data obtained showed that soil fertility, nutrient content, moisture, and climatic factors can cause changes in morphological features of *F. sogdiana*. Analysis of soil conditions in the valleys of the Temirlik and Boralday Rivers revealed changes in the anatomical and morphological features of plants depending on the depth of the groundwater table, degree of formation, and water–physical properties of the soils. Morphogenetic features of floodplain forest–meadow soils were compared, including soils of different formation time, occupying different positions in the relief, differing in classification (type, variety), physical and chemical properties, formation by floodplain processes, and the influence of zonality.

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Nomenclature

Abbreviations	Anatomical features
ue	upper epidermis
pa	palisade parenchyma
me	mesophyll
sp	sponge parenchyma
le	lower epidermis
tr	trachea
th	tracheid
x	xylem
ph	phloem
co	cortex
pe	periderm
tc	trichom
pi	pith
sc	sclerenchyma

Appendix A

Table A1. Results of chromatographic analysis of *F. sogdiana* extract (Almaty region).

№	Retention Time, min	Compounds	Probability of Identification, %	Percentage Content, %
1	5.46	2-Cyclopenten-1-one	81	0.11
2	6.18	2-Cyclopenten-1-one, 3,4-dimethyl-	87	0.15
3	6.47	2-Cyclopenten-1-one, 2-hydroxy-	89	0.59
4	6.78	Benzaldehyde	96	1.97

Table A1. *Cont.*

№	Retention Time, min	Compounds	Probability of Identification, %	Percentage Content, %
5	6.95	Butanoic acid, 4-hydroxy-	93	0.21
6	7.32	Glycerin	78	1.30
7	7.63	2H-Pyran-2-one	77	0.38
8	7.84	Benzyl alcohol	92	0.42
9	8.11	2-Hydroxy-gamma-butyrolactone	73	0.79
10	8.36	Benzaldehyde, 3-methyl-	80	0.15
11	8.57	Benzoic acid, methyl ester	86	0.52
12	9.14	Phenylethyl Alcohol	83	0.27
13	9.51	Maltol	81	0.50
14	9.69	Phenol, 4-ethyl-	70	0.35
15	9.95	Cyclopropyl carbinol	78	0.32
16	10.63	Catechol	61	0.37
17	10.85	2(3H)-Furanone, 5-acetyldihydro-	64	0.22
18	10.98	Benzofuran, 2,3-dihydro-	84	0.34
19	11.13	2-Propenal, 3-(2-furanyl)-	83	1.07
20	11.72	Phenol, 3-(diethylamino)-	76	0.38
21	11.87	3,6-Dianhydro-α-d-glucopyranose	80	0.38
22	12.26	Acetic acid, 2-oxa-7-thia-tricyclo [4.3.1.0(3,8)]dec-10-yl ester	61	0.13
23	12.88	2-Methoxy-4-vinylphenol	81	0.50
24	13.41	2H-Pyran-5-carboxylic acid, 2-oxo-, methyl ester	82	1.03
25	13.79	3-Pyridinecarboxylic acid, 5-ethenyl-, methyl ester	77	0.17
26	14.80	Benzoic acid, 4-formyl-, methyl ester	92	6.30
27	15.65	3-Buten-2-one, 4-(2,6,6-trimethyl-1-cyclohexen-1-yl)-	74	0.08
28	16.75	Benzeneethanol, 4-hydroxy-	89	27.59
29	18.17	N-Acetyltyramine	78	0.28
30	18.45	3,4-Dihydroxyphenylacetylformic acid	68	0.29
31	19.49	Homovanillyl alcohol	73	0.58
32	19.70	2(4H)-Benzofuranone, 5,6,7,7a-tetrahydro-4,4,7a-trimethyl-	75	0.19
33	20.11	N-Acetyltyramine	82	0.75
34	20.53	Benzene, 1,1′-tetradecylidenebis-	68	0.63
35	21.52	2-Hexadecene, 3,7,11,15-tetramethyl-	71	0.17
36	21.72	3,7,11,15-Tetramethyl-2-hexadecen-1-ol	88	1.57
37	21.99	Acethydrazide, 2-(2-benzothiazolylthio)-N2-(3-fluorobenzylideno)-	63	0.30
38	23.12	2-Pentadecanone, 6,10,14-trimethyl-	71	0.37
39	23.88	5a,9,9-Trimethyloctahydro-2H,4H-cyclopropa[e][3]benzoxepine-2,4-dione	66	0.20
40	24.39	2H-Pyran-2-one, 5-ethylidenetetrahydro-4-(2-hydroxyethyl)-	73	1.71
41	25.15	5-Chlorovaleric acid, hexadecyl ester	61	0.74
42	26.01	5,5,8a-Trimethyl-3,5,6,7,8,8a-hexahydro-2H-chromene	70	0.76
43	26.18	Deoxyqinghaosu	65	0.25
44	26.30	Hexadecanoic acid	83	0.71
45	26.44	Hexadecanoic acid, ethyl ester	90	0.86
46	26.81	Acetic acid, 2-(2,2,6-trimethyl-7-oxa-bicyclo [4.1.0]hept-1-yl)-propenyl ester	70	0.62
47	27.24	Benzoic acid, 3-formyl-4,6-dihydroxy-2,5-dimethyl-, methyl ester	64	1.02
48	28.81	Phytol	91	6.70
49	29.51	9,12,15-Octadecatrienoic acid, methyl ester	71	0.20

Table A1. *Cont.*

№	Retention Time, min	Compounds	Probability of Identification, %	Percentage Content, %
50	30.10	Ethyl Oleate	81	0.46
51	30.29	Octadecanoic acid, ethyl ester	86	1.80
52	30.67	9,12,15-Octadecatrienoic acid	87	3.17
53	31.64	Drometrizole	86	0.35
54	32.73	17-Pentatriacontene	67	0.08
55	33.77	Methyl 19-methyl-eicosanoate	60	0.08
56	34.55	Hexanedioic acid, bis(2-ethylhexyl) ester	75	0.17
57	35.82	Tetratetracontane	66	0.15
58	36.41	γ-Sitosterol	85	3.72
59	37.53	Hexadecanoic acid, 2-hydroxy-1-(hydroxymethyl)ethyl ester	84	1.40
60	37.89	Diisooctyl phthalate	86	0.59
61	38.84	Octacosane	76	0.21
62	40.47	Squalene	93	1.40
63	40.67	Octadecanoic acid, 2-hydroxy-1-(hydroxymethyl)ethyl ester	86	9.97
64	41.11	9,12,15-Octadecatrienoic acid, 2,3-dihydroxypropyl ester	72	1.84
65	41.80	Distearin	66	1.90
66	43.04	Tetratriacontane	91	2.99
67	45.71	γ-Tocopherol	89	0.98
68	46.24	β-Sitosterol acetate	70	0.31
69	46.47	Hexatriacontane	72	1.24
70	47.42	Vitamin E	84	1.17
71	51.92	Stigmasterol	63	0.52

Appendix B

Table A2. Results of chromatographic analysis of *F. sogdiana* extract (Turkestan region).

№	Retention Time, min	Compounds	Probability of Identification, %	Percentage Content, %
1	5.18	Acetic acid	84	2.56
2	5.47	2-Propanone, 1-hydroxy-	92	2.20
3	5.59	Propanoic acid, 2-hydroxy-, ethyl ester	86	0.22
4	6.21	2-Butenal, 2-ethenyl-	89	1.01
5	6.48	2-Cyclopenten-1-one	81	0.14
6	7.25	2-Cyclopenten-1-one, 2-methyl-	79	0.10
7	7.29	Ethanone, 1-(2-furanyl)-	84	0.15
8	7.45	2-Cyclopenten-1-one, 3,4-dimethyl-	67	0.18
9	7.84	1,2-Cyclopentanedione	87	0.49
10	8.19	Benzaldehyde	90	1.18
11	8.29	Mesitylene	68	0.27
12	8.44	Butanoic acid, 4-hydroxy-	96	0.49
13	8.66	2-Cyclopenten-1-one, 3,4-dimethyl-	78	0.25
14	8.85	1,2,3-Butanetriol	79	1.71
15	9.01	1,2,4-Butanetriol	64	0.55
16	9.26	2H-Pyran-2-one	60	1.12

Table A2. *Cont.*

№	Retention Time, min	Compounds	Probability of Identification, %	Percentage Content, %
17	9.61	2-Cyclopenten-1-one, 2,3-dimethyl-	79	0.24
18	9.67	2-Cyclopenten-1-one, 2,3,4-trimethyl-	78	0.27
19	9.84	2-Hydroxy-gamma-butyrolactone	76	1.03
20	11.01	Phenylethyl Alcohol	85	0.44
21	11.42	Maltol	68	0.24
22	11.91	Cyclopropyl carbinol	69	0.30
23	13.05	Benzofuran, 2,3-dihydro-	83	1.07
24	13.19	2-Propenal, 3-(2-furanyl)-	85	1.40
25	13.71	Phenol, 3-(diethylamino)-	72	0.52
26	13.98	3,6-Dianhydro-α-d-glucopyranose	81	0.35
27	15.04	2-Methoxy-4-vinylphenol	85	0.38
28	15.58	2H-Pyran-5-carboxylic acid, 2-oxo-, methyl ester	89	0.89
29	15.97	3-Pyridinecarboxylic acid, 5-ethenyl-, methyl ester	80	0.30
30	16.99	Benzoic acid, 4-formyl-, methyl ester	91	7.95
31	18.96	Benzeneethanol, 4-hydroxy-	89	35.54
32	19.89	2(5H)-Furanone, 4-methyl-3-(2-methyl-2-propenyl)-	75	0.45
33	20.39	Tyramine, N-formyl-	70	0.21
34	20.67	Benzenepropanoic acid, 3,4-dihydroxy-, methyl ester	63	0.27
35	22.35	N-Acetyltyramine	82	0.54
36	22.77	Benzene, 1,1′-tetradecylidenebis-	70	0.72
37	23.97	3,7,11,15-Tetramethyl-2-hexadecen-1-ol	88	1.39
38	25.38	2-Pentadecanone, 6,10,14-trimethyl-	78	0.27
39	28.43	Deoxyqinghaosu	63	0.28
40	28.56	Hexadecanoic acid	84	1.06
41	28.70	Hexadecanoic acid, ethyl ester	89	1.14
42	29.07	Acetic acid, 2-(2,2,6-trimethyl-7-oxa-bicyclo [4.1.0] hept-1-yl)-propenyl ester	70	1.02
43	29.49	2-Propenoic acid, 3-(3-hydroxy-2,6,6-trimethyl-1-cyclohexen-1-yl)-, methyl ester	66	0.64
44	30.77	Dibutyl phthalate	87	0.34
45	31.08	Phytol	89	14.20
46	31.78	9,12,15-Octadecatrienoic acid, methyl ester	76	0.33
47	32.36	Ethyl Oleate	85	0.70
48	32.54	Linoleic acid ethyl ester	70	0.85
49	32.92	Ethyl 9,12,15-octadecatrienoate	88	3.11
50	33.90	Drometrizole	86	0.33
51	36.81	Hexanedioic acid, bis(2-ethylhexyl) ester	66	0.14
52	38.59	γ-Sitosterol	76	2.74
53	39.78	Glycerol 1-palmitate	72	0.71
54	40.15	Diisooctyl phthalate	90	0.93
55	42.73	Squalene	88	0.83
56	45.28	Tetratetracontane	83	0.81
57	47.97	γ-Tocopherol	89	1.04
58	48.50	Stigmast-5-en-3-ol, oleate	69	0.41
59	49.67	dl-α-Tocopherol	82	0.48
60	54.18	Stigmasterol	65	0.46

Appendix C

Table A3. Results of chromatographic analysis of *F. pennsylvanica* extract (Turkestan region).

№	Retention Time, min	Compounds	Probability of Identification, %	Percentage Content, %
1	5.33	Furfural	86	0.22
2	5.45	2-Cyclopenten-1-one	82	0.22
3	6.01	Pentanoic acid	61	0.36
4	6.04	Ethanone, 1-(2-furanyl)-	87	0.32
5	6.38	2-Cyclopenten-1-one, 2-hydroxy-	68	0.44
6	6.71	Benzaldehyde	84	0.37
7	6.78	Mesitylene	81	0.51
8	6.82	Butanoic acid, 4-hydroxy-	75	0.35
9	7.03	2-Cyclopenten-1-one, 3,4-dimethyl-	77	0.92
10	7.12	5-Methylene-1,3a,4,5,6,6a-hexahydropentalen-1-ol	60	0.33
11	7.53	p-Cresol	72	0.33
12	7.61	Benzyl alcohol	67	0.93
13	7.71	2-Cyclopenten-1-one, 2,3-dimethyl-	71	0.72
14	7.75	2-Cyclopenten-1-one, 2,3,4-trimethyl-	84	1.04
15	8.30	2-Cyclopenten-1-one, 3,4,5-trimethyl-	72	0.49
16	8.36	2-(2-Isopropenyl-5-methyl-cyclopentyl)-acetamide	69	0.60
17	8.70	Phenylethyl Alcohol	87	1.97
18	8.86	Phenol, 2,5-dimethyl-	60	0.95
19	9.64	p-Propargyloxytoluene	61	0.86
20	10.15	Benzofuran, 2,3-dihydro-	84	1.53
21	10.67	Phenol, 2,4,5-trimethyl-	62	1.09
22	10.82	1,4:3,6-Dianhydro-α-d-glucopyranose	73	1.03
23	11.08	5-Hydroxymethylfurfural	87	3.34
24	11.62	2-Methoxy-4-vinylphenol	62	0.80
25	11.79	1-Naphthalenol, 4-methyl-	67	0.80
26	13.38	Benzoic acid, 4-formyl-, methyl ester	81	0.46
27	14.92	Benzeneethanol, 4-hydroxy-	73	1.01
28	18.49	Acetic acid, chloro-, octadecyl ester	72	0.97
29	19.57	3,7,11,15-Tetramethyl-2-hexadecen-1-ol	88	2.02
30	20.78	2-Ethylhexyl salicylate	79	0.68
31	20.90	2-Pentadecanone, 6,10,14-trimethyl-	68	0.64
32	22.27	Benzoic acid, heptyl ester	65	0.61
33	22.77	Benzoic acid, pentyl ester	66	0.62
34	24.08	Hexadecanoic acid, ethyl ester	86	1.90
35	24.45	Ether, (2-ethyl-1-cyclodecen-1-yl)methyl methyl	61	0.47
36	26.13	Phthalic acid, butyl isohexyl ester	73	0.42
37	26.40	Phytol, acetate	90	12.45
38	26.75	1-Tricosanol	70	0.43
39	27.69	Ethyl Oleate	65	1.76
40	27.87	Octadecanoic acid, ethyl ester	68	1.55
41	28.24	Ethyl 9,12,15-octadecatrienoate	88	2.11
42	29.23	Drometrizole	79	0.88

Table A3. *Cont.*

№	Retention Time, min	Compounds	Probability of Identification, %	Percentage Content, %
43	31.78	Hexacosane	70	0.41
44	31.95	Hexanedioic acid, bis(2-ethylhexyl) ester	89	3.68
45	32.52	2-Propenoic acid, 3-(4-methoxyphenyl)-, 2-ethylhexyl ester	90	2.11
46	34.91	Octacosane	77	0.65
47	35.44	Diisooctyl phthalate	83	0.67
48	36.64	Tetracosanoic acid, methyl ester	76	1.18
49	38.03	Squalene	95	10.34
50	39.48	Hexacosanoic acid, methyl ester	68	1.10
51	40.52	Tetratriacontane	91	19.76
52	43.26	γ-Tocopherol	88	2.35
53	43.93	Tetratetracontane	86	6.42
54	44.96	Vitamin E	82	1.84

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