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MORPHOLOGICAL AND ANATOMICAL STUDIES OF MAHONIA AQUIFOLIUM (PURSH) NUTT. LEAVES

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Summary.

Mahonia aquifolium (Pursh) Nutt., the most common species within the genus Mahonia, is native to western North America. . Biologically active compounds derived from Mahonia aquifolium (Pursh) Nutt. exhibit a broad spectrum of pharmacological activities, including antioxidant, antimicrobial, antibacterial, anticancer, antimutagenic, antimalarial, antitumor, immunomodulatory, and anti-inflammatory effects. This species is also employed in the treatment of dermatological conditions, such as psoriasis and atopic dermatitis. In Ukraine, Mahonia aquifolium (Pursh) Nutt. is cultivated primarily as an ornamental plant. To date, comprehensive pharmacognostic studies of this species have not been conducted in Ukraine. An analysis of the available scientific literature indicates a lack of systematic data concerning the morphological and anatomical characteristics of Mahonia aquifolium (Pursh) Nutt. introduced and cultivated under Ukrainian conditions.

***The aim of the study:** to establish the main macro- and microscopic diagnostic features of the leaves of the introduced Mahonia aquifolium (Pursh) Nutt. in Ukraine, which will be used to identify and create a draft quality control methods (QCM) for new medicinal plant raw materials.*

***Materials and methods of the study.** The research utilized leaves of Mahonia aquifolium (Pursh) Nutt., collected in 2024 from the experimental plots of the Laboratory of Medical Botany at the M. M. Hryshko National Botanical Garden of the National Academy of Sciences of Ukraine (Kyiv).*

The morphological analysis of the raw material of Mahonia aquifolium (Pursh) Nutt. was conducted using a magnifying lens and a binocular microscope. The investigation of anatomical characteristics was performed in compliance with the monograph «2.8.23. Microscopic study of medicinal plant raw materials» of the State Pharmacopoeia of Ukraine. The study employed both air-dried raw materials and freshly collected plant specimens fixed in an ethanol-glycerol-water mixture (1:1:1). Temporary slides were prepared from the lower and upper epidermis of the leaf blade. Microscopic examination was carried out using a Delta Optical Genetic Pro light microscope, and images were captured and fixed with a Delta Optical DLT-Cam Pro camera.

***Results.** The investigation of Mahonia aquifolium (Pursh) Nutt. cultivated in Ukraine identified key diagnostic morphological features, including leaf coloration, lamina shape, and margin morphology. These characteristics are proposed for use in the primary identification and standardization of this raw material. Microscopic analysis revealed distinct anatomical features of the leaves. The adaxial epidermis consists of cells with weakly convoluted anticlinal walls, while the abaxial epidermis is composed of cells with distinctly convoluted anticlinal walls. Stomata are of the anomocytic type.*

***Conclusions.** 1. The principal morphological features for the identification of Mahonia aquifolium (Pursh) Nutt. grown in Ukraine are are the specific coloration and the shape of the leaf lamina. These features are suitable for the primary pharmacognostic evaluation and subsequent standardization of the raw material. 2. Characteristic microscopic diagnostic features of the leaves include adaxial epidermal cells with slightly wavy anticlinal walls, abaxial epidermal cells with distinctly wavy anticlinal walls, and the presence of anomocytic-type stomata. 3. The obtained data on the morphological and anatomical diagnostic features will be applied for the authentication of plants within the genus Mahonia and will form the basis for developing a draft quality control method (QCM) for this new medicinal plant raw material.*

***Keywords:** Morphological features; Anatomical features; Leaves; Mahonia aquifolium (Pursh) Nutt.*

Introduction

The genus *Mahonia (Mahonia Nutt.)* comprises, according to various sources, between 60 to 70 species of evergreen shrubs or small trees, valued for their ornamental appeal, medicinal properties, and use as sources of natural dyes [1]. Species of this genus are predominantly distributed across East and Southeast Asia, western North America, Central America, and western South America, with 31 species reported in China [2, 3].

Plants of the genus *Mahonia* are recognized for their antibacterial, antifungal, and anti-inflammatory properties and are extensively utilized in global traditional medicine. They are employed in the treatment of conditions such as tuberculosis, dysentery, jaundice, internal and external hemorrhage, pharyngolaryngitis, eczema, and various dermatological disorders [4-6].

The most prevalent species within the genus is *Mahonia aquifolium* (Pursh) Nutt., indigenous to western North America. The specific epithet *aquifolium* is derived from the Latin *acus* (needle) and *folium* (leaf), referring to the leaf morphology.

Mahonia aquifolium (Pursh) Nutt. is an evergreen shrub 1-1.5 m in height. Its leaves are evergreen, compound,

pinnate, consisting of 5-9 glossy, lanceolate-ovate leaflets with serrate margins. The yellow flowers are are fragrant, arranged in terminal, multi-branched racemes. The fruit is a dark blue, oblong-elliptical berry with a bluish wax coating, containing 2-8 oval-ribbed or oblong seeds; the berries are edible, with a sweet-sour taste. The species possesses a a robust, branched root system. *Mahonia aquifolium* (Pursh) Nutt. flowers from April to May and fruits from August to September [4] (Fig. 1).

This species demonstrates resilience to adverse environmental conditions, thriving in shaded and partially shaded locations on calcareous soils.

Fig. 1. Mahonia aquifolium (Pursh) Nutt. in the experimental plots of the Laboratory of M. M. Hryshko National Botanical Garden of NAS of Ukraine (Kyiv) (winter period 2025).

Scientific literature from numerous international authors indicates that *Mahonia aquifolium* (Pursh) Nutt. contains a wide spectrum of biologically active compounds and is a known source of isoquinoline alkaloids, including berberine, palmatine, and jatrorrhizine [2, 7].

Furthermore, *Mahonia aquifolium* (Pursh) Nutt. is a rich source of phenolic compounds, flavonoids, and anthocyanins, which contribute to its pronounced antioxidant activity. Studies by Lastovychenko Ye. et al. [8, 9] have investigated the profile of amino acids and fatty acids in the leaves, fruits, inflorescences, and roots of *Mahonia aquifolium* (Pursh) Nutt.

In vitro and *in vivo* studies have demonstrated that the biologically active compounds of *Mahonia aquifolium* (Pursh) Nutt. exhibit a broad spectrum of pharmacological activities, including antioxidant, antimicrobial and antibacterial, anticancer, antimutagenic, antimalarial, antitumor, immunomodulatory and anti-inflammatory effects [2, 10-13]. *Mahonia aquifolium* (Pursh) Nutt. is also employed in the treatment of dermatological conditions, such as psoriasis [17] and atopic dermatitis [14, 15]. Different plant organs of *Mahonia aquifolium* (Pursh) Nutt. possess distinct biological activities [16].

In North America and Europe, the fruits of the *Mahonia* are utilized for culinary purposes and as a source of natural dyes [2].

In Ukraine, *Mahonia aquifolium* (Pursh) Nutt. is cultivated as an ornamental plant and is widely used in landscape design.

However, this species has not been subjected to comprehensive pharmacognostic study in Ukraine and is not official in the national pharmacopeia.

An analysis of the available scientific literature indicates a scarcity of systematic data on the morphological and anatomical characteristics of *Mahonia aquifolium* (Pursh) Nutt. introduced and cultivated under Ukrainian conditions.

Given the growing demand for natural remedies in medicine, pharmacy, and cosmetology, pharmacognostic research of *Mahonia aquifolium* (Pursh) Nutt., encompassing detailed morphological and anatomical analysis, is currently highly relevant.

A critical stage in the investigation of a new medicinal plant is the development of a quality control method (QCM) for its raw materials. Morphological and anatomical studies constitute an integral part of this process, enabling the unequivocal authentication of the plant species and verification of its conformity to the stated scientific name. Particular emphasis must be placed on identifying and documenting the principal macro- and microscopic diagnostic features of the raw material.

The aim of the study is to establish the principal macro- and microscopic diagnostic features of the leaves of *Mahonia aquifolium* (Pursh) Nutt. introduced in Ukraine. These features are intended for use in the identification of this raw material and will form the basis for drafting a quality control method (QCM).

Materials and methods of the study. The authentication of medicinal plant raw materials (MPM) is a fundamental step in their preparation. This process involves, among other criteria, the examination of a complex of macro- and microscopic diagnostic features to confirm identity, in accordance with the guidelines of the State Pharmacopoeia of Ukraine.

The plant material for this study consisted of leaves of *Mahonia aquifolium* (Pursh) Nutt., harvested in 2024 from the experimental plots of the Laboratory of Medical Botany at the M. M. Hryshko National Botanical Garden of the National Academy of Sciences of Ukraine (NAS of Ukraine), located in Kyiv.

The morphological analysis of the raw material of *Mahonia aquifolium* (Pursh) Nutt. was conducted using a magnifying lens and a binocular microscope. The anatomical examination was performed in strict accordance with the monograph «2.8.23. Microscopic study of medicinal plant raw materials» of the State Pharmacopoeia of Ukraine. The study utilized both air-dried raw materials and freshly collected plant specimens fixed in an ethanol-glycerol-water (1:1:1) solution. Cross-sections and surface preparations of the lower and upper epidermis of the raw leaf blade were analyzed. Temporary slides were examined using a Delta Optical Genetic Pro light microscope, and photomicrographs were captured using a Delta Optical DLT-Cam Pro camera system.

Results. The investigated species, *Mahonia aquifolium* (Pursh) Nutt., belongs to the division *Magnoliophyta (Angiospermae);* class *Magnoliopsida (Dicotyledones);* subclass *Ranunculidae;* order *Ranunculales;* family *Berberidaceae;* genus *Mahonia* Nutt. This species is currently being actively introduced into natural and semi-natural, synanthropic phytocenoses This species is currently undergoing active introduction into natural, semi-natural, and synanthropic phytocenoses in the region.

An important criterion for assessing the potential of introduced species for cultivation is their general habitus and morphometric parameters. The determination of leaf characteristics is crucial for identifying specimens with the largest leaves, which contributes significantly to the ornamental value of the shrub.

Analysis of the quantitative parameters of the leaf structure of *Mahonia aquifolium* (Pursh) Nutt. between the length, width of the leaf and the number of leaflets, and found that the correlation was insignificant. specifically the relationships between leaf length, leaf width, and the number of leaflets, revealed statistically insignificant correlations.

The most reliable diagnostic feature for distinguishing leaf blade forms of *Mahonia aquifolium* (Pursh) Nutt. was determined to be the degree of serration along the leaf margin. Based on this criterion, two distinct groups of plants with differing degrees of leaf edge serration were identified.

Macroscopic features of the leaves of the Mahonia aquifolium (Pursh) Nutt. The leaves are leathery, compound, pinnate, consisting of 5-9 lanceolate-ovate leaflets. Individual leaflets feature an acute apex, a dark green and glossy adaxial surface, and a paler, matte abaxial surface. The leaflets measure 4-8 cm in length and 1.5-2.5 cm in width and are attached via short (0.5-2 cm), reddish petiolules. The coloration of the foliage undergoes seasonal variation: young spring leaves exhibit a reddish hue, summer foliage is a deep green, and autumn/winter leaves acquire bronze, golden, to fiery red pigmentation (Fig. 2).

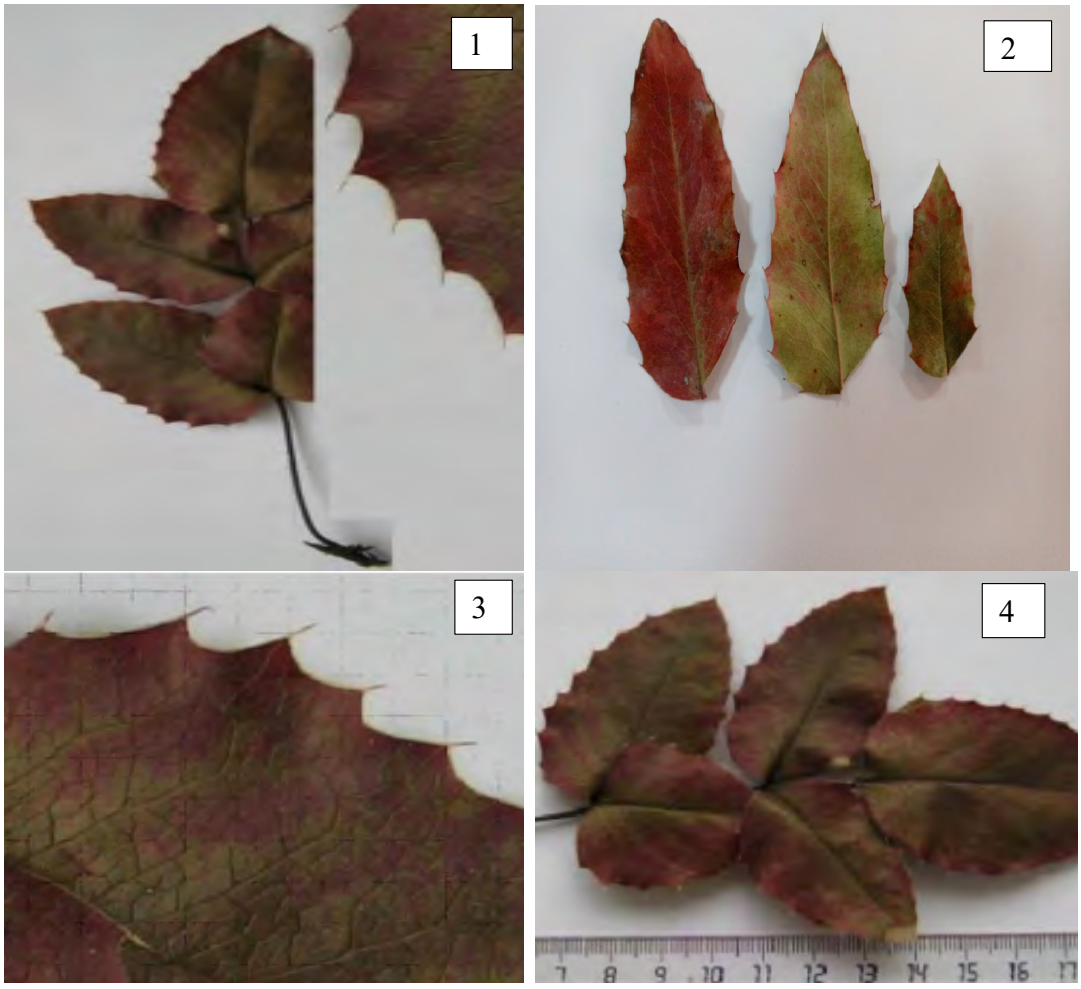

Fig. 2. Morphological structure of the leaf blade of Mahonia aquifolium (Pursh) Nutt.: 1, 3 – medium notch of the leaf edge, 2, 4 – weak notch of the leaf edge

Anatomical structure of the leaf blade. The leaf blade is covered by a thick cuticular layer. The leaf of *Mahonia aquifolium* (Pursh) Nutt. is hypostomatic, with stomata sunken within the epidermal layer. The adaxial epidermal cells are rounded, relatively small, and parenchymatous, with slightly thickened anticlinal walls. The abaxial epidermal cells exhibit uniformly sinuous (convoluted) anticlinal walls. The cells of the abaxial epidermis are generally smaller than those of the adaxial epidermis. The stomatal complex is predominantly anomocytic, typically surrounded by four or more subsidiary cells. Trichomes are absent on both the adaxial and abaxial epidermal surfaces (Fig. 3).

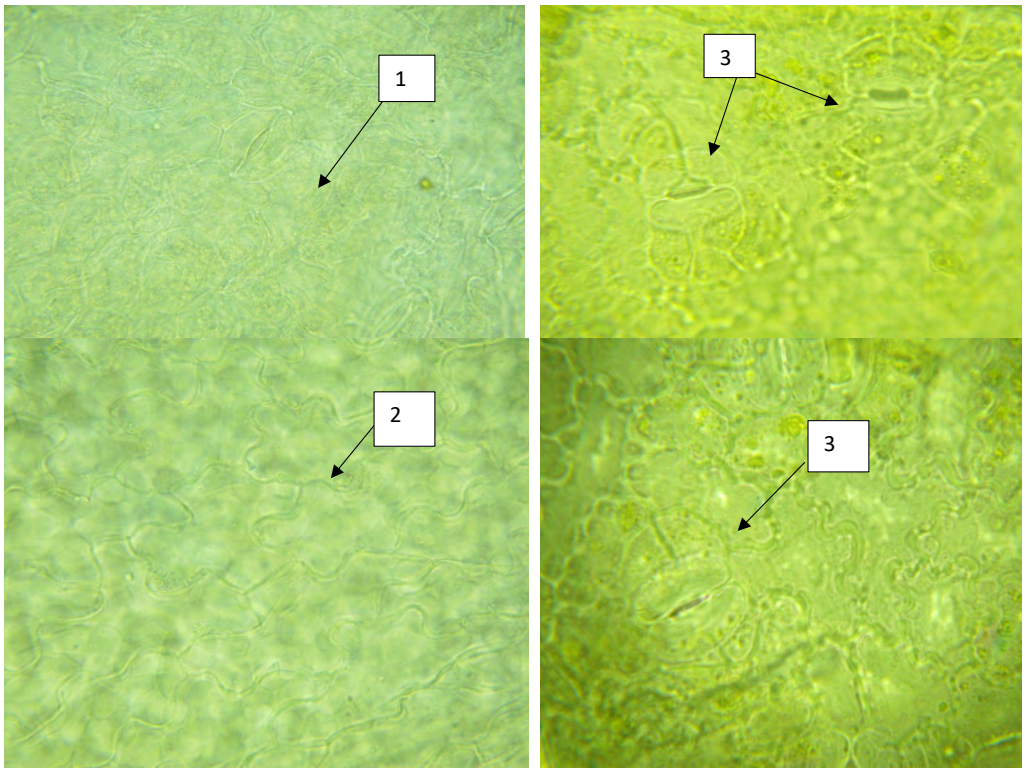

Fig. 3. Anatomical features of the leaf of Mahonia aquifolium (Pursh) Nutt.: 1 – cells of the upper epidermis, 2 – cells of the lower epidermis, 3 – stomata of the anomocytic type.

Conclusions

1. The principal morphological diagnostic characteristics of *Mahonia aquifolium* (Pursh) Nutt. cultivated in Ukraine are the distinctive coloration and shape of the leaf lamina. These features are applicable for the primary identification and subsequent standardization of this raw material.

2. Microscopic analysis identified key diagnostic features of the leaves: adaxial epidermal cells with slightly wavy (weakly convoluted) anticlinal walls, abaxial epidermal cells with distinctly sinuous (convoluted) anticlinal walls, and the presence of anomocytic-type stomata confined to the abaxial epidermis.

3. The obtained morphological and anatomical data will be utilized for the authentication of plants within the genus *Mahonia* and will form the foundational basis for developing a draft quality control method (QCM) for this medicinal plant raw material.

Prospects for further research

The findings from this study on the morphological and anatomical structure of *Mahonia aquifolium* (Pursh) Nutt. leaves will be directly applied in the development of a draft quality control method (QCM) for the new medicinal plant raw material «*Mahonia aquifolium* (Pursh) Nutt. Leaves».

This research also underscores the necessity for further comprehensive pharmacognostic and pharmacological investigations of *Mahonia aquifolium* (Pursh) Nutt.

Conflict of interest: the authors declare no conflict of interest

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МОРФОЛОГО-АНАТОМІЧНІ ДОСЛІДЖЕННЯ МАГОНІЇ ПАДУБОЛИСТОЇ (MAHONIA AQUIFOLIUM (PURSH) NUTT.) ЛИСТКІВ

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Резюме.

Найпоширенішим видом роду Магонія є магонія падуболиста (*Mahonia aquifolium* (Pursh) Nutt.), яка походить із західної частини Північної Америки. Біологічно активні сполуки магонії падуболистої проявляють широкий спектр фармакологічних ефектів, включаючи антиоксидантну, антимікробну та антибактеріальну, протиракову, антимутагенну, протималярійну активність, протипухлинну, імуномодулюючу та протизапальну дію. Магонію падуболисту також використовують при лікуванні шкірних захворювань, таких як псоріаз і атопічний дерматит. В Україні магонію падуболисту вирощують як декоративну рослину. Фармакогностичні дослідження магонії падуболистої в Україні не проводились. Аналіз даних доступних джерел наукової літератури свідчить про відсутність систематизованих відомостей про морфолого-анатомічну будову магонії падуболистої – виду інтродукованого в Україні.

Мета дослідження. Встановлення основних макро- і мікроскопічних діагностичних ознак листків інтродукованої в Україні магонії падуболистої, які будуть використанні для ідентифікації і створення проєкту методів контролю якості (МКЯ) на нову лікарську рослинну сировину.

Матеріали і методи дослідження. Матеріалом для досліджень були листки магонії падуболистої, заготовлені на дослідних ділянках лабораторії медичної ботаніки Національного ботанічного саду імені М. М. Гришка НАН України (м. Київ) у 2024 році.

Морфологічну будову сировини магонії падуболистої вивчали використовуючи лупу та бінокулярний мікроскоп. Вивчення анатомічних ознак здійснювали відповідно до вимог монографії Державної Фармакопеї України «2.8.23. Мікроскопічне дослідження лікарської рослинної сировини». Використовували повітряно-суху сировину та свіжозібрану і фіксовану в етанольно-гліцериновій суміші (1:1:1) рослинну сировину (нижню і верхню епідерму листкової пластинки). При вивченні тимчасових препаратів використовували оптичний прилад Delta Optical Genetic Pro та фіксували за допомогою камери Delta Optical DLT-Cam Pro.

Результати та їх обговорення. У результаті проведених досліджень встановлено, що відмінними морфологічними ознаками для *Mahonia aquifolium* (Pursh) Nutt., які зростають на території України, є забарвлення листків, форма та край листкової пластинки. Ці ознаки можна використовувати для ідентифікації сировини та в подальшому для її стандартизації. Методом мікроскопічного аналізу встановлено діагностичні ознаки листків *Mahonia aquifolium* (Pursh) Nutt.: слабозвивисті клітини верхнього і звивистостінні клітини нижнього епідермісу, продихи аномоцитного типу.

Висновки: 1. Встановлено, що морфологічними ознаками для *Mahonia aquifolium* (Pursh) Nutt., які зростають на території України, є забарвлення та форма листкової пластинки рослини. Ці ознаки можна використовувати для ідентифікації сировини та в подальшому для її стандартизації. 2. Методом мікроскопічного аналізу встановлено характерні діагностичні ознаки листків *Mahonia aquifolium* (Pursh) Nutt.: слабозвивисті клітини верхнього і звивистостінні клітини нижнього епідермісу, продихи аномоцитного типу. 3. Отримані дані будуть використані при ідентифікації рослин роду Магонія та при розробці проєкту методів контролю якості (МКЯ) на нову дікарську рослинну сировину.

Ключові слова: морфологічні ознаки; анатомічні ознаки; листки; магонія падуболиста (Mahonia aquifolium (Pursh) Nutt.).

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