MEDICINAL PLANTS: PROPERTIES, APPLICATIONS, AND PROSPECTS

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Medicinal plants have played a crucial role in maintaining human health since ancient times. They served as the foundation for traditional medicine and later contributed to modern pharmacology. It is known that as early as ancient Greece and Rome, physicians actively used infusions and extracts to treat various diseases. In Chinese medicine, medicinal plants became the basis of entire healing systems, which are still in use today. In Ayurveda, the Indian traditional medical system, the use of plants for treating ailments developed into a true art, encompassing thousands of plant species.

The growing interest in natural remedies is driven by the demand for environmentally friendly products and the search for alternatives to conventional pharmaceutical drugs. Medicinal plants are becoming an essential component of modern life due to their ability to address stress-related issues, chronic diseases, and the prevention of infectious illnesses. Additionally, the introduction of advanced technologies, such as genetic engineering and hydroponic cultivation, enables the more efficient use of natural resources.

Moreover, medicinal plants have significant ecological importance. They contribute to biodiversity conservation, prevent soil degradation, and play a key role in maintaining ecosystem balance. The use of medicinal plants also holds economic potential, as the production of plant-based medicines generates employment opportunities and supports the growth of the pharmaceutical industry[2,3].

Research Objectives

The aim of this study is to summarize contemporary knowledge about medicinal plants, analyze their properties and cultivation prospects, and assess their significance in medicine, industry, and ecology.

Tasks:

- Provide a classification of medicinal plants and describe their main active compounds.
- Characterize the methods of growing and harvesting medicinal plants.
- Analyze the various applications of medicinal plants.
- Highlight ecological aspects and new research directions.

Medicinal plants hold global significance not only in medicine but also in ecology and economics. Their preservation and rational use are essential for sustainable development, food security, and biodiversity conservation.

Definition and Classification of Medicinal Plants

Medicinal plants are species of flora that contain biologically active compounds capable of influencing the physiological functions of the body. They can be categorized based on their active compounds, geographical distribution, and medicinal uses:

• By active compounds: alkaloids, essential oils, flavonoids, saponins, etc. For example, chamomile contains flavonoids with calming properties, while ginseng contains saponins that stimulate the immune system.

• By medicinal use: anti-inflammatory (chamomile), antiseptic (sage), sedative (valerian), diuretic (horsetail).

• By geographical distribution: local (chamomile, St. John's wort) and exotic (ginseng, aloe).

It is also important to distinguish between medicinal and toxic plants. Some poisonous plants, in low concentrations, are used as medicines (e.g., foxglove).

Main Active Compounds and Their Properties

Medicinal plants play a vital role in pharmacology and traditional medicine due to their wide range of biologically active compounds that affect the human body. Thanks to their unique chemical properties, they are used for treatment, prevention, and health maintenance. The main groups of biologically active substances include:

1. Alkaloids

• Alkaloids are nitrogen-containing organic compounds that have a strong physiological effect. They are widely used in medicine, including:

• Morphine (derived from poppy) – one of the most potent natural analgesics, used in anesthesiology and palliative medicine.

• Codeine – an effective cough suppressant that also has mild analgesic properties.

• Atropine (from belladonna) – used in cardiology, ophthalmology, and gastroenterology, as it relaxes muscles and dilates pupils.

• Quinine (from the bark of the cinchona tree) – used to treat malaria and has antipyretic properties.

2. Essential Oils

• Essential oils are aromatic substances with a wide range of pharmacological effects, including antiseptic, anti-inflammatory, and calming properties:

• Lavender oil – used in aromatherapy to relieve stress and improve sleep.

• Eucalyptus oil – has expectorant properties and helps with respiratory diseases.

• Tea tree oil – known for its antiseptic and antifungal properties, widely used in dermatology.

3. Glycosides

• Glycosides are organic compounds that contain a carbohydrate part and have medicinal properties:

- Digitoxin (from foxglove) used in cardiology to treat heart failure.
- Sennosides (from senna) have a laxative effect and are used for constipation.

• Stevioside (from stevia) – a natural sweetener that also has antioxidant and antihypertensive properties.

4. Flavonoids

• Flavonoids are natural antioxidants that strengthen blood vessels and have anti-inflammatory and immune-boosting effects:

• Quercetin (found in onions, apples, green tea) – reduces inflammation and strengthens capillary walls.

• Rutin (in buckwheat, citrus fruits) – supports vascular elasticity and prevents blood clots.

• Catechins (in green tea) – have strong antioxidant and antimicrobial properties.

5. Saponins

• Saponins are substances with cleansing, expectorant, and immune-stimulating properties:

- Ginseng stimulates the immune system, increases endurance, and enhances overall body tone.
- Licorice has anti-inflammatory and expectorant properties, helping with respiratory diseases.

• Horse chestnut – used to strengthen blood vessels and improve circulation.

6. Tannins (Tannic Substances)

• Tannins are polyphenolic compounds with astringent, anti-inflammatory, and antibacterial properties:

• Oak bark – used for inflammation of mucous membranes and gum strengthening.

• Tea – contains tannins that help fight bacteria and improve digestion.

• Buckthorn – used as a mild laxative[5,10].

Conclusion

Medicinal plants are an invaluable source of natural compounds used in both traditional and modern medicine. Thanks to their unique properties, they help treat various diseases, strengthen the immune system, and improve overall health. Research on biologically active substances continues, opening new possibilities for medicine and pharmaceuticals.

In traditional medicine, medicinal plants were the primary method of treatment, as they contain natural active substances that affect the body. Decoctions, infusions, extracts, and ointments based on plants have been used to treat various diseases since ancient times. For example, an infusion of willow bark was used as an antipyretic and analgesic due to the presence of salicylates— compounds with anti-inflammatory properties.

In Chinese medicine, ginseng was considered a plant of longevity and energy. It was used to improve the functioning of the cardiovascular and nervous systems, enhance endurance, and boost the overall tone of the body. In Indian Ayurveda, ashwagandha was used as an adaptogen—a remedy that helps the body adapt to stress, strengthens the immune system, and promotes energy restoration.

In European folk medicine, St. John's wort was widely used for its antidepressant properties, while chamomile was known for its calming, antiseptic, and anti-inflammatory effects. Garlic and onions were recognized as natural antiseptics and were used to fight infections[11,15].

With the advancement of science, medicinal plants became the basis for the creation of many pharmacological drugs. For example, acetylsalicylic acid (aspirin) was synthesized based on salicylate extracted from willow bark. Alkaloids obtained from the Madagascar periwinkle (vinca alkaloids) are used in oncology to treat leukemia, as they affect the division of cancer cells.

Some modern medications, such as echinacea extracts that strengthen the immune system or valerian tincture with its calming effect, are based on standardized active substances, ensuring their effectiveness and safety. They are actively used in phytotherapy—a treatment method based on the use of plant-based medicines, which is a popular alternative to synthetic drugs in many countries.

Beyond medicine, medicinal plants are widely used in cosmetology. For instance, aloe vera extract is utilized for moisturizing and regenerating the skin, while calendula aids in wound healing and reducing irritation. Tea tree oil is a powerful natural antiseptic used in products for problematic skin.

Today, medicinal plants remain an important part of the pharmaceutical and cosmetic industries. Thanks to scientific research, they are used not only in folk medicine but also in evidence-based pharmacology, providing effective treatment and prevention of many diseases.

Medicinal plants have a wide range of natural habitats, depending on their biological characteristics and adaptation to environmental conditions. Studying natural habitats is key to understanding their cultivation requirements, biodiversity conservation, and effective use on an industrial scale[20].

Climatic Conditions

Plants used in medicine grow in various climatic zones:

• Tropical Climate: Characterized by high humidity and temperature. Medicinal plants such as aloe, turmeric, ginger, passionflower, and various tropical herbs thrive in this zone. These plants require constant warmth, regular moisture, and well-drained soils.

• Temperate Climate: Chamomile, mint, echinacea, calendula, valerian, and St. John's wort are widely distributed in temperate zones. They are adapted to moderate temperatures and seasonal changes, making their cultivation possible in various regions worldwide.

• Alpine Zones: High-altitude medicinal plants, such as arnica, rhodiola rosea, and edelweiss, are adapted to low temperatures and high solar radiation. They exhibit high concentrations of active substances due to the stressful growth conditions.

• Arid Regions: Species like sage, thyme, ginseng, and lavender are well adapted to low humidity and high temperatures. Their cultivation requires well-drained soils and minimal irrigation. *Soil Conditions*

Different medicinal plants have specific soil requirements:

• Fertile Soils: Echinacea, valerian, medicinal peony, and calendula thrive in organic-rich soils with good water and air exchange.

• Sandy Soils: Ideal for lavender, thyme, rosemary, and coriander, which require well-drained soils and exhibit high drought resistance.

• Marshy Soils: Moist, organic-rich soils are optimal for calamus, marsh marigold, and marsh mint.

• Acidic Soils: Some plants, such as lingonberry and cranberry, grow well in low-pH soils. *Ecological Requirements*

Medicinal plants have specific ecological needs that must be considered when cultivating them:

• Sunlight Exposure: Plants like chamomile, sage, and calendula require open, sunny areas, while ginseng and valerian grow better in partial shade.

• Moisture: Certain species, such as mint, lemon balm, and marshmallow, need regular watering, whereas others, like thyme and rosemary, thrive in dry conditions.

• Temperature Adaptation: Temperature requirements vary by species. For example, tropical plants need temperatures above 15°C, while alpine species can withstand frost down to -20°C.

Interaction with the Environment

Medicinal plants not only adapt to their surroundings but also influence them:

• Soil Improvement: Some plants, such as alfalfa, clover, and licorice, contribute to nitrogen fixation in the soil, enhancing its fertility.

• Biodiversity Conservation: Using medicinal plants in conservation programs helps protect rare species populations.

• Erosion Stability: Plants with strong root systems, such as echinacea and arnica, help prevent soil erosion.

• Pest Protection: Certain plants, such as wormwood and mint, have repellent properties, making them useful for natural garden and field protection.

Understanding the natural habitats and ecological requirements of medicinal plants allows for optimizing their cultivation and ensuring high-quality raw materials. This also promotes ecosystem conservation and the development of sustainable agriculture, which is a crucial component of modern agroecology. Considering climatic and soil conditions, as well as the ecological needs of plants, helps improve yield and efficiency in the use of medicinal crops in the pharmaceutical, cosmetic, and food industries.

Traditional Methods

Sowing in open soil remains the most common method of cultivating medicinal plants, especially on farms and in home gardens. After sowing, careful maintenance is required, including:

• Manual weeding to remove weeds that could outcompete cultivated plants.

• Fertilization with organic (manure, compost, humus) or mineral fertilizers to ensure optimal growth.

• Watering depending on the type of plants and climatic conditions, ranging from drip irrigation to natural moisture.

• Pest protection using biological or mechanical methods, with chemical agents used less frequently.

This method is applied to many medicinal plants such as chamomile, mint, lemon balm, valerian, echinacea, and others[27].

Innovative Methods

- 1. Hydroponics
- Growing plants without soil in special nutrient solutions.
- Allows for stable yields regardless of weather conditions.
- Saves up to 90% of water compared to traditional farming.
- Widely used for cultivating basil, mint, lavender, and other medicinal plants.
- 2. In Vitro Method
- A laboratory method for propagating plants under sterile conditions.
- Enables rapid plant growth from a single cell or tissue fragment.
- Used for preserving and restoring rare and endangered species such as ginseng or arnica.
- 3. Vertical Farms
- Utilize multi-level structures with artificial lighting and a controlled microclimate.
- Enable cultivation even in urban environments.
- Ideal for compact medicinal plants such as basil, oregano, and mint.

By combining traditional and modern methods, agronomists can significantly increase yields, improve raw material quality, and conserve natural resources.

Seed Propagation

Seed propagation is a cost-effective way to produce large quantities of plants and is widely used in agriculture and ornamental landscaping. However, it is associated with significant genetic variability, which can lead to differences in the morphological and biological characteristics of offspring. This is particularly important for medicinal and essential oil crops, where the stability of chemical composition plays a key role.

Plants commonly propagated by seeds include medicinal chamomile, purple coneflower (Echinacea purpurea), and medicinal calendula. Before sowing, seeds of some crops require stratification (exposure to cold and humid conditions) to improve germination and uniform sprouting. For certain species, scarification (breaking the seed coat) or soaking in growth stimulators is also used.

Seed propagation of medicinal plants in Ukraine is significantly smaller in scale compared to other countries. Yields and production volumes are lower than those of European competitors. Ukraine's share in the global production of medicinal plants is minor (2.1%).

Parameter	Ukraine	Other Countries	Comparison (Ukraine vs. Other Countries, %)	
Cultivation Area (thousand ha)	6.8	Hungary – 42, Germany – 18, France – 25	From 10% (Hungary) to 38% (Germany)	
Yield (q/ha)	12–15	Hungary – 18, Germany – 20, France – 22	60–75% of the yield in Germany and France	
Production Volume (thousand tons/year)	80	Hungary – 700, Germany – 300, France – 350	From 11% (compared to Hungary) to 26% (compared to Germany)	
Share in Global Production (%)	2.1%	Hungary – 17%, Germany – 8%, France – 9%	Ukraine's share is 8 times smaller than Hungary's	

Table 1. Characteristics of seed propagation of medicinal plan	nts
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To improve the efficiency of seed propagation, it is necessary to implement modern cultivation technologies, enhance the quality of seed material, and improve agronomic practices.

Vegetative propagation allows for the production of offspring that fully retain the characteristics of the parent plants, including their chemical composition, shape, size, and yield. This is particularly important for aromatic and medicinal plants, where the stability of active substances is crucial.

Plants propagated vegetatively include peppermint, lavender, lemon balm, sage, rosemary, and others. The main methods of vegetative propagation include:

• Rhizome division – used for perennial plants (e.g., mint and lemon balm);

• Cutting propagation – rooting of stem or leaf cuttings (widely used for lavender);

• Layering – rooting of branches or stems without separating them from the mother plant (common for thyme and sage).

Vegetative propagation is more prevalent in Ukraine than seed propagation and ensures higher yields and production efficiency. However, compared to Bulgaria, Poland, and France, Ukraine still lags significantly in production volumes.

Parameter	Ukraine	Other Countries	Comparison (Ukraine vs Other Countries, %)
Cultivation Area (thousand ha)	9.1	Poland – 15, Bulgaria – 35, France – 30	From 26% (Bulgaria) to 60% (Poland)
Yield (q/ha)	25–30	Poland – 32, Bulgaria – 35, France – 38	71–88% of the yield in Bulgaria and France
Production Volume (thousand tons/year)	230	Poland – 480, Bulgaria – 900, France – 700	From 25% (of Bulgaria) to 48% (of Poland)
Share in Global Production (%)	3.5%	Poland – 7%, Bulgaria – 13%, France – 10%	Ukraine has 2–4 times a smaller share than these countries

Table 2. Characteristics of vegetative propagation of medicinal plants

It is necessary to expand cultivation areas and improve plant care technologies to achieve competitiveness in the international market.

Seed propagation has advantages in terms of genetic diversity and economic efficiency but is inferior to vegetative propagation in terms of reproduction speed and raw material quality stability. Vegetative propagation allows preserving the characteristics of the mother plant but requires careful maintenance.

Table 3. Comparison of seed and vegetative propagation of medicinal plants

Parameter	Seed Propagation	Vegetative Propagation	
Cultivation area in Ukraine (thousand ha)	6.8	9.1	
Cultivation area in other countries	Hungary – 42, Germany – 18,	Poland – 15, Bulgaria – 35,	
(thousand ha)	France – 25	France – 30	
Comparison (Ukraine vs other countries,	From 10% (Hungary) to 38%	From 26% (Bulgaria) to 60%	
%)	(Germany)	(Poland)	
Yield (quintals/ha)	12–15	25–30	
Viold in other countries (quintels/he)	Hungary – 18, Germany – 20,	Poland – 32, Bulgaria – 35,	
f leid in other countries (quintais/na)	France – 22	France – 38	
Production volume in Ukraine (thousand	80	230	
tons/year)	80	250	
Production volume in other countries	Hungary – 700, Germany – 300,	Poland – 480, Bulgaria – 900,	
(thousand tons/year)	France – 350	France – 700	
Ukraine's share in global production (%)	2.1%	3.5%	
Other countries' share in global production	Hungary – 17%, Germany – 8%,	Poland – 7%, Bulgaria – 13%,	
(%)	France – 9%	France – 10%	
Advantages	High productivity, genetic	Preservation of mother plant	
Auvaillages	diversity, economic efficiency	traits, rapid propagation	
Disadvantages	Possible genetic variability, need	Smaller initial material quantity,	
Disauvaillages	for stratification	requires care	

Both methods have their advantages and disadvantages. The optimal approach for Ukraine may be a combined use of seed and vegetative propagation, which will help increase the yield and production volumes of medicinal plants.

Seed propagation covers 6.8 thousand hectares in Ukraine and yields 12–15 centners per hectare, whereas in European countries, these figures are higher (up to 22 centners per hectare). Vegetative propagation occupies a larger area (9.1 thousand hectares) and ensures significantly higher

yields (25–30 centners per hectare). Despite the complexity of maintenance, this method is more effective, as confirmed by global practice (up to 38 centners per hectare in France).

Clonal propagation in vitro is a modern biotechnological method used for the reproduction of rare, valuable, or difficult-to-cultivate species. This technique is based on the cultivation of plant tissues under sterile laboratory conditions. The main advantages of this method include:

• Genetic identity of the obtained plants (all clones have the same set of genes);

• High propagation efficiency – a small part of a plant can produce hundreds of new seedlings;

• Protection from diseases and pests – due to sterile conditions, cultures are not infected by viruses or bacteria;

• Possibility of obtaining virus-free planting material, which is important for the industrial cultivation of medicinal plants.

Clonal propagation is widely used for growing lavender, ginseng, orchids, echinacea, and some rare species of mint and lemon balm.

Reproduction Method	Advantages	Disadvantages	Plant Examples
Seed Propagation	High productivity, genetic diversity	Possible genetic variability	Chamomile, Echinacea
Vegetative Propagation	Preservation of parent plant traits	Limited initial material	Mint, Lavender, Lemon Balm
In vitro	Possibility of preserving rare species	High equipment cost	Orchids, Ginseng
Hydroponics	Efficient resource use	Dependence on technical systems	Basil, Mint

Table 4. Comparison of medicinal plant propagation methods

Based on the analysis of the presented data, it can be concluded that the choice of medicinal plant propagation method depends on the target purpose and growing conditions. For mass production, seed or hydroponic propagation is optimal due to its high productivity and economic efficiency. For the preservation of rare species and the propagation of crops with specific properties, in vitro and vegetative propagation methods are more appropriate. These methods ensure the stability of genetic characteristics and support natural biodiversity.

The effectiveness of different medicinal plant propagation methods depends on various factors, such as plant type, growing conditions, economic costs, and the need to preserve genetic traits. Seed propagation ensures high productivity but may lead to the loss of certain genetic characteristics. Vegetative propagation maintains trait stability but is less productive. In vitro propagation is highly precise in preserving rare species but is an expensive method. Hydroponics allows for resource optimization and increased yield under controlled conditions.

Table 5. Co	omparison	of propaga	tion methods	by efficiency
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Reproduction Method	Productivity (%)	Trait Retention (%)	Economic Benefit (%)
Seed Propagation	80	60	70
Vegetative	60	90	50
In vitro	50	95	40
Hydroponics	70	80	80

The provided data is based on the generalization of field research results conducted in specialized agronomic centers, as well as the analysis of literary sources on the cultivation of medicinal plants. The percentage indicators reflect the average efficiency values obtained through the evaluation of productivity, preservation of properties, and economic feasibility of different

propagation methods. This allows for their comparison in terms of suitability for commercial cultivation and biodiversity conservation.

Medicinal Plant Care Includes:

• Watering: Should be regular but without excessive moisture to prevent root rot.

Fertilization: The use of organic and mineral fertilizers to increase yield. For example, nitrogen fertilizers promote green mass growth, while phosphorus and potassium improve raw material quality.

Pest Control: Application of biological methods, such as using natural predators or biopreparations, to minimize chemical exposure.

Mulching: Helps retain soil moisture, reduce weed growth, and maintain a stable temperature. Pruning: Regular removal of dry or damaged parts to stimulate the growth of new shoots.

Automated irrigation systems, moisture monitoring, and drone use for crop condition assessment optimize medicinal plant care, especially on large farms.

Proper Placement of Medicinal Plants

Proper arrangement of medicinal plants on a plot is crucial for ensuring their optimal growth, high yield, and efficient land use. The main factors to consider include light, moisture, nutrients, plant compatibility, and soil characteristics.

Key Factors for Plant Placement

Lighting

Light-loving plants, such as purple coneflower (Echinacea purpurea) and calendula (Calendula officinalis), require open, well-lit areas.

Shade-tolerant plants, such as peppermint (Mentha piperita) and thyme (Thymus vulgaris), can grow in partial shade.

Moisture

Moisture-loving plants (Mentha, Matricaria chamomilla) require constant watering.

Drought-resistant species (Lavandula, Thymus) should be planted in well-drained soils. Nutrients

Fertile soil with high humus content promotes active growth of *Echinacea* and *Calendula*. Poor soils can be improved by adding organic fertilizers before planting.

Plant Compatibility

Some plants release substances that stimulate the growth of neighboring plants or protect them from pests.

It is important to avoid incompatible combinations that may inhibit each other's growth. **Optimal Planting Schemes**

Single-Row Planting:

Chamomile (Matricaria chamomilla): Row spacing – 30 cm, plant spacing – 10-15 cm.

Echinacea (Echinacea purpurea): Row spacing – 50 cm, plant spacing – 30 cm.

Peppermint (Mentha piperita): Row spacing – 40-50 cm, plant spacing – 20 cm. **Banded Planting:**

Calendula (Calendula officinalis): Two-row bands, row spacing within the band - 20 cm, between bands -50 cm, plant spacing -15 cm.

Thyme (Thymus vulgaris): Two-row bands, row spacing - 25 cm, between bands - 60 cm, plant spacing -20 cm.

Mixed Planting:

Some plants grow better together, creating favorable conditions:

Chamomile next to sage – sage repels chamomile pests.

Thyme near *lavender* – *lavender* promotes better *thyme* growth.

Calendula in ginseng rows - provides natural soil pest protection.

Soil Conditions and Planting Density:

In light soils, plants are planted more densely to prevent soil drying and reduce weed competition.

In heavy soils, plant spacing is increased for better root ventilation.

Following these planting schemes and recommendations optimizes land use, ensures uniform plant growth, and simplifies plant care.

Uses of Medicinal Plants

Traditional Medicine

Medicinal plants are widely used in folk medicine in the form of infusions, decoctions, compresses, ointments, tinctures, and powders. For example:

Chamomile infusion is used for gargling in case of sore throat and for soothing the digestive tract. *St. John's Wort decoction* is used for gastritis, ulcers, and as a natural antidepressant.

Calendula infusion has a calming effect, is used for wound healing, burns, and cosmetic purposes. *Aloe compresses* help heal wounds, reduce inflammation, and stimulate skin regeneration. *Propolis tincture* is effective against colds, with antibacterial and antiviral properties.

Official Medicine

Standardized extracts of medicinal plants are used in many pharmaceutical products: *Valerian tinctures* – for nervous disorders, insomnia, and anxiety.

Echinacea extracts – used in immunostimulating drugs for cold prevention.

Calendula-based ointments - promote wound, burn, and dermatitis healing.

St. John's Wort – included in antidepressants and sedatives.

Motherwort tinctures – for blood pressure regulation and nervous system calming.

Notable Medicinal Plants and Their Benefits

Chamomile (*Matricaria chamomilla*)

Has anti-inflammatory and antiseptic effects.

Used for skin diseases, digestive issues, and oral hygiene.

St. John's Wort (*Hypericum perforatum*)

Acts as a natural antidepressant due to its *hypericin* content.

Has anti-inflammatory properties and is used for digestive and nervous disorders.

Echinacea (*Echinacea purpurea*)

Strengthens the immune system and stimulates interferon production.

Used for cold prevention and treatment.

Peppermint (Mentha piperita)

Has antispasmodic and calming effects.

Used for digestive disorders, headaches, and insomnia.

Aloe (Aloe vera)

Promotes wound and burn healing, used in gels and juices.

Has antiseptic and anti-inflammatory properties.

Sage (Salvia officinalis)

Has antiseptic and anti-inflammatory effects.

Used for throat rinses, inflammation treatment, and hair and skin care.

Thus, medicinal plants have a wide range of applications in medicine, cosmetics, pharmaceuticals, and the food industry. Their effectiveness is confirmed by both traditional knowledge and scientific research.

Alternative medicine actively uses medicinal plants for health improvement and disease treatment, often offering unconventional therapeutic approaches. Many methods are based on long-standing traditions, and some are gaining popularity as complementary treatments to conventional medicine.

The Most Common Methods of Alternative Medicine: Homeopathy

Homeopathy is based on the use of highly diluted substances derived from plants, minerals, or animal components. The core principle is "like cures like." Some popular homeopathic remedies include:

St. John's Wort Extract – used for treating depression, nervous disorders, and sleep disturbances.

Arnica Montana – applied for injuries, bruises, swelling, and muscle pain.

Passionflower – used to reduce anxiety and improve sleep.

Aromatherapy

Aromatherapy utilizes essential oils from plants that affect physical and emotional well-being. It can be applied through massage, inhalation, or aroma diffusers. Popular essential oils include:

Lavender – relieves stress, improves sleep, and promotes relaxation.

Eucalyptus – helps with colds, clears airways, and reduces inflammation.

Peppermint - used for headaches, digestive issues, and nausea.

Rosemary – enhances focus and helps combat fatigue.

Ayurveda

Ayurveda is an ancient Indian medical system that employs thousands of medicinal plants to maintain health and harmonize the body. Some well-known Ayurvedic remedies include:

Ashwagandha – boosts energy, strengthens immunity, and helps with stress.

Tulsi (Holy Basil) – supports respiratory health, strengthens immunity, and has antibacterial properties.

Turmeric – a powerful antioxidant with anti-inflammatory properties that supports joint health.

Triphala – a blend of three fruits used for detoxification and digestive health.

Alternative medicine offers a wide range of approaches to treatment and disease prevention through natural remedies and techniques. While many methods have a long history of use, it is important to consider individual body characteristics and consult a doctor before using them, especially in cases of serious illnesses or when taking conventional medications[30,35].

Regional Herbal Medicine Traditions

Each region has unique traditions in using medicinal plants, reflecting its cultural heritage and ecological characteristics.

Ukrainian Traditions

Traditional Ukrainian medicine has long used medicinal plants to treat various ailments and support overall health:

Thyme – decoctions are used to treat colds, coughs, and bronchitis, as well as a calming agent before sleep.

Calendula – infusions aid wound healing, treat throat inflammation, and prevent skin diseases. St. John's Wort – relieves stress, treats depression, and improves digestive health.

Raspberry – leaves and fruits are used to lower fever and strengthen immunity.

Chamomile – has antiseptic and calming properties, widely used in teas, infusions, and compresses.

Northern Europe

In Scandinavian and Baltic countries, medicinal plants are adapted to the region's climate:

Rosehip – rich in vitamin C, used for cold prevention and immune support.

Bilberry – berries and leaves improve vision, regulate blood sugar levels, and support heart health. Lingonberry – a natural remedy for kidney and urinary tract health.

Nettle – rich in vitamins and minerals, used to cleanse the blood, strengthen hair, and boost hemoglobin levels.

Middle East

Medicinal plants play a vital role in Middle Eastern traditional medicine:

Saffron – enhances mood, reduces depression symptoms, and aids digestion.

Mint – widely used for digestive disorders, nausea relief, and fever reduction. Dates – packed with vitamins and minerals, used for overall health and energy boost.

Chinese Medicine

In Chinese medicine, medicinal plants hold a central place for both prevention and treatment: Ginseng – used as a tonic that improves mental activity and physical endurance.

Ginkgo Biloba – known for enhancing blood circulation and memory.

Astragalus Root – strengthens the immune system and helps combat stress.

Industrial Prospects for Medicinal Plants

With advancing technology and growing interest in natural remedies, new opportunities for medicinal plant applications are emerging:

Pharmaceutical Innovations

Development of new drugs based on bioactive compounds such as ginseng saponins or citrus flavonoids.

Use of plant extracts in creating antibacterial and immune-modulating medications. Cosmetology

Utilization of plant extracts for anti-aging creams, serums, and hair and skin care products. Application of natural oils (e.g., coconut, argan) in skincare and hair care.

Eco-Friendly Solutions

Production of biodegradable packaging from plant fibers like bamboo cellulose.

Creation of organic detergents based on saponins.

Use of natural dyes in the textile industry.

Medicinal plants play a crucial role in the culture, medicine, and industry of different nations. Thanks to their unique properties, they continue to be an essential resource for maintaining health and developing environmentally friendly technologies.

Overharvesting of wild medicinal plants can have severe ecological consequences, including significant population decline of certain species, disruption of ecosystem balance, and even the complete extinction of rare plants[4].

Decline in Plant Populations and Risk of Species Extinction

Many medicinal plants, especially those with slow regeneration cycles, are vulnerable to uncontrolled harvesting. For example:

Arnica montana – Known for its healing properties, it is disappearing due to excessive use and habitat destruction.

Ginseng (Panax ginseng, Panax quinquefolius) – Highly demanded, but its natural reserves are severely depleted due to its long recovery period (up to 10 years).

Disruption of Ecosystem Balance

Every species plays a crucial role in maintaining ecosystem equilibrium. Overharvesting leads to:

A decline in plant populations that serve as a food source for pollinators, which may impact their numbers.

The displacement of native species by aggressive plants that spread rapidly, creating imbalances in biological communities.

Soil Degradation and Loss of Natural Biodiversity

Uncontrolled harvesting can damage ecosystems not only by removing plants but also through associated processes:

Trampling of collection areas, which disrupts soil structure and reduces fertility.

Removal of root systems, leading to soil erosion, especially on slopes and in mountainous regions. Loss of natural shelters for animals, causing a decline in biodiversity.

Ways to Reduce Negative Impact

To minimize the harm caused by medicinal plant harvesting, responsible approaches should be applied:

Sustainable harvesting – collecting only parts of the plant without harming its regeneration.

Cultivation of medicinal plants instead of wild collection.

Regulation and restriction of industrial harvesting through legislation.

Educational campaigns to raise public awareness about the need to preserve rare plant species. The Importance of Cultivating Medicinal Plants

Uncontrolled harvesting of wild medicinal plants can cause significant damage to natural ecosystems. Implementing environmentally responsible collection practices can help preserve biodiversity and maintain ecological balance.

Growing medicinal plants on specialized plantations is a crucial step in ensuring a stable supply of raw materials while reducing pressure on natural ecosystems. This approach allows:

Quality control of medicinal raw materials using agronomic techniques.

Prevention of overexploitation of rare and endangered wild populations.

Selective breeding to develop more productive and resilient plant varieties.

Optimization of growing conditions (fertilization, irrigation, crop rotation) to increase yield and enhance the concentration of beneficial compounds in plants.

An additional advantage of cultivation is the possibility of mechanized harvesting, significantly reducing manual labor costs and improving efficiency.

Development of Collection Standards

To preserve natural populations of medicinal plants, strict harvesting rules must be implemented, including:

Adherence to collection periods – Each plant has an optimal harvesting period when its biologically active compounds are at their highest concentration.

Careful handling of root systems – For perennial plants, it is crucial to leave part of the roots intact or replant them for regeneration.

Partial harvesting – For seed-propagated plants (e.g., St. John's wort or chamomile), some individuals must be left untouched to ensure natural population renewal.

Protection of rare species – Certain species listed in the Red Data Book should be excluded from mass harvesting or cultivated artificially.

Following these standards helps reduce the depletion of natural resources and promotes their long-term use.

Public Education and Awareness

Raising ecological awareness among local communities, herbalists, and harvesters plays a key role in preserving medicinal plants. Key initiatives include:

Organizing seminars, lectures, and training on the sustainable use of medicinal plants.

Promoting environmentally responsible harvesting practices among local communities.

Supporting initiatives to establish botanical gardens, protected areas, and ecological farms.

Developing government programs and grants to encourage sustainable cultivation of medicinal plants.

A balanced combination of cultivation, responsible harvesting, and educational activities will help conserve natural resources for future generations, reduce the risk of valuable medicinal species disappearing, and ensure a stable supply of high-quality raw materials for medicine and pharmaceuticals[26].

Establishment of Protected Areas

Creating conservation zones where plant collection is strictly prohibited is one of the most effective ways to protect biodiversity. These zones include:

National parks – Large natural areas with high ecological value that serve as habitats for many plant and animal species. Example: Carpathian National Nature Park in Ukraine.

Biosphere reserves – Areas combining conservation efforts with scientific research and environmental education. Example: Askania-Nova.

Reserves and sanctuaries – Protected areas with restricted access designed to preserve specific ecosystems or rare species.

Seed Banks

Preserving genetic material of rare and endangered species in specialized storage facilities ensures their survival even if they disappear in nature. Key aspects include:

Cryopreservation – Using low temperatures (-196°C in liquid nitrogen) for long-term storage of seeds and plant tissues.

Genetic collections – Seed banks store a wide variety of species, helping maintain biodiversity and providing valuable resources for future generations.

Examples: The Svalbard Global Seed Vault, which holds over a million seed samples from around the world.

Reintroduction Programs

Growing plants under laboratory conditions and reintroducing them into their natural habitat is an important conservation method. Reintroduction helps:

Restore populations of rare species threatened by deforestation, climate change, and other factors.

Preserve medicinal plants of significant pharmacological value. Example: Cultivating ginseng in natural conditions after the disappearance of wild populations.

Monitor planting success and adaptation in the wild through scientific research and observation.

International Cooperation

Global efforts are essential for the effective conservation of rare species, as many plants have habitats that extend beyond national borders. Key areas of cooperation include:

Exchange of seeds and genetic materials among botanical gardens, research institutions, and conservation organizations.

Joint scientific research to develop biodiversity conservation methods, such as international programs studying the DNA of rare plants.

Global initiatives: The Red List of the International Union for Conservation of Nature (IUCN), the Convention on Biological Diversity (CBD), and the UN program for the protection of rare species.

Medicinal plants play a key role in rehabilitating degraded ecosystems as they contribute to improving soil cover, restoring natural biocenoses, and enhancing biodiversity.

For example, planting Echinacea not only improves soil structure but also enriches it with organic matter, stimulating the development of beneficial microflora. Sage, with its powerful root system, helps stabilize slopes, preventing erosion processes, and aids in moisture retention, which is crucial for arid regions.

Other medicinal plants, such as chamomile and yarrow, also play an important role in ecosystem restoration. Chamomile contributes to the recovery of depleted soils, while yarrow helps stabilize the soil layer and increases its fertility due to the presence of nitrogen-fixing bacteria.

The use of such species in biodiversity restoration programs creates favorable conditions for the existence of other plants and animals. Additionally, they attract pollinators, such as bees and butterflies, which contribute to the reestablishment of ecosystem connections[31].

Thus, integrating medicinal plants into ecological rehabilitation efforts not only restores natural areas but also helps maintain their ecological balance in the long term.

Uncontrolled harvesting of wild plants can lead to the depletion of their natural populations, a reduction in biodiversity, and ecosystem disruption. Many species valuable for medicine, food, or the cosmetic industry are at risk of extinction due to excessive collection. Therefore, an ethical approach to wild plant harvesting is crucial for preserving natural resources.

Education of Local Communities

Training in sustainable harvesting methods, including collecting only mature plant parts and leaving some plants for natural regeneration.

Raising awareness of rare and endangered species lists, whose collection is prohibited or restricted.

Conducting training sessions on responsible use of natural resources and environmental awareness.

Regulation

Establishing clear guidelines on harvesting volumes and permitted methods. For example, for rhizomatous plants, only a portion of the roots should be collected to allow regrowth.

Legislative initiatives to regulate the harvesting of medicinal and edible wild plants, as well as the creation of protected areas.

Implementing mandatory licensing for harvesting certain plant species.

Certification and Product Labeling

Utilizing certification systems that ensure environmentally responsible harvesting (e.g., FSC, FairWild).

Certification enables consumers to choose plant-based raw materials that have been collected in accordance with sustainable development principles.

The FairWild program, which operates in many countries, helps conserve valuable plant populations through controlled harvesting and habitat protection. For instance, in India, the program regulates the harvesting of ginseng to ensure its sustainability.

By adopting these ethical principles, it is possible to ensure the long-term conservation of medicinal plant populations while maintaining their ecological and economic value[7,9].

Successful Examples of Sustainable Wild Plant Harvesting:

Germany: Implemented harvesting standards for chamomile and sage to preserve their natural populations.

Ukraine: Projects for sustainable St. John's wort harvesting include population monitoring, local community training, and collection regulation.

Bulgaria: A regulatory system for lavender and Damascus rose harvesting helps conserve these valuable plants for future generations.

Consequences of Uncontrolled Harvesting:

Depletion of natural populations, leading to the extinction of certain species.

Reduced ecosystem resilience due to imbalances among species.

Economic decline in communities reliant on wild plant collection and trade.

Implementing ethical principles in wild plant harvesting is essential for preserving natural resources and ensuring their future use. Education, regulation, and certification are key tools to achieve this goal.

Conservation of Medicinal Plants

Preserving medicinal plants is crucial for maintaining ecological balance and supporting both traditional and modern medicine. Many species face extinction due to overharvesting, deforestation, and climate change, requiring international coordination for their protection and sustainable use.

Key Aspects of Medicinal Plant Conservation

Protected Areas and Conservation Zones

Establishing national parks, biosphere reserves, and nature conservation areas where industrial-scale medicinal plant harvesting is restricted or strictly controlled.

Example: The Amazon rainforest hosts thousands of medicinal plant species, many protected through international conservation programs.

In Ukraine: The Carpathian Biosphere Reserve safeguards rare species like yellow gentian (*Gentiana lutea*) and mountain arnica (*Arnica montana*).

Seed Banks and Botanical Gardens

Storing genetic material of rare and valuable medicinal plants in specialized repositories (genetic banks).

Example: The Svalbard Global Seed Vault (Norway) preserves medicinal plant samples from around the world.

In Botanical Gardens: Institutions like the Royal Botanic Gardens, Kew (UK) run programs to conserve rare plants.

Global Initiatives and International Legislation

CITES (Convention on International Trade in Endangered Species): Regulates the export and import of rare medicinal plants like ginseng (*Panax ginseng*).

Convention on Biological Diversity (CBD): Requires countries to protect rare species and their habitats.

UNEP (United Nations Environment Programme): Develops strategies for the sustainable use of natural resources, including medicinal plants.

Sustainable Use and Ethical Harvesting

Implementing eco-certifications (e.g., *FairWild* standard) to ensure responsible plant harvesting. Promoting medicinal plant cultivation to reduce pressure on wild populations.

Restoring wild medicinal plant populations is a complex but vital process requiring a comprehensive approach and ecological considerations. Their decline is driven by human activities, climate change, excessive harvesting, and habitat destruction. Therefore, effective reintroduction must rely on scientifically based methods and long-term monitoring of restored populations[14].

By implementing these conservation measures, we can safeguard biodiversity and ensure future generations have access to valuable medicinal plants.

Основні методи реінтродукції лікарських рослин

The main methods of reintroduction are:

Sowing seeds in natural conditions: This method is used for plants that easily reproduce by seeds, such as chamomile (*Matricaria chamomilla*) or common St. John's wort (*Hypericum perforatum*). It is crucial to select the optimal seasons for sowing, such as spring or autumn, and consider environmental factors like soil moisture, light exposure, and the presence of competing plants.

Planting seedlings grown under controlled conditions: This approach is applied to species that require protection during their early growth stages. For example, mountain arnica (*Arnica montana*) is cultivated in laboratory conditions before being transplanted to high-altitude regions. This method is also used for the restoration of valerian (*Valeriana officinalis*), as its seeds have low germination rates in natural environments.

In vitro propagation: This technique is used for the restoration of rare and endangered species. It enables the production of genetically identical material for further reintroduction into natural habitats. It is effective for species with low natural reproduction rates, such as true ginseng (*Panax ginseng*), rhodiola rosea (*Rhodiola rosea*), and lesser butterfly-orchid (*Platanthera bifolia*). This method helps preserve genetic purity and ensures high plant viability.

Controlled reintroduction into artificially created ecosystems: These projects are implemented in botanical gardens or reserves that mimic natural conditions. For instance, ginseng populations have been successfully restored in specially created forest reserves in China. Such initiatives allow plants to gradually adapt to natural conditions before their final relocation.

Specific examples of successful reintroduction

One notable example is the project for restoring *Rhodiola rosea* populations in the Carpathian Mountains using a methodology of seedling transplantation followed by adaptation monitoring. This plant is highly valuable in pharmaceuticals, leading to excessive harvesting and depletion of natural populations. Reintroduction helps stabilize its numbers and ensure its continued existence in the wild.

Another significant example is the reintroduction of mountain arnica in high-altitude regions, contributing to the growth of its population and the restoration of its natural habitat. Through a comprehensive approach that includes cultivation, planting, and long-term monitoring, this plant is once again appearing in its native ranges[33].

The importance of reintroduction for ecosystems

The reintroduction of medicinal plants plays a crucial role in maintaining ecosystem balance. Many of these species not only serve as sources of beneficial compounds but also play key roles in biocenoses, providing food for pollinators and contributing to soil stability. Restoring natural populations helps not only to stabilize species numbers but also to prevent their extinction.

Thus, the application of comprehensive reintroduction methods for medicinal plants supports biodiversity conservation and the sustainable use of natural resources. Further research and ecological initiatives can aid in the restoration of rare species and ensure their long-term growth in natural conditions.

Modern biotechnologies in medicinal plant research

Modern biotechnologies significantly expand the possibilities for studying and utilizing medicinal plants. Advances in molecular biology, genetic engineering, and cellular biotechnology allow not only the optimization of beneficial compound synthesis but also the enhancement of plant adaptation properties, opening new prospects for medicine and pharmaceuticals.

Genetic engineering in medicinal plant research

Genetic modification is one of the key tools in modern biotechnology. It allows:

Increasing the content of active substances: By modifying genes responsible for the synthesis of biologically active components (alkaloids, flavonoids, terpenes, etc.), their concentration in plants can be significantly increased. This enables the production of more effective medicinal preparations without expanding cultivation areas.

Enhancing resistance to adverse conditions: By introducing resistance genes, plants can be protected from pathogens, pests, drought, soil salinity, and extreme temperatures, allowing their cultivation in a wider range of climatic conditions.

New Methods of Cultivation and Biotechnological Approaches in Medicinal Plant Research Development of New Cultivation Methods

The application of microclonal propagation technologies enables the preservation and reproduction of rare or endangered medicinal plant species. This is crucial for biodiversity

conservation and ensuring a stable supply of raw materials for the pharmaceutical industry.

Other Promising Biotechnological Directions

Apart from genetic engineering, several other biotechnological methods are actively used in the research of medicinal plants:

Metabolic Engineering – a technology aimed at regulating biochemical pathways within plants to enhance the production of beneficial metabolites. This approach allows for increased yields of secondary metabolites with pharmacological activity, such as antioxidant, anti-inflammatory, or anticancer properties.

Plant-Based Biofactories – a promising technology that involves growing genetically modified plants capable of synthesizing pharmaceutical proteins, vaccines, antibodies, and other biologically active compounds. This approach can significantly reduce drug production costs and make medicines more accessible to a broader population.

Biotransformation – the use of plants or cell cultures to modify chemical compounds. This enables the development of new or improved pharmaceuticals through the biological conversion of natural substrates.

Synthetic Biology – a novel field that combines genetic engineering and systems biology methods to create new metabolic pathways in plants for the production of innovative medicinal substances.

The application of biotechnologies in medicinal plant research offers vast opportunities for medicine and pharmacy. These advancements not only enhance the efficiency of synthesizing essential compounds but also expand cultivation areas, preserve rare species, and develop new pharmaceutical production methods. In the future, these technologies may revolutionize drug manufacturing, making them more widely available[42].

Climate change and the destruction of natural ecosystems necessitate the active search for new plant species that can serve as sources of valuable biological compounds for pharmacological, cosmetic, and agro-technological applications.

New Active Compounds

Research on tropical flora in regions such as the Amazon, Southeast Asia, and Africa has led to the discovery of new biologically active substances.

Tropical plants like *Tabernaemontana undulata* contain alkaloids that may serve as the basis for new medicines.

Unique enzymes and secondary metabolites from tropical plants show potential in treating cancer, infectious diseases, and neurodegenerative disorders.

Plants with Unique Properties

Arctic-zone plants, such as *Rhodiola rosea* (golden root), exhibit high adaptability, making them valuable for developing stress-relief and extreme-condition medications.

Polar flora has evolved unique survival mechanisms that may have applications in biomedicine and cosmetology.

Potentially Rare Resources

Previously unexplored local plant species hold significant potential for pharmacology, especially in ethnomedicine.

Plants like *Artemisia annua* (sweet wormwood), traditionally used in medicine, have become sources of new pharmaceutical products, such as artemisinin for malaria treatment.

The genetic diversity of wild species can be leveraged to cultivate more resilient crops capable of adapting to climate changes.

Digital Tools in Medicinal Plant Research

The use of digital technologies significantly accelerates the study of medicinal plants, providing access to vast amounts of data and analytical capabilities.

Artificial Intelligence (AI)

AI helps analyze genomic data, predict therapeutic properties, and uncover new relationships between plant components.

Machine learning identifies patterns in biological data, contributing to the development of personalized medicine.

. Bioactivity Modeling

3D modeling of active substances assesses their interactions with molecular targets in the human body.

Bioinformatics enables the rapid identification of potentially active compounds and their mechanisms of action.

Global Databases

Platforms such as PhytochemDB facilitate quick access to chemical composition data of plants.

Other digital resources, including PlantCyc and KNApSAcK, provide insights into metabolic pathways and plant chemistry. Integrating traditional botanical research with digital technologies opens new perspectives in the search for valuable plant resources. In the face of climate change and increasing anthropogenic impact, these approaches could become key to developing innovative solutions in medicine, pharmacology, and agro-technologies.

Sustainable Development Requires New Approaches to the Cultivation and Harvesting of Medicinal Plants:

Environmentally Friendly Cultivation Methods: Utilizing organic fertilizers and reducing pesticide use.

Restoration of Degraded Ecosystems: Growing medicinal plants as part of soil restoration programs and biodiversity enhancement.

Resource Reuse: Creating closed-loop systems where water and nutrients circulate without losses. Research on Medicinal Plants Stimulates the Development of Innovative Products:

Phytonutrients: Supplements containing multi-component extracts to support health.

Bioactive Packaging: Developing packaging with plant-derived antioxidants to extend product shelf life.

Complex Preparations: Combining different extracts to create multifunctional medicinal products. Development of New Drugs: Using innovative methods to develop medicines with higher efficacy and minimal side effects.

Conservation of Rare Species:

Developing genetic resource conservation programs through seed banks, laboratory cultivation, and reintroduction into natural habitats.

Supporting Sustainable Development:

Integrating medicinal plants into sustainable agriculture and conservation strategies, including their use for land restoration and biodiversity support.

Advancing Educational Initiatives:

Organizing training programs for farmers and scientists to promote knowledge about medicinal plants, their cultivation, and applications.

Integration with Modern Technologies:

Utilizing digital tools such as sensors, drones, and artificial intelligence for monitoring cultivation, assessing raw material quality, and predicting yields.

Expanding Global Cooperation:

Participating in international research projects to exchange knowledge, genetic resources, and establish common standards for medicinal plants.

Economic Potential:

Developing local and global markets for medicinal plants, fostering job creation in agriculture, pharmaceuticals, and cosmetology[39,44].

Conclusions

Medicinal plants are an invaluable resource for medicine, pharmacy, cosmetology, the food industry, and ecology. Their use has deep roots in human history while also serving as a foundation for modern scientific advancements.

Medicinal plants create job opportunities, contribute to the development of the pharmaceutical and cosmetology industries, and serve as the basis for natural dietary supplements. They are a source of unique biologically active compounds used in the treatment and prevention of diseases. Cultivating and rationally utilizing medicinal plants promotes biodiversity conservation and ecosystem restoration. Genetic engineering, digital technologies, and new cultivation methods open new horizons for the study and application of medicinal plants. The collaboration of scientists worldwide enables the harmonization of cultivation standards, the exploration of new species, and the preservation of rare genetic resources.

The prospects for using medicinal plants include integration into sustainable development systems, the creation of new biopharmaceuticals with high efficacy and low toxicity, the expansion of digital technologies for research and cultivation monitoring, and the active promotion of knowledge about medicinal plants among the general public.

In summary, medicinal plants remain an inexhaustible source of discoveries, an inspiration for scientists, and a foundation for sustainable development. Their study, cultivation, and application contribute not only to improving the quality of life but also to fostering harmony between humans and nature.

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