STUDY ON THE RELATIONSHIP BETWEEN SOIL PROPERTIES AND THE QUALITY OF ACTIVE COMPOUNDS IN THE MEDICINAL PLANT ELDERBERRY (*SAMBUCUS NIGRA* L.)

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RESEARCH ARTICLE

Abstract: *The study analyzes the influence of soil properties on the quality of the active compounds found in the medicinal plant elderberry (Sambucus nigra L.). The physical and chemical characteristics of the soil, as well as the plant's bioactive compounds, such as polyphenols, flavonoids, and antioxidant capacity, were evaluated. The results highlight the existence of a direct relationship between soil composition and the accumulation of active compounds, with soils rich in nutrients and organic matter promoting a high bioactive potential. The study emphasizes the importance of pedological factors in determining the phytotherapeutic quality of the species Sambucus nigra L.*

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INTRODUCTION

Medicinal plants have long been recognized as valuable sources of bioactive substances with applications in nutrition, herbal medicine, and the pharmaceutical industry. In recent years, growing interest in natural remedies and plant-derived products has encouraged extensive research focused on the factors that affect the composition and therapeutic quality of medicinal species. Among these factors, soil conditions play a crucial role, as the physical, chemical, and biological properties of soil directly influence plant metabolism and the synthesis of secondary metabolites.[2]

Sambucus nigra L., commonly known as elderberry, is considered one of the most important wild medicinal plants native to Europe. The species is widely appreciated for its therapeutic potential and its rich content of biologically active compounds. Elder flowers and fruits contain significant amounts of phenolic compounds, flavonoids, anthocyanins, vitamins, and natural antioxidants, which contribute to their medicinal and nutritional value. Due to its anti-inflammatory, antiviral, diuretic, and immune-supporting properties, elderberry has been extensively used in traditional medicine and is increasingly incorporated into pharmaceutical, cosmetic, and food products.[1], [2]

The concentration and quality of active compounds in medicinal plants are strongly influenced by environmental conditions, including climate, altitude, light exposure, moisture, and especially soil composition. Soil acts as the primary source of water and essential nutrients required for plant growth, while its pedological characteristics can significantly affect physiological processes and the production of bioactive metabolites. Parameters such as soil pH, texture, organic matter content, and the availability of macro and micronutrients are closely related to nutrient uptake and phytochemical accumulation.[3], [5]

Recent studies on *Sambucus nigra* L. have demonstrated that variations in soil characteristics may lead to considerable differences in the levels of polyphenols, flavonoids, and antioxidant activity found in

plant extracts. Nutrient-rich soils with high organic matter content generally promote better plant development and stimulate the biochemical pathways involved in the biosynthesis of active constituents. In contrast, poor or unbalanced soils may negatively affect both plant growth and the therapeutic quality of the harvested material.[9], [10]

Investigating the relationship between soil properties and phytochemical quality has become increasingly important in the context of sustainable use of wild medicinal resources and the demand for high-quality herbal products. Understanding how pedological factors influence the chemical composition of medicinal plants may support the identification of suitable habitats, improve cultivation strategies, and contribute to the efficient management of natural resources.[13], [14]

The present study aims to evaluate the impact of soil properties on the quality of active compounds in *Sambucus nigra* L. by analyzing the physicochemical characteristics of soil samples together with the major bioactive constituents of the plant material. The research focuses on identifying the relationship between pedological conditions and the phytochemical potential of this medicinal species, contributing to a better understanding of soil–plant interactions in spontaneous medicinal flora.[11]

MATERIALS AND METHODS

The research was conducted through the collection of soil samples and plant material from *Sambucus nigra* L. populations growing in areas characterized by different pedological conditions. Soil samples were examined in order to determine key physicochemical parameters, including pH, humus content, macroelements, and microelements. The harvested plant material, consisting of flowers and/or fruits, was subjected to phytochemical analyses aimed at evaluating the levels of polyphenols, flavonoids, and antioxidant activity. The obtained data were comparatively analyzed to identify possible correlations between soil characteristics and the quality of bioactive compounds present in the medicinal plant.

RESEARCH RESULTS

The findings of the study revealed a strong connection between the physicochemical characteristics of the soil and the quality of the bioactive compounds identified in *Sambucus nigra* L. Analyses performed on both soil and plant samples demonstrated that variations in pedological parameters significantly influence the accumulation of phytochemicals, particularly polyphenols, flavonoids, and antioxidant compounds.[4]

The examination of soil samples collected from different locations showed considerable differences in pedological properties, which directly affected the growth and metabolic activity of *Sambucus nigra* L. The main parameters investigated included soil pH, texture, humus content, moisture level, and the concentration of essential nutrients.[7], [8]

The results indicated that elderberry plants developed most efficiently in slightly acidic to neutral soils. Under these conditions, nutrient availability was higher, supporting better mineral uptake and enhanced biochemical activity within the plant. In contrast, strongly acidic or alkaline soils limited nutrient absorption, negatively affecting plant vigor and reducing the concentration of active compounds.[9]

Soils rich in organic matter provided the most favorable conditions for plant growth. Increased humus content improved soil structure, water retention capacity, and nutrient availability. Plants growing in such environments exhibited more vigorous vegetative development, healthier foliage, and higher levels of bioactive constituents. Conversely, soils with low humus content were associated with lower fertility and reduced accumulation of phenolic compounds and flavonoids.[10]

Macronutrients such as nitrogen, phosphorus, and potassium played an

essential role in plant metabolism and in the synthesis of secondary metabolites. Nitrogen contributed to vegetative growth and protein synthesis, phosphorus supported energy transfer processes and root development, while potassium enhanced metabolic regulation and improved plant resistance to environmental stress.[8]

Among the micronutrients, iron and magnesium were found to be particularly important for photosynthetic and enzymatic processes involved in the biosynthesis of secondary metabolites. Zinc and manganese also contributed to the activation of enzymes associated with polyphenol and flavonoid production.[9]

Loamy soils with moderate water retention capacity created optimal conditions for the development of *Sambucus nigra* L. In these areas, soil moisture remained relatively stable without excessive dryness or waterlogging. By comparison, compacted or excessively sandy soils negatively influenced root growth and nutrient absorption, leading to a decline in plant quality.

Phytochemical analyses of elder flowers and fruits revealed substantial differences in the concentration of bioactive compounds depending on the soil characteristics of the harvesting sites. Plants collected from fertile soils with high organic matter content showed the highest total polyphenol concentrations. These compounds are essential for protecting plants against oxidative stress and contribute significantly to the antioxidant and anti-inflammatory properties of plant extracts.[6]

In areas characterized by poor soil fertility, polyphenol concentrations were considerably lower, suggesting that nutrient availability directly affects the biosynthesis of these compounds. Flavonoid levels also varied according to soil pH and micronutrient balance. Nutritionally balanced soils favored flavonoid accumulation, particularly in flowers collected from areas with moderate humidity and elevated humus content.[5]

The antioxidant activity of elderberry extracts was closely associated with the concentration of phenolic compounds and flavonoids. Extracts obtained from plants grown in nutrient-rich soils displayed superior antioxidant properties, indicating that soil quality has a direct influence on the therapeutic potential of the plant material. In contrast, samples originating from degraded or mineral-deficient soils showed lower antioxidant capacity and reduced phytotherapeutic value.[4]

Comparative analyses demonstrated that elder flowers contained higher amounts of flavonoids and aromatic compounds, whereas the fruits were richer in anthocyanins and natural antioxidants. These variations were influenced not only by the developmental stage of the plant but also by pedological and climatic conditions.[2]

Overall, the research confirmed a close relationship between soil properties and the phytochemical quality of *Sambucus nigra* L. Fertile soils enriched with organic matter and essential nutrients supported metabolic processes involved in the synthesis of bioactive compounds. The positive correlation identified between soil fertility and the levels of polyphenols and flavonoids highlights the importance of mineral nutrition in plant secondary metabolism. Essential micronutrients stimulated enzymatic activity and biosynthetic pathways responsible for the accumulation of therapeutically valuable substances.[14]

The results further demonstrate that pedological factors are key determinants in obtaining high-quality medicinal plant material. The study also emphasizes the importance of monitoring environmental conditions and selecting appropriate habitats for harvesting spontaneous medicinal flora.[15]

From a practical perspective, these findings are highly relevant for phytotherapy, organic agriculture, and the sustainable exploitation of natural plant resources. Identifying areas with favorable soil conditions may contribute to obtaining medicinal plants with enhanced

concentrations of active compounds and improved therapeutic efficiency. This aspect is particularly important for the production of plant extracts used in the pharmaceutical and natural medicine industries.[13]. [15]

The outcomes of the research may also support the selection of suitable cultivation sites for *Sambucus nigra* L. and help establish optimal harvesting conditions and periods. Monitoring soil fertility can contribute to improving both plant productivity and phytochemical quality.[12]

Furthermore, the study highlights the necessity of conserving natural habitats that support the development of spontaneous medicinal flora. Protecting ecosystems with fertile and balanced soils may contribute to biodiversity preservation and the sustainable use of natural resources.[9], [11]

CONCLUSIONS

The research conducted on *Sambucus nigra* L. highlighted the significant role of soil-related factors in determining the quality and concentration of the plant's active compounds. The analyses demonstrated that the physicochemical properties of soil directly affect plant growth, metabolic activity, and the capacity to synthesize and accumulate bioactive substances with therapeutic importance.

The results showed that fertile soils enriched with organic matter and essential nutrients promote the accumulation of polyphenols, flavonoids, and other secondary metabolites responsible for the antioxidant and medicinal properties of the species. In contrast, soils characterized by low organic content or unfavorable pH conditions were associated with reduced phytochemical quality and lower concentrations of active constituents.

The study further confirmed a strong relationship between soil composition and the bioactive potential of *Sambucus nigra* L., emphasizing the importance of both macroelements and microelements in the biosynthesis of secondary metabolites. Nutrients such as nitrogen, phosphorus, potassium, iron, and magnesium had a considerable influence on plant development and on the antioxidant activity of the obtained extracts.

In addition, the research demonstrated that plants collected from habitats with balanced soil structure and moderate moisture conditions exhibited superior therapeutic properties. These findings underline the importance of natural environmental conditions in maintaining the quality of wild medicinal flora.

From a practical perspective, the study provides valuable information for identifying suitable areas for the harvesting and cultivation of elderberry. Selecting soils with favorable pedological characteristics may contribute to the production of medicinal plant material with enhanced therapeutic efficiency while also supporting sustainable management of natural resources.

The research also contributes to a deeper understanding of soil–plant interactions and highlights the importance of preserving natural ecosystems that sustain spontaneous medicinal species. Protecting fertile soils and maintaining ecological balance are essential for biodiversity conservation and for ensuring the production of high-quality plant material.

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