THE EFFECTS OF HEAVY METAL POLLUTION ON THE METABOLISM OF PLANTS

EFECTELE POLUĂRII CU METALE GRELE ASUPRA METABOLISMULUI PLANTELOR

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Abstract.
The present study aims to show the influence of phytohormones on the defense mechanism of plants to the stress caused by heavy metal pollution. This type of pollution influences both biochemical and physiological reactions. The study also highlights the importance of new technologies used and international collaboration to protect the therapeutic potential of plants by reducing environmental contamination in the first place. The most effective strategy to reduce the impact on the defense capacity of plants is the application of effective strategies to mitigate the causes that lead to environmental pollution with heavy metals.
Key words: plants, heavy metals, therapeutic potential

Rezumat.
Studiul de față are rolul de a arăta influența fitohormonilor asupra mecanismului de apărare al plantelor la stresul produs de poluarea cu metale grele. Acest tip de poluare influențează deopotrivă reacțiile biochimice și cele fiziologice. Studiul evidențiază și importanța noilor tehnologi utilizate și colaborarea internațională pentru a proteja potențialul terapeutic al plantelor prin reducerea în primul rind a contaminării factorilor de mediu. Cea mai eficientă strategie de reducere a impactului asupra capacității de apărare a plantelor o reprezintă aplicarea unor syrategii eficiente de atenuare a cauzelor care conduc la poluarea mediului cu metale grele.
Key words: plante , metale grele, potential therapeutic

INTRODUCTION

Over time, medicinal plants have proven their role as constant partners of man to maintain health and heal. In addition to therapeutic properties, medicinal plants symbolize the continuity of ancestral practices that shaped the relationship between man and nature over time. In modern days, these botanical resources with varied bioactive compounds are of great importance in identifying and creating new effective therapeutic solutions. Alkaloids, flavonoids, terpenoids and polyphenols are chemicals with therapeutic effects [Asiminicesei *et al.*, 2024].

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Investigating how heavy metals influence the therapeutic efficacy of active compounds in medicinal plants contributes to a better understanding of the impact that pollutants have on plants, and therefore, human health.

Oxidative stress and free radicals are factors responsible for the appearance of various diseases and are directly involved in the aging process. Science can provide us with information about the connection between the antioxidant capacity of medicinal plants and the influence that pollutants have on the well-being of the organisms on which they act.

MATERIAL AND METHOD

Comprehensive database research was conducted to identify sources of relevant information for this study. The following sources of information were used:

Databases: Major databases such as ScienceDirect, Springer, Wiley, PubMed, Scopus and Web of Science were searched to retrieve relevant studies. These databases cover the period 2010-2024.

The search strategy was carefully designed to be both broad and specific, aiming to capture all relevant studies addressing heavy metal toxicity and antioxidant levels in medicinal plants. Great attention to detail has been paid to ensure that no significant research is omitted. Also, the strategy was documented in detail and transparently so that it could be easily replicated by other researchers, guaranteeing the consistency and rigor of the documentation process.

The study selection process was carried out in several steps to ensure the inclusion of relevant studies of high scientific quality.

The search strategy was carefully designed, involving the systematic exploration of major scientific databases, including ScienceDirect, Scopus and Web of Science. These resources were selected for their breadth and diversity, covering a wide range of scientific literature in the field of heavy metal toxicity and herbal antioxidants. The choice of databases was made with the aim of ensuring the inclusion of studies of the highest quality and relevance in the present work.

The search terms were carefully selected to optimally capture all relevant aspects of the topic under study. They included specific keywords related to heavy metal toxicity, antioxidants, and medicinal plants, thus ensuring complete coverage of the literature. In order to refine and increase the precision of the results, Boolean operators (such as AND, OR and NOT) were used, which allowed the variable combination of terms, thus reducing the information and creating the relevance of the identified articles.

The search strategy was also optimized by applying additional filters, such as public data, to focus on the most recent research, thus ensuring that the studies considered reflect the most current findings in the field. The language of the articles was restricted to English to facilitate access to widely accepted and internationally accessible reference works.

Date of last search: Databases limited to studies published after the year 2015 to ensure that the most recent studies were included in the review.

The study included both theoretical and experimental research that explored the link between heavy metal toxicity and antioxidant levels in plants.

RESULTS AND DISCUSSIONS

Antioxidants can be classified according to several parameters, including their origin, biochemical activity, and suitability for efficient nanoparticle synthesis. The main classes of antioxidant compounds are: polyphenols, flavonoids, alkaloids, carotenoids, terpenes, phenolic acids and saponins.

They can be found in various natural extracts prepared from different available species such as plants, fungi, bacteria, algae, lichens and actinomycetes.

Understanding and harnessing plant antioxidant defense mechanisms is essential for improving crop yield, promoting sustainable agriculture and conserving biodiversity [Cao *et al*., 2023; Chan, 2012].

Antioxidants help plants combat oxidative stress, which occurs due to an imbalance between the production of reactive oxygen species (ROS) and the plant's ability to detoxify them.

ROS are generated during normal metabolic processes and are exacerbated by environmental stressors such as UV radiation, pollutants and pathogen attacks [Kumar *et al.*, 2021]. Therefore, antioxidants are essential for plant defense mechanisms against pathogens. When a plant encounters pathogenic microorganisms, it initiates a defense reaction of the oxidative exposure type.

Antioxidant activity is crucial for maintaining human health, it helps combat the negative effects of oxidative stress, which arises from the imbalance between reactive oxygen species (ROS) and the body's ability to neutralize them. Antioxidants play an important role in the prevention and management of various diseases such as cardiovascular disease, diabetes and neurodegenerative disorders. They act as preventive agents and, in certain cases, can support treatment against certain conditions.

The antioxidant activity of plants can be positively or negatively influenced by a number of factors such as: climatic conditions, exposure to light, soil quality, phytosanitary treatments.

The most important factor that negatively affects the antioxidant capacity is pollution, Heavy metals, pesticides, industrial residues can be absorbed by plants changing their chemical structure and implicitly reducing the health benefits or can cause health problems such as cancer or neurological diseases and can seriously affect the reproductive capacity of human and animal organisms. The interaction between heavy metals and plants is a complex one.

Pesticides, in particular, can disrupt the plant's antioxidant defense system [Fan *et al.*, 2023; Aye *et al.*, 2019].

Atmospheric emissions can be absorbed by plants increasing their oxidative stress. Ozone affects photosynthesis and nitrogen oxides influence the amount of flavonoids and phenolic acids in plants.

Inadequate quality control measures for herbal products may lead to the unintended inclusion of contaminated plant material on the market [Hlihor *et al.*, 2022; Asiminicesei *et al.*, 2020].

Molecular biology and genomic investigations are making essential contributions to the detailed understanding of the structure and function of genetic variation for stress-related traits in plants. These domains allow not only the identification and characterization of genetic traits related to stress tolerance, but also the integration of this information into gene-assisted selection programs. By identifying molecular markers and using high-throughput genotyping technologies, researchers are able to expand the gene pool available for plant breeding, opening the way for exploiting new sources of stress resistance.

These discoveries are directly applied to plant breeding, which translates them into practice by developing crop varieties more resistant to abiotic and biotic stress conditions.

CONCLUSIONS

The work highlights the risks of toxic accumulation in plants that lead to changes in the balance between antioxidant capacity and oxidative stress. Genetic modification of plants in order to increase resistance to polluting agents can be considered a promising solution for the purpose of protecting bioactive compounds in plants. Further research and the finding of new innovative solutions to prevent the contamination of environmental factors with pollutants are important. Investigating the change in plant bioactive compounds following exposure to heavy metals can provide valuable information about the risks of consuming plants from polluted areas.

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