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Lead tolerance and phytoremediation efficiency of *Cercis canadensis* and *Tetradium daniellii*

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Abstract
Lead (Pb) is one of the most hazardous heavy metals, posing serious threats to plants, animals, and human health. To mitigate its environmental impact, phytoremediation using plants to extract, stabilize, or detoxify pollutants offers a sustainable and cost-effective solution for soil rehabilitation. This study aimed to evaluate the tolerance and phytoremediation capacity of *Cercis canadensis* and *Tetradium daniellii* seedlings grown in lead-contaminated soils. Two-year-old plants were exposed to lead acetate solutions at concentrations of 100 mg/kg and 300 mg/kg of soil, while control plants received only water. Plant physiological responses were assessed one week, one month, and two months after exposure. The content of chlorophylls, carotenoids, and malondialdehyde, as well as peroxidase activity, were determined spectrophotometrically. Photosynthetic performance was measured using fluorimetry, and the distribution of mobile lead compounds in leaves, stems, and roots was analyzed by atomic absorption spectrophotometry. Both species demonstrated high tolerance to lead exposure, with minimal impairment of the photosynthetic system. Notably, a short-term increase in chlorophyll content and stimulated shoot growth were observed in plants treated with 100 mg/kg Pb. Lead accumulation in *C. canadensis* occurred predominantly in the roots, whereas *T. daniellii* accumulated lead in both roots and stems. These findings indicate that both species possess considerable resistance to lead stress and potential for phytostabilization and phytoextraction. Consequently, *Cercis canadensis* and *Tetradium daniellii* can be recommended as effective ornamental species for greening and rehabilitating lead-polluted urban and industrial areas.

Keywords*:* *heavy metal pollution, malondialdehyde, antioxidant system, chlorophyll fluorescence, carotenoids, phytoremediation*

Introduction

Environmental pollution with heavy metals is one of the most important environmental problems world-wide (Lin *et al*., 2015; Sun *et al*., 2018; Bondar *et al*., 2019, Broomandi *et al.,* 2020). Among the existing pollutants, lead is one of the most toxic metals, causing damage to the nervous, cardiovascular, reproductive systems, kidneys and bones of humans (Engwa *et al*., 2019; Collin *et al.,* 2022). The consequences of pollution manifest themselves in respiratory and visual disorders

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land blood formation disorders in people living in contaminated areas. Lead enters the human body through water, air and plants that have grown in contaminated areas and are then consumed as food. Human activities such as industry (mining, metallurgy, oil refining), the use of batteries, lead paints and pipes, lead additives in petrol, and landfills are the main sources of lead pollution in soil, water and air (Xu *et al.* 2021; Xu *et al.*, 2022; Zhang *et al.,* 2023). In addition, military conflicts and combat operations significantly increase heavy metal pollution in the environment (Symochko *et al.* 2024; Solokha *et al.*, 2024). Constant bombing, destruction of industrial facilities and infrastructure, and fires lead to massive emissions of toxic substances, including heavy metals such as lead, copper, cadmium, antimony, chromium, nickel and zinc, into the air, soil and water (Shukla *et al.,* 2023). This, in turn, causes a significant excess of background levels of heavy metals in the soils of military landscapes (Dinake *et al.,* 2018; Tonkha *et al.,* 2025). Particularly high concentrations have been found for lead (Islam *et al.*, 2016; Rodriguez-Seijo *et al.,* 2016). In military training areas and in peacetime, firearm residues and military waste disposal pose a threat to the environment (Gorecki *et al.,* 2017; Rodriguez-Seijo *et al.,* 2025). The situation is particularly critical at shooting ranges, where lead concentrations can reach dangerous levels, posing a threat to the environment and human health (Urrutia-Goyes *et al.,* 2017; Bai & Zhao, 2020). Various land restoration strategies are being actively developed to overcome this problem. These include removing lead or immobilising it in the soil (Kamari *et al.*, 2015; Black *et al.*, 2021). However, the use of various physical and chemical methods has many drawbacks, including high cost, labour intensity, and changes in soil properties, including microbiota (Demyanyuk *et al.*, 2020; Symochko *et al.*, 2025). Phytoremediation, i.e. purification using plants, is considered one of the most promising and effective methods (Ali *et al.,* 2013; Zhang *et al.,* 2024). It is economical, environmentally friendly and practical. Although fast-growing herbaceous plants are often used for phytoremediation of agricultural areas (Cleophas *et al.*, 2023), in urban and industrial regions, when restoring old shooting ranges, as well as in contaminated forest belts, the use of tree plantations has a number of important advantages: they can cleanse deep soil layers (which is especially important for contamination resulting from military actions involving the formation of craters), accumulate toxins over a long period of time without the need for disposal, and reduce soil erosion (Suman, *et al.*, 2018; Shah. and Daverey, 2020). In addition, expanding green areas in cities improves the microclimate, reduces the negative effects of the 'urban heat island' and has a positive impact on the health and overall well-being of residents (Branas *et al.*, 2018). In view of the above, the aim of our study is to identify tree species that are resistant to growth on lead-contaminated soils and to establish their potential for phytoremediation.

Materials and Methods

The effects of lead were investigated in two tree species, *Cercis canadensis* L. and *Tetradium daniellii* (Benn.) T.G. Hartley, originating from temperate and continental climate zones. These plants, which grow up to 10 m in height, are known for their drought resistance and efficient photosynthesis (Nuzhyna and Ivanova, 2023; Nuzhyna et al., 2023), which makes them economically attractive for cultivation. *C. canadensis* is a frost-resistant and pest-resistant highly decorative plant. *T. daniellii* is also a decorative plant and is characterised by high honey productivity, which is why it is also called the 'honey tree' and is used to treat various diseases (Zhao et al., 2019). For the experiment, two-year-old seedlings grown in separate pots with soil pH 6.2 were used. The plants were watered once with a solution of lead acetate at a concentration of 100 mg/kg or 300 mg/kg of soil. Control plants were watered with plain water. Each group included three plants of each species. Each parameter was measured with a repeat on each plant (total n=6). Twice (after a week and a month), the content of pigments of the photosynthetic system was determined using a SF-2000 spectrophotometer: chlorophylls and carotenoids, which were extracted with 80% acetone and measured at λ = 663, 646 and 470 nm (Lichtenthaller, 1987); the stress level was determined by the content of malondialdehyde (MDA) at λ = 533 nm (Kumar, 1997); and the activity of peroxidase, as one of the links in the antioxidant system, was studied by the rate of benzidine oxidation in the presence of H2O2 at λ = 590 nm (Sharifi, 2010).
The length of the shoots was measured three times: before treatment with lead solution, one month and two months after treatment, in order to study the effect of lead on plant growth. Within two months after treatment with lead, the state of the photosynthetic system was measured three times (after one week, one month and two months) using a Floratest fluorimeter (Ukraine). The plants were kept in darkness for 10 minutes; each measurement took 4 minutes; Microsoft Office Excel 2007 software was used to construct chlorophyll fluorescence induction curves and analyse them. The

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photosynthetic system of the upper leaves was diagnosed. The chlorophyll fluorescence induction curves were analysed and the K1, K2, K3, Kpl and Fv indices were calculated, which reflect the efficiency of photosynthesis, viability and the presence of possible disorders, which indicators were calculated using the following formulas (Romanov et al., 2009; Strasser et al., 2004):

K1 – shows the maximum potential efficiency with which electrons can be transported through PSII if all reaction centres are open and ready for operation; it is an indicator of the efficiency of the light phase of photochemical reactions [1]:

$$K1 = (Fm - FO)/Fm \quad [1]$$

K2 – is an important indicator of the overall coordinated work of the light and dark phases of photosynthesis. It helps to assess how efficiently the energy obtained from light is converted into stable chemical compounds in the Calvin cycle and other metabolic pathways [2]:

$$K2 = (Fm - FS\tau)/Fm \quad [2]$$

K3 - is an indicator of plant viability that is sensitive to external (exogenous) factors. This indicator is important for assessing the long-term response of plants to stress, as it integrates both the efficiency of photochemical processes and protective mechanisms (Stirbet and Govindjee, 2011) [3]:

$$K3 = (Fmax2 - FS\tau)/FS\tau \quad [3]$$

Kpl – helps to assess how quickly and efficiently the plant's photosynthetic apparatus responds to light. High Kpl values may indicate disturbances in electron transport or damage to the photosynthetic apparatus, which may be a sign of disease or severe stress. If electrons cannot move efficiently along the chain, they accumulate, leading to increased fluorescence at certain stages [4]:

$$Kpl = (Fpl - F0)/(Fm - F0) \quad [4]$$

Fv is an indicator of photochemical oxidation-reduction processes and characterises the activity of the initial stages of photosynthesis. A high Fv value indicates a healthy, functional PSII with high efficiency in using light energy to convert it into chemical energy. A decrease in Fv indicates a disruption in the functioning of PSII, which can be caused by various stress factors (e.g., heavy metals, drought, low/high temperatures, diseases). A decrease in Fv indicates a decrease in the potential activity of the photosynthetic apparatus of plants; decreases as the environmental conditions deviate from the temperature optimum [5]:

$$Fv = Fm - F0 \quad [5]$$

The content of mobile lead compounds in various plant organs (upper and lower leaf layers, stem, root) was determined by atomic absorption spectrophotometry after dry mineralisation of the samples. The grey ash was moistened with concentrated nitric acid, evaporated, then placed in a muffle furnace and burned to form white ash. The ash contentwas transferred to a measuring flask, washed with distilled water, and after filtration, the lead content (mg/kg or ppm) was measured on an atomic absorption spectrophotometer (AAS KVANT-2AT) (Estefan et al., 2013) [6]:

$$Pb\ content = (ppm\ trace\ elements * V)/W \quad [6]$$

where: V = total volume of the plant digest (ml), W = Weight of dry plant (g).

Statistical data processing was performed using Prism Graphpad 8 software with Tukey's corrected ANOVA multivariate analysis.

Results and Discussion

Lead is a non-essential heavy metal; it is not necessary for the life of organisms even in microdoses (Cobbett, 2003). In concentrations exceeding the threshold value, lead has a negative effect on any living organisms, as it interferes with the normal functioning of living systems (Ali et al., 2013). One of the most important effects of heavy metals on plants is damage to the photosynthetic system (decrease in the amount of photosynthetic pigments, inhibition of electron transport, reduction in CO_2 fixation, photooxidative damage) (How et al., 2017; Souahi et al., 2017; Sperdouli, 2022). One week after treatment with lead, Cercis canadensis trees showed an increase in chlorophyll content in the leaves, with a greater increase in chlorophyll b, which was accompanied by a decrease in the chl a/chl b ratio. It is possible that this increase in chlorophyll content is a manifestation of the plants' protective reactions (Fig. 1 a, b, d). At the same time, after a month, a decrease in the amount of chlorophyll b and an increase in the amount of carotenoids can be observed (Fig. 1 c), which may indicate, on the one hand, the inclusion of other adaptive links and, on the other hand, an increase in the inhibitory effect of lead on plants over time. The increase in the chl a / chl b ratio when treated with lead at a dose of 300 mg/kg of soil indicates that the negative effect depends on the dose of heavy metal. Soil contamination with high doses of lead did not af-

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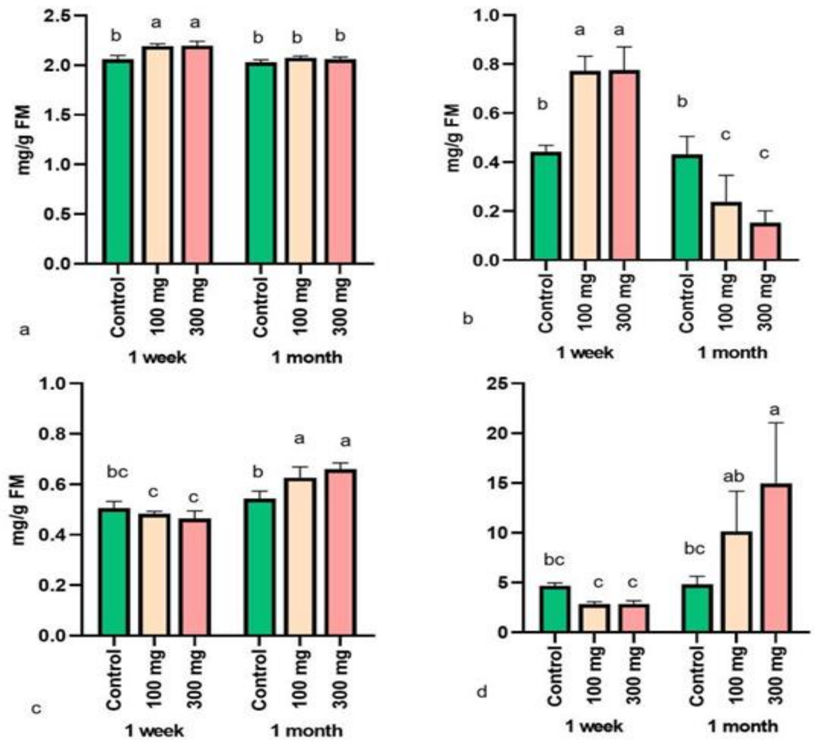

Figure 1
Pigment content of the photosynthetic system of Cercis canadensis under the influence of different doses of lead: chlorophyll a (a), chlorophyll b (b), carotenoids (c), chlorophyll a/chlorophyll b (d); (x ± SD, n = 6). Different letters indicate significant differences within the parameter (P < 0.05) according to the results of the Tukey multiple comparison test.

fect the content of chlorophyll a in *Tetradium daniellii* leaves, while the content of chlorophyll b increased, which may be an adaptive response of plants to a stress factor (Fig. 2 a, b). It was the increase in chlorophyll b that caused a decrease in the chl a / chl b ratio. Both high and very high doses of lead stimulated the growth of chlorophyll b content in *Tetradium daniellii* leaves to the same extent. The carotenoid content under stress conditions, on the contrary, decreased, especially one month after lead treatment (Fig. 2 c, d).

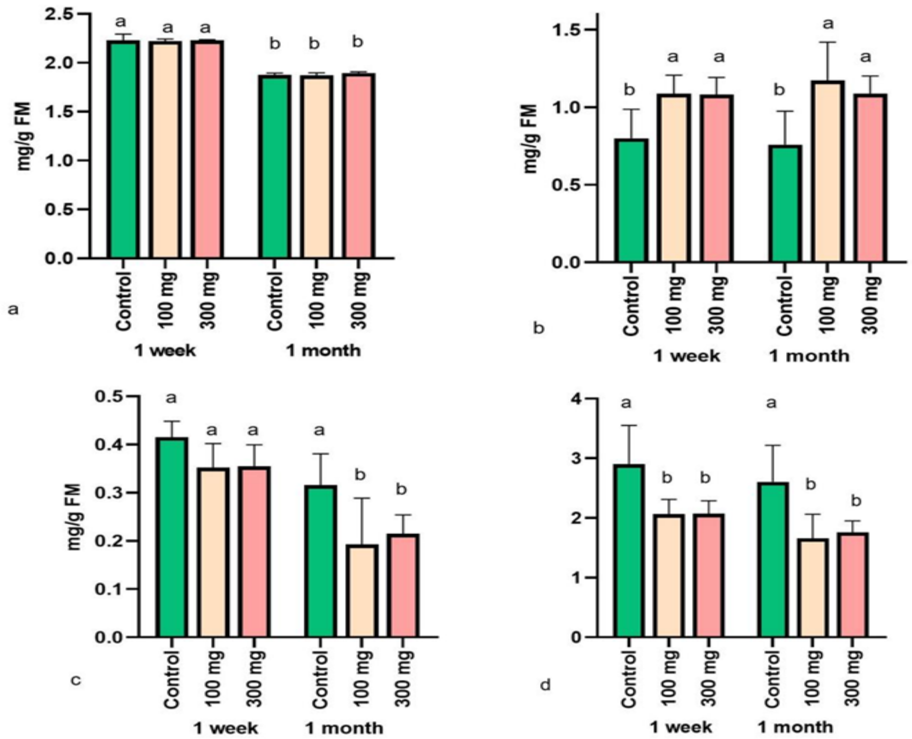

Figure 2
Pigment content of the photosynthetic system of Tetradium daniellii under the influence of different doses of lead: chlorophyll a (a), chlorophyll b (b), carotenoids (c), chlorophyll a/chlorophyll b (d); (x ± SD, n = 6). Different letters indicate significant differences within the parameter (P < 0.05) according to the results of the Tukey multiple comparison test.

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Therefore, a week after lead treatment, adaptive mechanisms were activated in C. canadensis and T. daniellii, manifested in increased chlorophyll synthesis, especially chlorophyll b. An adaptive increase in this pigment was also found under the influence of other stress factors (Nuzhyna et al., 2017; Nuzhyna et al., 2020). An increase in chlorophyll b synthesis along with a decrease in carotenoids is observed in *T. daniellii* one month after treatment, while in C. canadensis, a month later, there is a depletion of chlorophyll pools and an increase in carotenoids as a protective mechanism. Chlorophyll b was found to be more sensitive to the effects of lead than chlorophyll a for both species. No difference was found in the effect on pigments between lead doses of 100 and 300 mg/kg of soil. Despite the general knowledge about the destructive effect of lead on the photosynthetic system, some researchers also noted a different effect on pigments in different plants, which probably depended on the level of plant resistance to a particular stress factor (Souahi et al., 2021). The efficiency of photosynthesis in *C. canadensis* remained almost unchanged after lead treatment. In particular, one week, one month and two months after treatment with high doses of lead, the efficiency of the light and dark phases of photosynthesis (K1 and K2), as well as the viability index (K3), did not differ from those in the control groups (Fig. 3 a,b,c). The decrease in the viability index in all groups after one month and two months is associated with changes in the weather conditions for plant cultivation in different months. Only two months after treatment with a heavy metal salt solution at a dose of 100 mg/kg of soil was a decrease in the Fv coefficient and an increase in the Kpl coefficient observed one month after treatment, indicating a greater susceptibility to damage by exogenous factors, in particular pests, infectious diseases or deviations from the optimal temperature (Fig. 3 d,e)

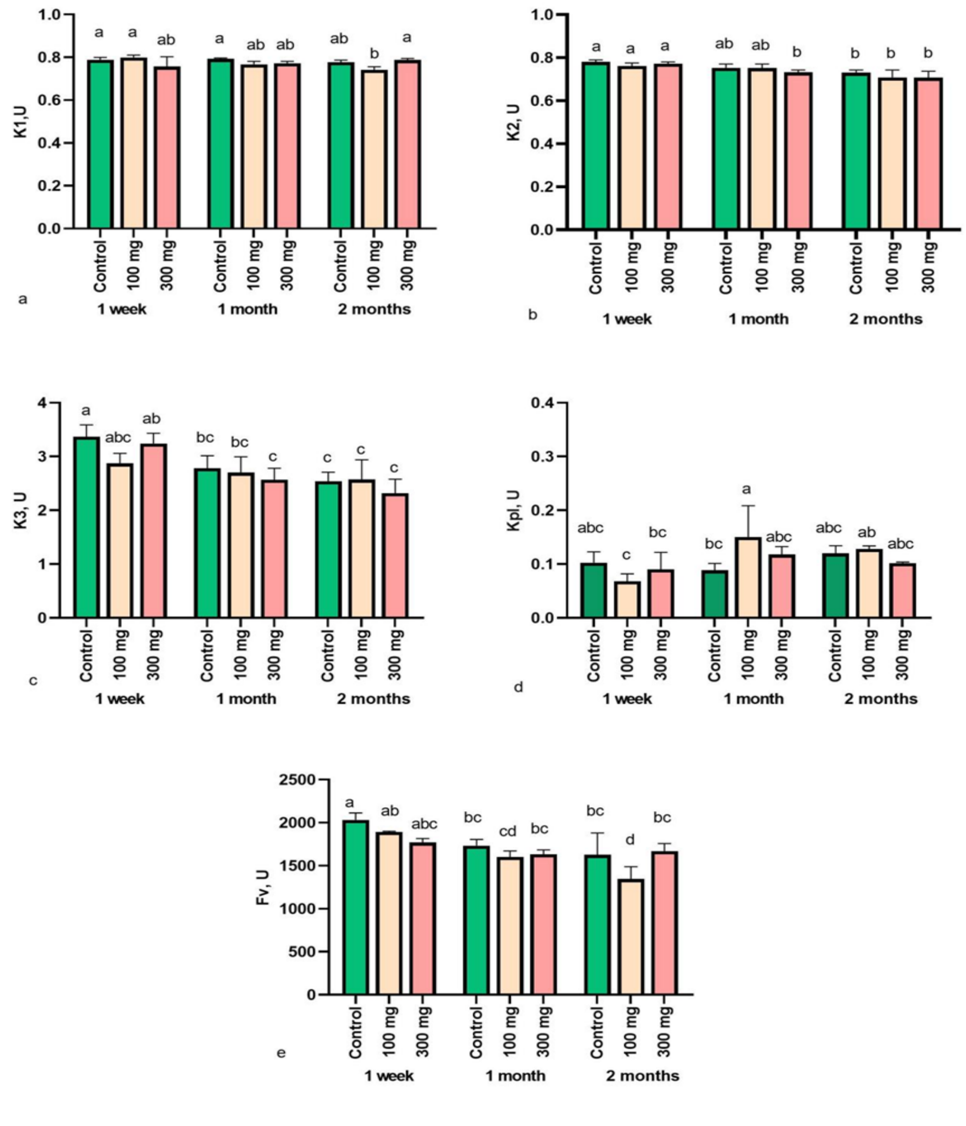

Figure 3
Photosynthetic efficiency indices in Cercis canadensis leaves under the influence of different doses of lead (x ± SD, n = 6). Different letters indicate significant differences within the parameter (P < 0.05) according to the results of the Tukey multiple comparison test.

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At the same time, in *Tetradium daniellii* a decrease in the efficiency of the light phase of photosynthesis (K1) was observed one month after treatment with a lead solution, probably due to a decrease in the content of carotenoids, which are one of the first links in the perception of photons in photosystems, causing a decrease in this indicator (Fig. 4 a). No negative effect on the efficiency of dark reactions of photosynthesis was found (Fig. 4 b). Also, a fairly high viability index (K3) and an equally low Kpl index in all groups indicate the resistance of plants to pollution in all studied groups (Fig. 4 c,d). Only one month after treatment with a lead solution at a dose of 100 mg/kg of soil was a decrease in the activity of the initial stages of photosynthesis (Fv) observed, but after two months this indicator in the experimental groups did not differ from the control (Fig. 4 e). Thus, over time, the plants adapted to growing in soil contaminated with high doses of lead

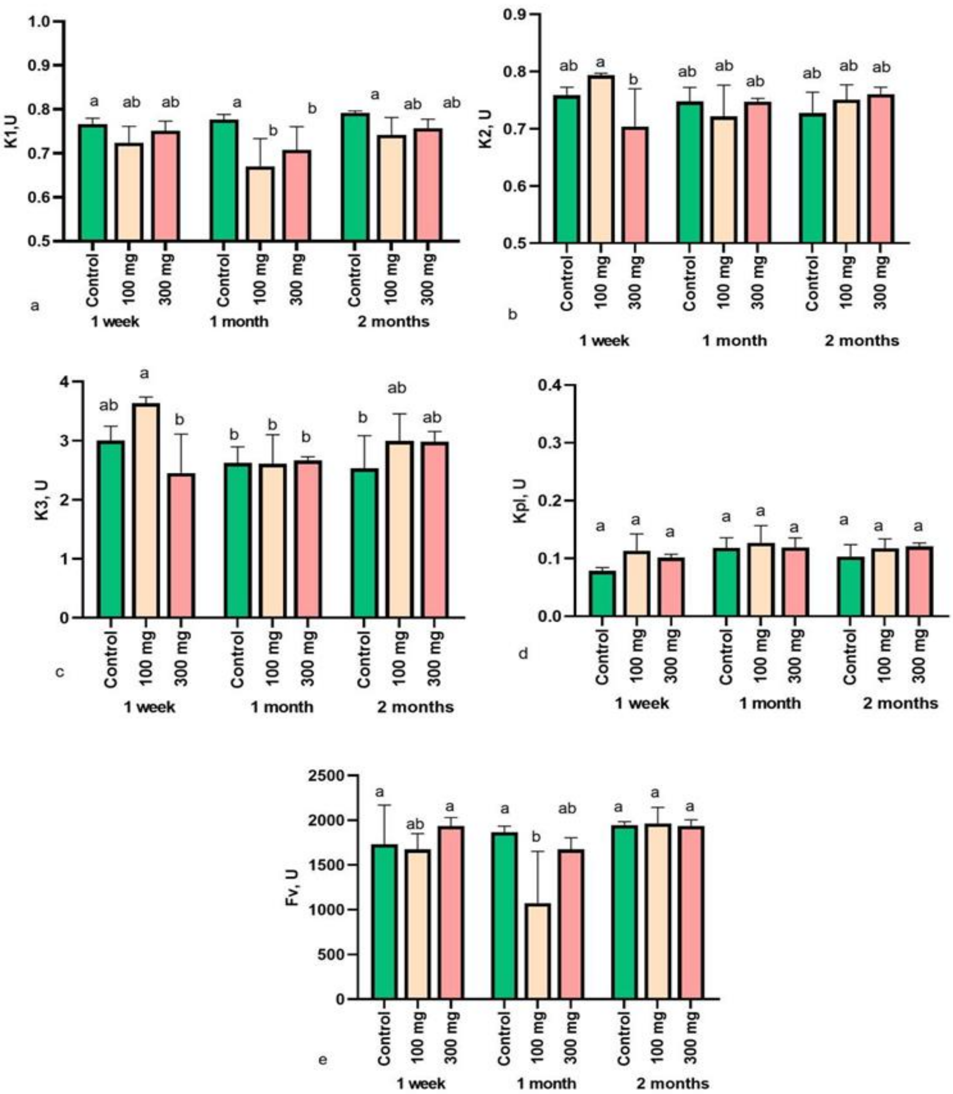

Figure 4
Indicators of photosynthetic efficiency in Tetradium daniellii leaves under the influence of different doses of lead ($x \pm SD$, $n = 6$). Different letters indicate significant differences within the parameter ($P < 0.05$) according to the results of the Tukey multiple comparison test.

The photosynthetic efficiency indicators in the leaves of the all studied plants one week after lead treatment did not differ from the control values. After one month, *C. canadensis* exposed to lead at a dose of 100 mg/kg showed an increase in the Kpl coefficient, which may indicate damage to the photosynthetic apparatus due to stress factors, while in *T. daniellii*, at the same dose, the K1 and Fv coefficients decreased one month after lead exposure, which also indicates a disruption in the functioning of PSII, which may be caused by various stress factors. In C. canadensis, two months after treatment with a heavy metal salt solution

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at a dose of 100 mg/kg of soil, a decrease in the Fv coefficient was also observed. Thus, it can be said that only after a month of growth on contaminated soil do negative changes occur in the photosynthetic system of the studied plants. Moreover, at a dose of 100 mg/kg of soil, such changes are more pronounced. This may be due to the activation of other, more powerful protective mechanisms at higher doses of heavy metal. Most plants, especially herbaceous ones, suffer damage to their cell membranes under the influence of heavy metals and show high levels of stress (Sujetovienė and Česynaitė, 2020; Liao et al., 2022). The MDA stress indicator in *C. canadensis* did not increase significantly in the heavy metal groups either one week or one month after the start of the experiment (Fig. 5a). At the same time, after one week, lead reduced peroxidase activity, especially at a dose of 100 mg/kg of soil (Fig. 5b). The stress and antioxidant system indicators in *Tetradium daniellii* indicate the presence of stress on plants one month after treatment with heavy metal solutions, with the highest stress level observed when growing on soil contaminated with lead at a dose of 100 mg/kg of soil, and it is in this group that peroxidase is more activated. A similar picture, but less pronounced, occurs in the group with contamination of 300 mg/kg of soil. The more pronounced negative effect of a lower dose of lead one month after treatment on most of the para-meters studied, compared to a higher dose of lead, may indicate the activation of adaptive defense mechanisms at extremely high doses, which were not studied in this experiment. At the same time, the groups with high and extremely high doses of lead adapted already two months after treatment (Fig. 6 a,b). A study of stress in plants grown on lead-contaminated soil showed that the amount of MDA did not change at all in C. canadensis, while in *T. daniellii*, this stress indicator increased after one month at both concentrations, espe-

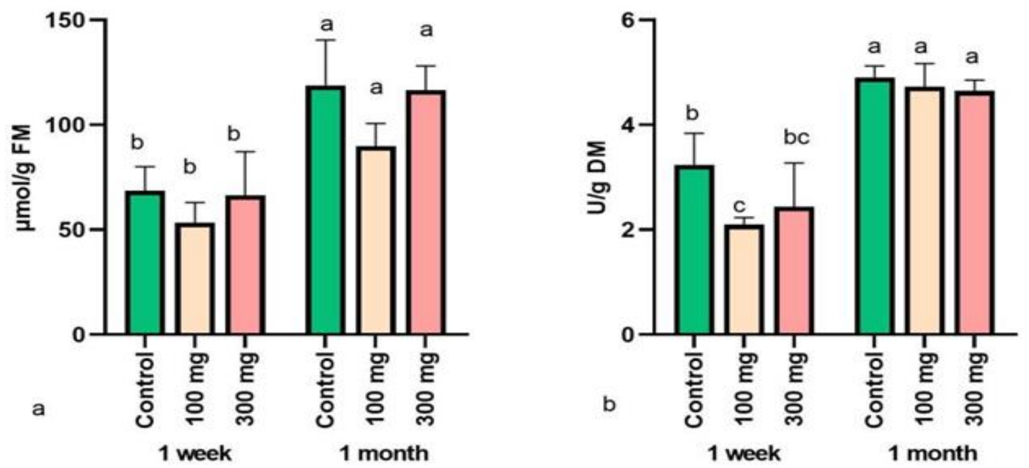

Figure 5
Malondialdehyde content (a) and peroxidase activity (b) in Cercis canadensis leaves under the influence of different doses of lead ($\bar{x}$ ± SD, n = 6). Different letters indicate significant differences within the parameter (P < 0.05) according to the results of the Tukey multiple comparison test

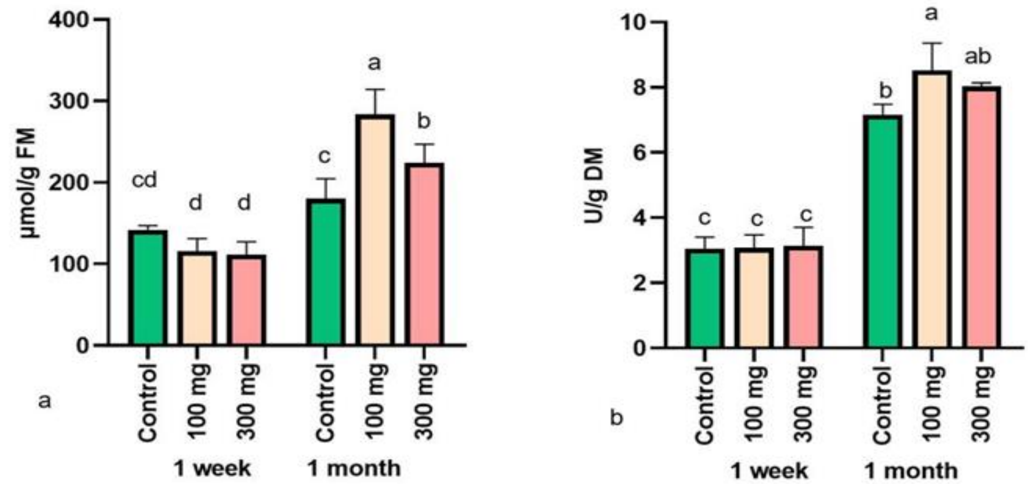

Figure 6
Malondialdehyde content (a) and peroxidase activity (b) in Tetradium daniellii leaves under the influence of different doses of lead ($\bar{x}$ ± SD, n = 6). Different letters indicate significant differences within the parameter (P < 0.05) according to the results of the Tukey multiple comparison test

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cially at a dose of 100 mg/kg of soil. At the same time, in *T. daniellii*, at a dose of 100 mg/kg of soil, one of the first links in the antioxidant system was activated after a month – the activity of peroxidase increased. In contrast, in *C. canadensis*, after a week, lead reduced the activity of peroxidase, especially at a dose of 100 mg/kg of soil, possibly due to the depletion of the available enzyme pool during the initial period after the onset of the stress factor, or due to the inhibition of antioxidant system enzymes, which is observed in many plants (Sperdouli, 2022). However, after a month, peroxidase activety no longer differs from that in the control group. In general, *C. canadensis* shows greater stress resistance, with a background MDA level twice lower than that of *T. daniellii* throughout the study. It is possible that the rapid involvement of enzyme links, in particular peroxidase, allows stress levels to be reduced from the very beginning of lead exposure. Also, resistance to heavy metal pollution and even some stimu-lation of plants is indicated by the increase in growth rates in plants that were treated with a lead acetate solution at a dose of 100 mg/kg of soil in both species, compa-red to the control group. In *C. canadensis* a higher dose (300 mg/kg) also had a stimulating effect on growth two months after treatment (Table 1). The tendency towards stimulation with lead at a dose of 100 mg/kg is already evident one month after treatment, but a significantly greater increase is only observed after two months in *T. daniellii* (Table 2). In general, no significant accumulation of lead was observed in the vegetative organs of C. canadensis. Determination of lead content in vegetative organs after three months of growth on contaminated soil showed that only the leaves of the upper tier of the group growing under

Table 1. *Shoot length increase of Cercis canadensis at high lead doses (cm, x ± SD, n = 3)*

Groups	1 month	2 months
Control (without Pb)	0,67±0,58[c]	1,33±0,58[c]
100 mg/kg (Pb)	4,07±0,60[a]	4,77±1,17 [a]
300 mg/kg (Pb)	1,90±0,36[bc]	3,43±0,60 [ab]

Note: different letters indicate significant differences between all groups (P < 0.05) according to the results of the Tukey multiple comparison test

Table 2. *Shoot length increase of Tetradium daniellii at high lead doses (cm, x ± SD, n = 3)*

Groups	1 month	2 months
Control (without Pb)	1,05±0,21 [b]	1,95±0,07 [b]
100 mg/kg (Pb)	2,97±0,15 [b]	6,03±1,85 [a]
300 mg/kg (Pb)	1,05±0,07 [b]	1,95±0,35 [b]

Note: different letters indicate significant differences between all groups (P < 0.05) according to the results of the Tukey multiple comparison test

conditions of lead contamination at a dose of 300 mg/kg of soil contain more lead (up to 10.36±3.43 mg/kg, compared to 0.37±0.09 and 0.59±0.13 mg/kg in the control and 100 mg/kg groups, respectively). No differences from the control group were observed in the leaves of the lower tier. The lead content in the stem increased less than threefold in the 300 mg/kg soil group compared to the control, and this indicator is quite low, namely 5.43±1.48 mg/kg of dry weight. The highest lead content was found in the roots: control – 2.38±0.41 mg/kg, 9.75±2.46 and 16.72±4.51 mg/kg with contamination by doses of lead 100 and 300 mg/kg of soil, respectively. In all organs, except for the lower tier of leaves, a certain dependence of lead content on the applied dose was observed (Fig. 7).

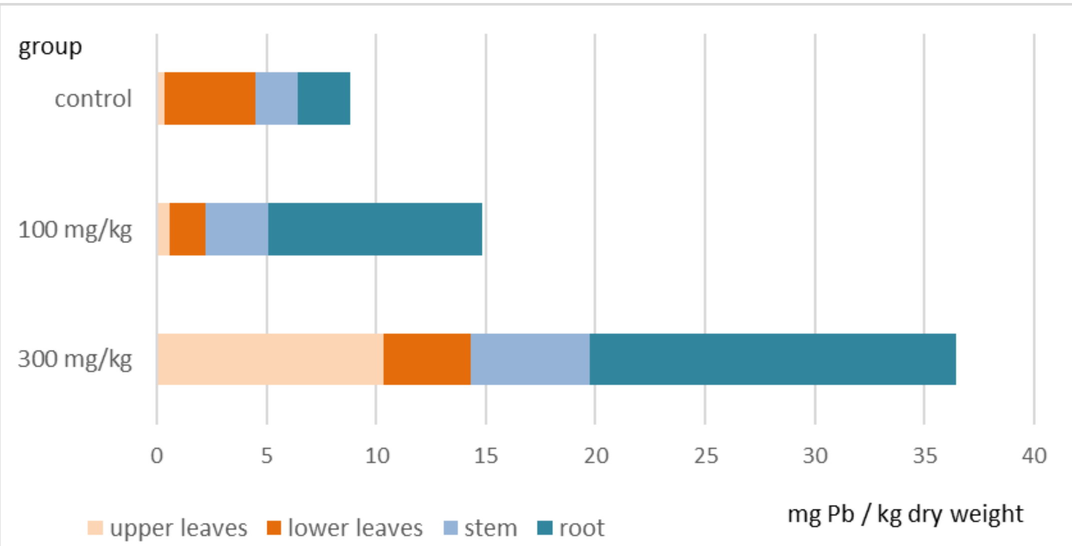

Figure 7
Content of mobile lead compounds in different vegetative organs of Cercis canadensis

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No significant phytoremediation capacity was found in *T. daniellii*. In particular, the lead content in the leaves of the control group, both in the upper and lower tiers, was similar to that of the experimental groups and averaged 4.90±1.34 mg/kg of dry matter in the leaves of the lower tier when treated with 100 mg of lead per kg of soil. to 9±2.45 mg/kg of raw material in the leaves of the lower tier in the group with a dose of 300 mg of lead per kg of soil. Lead accumulated slightly more in the stem than in the leaves. In the roots, as in the other species studied, lead accumulation is highest (24.85+5.46 mg/kg dry weight at a dose of 300 mg/kg soil), but the experimental groups do not differ significantly from the control (Fig. 8). *T. daniellii* has thicker leaf coverings: cuticles, adaxial and abaxial leaf epidermis, thicker columnar and spongy mesophyll than C. canadensis (Nuzhyna & Ivanova, 2023). On the one hand, these indicators contribute to the greater drought resistance of T. daniellii. On the other hand, a more developed leaf mesophyll may contribute to better accumulation of heavy metals, as it is known that they settle in vacuoles, which are best developed in the mesophyll (Jabeen et al., 2009). On the other hand, more intense accumulation of lead in *T. daniellii* leaves compared to C. canadensis leaves could be the reason for higher stress levels in *T. daniellii* leaves. The intensity of phytoremediation in C. canadensis and T. daniellii species is moderate. In general, after two months of growth on contaminated soil at a dose of 300 mg/kg of soil, the biennial plant accumulated lead in its vegetative mass at an average of up to 37 mg/kg of dry mass in C. canadensis and up to 52 mg/kg of dry mass in T. daniellii. According to the literature, various metallophytic plants that grew spontaneously in lead-contaminated areas accumulated lead from 9 to 255 mg/kg (Stefanowicz et al., 2016), compared to 2-11 mg/kg in control plants that grew in uncontaminated areas. At the same time, since T. daniellii is a powerful honey plant, its ability to transfer lead to its leaves must be taken into account, which potentially allows us to assume the transfer of heavy metals to flowers. In plants intended for human consumption, the permissible amount of lead is determined by standards established by law, in particular, based on European Union regulations. The specific levels of permissible lead content depend on the type of product and range from 0.10 mg/kg to 0.30 mg/kg of raw weight (Vannini et al., 2021). A positive aspect is that most of the accumulated metal is concentrated in the roots in C. canadensis and in the stem and roots in T. daniellii, which promotes better accumulation in one place and eliminates the need to worry about cleaning and disposing of leaf litter. Although in most cases, especially when using herbaceous phytoremediation plants, harvesting is not feasible in biomass of roots (Zacchini et al., 2009), however, in the case of trees that grow for a long time in one place and accordingly accumulate high doses of heavy metals, removing the roots after felling old trees is a completely accessible and economically viable process. In the studied species, there is a certain dependence of lead absorption on its dose in the soil, which is quite logical and confirmed by many researchers on other plants (Cenkci et al., 2010; Conesa et al., 2012; Liao et al., 2022). Growing highly decorative trees that are resistant to pollution in industrial cities alongside fast-growing phytoremediation trees, such as poplar and willow, that used for energy production, will ensure a stable microclimate and improve the comfort of residents in polluted urban areas. Also, growing trees for a long time in areas polluted with heavy metals prevents soil erosion (Abhilash et al., 2012; Chaudhry et al., 1998).

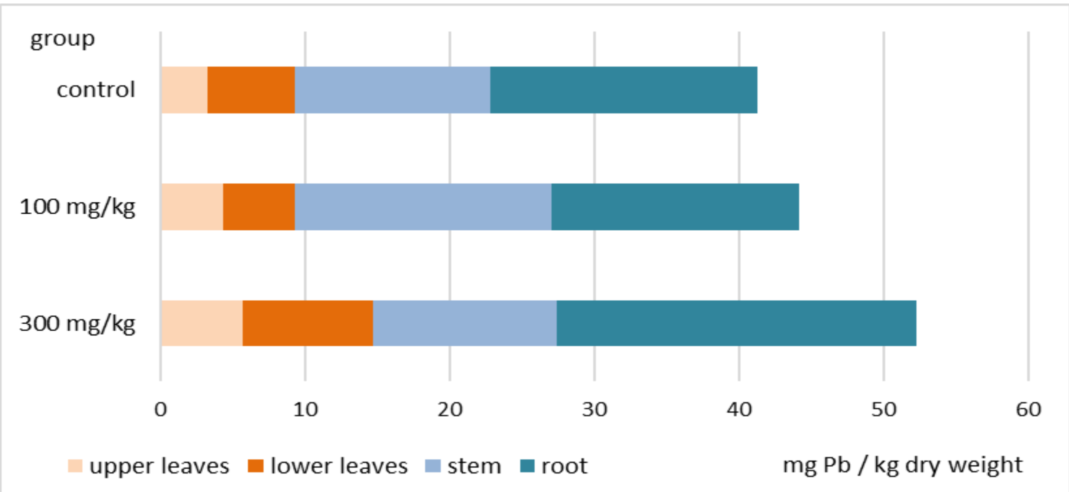

Figure 8
Content of mobile lead compounds in different vegetative organs of Tetradium daniellii

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Conclusions

Plants of the genera *Cercis* and *Tetradium* can be recommended for cultivation in areas contaminated with elevated concentrations of lead (Pb). Among the two species studied, *Cercis canadensis* exhibited greater tolerance to Pb stress compared to *Tetradium daniellii*. In *Cercis*, the content of the oxidative stress marker malondialdehyde (MDA) remained stable, and the photosynthetic efficiency of plants cultivated in Pb-contaminated soils (100 and 300 mg Pb/kg) did not differ significantly from that of the control group. Furthermore, the concentrations of chlorophyll *a* and *b* increased after one week of exposure, while a reduction in chlorophyll *b* was observed only after one month. Notably, Pb exposure stimulated plant growth, particularly at the lower concentration (100 mg Pb/kg). *Tetradium daniellii* also demonstrated a considerable degree of Pb tolerance. Chlorophyll *a* levels did not differ between the control and Pb-treated plants, whereas chlorophyll *b* content increased under Pb exposure. Similarly, photosynthetic efficiency measured at the onset and after two months of cultivation in Pb-contaminated soils (100 and 300 mg Pb/kg) remained comparable to the control. After one month of Pb exposure, MDA levels increased; however, this response was accompanied by enhanced peroxidase activity, indicating activation of the antioxidant defense system. As observed in *Cercis*, Pb exposure stimulated growth in *Tetradium*, particularly at 100 mg Pb/kg. The phytoremediation potential of both species can be characterized as moderate. After two months of cultivation in soil containing 300 mg Pb/kg, *Cercis* accumulated an average of 37 mg Pb/kg dry weight, whereas *Tetradium* accumulated approximately 52 mg Pb/kg dry weight. In both species, Pb accumulation was highest in the roots. The cultivation of these ornamental and drought -tolerant species in heavily polluted, anthropogenic areas could contribute to the gradual remediation of Pb -contaminated soils, while simultaneously improving local microclimatic conditions, preventing soil erosion, and enhancing ecosystem services related to human health and well-being.

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