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Characteristics of the respiratory metabolism of *Typha angustifolia* under influence of lead

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Abstract
The purpose of this research was to study the respiratory activity of leaves and adventitious roots (soil and water) of *Typha angustifolia* under the influence of different concentrations of lead acetate in the seasonal dynamics. Features of the respiratory metabolism of various organs of *Typha angustifolia* determined by the degree of stress, their adaptation abilities, and by vegetation period. We detected a sufficiently high lability of the respiratory activity of various organs of *Typha angustifolia* under a stress. This property allows to reconstruct the direction of processes of metabolism, resist to the adverse effects of the environment, promote ecological plasticity in plants. Reaction of leaves, aquatic and soil roots to stress is different. Moderate stress in the first days after the introduction of a pollutant inhibited the respiratory activity of the leaves. After that, we detected its activation, the period of which increases with the lead concentration (3.0 mg/l). Lead concentration of 10 mg/l during the entire study period (June-September) suppressed plant respiration. At the lowest concentration (2.5 mg/l), revealed adaptive redistribution of respiratory activity from aquatic roots directly contacting with a solution of a toxicant in water to soil roots. Lead in concentrations of 3.0 and 10.0 mg/l promoted unidirectional changes in the respiratory activity of aquatic and soil roots. The results of our experiments suggest that moderate stress rather quickly overcome by the plant, including by strengthening the respiratory system and, consequently, the energy potential of the cells. High concentrations of a pollutant significantly reduce or inhibit the rate of process.

Keywords: *Typha angustifolia*; lead; respiration; leaf; root.

Introduction

Plant's lifecycles undergo various adverse influences; due to any variation of the habitat plants meet a complex of adaptive rearrangements anatomical–morphological, physiological, and biochemical ones aimed at preserving the viability of the organisms in the changed circumstances [1,2].

According to Semikhatova [3], the ability of plants to maintain homeostasis is achieved primarily due to the energy rearrangements. This integral index for a vitality makes it possible to judge on the reliability of the biological system in defined conditions, the boundaries of adaptive capacities of plants, and directional adaptive metabolism. Until the varying conditions do not exceed the critical limits of the adaptive reactions of the organism, the plant continues to operate and adapt to unfavorable factors.

The existing literature on the respiration of plants, primarily for the land ones, evidence on their increased resistance to heavy metals [4-7].

The main reasons for the gain of the respiration rate under the influence of heavy metals are as follows: the activation of certain enzymes, increased energy expenditure of the body to maintain and repair processes in damage to cells caused by the action of a stress factor [8,9], the necessity of synthesis of organic acids (malate, citrate, succinate), which are heavy metal chelators [4,10,11]. According to Ref. [12], increased respiration rate at relatively low concentrations of heavy metals is a compensatory mechanism to ensure accumulation of ATP in the inner mitochondrial membrane.

The purpose of this research was to study the respiratory activity of leaves and adventitious roots (soil and water) of *Typha angustifolia* under the influence of different concentrations of lead acetate in the seasonal dynamics.

Materials and Methods

In the experiments, one of the most common plants from reservoirs in central Russia – *Typha angustifolia* L. was used. This is a representative of a transitional form from terrestrial plants to water (helophyte). Its root system is characterized by a number of morphological and anatomical structural features presented in typical aquatic plants – the presence of thick and thin rhizomes of adventitious roots – aquatic and soil ones, well-developed pneumatic tissue – aerenchyma [13].

Research conducted under the conditions of the experimental ponds including natural water of 30 l volume with concomitant hydrobionts, soil clumps, and a representative of higher aquatic plants – *Typha angustifolia*, imported from Middle Kaban Lake. It is located in the city of Kazan, Republic of Tatarstan of the Russian Federation. When selecting the volume of experimental ponds, we were guided by methodical data by Tsirtsis [14]. Xu [15] noted that the volume of 30 l produces satisfying reproducibility and good agreement of experimental results with calculations on the model [14]. We simulated two types of habitats – overgrown (with *Typha angustifolia*) and open (without it).

As the contaminant we used lead acetate salt $Pb(CH_3COO)_2$ in concentrations of 2.5, 3.0, and 10 mg/l. In the experimental ponds lead acetate was added once in two weeks after the post-design of experiments, when the system is stabilized, and then the plants have taken root (beginning of June). Samples of leaves and roots were carried out during the growing season of the plant (after 1, 7, 30, 60, and 90 days after lead introduction, with the lead concentration of 3.0 mg/l samples were taken after an additional 3 h) in triplicate.

The intensity of dark respiration (by absorption of oxygen) of *Typha angustifolia* leaves, two types of adventitious roots were defined using manometric method at Warburg apparatus WA 0130 (Germany) at T = 25-26°C [16,17].

Experiments were carried out with freshly cut roots and leaves of *Typha angustifolia*. Adventitious roots of two types (water and soil), and were washed with water and were dried with filter paper. During the process of washing, we removed dead and dying particles. Samples of aquatic and soil roots (500 mg) were placed into vials of Warburg with natural water (from the experimental ponds) with volume of 4 ml. The respiration rate of leaves was measured in the air phase of vials. The amount of leaves was 500 mg. In the study of the specificity of the breath of adventitious roots in the process of adaptive aging (after their clipping) measuring respiration was performed every hour during the day. The intensity of the dark respiration of *Typha angustifolia* was expressed in ml O_2 per gram of wet weight for 1 h.

Results and Discussion

Leaves

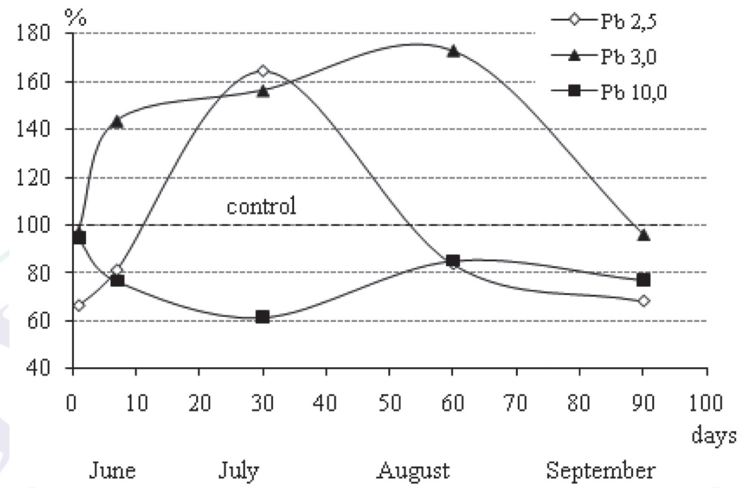
Figure 1 shows the curves of a seasonal dependence of the respiration intensity leaves (% of control) under different concentrations of lead. It is of nonlinear character.

The lead concentration of 2.5 mg/l inhibited the respiratory activity of leaves from 66.5% of the control in the first day to 81.3% on the 7th day after the introduction of a pollutant. Then the activity of respiration was increasing, reaching a maxim after 30 days, and was falling again, since August, to the most low values noted in the beginning of our studies. Hydrochemical analysis of lead content in water showed a rapid decline in variants with cattails: after 3 h – 2 times, after a day – 20 times, and after 2 days – 100 times. Disappearance of lead from water indicates its redistribution in microecosystem, particularly due to absorption by plants that have an effect on current physiological processes, including respiration.

A different pattern was revealed at 3.0 mg/l of lead: a day later, the respiratory activity of the leaves were slightly suppressed. In prospect, during the next 60 days, the plant respiration was more active in comparison with control and experimental plants, exposed to a concentration of 2.5 mg/l whose respiration activity reduced after the 30th day. Only by 90th day their respiratory activity was closing to that of the control plants. This indicates on a greater and more prolonged consumption of energy by the plant focused on maintaining its life after lead exposure in a given concentration (Figure 1). Increasing concentrations of lead till 10 mg/l resulted in inhibition of respiratory activity of the leaves relatively to the controls throughout the experiment (Figure 1).

Figure 1: The respiration of leaves of *Typha angustifolia* at different concentrations of lead (mg/l) in the seasonal dynamics (% of control).

Here and in Figures 2-4: X axis – time (in days) since the introduction of lead acetate.



Aquatic and soil roots

The study of the absorption of oxygen by aquatic and soil roots under contamination with heavy metals showed the differences in the seasonal and concentration dynamics (Figures 2-4).

Curves reflecting the seasonal dynamics of the respiration rate for aquatic and soil roots of cattail (% of control), as well as the leaves are of nonlinear character. Their respiratory activity on the first day after lead introduction to a medium at a concentration of 2.5 mg/l was inhibited (for aquatic – 82.5% of control, for soil – 34.3%) (Figure 2). A week later, soil roots strengthened their respiratory activity (173.1% of control), thus helping to the plant to adapt to stress. Respiration of aquatic roots was more suppressed (26.9% of control) than during the first day. We detected a shift of the maximal respiratory activity of the studied roots relatively to

Figure 2: Respiration intensity of aquatic (AR) and soil (SR) roots of *Typha angustifolia* under lead action (2.5 mg/l) in seasonal dynamics (% of control).

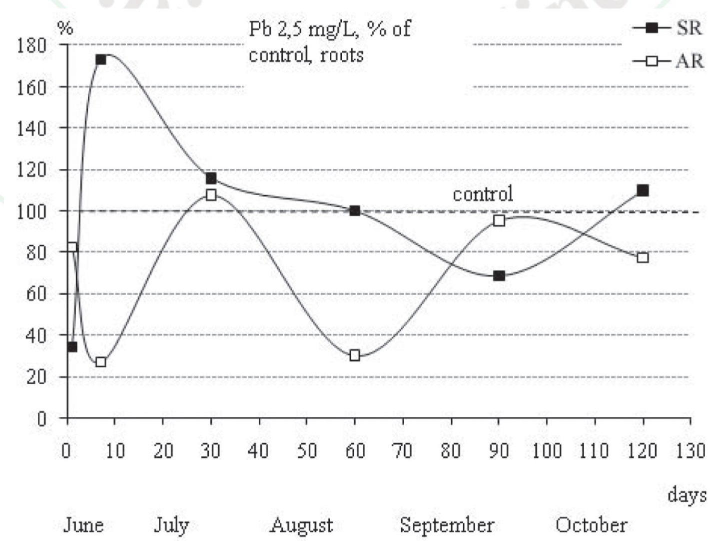


Figure 3: The respiration rate of aquatic roots (AR) and soil (SR) of *Typha angustifolia* under lead load (3.0 mg/l) in the seasonal dynamics (% of control).

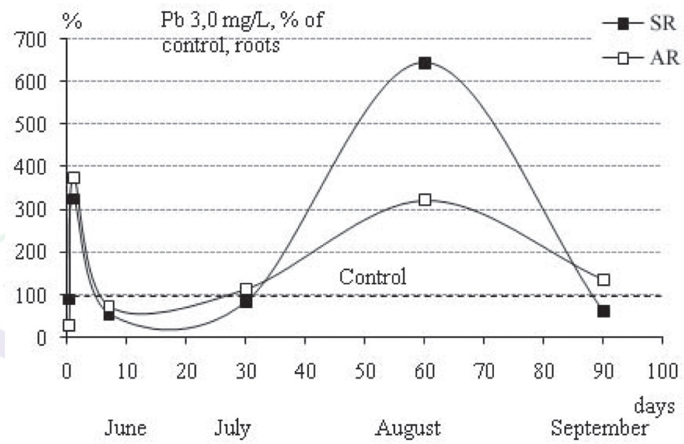
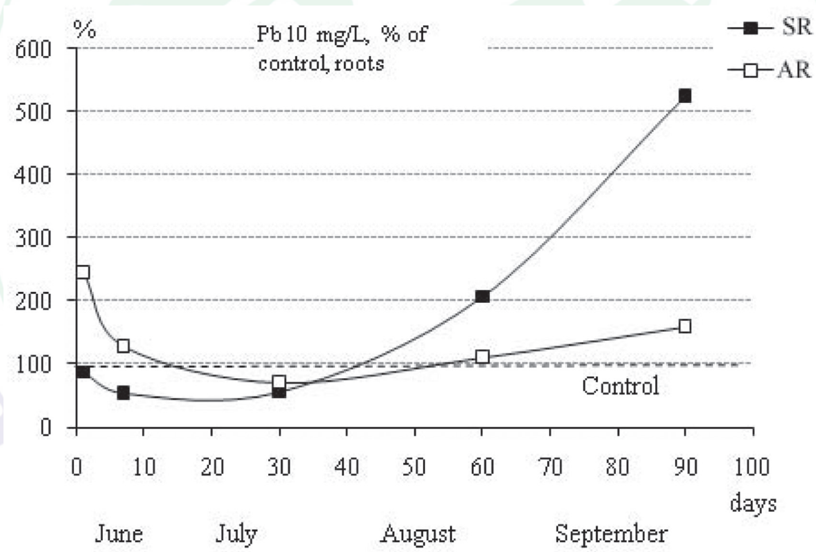


Figure 4: The respiration rate of aquatic roots (AR) and soil ones (SR) of *Typha angustifolia* under lead (10.0 mg/l) in the seasonal dynamics (% of control).



the control: it was detected in soil roots a week after introducing the contamination (173.1%), in aquatic roots – 30 days later (107.7%). This is confirmed that the soil roots began to adapt to lead much earlier and that the adaptation was effective than aquatic roots.

Curves reflecting the respiratory activity of roots had an expressed sinusoidal form: periods of activation of respiration (the first and the 60th day after the introduction of lead) alternated with periods of its suppression. So, during the the first day we detected the rise of the respiratory activity in soil and aquatic roots. After 30 days, the respiration of the studied roots was restored approaching the control value.

Periodic increases of respiration rate of soil and aquatic roots indicate that the plant, overcoming stress, directs a significant amount of energy to metabolism.

At lead concentration of 10 mg/l, the curves of the respiratory activity of soil and aquatic roots during the study period was unidirectional (like at 3.0 mg/l) (Figure 4). Within 30 days, there was gradual reduction of respiration for aquatic roots: from 244.7% to 71.2%; for soil ones from 86.7 to 55.7%. In the future, until the end of the experiment, we observed the activation of the respiratory activity of roots; it was more clearly expressed in the soil ones. Compared with lead concentration of 3.0 mg/l, the rise of respiration was significantly lower (aquatic – 110.8% of the control, soil roots – 206.8%), but by the time it lasts longer (until the end of the experiment). This is apparently due to adaptation to a greater concentration of lead requires longer time energetical costs (Figure 4).

In general, these experiments allow to state a high ability of soil roots compared to aquatic ones to adaptability, which is manifested in different periods of the vegetation season. This conclusion is consistent with the existing research of specifics of the respiration rate of aquatic and soil adventitious roots of *Typha angustifolia* at condition of a clipping them from the rhizomes of the plant during the adaptive aging [18]. This author found that the speed of the response to stress factors (cutoff) in soil roots is higher than in aquatic ones, and therefore adaptability of soil roots is higher.

Conclusion

Analyzing the results described above, it can be concluded that features of the respiratory metabolism of various organs of *Typha angustifolia* determined by the degree of stress, their adaptation abilities, and by vegetation period.

We detected a sufficiently high lability of the respiratory activity of various organs of *Typha angustifolia* under a stress. This property allows to reconstruct the direction of processes of metabolism, resist to the adverse effects of the environment, promote ecological plasticity in plants. This conclusion is consistent with the findings of a number of authors [19-24].

Reaction of leaves, aquatic and soil roots to stress is different. Moderate stress (2.5, 3.0 mg/l of lead) in the first days after the introduction of a pollutant inhibited the respiratory activity of the leaves. After that, we detected its activation, the period of which increases with the lead concentration (3.0 mg/l). Lead concentration of 10 mg/L during the entire study period (June-September) suppressed plant respiration.

At the lowest concentration (2.5 mg/l) revealed adaptive redistribution of respiratory activity from aquatic roots directly contacting with a solution of a toxicant in water to soil roots.

Lead in concentrations of 3.0 and 10.0 mg/l promoted unidirectional changes in the respiratory activity of aquatic and soil roots. During a moderate stress (3.0 mg/l) there was an elevated respiratory activity, synchronized in soil and aquatic roots. At lead concentration of 10.0 mg/l respiratory activity of roots decreased from the first day for a month, then we detected its adaptive reallocation from aquatic roots to the soil ones, and the increase was more significant in the soil roots. Thus, even at high stress roots, unlike leaves, are capable to adapt with a time.

The results of our experiments suggest that moderate stress rather quickly overcome by the plant, including by strengthening the respiratory system and, consequently, the energy potential of the cells. High concentrations of a pollutant significantly reduce or inhibit the rate of pro-process.

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