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Ecologic Plasticity of *Typha angustifolia* under the Action of Nitrate-Nitrogen

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Abstract: It was detected that *Typha angustifolia* Linnaeus, 1753, has a significant level of ecologic plasticity under action of nitrate-nitrogen. It included alterations in production processes (increase in number of bines, chlorophyll *a* and *b* concentration, potential seed productivity, general biomass, average height of plants) and respiration metabolism (restoration of the oxygen consumption till initial values). Adaptation of the macrophyte to anthropogenic load also resulted in enhancement of the excretory potency of the plant and in intensification of its algaecide and sanative activities. In biotopes without the macrophyte the effects were not detected.

Key words: Macrophyte · *Typha angustifolia* L. · Ecologic plasticity · Nitrate-nitrogen · Water quality

INTRODUCTION

The increase of anthropogenic load (including nitrogen pollution) on hydroecosystems may result in reduction of autopurification processes in natural waters [1]. The above-mentioned processes are realized at physical, chemical and biological levels and aquatic plants may play a significant role in it [2, 3]. The level of plant activity depends on the biological properties of the species as well as on the plasticity of physiologic and production processes under pollution. Up to now, data on the possibility and timing of autopurification events in hydroecosystems is absent. Also, details of restoration of the accessory phytoplankton and hydrochemical regimes after removal of anthropogenic load are not clearly detected.

The present investigation was carried out to elucidate the ecologic plasticity of *Typha angustifolia* and its role in regulation of structure of the accessory phytoplankton and hydrochemical regimes in conditions of the different anthropogenic load on the nitrate-nitrogen.

MATERIALS AND METHODS

Experiments were performed in 30 L tanks with natural water and plants of *T. angustifolia* (average area of a plant is about 0.5 m^2) during three vegetation periods in 2005-2007. Macrophytes were taken from Sredniy Kaban lake (Kazan, Republic of Tatarstan, Russia). Two types of biotopes were simulated-overgrown (with the macrophyte) and a clear one (without the macrophyte). In June, $NaNO_3$ was added to the natural water at the following concentrations-40 mg/L and 400 mg/L (1 and 10 maximum permissible concentrations).

To analyze physiological and production processes in the macrophyte, samples were taken from June till September (2, 6, 10 and 14 weeks since the beginning of the experiment). To study hydrochemistry and the structure of phytoplankton, samples were taken from July till September (6, 10 and 14 weeks since the beginning of the experiment). In the control samples (natural water), additives were absent. In the experiments, various concentrations of nitrate-nitrogen were added to natural water.

The intensity of the dark respiration (on oxygen consumption) by the macrophyte was measured using manometric method (Warburg WA 0130 apparatus, Germany) at temperature 25-26°C. Water and soil borne roots were washed wish natural water and wiped with bibulous paper. A button of each organ (500 mg) was put into Warburg flask filled with 4 mL of water. After 60 min of temperature-controlling, the respiration of roots was measured. The amount of chlorophyll *a* and *b* was detected using spectrophotometric method. The pigments were extracted from dried material with 80% acetone. Concentration of the pigments were detected using Lambda 25 spectrophotometer (Perkin Elmer, USA).

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Biomass of above-ground and underground parts of the macrophyte as well as the potential seed productivity (PSP, a number of seed-buds per one generative bine) was analyzed according to method of Gorbik (1984):

PSP = L × [(D +d) / 2] × K, where PSP-the potential seed productivity, 1000 pieces, L-the length of spadix, mm; D and d-diameters of the high and low parts of the spadix axis, respectively, mm; K-a number of flowers at 1 mm^2 (95.86 for *T. angustifolia* L.).

The exometabolites of *T. angustifolia* were analyzed using radiocarbon measurements. Radioactive label (water solution of ^{14}C-acetate) was introduced to the macrophyte apex with the use of a syringe. A month later, water samples were collected for analyzing. Water was gradually evaporated at 30°C, precipitation was diluted with the scintillation liquid and analyzed on scintillation counter Delta-300.

Chemical analysis of natural water was performed in the Biogeochemistry Laboratory (State Budgetary Establishment Research Institute for Problems of Ecology and Mineral Wealth Use of Tatarstan Academy of Sciences).

Experiments Were Performed in Triplicate: The data on figures are presented as mean±standard deviation.

RESULTS AND DISCUSSION

The nitric compounds were shown to be able to act as a toxicant [4, 5]. Despite the results of other authors, we did not detect significant deteriorations in the morphology and metabolism in the macrophyte under study due to action of high concentrations of the nitrate-nitrogen.

The ability of plants to preserve a homeostasis in the environment is mediated by energetic changes within an organism [6]. Under the nitrate-nitrogen action, there was a redistribution of the respiration metabolism from water roots toward soil borne ones. In June, the intensity of oxygen consumption by water roots decreased while increased by soil borne ones (Table 1). This mechanism allowed realizing a principle of economy of energetic resources of water roots contacting with the dissolved nitrate-nitrogen. At 40 mg/L concentration of nitrate-nitrogen, we detected the restoration of the intensity of oxygen consumption by adventitious roots till initial values after 14 weeks while at concentration 400 mg/L-after 10 weeks by soil borne and after 6 weeks by water roots (Table 2).

Production and growth characteristics are criteria for evaluation of adaptation abilities of plants in the changing environment [7]. Although some authors stated reduction of biomass in plants at high nitrogen concentrations [8], we found magnification of a number of bines (at 40 mg/L-17, at 400 mg/L-22, in control-14), average height of a plant (at 40 mg/L-150 ± 7.5 cm, at 400 mg/L-162 ± 8.1 cm, in control-140 ± 7.0 cm), seed productivity (at 40 mg/L-397.3 ± 19.9 x10^3 specimens, at 400 mg/L-420.6 ± 21.0 x10^3 specimens, in control-207.4 ± 10.4 x10^3 specimens), general biomass (at 40 mg/L-346.8 ± 14.6 g of dried weight, at 400 mg/L-459.8 ± 22.5 g of dried weight, in control-246.4 ± 11.8 g of dried weight). Probably, the intensification processes can be explained by the lower toxicity of the nitrate-nitrogen in comparison to the ammonium form.

Literature data suggest that high nitrogen concentrations (in the form of ammonium) may cause inhibition of photosynthesis in the environment [9]. Contrary to the results, we detected intensification of the process. Namely, at 400 mg/L concentration of chlorophyll *a* was increased (11.46 ± 0.63 mg/g of dried weight in comparison with 8.96 ± 0.47 mg/g in control). At the same concentration of nitrate-nitrogen, chlorophyll *b* increased from 3.89 ± 0. 22 mg/g (a control value) till 6.19 ± 0.27 mg/g. At 40 mg/L, the corresponding values took intermediate values.

It is known from the literature that the peculiarities of endometabolic processes determine excretive activity of macrophytes. Excretas are specific to species of a plant, period of vegetation, load on nitrogen and phosphorus [10]. We detected radioactive label in the medium where plants of *T. angustifolia* were grown. At 400 mg/L concentration, a pool of exometabolites increased 5.5-fold in comparison with control. This is in agreement with our previous data [11] that the quantitative and qualitative content of plant exometabolites depend on conditions of mineral supply and phase of growth. The nitrate-nitrogen increased an amount of the excreted chemicals, especially amino acids.

Due to the presence of a complex interaction between components of hydroecosystems [10], it seemed interesting to study the role of ecologic plasticity in maintenance of the structure of phytoplankton and hydrochemical regime. In the control samples (biotopes without aquatic macrophytes where action of the nitrate-nitrogen was absent), green algae were dominant from July till September (a number varied from 83.5 % to 100 %, biomass varied from 98.4 % to 100 %). In biotopes with aquatic macrophytes, diatoms were dominant (a number varied from 54.2 % to 91.8 %, biomass varied from 50.5 % to 98.3 %). An amount of the nitrate-nitrogen in biotopes

Table 1: The influence of nitrate-nitrogen on the intensity of oxygen consumption (Q, $\mu LO_2 \cdot g^{-1}h^{-1}$) by different types of *T. angustifolia* roots

Concentration of a pollutant	Type of root (water or soilborne)	June	July	August	September
Control	water	345.0±13.8	107.6±4.5	111.4±5.4	190.6±7.6
	soilborne	143.7±5.0	184.5±5.5	175.9±8.1	175.0±7.7
40 mg/L	water	243.2±9.9	235.8±9.7	258.4±11.6	192.8±8.8
	soilborne	209.0±9.4	115.7±4.2	127.7±4.7	153.4±5.8
400 mg/L	water	120.0±3.8	150.2±4.4	94.7±3.1	224.0±8.3
	soilborne	272.4±10.6	163.2±7.0	182.6±6.0	158.3±5.4

Table 2: The intensity of respiration of abventitious roots (water and soilborne ones) in a seasonal dynamics. (?D, $\mu L\ O_2$). Note: negative values indicate reduction (in percents, %) of the markers and positive values indicate the increase (in percents, %) in relation to control.

Type of root	Concentration of a pollutant	June	July	August	September
water	40 mg/L	70	-60	-50	25
	400 mg/L	130	-20	-7	-15
soilborne	40 mg/L	-100	-145	-50	2,8
	400 mg/L	-220	-2	-15	32

Table 3: Seasonal dynamics of the nitrate-nitrogen content (mg/L, NO_3^-) in natural water in biotopes with and without aquatic macrophytes

Type of biotopes	Concentration of a pollutant	July	August	September
Without aquatic macrophytes	control	2.7	2.3	1.2
	40 mg/L	96	46.8	1.2
	400 mg/L	1490	1248	620
With aquatic macrophytes	control	2.3	1.9	1.7
	40 mg/L	32.7	28	1.9
	400 mg/L	9.4	8.0	2.3

with and without macrophytes varied insignificantly- from 1.2 mg/L to 2.7 mg/L and 1.7 mg/L to 2.3 mg/L, respectively (Table 3).

At a concentration of 40 mg/L of nitrate-nitrogen, we did not detect changes in the structure of phytoplankton and hydrochemical regime in biotopes with and without macrophytes. At concentration 400 mg/L in biotopes without macrophytes, blue-green algae were dominant (a number varied from 98.6 % to 99.5 %, biomass varied from 56.5 % to 61.4 %). *Oscillatoria planctonica* Woloszynska, 1911 was the dominant species. In biotopes with macrophytes at the same concentration of pollutant after 1 month of its addition, we detected interchange of diatoms by green algae. *Golenkiniopsis solitaria* Korschikoff, 1953 was the dominant species (92.3 % in number and 73.7 % in biomass). In the next months, there was the opposite change-green algae were replaced with diatoms with no dominant species. In August, a number of diatoms were 86.4 % and biomass-92.8 %. In biotopes with macrophytes, an amount of nitrate-nitrogen was 2.3 mg/L after 3 months. In biotopes without macrophytes, an amount of nitrate-nitrogen was 620.0 mg/L.

Thus, the obtained results confirmed the fact that plants of *T. angustifolia* play a significant role in regulation of phytoplankton content and hydrochemical regime. This, in turn, suggests the possible usage of aquatic macrophytes for recovery purposes in conditions of intensive anthropogenic load. The presented results have fundamental and applied interest. On one side, mechanisms of autoregulation of the helophyte homeostasis and their exometabolism, regulating structural and functional organization of the accessory species of hydrobionts, were clarified. On the other side, the obtained results allow the development of methodological recommendations for detecting physiological ambits of plant plasticity in conditions of pollution with various chemicals. This has a very important significance for saving species biodiversity of helophytes playing a multifunctional role in the vital activity of hydroecosystems

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