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Defense Mechanisms in Hydrobiosystems

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Abstract: This mini-review summarizes our experimental data devoted to constitutive and inducible mechanisms of defense in biosystems of various levels of organization. Auto- and heterotrophic components of the transformed hydroecosystems are taken into consideration. The role of higher aquatic plants in the defense mechanisms is considered.

Key words: Hydrobiosystem % Macrophyte % Metabolite % Plankton % Communication

INTRODUCTION

Multifunctional role of consortia of aquatic macrophytes in regulation of vital activity of cocurrent hydrobiocoenosis was reported in a range of publications [1-3]. It was showed that the basic gene pool is formed namely in overgrown biotopes of littorals. The production potential of the transit flows is not significant. They are appended with biocomponents owing to illuviation of the latter from ecotone zones. By this reason, investigation of the protective properties of the higher aquatic plants in the transformed hydroecosystems seems very actual.

The first and the most secure level of defense of every organism are evolutionary formed constitutive mechanisms realizing at anatomical and morphological scales. Defense mechanisms in biosystems of various levels of organization of helophytes in conditions with different eutrophic load on nitrate-nitrogen were studied using model microcosms with natural water, cocurrent hydrobionts and curtains of reed mace (*Typha angustifolia*). In the area of maximum allowable concentration (MAC) (40 mg/L) nitrate-nitrogen provokes a slight shift in anatomical features of pore aerenchyma - increase of its area on 10% in comparison with control. At that, distortion of its thin-slab parenchyma cells was not detected. Disturbing factor whose strength of action exceeds the protective potential of every hydrobiosystem (eutrophic load on nitrate-nitrogen is 10-fold of MAC) results in activation of inducible defense mechanisms - enhancement of aeration in adventitious roots of *T. angustifolia* and, consequently their resistance in conditions of oxygen starvation due to disturbances of parenchyma cells and 2.5-fold increase of the volume of auriferous sinuses [4]. While this level of defense is not sufficient, then defense mechanisms at other levels are activated. These include regulation mechanisms at various levels of organization of life. The present mini-review is intended to envisage these regulation events.

Regulation at Subcellulat Level: Alterations in the barrier functions of cell membranes in tissues of plants may be referred to regulation mechanisms at subcellular level. Modifications of plasmalemma with the membrane-active compounds or due to changes of environment (water deficit, temperature changes, etc.) may result in adaptation rearrangements owing to alterations of hydrophobic, ionic and other links, microviscosity of hydrophobic or hydrophilic areas, energetic processes. This results in complex changes of membrane permeability for water and ions. It was found that chemicals affecting the structure of cell membranes (for example, heavy metals) cause the most prominent alterations in the barrier functions. Compounds affecting energetic processes may cause slight changes in plasmalemma functions. Intracellular regulation of the barrier function of plasmalemma of plant cells plays an important role in the maintenance of water and energetic status, cell homeostasis, transport of nutrients, excretion of products of cell metabolism [5].

Regulation at the Level of Whole Organism: Regulation of a tolerance of organism level of helophytes is mediated by a complex system of transferring of stress signal using inter-organ ways of communication.

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There is a reprogramming of respiration and metabolic processes leading to changes of levels of energetic resources, qualitative and quantitative content of endo- and exometabolites. Differences of respiration reaction toward nitrogen stress in aquatic and soil roots of *T. angustifolia* were revealed [6]. During 10-fold exceeding MAC, there is re-distribution of the intensity of respiration metabolism from aquatic roots toward soil ones. At that, a proportion of glycolysis in respiration of aquatic roots is reduced till 41% contrary to the level of MAC (77%) while the role pentosophosphate pathway is increased (from 23 till 59%, respectively). This may be limited with deficiency in respiration substrates (carbohydrates) in aquatic roots. The present mechanism allows to realize a principle of economy of energetic resources in aquatic roots (contacting with dissolved nitric compounds) in conditions of nitrogen stress.

Three-phase reaction of changes of the intensity of dark respiration (physiological depression, reparation and stabilization) was revealed due to investigation of time dynamics of various types of cut roots of *T. angustifolia*. Reparation phase in aquatic and soil roots took place by 4-5 h after their cutting, stabilization phase - by 14-15 h in aquatic roots and by 10-11 h in soil roots [7]. This allows to make a suggestion on higher level of adaptation abilities of soil roots in comparison with water ones.

Using radiocarbon method, one of the mechanisms for decreasing eutrophic overload (10-fold MAC) on nitrate-nitrogen was revealed. This is consisted of redistribution in the system “aquatic medium-macrophytes” in favor of the latter, participating in the metabolic processes, long-term localization of assimilates in leaves (53.6% from total biomass), not in culms (as it was in variant with MAC and in control: 64.7% and 67.6%, respectively). This allows to a plant to stimulate synthesis of proteins (maximal amount in comparison with other fractions), lipids (newly synthesized chlorophyll) as well as protein-bound polysaccharide fraction. Acceleration of endometabolic processes stimulates excretory and communicative activity of macrophytes. Their vital excretas are specific to plant species, period of vegetation, eutrophic load on nitrates, phosphorus, aquatic deficit [2].

Regulation at Higher Levels: The presence of a general regulating mechanism for homeostasis of hydroecosystems toward disturbing factors of the environment realized owing to interactions between the particular mechanisms of biosystem maintenance was detected. At population level, that structural and functional organization of bacterioplankton is regulated owing to perception of regulating signals (exometabolites) from higher aquatic plants [3, 8]. The increased oxidative activity of bacterial cultures of associating to macrophytes is connected with predominance of amino acids, carbohydrates and organic acids that are consuming by bacteria. Symbiotic interactions between macrophytes and hydrocarbon-oxidizing microflora are reduced by the end of the vegetative period due to increasing slightly active (in physiological sense) compounds) [8, 9].

The role of amino acids is in biostimulation of the process of rearrangements of enzymatic system in bacterial cells. Bacteria start to produce enzymes needed to oil transforation (it is known those amino acids are slightly used as a source of hydrocarbons: [10]. It is followed from reduction of a time period between inoculation and reaching maximal rate of growth in medium with amino acids. It was showed with method of liquid chromatography that glutamic acid is used completely and alanine - on 98% by the end of 3rd day [11]. Organic acids and carbohydrates are used as easy-to-consume compounds in bacterial cultures. A principle ability for increasing oxidative activity in bacterial cultures was stated in the period of inhibition of symbiotic connections with macrophytes as well as in stress conditions (water deficit, eutrophic conditions) owing to enhancement of the process of exometabolism using regulation of nitrogen and phosphorus nutrition [2, 9].

It was detected that increasing biogenic elements (nitrogen or phosphorus) in the environment results in enhancement of excretory activities by macrophytes. At that, a proportion of physiologically active (toward microflora) chemicals (mainly, glutamic acid) are increased in the plant excreta. The action of nitrogen is depended on a period of its introduction to the environment [11]. This results in increasing number of bacterial destructors that, in turn, are competitors for biogenic elements of hydrobionts of other taxonomic groups, firstly phytoplankton.

In the content of microbiological component of overgrown biotopes at the background of nitrogen stress (400 mg/L) there were the following distributions of bacteria: saprophiles (15.5-fold increase of bacterial number in comparison with open biotopes), denitroficators (10-1000-fold increase), nitroficators (38-100-fold increase). These bacteria are actively participating in processes of destruction of organics compounds (including nitrogen substances) that reduces overload of hydroecosystem. This is confirmed by 2-fold increasing coefficient of oligotrophy in overgrown biotopes (being in conditions of nitrogen stress) in comparison with open biotopes of littorals as well as by significant changes of nitrogen amount in the environment. In open biotopes, the amount of nitrate-nitrogen is saved during all vegetation period even after elimination of its load (about a few hundreds of mg per liter). In overgrown biotopes, the amount of the compound reduces till a few mg per liter after one month. At the biocenotic level, the unique mechanism of functioning aquatic invertebrates in unfavorable conditions was detected. Namely, it was confirmed on the following species: *Daphnia magna*, *Simocephalus vetulus*, *Brachionus calyciflorus* as well as on toxicants with different mechanism of action referring to class of priority pollutant [12]. Toxicoresistance of separate populations of aquatic invertebrates depends of seasonal features of their interactions with other representatives of plankton and products of their vitality. Allelogonic channel is the most important for resistance of hydrobionts to action of pollutants taking into account survivability [2]. The role of allelopthatic channel is increased at regulation of reproductive processes. The revealed regularities may be used in development of biota-saving methods for detecting acute and chronic toxicity of water [13].

CONCLUSION

The revealed particular mechanisms are manifesting at the ecosystem level owing to the role of lotic macrophytes in regulation of water quality, biodiversity, stimulation of reproductive activity of zooplankton and macrofauna, inhibition of development of algal flora (predominantly, blue-green algae) autopurification of water from chemical and bacterial pollution [14-17].

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