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Main subject

Functioning of redox systems in plant cells

Main topics

1) Contribution of apoplastic redox enzymes and nitrate reductase in the formation and metabolism of reactive oxygen and nitrogen species in plant roots and leaves under abiotic stress

2) Role of autophagy in the survival and death of plant cells

3) Role of sterols as raft-forming lipids and membrane activity in root cells

Main achievements for 2008-2012

- Peroxidases responsible for detoxification and formation of reactive oxygen species in the apoplast of plant cells were identified and characterized. The bioinformatic analysis of the coding and non-coding regions in genes, the changes in gene expression and catalytic activity of stress-induced peroxidases enabled unraveling t he physiological roles of these enzymes in plants under abiotic stress. It was found that the release of peroxidases from cells and the switch between peroxidative and oxidative regimes of extracellular peroxidases is a key early stress response of plant cells.

- The oxidative burst in lichens, mosses and liverworts induced by desiccation / rehydration was demonstrated for the first time (in collaboration with Professor Richard Beckett, University of KwaZulu-Natal, South Africa). The main involved enzymes were found to be cell wall laccases, tyrosinases and peroxidases.

- New mechanisms of redox regulation of seed germination and survival under the changing water supply have been suggested (in collaboration with Professor Ilse Kranner, University of Innsbruck, Austria and Professor Richard Beckett, University of KwaZulu-Natal, South Africa). It was found that the redox shifts in seeds are defined by the activity of peroxidases and the ratio of reduced/oxidized glutathione. These results provide a fundamental basis for the improvement of protocols of seed storage, in particular cryopreservation of recalcitrant seeds.

- The features of autophagic degradation of oxidized macromolecules and damaged organelles in plant cells during the oxidative stress were characterized. The main stages of the formation of autophagosomes containing the fragments of cytoplasm and organelles were identified. The analysis of the expression profile of autophagic genes proves the importance of autophagic proteins in the formation of autophagosome and the degradation of organelles, in particular mitochondria.

- The role of membrane sterols as structural macromolecules of plasma membrane and components of lipid microdomains (rafts) has been studied. Sterol saturation induces the alteration in membrane characteristics indicating a decrease in ion membrane permeability. In contrast, the binding of endogenous sterols by nystatin induces an increase in plasma membrane permeability and the changes in composition of glycoceramides, the raft-forming lipids. The physiological response triggered in plant cells by the changes in plasma membrane is accompanied with oxidative stress, formation of autophagosomes and a decline in cell viability.

- An induction of oxidative and nitrosative stresses has been demonstrated to occur in leaves under the excess of nitrogen supply. The changes in biochemical characteristics, electron paramagnetic spectra and fluorescence detected by using specific dyes and traps suggest the involvement of nitrate reductase in the NO production in leaves.

Financial support

Russian Foundation for Basic Research Federal Program of Ministry of Education and Science of RF Program of President of RF on the support of Higher Science Schools P rogram of Algarysh (Ministry of Education and Science of RT)

Leverhulme Trust Foundation (UK)

DFG (Germany)

Finnish Academy of Science

National Research Foundation (South Africa)

Collaboration

Ilse Kranner (University of Innsbruck, Austria) - redox signaling in seeds Richard Beckett (University of KwaZulu-Natal, Republic of South Africa) - redox activity in lower plants

Sabine Lüthje (University of Hamburg, Germany) - identification of apoplastic peroxidases

Mariana Sottomayor (University of Porto, Portugal) – analysis of gene sequences of plant peroxidases

Kurt Fagerstedt and Olga Blokhina (University of Helsinki, Finland) - ROS and NO production in transformed Arabidopsis plants

Irina Ryzhkina (Institute of Organic and Physical Chemistry, Kazan) - aggregation of synthetic compounds and biological macromolecules

Khalil Gainutdinov (Zavoisky Physical-Technical Institute, Kazan) - EPR studies of reactive nitrogen species

Kotlova E.R. (Komarov Botanical Institute, RAS, Saint-Petersburg) - identification of membrane lipids

PhD theses defended in 2008-2012 г.г.

Dmitrieva S.A. “Structural and functional changes in the cells of wheat roots in conditions of oxidative stress”, 2008

Pedagogical activity

Chairing the State Qualification Committee in KSTU (Minibayeva F.V.) Course of lectures on Photobiology in KFU (Chasov A.V.)

Supervision of students' research and diploma projects.

Selected papers for 2008-2012

2008

Roach T., Ivanova M., Beckett R.P., Minibayeva F.V., Green I., Pritchard H.W., Kranner I. (2008) An oxidative burst of superoxide in embryonic axes of recalcitrant sweet chestnut seeds as induced by excision and desiccation. Physiologia Plantarum, 133: 131-139.

Gordon L., Minibayeva F., Rakhmatullina D. (2008) Salicylic acid and energy exchange in plant cells. In: Abiotic Stress and Plant Responses. Eds. NA Khan and S Singh. IK International, p. 263-275.

Beckett R.P., Kranner I., Minibayeva F.V. (2008) Stress physiology and the symbiosis. In: Lichen Biology. Eds. T.H. Nash, Cambridge University Press, p. 134-151.

Dmitrieva S.A., Ponomareva A.A., Minibayeva F.V., Gordon L.K. (2008) ROS- and

proton-mediated effects of salicylic acid on the growth and ultrastructure of root cells. The Scientific Reports of Kazan University, 150(3): 123-135 (in Russian).

2009

Chasov A.V., Minibayeva F.V. (2009) Effect of exogenous phenols on superoxide production by extracellular peroxidase from wheat seedling roots. Biochemistry (Moscow), 74(7): 766-774.

Laufer Z., Beckett R.P., Minibayeva F.V., Lüthje S., Böttger M. (2009) Diversity of laccases from lichens in Suborder Peltigerineae. Bryologist, 112(2): 418-426.

Minibayeva F., Kolesnikov O., Chasov A., Beckett R.P., Lüthje S., Vylegzhanina N., Buck F., Böttger M. (2009) Wound-induced apoplastic peroxidase activities: their roles in the production and detoxification of reactive oxygen species. Plant, Cell & Environment, 32: 497-508.

Maksyutova N., Galeeva E., Mukhitov A., Rumyantseva N., Viktorova L. (2009) Changes in the growth of Tartary buckwheat (*Fagopyrum tataricum* (L.) Gaertn.) calli with different ability for morphogenesis induced by salicylic acid. The European Journal of Plant Science and Biotechnology, 3: 71-74.

2010

Minibayeva F.V. (2010) Redox signals in plant cells under stress: the focus on the apoplast. *In*: Cellular signaling. Fen, Academy of Sciences of RT, Kazan, Ed. A.N.Grechkin, p. 81-89 (in

Russian).

Whitaker C., Beckett R.P., Minibayeva F.V., Kranner I. (2010) Production of reactive oxygen species in excised, desiccated and cryopreserved explants of *Trichilia dregeana* Sond. South African Journal of Botany, 76: 112-118.

Whitaker C., Beckett R.P., Minibayeva F.V., Kranner I. (2010) Alleviation of dormancy by reactive oxygen species in *Bidens pilosa* L. seeds. South African Journal of Botany, 76: 601-605.

Roach T., Beckett R.P., Minibayeva F.V., Colville C., Whitaker C., Chen H., Bailly C., Kranner I. (2010) Extracellular superoxide production, viability and redox poise in response to desiccation in recalcitrant *Castanea sativa* seeds. Plant, Cell & Environment, 33: 59-75.

Li J.L.Y., Sulaiman M., Beckett R.P., Minibayeva F.V. (2010) Cell wall peroxidases in the liverwort *Dumortiera hirsuta* are responsible for extracellular superoxide production, and can display tyrosinase activity. Physiologia Plantarum, 138: 474-484.

Kranner I., Roach T., Beckett R.P., Whitaker C., Minibayeva F.V. (2010) Extracellular production of reactive oxygen species during seed germination and early seedling growth in *Pis um sativum*
. Journal of Plant Physiology, 167: 805-811.

Valitova Yu.N., Kotlova E.R., Novikov A.V., Shavarda A.L., Artemenko K.A., Zubarev R.A., Minibayeva F.V. (2010) Binding of sterols affects membrane functioning and sphingolipid composition in wheat roots. Biochemistry (Moscow), 75(5): 554-561.

Viktorova L.V., Maksyutova N.N., Trifonova T.V., Andrianov V.V. (2010) Production of hydrogen peroxide and nitric oxide following introduction of nitrate and nitrite into wheat leaf apoplast. Biochemistry (Moscow), 75(1): 95-100.

Chasov A.V., Alekseeva V.Ya., Kolesnikov O.P., Minibayeva F.V. (2010) Activation of extracellular peroxidase of wheat roots under the action of xenobiotics. Applied Biochemistry and Microbiology, 46(4): 431–437.

Trifonova T.V., Maksyutova N.N., Viktorova L.V., Galeeva E.I., Yafarova G.G., Minibayeva F.V. (2010) Regulation of nitrate reductase activity and its involvement in the production of nitric oxide in wheat leaves. Doklady Biological Sciences, 435: 457–460.

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2011

Beckett R.P., Alyabyev A.J., Minibayeva F.V. (2011) Patterns of heat production during desiccation and rehydration in lichens differing in desiccation tolerance. Lichenologist, 43(2): 178-183.

Beckett R.P., Alyabyev A.J., Minibayeva F.V. (2011) Patterns of heat production during desiccation and rehydration in lichens differing in desiccation tolerance. Lichenologist
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43(2): 178-183.

Valitova J.N., Minibayeva F.V., Kotlova E.R., Novikov A.V., Shavarda A.L., Murtazina L.I., Ryzhkina I.S. (2011) Sterol depletion by nystatin increases membrane permeability and modifies sphingolipid composition in wheat roots. Phytochemistry, 72: 1751–1759.

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Leptogium saturninum
oxidizes high-redox potential substrates
. Fungal Genetics and Biology, 48(12): 1139-1145.

2012

Dmitrieva, S.A., Ponomareva, A.A., Ryabovol, V.V., Minibayeva, F.V. (2012) Effects of oxidative stress on ultrastructure and functional activity of plant mitochondria *in vivo*. Biologicheskie Membrany, 29(4): 267-275 (in Russian).

Galeeva E.I., Trifonova T.V., Ponomareva A.A., Viktorova L.V., Minibayeva F.V. (2012) Nitrate reductase from *Triticum aestivum* leaves: regulation of activity and possible role in production of nitric oxide. Biochemistry (Moscow), 77(4): 404-410.

Minibayeva F., Dmitrieva S., Ponomareva A., Ryabovol V. (2012) Oxidative stress-induced autophagy in plants: the role of mitochondria. Plant Physiology and Biochemistry, 59: 11-19.

Chasov, A.V., Beckett, R.P., Minibayeva, F.V. (2012) Peroxidases of Anthoceros natalensis, an evolutionary precursor of vascular plants. Doklady Biological Sciences 447 (1), pp. 357-359.

Beckett R.P., Minibayeva F.V., Liers C. (2012) Occurrence of high tyrosinase activity in the non-Peltigeralean lichen *Dermatocarpon miniatum* (L.)W. Mann. Lichenologist, 44(6): 827–832.