## Changes in the *Arabidopsis thaliana* and *Hypericum perforatum* metabolome in response to treatment with the metal nanoparticles

## Abstract

Nanotechnology is a rapidly developing field of science that has multiple applications in many aspects of modern life and knowledge. Application of nanomaterials such as nanoparticles of metals and their oxides becomes common in pharmacy (as modern medicine carriers), cosmetology, electronics and chemical industry. Presently it becomes obvious that nanomaterials may have wide range of applications in agriculture as fertilizers, components of plant protectants or stimulators of plant resistance as well as in biotechnology as elicitors increasing accumulation of important secondary metabolites or modern carriers of gene constructs. An important question remains explaining the mechanism of plant primary and secondary metabolism elicitation by nanoparticles, including significant phytoalexins.

The main objective of this work was the evaluation of nanoparticles activity as stimulants of metabolomic response of plants and recognition of its potential mechanisms. Changes in metabolomic profiles of cell cultures derived from an important medicinal plant St. John's wort (*Hypericum perforatum*) as well as in seedlings of the model plant *Arabidopsis thaliana* have been monitored using a modern metabolomic platform – ultraperformance liquid chromatography hyphenated to mass spectrometry.

Effect of application of metal (Ag, Au, Cu, Pd) and metal oxide (CeO<sub>2</sub>, CuO, TiO<sub>2</sub>, ZnO) nanoparticles was studied using cell culture of *Hypericum perforatum*. It has been found that silver and gold nanoparticles induce accumulation of significant secondary metabolites from the structural groups of benzophenones, xanthones and anthraquinones which play role of phytoalexins in this species. Concentrations of both these nanoparticles that induce the highest increase of secondary metabolites contents have been uncovered. However, their distinct toxicity against plants caused different influence on accumulation of such compounds as benzoic acid derivatives, xantholignans and xanthoids. The observed trends in metabolites accumulation confirm the alternate mechanisms of these nanoparticles activities.

Targeting at elucidation of potential phytohormonal mechanism accompanying the metabolomic changes caused by nanoparticles their influence at three signal molecules: abscisic acid, jasmonic acid and salicylic acid has been studied. Presence of Ag and Au nanoparticles substantially increased concentration of jasmonic acid and decreased concentration of abscisic acid in the cell culture of St. John's wort. On the other hand, the level of salicylic acid was increased only after treatment with Ag nanoparticles after 4 hours of elicitation. Changes of these phytohormones correspond

with the secondary metabolites accumulation in the *H. perforatum* cultures and sustain hypothesis that these nanomaterials may be used as effective elicitors.

Influence of silver nanoparticles on seedlings of the model plant *Arabidopsis thaliana*, closely related to *Brassicaceae* crop plants, has been described in the further part of this dissertation. Studies performed using this experimental model have shown that Ag nanoparticles are capable for induction of phytoalexin camalexin and its derivatives biosynthesis. Camalexin is a compound of wide range of antimicrobial activities. It has been demonstrated that induction of this compound level depends not only on the nanoparticles concentration but also on their size, treatment time and the free Ag<sup>+</sup> ions quantity. Due to their ability to induce phytoalexin and other important secondary metabolites accumulation, nanoparticles may be used as potential plant resistance stimulants.