актуальні питання сучасної фітофізіології. Були проведені також наукові читання: у 2005 – присвячені 100-річчю з дня народження колишнього завідувача кафедри професора С.О. Гребінського, засновника наукового напрямку «Фізіологія росту рослин», та у 2012 – з нагоди 20-річчя відновлення роботи самостійної кафедри.

На кафедрі виконувалась низка держбюджетних, міжфакультетських та госпдоговір них тематик, а також українсько-угорський проект науково-технічного співробітництва «Очищення прируслової ділянки ріки Тиса методами фіторемедіації (2007-2008 рр). Отримано 10 патентів на винаходи. Зараз виконується українсько-американський проект «Сталі підходи до поліпшення врожайності і поживної цінності пшениці».

Отже, перспективними напрямками розвитку кафедри фізіології та екології рослин на майбутнє залишається підготовка висококваліфікованих кадрів та поглиблене вивчення регуляції росту і розвитку рослин та шляхів адаптації до несприятливих чинників.

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BIOAVAILABILITY OF ELEMENTS FOR EFFECTIVE PHYTOREMEDIATION AND PHYTOMINING: THE ROLE OF RHIZOSPHERE PROCESSES FOR GERMANIUM

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The success of phytoremediation (especially phytoextraction) and phytomining depends heavily on the bioavailability of target elements, which, among others, is a function of soil mineral phases, soil organic matter, pH and redox potential. The use of soil additives which, e.g., change soil pH or increase the amount of chelating compounds, has been propagated in the past in order to desorb the target elements from the soil matrix. These additives, however, may have negative environmental consequences by causing leaching of toxic elements from the soil due to enhanced mobility in the soil solution. For this reason less dangerous alternatives are necessary which use the natural capacity of plants to increase availability of target elements in their root environment. Here we report on rhizosphere mechanisms of various plant species to increase bioavailability of germanium (Ge), an economically valuable element relevant for phytomining, also on polluted sites.

Several species of forbs (e.g. *Lupinus albus, L. angustifolius, Fagopyrum esculentum, Brassica napus)* and grasses (e.g. *Hordeum vulgare, Panicum miliaceum, Phalaris arundinacea, Zea mays, Phragmites australis, Miscanthus giganteus*) were grown on various substrates, either without or with addition of organic acids, both in the greenhouse and in the field. Plants were harvested, and the concentration of germanium was analyzed in the dried plant material via ICP-MS following micro-wave digestion with concentrated HNO_3 and HF. Germanium was also determined in different soil fractions after sequential extraction.

The addition of carboxylates (e.g. 1 and 10 mM citric acid) dramatically increased the mobility of Ge in soils (the amount of extractable Ge was increased up to 10-fold) and Ge contents in the plant material (ca. 50%). However it seems that this mobilization is restricted to very acidic conditions (pH < 4). The accumulation of Ge in aboveground plant material was by a factor of 10 higher in grasses than in forbs. For those plants

with a high capacity for lowering pH and releasing carboxylates from roots (e.g. genus *Lupinus*), which is a common strategy of plants to mobilize poorly available nutrients such as Fe, Mn and P in the rhizosphere, we could demonstrate that they were able to mobilize Ge. However, it seems that these species are not able to take up the mobilized Ge from soil solution.

Due to the chemical similarity between Si and Ge grass species, which accumulate Si in their shoots, are able to take up higher amounts of Ge than forbs. On the other hand, forbs which can release a high amount of organic acids from their roots and thus mobilize Ge in the soil, show only a limited capacity for Ge uptake, most probably because of the formation of soluble Ge-organic complexes. The mobilization of Ge seems to be restricted to the rhizosphere with its distinct pH and carboxylate gradients. Due to the higher reactivity of Ge in the soil, plant availability of Ge is lower compared to Si. This demonstrates that mobility of elements in the soil solution *per se* is not necessarily a good indicator for bioavailability of target elements in phytomining and phytoremediation.

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CALCIUM-DEPENDENT INDUCTION OF PLANT CELLS HEAT RESISTANCE BY HYDROGEN SULFIDE DONOR

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Hydrogen sulfide (H_2S) is currently regarded as an important signal mediator, along with reactive oxygen species (ROS) and nitric oxide (NO) (Hancock, 2016). An increase in the endogenous content of hydrogen sulfide in plant cells under action of stress factors of various nature have been shown (Jin et al., 2011; Shi et al., 2014). Data were also obtained on an increase in resistance of plants under the influence of hydrogen sulfide donors, the most popular of which a sodium hydrosulfide (NaHS) is (Lisjak et al., 2013). In some papers, results have been obtained that indicate the participation of ROS in transduction of hydrogen sulfide signal and H_2S-induced activation of antioxidant system (Wang, 2012; Kolupaev et al., 2017). It is known that the formation of signaling ROS is largely dependent on calcium homeostasis. This is due, in particular, to the direct and indirect influence of calcium on the activity of NADPH oxidase (Ogasawara et al., 2008). It can be assumed that the influence of hydrogen sulfide on the ROS formation and antioxidant activity is mediated by calcium ions. However, specific experimental data suggesting a possible causal relationship between changes in calcium homeostasis, activation of the antioxidant system and the development of plant cell resistance to hyperthermia under the action of exogenous hydrogen sulfide were absent at the time of our work. In connection with the above, the aim of this work was to elucidate the participation of calcium ions in the inducing of antioxidant enzymes and heat resistance of wheat coleoptile cells by the action of the hydrogen sulfide donor.

Coleoptiles, separated from 4-day-old wheat (*Triticum aestivum* L.) seedlings of variety Dosconala, were incubated at 2% sterile sucrose with penicillin addition. 100 μM NaHS was added to the incubation medium of coleoptiles of experimental variants, which were incubated there for 24 hours, then the activity of superoxide dismutase (SOD), catalase and guaiacol peroxidase (GPO) was determined in coleoptiles. A part