

Introduction and aims of the study:

Human activities including agriculture, industry, and households alter global N, P cycles towards higher availability and mobility of nutrients worldwide (Smith et al. 1996, Vitousek et al. 1997, FAO 2004, Khan and Ansari 2005). In wetlands, nutrient enrichment and subsequent eutrophication are forces seriously affecting their functions, stability (EEA 1999), diversity, and the rate of natural succession (Khan and Ansari 2005). The addition of N generally leads to the stimulation of overall biomass productivity, but losses in diversity (Vitousek et al. 1997, Güsewell and Bollens 2003). Massive growth of algae and duckweeds triggers a decline of submerged macrophytes (e.g. isoetids, characeans) due to shading effect (Khan and Ansari 2005). Moreover, a retreat of species using efficient N utilization as the competitive advantage occurs in favour of highly productive species; together with the loss of rare and uncommon species (Verhoeven et al. 1996, Vitousek et al. 1997, Levine et al. 1998, Bedford et al. 1999, Sand-Jensen et al. 2000, Hejný et al. 2002, Güsewell and Bollens 2003, Khan and Ansari 2005). At many localities, anthropogenic impact is related also to the invasion of non-native plant dominants (Bedford et al. 1999, Cronk and Fennessy 2001). The spreading of *Typha domingensis* (Vaithianathan and Richardson 1999, Lorenzen et al. 2001, Cronk and Fennessy 2001) or non-native clones of *Phragmites australis* (Saltonstall 2002, Tewksbury et al. 2002) in North American wetlands, positively related to N, P enrichment, are some of the typical examples.

In Europe, vice versa, wetlands instability and changes in sediment properties caused by eutrophication resulted in a considerable retreat of *Phragmites australis* during last decades (Ostendorp 1989, Kühl and Kohl 1992, van der Putten 1997, Kubín and Melzer 1997, Fogli et al. 2002). This large-scale reed die-back occurring at eutrophic habitats shows us that even fast-growing dominant species may suffer from the altered growth conditions. The loss of *Phragmites* in Europe was even so serious, that the species gained the global interest (Ostendorp 1989, van der Putten 1997, Brix 1999). This effort, integrated particularly in EUREED I and II projects of the European Union (1993-1994 and 1996-1998; for further details see Brix (1999)), brought about the knowledge of many theoretical and practical aspects of wetland plant performance, identifying several mechanisms of eutrophication impact. Among others, litter accumulation and phytotoxicity of its degradation products, high oxygen demand in the sediment, mechanical damage caused by biotic or abiotic factors, delayed translocation of storage compounds, disturbance of carbon balance, and/or changes in

plant morphology and anatomy induced by high nutrient availability can be mentioned (for summary see e.g. (Ostendorp 1989)).

However, it seems to us, that less attention was generally paid to the “**primary nutritional aspects of N addition**”, it means to general characteristics of N acquisition in wetland plants. In terrestrial habitats, not only the availability of N *per-se*, but also the form of available N (NH_4^+ versus NO_3^-), and the ratio to other nutrients (particularly N/P) affect plant performance and community composition considerably (Chapin et al. 1986, Marschner 1995, Troelstra et al. 1995a, Kronzucker et al. 1997, Nordin et al. 2001). Similar mechanisms may act in wetlands, but the extent to which they really affect performance and competition ability of individual species is not completely clear. Among others, Güsewell and co-workers showed the importance of N/P ratio, especially under N or P limiting conditions (Güsewell and Bollens 2003, Güsewell et al. 2003). Similarly, the observations of Smolders et al. (1996), Dorland et al. (2003), Paulissen et al. (2004), and Paulissen et al. (2005) indicate that the shift in $\text{NH}_4^+/\text{NO}_3^-$ ratio affect the composition of wetland community. Especially some aquatic communities (e.g. isoetids of soft-water lakes) seem very sensitive towards high relative abundance of NH_4^+ (Bobbink et al. 1998). Obviously, the interspecific differences in NH_4^+ tolerance may exist in relation to the conditions of microhabitat, as $\text{NH}_4^+/\text{NO}_3^-$ ratio differs among individual wetlands as well as within the wetland. $\text{NH}_4^+/\text{NO}_3^-$ ratio also increases along with the eutrophication, as the litter accumulation increases microbial activities and oxygen demand, which leads to the diminution of NO_3^- from the sediment (Kühl and Kohl 1992, Čížková et al. 2001b). Furthermore, NH_4^+ is the substantial form of N in wastewater (see e.g. Cottingham et al. (1999), Szogi et al. (2003), Edwards et al. (2006); for further details see Tab. 1), which is commonly treated with the help of wetland or aquatic plants (Gopal 1999, Květ et al. 1999, Vymazal 2002).

Therefore, **the general aim of this thesis** is to follow basic aspects of N acquisition and utilization in wetland plants, and/or their growth and metabolic responses to N level, N/P ratio, and $\text{NH}_4^+/\text{NO}_3^-$ ratio. Simplified water or sand cultivations (Fig. 2) are used to separate the nutritional aspects of plant performance from other potentially interfering factors acting at natural habitats. The study is a part of broader physiological effort of the team of Dr. Olga Votrubová (Department of Plant Physiology, Charles University in Prague), focused on different aspects of wetland plant performance (see diploma and PhD theses: Soukup (1997), Vojtíšková (1999), Erhart (2000), Říhová (2000), Munzarová (2000), Raimanová (2001), Lichtenberková (2002), Jirovská (2003), Soukup (2005), Steinbachová (2006), and the publications therein). The study was realised in the collaboration with the Department of

Biological Sciences, Aarhus University (the team of Prof. Hans Brix; <http://person.au.dk/en/hans.brix@biology.au.dk>) and with the Department of Plant Physiology and Anatomy, Faculty of Science of Masaryk University in Brno (the team of Dr. Vít Gloser; <http://www.muni.cz/people/2691>). The study focuses particularly on two dominants of our littoral vegetation: *Phragmites australis* (Cav.) Trin. Ex Steud. and *Glyceria maxima* (Hartm.) Holmb., which occupy similar habitats, but differ in the growth strategy (e.g. dormancy requirement, rooting depth), and sensitivity to eutrophication. While *Phragmites* seems positively responding to early stages of eutrophication, *Glyceria* is more tolerant to highly eutrophic sediments rich in organic matter (Ozimek and Klekot 1979, Crawford and Brändle 1996, Hroudová and Zákavský 1999, Hroudová and Zákavský 2002), and its spread following reed retreat was repeatedly documented (e.g. Hroudová and Zákavský (1999), Hroudová and Zákavský (2002)); for further characteristics of selected species see Fig. 1). Therefore, they represent useful model species for understanding the mechanisms underlying competition ability in the changing environment. Both species are also commonly used in wastewater-treating systems (Květ et al. 1999, Vymazal 2002).

The original findings of the thesis are summarised in the following original papers (or submitted manuscripts), and are confronted with the current general view on the topics, given as the review.