1 Summary of Ph.D. Thesis

1.1 Introduction

Anthropogenic soil contamination with Cd represents an important environmental problem in view of the relatively high solubility of Cd in soils and its high toxicity to plants and animals in comparison with other heavy metals (HMs) (Schachtschabel et al. 1992). In many plants, a high proportion of the Cd uptake is effectively bound in roots, but *Nicotiana tabacum* (tobacco) usually accumulates more Cd per unit biomass in leaves than in roots (Lugon-Moulin et al. 2004). In commercially produced tobacco, reducing Cd concentrations in the leaves is an important aim due to the health risks connected to Cd in tobacco smoke. On the other hand, the preferential Cd accumulation in the leaves and high biomass production make tobacco a potential candidate plant for Cd phytoextraction, i.e. Cd removal from contaminated soils within the harvestable parts of plants (Salt et al. 1995).

Arbuscular mycorrhiza (AM) is an almost ubiquitous rhizospheric interaction of plants and soil fungi of the order Glomeromycota and influences plant physiology in such a complex way that mycorrhizal plants often differ from non-mycorrhizal plants in parameters seemingly little related to the main nutritional functions of the symbiosis. Among others, considerable body of information has been collected on how AM affects the survival, growth and HM uptake of plants. However, the understanding of this interaction is hampered especially by contradicting reports on the effects of AM symbiosis, difficulties in the reproducibility of the obtained results and lack of knowledge on the responsible mechanisms (as reviewed by Leyval et al. 1997).

AM can decrease the Cd concentrations in the shoots of plants (e.g. Gildon and Tinker 1983, Weissenhorn et al. 1995, Vogel-Mikus et al. 2006), but the opposite effect of AM was reported as well (e.g. Rivera-Becerril et al. 2002, Andrade et al. 2005). Similarly to the situation with other mycorrhizal effects, several factors seem to play a role, especially the plant species (Joner and Leyval 2001) or even variety (Rivera-Becerril et al. 2002), the AM fungal isolate involved (Liao et al. 2003, Wang et al. 2005) and the Cd concentration in soil (Heggo et al. 1990). In addition to affecting Cd uptake by plants, AM symbiosis can also alleviate Cd stress to plants growing in Cd contaminated soils (Gildon and Tinker 1983, Tonin et al. 2001, Rivera-Becerril et al. 2002). This can be associated with both lower (Weissenhorn et al. 1995) and higher (Rivera-Becerril et al. 2002) Cd concentrations in the biomass of the mycorrhizal plants.

Higher Cd uptake of mycorrhizal plants can be explained by the ability of AM fungal extraradical mycelium (ERM) to take up this non-essential element and transport it into plant roots (Guo et al. 1996, Joner and Leyval 1997, Hutchinson et al. 2004). However, the interactions responsible for lower Cd uptake of mycorrhizal plants are less clear. Improved growth of mycorrhizal plants and related biomass dilution effects have been suggested e.g. by Weissenhorn et al. (1995), Hutchinson et al. (2004) and Shen et al. (2006). Mycorrhizal plants often translocate less Cd from roots into shoots than non-mycorrhizal plants, probably due to Cd immobilisation in the intraradical mycelium of AM fungi (Loth and Höfner 1994, Tonin et al. 2001, Hutchinson et al. 2004). Furthermore, it has been proposed that AM symbiosis decreases Cd availability in soil due to Cd immobilisation by the ERM of the fungus (Joner et al. 2000) or due to higher rhizospheric pH of mycorrhizal plants (Shen et al. 2006). The latter effect of mycorrhiza seems to be plant-mediated rather than related to the presence of ERM in soil (Marschner and Baumann 2003). Hence, lower HM uptake of mycorrhizal plants can be based both on direct and plant-mediated effects of mycorrhiza. In addition to "filtering" HM ions in soil or plant roots, AM fungi may affect HM uptake by their host plants, total or per unit of biomass, by improving their growth or affecting other physiological processes.

These briefly outlined effects of AM symbiosis on the interaction of plants with soil Cd indicated that mycorrhizal tobacco might well differ in Cd uptake and tolerance from non-mycorrhizal tobacco. However, it was difficult to predict how and the main objective of this study was therefore to describe this difference as well as the factors involved. Exploring more thoroughly a defined model system was designed to contribute to a better understanding of the processes and responses involved in the mycorrhizal effects. Additionally, the idea that AM could be applied to support phytoremediation of HM contaminated soils (e.g. Gaur and Adholeya 2004, Göhre and Paszkowski 2006) should be supported or contradicted by for tobacco and Cd.

1.2 Aims and Scopes

- To determine **how AM affects Cd accumulation** by tobacco. Specifically, the role of the following factors:
    - mycorrhizal effects on growth and Cd tolerance
    - mycorrhizal effects on Cd concentrations in biomass
    - mycorrhizal effects on Cd translocation from roots to shoots
    - Cd concentration in soil.
- To assess, **which physiological responses to AM symbiosis contribute to the mycorrhizal effects on Cd uptake** by tobacco, especially the role of:
    - mycorrhizal effects on biomass production (the biomass dilution effect)
    - mycorrhizal contribution to Cd immobilisation in roots
    - differences in Cd availability between mycorrhizal and non-mycorrhizal rhizosphere.
- To determine **how mycorrhiza affects Cd accumulation by a transgenic tobacco with improved Cd tolerance and higher Cd uptake** in comparison with wild type plants.
- To evaluate **whether the mycorrhizal effects on Cd accumulation by tobacco could be exploited**
    - in the phytoremediation of Cd contaminated soils
    - in decreasing Cd concentrations in the leaves of commercially produced tobacco.