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Effects of Cadmium on *Pinus sylvestris* and Its Mycorrhizal Symbionts

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The effects of Cd, one of the most hazardous heavy metals, on a host plant *Pinus sylvestris* and ectomycorrhizal fungi *Paxillus involutus* and *Suillus bovinus* were investigated. Cd treatment of *P. sylvestris* grown in mineral forest soil increased Cd concentrations in tissues. Cd accumulated in roots up to 325 mg kg-1. Root growth was less affected by Cd than shoot growth, which showed a significant reduction in the 100 mg Cd kg-1 treatment. Soil organic matter was not found to ameliorate Cd toxicity in terms of shoot growth, however, Cd levels in shoots were lower in seedlings grown in organic soil than those grown in mineral soil. Improved nutrition of the seedlings in organic soil and organic complexing might be responsible for reduced Cd accumulation in shoots. The growth of *S. bovinus* was found to be more sensitive to Cd than that of *P. involutus*. The radial growth of *S. bovinus* on MMN agar was inhibited at concentrations as low as 0.1 mg Cd L-1, whereas there was no growth inhibition in *P. involutus* at the same level of Cd treatment. Dry matter production of *S. bovinus* in MMN liquid solution was also more affected by Cd than that of *P. involutus*. Greater production of hyphae of *P. involutus* than *S. bovinus* appeared to confer some degree of Cd resistance, possibly by binding Cd onto cell walls. Growth of the fungi was increased by glucose addition. While Cd reduced dry matter production of the fungi, there were no differences in glucose consumption caused by Cd treatment. This suggests that the use of glucose might have been diverted to detoxification and/or repair mechanisms. From the results of the study, a decline of *S. bovinus* in Cd-contaminated forests and a higher sensitivity to Cd of *S. bovinus*-infected plants than *P. involutus*-infected plants would be expected. A subsequent test of the fungal performance in symbiosis with their host plant, *P. sylvestris*, was also carried out since fungal physiology in vitro could be different from that in symbiosis. While infection by *S. bovinus* improved stem growth, infection by *P. involutus* had no effect on growth of seedlings. There was no Cd-ameliorating effect of infection in terms of either shoot or root growth. The proportion of living mycorrhizal root tips of *S. bovinus*-inoculated seedlings was reduced as a result of Cd addition. However, no such effect was found in *P. involutus*-inoculated seedlings. Shoot Cd levels in the 100 mg Cd kg-1 treatment were lower in *S. bovinus*-inoculated seedlings than uninoculated and *P. involutus*-inoculated seedlings. The proportion of living mycorrhizal root tips of seedlings inoculated with *P. involutus*was unaffected by Cd treatment. In a Cd-contaminated environment, not only mature trees which have fully established mycorrhizal structures but also seeds and young seedlings can be exposed to Cd. Cd taken up by young seedlings may influence mycorrhizal infection, which might in turn influence resistance to Cd toxicity. In order to eliminate soil-mediated responses of mycorrhizal infection to Cd, *P. sylvestris*seedlings were exposed to Cd prior to fungal inoculation and replanted to clean substrates with fungal inoculum. The proportion of living mycorrhizal short roots of seedlings inoculated with *S. bovinus* was not affected by Cd pretreatment, whereas that of seedlings inoculated with *P. involutus* was reduced by Cd pretreatment. Infection by *P. involutus* appeared to be affected by Cd taken up by seedlings. Therefore, mycorrhizas may be affected not only directly by external soil Cd but also indirectly by disturbed plant physiology.