DOCTORAL THESIS

The role of arbuscular mycorrhizal fungi (AMF) on the tolerance and accumulation of arsenic in rice (Oryza sativa L.)

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The Role of Arbuscular Mycorrhizal Fungi (AMF) on the Tolerance and Accumulation of Arsenic in Rice (*Oryza sativa* L.)

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Abstract

This study aimed to investigate the effects of arbuscular mycorrhizal fungi (AMF) infection and phosphorus (P) uptake by lowland rice under different water regimes. Specifically, the effects of AMF on arsenic (As), P accumulation and As uptake kinetics in lowland and upland rice, and As concentration in soil solutions under the influence of AMF. Furthermore, As speciation in rice with different radial oxygen loss under the influence of AMF will also be investigated.

Lowland rice was inoculated with eight populations of AMF grown in four water regimes (50%, 70%, 100% of water holding capacities and waterlogged soil) in a greenhouse trial. The highest increase of shoot biomass was registered in lowland rice inoculated with AMF under soil of 100% water holding capacity. In general, shoot biomass and concentration of phosphorus (P) of rice increased in the presence of AMF when compared with control (without AMF).

The effects of AMF - *Glomus intraradices* and *G. geosporum* on As and P uptake by lowland (Guangyinzhan) and upland rice (Handao 502) grown in soil, with and without addition of As (60 mg As kg^{-1}) were then investigated. As tolerance, grain P content and grain yield were enhanced when Guangyinzhan was inoculated with *G. intraradices* and Handao 502 was inoculated with *G. geosporum* in As-contaminated soils. However, when Guangyinzhan was inoculated with *G. geosporum* and Handao 502 was inoculated with *G. intraradices*, results showed decreased grain P content, grain yield and the molar ratio of grain P/As content, increased As concentration and the ratio of grain/straw As concentration. The variation in the transfer and uptake of As and P reflected strong functional diversity in AM (arbuscular mycorrhizal) symbioses.

In addition, the effects of *G. intraradices* on the uptake of four As species (arsenate; arsenite; dimethylarsinic acid, DMA; and monomethylarsonic acid, MMA) by lowland rice and upland rice were investigated. The results showed that mycorrhizal roots of two rice cultivars reduced arsenate (As(V)) uptake significantly ($p < 0.001$) in low-affinity uptake system, and decreased uptake of arsenite (As(III)) and MMA noticeably ($p < 0.05$) in high or low-affinity uptake systems. The influx of four As species was significantly different ($p < 0.05$) between two rice varieties in low-affinity uptake system.

Furthermore, the role of *G. intraradices* on growth, As uptake, grain As speciation, and As concentrations in the soil rhizosphere and non-rhizosphere solutions of six rice cultivars were investigated in a rhizobag system, with and without the addition of As (60 mg kg^{-1} soil). The ratios of inorganic/organic As concentrations in rice grains of all cultivars were significantly ($p < 0.05$) reduced in the presence of AMF, which favored the detoxification of As in rice. Moreover, there were significant correlations ($p < 0.05$) between As in rice grain and As in the soil rhizosphere/non-rhizophere solution, indicating that the survey of As concentration in soil solution could be an effective measure for evaluating As in rice grains.

Lastly, As speciation in rice (TD 71 and Xiushui 11) with different radial oxygen loss (ROL) under the influence of *G. intraradices* was investigated in soil with and without the addition of As (30 mg kg^{-1}). Mycorrhizal inoculation enhanced the root ratio of As(III) conc./As(V) conc. in TD71 with high ROL at three growth periods (day 7, day 35 and day 63 after flooding the soil) in As-contaminated soils ($p < 0.05$). Furthermore, TD 71 with high ROL led to higher root colonization rates. The ratios of As(III) conc./As(V) conc. in roots of TD71 were significantly more than Xiushui 11 when colonized by *G. intraradices* at

three growth periods in 30 mg As kg^{-1} soil ($p < 0.05$). In conclusion, rice with high ROL can favor AM fungal infection and enhance root ratio of As(III) conc./As(V) conc. in the presence of AMF.

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