EFFECTS OF RHIZOSPHERE AND MYCORRHIZOSPHERE ON GRADIENT DISSIPATION OF PENTACHLOROPHENOL IN SOIL

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Abstract

A greenhouse experiment was carried out using a specially designed rhizobox to investigate the rhizosphere and mycorrhizosphere effects on the PCP degradation. The degradation gradients of PCP followed the order: near rhizosphere > root compartment > far rhizosphere. The largest loss of PCP in planted soil was observed at the distance of 2 mm from root surface. In order to explain this interesting phenomenon, millimeter spatial changes in rhizosphere of soil microbial biomass, soil alkaline phosphatase and soil phenol oxidase activities were investigated. The results showed that both the soil enzyme activities and the soil microbial biomass were highly dependent on the proximity to the root surface and the peaks appeared at the 2 mm distance from root surface. Regression analysis was further performed and indicated that PCP degradation was in close relationship with the microbial biomass and enzyme activities in rhizosphere. The impact of arbuscular mycorrhiza (AM) was also assessed. As a result, AM promoted the PCP degradation and elevated the soil phenol oxidase activity, soil microbial biomass in rhizosphere.

Introduction

Pentachlorophenol (PCP) is extensively used as wood preservative as well as in a wide variety of agricultural and industrial applications, which has led to its contamination in environment matrices particularly in soils. Rhizodegradation of organic pollutants depends on plant-microbe interactions in the rhizosphere, but the extent and intensity of such rhizosphere effects are likely to decrease with increasing distance from the root surface[1].

Arbuscular mycorrhiza (AM) is a ubiquitous symbiosis between soil fungi and roots of most herbaceous plant species[1]. Once arbuscular mycorrhizal association has developed, mycorrhizal hyphae act as the roots of the roots, and may thus extend the rhizosphere into the bulk soil by creating a new interface of soil-plant interactions: the mycorrhizosphere[2]. As hyphae allocate relatively significant amounts of carbon to this soil compartment, both as exuded glycoproteins and through subsequent hyphal decay, one may thus observe elevated microbial activity and identify highly specific bacterial populations in this soil compartment which may potentially enhance the degradation of organics[3]. However, the question of how far a mycorrhizosphere effect on degradation of organic pollutants may extend has so far not been addressed.

The aim of this study was to find out how far rhizosphere and mycorrhizosphere effect may extend and how intense this effect may exert on the degradation of soil organic pollutants according to the distance from the root surface as well as to elucidate the mechanism of AMF affecting the degradation process of organic pollutants in soil and their uptake by plant.

Materials and Methods

Ryegrass (*Lolium perenne* L.) was used as test plants. AM fungus Glomus mosseae (BGC XJ01) was as inoculum. Two PCP rates (0, 10.0 mg/kg) were set up and mycorrhizal and non-mycorrhizal treatments were compared. Each rhizobox received 2200 g of incubated soil. All treatments were performed in triplicate. Pots were kept in a controlled environment growth chamber for 60 days. Shoots and roots were harvested separately. The water content of the plant was calculated from the weight difference between the fresh and dry matters divided by the fresh weight. All of the soil samples were stored at –70℃ for determination of PCP, soil enzyme activities and soil microbial community. The data were analyzed by two-way analysis of variance using the SPSS (version 11.5) software package.

Results and Discussion

Mycorrhizal root colonization and plant biomass. Mycorrhizal colonization of the roots was decreased with PCP addition in the soil. Ryegrass biomass was significantly affected by PCP addition and mycorrhizal colonization. Mycorrhizal colonization led to an increase in biomass of ryegrass, while PCP addition tended to decrease both shoot and root biomass (Table 1).

PCP dissipation in soil. Fig. 1 shows the residual concentrations of PCP in the rhizosphere according to the distance from root surface. The degradation gradients of PCP followed the order: near rhizosphere > root compartment > far rhizosphere. The maximum PCP dissipation value exists in 2 mm near-rhizosphere layer, which is against our expectation that the peak value should be in the root compartment. The mycorrhizal treatments degraded more PCP in all compartments and sub-layers than did non-mycorrhizal.

Soil enzyme activities and soil microbial biomass. Soil alkaline phosphatase activities, phenol oxidase activities and microbial biomass in the rhizosphere according to the distance from root surface were shown in Fig.2, 3 and 4. All of them were greatly influenced by the proximity to the roots and consistent with the PCP dissipation trend in soil, that is near rhizosphere > root compartment > far rhizosphere. Maximum values all exist in 2 mm near-rhizosphere layers as expected. AM can elevate the soil phenol oxidase activity, microbial biomass in rhizosphere, but has negligible effect on soil alkaline phosphatase activity.

Regression Analysis. In order to find out the interaction among PCP degradation, soil enzyme activities and microbial biomass, linear regression analysis was performed. Good correlations were shown in all treatments. The coefficients (not given) of PCP concentration and phenol oxidase activity (0.5595 ~ 0.9662) were especially higher than those of the phosphatase activity (0.4569 ~ 0.8424) and microbial biomass (0.5191 ~ 0.8469). Therefore, we might say that high PCP dissipation in the rhizosphere is in close relationship with the high soil microbial and enzyme activities, which are probably the key components in rhizodegradation.

Acknowledgements

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References

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2. Joner E.J., Leyval C. Agronomie 2003; 23: 495.

3. Linderman R.G. Phytopathology 1988; 78: 366.

Figures and Tables

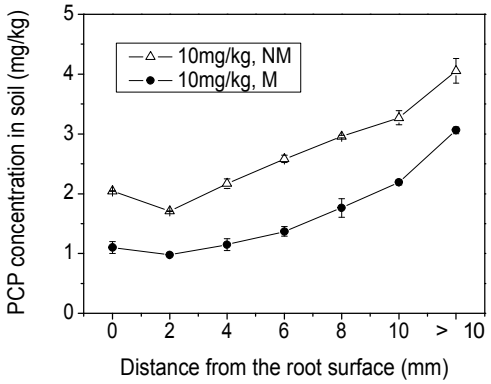

Figure 1. PCP concentration in rhizosphere soil with respect to the distance from the root surface

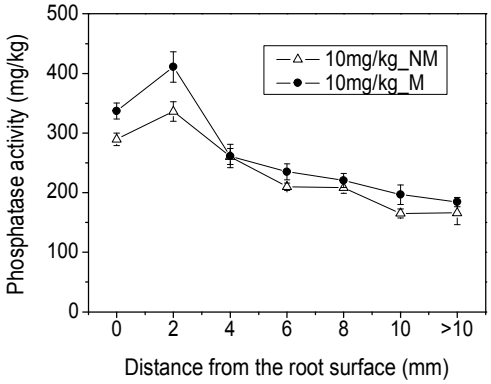

Figure 2. Alkaline phosphatase activity in rhizosphere with respect to the distance from the root surface

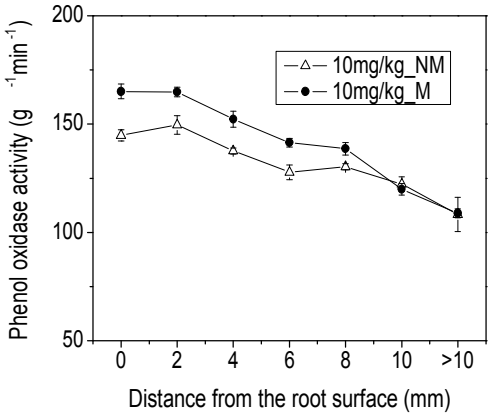

Figure 3. Phenol oxidase activity in rhizosphere with respect to the distance from the root surface

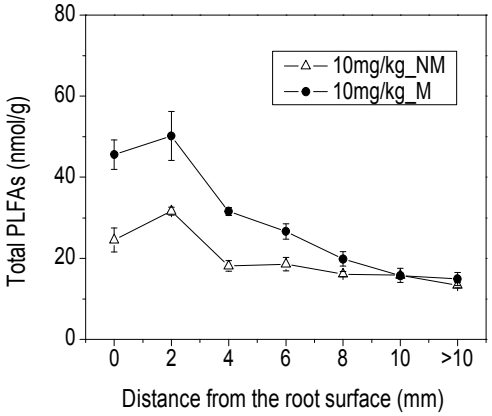

Figure 4. Total PLFAs concentrations in rhizosphere with respect to the distance from the root surface

Table 1. Mean shoot and root dry matter yield (freeze-dried basis) and proportion of root length colonized by the AM fungus after cultivation of mycorrhizal ryegrass and non-mycorrhizal controls in soil containing different levels of added PCP (mean±SE, n=3)

Initial PCP addition (mg kg^{-1})	Mycorrhizal addition	Shoot weight (g pot^{-1})	root weight (g pot^{-1})	Mycorrhizal colonization (%)
0	Non-mycorrhizal	6.54±0.27 b	2.41±0.13 b	0
	Mycorrhizal	6.83±0.17 a	2.57±0.08 a	18.46±0.73 a
10	Non-mycorrhizal	5.16±0.18 e	1.82±0.05 d	0
	Mycorrhizal	5.92±0.13 cd	2.14±0.07 c	11.75±0.82 d

Values followed by the same letter within a column are not significantly different according to Duncan's multiple range test at the 5% level