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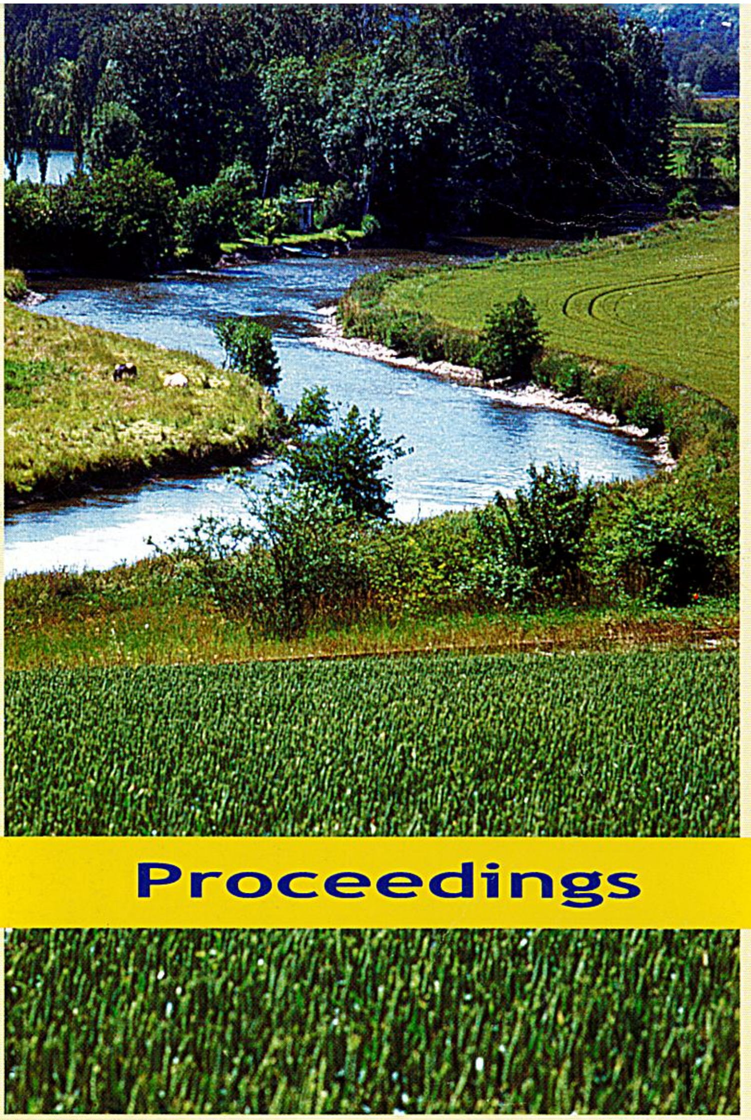

May 25-27, 2005
Paris, France

Proceedings

International workshop on

GREEN PORK PRODUCTION

"Porcherie verte", a research initiative on environment-friendly pig production

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Effect of repeated annual application of pig manure or pig slurry on C and N dynamics in the rhizosphere of maize

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[Results obtained within the research initiative « Porcherie verte »]

Introduction

The use of pig effluents as organic fertilizers for crops allows the recycling of minerals whilst improving the overall soil fertility. The availability to the plant of minerals derived from organic fertilisers depends to a large extent on the net mineralisation of the organic matter by the activity of soil microorganisms, which is strongly stimulated in the root vicinity (the rhizosphere) by the release of root mucilage and root exudates (rhizodeposition). Two questions were adressed in this study. Firstly, how repeated applications of organic fertilizers (pig slurry or pig manure) impact on microbial activity and on gross fluxes of mineralization and immobilization of N in the rhizosphere of field-grown maize ? Secondly, do repeated applications of pig manure change the N dynamics during the microbial assimilation of mucilage and exudates?

Materials and methods

Samples of soil adhering to roots were collected (0-15 cm – 5 replicates) at the 9-13 unfolded leaves stage in two long term experimental sites planted with maize and annually fertilized with pig slurry vs ammonium nitrate for 10 years, and composted pig manure vs ammonium nitrate for 8 years. The year of the experiment, all plots received 80 kg of mineral N ha^{-1} as unique fertilisation to assess the residual effects of the organic fertilization. We analyzed the density of root branches and the root soluble C content as indicators of rhizodeposition (Henry *et al.*, 2005). Microbial activity was evaluated *in situ* by the measurement of soil respiration and *in vitro* by the intensity of the mineralization of ^{14}C-glucose (Nguyen and Henry, 2002). Gross fluxes of N mineralization and immobilisation were assessed by the ^{15}N isotope dilution technique (Hart *et al.*, 1994). The soil was labelled by adding a $(^{15}NH_4^+)(^{15}NO_3^-)$ solution using the spraying mixing technique, and was extracted at t_1 (24 h) or t_2 (72 h) after labelling. The gross N turnover rates between t_1 and t_2 were calculated using the FLUAZ model (Mary *et al.*, 1998).

In a second laboratory experiment, a single pulse of rhizodeposition was simulated by adding root mucilage or artificial root exudates (ARE) (90µg C /g soil) to the soils that were fertilized with pig manure or ammonium nitrate. Changes in soil mineral N content (nitrate+ammonium) were monitored for one month by destructive samplings of incubators. The mineralization of mucilage and of ARE was followed by the determination of soil respiration trapped in NaOH. Soil incubated without additions of C were used as controls.

Results and discussion

Compared to the ammonium nitrate plots, plants of the organic plots produced significant greater shoot biomass and in the manure plot, roots were more branched and had more soluble C in their tissues. We observed an increase in the soil respiration and in the microbial activity in the rhizosphere soil compared to the bare soil. This rhizosphere effect was more marked in the manure plot than in the ammonium nitrate plot. Taken with the increase in density of root branches and in soluble root carbon, these results suggest that repeated applications of manure enhanced rhizodeposition. Furthermore, gross N mineralization and nitrification rates were strongly enhanced in the slurry and manure amended soils, in comparison with the soils fertilized with ammonium nitrate. Gross immobilization rates were higher than mineralization rates, indicating a net immobilisation of N in the rhizosphere soil for all treatments. Higher rates of N mineralization and immobilisation were observed for the pig slurry/ammonium nitrate site and were likely due the fact that plants of this site were 3 weeks older than those of the pig manure/ammonium nitrate site.

Under controlled conditions, compared to the ammonium nitrate soil, the manure soil demonstrated a higher basal respiration and a higher net N mineralization. When added to the soil, mucilage or artificial root exudates (ARE) were rapidly mineralized at 54%, faster in the manure soil compared to the ammonium nitrate soil, likely in relation to the higher basal microbial activity of the former soil. Microbial assimilation of rhizodeposits induced a rapid immobilization of 0.09 μgN/μg of added C, whatever the soil and the substrate. The N immobilization was followed by a slow net mineralization, which released gradually the N previously immobilized. This mineralization did not depend on the substrate but it was more rapid in the manure soil

Conclusions

In conclusions, our results pointed out that repeated applications of pig slurry or pig manure induced changes in the C and N dynamics in the soils, which persisted one year after the last application, especially for manure. The stimulation of the microbial activity in the rhizosphere was enhanced likely because of a higher rhizodeposition. As expected from the high C/N ratio of the rhizodeposits, gross N immobilisation rates were higher than gross N mineralisation fluxes. Gross mineralisation and nitrification were stimulated in the slurry and manure amended soils, suggesting that the organic fertilization would provide better conditions of N availability to the roots in the rhizosphere. Moreover, the results of the incubations in controlled conditions suggest that the processes of immobilization-remineralization of N that occur during the microbial utilization of rhizodeposits, could contributed to buffer N availability to the plant.

Acknowledgements

Results obtained within the research initiative “Porcherie verte”.

The authors adress special thanks to P. Desvignes and V. Bouetel (ARVALIS) to facilitate the access to the manure/ammonium nitrate site, and to O. Delfosse and P. Marchal and S. Bienaimé (INRA) for their helpful contributions to anayses.

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