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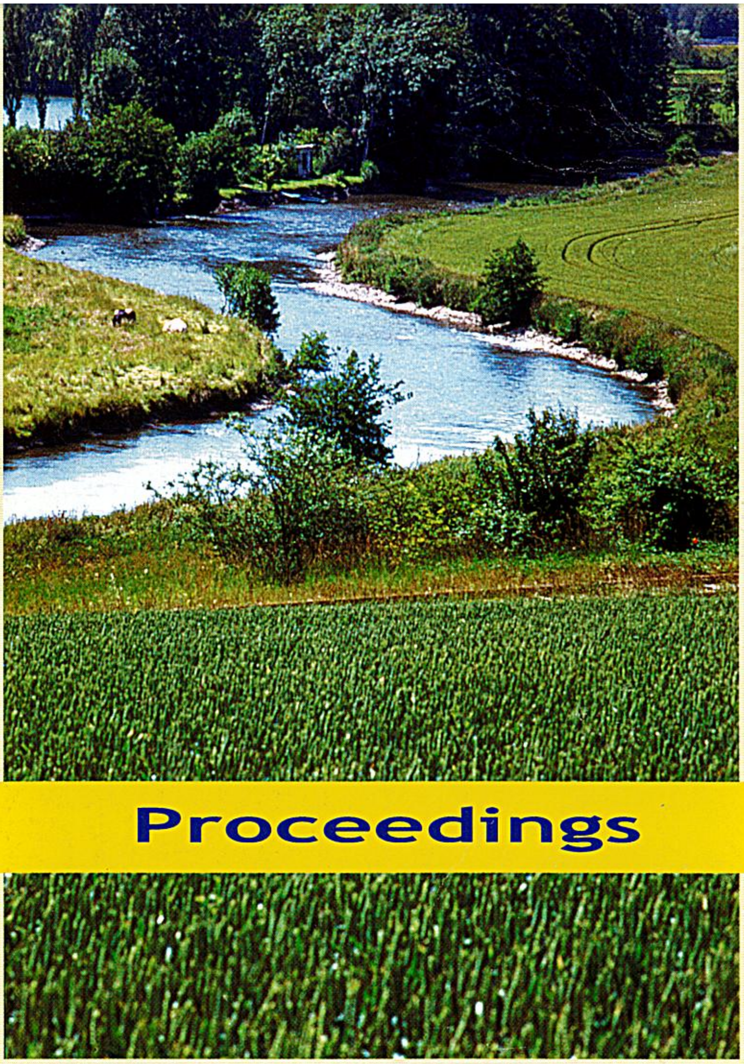

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Introduction

Fertilization of crops with pig manure or pig slurry allows the recycling of effluents. Repeated applications of organic amendments may induce changes in the status of the soil organic matter with significant consequences on soil fertility and on environmental impacts. The present study examined whether one year after the last application, the soil C and N status, the C and N dynamics and the plant growth were changed by a previous 7-10 years long fertilization with pig slurry or composted manure on maize culture.

Materials and methods

We studied two experimental sites cultivated with maize and annually fertilized with composted pig manure (27 t ha^{-1} an^{-1}) *versus* ammonium nitrate for 7 years or with pig slurry (33 m^3 ha^{-1} an^{-1}) *versus* ammonium nitrate for 10 years. The year of the experiment, all plots received 80 kg of ammonium nitrate N ha^{-1} as unique fertilization to assess the residual effects of the previous organic amendements. Soil samples collected at 25 cm depth on june and october 2003 and on march 2004 were used to determine the organic C and N contents, the potential C and N mineralization (270 days incubation at 15°C) and the gross rates of N transformations (^{15}N isotope dilution technique, Hart *et al.*, 1994). Bare soil and rhizosphere soil were also collected (0-15 cm) at the 9-13 unfolded leaves stage and the following variables were determined: gross fluxes of N transformations (only in the rhizosphere soil), microbial activity (*in vitro* mineralization of ^{14}C-glucose, Nguyen and Henry, 2002) and potential denitrification evaluated by the acetylene inhibtion method and quantification of N_2O by gas chromatography. Finally, in a laboratory experiment, changes in soil mineral N content were monitored during incubation of soil with root mucilage or artificial root exudates.

Results and discussion

Compared to fertilization with ammonium nitrate, previous repeated amendements of pig effluents increased the soil organic matter of bare soil: in the slurry plot, the organic C content was increased by +6% and the organic N by +9% and in the manure plot the increase was +16% and +14%, respectively. Compared to the soil fertilized with ammonium nitrate, the potential mineralization of C and N was always higher in the soil amended with pig manure, whereas in the soil fertilized with pig slurry the increase fluctuated with the sampling date (from 0 to +53 % for the net N mineralization). Gross fluxes of N confirmed that the stimulation of the mineralisation-immobilisation turnover (MIT) was higher for pig manure than for pig slurry. Modeling of C mineralization kinetics suggested that previous fertilization with pig manure significantly increased the size of two active organic matter pools.

At the 9-13 leave stage, greater shoot biomass was observed in plots fertilized with organic effluents (x 1, 5-2) compared to the fertilization with ammonium nitrate. In addition, in the manure plot, roots were more branched and had more soluble C in their tissues and the microbial activity in the rhizosphere soil was enhanced, which suggests an increase in root exudation of organic compounds (exudates, mucilage). Furthermore, the gross N mineralization and nitrification rates in the rhizosphere soils were strongly higher in the manure plot than in the ammonium nitrate plot. This may be explained by the rapid microbial assimilation of exudates and mucilage observed *in vitro*, which induced an immobilization of N of 0.09 µgN/µg of added C followed by a slow mineralization of the N immobilized. These results suggest that the stimulation of plant growth in the manure plot may be partially explained by a stimulation of the mineralization/immobilization turnover (MIT) of N in the rhizosphere as a result of an enhanced release of root exudates and mucilage. The effect of the previous fertilization with pig slurry on the MIT of N was less marked and we did not find evidences of an enhanced release of root exudate and mucilage.

Among the two end products of denitrification (N_2 and N_2O), N_2O has an environmental impact because of its contribution to the greenhouse effect. On one hand, during laboratory incubations, the $N_2O/(N_2O+N_2)$ ratio was decreased in the soil amended with slurry or with manure *versus* the soil fertilized with ammonium nitrate and in this latter treatment, in the rhizosphere soil *versus* the bare soil. This modification of the $N_2O/$ (N_2O+N_2) ratio could be due to the shifts that we observed in the structure of the denitrifying bacterial community. On the other hand, previous organic fertilization strongly increased the potential denitrification in bulk and rhizosphere soil. As a result, compared to ammonium nitrate, the potential release of N_2O was increased by the fertilization with pig manure but not by the fertilization with pig slurry.

Conclusions

Our results pointed out that annual and moderate applications of pig slurry or pig manure for 7 to 10 years induced changes in the C and N dynamics in soil, especially for manure, with consequences on plant growth and potential environmental impacts. These effects persisted at least one year after the last application. Hence, when examining the trade off between the positive effects of organic fertilization (increase of soil fertility, recycling of nutrients) and the negative effects (increased production of N_2O by denitrification), both short and mid term time scales have to be considered.

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References

Hart, S.C., Stark, J.M., Davidson, E.A., Firestone, M.K. 1994. Nitrogen mineralization, immobilization and nitrification. Methods of Soil Analysis, Part 2. Microbiological and Biochemical Properties-SSSA, Book, Series, no 5, 985-1018.

Nguyen C., Henry, F. 2002. A carbon-14-glucose assay to compare microbial activity between rhizosphere samples, Biology and Fertility of Soils, 35, 270-276.