Ammonia emissions and potential nitrate leaching in soil amended with cattle slurry: Effect of slurry pre-treatment by acidification and/or soil application method

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Abstract

Ammonia (NH_3) emissions and nitrate (NO_3) leaching are two of the main environmental problems caused by slurry application to soil. Slurry pre-treatment by acidification or separation as well as slurry injection has been proposed to mitigate NH_3 emissions but little is known about their impact on leaching. Hence, a field experiment was conducted to assess the effect of slurry treatment/method on NH_3 emissions and NO_3 leaching in two soils (sandy and loamy soil). Concerning NH_3 emissions, acidified slurries (with and without incorporation) and slurry injection did not lead to any NH_3 volatilization in either soil. Surface application of untreated slurry induced significant NH_3 emissions in the sandy soil but no NH_3 volatilization was observed from the loamy soil. Relative to NO_3 potential leaching, the results between the two soils differed significantly: for the sandy soil, higher values of NO_3 concentration in soil solution were measured in treatments with slurry injection or acidified slurry applied to the soil surface without incorporation ($P<0.05$) than in the other treatments. In this same soil, a significant reduction in potential NO_3 leaching ($p<0.05$) should be achieved by incorporating the acidified slurry. In the loamy soil, smaller differences were observed between treatments, but the injection method led to higher NO_3 concentrations ($P<0.05$) than the other treatment/methods. Considering losses by NH_3 emissions and NO_3 leaching, the best option in sandy soil is the application of acidified slurry followed by incorporation, while in loamy soil the best options are the application of acidified slurries (with or without incorporation).

Introduction

It has been common to use slurry on soils due to its fertilizing value and since it is a practical way for farmers to get rid of this type of waste. However, the application of slurry to soil may have a negative impact on the environment since it may lead to ammonia emissions [1], [2], [3] or/and nitrate leaching [4]. In that sense, many studies have been performed to assess the efficiency of slurry pre-treatment and soil application methods to reduce the environmental impacts described above. Slurry injection is the currently recommended method for slurry applications to soil since it minimizes ammonia emissions [1, 5, 6] but this technique implies high financial investment and is not applicable for some soils [7]. Furthermore, a reduction in ammonia emissions may in some instances lead to an increase in nitrate leaching [8]. Another method shown to be efficient to decrease NH_3 emissions following surface application is slurry acidification [9, 10]. However, it is not clear if surface application of acidified slurry has to be followed by soil incorporation or if this step can be avoided.

Our main hypothesis is that slurry injection could be substituted by surface application of acidified slurry and that soil incorporation of acidified slurry can be avoided.

In that sense, NH_3 emissions and potential NO_3 leaching were measured in two contrasting soils treated with raw cattle slurry injected at 10cm or surface applied and acidified cattle slurry applied to the soil surface and followed or not by incorporation.

Material and Methods

A medium scale experiment ($1m^2$ plots) was performed on two different soils: a sandy soil and a loamy soil. The sandy soil had a pH of 7.03 and its composition was 70% coarse sand, 17% fine sand, 9.7% silt and 2.6% clay; the loamy soil had a pH of 6.11 and its composition was 27.1% coarsesand, 55.8% fine sand, 7.2% slit and 9.9% clay. Cattle slurry was obtained from a commercial dairy farm and one part was acidified with sulphuric acid to pH 5.5 whereas the other half was preserved at its original pH (7.4) (Table 1). Four treatments were applied: untreated slurry injected at 10 cm (SINJ),

surface application of untreated slurry followed by incorporation (SSI), surface application of acidified slurry followed by incorporation (ASI) and without incorporation (ASNI). A control without amendment was also included. Three replicates of each treatment and control were performed. An amount of acidified or untreated slurry equivalent to 90 kg N ha^{-1} was applied to each plot. Ammonia emissions were measured over the first 10 days of experiment using dynamic chambers. For this purpose, we used cylindrical chambers (17.5 cm x 21.0 cm x 5.5cm height) connected to Erlenmeyer flasks containing 200ml of orthophophosric acid (0.05M). A constant air flow (3 l min^{-1}) was maintained in all chambers. Oats were sown ten days after slurry application and nitrate concentration in the soil solution [NO_3] was determined using porous suction cups buried 70cm in the soil in each plot as described in [4]. The ceramic cups were put under suction 24h before raining using a pressure of 60-70kpa. Samples were collected after a raining day and [NO3] measured by molecular absorption spectrophotometry (Skalar). The precipitation and temperature data were recorded by a local station.
Results were analyzed by analysis of variance (one way-ANOVA) to test the effects of each treatment in each type of soil. The statistical software package used was Statistix 7. The LSD (Least Significant Difference) test was used for multiple comparisons of means ($p<0.05$).

Table 1. Main characteristics of the slurry used (mean of 3 replicates)

	pH	**Dry Matter ($g\ kg^{-1}$)**	**Organic matter ($g\ kg^{-1}$)**	**Kjeldhal N ($g\ kg^{-1}$)**	**NH_4^+ - N ($g\ kg^{-1}$)**
Acidified	5.5	8.7	5.8	3.0	1.4
No acidified	7.4	8.0	5.3	3.1	1.5

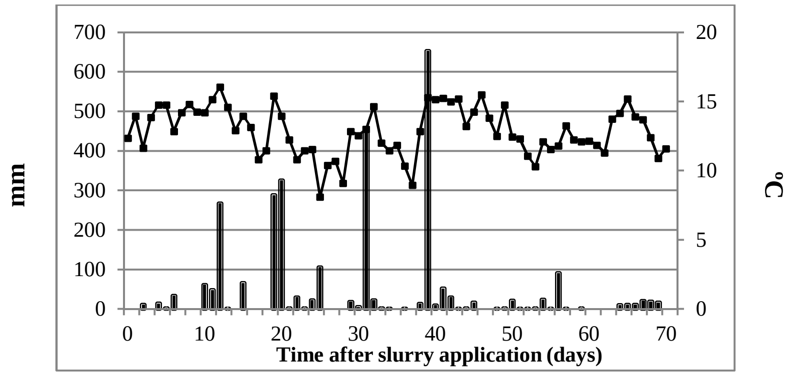

Figure 1. Precipitation and average temperature during the experiment.
Precipitation Temperature

Results and Discussion

Ammonia emission
Significant NH_3 emissions were observed only in the SSI treatment and in the sandy soil whereas in all other treatments, the NH_3 emissions were negligible in both soils throughout the measurement period. The different results obtained with SSI for the two soils may be explained by the higher cation exchange capacity of the loamy soil resulting from its higher clay and organic matter content [11].
According to our results, it is highly recommended to use slurry injection or acidified slurry in sandy soils to minimize NH_3 emissions, while in loamy soil no specific treatment or application method should be required.

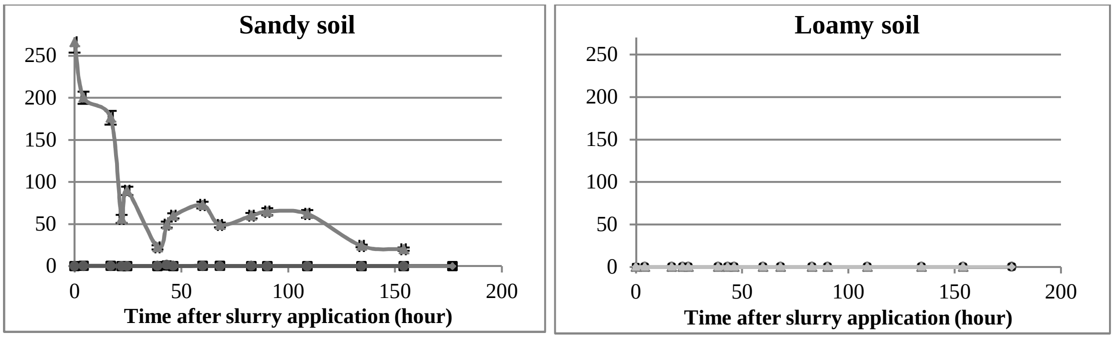

Figure 2. Ammonia emission rates measured in the different treatments considered (N=3)

Control — Injected(SINJ) — Surface INC(SSI) — Acidf INC(ASI) — Acidf No INC(ASNI)

Potential Nitrate leaching

In the sandy soil, the NO_3 concentration in soil solution was very similar (8-17 mg NO_3-N l^{-1}) for all treatments during the first 15 days of experiment but after day 20 (first intense rainfall) significantly higher values were observed in SINJ and ASNI treatments. The NO_3 concentration in SSI was lower than in ASI and ASNI indicating that slurry acidification may lead to an increase in potential nitrate leaching. Furthermore, values from ASNI leachates were always significantly ($P<0.05$) higher than in ASI indicating that incorporation of acidified slurry is important to minimize the negative impact of slurry acidification on nitrate losses. Nevertheless, lower nitrate concentrations were observed in ASI than in SINJ after day 20.

In the loamy soil, greater differences between treatments in terms of NO_3 concentrations in leachates were observed during the first 20 days with highest values in SSI, ASNI and ASI. However, after day 20, the highest values were always observed from SINJ.

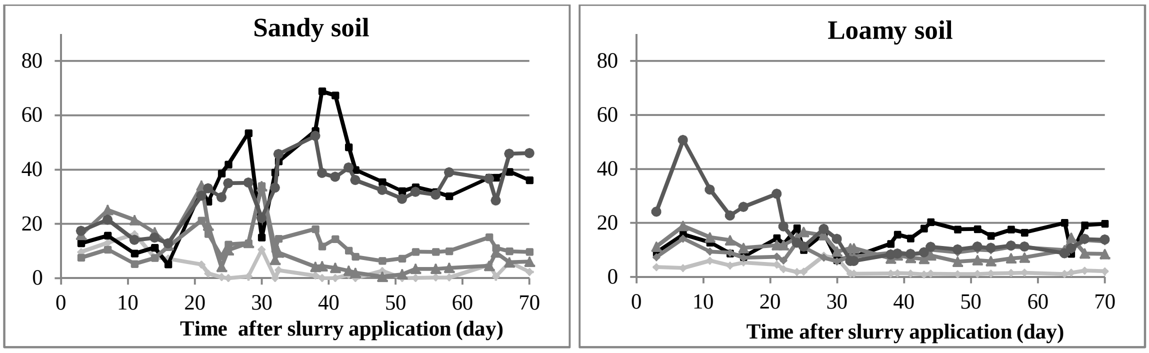

Figure 3. Nitrate concentration in the soil solution sampled in the different treatments considered (N=3)

Control — Injected(SINJ) — Surface INC(SSI) — Acidf INC(ASI) — Acidf No INC(ASNI)

pH and Electrical conductivity (EC)

The pH values did not differ signifncantly between treatments in both soils, indicating that the acidified treatments did not change the pH of soil solution (data not shown).

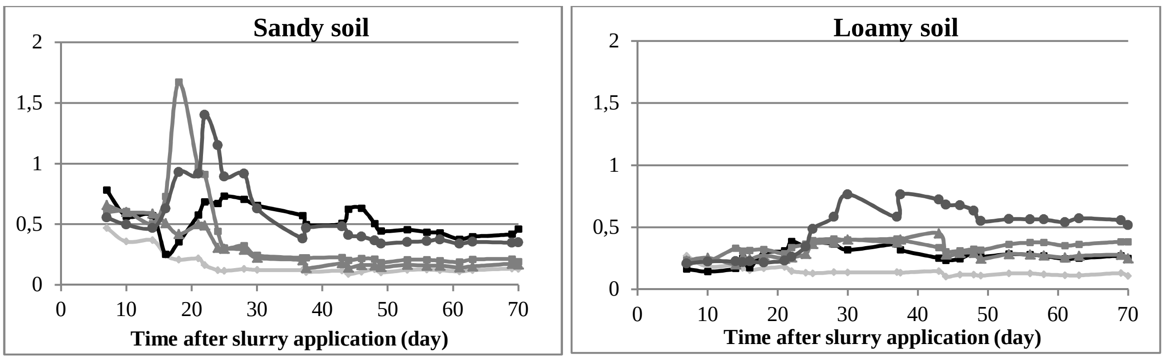

Figure 4. Electrical conductivity of the soil solution sampled in the different treatments considered (N=3)

Control — Injected(SINJ) — Surface INC(SSI) — Acidf INC(ASI) — Acidf No INC(ASNI)

As can be seen in Figure 4, the treatment effect on the EC of soil solution was more significant in the sandy soil than in the loamy soil. In the sandy soil, a significant increase in EC ($p<0.05$) was observed for the acidified slurries (ASI and ASNI) and the SINJ treatments following the first rainfall (days 10-15). As for [NO3], the highest values of EC were observed in SINJ and ASNI treatments from day 20 onwards in the sandy soil.

In the loamy soil, the EC values remained very similar for all amended soils throughout the experiment except for the ASNI treatment in which it increased significantly after day 25 and remained higher than all the other treatments until the end of the experiment.

Conclusion and perspectives

Our results showed that slurry injection may be replaced by surface application of acidified slurry in order to minimize NH_3 emissions. Furthermore, in the case of sandy soil, surface application of acidified slurry followed by incorporation appears to be a more efficient solution than injection of non-treated slurry to minimize NO_3 losses. However, an increase in the EC of the soil solution was observed in both soils when applying acidified slurries (ASI and ASNI).

It can be concluded that acidified slurry with incorporation is the best option to reduce N loss via NO_3 and NH_3 emission in both sandy and loamy soils when compared to slurry injection.

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