Ammonia volatilization from soil amended with swine slurry: effect of application method and use of nitrification inhibitor

Grave Roberto A.[1], **Nicoloso Rodrigo S.**[2*], **Correa Juliano C.**[2], **Cassol Paulo C.**[1], **Aita Celso**[3]
(1) Santa Catarina State University, 88520-000, Lages, SC, BR.
(2) EMBRAPA Swine and Poultry, 897000-000, Concórdia, SC, BR.
(3) Federal University of Santa Maria, 97105-900, Santa Maria, RS, BR.
*Corresponding author: rodrigo.nicoloso@embrapa.br

Abstract

Ammonia volatilization is among the main causes of N loss from agricultural soils. Injection of N fertilizers (swine slurry, urea) could control NH_3-N losses. However, use of nitrification inhibitors like dicyandiamide (DCD) to slow nitrification and denitrification processes could enhance NH_3 volatilization. The objective of this study was to evaluate fertilizer application methods and the use of the nitrification inhibitor dicyandiamide (DCD) over the NH_3 volatilization from a soil amended with swine slurry and urea. A field experiment was established comparing fertilizer application methods: surface broadcast (SB) and injection into the soil (IJ); and fertilization treatments: control without fertilization (CTR), swine slurry (SL), SL+DCD, urea (U), and U+DCD. Fertilizer injection into the soil reduced N losses by NH_3 volatilization by 62%. Use of DCD had no effect over NH_3 volatilization from swine slurry amended soils but could increase N losses when associated to urea.

Introduction

Ammonia volatilization is among the main processes of atmospheric pollution and N loss from agricultural soils. Atmospheric NH_3 could promote changes on rain pH, affect the O_3 layer, and react with NO_2 leading to N_2O formation, a potent greenhouse gas [1]. Returning to soil, NH_3 could enhance NO and N_2O emissions during its nitrification and denitrification [2].

The injection of swine slurry into the soil could control up to 100% of NH_3-N losses in relation to the surface application [3]. However, use of nitrification inhibitors to reduce N losses through NO_3^- lixiviation or N_2O/N_2 emissions could enhance NH_3 volatilization, since the N is maintained for a longer period as NH_4^+ in the soil [4]. The objective of this study was to evaluate fertilizer application methods and the use of the nitrification inhibitor dicyandiamide (DCD) over the NH_3 volatilization from a soil amended with swine slurry and urea.

Material and Methods

Field experiment

The experiment was established in Concordia-SC, BR (27º 18’ 41” S, 51º 59’ 26” W) over a Rhodic Kandiudox and was arranged in a split-plot randomized blocks design with four replications in plots with maize (Zea mays L.). The soil had the following characteristics: clay content: 550 g kg^{-1}; $pH_{(H2O\ 1:1)}$: 5.1, SOM: 41.1 g kg^{-1}, $P_{Mehlich\text{-}I}$: 12 mg dm^{-3}, $K_{Mehlich\text{-}I}$: 321 mg dm^{-3}, Ca: 10.1 $cmol_c$ dm^{-3}, Mg: 3.8 $cmol_c$ dm^{-3}, and CEC: 15.1 $cmol_c$ dm_{-3}.

The investigated fertilizer application methods (main plots) were surface broadcast (SB) and injection (IJ) into the soil. The slurry injector (Figure 1a) was equipped with eight injection lines spaced 0.7 m and regulated to inject the fertilizers 0.1m into the soil. The sub-plots (5x8m) contained the following treatments: swine slurry (SL), swine slurry+DCD (SL+DCD), urea (U), urea+DCD (U+DCD), and a control treatment without fertilization (CTR). Swine slurry (42 m^3 ha^{-1}, 4.4 kg TKN m^{-3}) and urea (329 kg ha^{-1}) were applied to supply 148 kg ha^{-1} of available N for maize crop, considering 80% of N agronomic efficiency for swine slurry [5]. The DCD (10 kg DCD ha^{-1}) was mixed to the swine slurry and urea immediately prior application. In the IJ treatments, urea and urea+DCD were manually applied in the injection lines previously opened by the slurry injector.

Ammonia volatilization assessment

Ammonia volatilization was assessed with polyurethane foam absorbers imbibed with 11 mL of 0.167 mol L^{-1} phosphoric acid solution [6]. The foams measuring 8x8 cm (density 20 kg m^{-3}) were placed above PVC plates (10x10x0.2 cm) and wrapped in a layer of ammonia-permeable and water impermeable polytetrafluoroethylene tape (PTFE). The evaluations started immediately after the application of the treatments and were carried out continuously for 17 days. The foam absorbers were placed distant 1 cm from soil surface inside a perforated metal/wood box (Figure 1b) and were collected for NH_3-N content analysis and replaced every 48h or 72h.

Statistical Analysis

Analysis of Variance (ANOVA) was performed using SAS PROC GLM and the means were compared by the Fisher's LSD test [7] . The results were considered significantly different at $p<0.05$.

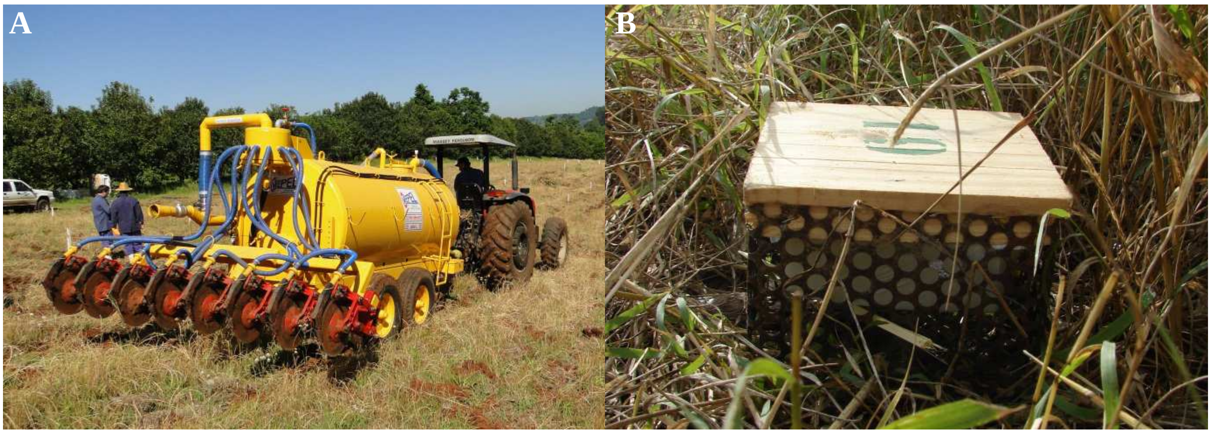

Figure 1. Swine slurry injector (a) and the foam absorbers for assessment of ammonia volatilization from soil (b).

Results

There was no significant interaction between application methods and fertilization treatments (p=0.1572). After 17 days of evaluation, NH_3-N volatilization on the average of SB and IJ treatments was 7.4±4.1 and 2.8±2.0 kg NH_3-N ha^{-1}, respectively (Figure 2). Although the injection of mineral and organic fertilizers into the soil decreased 62% the NH_3-N volatilization in comparison to surface broadcast, ANOVA showed no significant differences among SB and IJ application methods on the average of fertilization treatments (p=0.0685).

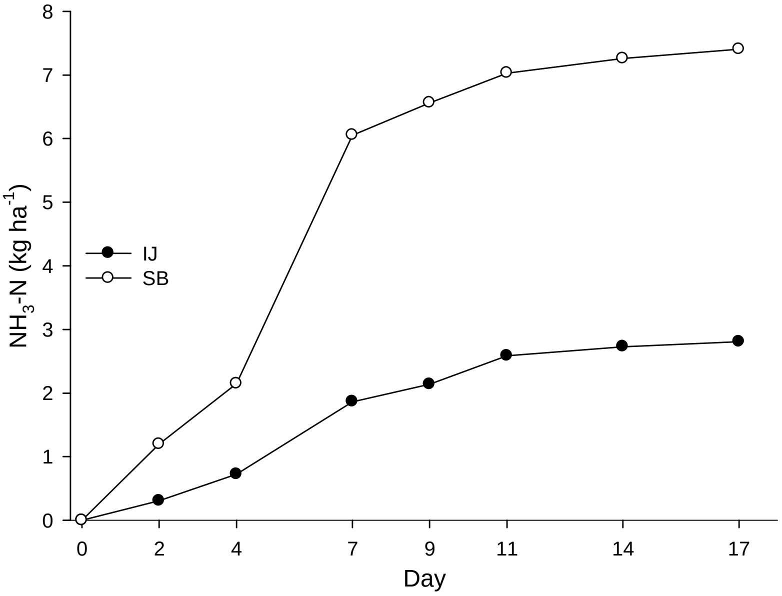

Figure 2. Cumulative NH_3-N emissions from soil according fertilizer application methods. SB: Surface broadcast; IJ: Injection into the soil.

Total NH_3 volatilized from control treatment without N amendment achieved 2.2±0.6 kg NH_3-N ha^{-1}, on the average of application methods (Figure 3). No significant increases on NH_3-N losses were registered from soil amended with SL, SL+DCD and U (2.6±0.7, 2.4±0.4, and 7.0±3.3 kg NH_3-N ha^{-1}, respectively). Use of the nitrification inhibitor DCD with urea increased NH_3-N losses to 11.2±3.4 kg NH_3-N ha^{-1}. U+DCD had NH_3-N losses similar to U treatment, but was significantly different from CTR, SL, and SL+DCD treatments ($p=0.0035$).

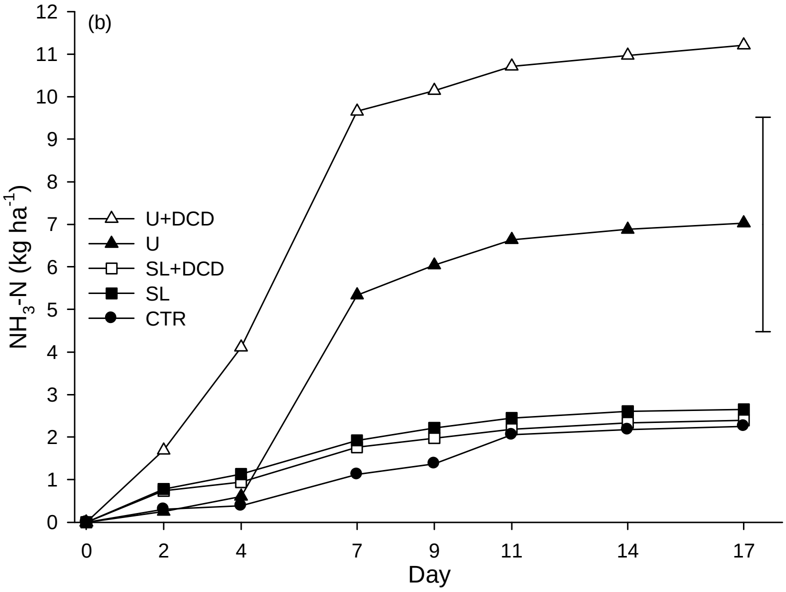

Figure 2. Cumulative NH_3-N emissions from soil according fertilization. CTR: control without fertilization: SL: swine slurry; SL+DCD: swine slurry + dicyandiamide; U: urea; U+DCD: urea + dicyandiamide. Vertical bar represents the LSD ($p<0.05$) for total NH_3-N losses after 17 days of evaluation.

Lower NH_3-N losses from swine slurry than from urea amended soils could be related to the lower input of NH_4^+-N to the soil (114 and 148 kg NH_4^+-N ha-1, respectively), since 62% of total N from swine slurry was in the organic form. Rapid infiltration of swine slurry into the soil could have also reduced NH_3-N volatilization in relation to urea [4]. Higher concentration of NH_4^+-N in the urea injection line and inhibition of nitrification by DCD could have increased NH_3-N in the U+DCD treatment.

Conclusion and perspectives

Fertilizer injection into the soil reduced N losses by NH_3 volatilization by 62% in relation to surface broadcast. Use of DCD had no effect over NH_3 volatilization from swine slurry amended soils but could increase N losses when associated to urea. These results should be confirmed in further studies.

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