



Investigating sources and sinks for ammonia exchanges between the atmosphere and a wheat canopy following slurry application with trailing hose



Erwan Personne^{a,*}, Florence Tardy^b, Sophie Générumont^a, Céline Decuq^a, Jean-Christophe Gueudet^a, Nicolas Mascher^a, Brigitte Durand^a, Sylvie Masson^a, Michel Lauransot^a, Christophe Flécharde^c, Jürgen Burkhardt^d, Benjamin Loubet^b

^a UMR 1091 Environnement et Grandes Cultures, INRA-AgroParisTech, 78850 Thiverval-Grignon, France

^b UR 26 Systèmes de culture à base de bananiers, ananas et plantains, CIRAD, Station de Neufchâteau, Sainte Marie, 97130 Capesterre-Belle-Eau, Guadeloupe FWI, France

^c UMR 1069, SAS, INRA-AgroCampus Ouest, 65 Rue de Saint-Brieux, 35042 Rennes, France

^d University of Bonn, Institute of Crop Science and Resource Conservation, Plant Nutrition Group, Karlrobert-Kreiten-Str. 13, 53129 Bonn, Germany

ARTICLE INFO

Article history:

Received 24 September 2014

Received in revised form

19 December 2014

Accepted 5 March 2015

Keywords:

Biosphere-atmosphere exchanges

Compensation point

Reactive nitrogen

Model

Fertilizer application

Field

Wheat

ABSTRACT

Ammonia exchanges between the atmosphere and terrestrial ecosystems are composed of several pathways including exchange with the soil, the litter, the plant surfaces (cuticle) and through the stomata. In this study, the fate of nitrogen in the different pools (soil and plant) was analyzed with the aim of determining the sources and sink of atmospheric ammonia after slurry application on a wheat canopy. To do this, we measured ammonia exchanges between a winter wheat canopy and the atmosphere following cattle slurry application with a trailing hose. From 12 March to 8 April in Grignon near Paris, France, the ammonia fluxes ranged from an emission peak of $54,300 \text{ NH}_3 \text{ ng m}^{-2} \text{ s}^{-1}$ on the day of slurry application (with a median during the first 24 h of $5990 \text{ NH}_3 \text{ ng m}^{-2} \text{ s}^{-1}$) to a deposition flux of $-600 \text{ NH}_3 \text{ ng m}^{-2} \text{ s}^{-1}$ (with a median during the last period of $-16 \text{ NH}_3 \text{ ng m}^{-2} \text{ s}^{-1}$). The ammonia compensation points were evaluated for apoplasm, foliar bulk, root bulk and litter bulk tissue, as well as for soil surface. Ammonia emission potentials defined by the ratios between the concentration in $[\text{NH}_4^+]$ and $[\text{H}^+]$ for each N ecosystem pool were in the same order of magnitude for the plant decomposed in apoplasmic liquid, green leaf bulk tissue and cuticle, respectively, averaging at 73, 160 and 120; in green leaf bulk tissues, the emission potential decreased gradually from 230 to 78 during the period after slurry application, while in the dead leaf bulk tissues considered as litter, the emission potential reached a maximum of 50,200 after application stabilized at around 20000. The dynamic of the emission potential for roots was similar to the ammonium concentration in the first two centimeters of the soil, with a maximum of 820 reached two days after application and a minimum of 44 reached three weeks later. The surfatm- NH_3 model interpreted the emission and deposition fluxes by testing soil surface resistance. We conclude that emission of the first day application was driven by climatic conditions and ammonia concentration at the soil surface, with no surface resistance and with only soil surface emission potential. On the next three days, the ammonia emission originated from the soil surface with the growth of a dry surface layer inducing surface resistance and regulated by slurry infiltration. The following days need a more detailed description of soil surface processes and the integration of vegetation exchanges (stomatal and cuticle pathways), particularly in the last period, in order to explain the ammonia deposition.

© 2015 Z. Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

1. Introduction

Since the discovery of the “Haber-Bosch process” (Howard and Rees, 1996), synthetic fertilizer production has increased the

quantity of reactive nitrogen (Nr) dispersed in the environment, leading to a series of impacts, labelled collectively as the nitrogen cascade (Galloway et al., 2008). Reactive nitrogen accumulation in the environment is contributing to the acidification and eutrophication of ecosystems and the impact of air quality and greenhouse gas balance (Sutton et al., 2011). One of the most mobile reactive nitrogen compounds is ammonia (NH_3) and its mobile ionic form ammonium (NH_4^+) which is mainly emitted by agriculture

* Corresponding author. Tel.: +33 1 30 81 55 70; fax: +33 1 30 81 55 63.
E-mail address: erwan.personne@agroparistech.fr (E. Personne).

and especially livestock farming (Hertel et al., 2012; Webb and Misselbrook, 2004). Cultivated fields, especially after land spread manure, also emit ammonia (Sommer et al., 2003). Croplands can however be a source or a sink of ammonia, depending on the difference between the concentration above and within the canopy (Spirig et al., 2010; Sutton et al., 1993b). The NH_3 exchanges between the atmosphere and terrestrial ecosystems are composed of several pathways including exchange with the soil, the litter, the plant surfaces (cuticles) and through the stomata (Massad et al., 2010; Nemitz et al., 2004; Sutton et al., 2009). These exchanges always include equilibrium processes between the gaseous and the aqueous phase (the Henry equilibrium), and acid-base equilibrium either in the apoplast (Massad et al., 2008), in the water layer on the cuticles (Burkhardt et al., 2009; Flechard et al., 1999) or in the soil (Genermont and Cellier, 1997). For each compartment involved, a compensation point can be defined (soil, litter, apoplast, and cuticle). Several factors regulate stomatal fluxes such as plant metabolism, development stage, nitrogen status and climatic conditions (Massad et al., 2008). Factors impacting deposition on cuticles are the presence of liquid water on the cuticle and the pH of this water, which is itself dependent on the acid and basic compounds in this water layer (Burkhardt et al., 2009; Flechard et al., 2011).

Because of its complexity, the NH_3 exchange between terrestrial ecosystems and the atmosphere is still not very well parametrized in models, despite recent advances towards general schemes (Flechard et al., 2013; Massad et al., 2010). Comprehensive datasets including NH_3 fluxes as well as NH_x content of each compartment of the ecosystems are required to improve our qualitative understanding and provide parametrization for the ammonia exchange models. This is especially true for bi-directional NH_3 exchanges over crops which have rarely been studied after fertilizer application (Bash et al., 2010; Cooter et al., 2010; Loubet et al., 2012; Walker et al., 2012). Measurements of NH_3 emissions using up-to-date methods over large fields are also required to validate NH_3 emission factors as there are doubts about early work on NH_3 emissions using small fields (Sintermann et al., 2012).

In order to properly understand the ammonia exchanges with the atmosphere, we analyzed the fate of the nitrogen in the different pools (soil and plant) with the objective of determining the sources and sink of atmospheric ammonia after slurry application on a wheat canopy. The focus was on the evolution of the concentrations of the different forms of nitrogen for the compartments potentially involved by this slurry application (soil and plant) and so investigating the origin of the key exchanges with the atmosphere.

The experiment took place near Paris during the stem elongation development stage. Apart from NH_3 fluxes and concentrations, the NH_x and NO_3^- content were measured in most compartments at several dates. Chemical compounds on the cuticles were also extracted and analyzed. The Surf_{atm}- NH_3 model (Personne et al., 2009) was used to interpret the observations. Finally, the location, magnitude and temporal pattern of the sources and sinks of NH_3 in the canopy are discussed.

2. Materials and methods

2.1. Field site

The experimentation took place at the Grignon site (NitroEurope IP field site FR-Gri 48°51'N, 1°58'E) about 30 km west of Paris, France, from 12 March to 5 April 2012. The field was a 19 ha winter wheat crop (*Triticum aestivum* cv. Premio), located on a plateau with a gentle slope of 1%, sown on 20 October 2011 at a theoretical density of 230 seeds per m^2 (measured 126 ± 23). The soil type was a luvisol (loamy clay: 25% clay, 70% silt and 5% sand).

The mean annual precipitation and temperature were 700 mm and 11.5 °C, respectively. The field was surrounded by other agricultural fields and a livestock farm approximately 500 m to the south-west (220–240 deg wind direction sector). Two kilometres further in the same direction was a waste incineration plant. During the experimentation, the main wind directions were north-west to south-west.

The field was managed with a maize/winter wheat/winter barley/or triticale, mustard or *Phacelia* rotation. The previous crop was maize which was harvested on 6 September 2011 and stalks left on the ground prior to reduced tillage and wheat seedling on 17 September 2011. This field has been managed with reduced tillage since 2000.

The field was fertilized on 13 March 2012 with cattle slurry using a trailing hose system at a target rate of 120 kg N ha^{-1} . On 23 March, a growth reducer, chlormequat chloride (2-chloroethyl-trimethyl-ammonium chloride, $\text{C}_5\text{H}_{13}\text{Cl}_2\text{N}$) was applied at a rate of 0.92 kg ha^{-1} , which corresponds to a 90 g N ha^{-1} and 413 g Cl ha^{-1} .

Soil, plants and slurry were sampled on three 10 × 10 m sampling plots before and after fertilization. These plots were chosen within a 50 m radius around the flux tower. The crop was at stem elongation (stage 5 on Feekes' scale, (Zadoks et al., 1974)) during the experiment. From 29 February to 26 March the crop grew from 0.15 m to around 0.30 m height and the leaf area index (LAI) increased from 0.45 to 1.2 $\text{m}^2 \text{m}^{-2}$.

2.2. Micrometeorological measurements

The three components of the wind velocity (u, v, w) and temperature (T_{son}) were measured using an ultrasonic anemometer (Gill Instruments Ltd., UK) at 50 Hz 3 m above the ground. The CO_2 and H_2O concentrations were measured at 20 Hz with an open-path infra-red gas analyzer (Licor, Li-7500, USA) at the same height. The latent (LE) and sensible (H) heat fluxes were determined with the Eddy-covariance method. The LE fluxes were corrected with the Webb Pearson Leuning method for the variations in air density due to heat and water vapour fluxes (Aubinet et al., 2000). An HMP-45 (Vaisala, FI) was used to record air temperature (T_a) and relative humidity (RH) at 3 m height. Global (R_g) and net (R_n) radiation were measured at 3 m height, respectively, with a pyranometer (CM7B Albedometer Kipp & Zonen, NL) and a pyrrometer (NR-Lite, Kipp & Zonen, NL). The soil temperature (T_{soil}) was measured at 7 depths, with homemade copper-constantan thermocouples between 0 and 20 cm (0.5 cm, 2 cm, 5 cm, 10 cm, 20 cm) and with temperature probe (107, Campbell Sci. USA) at 30 and 90 cm. The soil water content (SWC) was recorded with TDR probes (CS616 time domain reflectometry, Campbell Sci. USA). Potential leaf wetness (DH) was measured with 237 wetness sensing grids (Campbell Sci. USA) and precipitations with an ARG 100 tipping bucket rain-gauge (Campbell Sci. USA). Full details of the micrometeorological measurements can be found in Loubet et al. (2011).

2.3. Ammonia concentrations and fluxes

Ammonia concentration was integrated during 30 min at 1.6, 0.75 and 0.4 m above ground using the ROSAA device (Robust and Sensitive Ammonia Analyzer, patent registration 10 55253, UCPI, France). The ROSAA analyzer is based on trapping atmospheric ammonia in a continuous flow of an 0.5 g L^{-1} H_2SO_4 acid solution drained through three low-flow vertical glass wet denuders. The acid solution is then analyzed with a conductimeter equipped with a semi-permeable membrane for ammonia selectivity. A detailed description of the analyzer can be found in (Loubet et al., 2012). The calibration was performed with standard solutions varying from 50, 100, 250 and 500 $\mu\text{g NH}_4^+ \text{kg}^{-1}$ to 230, 530, 750 and 1000 $\mu\text{g NH}_4^+ \text{kg}^{-1}$ passed every 2 h. A quality control was performed by

Download English Version:

<https://daneshyari.com/en/article/6537295>

Download Persian Version:

<https://daneshyari.com/article/6537295>

[Daneshyari.com](https://daneshyari.com)