Soil & Tillage Research 169 (2017) 54–64

Contents lists available at ScienceDirect

Soil & Tillage Research

journal homepage: www.elsevier.com/locate/still

Impact of slurry strip-till and surface slurry incorporation on NH_3 and N_2O emissions on different plot trials in Central Germany

Benjamin Pietzner[a,*], Jan Rücknagel[a], Barbara Koblenz[a], Denise Bednorz[a], Nadine Tauchnitz[b], Joachim Bischoff[b], Sarah Köbke[c], Katharina H.E. Meurer[d], Ralph Meißner[e], Olaf Christen[a]

[a] Martin-Luther-University Halle-Wittenberg, Department of Agronomy and Organic Farming, Betty-Heimann-Str. 5, 06120 Halle/Saale, Germany
[b] Landesanstalt für Landwirtschaft, Forsten und Gartenbau, Strenzfelder Allee 22, 06406 Bernburg, Germany
[c] Georg-August-University Göttingen, Department of Crop Science, Plant Nutrition & Crop Physiology, Carl-Sprengel-Weg 1, 37075 Göttingen, Germany
[d] Helmholtz-Centre for Environmental Research – UFZ, Department of Soil Physics, Theodor-Lieser-Str. 4, 06120 Halle, Germany
[e] Helmholtz-Centre for Environmental Research – UFZ, Department Soil Physics, Lysimeterstation, Falkenberg 55, 39615 Altmaerkische Wische, Germany

ARTICLE INFO

Article history:
Received 8 August 2016
Received in revised form 13 January 2017
Accepted 16 January 2017
Available online 4 February 2017

Keywords:
Greenhouse gases
Nitrous oxide
Ammonia
Slurry-strip-till
Lysimeter
Nitrification inhibitor

ABSTRACT

Greenhouse gases (GHG) cause damage to the biosphere and atmosphere, and essentially lead to a reduction in fertilization efficiency. Different slurry application techniques can influence the emission of GHG. In the years 2014 and 2015, two parallel trials (sites: Lückstedt and Kossebau) and one lysimeter trial (site: Falkenberg) were set up in Central Germany (federal state: Saxony-Anhalt) in order to investigate the influence of the slurry strip-till method on ammonia (NH_3) and nitrous oxide (N_2O) emissions when compared to surface slurry incorporation. The effect of the nitrification inhibitor (NI) (PIADIN®) on GHG emissions was also examined. NH_3 was measured using a combination of passive samplers and the Dräger Tube method (DTM). N_2O was measured using the closed chamber method (CCM) both in the maize row and in the interrow space. In the two years of the experiment, NH_3volatilization fluctuated between 0.6 and 3.5 kg NH_3-N ha^{-1}. In 2014, the slurry strip-till treatments in Lückstedt emitted significantly less NH_3 than surface slurry incorporation. In 2015, at the Kossebau site NH_3 volatilization was significantly lower in the treatments with NI than those with no NI. In both years, N_2O emissions were between 0.5 kg and 2 kg N_2O-N ha^{-1}.

In the lysimeter trial, in 2014 significantly higher N_2O emissions were detected in the unfertilized control than in the fertilized treatments. In the plot trial in Kossebau, in 2015 significantly lower N_2O emissions were recorded in the row than interrow. These differences are probably due to the uptake of mineral nitrogen by the plants in the row as a starting material for nitrification and denitrification. In Kossebau there were significant correlations between N_2O emissions and soil temperature. As regards the slurry strip-till method, no significant reduction in N_2O emissions was observed in comparison to surface slurry incorporation. The influence of the slurry strip-till method on NH_3 and N_2O emissions depends on annual weather conditions and it cannot generally be regarded as preferable to conventional, surface slurry incorporation.

1. Introduction

Although nitrogenous fertilizers are used to increase yield and quality, this leads to the release of gases which are harmful to the climate, including nitrous oxide (N_2O) and ammonia (NH_3) (Senbayram et al., 2009). Agriculture is responsible for approximately 11% of anthropogenic GHG emissions and 58% of N_2O emissions globally (Burney et al., 2010). Of all GHG, N_2O has the greatest impact on climate. It has a global warming potential (GWP) value of 298 times that of CO_2 (Robertson et al., 2000; Halvorson et al., 2011). NH_3 is a precursor that may contribute to the formation of GHGs. By contrast, due to its short atmospheric lifetime NH_3 has an indirect impact on climate, but it induces the formation as well as a longer lifetime of more climate-relevant gases elsewhere, such as N_2O. It is postulated that approximately 1–2% of NH_3 nitrogen is reemitted as N_2O nitrogen (IPCC, 1997; Wulf et al., 2002). GHGs contribute to the destruction of the ozone

* Corresponding author.
E-mail address: Benjamin.Pietzner@landw.uni-halle.de (B. Pietzner).

http://dx.doi.org/10.1016/j.still.2017.01.011

layer in the stratosphere (Hosen et al., 2002). GHGs also enter into other ecosystems via wind and rainfall (Basten, 2010). As a result, sensitive areas may be subject to eutrophication and soil degradation may occur (Van der Molen et al., 1988; Dosch and Gutser, 1996). The further effect attributed to GHGs is a reduction in fertilization efficiency, meaning that lost N has to be purchased in the form of mineral fertilizer (Dosch and Gutser, 1996). For a number of years now there have been targeted efforts to reduce harmful emissions globally. To this end, Germany has entered into a number of international agreements (DeBaey-Ernsten, 2010). Countries that have signed the United Nations Framework Convention on Climate Change ("Kyoto Protocol") are required to develop a national system for estimating anthropogenic emissions of trace gases that are responsible for global warming (UNFCCC, 1997). Application technique has a major impact on the emission of GHG, especially when using an organic fertilizer (Hansen et al., 2003). In Central Europe, organic fertilizers are mainly applied to the surface slurry incorporation of the field before being worked approximately 6–8 cm into the soil using a disc harrow or field cultivator. One new option for spreading slurry is the slurry strip-till method. Advances in slurry technology mean it is possible to deposit the slurry inside a slit approximately 20 cm deep beneath the subsequent seed row. This area, which can be reached by the plants, contains a high concentration of nutrients. The method is a combination of reduced tillage in the form of strip tillage with a slurry injection (Nowatzki et al., 2009). The basis of the slurry strip method is the strip-till method. It was developed in Canada in around 1980 and grew out of the no-tillage approach (Horsch et al., 2011). This method soon also become widespread in the US for crops such as maize, soya beans, sugar beets, sunflowers, peanuts and cotton (Luna and Staben, 2003; Mitchell et al., 2009; Nowatzki et al., 2009). This tillage method involves no turning of the soil, with only the subsequent seed row being loosened (Röseler et al., 2010). This is a departure from the conventional approach of surface slurry incorporation, leaving approximately 60% of the soil surface untilled and covered with dead plant material (Gajri et al., 1999). While in the US the strip-till method is used in intensive farming due to the occurrence of droughts, in Europe it is an extensive farming measure.

In Central Europe, the nutrient requirements of maize (*Zea mays* L.) are usually covered by organic fertilization, above all with slurry (Daudén and Quílez, 2004; Nevens and Reheul, 2005; Berenguer et al., 2008). The nitrogen effect of organic fertilizers is more complex and thus more difficult to predict than that of mineral fertilizers. Organic fertilizers act predominantly through the nitrogen pool in the soil. Milieu conditions in animal excrement, which influence the degree of emissions, are extremely complex and it is virtually impossible to simulate these in the laboratory (Fless aand Beese, 2000b). For this reason, realistic emission measurements are required in the field. Previous trials in the open air have investigated emissions on grassland and arable fodder with an open-slot application (Rubaek et al., 1996; Smith et al., 2000). Other investigations only involved depositing slurry at a depth of 10–15 cm (Dosch and Gutser, 1996; Dell et al., 2012) or using a mineral fertilizer in maize cultivation in combination with the strip-till method (Drury et al., 2006; Halvorson et al., 2011). So far there are no publications dealing with the direct influence of the slurry strip-till method on the release of GHG in maize cultivation at a slurry application depth of 20–25 cm. Furthermore, it has been found that working slurry deep into the soil can result on the one hand in a reduction in NH_3 volatilization, and on the other increased emissions of the GHG N_2O (Rubaek et al., 1996; Flessa and Beese, 2000a,b; Wulf et al., 2002).

The aim of this study was to investigate whether the slurry strip-till method can contribute to a reduction in GHG emissions in maize cultivation in Central Europe. This involved attempting to quantify and evaluate nitrogen losses through N_2O emissions and through NH_3 volatilization following organic fertilization under field conditions when cultivating silo maize using different application methods. Furthermore, it was to be examined what effects both the fertilized seed row and the interrow have on N_2O emissions. This study should contribute to more accurately assessing the potential of different application methods for reducing emissions.

2. Materials and methods

2.1. Trial locations

2.1.1. Falkenberg

At the UFZ lysimeter station in Falkenberg (Germany, federal state Saxony-Anhalt, 52.51° N, 11.48° O; 21 m above sea level), investigations were carried out in 2014 to examine N_2O emissions under different slurry application methods. In the year 1981, non-weighable, box-shaped gravitation lysimeters were set up in Falkenberg and manually filled with soil. The lysimeters are square in shape and 1 m^2 in size, with a depth of 1.25 m. The soil is from former agricultural land from the local region (Germany, federal state Saxony-Anhalt, 52.50° N, 11.39° O; 37 m above sea level), situated approximately 12 km southwest of the lysimeter station (Meissner et al., 2010). The proportions of sand, silt and clay in the topsoil are 73.6%, 14.3% and 12.1% respectively (soil class: sandy loam, (USDA, 1997)). The C_{org} content is 1.1% and the soil has a pH value of 5.8 (Aust et al., 2010). The soil was manually added to the lysimeters, with the topsoil and subsoil having been removed separately and homogenised. Topsoil material was used for the top 30 cm, and the rest forms the subsoil. Bulk density in the lysimeteris 1.50 g cm^{-3}. Lysimeter experiments are an appropriate means of examining relationships of cause and effect. They can be used to simulate small-scale effects of processes and transfer these to larger scales, enabling an objective and comparative assessment (Müller, 2015). Due to the close geographical proximity of all three of the experimental sites, the entire area under investigation is located in the continentally influenced climate area of the temperate zone, with a long-term precipitation level of 540 mm and maximum precipitation falling in June and July (Meissner et al., 2010) and a long-term average temperature of 8.5 °C (long-term mean from 1961 to 1990). Changes in air temperature and precipitation levels during the study are shown in Fig. 1. March 2014 started off very dry, with the first precipitation falling in the middle of the month. At around 30 mm, in both years the highest daily rainfall levels were measured during the summer. What was particularly striking in the daily changes in temperature were the large fluctuations in June and July. The temperature dropped significantly from October.

2.1.2. Lückstedt

In parallel to the lysimeter experiments, a field trial was conducted at the same time in Lückstedt (Germany, federal state Saxony-Anhalt, 52.50° N; 11.35° E; 34 m above sea level) The site is located approximately 16 km southwest of the lysimeter station. The soil corresponds to that of the lysimeter in Falkenberg (soil class: sandy loam (USDA, 1997), soil type: Stagnic Gleysol Luvisol (FAO, 1998)). In May the experiments involved mineral fertilization in addition to organic fertilization.

2.1.3. Kossebau

The test site in Kossebau (Germany, federal state Saxony-Anhalt, 52.49° N; 11.33° E; 27 m above sea level) is located around 3 km southwest of the Lückstedt test site. The soil at the Kossebau site is very similar to that of the other two sites of the slurry strip-till experiment, since it comes from the local region not far from