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Effect of the nitrogen fertiliser rate on the nitrous oxide flux from haplic luvisol soil in the laboratory experiment

T. Šima[1,*], L. Nozdrovický[2], K. Krištof[3], M. Dubeňová[4] and J. Krupička[5]

[1,2,3]Slovak University of Agriculture in Nitra, Faculty of Engineering, Department of Machines and Production Systems, Tr. A. Hlinku 2, 94976 Nitra, Slovak Republic;
[*]Correspondence: tomasko.sima@gmail.com
[4]Slovak University of Agriculture in Nitra, Faculty of Engineering, Department of Production Engineering, Tr. A. Hlinku 2, 94976 Nitra, Slovak Republic
[5]Czech University of Life Sciences Prague, Faculty of Engineering, Department of Agricultural Machines, Kamýcká 129, 16521 Prague, Czech Republic

Abstract. The aim of the experiment was to study the effect of the variable rate of nitrogen fertiliser on the amount of nitrous oxide (N_2O) flux from the soil within a laboratory experiment. We have conducted experiments for 30 days under laboratory conditions in order to eliminate the effect of field factors which could affect the results. During the experiment the nitrogen fertiliser DASAMAG® (manufacturer DUSLO, Inc., Slovakia) was used. The haplic luvisol soil properties were determined by pedological analysis. The amount of N_2O emissions emitting from soil was measured by photo-acoustic field gas monitor INNOVA 1412 with multipoint sampler INNOVA 1309. There were carried out 3 variants of the experiment (application rates 0, 500 and 1,000 kg ha^{-1}) with two replications. The fertiliser was incorporated into the soil in sampling tubes to a depth of 80 mm after 24-hours measurement. Subsequently, after every 24 hours of measurements, 48 hours rest was carried out, and this measuring cycle was repeated 10 times. During the experiment the concentration of emissions in sampling tubes considerably varied in comparison with the emissions concentration before fertilising. Maximum values were measured on the 24th day after incorporation of fertiliser for both application rates. The results of our experiment show that the application rate of fertiliser has a significant effect on N_2O flux and have confirmed the importance of the accurate and even fertilisers application in order to eliminate the negative environmental effects.

Key words: nitrous oxide, soil emissions, fertilising, application rate.

INTRODUCTION

Nitrogen fertilisation is an important factor affecting crop yields (Ložek et al., 1997; Ambus et al., 2011). The use of fertilisers is considered as a very important factor to intensify crop production (Šima et al., 2011). Nitrous oxide (N_2O) emissions from agriculture are ranged from 60% (IPCC, 2007) to 75% (Jackson et al., 2009) of the N_2O emissions produced in the world. Agricultural soils are a major source of atmospheric N_2O (Ruser et al., 2001). Global atmospheric concentration of N_2O has increased significantly within the last 150 years and it directly affects the atmospheric

environment – increased GHG emissions. In addition, the global warming potential (GWP) of nitrous oxide is 298-times higher in comparison with carbon dioxide (IPCC, 2007). It means that N_2O is one of the major greenhouse gases and contributes to stratospheric O_3 (ozone) depletion (Skiba et al., 2001). Usage of fertilisers is currently connected with the increased flux of N_2O emissions from the soil into the atmosphere (Jones et al., 2007; He et al., 2009; Pang et al., 2009; Lin et al., 2010). Nitrous oxide is produced in soil mainly by two biological processes: nitrification and denitrification (Davidson, 1991; Williams et al., 1992; Ložek et al., 1997; Ambus et al., 2006). Inaccurate application of fertiliser causes the local overdosing of fertiliser on the field surface resulting in an increased release of CO_2 and N_2O from the soil into the atmosphere (Šima et al., 2012[b]; Šima et al., 2012[d]). It is apparent than the improved work quality of a fertiliser spreader has a positive environmental effect. The incorrect application rate of fertiliser can result in the increased cost of fertilisers, reduction of crop growth and also negative environmental effects. Therefore for effective application it is necessary to know the transversal uniformity of the fertiliser distribution on the field surface (Šima et al., 2011; Šima et al., 2012[b]; Šima et al., 2012[d]).

The amount of N_2O emissions released from soil into the atmosphere is affected by many factors such as nitrogen application rate, soil properties (pH reaction, humidity, texture, organic matter content, temperature) and weather conditions. The most important of these factors is the size of the application rate of fertiliser. Mainly because local overdosing causes an increased concentration of nitrogen on the fields. And at the same time an increased amount of nitrogen fertiliser is unusable for plants and in many cases it is harmful to the environment.

The aim of this paper is to study the effects of solid fertiliser application rates on the production of N_2O emissions under laboratory conditions. Extreme application rates were used to highlight the nitrogen fertiliser impact on the nitrous oxide emissions released from soil into the atmosphere.

MATERIALS AND METHODS

During the experiments the soil samples were collected by six sampling probes from one specific location. Used sampling probes are used for collecting of soil samples (Šima et al., 2012[a]; Šima et al., 2012[c]; Šima & Dubeňová, 2013). The aim was to obtain soil samples with uniform soil properties and reduce the natural heterogeneity of soil properties across the arable fields. Nitrous oxide released from the soil into the atmosphere was measured in non fertilising collected sampling probes for 24 hours. Subsequently, there were incorporated an equivalent amount of application rates of the fertiliser to the soil in the sampling probes under laboratory conditions. There were used three variants of fertiliser application rate: 0 kg ha^{-1}, 500 kg ha^{-1}, 1,000 kg ha^{-1} and with two repetitions for each variant. Measurements were started 48 hours after fertiliser incorporation and were carried out for 24 hours with 48 hours rest between the measurements, and this measuring cycle was repeated 10 times.

Soil properties (Table 1) were analysed at the Department of Soil Science and Geology at the Slovak University of Agriculture in Nitra, Slovak Republic. Soil moisture content of the soil samples was measured by gravimetric method. Soil type

was identified as haplic luvisol with a slightly alkaline pH reaction and middle humus content.

Table 1. Soil properties

soil type	Haplic luvisol
soil moisture	32–34%
clay	37.7%
silt	39.43%
sand	22.87%
pH H_2O	7.78
pH KCl	6.87
CO_X	1.624%
Hm	2.799%

During the experiment the nitrogen fertiliser DASAMAG® (manufacturer DUSLO, Inc., Slovakia) was used. Basic characteristics of the used fertiliser are shown in table 2. Equivalent amounts of application rate of the fertiliser were calculated depending on the diameter of sampling probes. In our case inlet diameter was 106.4 mm and the equivalent of application rates 500 and 1,000 kg ha^{-1} were 0.4437 and 0.8874 g of fertiliser, respectively.

The amount of N_2O emissions emitting from the soil was measured by INNOVA devices (Lumasense Technologies, Inc.) with a measurement system based on the photo-acoustic infrared detection method. The photo-acoustic field gas monitor INNOVA 1412 and multipoint sampler INNOVA 1309 were used due to the possibility to analyse a number of samples simultaneously (Dubeňová et al., 2013).

Table 2. Chemical composition of DASAMAG® fertiliser

Technical specification	Content, %
total nitrogen content (N)	24
ammoniac nitrogen content	16.2
nitrate nitrogen content	7.8
sulphur (S) soluble in water content	10
total magnesium oxide (MgO) insoluble in water	6

RESULTS AND DISCUSSION

The concentration of N_2O emissions in sampling probes due to the time period considerably fluctuated in comparison with the emission concentration before fertilising (Fig. 1, Table 3).

Concentration of the nitrous oxide for application rate 500 kg ha^{-1} and 1,000 kg ha^{-1} varied from 97.39 to 208.84% and from 97.26 to 275.96%, respectively. While for control variant (no fertiliser was applied) N_2O concentration varied from 97.75 to 101.81%. An increased flux of N_2O emissions was observed, on the 12^{th} day after the incorporation of fertiliser for the variant with 1,000 kg ha^{-1} rate and in the 15^{th} day for the variant with 500 kg ha^{-1} rate, after fertilisation.

Table 3. Average values of nitrous oxide concentration, ppm

Time, Days	Application rate of fertiliser, kg ha^{-1}					
	0	0	500	500	1,000	1,000
0	0.5742 $^{v}_{ab}$	0.5529 $^{tu}_{bc}$	0.5665 $^{uv}_{b}$	0.5238 $^{s}_{a}$	0.5480 $^{t}_{ab}$	0.5564 $^{tu}_{a}$
3	0.5723 $^{v}_{a}$	0.5607 $^{uv}_{c}$	0.5517 $^{tu}_{a}$	0.5380 $^{s}_{b}$	0.5456 $^{st}_{ab}$	0.5411 $^{st}_{a}$
6	0.5737 $^{u}_{ab}$	0.5476 $^{st}_{ab}$	0.5584 $^{t}_{ab}$	0.5476 $^{st}_{bc}$	0.5421 $^{s}_{a}$	0.5439 $^{s}_{a}$
9	0.5829 $^{u}_{bc}$	0.5439 $^{s}_{ab}$	0.5470 $^{s}_{a}$	0.5454 $^{s}_{bc}$	0.5684 $^{t}_{b}$	0.5630 $^{t}_{a}$
12	0.5754 $^{u}_{abc}$	0.5405 $^{s}_{a}$	0.5529 $^{t}_{a}$	0.5533 $^{t}_{c}$	0.6427 $^{z}_{c}$	0.6251 $^{v}_{b}$
15	0.5847 $^{t}_{c}$	0.5489 $^{s}_{ab}$	0.5997 $^{t}_{c}$	0.6002 $^{t}_{d}$	0.9039 $^{u}_{d}$	0.9274 $^{v}_{c}$
18	0.5718 $^{t}_{a}$	0.5456 $^{s}_{ab}$	0.7070 $^{u}_{d}$	0.7023 $^{u}_{e}$	1.2729 $^{v}_{g}$	1.2535 $^{z}_{e}$
21	0.5709 $^{t}_{a}$	0.5471 $^{s}_{ab}$	0.9425 $^{u}_{g}$	0.9422 $^{u}_{h}$	1.4843 $^{v}_{h}$	1.4796 $^{v}_{f}$
24	0.5750 $^{s}_{ab}$	0.5476 $^{s}_{ab}$	1.1126 $^{t}_{h}$	1.0939 $^{t}_{i}$	1.5122 $^{u}_{i}$	1.4967 $^{u}_{f}$
27	0.5746 $^{s}_{ab}$	0.5474 $^{s}_{ab}$	0.8675 $^{u}_{f}$	0.8205 $^{t}_{g}$	1.1300 $^{v}_{f}$	1.1529 $^{v}_{d}$
30	0.5724 $^{t}_{a}$	0.5480 $^{s}_{ab}$	0.7453 $^{v}_{e}$	0.7190 $^{u}_{f}$	0.9561 $^{z}_{e}$	0.9552 $^{z}_{c}$

Different letters in the rows (^{s,t,u,v,z}) mean the effect of the application rate and in the columns ($_{a,b,c,d,e,f,g,h,i}$) mean the effect of the time. It indicates that means are significantly different at $P < 0.05$ according to the LSD multiple-range test at the 95.0 % confidence level.

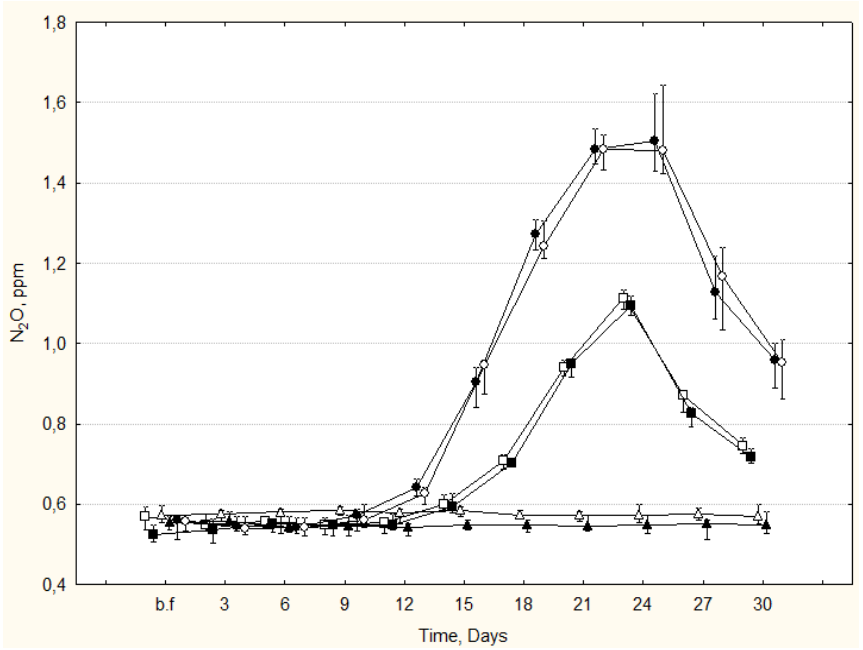

Figure 1. Nitrous oxide concentration in ppm (parts per million), b.f. – before fertilisation; point – median; whisker – min.-max. values; ○ – the first replication of application rate 1,000 kg ha^{-1}; ● – the second replication of application rate 1,000 kg ha^{-1}; □ – the first replication of application rate 500 kg ha^{-1}; ■ – the second replication of application rate 500 kg ha^{-1}; Δ – the first replication of application rate 0 kg ha^{-1}; ▲ – the second replication of application rate 0 kg ha^{-1}.

Maximum values were observed on the 24th day after incorporation of fertiliser for both application rates. In addition, increasing of the application rate of the nitrogen fertiliser have caused the increase of the concentration of nitrous oxide emissions released from soil into the atmosphere. These results correspond with the results obtained by other researchers (e.g., Eichner, 1990; Bouwman, 1996; Verma et al., 2006; Jones et al., 2007; He et al., 2009; Pang et al., 2009; Lin et al., 2010; Mapanda et al., 2011) and simultaneously extending the evidence into more detail of this study area.

CONCLUSIONS

The aim of our experiments was to study the effects of solid fertiliser application rates on the production of N_2O emissions under laboratory conditions. Extreme application rates were used to highlight the nitrogen fertiliser impact on the nitrous oxide emissions released from soil into the atmosphere. The concentration of emissions in sampling probes due to the time period considerably fluctuated in comparison with the emission concentration before fertilising. Application rates 500 kg ha^{-1} and 1,000 kg ha^{-1} varied from 97.39 to 208.84% and from 97.26 to 275.96%, respectively. For control variant (no fertiliser was applied) N_2O concentration varied from 97.75 to 101.81%. An increased flux of N_2O was observed, on the 12th day after the incorporation of fertiliser for the variant with 1,000 kg ha^{-1} rate and in the 15th day for the variant with 500 kg ha^{-1}, after fertilisation. Maximum values were measured on the 24th day after incorporation of fertiliser for both application rates. The results of this experiment confirm that increasing the application rate caused the increase in the concentration of emissions and the process of the nitrous oxide flux from soil was accelerated. Obtained results confirm the importance of the correct adjustment of fertiliser spreaders to prevent unwanted overdosing of fertiliser due to overlapping of fertiliser working width, which ultimately results in increased production of N_2O emissions.

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