POSSIBILITIES OF THE REDUCTION OF NITROGEN LOSSES FROM SOIL AND THE IMPACT OF FERTILIZERS ON ENVIRONMENT BY UTILISATION OF NITRIFICATION INHIBITORS

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Abstract: *Aim of the paper was to compare the effects of two very similar fertilisers on nitrous oxide (N_2O) flux from soil to the atmosphere in laboratory conditions. There were used following fertilisers: granulated nitrogenous fertiliser DASA® 26/13 with content of nitrogen is 26 %, content of sulphur is 13 %, and nitrogen fertiliser ENSIN® containing sulphur and nitrification inhibitors dicyandiamide DCD and 1,2,4-triazole (TZ). Both fertilisers are produced by the same manufacturer DUSLO, Inc., Šala, Slovakia. For both fertilisers there were carried out three variants of experiments for equivalent of application rates 0, 250 and 500 kg.ha^{-1}. The amount of N_2O emissions released from soil to the atmosphere was measured by photo-acoustic field gas monitor INNOVA 1412 connected to multipoint sampler INNOVA 1309. The experiments were conducted for 30 days in laboratory conditions. 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 measurement, another 48 hours was carried out, and this measuring cycle was repeated 10 times. The results of our experiment have confirmed that the fertiliser application rate and type of used fertiliser have a significant effect on N_2O flux and have confirmed the importance of accurate and uniform application of the fertilisers in field conditions in order to eliminate the negative environmental effects.*
KEY WORDS: *NITRIFICATION INHIBITORS, 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 Kajanovičová 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, Šima et al., 2013). 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., 2012b; Šima et al., 2012d, Šima et al., 2013d). 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., 2012b; Šima et al., 2012d, Šima et al., 2013d). The need for using fewer amounts of fertilizers means that it must be applied in a right way, and fertiliser losses are reduced to an absolute minimum. An optimal application of fertilizers, minimisation of the spoilage of fertilizers, improvement of existing and development of possible new application techniques, all this requires a detailed knowledge of the processes and factors that affect the spreading of fertilisers (Hofstee, 1993).

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. One of 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 (Šima et al., 2013a). 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. Next, but also very important factor may be content of nitrification inhibitors in the fertilisers. Nitrification inhibitors has effects on the granulometric composition (Šima et al., 2013b) of fertilisers and on the electrical conductivity (Šima et al., 2013c) of fertiliser.

The aim of the paper is the study of the effects of nitrification inhibitors of the two very similar nitrate fertilizers from the same manufacturer on the production of N_2O emissions released from soil to the atmosphere under laboratory conditions - in the laboratory experiment. There were used granulated nitrogen fertilizer with sulphur content DASA® 26/13 and nitrogen fertilizer ENSIN® containing sulphur and nitrification inhibitors dicyandiamide DCD and 1,2,4 triazole – TZ.

MATERIAL AND METHODS

During the experiments the soil samples were collected by five sampling probes from one specific location. Used sampling probes are used for collecting of soil samples (Šima et al., 2012a; Šima et al., 2012c; Šima & Dubeňová, 2013; Šima et al., 2013e; Šima et al., 2013f). The aim was to obtain soil samples with uniform soil properties and reduce the natural heterogeneity of soil properties across the arable fields (Šima et al., 2013a). 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}, 250 kg ha^{-1}, 500 kg ha^{-1} and with two repetitions for each variant of non-zero application rate. 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%
ilt	39.43%
sand	22.87%
pH H_2O	7.78
pH KCl	6.87
CO_X	1.624%
Hm	2.799%

During experiments we have used the two very similar fertilizers from the same manufacturer DUSLO, Inc. There was used granulated nitrogen fertilizer with sulphur content DASA® 26/13. Nitrogen is in ammonium and nitrate form and sulphur is in water-soluble sulphate form. The granulate has a pink to brown colour and surface is treated by coating agent. As a second used fertilizer we have used a granular nitrogen fertilizer ENSIN® containing sulphur and nitrification inhibitors dicyandiamide DCD and 1,2,4 triazole – TZ. The granulate is treated by coating agent and has green colour. The nitrification inhibitors ensure transformation of ammonium nitrate to nitrogen nitrate in the soil. The advantages of ENSIN® usage compared to DASA® 26/13 are that the fertilizer is applied in 1 dosage and re-application of fertilizer is not necessary. It allows farmers to save the time and money, increase the crop yields and allows better quality of crops, fertilizer is specially environment friendly, reduces nitrate leaching and reduces emissions of nitrous oxide to the atmosphere.

Chemical composition of the DASA® 26/13 and ENSIN® fertilizers are presented in Tables 2 and 3, respectively. Grain-size distribution of the DASA® 26/13 and ENSIN® fertilizers are shown in Table 4.

Table 2. Chemical composition of DASA® 26/13 fertilizer

Technical specification	Content, %
total nitrogen content (N)	26
ammonium nitrogen content	18.5
nitrate nitrogen content	7.5
sulphur (S) soluble in water	13

Table 3. Chemical composition of ENSIN® fertilizer

Technical specification	Content, %
total nitrogen content (N)	26
ammonium nitrogen content	18.5
nitrate nitrogen content	7.5
sulphur (S) soluble in water	13
dicyandiamide DCD and 1,2,4 triazole content	0.37–0.74
DCD:TZ ratio	10:1

Table 4. Grain-size distribution of the DASA® 26/13 and ENSIN® fertilizers

Dimension, mm	Content of particles, %	
	DASA® 26/13	ENSIN®
<1	max. 1	max. 1
2–5	min. 90	min. 90
>10	0	0

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 rate 250 and 500 $kg.ha^{-1}$ were 0.2219 and 0.4437 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).

Data obtained were analysed by using the ANOVA test, after normality test by using the *Kolmogorov-Smirnov* test and the homogeneity of variance by using the *Levene's* test. With ANOVA $P<0.05$ we continued in the post-hoc LSD multiple range test. We have used the software STATGRAPHICs Centurion XVI.I (Statpoint Technologies, Inc.; Warrenton, Virginia, USA). Graphic processing of results was performed bz using of software STATISTICA 7 (Statsoft, Inc.; Tulsa, Oklahoma, USA).

RESULTS AND DISCUSSIONS

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 5).

Table 5. Average values of nitrous oxide concentration, ppm

Time, Days	Application rate of fertiliser, kg ha^{-1}				
	NF	Dasa250	Dasa500	Ensin250	Ensin500
0	0.5502_a^{s}	0.5594_a^{s}	0.5656_a^{s}	0.5587_a^{st}	0.5613_a^{s}
3	0.5620_{ab}^{st}	0.5714_{bc}^{s}	0.5776_c^{s}	0.5552_a^{st}	0.5649_{abc}^{s}
6	0.5651_a^{t}	0.6095_b^{t}	0.6178_b^{s}	0.5509_a^{s}	0.5540_a^{s}
9	0.5641_a^{t}	0.6149_c^{tu}	0.6997_d^{t}	0.5830_{ab}^{tu}	0.6124_{bc}^{t}

12	0.5601_{a}^{st}	0.6433_{c}^{uv}	0.8192_{e}^{u}	0.6014_{b}^{uv}	0.6818_{d}^{u}
15	0.5616_{a}^{st}	0.6892_{c}^{xy}	0.9104_{d}^{v}	0.6216_{b}^{v}	0.7140_{c}^{u}
18	0.5579_{a}^{st}	0.7102_{c}^{y}	1.0019_{e}^{x}	0.6548_{b}^{x}	0.7720_{d}^{v}
21	0.5553_{a}^{st}	0.7109_{b}^{y}	1.0726_{d}^{y}	0.6794_{b}^{xy}	0.8331_{c}^{x}
24	0.5581_{a}^{st}	0.6993_{b}^{y}	0.9983_{d}^{x}	0.6931_{b}^{yz}	0.8657_{c}^{xy}
27	0.5595_{a}^{st}	0.6571_{b}^{vx}	0.8451_{d}^{u}	0.7099_{c}^{yz}	0.8778_{d}^{y}
30	0.5650_{a}^{t}	0.6459_{b}^{uv}	0.8055_{c}^{u}	0.6905_{b}^{z}	0.8571_{d}^{xy}

Different letters in the rows ($_{a,b,c,d,e}$) mean the effect of the application rate and in the columns (^{s,t,u,v,x,y,z}) 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.

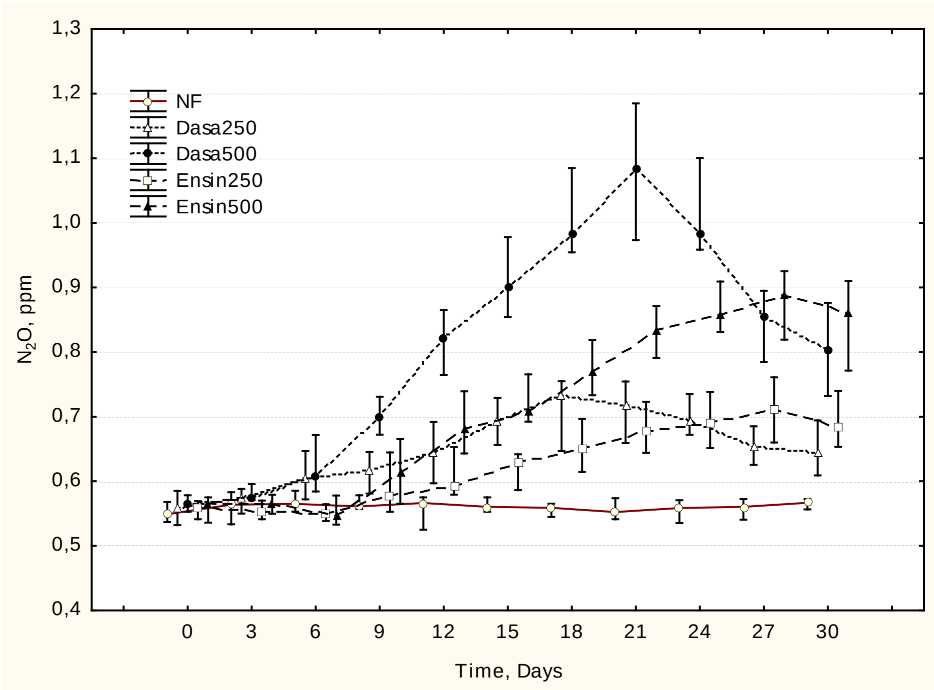

Fig. 1. Nitrous oxide concentration in ppm (parts per million), NF – non fertilizing, point – median, whisker – min.-max. values

Based on the obtained results we found the effect of nitrification inhibitors to intensity and time interval of nitrous oxide emissions released from soil to the atmosphere in laboratory conditions. Content of nitrification inhibitors in fertilisers slow down the intensity of nitrous oxide emissions releasing. Maximum values, the peak of nitrous oxide flux, after using the "non inhibitors fertiliser" DASA® 26/13 were measured for 18 and 21 days after application of fertiliser to the soil for application rates 250 and 500 kg.ha^{-1}, respectively. The peak of nitrous oxide flux after using ENSIN® fertiliser was measured 27 days after application of fertiliser for both application rates. 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 around nitrification inhibitors effects to releasing of soil emissions and properties of fertilisers. There were also found the effect of the size of application rate to amount of nitrous oxide emissions released from soil to the atmosphere what is in agreement with our previous studies (e.g.: Šima et al., 2012c; Šima et al., 2013a; Šima et al., 2014).

CONCLUSIONS

Aim of the paper was to compare the effects of two very similar fertilisers on nitrous oxide (N_2O) flux from soil to the atmosphere in laboratory conditions. Used fertilisers DASA® 26/13 and ENSIN® produced by the same manufacturer DUSLO, Inc., Šala, Slovakia were used for application rates 0, 250 and 500 kg.ha^{-1}. The amount of N_2O emissions released from soil to the atmosphere was measured by photo-acoustic field gas monitor INNOVA 1412 connected to multipoint sampler INNOVA 1309. The experiments were conducted for 30 days in laboratory conditions. 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 measurement, another 48 hours was carried out, and this measuring cycle was repeated 10 times. Maximum values, the peak of nitrous oxide flux, after using the "non inhibitors fertiliser" DASA® 26/13 were measured for 18 and 21 days after application of fertiliser to the soil for application rates 250 and 500 kg.ha^{-1}, respectively. The peak of nitrous oxide flux after using ENSIN® fertiliser was measured 27 days after application of fertiliser for both application rates. Content of nitrification inhibitors in fertilisers slow down the intensity of nitrous oxide emissions releasing. There were also found the effect of the size of application rate to amount of nitrous oxide emissions released from soil to the atmosphere where increasing of application rates causes increasing of amount of nitrous oxide emissions released from soil to the atmosphere.

ACKNOWLEDGEMENTS
The paper reflects the results obtained within the research project VEGA 1/0786/14 "Effect of the environmental aspects of machinery interaction to eliminate the degradation processes in agro technologies of field crops".

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