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# Impact of the quality of work of fertiliser spreader on nitrous oxide emissions released from soil to the atmosphere

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**Abstract.** Quality of work of fertiliser spreader is one of the most important factors that affect the nitrous oxide ($N_2O$) flux from soil to the atmosphere. Calk ammonium nitrate (CAN) with 27% nitrogen content was spread by a fertiliser spreader VICON RS-L connected with a tractor ZETOR 16145 and incorporated into the soil by a power harrow PÖTTINGER LION 301 six hours after its spreading. Application rate of fertiliser was set for 200 kg ha$^{-1}$. There were selected five monitoring points based on the deviations of application rate for values 172.14, 188.01, 200.68, 213.08 and 227.34 kg ha$^{-1}$, which means 46.48, 50.76, 54.18, 57.53 and 61.38 kg N ha$^{-1}$, respectively. Nitrous oxide emissions were measured 7, 14, 21 and 28 days after fertiliser application and incorporation into the soil by a photoacoustic field gas monitor INNOVA 1412 with a multipoint sampler INNOVA 1309. Concentration of $N_2O$ ranged from 0.4264 ppm to 1.2970 ppm. Maximum values were measured 21 days after fertilisation for each variant of the experiment. Based on the data obtained, there were found statistically significant differences among time intervals and among the size of deviations of the application rate at a 95.0% confidence level. Results have shown an impact of the 6% deviation (21 days after fertilisation) and 13.7% deviation (14 and 28 days after fertilisation) from the size of fertiliser application rate on nitrous oxide flux from soil to the atmosphere. There were also found the effects of time interval on nitrous oxide flux from soil to the atmosphere for each of the time intervals 7, 14, 21 and 28 days after fertilisation.

**Key words:** nitrous oxide, soil emissions, fertiliser, fertiliser spreader, quality of work.

## INTRODUCTION

Nitrogen, as an essential element for plant growth (Ambus et al., 2011), is supplied to plants by fertilisers (Kajanovičová et al., 2011). Nitrogen fertilisation is an important factor affecting crop yields (Ložek et al., 1997; Ambus et al., 2011; Kajanovičová et al., 2011). Nitrogen dynamics directly affect a crop growth, soil fertility and potential pollution problems such as $NH_3$ volatilization, soil acidification, increased $NO_3$ loads of drinking water, eutrophication of surface water and emissions of the greenhouse gas $N_2O$ (Ludwig et al., 2011). Agriculture contributes to the increase in atmospheric $N_2O$, accounting for 24% of global annual emissions (IPCC

2007). Nitrous oxide ($N_2O$) is among the most important greenhouse gases, contributing by 6% to global warming (Loubet et al., 2011; Ranucci et al., 2011), and directly affects the stratospheric ozone layer (Willianms et al., 1992; Ravishankara et al., 2009). 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). Nitrous oxide emitted from soils leads to N loss from the ecosystem and is produced by nitrification and denitrification microbiological activities (Ambus et al., 2006; Jiang-Gang et al., 2007; Senbayram et al., 2012) and chemodenitrification at low pH (< 5.5) (Van Cleemput, Samater 1996). The major $N_2O$ source is denitrification (Ruser et al., 2001). High rate of N fertiliser application increases concern regarding $N_2O$ emissions from intensively farmed fields (He et al., 2009; Pang et al., 2009; Lin et al., 2010; Zhu et al., 2011; Šima et al., 2013g). Although $N_2O$ emissions from the soil increase with the amount of N fertiliser (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), there is still a lack of data for fertiliser-intensive systems (Pfab et al., 2012). In a compiled data set, $N_2O$ emissions increased significantly with increasing rates of N added (Skiba et al., 2001). The incorrect application rate of fertiliser can result in the increased cost of fertilisers, reduction of crop growth and also negative environmental effects. Quality of work of fertiliser spreader has a positive environmental effect. Therefore for effective application it is necessary to know the transversal uniformity of the fertiliser distribution on the field surface (Šima et al., 2011; 2012a; 2012b; 2013a). 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 and temperature) and weather conditions. Granulometric composition of fertilisers is also very important factor, which must be taken into account (Šima et al., 2013e; 2013f). One of the most important of these factors is the size of the application rate of fertiliser, which depends upon the setting of the fertiliser spreader and quality (uniformity) of the application. Local overdosing causes an increased concentration of nitrogen on the fields (Šima et al., 2012c; 2013b).

The aim of the study was to explore the impact of the quality of work of the fertiliser spreader on the amount of nitrous oxide released from the soil to the atmosphere in different time intervals after fertiliser application.

## MATERIAL AND METHODS

The experiment was carried out in Dražovce village, 6 km from Nitra city, Slovakia in May and June 2012. The area is located on long. 48°20´ 56´´ N and lat. 18°4´ 1´´ E and there is a flat land with balanced microrelief after the harvest of perennial forage crops on a field. Temperature during the experiment ranged from

3.4°C to 28.7°C with average value 16.3°C. Air moisture ranged from 29.4 to 98.9% with average 70.1%.

The calk ammonium nitrate (CAN) used is formed by grey and white ammonium nitrate granulates with grounded dolomite decreasing the fertiliser natural acidity. The fertiliser is protected by anticaking surface treatment (www.duslo.sk). The official trade mark of this fertiliser produced by company Duslo, a. s. Šaľa is LAD 27. The chemical composition of LAD 27 consists of 27% of the total nitrogen content, 13.5% of the ammonium nitrogen content and 13.5% of the nitrate nitrogen content; these are important factors that affect the amount of nitrous oxide released from the soil to the atmosphere. The grain size distribution of the fertiliser affects the quality of work the fertiliser spreader. Based on laboratory analysis it was possible to state that there were 90% of particles from 2 to 5 mm in size, maximum 1% was below 1 mm, and no particles were of more than 10 mm. In order to collect fertilisers during measurements of uniformity distribution, there were used collecting trays with a compartment. Their technical parameters meet the Standard ISO 5690/1.

Soil samples were taken for pedological analysis before fertilising and they were analysed at the Department of Soil Science and Geology, the Slovak University of Agriculture in Nitra, Slovakia. The soil type was Haplic Luvisol with a content of clay, silt and sand 37.70, 39.43 and 22.87%, respectively. The humus content was 2.799%, $C_{ox}$ ($C_{org}$) was 1.624%, and pH was 7.78 and 6.87 for $H_2O$ and KCl, respectively. The soil moisture content of soil samples was measured by a gravimetric method and varied within the ranges 26–28 %, 25–26%, 23–25%, 24–26% and 22–24% during application, 7, 14, 21 and 28 days after application, respectively. During the $16^{th}$ and $17^{th}$ days after application of fertiliser there were recorded 3 mm of rainfall.

The double spinning disc fertiliser spreader VICON RS-L was connected with the tractor ZETOR 16145. The fertiliser spreader was set according to manufacturer´s instructions for this type of fertiliser and for the maximum spreading width (for 42 metres in our case). The application rate was 200 kg $ha^{-1}$ (54 kg N $ha^{-1}$). The machine operating speed was 12 km $h^{-1}$. The basic requirements for fertiliser application (the maximum wind speed, air moisture, air temperature, filling tray capacity, collecting tray size) given by the Standard ISO 5690/1 and national standards STN EN 13739, Part 1 and Part 2, were met. The spreading pattern was based on our previous research of work quality of fertiliser spreaders (Šima et al., 2011; 2012a; 2012b; 2013a). The application overlap of the working width was set to 50%. Determining the amount of the fertiliser applied to the chosen place requires this fertiliser to be removed for weighing. For this reason, there was not possible to determine the amount of the fertiliser applied to the chosen place where collecting trays with the compartment were placed. Collecting trays with the compartment were placed perpendicularly to the driving direction, in two lines with a 6 m distance. Monitoring points were placed between these lines (3 m from each other), with a calculated (average value) amount of the fertiliser. The position of monitoring points was determined by the amount of the fertiliser applied to the chosen place. The amount of fertiliser decreased with increasing the distance of monitoring points from the driving direction. There were recorded right sides of spreading pattern in both directions with 50% overlap. In this way, it was possible to choose monitoring points with the applied amount of fertiliser 172.14, 188.01, 200.68, 213.08 and 227.34 kg $ha^{-1}$ which means 46.48, 50.76, 54.18, 57.53 and 61.38 kg N $ha^{-1}$, respectively.

The fertiliser applied on the field surface was incorporated into the soil by tillage (power harrow PÖTTINGER LION 301) during seedbed preparation after six hours in the same day.

Nitrous oxide emissions released from the soil to the atmosphere were measured by the INNOVA measuring devices (LumaSense Technologies, Inc., Denmark), consisting of three main parts (Dubeňová et al., 2013). The photoacoustic field gas monitor INNOVA 1412 with a measurement system based on the photoacoustic infrared detection method is used for the gas analysis; the multipoint sampler INNOVA 1309 serves for gas sampling from 12 sampling points and for the transport of gas samples to INNOVA 1412 for analysis (www.lumasenseinc.com). A notebook with software is the third major component. Software is delivered by the apparatus manufacturer, and it is used for the setup and control of the analysis. Sampling probes were made from a seamless steel pipe with a 114.3 mm outer diameter, 4 mm wall thickness and length 300 mm. Nitrous oxide emissions released from the soil to the atmosphere were measured in selected monitoring points 7, 14, 21 and 28 days after fertilisation. Soil samples were taken to the laboratory within 90 minutes after samples were taken for the gas analysis by a laboratory method. Soil samples were monitored for 24 hours. There was used a 30 min. time interval for the gas analysis. The measuring method and its practical verification were described in our previous studies on $N_2O$ (Šima et al., 2012c; Šima et al., 2013c; Šima et al., 2013d;) and on $CO_2$ (Šima & Dubeňová, 2013). There were made three replications of the experiment, an average values of nitrous oxide concentration were used for analysis.

The data were analysed by using Kruskal-Wallis test after the normality test using Kolmogorov-Smirnov procedure and the homogeneity of variance by using Levene's test. Kruskal-Wallis test tests the null hypothesis that the medians within each of the samples are the same. Since the P-value is less than 0.05, there is a statistically significant difference occurs between the medians at 95.0% confidence level. The STATGRAPHICS Centurion XVI.I software (Statpoint Technologies, Inc.; Warrenton, Virginia, USA) was used for data analysis. The graphical processing of results was performed using Microsoft Excel 2010.

## RESULTS AND DISCUSSION

Spread patterns of the fertiliser were measured, and the position of lines was recorded and saved. Monitoring points were determined based on the calculated average value (Fig. 1) of the amount of applied fertiliser in the first and second spread pattern line. Five monitoring points were chosen with fertiliser application rate 172.14, 188.01, 200.68, 213.08 and 227.34 kg $ha^{-1}$ which means 46.48, 50.76, 54.18, 57.53 and 61.38 kg N $ha^{-1}$, respectively. Soil samples were taken 7, 14, 21 and 28 days after fertilisation (application and incorporation of the fertiliser).

The basic parameters of measured data are shown in Table 1. An impact of the work quality of fertiliser spreader on nitrous oxide emissions released from soil to the atmosphere 14, 21 and 28 days after fertilisation, however this impact was not found 7 days after fertilisation what could be caused by slower beginning of nitrification and denitrification processes under the given conditions. Fourteen days after fertilisation was found differences in nitrous oxide flux where deviations from set application rate (200 kg $ha^{-1}$) were above 13.67%. Deviations from set application rate above 6%

(5.995% is difference among the two closes measured application rates) causes statistically significant differences in to nitrous oxide flux. This impact was found 21 days after fertilisation. Decreasing trend and impact of nitrous oxide flux was found 28 days after fertilisation, but still there were significant differences in nitrous oxide flux with deviations from set application rate above 13.67%.

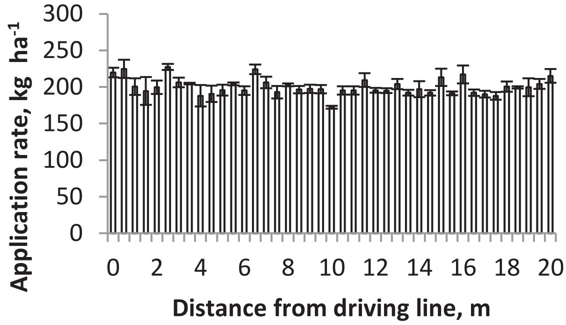


**Figure 1.** Spread pattern of average values of applied fertiliser with deviations (both replications).

**Table 1.** Selected parameters of summary statistic and multiple-range test LSD of nitrous oxide emissions released from the soil to the atmosphere, ppm (n = 48)

| Time interval, days | Application rate, $kg\ ha^{-1}$ | Attributes of summary statistics | | | |
|---|---|---|---|---|---|
| | | Mean, ppm | Minimum, ppm | Maximum, ppm | Range, ppm |
| 7 | 172.14 | $0.4559^{a}_{t}$ | 0.4283 | 0.4703 | 0.0420 |
| | 188.01 | $0.4555^{a}_{t}$ | 0.4264 | 0.4770 | 0.0506 |
| | 200.68 | $0.4589^{a}_{t}$ | 0.4384 | 0.4741 | 0.0357 |
| | 213.08 | $0.4542^{a}_{t}$ | 0.4340 | 0.4724 | 0.0384 |
| | 227.34 | $0.4579^{a}_{t}$ | 0.4277 | 0.4750 | 0.0473 |
| 14 | 172.14 | $0.6574^{a}_{u}$ | 0.6081 | 0.7152 | 0.1071 |
| | 188.01 | $0.6850^{b}_{u}$ | 0.6186 | 0.7318 | 0.1132 |
| | 200.68 | $0.6939^{b}_{u}$ | 0.6169 | 0.7360 | 0.1191 |
| | 213.08 | $0.6930^{b}_{u}$ | 0.6142 | 0.7294 | 0.1152 |
| | 227.34 | $0.7113^{c}_{u}$ | 0.6593 | 0.7573 | 0.0980 |
| 21 | 172.14 | $0.9893^{a}_{z}$ | 0.8477 | 1.1340 | 0.2863 |
| | 188.01 | $1.0318^{b}_{z}$ | 0.8693 | 1.1708 | 0.3015 |
| | 200.68 | $1.0907^{c}_{z}$ | 0.9165 | 1.2162 | 0.2997 |
| | 213.08 | $1.1384^{d}_{z}$ | 0.9649 | 1.2555 | 0.2906 |
| | 227.34 | $1.1795^{e}_{z}$ | 0.9963 | 1.2970 | 0.3007 |
| 28 | 172.14 | $0.7969^{a}_{v}$ | 0.7566 | 0.9023 | 0.1457 |
| | 188.01 | $0.8163^{b}_{v}$ | 0.7585 | 0.9043 | 0.1458 |
| | 200.68 | $0.8223^{b}_{v}$ | 0.7613 | 0.9142 | 0.1529 |
| | 213.08 | $0.8338^{b}_{v}$ | 0.7729 | 0.9115 | 0.1386 |
| | 227.34 | $0.8828^{c}_{v}$ | 0.8111 | 0.9351 | 0.1240 |

Different letters as the superscripts ($^{a, b, c, d, e}$) mean the effect of the application rate for selected time and as the subscripts ($_{t, u, v, z}$) mean the effect of the time for selected application rate. It indicates that means are significantly different at P < 0.05 according to the LSD multiple-range test at the 95.0 % confidence level.

Result also has shown an effect of time interval after fertilisation to nitrous oxide flux. The peak of nitrous oxide emissions flux was measured 21 days after fertilisation with increasing for 7, 14 and 21 days after fertilisation and decreasing after 28 days, although the measured values after 28 days was higher in comparison with emissions flux 14 days after fertilisation. These results are consistent with our previous study (Šima et al., 2014 in press) where the effects the size of application rates 0, 100, 200 and 300 kg $ha^{-1}$ were analysed. For application rate 200 kg $ha^{-1}$ nitrous oxide concentration ranged from 0.4365 ppm to 1.0397 ppm for 7 and 21 days, respectively.

The amount of nitrous oxide emissions was also highest 21 days after fertilisation. A decrease of nitrous oxide emissions flux was measured on the 28th day. This value of $N_2O$ flux was lower than the max. value measured during the 21st day but still higher than during the 14th day. Lowest $N_2O$ concentration was measured 7 days after fertilisation for both studies. Results are also consistent with another studies where increasing the size of the application rate of fertiliser significantly increased the nitrous oxide flux (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).

## CONCLUSIONS

Based on the results, there were found the effects of the quality of work of fertiliser spreader to nitrous oxide flux from soil to the atmosphere. Irregularity of application of fertiliser resulted in the change of released nitrous oxide emissions. Overdosing of fertiliser increased the amount of emissions. This effect is reflected also in 6% deviation from set application rate of fertiliser and therefore quality of work of fertiliser spreader and correct settings of it implements is even more important, not only from economical point of view but also from environmental aspects.

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