Impact of the size of nitrogen fertiliser application rate on N_2O flux

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Abstract

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The application rate of a nitrogen fertiliser is one of the most important factors that affect the nitrous oxide (N_2O) flux. Calk ammonium nitrate 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 spreading. Monitoring points were selected based on the size of application rate 0, 100, 200 and 300 kg/ha and were measured 7, 14, 21 and 28 days after fertiliser application and incorporation into the soil. Nitrous oxide emissions were measured by a photoacoustic field gas monitor INNOVA 1412 with a multipoint sampler INNOVA 1309. Based on the data obtained, there were found statistically significant differences among time intervals and among the size of the application rate at a 95.0% confidence level. Results have shown impacts of the size of fertiliser application rate and time interval after fertilisation on nitrous oxide flux.

Keywords: nitrous oxide; soil emissions; fertilising; fertiliser spreader

Nitrogen is an essential element for plant growth (Ambus et al. 2011) and is supplied to plants by fertilisers (Kajanovičová et al. 2011). Nitrogen dynamics directly affects 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 emitted from soils leads to N loss from the ecosystem and is produced by nitrification and denitrification microbiological activities (Skiba et al. 1993; 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 (Skiba et al. 1997; Skiba, Smith 2000; 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). Although N_2O emissions from the soil increase with the amount of N fertiliser (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).

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The aim of the study conducted was to explore the impact of the size of the nitrogen fertiliser application rate on the amount of nitrous oxide released from the soil to the atmosphere in different time intervals after fertilisation.

MATERIALS AND METHODS

The experiment was conducted on a flat land with balanced microrelief after the harvest of perennial forage crops on a field near Nitra city, Slovakia. The amount of the calk ammonium nitrate (CAN) fertiliser distributed by the fertiliser spreader VICON RS-L (Kverneland Group, Kvernaland, Norway) was captured by collecting trays. Sampling points with a different size of the fertiliser application rate (0, 100, 200 and 300 kg/ha) were chosen. Nitrous oxide released from the soil to the atmosphere was measured by the photoacoustic system of the INNOVA 1412 and 1308 devices (LumaSense Technologies, Ballerup, Denmark) 7, 14, 21 and 28 days after fertilisation. The own soil sampling method was used (Šima et al. 2012).

Experiments were carried out in Dražovce village, 6 km from Nitra, Slovakia. The area is located on long. 48°20'56''N and lat. 18°4'1''E.

The double spinning disc fertiliser spreader VICON RS-L was connected with the tractor Zetor 16145 (Zetor Tractors, Brno, Czech republic). The calcium ammonium nitrate used is formed by grey and white ammonium nitrate granulates with ground dolomite decreasing the fertiliser natural acidity. The fertiliser is protected by anticaking surface treatment (www.duslo.sk). The official trade mark of this fertiliser (Duslo, Šaľa, Slovak Republic) 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 of the fertiliser spreader. There were 90% of particles from 2 to 5 mm in size, max. 1% was below 1 mm, and no particles were of more than 10 mm. In order to capture fertilisers during measurements of uniformity distribution, collecting trays with a compartment were used. Their technical parameters meet the Standard ISO 5690/1 (1985).

Soil samples were taken for pedological analysis before fertilising and were analysed at the Department of Soil Science and Geology, the Slovak University of Agriculture in Nitra, Slovak Republic. 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%, CO_x 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 ranges 26–28%, 25–26%, 23–25%, 24–26% and 22–24% during application, 7, 14, 21 and 28 days after application, respectively.

Nitrous oxide emissions released from the soil to the atmosphere were measured by the INNOVA measuring devices (LumaSense Technologies, Ballerup, Denmark), consisting of three main parts (Dubeňová et al. 2011). 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 (LumaSense Technologies, Ballerup, Denmark) 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 lenght 300 mm. The measuring method and its practical verification were described in our previous study on N_2O (Šima et al. 2012).

The fertiliser spreader VICON RS-L was set according to manufacturer´s instructions for this type of fertiliser and for the max. spreading width (for 42 m in our case). The application rate was 300 kg/ha (81 kg.N/ha). The machine operating speed was 12 km/h. The basic requirements for fertiliser application (the max. wind speed, air moisture, air temperature, filling tray capacity, collecting tray size) given by the Standard ISO 5690/1 (1985) and national standards STN EN 13739 (2012), Part 1 and Part 2, were met. The spreading pattern was based on no overlaps carried out. Determining the amount of the fertiliser applied to the chosen place requires this fertiliser to be removed for weighing. For this reason, it 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. In this way, it was possible to choose monitoring points with the applied amount of fertiliser 300, 200, 100 and 0 kg/ha, which means 81, 54, 27 and 0 kg N/ha. The fertiliser applied to the field was incorporated into the soil by tillage (power harrow Pöttinger Lion 301; Alois Pöttinger Maschinenfabrik, Grieskirchen, Austria) during seedbed preparation after six hours the same day. 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 min after samples were taken for the gas analysis by a laboratory method described in our previous study (Šima et al. 2012). The photoacoustic gas monitoring system INNOVA was used. Soil samples were monitored 24 hours. A 30 min time interval for the gas analysis was used.

Statistical analysis. The Multifactor Analysis of Variance (MANOVA) was used for a complete evaluation in order to know which of the factors (time and application rate) affects the nitrous oxide flux. The Analysis of Variance (ANOVA) was used for comparing the values during the measurment of time intervals and the size of application rate. Data were analysed by using the Analysis of Variance after the normality test provided by the Kolmogorov–Smirnov test and the homogeneity of variance by using the Levene's test. With ANOVA or MANOVA, the *P*-value was lower than 0.05, and we have continued with the post-hoc LSD test. If the *P*-value of the test (MANOVA, ANOVA) is higher than 0.05, there is no statistically significant difference at the 95.0% confidence level. The software used was Statgraphics Centurion XVI.I (Statpoint Technologies, Warrenton, USA). The graphical processing of results was performed using Microsoft Excel 2010.

RESULTS AND DISCUSSION

Spread patterns of the fertiliser (Fig. 1a,b) were measured, and the position of lines was saved. Monitoring points were determined based on the calculat-

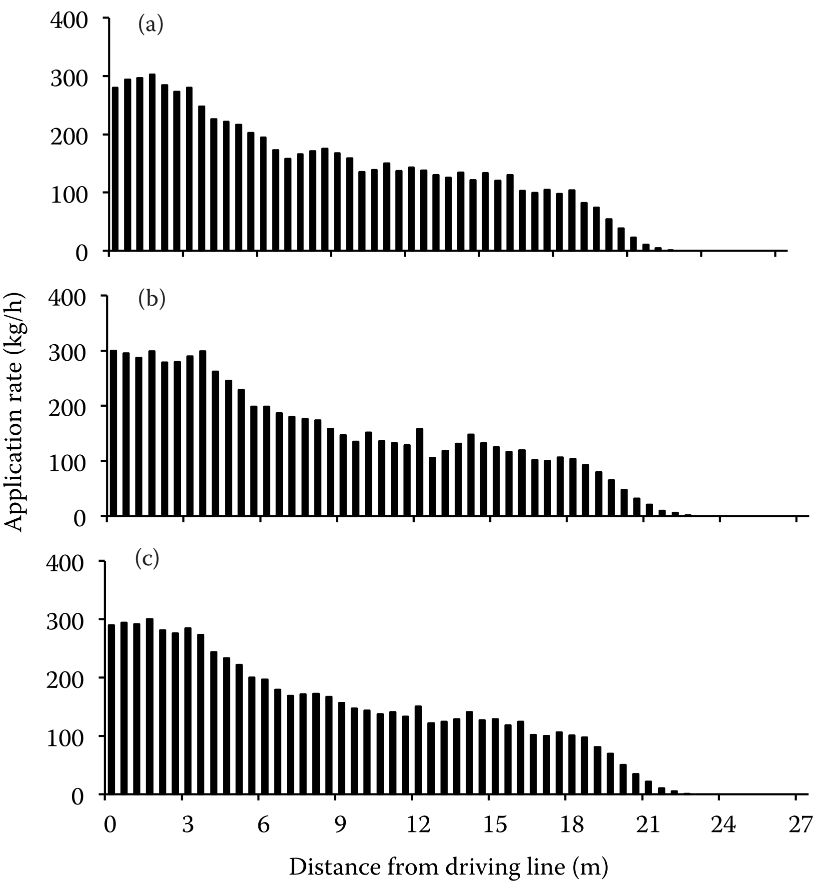

Fig. 1. First (a), second (b) and caluculated (c) line of the spread pattern of the applied fertiliser

Table 1. Summary statistic of nitrous oxide flux (n = 48)

Time interval (days)	Application rate (kg/ha)	Attributes of summary statistics						
		mean (ppm)	geometric mean (ppm)	median (ppm)	min. (ppm)	max. (ppm)	range (ppm)	standard deviation (ppm)
7	0	0.4568	0.4566	0.4619	0.4307	0.4741	0.0434	0.0128
	100	0.4606	0.4605	0.4631	0.4384	0.4729	0.0344	0.0104
	200	0.4644	0.4642	0.469	0.4365	0.4845	0.0481	0.0132
	300	0.4686	0.4684	0.4723	0.4452	0.4847	0.0395	0.0130
14	0	0.4472	0.4467	0.4527	0.4139	0.4739	0.0600	0.0202
	100	0.5973	0.5969	0.5961	0.5469	0.6445	0.0975	0.0214
	200	0.6782	0.6780	0.6792	0.6499	0.7078	0.0579	0.0135
	300	0.7937	0.7934	0.8043	0.7482	0.8307	0.0826	0.0237
21	0	0.4491	0.4490	0.4502	0.4276	0.4631	0.0355	0.0077
	100	0.8385	0.8383	0.8338	0.8160	0.8789	0.0629	0.0157
	200	1.0131	1.0130	1.0156	0.9687	1.0397	0.0711	0.0182
	300	1.1332	1.1331	1.1384	1.0964	1.1522	0.0558	0.0153
28	0	0.4561	0.4560	0.4563	0.4410	0.4686	0.0277	0.0064
	100	0.7723	0.7721	0.7729	0.7333	0.8021	0.0688	0.0175
	200	0.8512	0.8512	0.8525	0.8384	0.8603	0.0219	0.0054
	300	1.0021	1.0021	1.0025	0.9964	1.0091	0.0127	0.0034

ed average value (Fig. 1c) of the amount of the applied fertiliser in the first and second spread pattern line. Four monitoring points were chosen with fertiliser application rate 300.45, 200.32, 100.04 and 0 kg/ha, which means 81.12, 54.09, 27.01 and 0 kg N/ha, respectively. The basic parameters of the measured data are shown in Table 1. A complete comparison determines which of the factors (time and application rate) affect the nitrous oxide flux. Since all the three P-values of the Multifactor Analysis of Variance are lower than 0.05, these factors have a statistically significant effect on nitrous oxide flux at the 95.0% confidence level. Time, application rate and their interactions were analysed, and P-values were lower than 0.05 (all the three P = 0.0000). The Multiple Range Test LSD showed a statistically significant difference among all time factors (7, 14, 21 and 28 days) and all application rate factors (0, 100, 200 and 300 kg/ha). The analysis of variance was used as a comparison in different time periods, i.e. 7, 14, 21 and 28 days after fertilising. All P-values of the F-test are lower than 0.05 (P-values of nitrous oxide values measured 7, 14, 21 and 28 days after fertilisation were 0.0000). That means there are statistically significant differences between the mean values of variables at the 95.0% confidence level. To determine which mean values are significantly different from others, the LSD multiple range test (Table 2) was used. Seven days after fertilisation, statistically significant differences were found (Table 2) between nitrous oxide emissions in the monitoring points with the application rate of fertiliser 0 and 200 kg/ha, 0 and 300 kg/ha, and 100 and 300 kg/ha. Differences in nitrous oxide flux were not found (Table 2) in the monitoring points with the application rate of fertiliser 0 and 100 kg/ha, 100 and 200 kg/ha, and 200 and 300 kg/ha. Fourteen, twenty-one and twenty-eight days after fertilisation, statistically significant differences were found (Table 2) between all the mon-

Table 2. Multiple-range test LSD of nitrous oxide emissions released from the soil to the atmosphere

Time (days)	Application rate (kg/ha)			
	0	100	200	300
7	0.4568^{a}_{t}	0.4606^{ab}_{t}	0.4644^{bc}_{t}	0.4686^{c}_{t}
14	0.4472^{a}_{u}	0.5973^{b}_{u}	0.6782^{c}_{u}	0.7937^{d}_{u}
21	0.4491^{a}_{u}	0.8385^{b}_{z}	1.0131^{c}_{z}	1.1332^{d}_{z}
28	0.4561^{a}_{v}	0.7723^{b}_{v}	0.8512^{c}_{v}	1.0021^{d}_{v}

$^{a–d}$effect of the application rate; $_{t–z}$effect of the time (both) indicationg the significant difference at P < 0.05 according to the LSD multiple-range test at the 95.0% confidence level

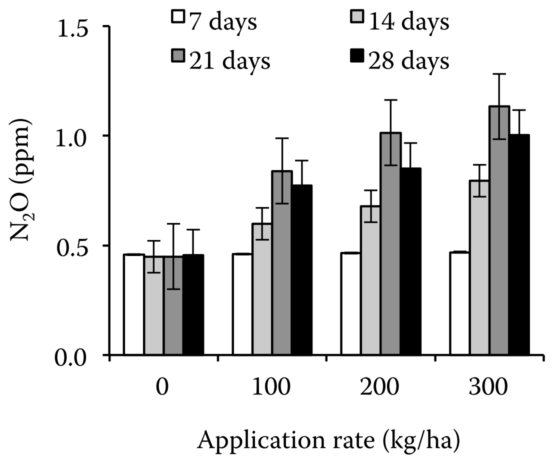

Fig. 2. Nitrous oxide flux from fertilised soil with the 95% confidence level for a different fertiliser aplication rate

itoring points with the application rates of fertiliser 0, 100, 200 and 300 kg/ha. This result (Fig. 2) has shown an impact of the fertiliser application rate on nitrous oxide flux from the soil to the atmosphere. Increasing the application rate of fertiliser significantly increased the nitrous oxide flux, which corresponds with the results obtained by other researchers (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). The time period significantly affects N_2O flux. The amount of nitrous oxide emissions was 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.

CONCLUSIONS

The aim of experiments was to study the impact of the size of nitrogen fertiliser application rate on nitrous oxide flux. The amount of N_2O emissions released from the soil to the atmosphere depended on the size of the fertiliser application rate. Increasing the application rate caused an increase in N_2O emissions. Seven days after fertilisation, statistically significant differences were found between nitrous oxide emissions in the monitoring points with the application rate of fertiliser 0 and 200 kg/ha, 0 and 300 kg/ha, and 100 and 300 kg/ha. Differences in nitrous oxide flux were not found in the monitoring points with the application rate of fertiliser 0 and 100 kg/ha, 100 and 200 kg/ha, and 200 and 300 kg/ha. Fourteen, twenty-one and twenty-eight days after fertilisation, statistically significant differences were found between all the monitoring points with the application rates of fertiliser 0, 100, 200 and 300 kg/ha. The time period significantly affected N_2O flux. The amount of nitrous oxide emissions was 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. The results obtained show the increase of nitrous oxide emissions released from the soil to the atmosphere with increasing the nitrogen fertiliser application rate. The amount of N_2O emissions grew during the first three weeks. During the fourth week of the experiment, a decrease of N_2O flux from the soil to the atmosphere was recorded for all the three application rates.

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