DENITRIFICATION AND N_2O PRODUCTION IN SUBSOIL IN WHEAT-MAIZE ROTATION FIELD IN NORTH CHINA PLAIN

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Introduction

Denitrification is an important pathway to remove the nitrate accumulated in subsoil. However, many studies of denitrfication only focus on the surface soils, whereas impacts of management practice and season on denitrification in subsoil and its function to remove nitrate accumulated beneath root zone are largely neglected. Deep soils have a high potential to store nitrate and carbon; therefore any management driven stimulation or repression of microorganisms in subsoil could impact denitrification and its products composition. If the denitrifying process predominantly produces N_2 rather than N_2O , the denitrification will be benefit to groundwater and atmospheric environment, such as: it will decrease nitrate accumulation in deep soil and repress nitrate leaching to groundwater; meanwhile, it will not induce N_2O accumulation in soil profile and will not cause N_2O emission to atmosphere. The aim of this study was to understand whether soil management affects (1) denitrfication and N_2O formation in the topsoil (0-15 cm), rooted zone beneath the plough layer (15-90 cm), and in the unrooted zone (90-190 cm); (2) contribution of N_2O produced beneath the plough layer to the N_2O emission.

Experimental site

The experiments were carried out at the Luancheng Agro-ecological Experimental Station (37.89° N, 114.67° E, at 50 m above sea level) of the Chinese Academy of Sciences. The station is located in the North China Plain. The area characterized by a sub-humid climate with a mean annual temperature of 12.3℃ and a mean annual precipitation of 537mm. Dominant land use in this area is a continuous wheat-maize crop rotation, with straw returned to the soil, at least for 20 years.

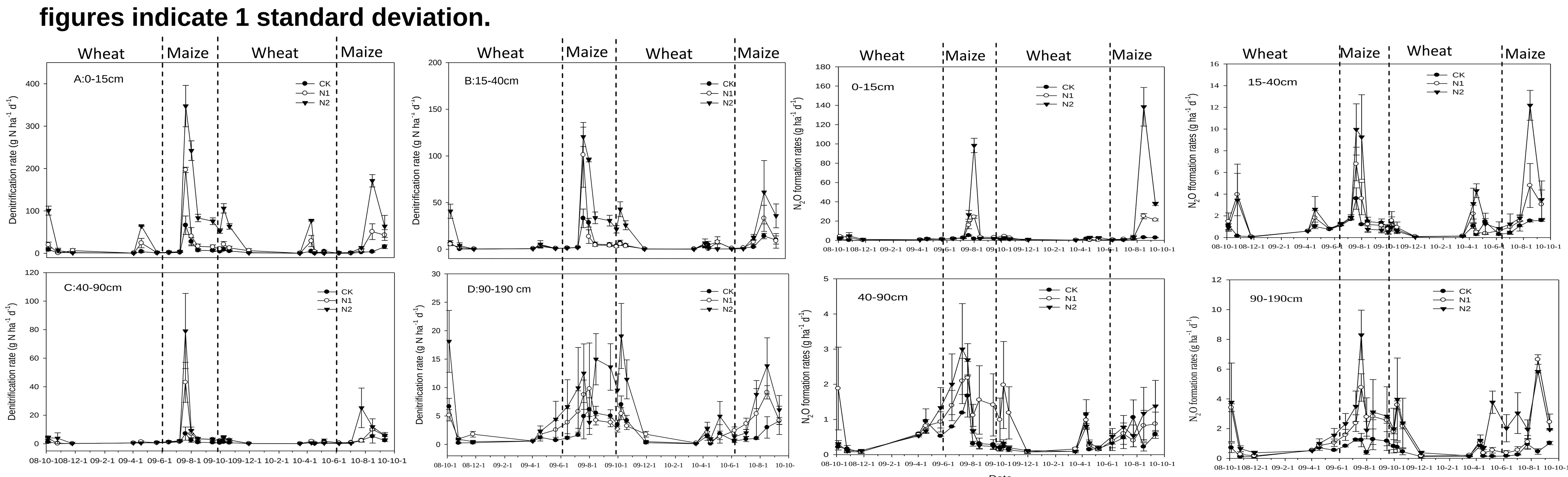
Experiments designed

Field experiments were established in 2002 with randomized complete block N-response plots (14 m × 7.5 m) with three replicates. The plots were fertilized 4 times per year at three different urea N application rates, i.e. no fertilizer input (CK), 450 kg N ha^{-1} yr^{-1} (N1) and 750 kg N ha^{-1} yr^{-1} (N2).

For assessing in-situ denitrification, 8 intact soil cores (5 cm diameter) were taken down to 200 cm depth from each plot per time. The soil cores (100cm length) were collected by Geoprobe machine, which collects intact soil cores in a Teflon tube. The soil cores were cut into 25 cm sections, apart from the uppermost 15 cm layer. The sections of the 8 soil cores were per layer equally divided over two incubation cylinders. One of the cylinders received sufficient C_2H_2 to obtain a partial pressure of 10 kPa, whereas the second cylinder remained untreated, as described by Chen et al (1996). After 24 h of incubation, gas samples (12 ml) were taken from the head space with a gas-tight syringe through a three way gas-tight valve and transferred to 10 ml vacuum tubes and then analysed for N_2O concentration by gas chromatography. We assume that the N_2O produced in the presence of C_2H_2 is mainly from denitrification, and that N_2O produced in the absence of C_2H_2 represents N_2O formation rates from (de)nitrification processes. Cumulative denitrification and N_2O-N formation were estimated for each plot by linearly interpolating data points and integrating the curve by Simpson's rule.

Results

Fig.1 The seasonal variation of (a) denitrification rates (n = 3) and (b) N_2O formation at various soil depths in wheat-maize double cropping rotation receiving 0(CK), 450(N1), 750(N2) kg of N per hectare per year from Oct. 2008 to Sept. 2010. Bars in figures indicate 1 standard deviation.



Tab.1 Total denitrification at various soil depths in wheat-maize double cropping rotation from Oct. 2008 to Sept. 2010, averages of two wheat seasons and two maize seasons, respectively

Depth (cm)	Wheat season (kg N/ha)			Maize season (kg N/ha)			Annual (kg N/ha)		
	CK	N1	N2	CK	N1	N2	CK	N1	N2
0-15cm	0.5	1.5	3.5	1.1	3.3	9.1	1.6	4.8	12.7
15-90cm	0.6	0.7	2.0	1.5	3.6	5.6	2.1	4.4	7.6
90-190cm	1.0	1.8	2.5	1.6	3.7	5.3	2.6	5.4	7.8
0-190cm	2.1 c	4.0 b	7.9 a	4.2 c	10.6 b	20.1 a	6.3 c	14.6 b	28.0 a
Percentage of applied N %		0.8	1.6		2.8	4.2		3.7	5.8

Table. 2 Total amount of N_2O formation at various soil depths and the contribution of subsoil (15cm-190cm) to the total N_2O emission in wheat-maize double cropping rotation from Oct. 2008 to Sept. 2010, averages of two wheat seasons and two maize seasons, respectively

	Wheat (kg N/ha)			Maize (kg N/ha)			Annual (kg N/ha)		
	CK	N450	N750	CK	N450	N750	CK	N450	N750
N_2O emissions (static chamber)	0.3	0.9	1.5	0.6	1.4	4	0.9	2.3	5.5
N_2O production in 0-15cm	0.1	0.2	0.4	0.2	1.1	2.7	0.3	1.3	3.1
N_2O production in 15-90cm	0.3	0.4	0.4	0.3	0.5	0.7	0.6	0.9	1.1
N_2O production in 90-190cm	0.4	0.6	0.8	0.4	1.2	1.5	0.7	1.7	2.3
N_2O production in 0-190cm	0.8 c	1.2 b	1.6 a	0.9 c	2.8 b	4.9 a	1.7 c	4.0 b	6.5 a
N_2O emissions from subsoils beneath 15cm	0.2	0.7	1.1	0.4	0.3	1.3	0.6	1.0	2.4

Conclusion

Denitrification rates in the 1.9 m deep soil profile showed the commonly observed responses to N fertilizer application, irrigation and rainfall, leading to strong a temporal variability. Nitrogen losses through denitrification were significantly higher (a factor of 2.0 to 2.7) in the maize growing season than in the wheat season, likely because of the more wet and warm weather conditions in the maize growing season. On average, only 26% of total denitrification activity in the 190 cm deep soil profiled occurred in the top soil (0-15 cm); 33% occurred in the 15 to 90 cm soil layer and 41% in the 90 to 190 cm soil layer in CK. The contribution of the top soil (0-15 cm) increased to ~ 45% and that of the subsoil (90-190 cm) decreased to ~ 28%, when the N fertilizer application increased to 750 kg per ha per year. The total amount of N lost via denitrification was 6, 15 and 28 kg N ha-1yr-1 in the CK, N1 and N2 treatments, respectively.

In conclusion, the subsoil (15-190 cm) was a large contributor to N losses via denitrification, although the total N losses via denitrification were only in the range of 1 to 6% of total N fertilizer application. Further studies should try to understand the mechanism and controlling factors of denitrification in the low-carbon subsoil.

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