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RESEARCH ARTICLE

Effects of different nitrogen fertilizer management practices on wheat yields and N_2O emissions from wheat fields in North China

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Abstract

Nitrogen (N) is one of the macronutrients required for plant growth, and reasonable application of N fertilizers can increase crop yields and improve their quality. However, excessive application of N fertilizers will decrease N use efficiency and also lead to increases in N_2O emissions from agricultural soils and many other environmental issues. Research on the effects of different N fertilizer management practices on wheat yields and N_2O emissions will assist the selection of effective N management measures which enable achieving high wheat yields while reducing N_2O emissions. To investigate the effects of different N management practices on wheat yields and soil N_2O emissions, we conducted field trials with 5 treatments of no N fertilizer (CK), farmers common N rate (AN), optimal N rate (ON), 20% reduction in optimal rate+dicyandiamide (ON80%+DCD), 20% reduction in optimal rate+nano-carbon (ON80%+NC). The static closed chamber gas chromatography method was used to monitor N_2O emissions during the wheat growing season. The results showed that there were obvious seasonal characteristics of N_2O emissions under each treatment and N_2O emissions were mainly concentrated in the sowing-greening stage, accounting for 54.6–68.2% of the overall emissions. Compared with AN, N_2O emissions were decreased by 23.1, 45.4 and 33.7%, respectively, under ON, ON80%+DCD and ON80%+NC, and emission factors were declined by 22.2, 66.7 and 33.3%, respectively. Wheat yield was increased significantly under ON80%+DCD and ON80%+NC by 12.3 and 11.9%, respectively, relative to AN while there was no significant change in yield in the ON treatment. Compared with ON, overall N_2O emissions were decreased by 29.1 and 13.9% while wheat yields improved by 18.3 and 17.9% under ON80%+DCD and ON80%+NC, respectively. We therefore recommend that ON80%+DCD and ON80%+NC be referred as effective N management practices increasing yields while mitigating emissions.

Keywords: dicyandiamide, nitrous oxide emissions, N fertilizer management, nano-carbon, wheat yields

1. Introduction

Nitrous oxide (N_2O) is one of the important greenhouse gases (GHG). The IPCC Fifth Assessment Report indicated that the atmospheric concentration of N_2O has reached 324 ppb, which is 20% higher than pre-industrial levels (IPCC 2013). It is estimated that 65% of the total N_2O emissions

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were released from soils (Mosier and Kroeze 2000) and N fertilization contributed about 36% of the direct N_2O emissions from worldwide agricultural soils (Mosier *et al.* 1998). Studies have shown that N_2O emissions occurred mainly due to the application of synthetic N fertilizers (Huang *et al.* 2011). In the North China Plain as one of the country's major grain producing areas, excessive application of N fertilizers is prominent, particularly in high-yielding wheat and maize production zones with an average amount of 500–600 kg N ha^{-1} which far more exceeds the crop N requirements (Chen *et al*. 2006).

Reducing N_2O emissions from agricultural soils has drawn great attention as global warming intensifies, and the current research on N_2O emission mitigation measures focuses on long-lasting fertilizers or organic fertilizers, the implementation of conservation tillage and fertilizers added with nitrification inhibitors (NI) (Oenema *et al.* 2005; Asing *et al.* 2008; Huang *et al.* 2011). Dicyandiamide (DCD) is one type of highly effective NI. Nie *et al.* (2012) reported that addition of DCD in combination with optimized N rate and water management resulted in a decrease of 67.3–83.8% and 74.4–85.7% respectively in N_2O flux peak and cumulative N_2O emissions compared with conventional practices. In the rice-wheat rotation ecosystem, relative to the controlled group with only urea, application of urea mixed with DCD for wheat could reduce N_2O emissions by 49% in the wheat growing season and by 18% in the rice growing season (Majumdar *et al.* 2000, 2002). Nano-carbon (NC) is a new type of fertilizer synergist and is found to be able to improve rice yield by 10.2% and N agronomic efficiency by 40.1% while minimizing N losses when added into urea compared to urea application alone (Wang *et al.* 2011). Nano carbon is a kind of modified carbon with low ignition point and non-conductivity. Its size is 5–80 nm, having small-size effect, surface effect and adsorption and other features. Nano carbon can filter toxic gases and harmful organisms and is currently widely used in the research field of new fertilizers which aim to improve crop yields and fertilizer use efficiency. However, it is not clear whether nano-carbon could also offer N_2O emission reduction potential, especially compared with DCD. There have been few studies on the effects of fertilizers added with NC on N_2O emissions and crop yields, nor the effects of different N management practices in the wheat and maize rotation cropping system in North China Plain.

In this context, we will investigate the effects of different N management practices on N_2O emissions and wheat yields based on the measurement of N_2O flux during the winter wheat growing season using the methods of static chamber/gas chromatogram in a field experiment. We aim to provide suggestions on N management practices for wheat production in North China that can achieve high and stable production, improve N use efficiency while decreasing N_2O emissions.

2. Results

2.1. N_2O flux

As shown in Fig. 1, N_2O flux at the sowing-greening stage generally followed the similar trends: rising first and then decreasing. Within the 30 d after sowing wheat, N_2O emission flux of each treatment showed an order of farmers common N rate (AN)>optimal N rate (ON)>20% reduction in optimal rate+nano-carbon (ON80%+NC)>20% reduction in optimal rate+dicyandiamide (ON80%+DCD)>no N fertilizer (CK), implying that decreasing N fertilizers can lower N_2O flux, especially with the addition of DCD and NC. N_2O flux peaked in the 11th day at 204.87 and 174.42 μg m^{-2} h^{-1} respectively under the AN and ON treatments. The N_2O flux peaks under the treatments of ON80%+DCD and ON80%+NC were delayed 2 d compared with AN and ON

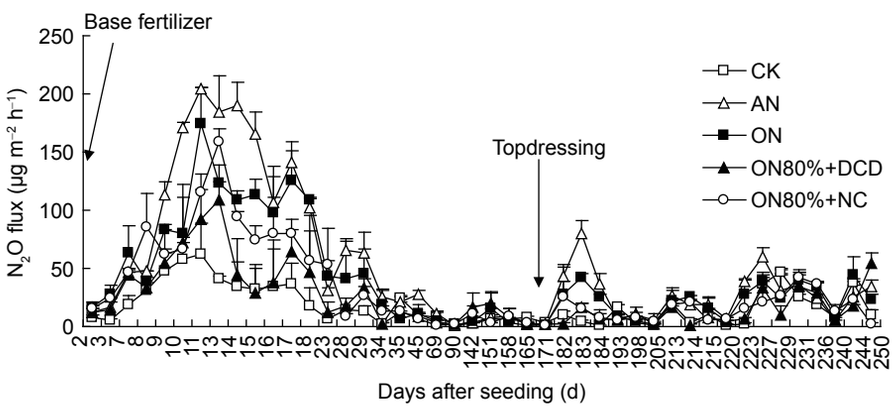

Fig. 1 Impacts of different N fertilizer management practices on N_2O flux. CK, no N fertilizer; AN, farmers common N rate; ON, optimal N rate; ON80%+DCD, 20% reduction in optimal rate+dicyandiamide; ON80%+NC, 20% reduction in optimal rate+nano-carbon.