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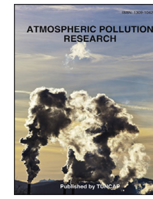

Original article

Variation in characteristics of air concentrations of NH_3, NO_2 and O_3 induced by applications of urea in soils of plastic greenhouses in suburban China

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ABSTRACT

Few studies have been carried out so far for measuring concentrations of NH_3, NO_2 and O_3 in plastic greenhouses. In this study, NH_3, NO_2 and O_3 concentrations were measured with passive sampler technology in a plastic greenhouse located in the Changsha suburb in southern China over a one and a half month period (November 30, 2008 to January 11, 2009). Soil in the greenhouse was subjected to four treatment (T) types (no N fertilizer T1, common urea T2, coated urea T3 and common urea with nitrification inhibitor dicyandiamide (DCD) T4. The average concentrations ($\mu g/m^3$) of NH_3, NO_2 and O_3 in descending order was: T4 (31.66) > T2 (25.93) > T3 (23.52) > T1 (7.96), T2 (10.99) > T3 (8.16) > T4 (7.48) > T1 (5.20), T2 (75.05) > T3 (64.20) > T4 (63.85) > T1 (49.02), respectively. This implied that photochemical reactions took place and that harmful gases accumulated after application of N fertilizer in the plastic greenhouse. DCD inhibited the conversion of ammonium to nitrate, increased NH_3 volatilization and decreased NO_2 level. The coated urea decreased the emissions of NH_3 and increased nitrogen use efficiency. We found significant positive correlations ($p < 0.01$) between temperature and both NH_3 and NO_2 levels. Correlations between soil pH and both NH_3 and NO_2 concentrations were also significant ($p < 0.01$). The O_3 average concentration from March 31, 2009 to April 10, 2009 in the higher latitude of the Yinchuan suburb in northern China was two times greater than that in the Changsha suburb in southern China. The O_3 daily concentrations in the Yinchuan suburb exceeded 160 $\mu g/m^3$ (i.e., China's Grade I standard), and the maximal value 214.83 $\mu g/m^3$ exceeded 200 $\mu g/m^3$ (i.e., China's Grade III standard).

1. Introduction

Recently, plastic greenhouse cultivation has become widely used for agricultural production in China. There are a large number of studies that refer to problems induced by increased nitrate nitrogen obtained in soils such as salt injury. However, very little information is available on the impacts of accumulated harmful gases. Gases released from soil rarely escape greenhouses after application of nitrogen fertilizers, leading to serious air pollution and terrestrial ecosystem damage (Akiyama et al., 2004; Mkhabela et al., 2006).

Agricultural activity is considered a major source of a number of pollutant gases including NH_3 and NO_x (van Aardenne et al., 2001). The NO_x released by soil emissions can account for up to 75% of the global NO_x budget (Roelle and Aneja, 2002b). Because soil emissions mainly result from the nitrification and denitrification processes, emissions of NH_3 from fertilizer applications are known to be controlled by such factors as soil type, soil moisture content, temperature, nutrient level and pH (Yamulki et al., 1995; Harrison and Webb, 2001). NO_2 and O_3 are both secondary pollutants and can result from photochemical processes involving NO_x and reactive hydrocarbons. High ozone levels are found in regions of high NO_x (Carmichael et al., 2003).

Urea is an important nitrogen fertilizer widely used in agriculture (Gioacchini et al., 2002; Zeng et al., 2006), but urea has been shown to have lower N use efficiency than other fertilizers. The aim

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of the present study was to quantitatively describe the concentration characteristics of NH_3, NO_2 and O_3 and to evaluate fertilizer N efficiency in plastic greenhouses as a result of different fertilizer applications. For this purpose, we designed and conducted field experiments at suburban areas of Changsha in Southern China to measure air concentrations of NH_3, NO_2 and O_3 by using diffusive samplers at vegetable fields that were treated with urea alone, coated urea or urea with a nitrification inhibitor (dicyandiamide, DCD). The factors affecting the levels of NH_3, NO_2 and O_3 were then evaluated in relation to the environmental conditions of study period. We also measured O_3 concentration from plastic greenhouses at two different latitudes (Yinchuan in northern China and Changsha in Southern China).

2. Materials and methods

2.1. Experimental sites

In this study, two locations were selected as sampling sites. The sketch map is shown in Fig. 1. A field experiment at site one (S1) was conducted at suburban areas of Changsha (28.2°N, 113.1°E) in Southern China. There were four tunnel plastic greenhouses with 3.0 m height, 10.0 m length and 6.0 m width. The field was operated with typical agronomic practices for the crop planted a few days prior to the fertilizer treatments. The soil was derived from river alluvial deposits in the Dongting Lake Plain and was air dried, and then passed to a 2-mm sieve. The soil had a pH of 5.78, CEC of 8.98 cmmol kg^{-1}, 24.3 g organic matter kg^{-1} and 112 mg available N kg^{-1}. At the second site (S2), measurements were gathered from one tunnel plastic greenhouse with 3.0 m height, 10.0 m length and 6.0 m width at suburban areas of Yinchuan (38.5°N, 106.3°E) in Northern China.

2.2. Experimental design

In this work, a field study was made to measure air concentrations of NH_3, NO_2 and O_3 from cultivated fields in plastic greenhouses at sampling site (only S1) after applying different doses of fertilizers. As shown in Table 1, the experiment was designed with four fertilizer treatments (T). The four T types were applied in separate plastic greenhouses to compare the concentration characteristics of NH_3, NO_2 and O_3. T1 was an application of P K fertilizers and represents the control treatment (no N) and T2 was an application of P K fertilizers with common urea added (46.0% N content, produced by Jiangfeng Chemical Factory, China). T3 was an application of P K fertilizers and coated urea (25.5% N content, produced by South China Agricultural University, China). T4 was an application of P K fertilizers and common urea with a nitrification inhibitor (dicyandiamide, DCD, produced by Jiangfeng Chemical Factory). The inhibitor was pre-coated onto the fertilizers. Treatments were broadcasted directly onto the respective cultivated plots by hand on November 29, 2008. Lettuce (Lactucapsativapl.var.asparaginap bailey) was planted in every plastic greenhouse on the same day. We then attempted to evaluate the factors affecting NH_3, NO_2 and O_3 levels in relation to the different fertilizer treatments.

The other field study was made to measure air concentrations of O_3 from cultivated fields in plastic greenhouses at two different latitudes (S1 and S2) with applying fertilizers which was the same

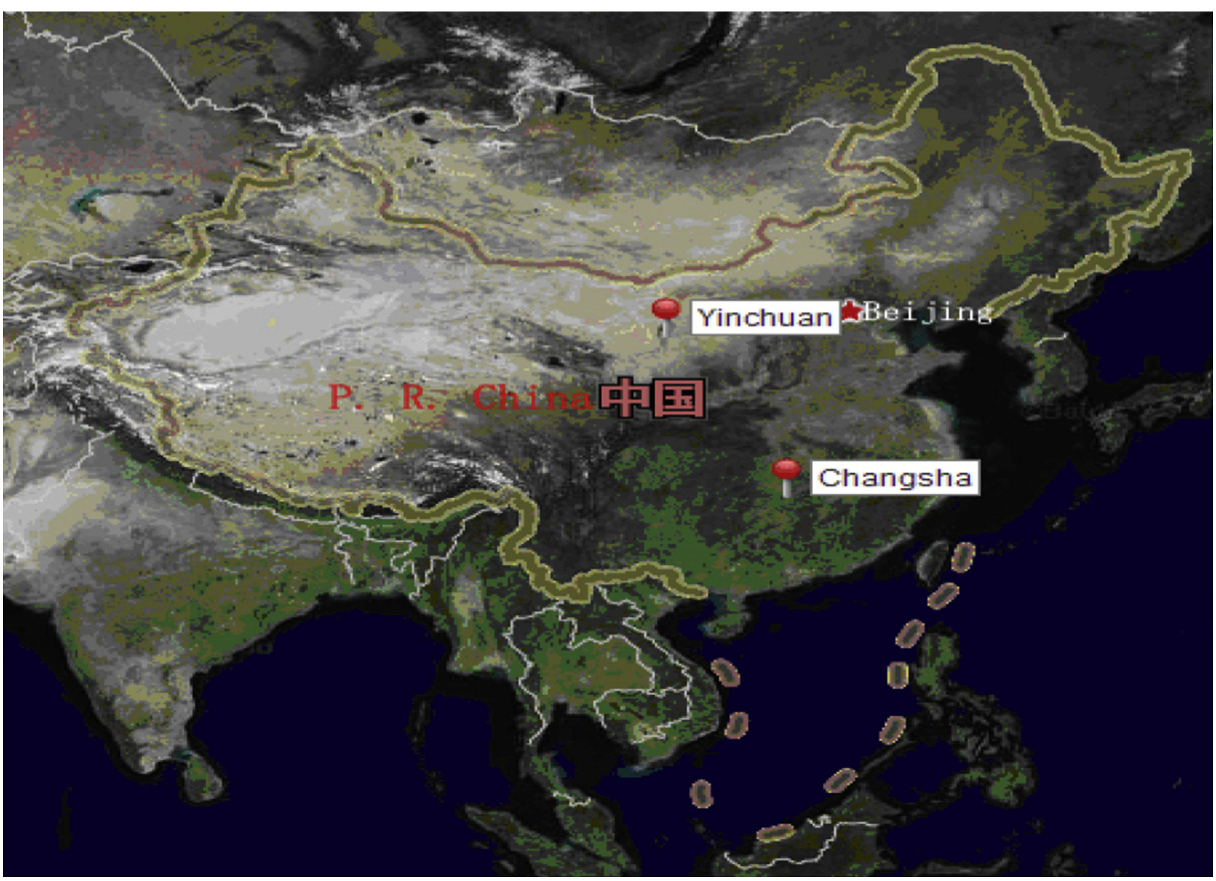

Fig. 1. The sketch map of sampling sites in China. Changsha is in the south and Yinchuan is in the north of China.