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Effects of conservation tillage practices on ammonia emissions from Loess Plateau rain-fed winter wheat fields

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HIGHLIGHTS

- Ammonia emissions were measured using a vented chamber method.
- Conservation tillage practices significantly reduce ammonia emissions.
- Deep-band application of nitrogen fertilizer reduces ammonia emissions.
- Film and stalk mulches can both reduce ammonia volatilization.
- Ammonia fluxes are strongly dependent on soil ammonium, moisture, and temperature.

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ABSTRACT

Ammonia emissions from agricultural activities contribute to air pollution. For the rain-fed winter wheat system in the Loess Plateau there is a lack of information about ammonia emissions. Current study aimed to provide field data on ammonia emissions affected by conservation tillage practices and nitrogen applications. A two-year field experiment was conducted during 2011–2013 wheat growing seasons followed a split-plot design. Main plots consisted of one conventional tillage (CT, as the control) and five conservation tillage systems, i.e., stalk mulching (SM), film mulching (FM), ridge tillage (RT), ridge tillage with film mulch on the ridge (RTfm), and ridge tillage with film mulch on the ridge and stalk mulch in the furrow (RTfmsm); while subplots consisted of two nitrogen application rates, i.e., 0 and 180 kg N ha^{-1}. Ammonia emissions were measured using an acid trapping method with vented chambers. Results showed ammonia fluxes peaked during the first 10 days after fertilization. On average, nitrogen application increased ammonia emissions by 26.5% (1.31 kg N ha^{-1}) compared with treatments without nitrogen application ($P < 0.05$). Ammonia fluxes were strongly dependent on soil ammonium, moisture, and temperature. Tillage systems had significant effects on ammonia emissions. On average, conservation tillage practices reduced ammonia emissions by 7.7% (0.46 kg N ha^{-1}) compared with conventional tillage ($P < 0.05$), with FM most effective. Deep-band application of nitrogen fertilizer, stalk mulches, and film mulches were responsible for reductions in ammonia emissions from nitrogen fertilization in conservation tillage systems, thus they were recommended to reduce ammonia emissions from winter wheat production regions in the southern Loess Plateau.

1. Introduction

Ammonia is the most abundant alkaline gas in the atmosphere, with agriculture as the largest source (Behera et al., 2013; Martinez-Lagos et al., 2013). Nitrogen fertilization is a key driving force in the biogeochemical cycle of atmospheric ammonia. Over the last few decades, ammonia emission has been increasing on a global scale, with adverse effects on global climate change, environment, and public health (Behera et al., 2013). For example, deposited ammonia increases nitrification and denitrification rates and then increases

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emissions of nitrous oxide, a potent greenhouse gas (Ferm, 1998). Ammonia reacts with acidic substances in the atmosphere to form ammonium salts which result in the formation of atmospheric particulate matter (e.g., $PM_{2.5}$), haze pollution, and visibility degradation, posing a substantial threat to human health as well as traffic (Gong et al., 2013a).

Ammonia emissions from agricultural activities are notable in China. For example, ammonia emission is 1.29–4.68 kg N ha^{-1} (0.3–1.9% of applied N) from winter wheat fields in the southern Loess Plateau of China (Shangguan et al., 2012). Over the past decade, China has suffered serious haze pollutions (Ma et al., 2012a), partially due to the increasing atmospheric ammonia. Consequently, it is time for China to take actions to reduce ammonia emission and deposition in agricultural systems, and alleviate their adverse impacts locally and globally (Liu et al., 2013).

Winter wheat is one of the most important cereal crops in the southern Loess Plateau of China (Fig. 1a), with urea as the predominant nitrogen fertilizer, which is usually applied in a single application before sowing wheat (Roelcke et al., 1996). However, urea has the potential for substantial losses of ammonia (Sanz-Cobena et al., 2011). Moreover, the high pH of calcareous soils in Loess Plateau results in great ammonia losses, with maximum losses reaching 50% of applied N (Roelcke et al., 1996). Therefore, strategies to reduce ammonia emissions from winter wheat fields in this region are critical for the nitrogen emission and deposition reduction in China. Conservation tillage practices have been recommended to maintain crop yield, leading to variations in ammonia emissions, which are sensitive to surface mulching

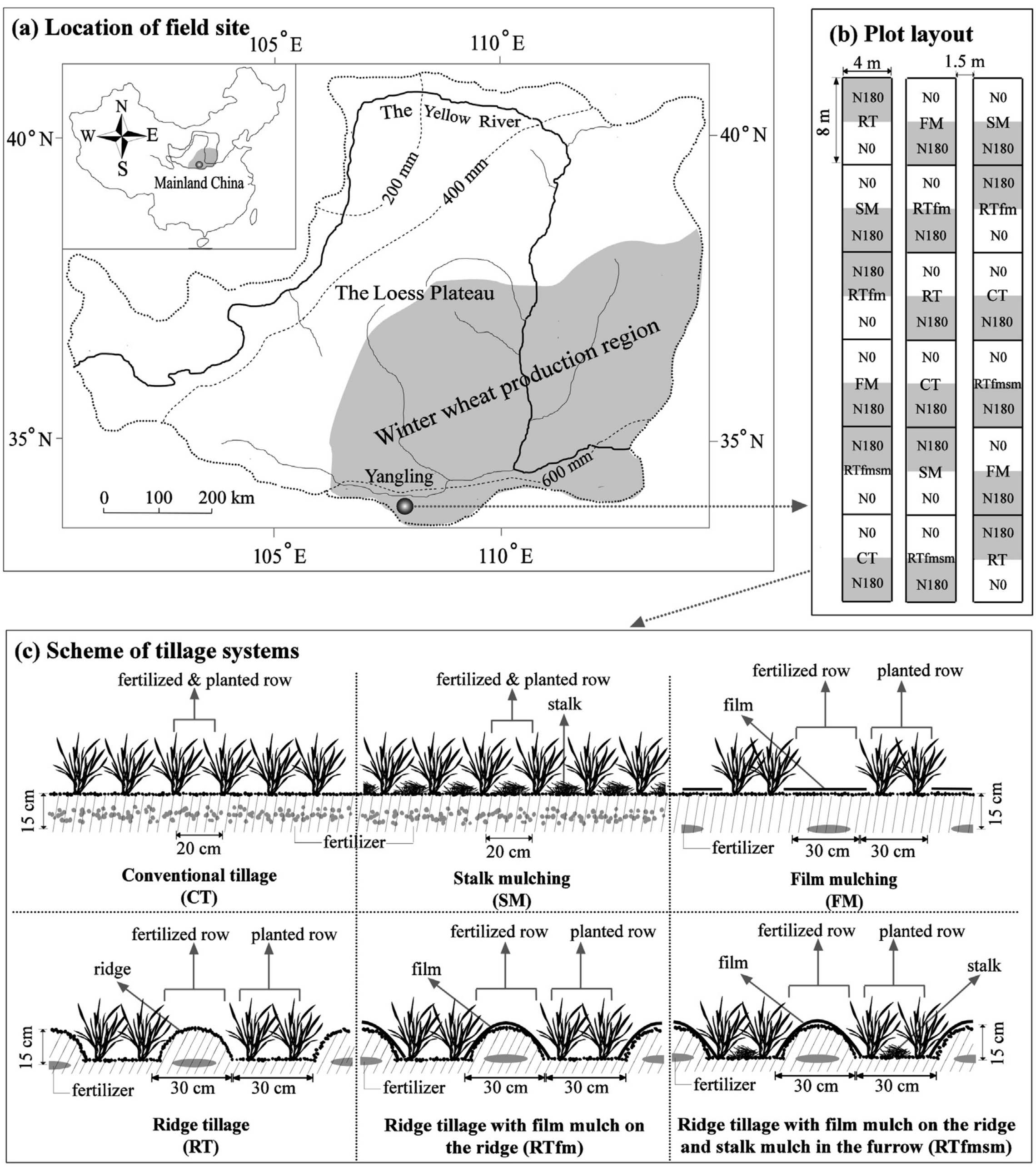

Fig. 1. Location of field site (a), plot layout (b), and scheme of tillage systems (c). The winter wheat production region is shown as the shaded area. Main plots (tillage systems) were split into two nitrogen fertilizer subplots.