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RESEARCH ARTICLE

Soil Nitrous Oxide Emissions Under Maize-Legume Intercropping System in the North China Plain

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Abstract

Many studies have focused on various agricultural management measures to reduce agricultural nitrous oxide (N_2O) emission. However, few studies have investigated soil N_2O emissions in intercropping systems in the North China Plain. Thus, we conducted a field experiment to compare N_2O emissions under monoculture and maize-legume intercropping systems. In 2010, five treatments, including monocultured maize (M), maize-peanut (MP), maize-alfalfa (MA), maize-soybean (MS), and maize-sweet clover (MSC) intercropping were designed to investigate this issue using the static chamber technique. In 2011, M, MP, and MS remained, and monocultured peanuts (P) and soybean (S) were added to the trial. The results showed that total production of N_2O from different treatments ranged from (0.87±0.12) to (1.17±0.11) kg ha^{-1} in 2010, while those ranged from (3.35±0.30) to (9.10±2.09) kg ha^{-1} in 2011. MA and MSC had no significant effect on soil N_2O production compared to that of M (P<0.05). Cumulative N_2O emissions from MP in 2010 were significantly lower than those from M, but the result was the opposite in 2011 (P<0.05). MS significantly reduced soil N_2O emissions by 25.55 and 48.84% in 2010 and 2011, respectively (P<0.05). Soil N_2O emissions were significantly correlated with soil water content, soil temperature, nitrification potential, soil NH_4^+, and soil NO_3^- content (R^2=0.160-0.764, P<0.01). A stepwise linear regression analysis indicated that soil N_2O release was mainly controlled by the interaction between soil moisture and soil NO_3^- content (R^2=0.828, P<0.001). These results indicate that MS had a coincident effect on soil N_2O flux and significantly reduced soil N_2O production compared to that of M over two growing seasons.

Key words: maize, legume, intercropping, soil nitrous oxide, environmental factors

INTRODUCTION

Increased atmospheric concentrations of carbon dioxide (CO_2) and other greenhouse gases, including nitrous oxide (N_2O) and methane (CH_4) as a result of anthropogenic activities, are of great concern due to the associated risk of global climate change (IPCC 2007). Atmospheric N_2O is an important contributor to global climate change and is the single most important ozone-depleting emission (Ravishankara *et al*. 2009). N_2O emission as a result of denitrification in anaerobic soil and nitrification in aerobic soil (Ball *et al*. 1999) from agriculture contributes 84% of the total N_2O emissions (Li *et al*. 2010). Therefore, reducing soil N_2O emission from agriculture is an important issue.

Various agricultural managements can be adopted

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to reduce N_2O emissions (Ball *et al*. 1999; Meng *et al*. 2005; Mendoza *et al*. 2006; Oorts *et al*. 2007; Juliana *et al*. 2009; Liu *et al*. 2011). Such management practices include tillage, fertilizing methods, and crop rotation. Intercropping, defined as any system of multiple cropping within the same space, has a long and successful history in tropical regions (Li *et al*. 2001; Whitmore and Schröder 2007). The intercropping of cereals and legumes is particularly common (Tsubo *et al*. 2005). To date, most research on intercrop systems has focused on grain yield, resource use and competition, nutrient-use efficiency, microbiological properties and weed, disease and erosion control (Trenbath 1993; Lesoing and Francis 1999; Li *et al*. 2001; Zhang and Li 2003; Walker and Ogindo 2003; Li *et al*. 2005; Song *et al*. 2007; Gao *et al*. 2009; Oelbermann and Echarte 2011). But studies on crop-based intercropping systems are rare. It is speculated that soil N_2O emission could be affected by intercropping because environmental factors related to its emission could be changed by this system compared to monocultural system. A reduction of N_2O in tree-based intercropping systems has been reported (Thevathasan and Gordon 2004; Beaudette *et al*. 2010). A recent paper showed that maize-soybean intercropping had reduced the soil N_2O emission compared to sole maize (Kyer *et al*. 2012). It remains unclear, however, whether crops that compete for nutrients in cereal-based systems could be successfully intercropped with one another to control soil N_2O emission.

The North China Plain, which produces about one-fourth of the country's total grain yield, is an intensive agricultural region with a winter wheat-summer maize rotation (Liu *et al*. 2001). In maize growing season N fertilizer application averaged (257±121) kg ha^{-1} in the farmers' fields in China (Chen *et al*. 2011). This high N fertilizer application largely induced soil N_2O emission and contributes substantially to agricultural N_2O emissions in this region. Many studies have shown that the cumulative N_2O emissions from a growing season of maize (3-4 months) are 1.2-6.6 times larger than those from a growing season of winter wheat (8-9 months) (Gao 2004; Meng *et al*. 2005; Ding *et al*. 2007; Wang *et al*. 2009; Jiang *et al*. 2010; Ju *et al*. 2011; Liu *et al*. 2011), indicating that it is important to reduce soil N_2O emissions during maize growing season.

Thus, we conducted field experiments to investigate the effect of conventional maize-legume intercropping on soil N_2O emissions in this region. Furthermore, soil moisture, temperature, inorganic nitrogen, and nitrification and denitrification potential were also determined to explain the relationship between these factors and soil N_2O emissions.

RESULTS

N_2O fluxes

Different treatments produced similar N_2O fluxes ranging from 0.10 to 3.46 µg m^{-2} min^{-1} in 2010 (Fig. 1-A) and from 0.10 to 33.55 µg m^{-2} min^{-1} in 2011 (Fig. 1-B). Soil N_2O emission increased in different treatments after N application during the two growing seasons and higher emission rates were observed after the second N application (top dressing). One distinct soil N_2O flux peak and difference of emission rate between treatments were observed in 2011, appearing after the application of N fertilizer. During this period, soil N_2O emissions increased sharply (7.34-33.55 µg m^{-2} min^{-1}). The highest emission rates were recorded from maize-peanut intercropping (MP), followed by monocultured maize (M), maize-soybean intercropping (MS), monocultured peanut (P) and soybean (S) remained in relatively lower emission rates. Cumulative soil N_2O flux in the M treatment was (1.17±0.11) kg ha^{-1}, which was significantly higher than those in the MP and MS treatments of (0.88±0.13) and (0.87±0.12) kg ha^{-1}, respectively, in 2010. MP and MS treatments reduced total soil N_2O flux by 24.73 and 25.55% compared to that in M, respectively ($P<0.05$, Table 1). Maize-alfalfa (MA) and maize-sweet clover intercropping (MSC) had no significant effect on soil N_2O emissions compared to M ($P<0.05$, Table 1). In the second growing season, total soil N_2O emissions were larger than that in the first growing season. The greatest total N_2O emissions occurred from MP of (9.10±2.09) kg ha^{-1}, which was significantly higher than that of M of (6.54±1.03) kg ha^{-1} ($P<0.05$). The cumulative soil N_2O flux from P, S, and MS were significantly lower than that of M by 40.67-48.84% of the total N_2O production compared to that of M ($P<0.05$, Table 1). N_2O production during 2 weeks after the second N application (top dressing) contributed 58.87-66.11% to total emissions.