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Nitrogen transformation in maize soil after application of different organic manures

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Abstract: The nitrogen transformation in maize soil after application of different organic manure was studied. The nitrogen mineralization in surface soil, NO_3^--N dynamics and distribution in soil profile, and N_2O emission were investigated. Eight treatments were laid out randomizing with three replications in 24 plots: maize plantation without fertilizer(CK1), bare soil without maize plantation and fertilization (CK2), swine manure(S1, S2), poultry manure(P1, P2), and cattle manure(C1, C2). Three manures were applied at two application levels(15 t/hm^2 and 30 t/hm^2). The results indicated that NH_4^+-N in surface soil showed the same temporal pattern without much variation among different treatments. But NO_3^--N in the same layer exhibited large temporal pattern in all treatments, which was mainly due to its easy eluviations of NO_3^--N in soil, its transformation to N_2O and the influence of precipitation. The distribution of NO_3^--N in the soil profile during maize growing season showed the leaching tendency from surface soil to subsoil, which was different among the treatments. The poultry treatments showed the largest leaching tendency. The study also revealed that the emissions of N_2O were affected by the application of organic manures in the order of P2 > S2 > C2 > P1 > S1 > C1 > CK1 > CK2. All these results showed that organic manure applications significantly affect nitrogen transformation and distribution in maize soil. Considering N_2O emission and NO_3^--N leaching, the management of organic manure in the agriculture needs further studies.

Keywords: organic manure; maize; NH_4^+-N; NO_3^--N; N_2O

Introduction

Animal wastes are usually applied to soil as organic manure. Application of organic manure to arable land is recommended for recycling valuable nutrient resources. However, if improperly used, organic manure may become a source of environmental problems, such as greenhouse gas emissions, ammonia volatilization and NO_3^--N leaching into groundwater (Williams, 1999). Nitrate leaching from arable land, which causes contamination of groundwater, has become a matter of worldwide concern. There are many documents on the effects of chemical fertilizer on NO_3^--N leaching(Diez, 1997; Granlund, 2000). Some studies have been carried out to evaluate the NO_3^--N leaching after organic manure applications(Dauden, 2003; Yuan, 2000). Although land-applied organic manure has been recognized as a significant source of greenhouse gas emissions, estimates are usually based on laboratory studies or relatively short-term field measurements from a single application(Thornton, 1998; Chantigny, 2002). Other studies have compared the difference of N_2O emissions between chemical and organic fertilizer or between fresh and composted organic manure in field experiments(Mahmood, 1998; Thornton, 1998).

Organic manure is a valuable fertilizer in China. The environmental effects of manure have not been paid enough attention. Limited information is available regarding both NO_3^--N leaching and N_2O emissions from manure application fields. With the rapid increase of animal stock in China, the kinds of input organic manure tended to become more singular. Therefore further study on NO_3^--N leaching and N_2O emissions after organic manure application may provide valuable information for developing organic manure management practices. The objectives of the studies were: (1) to determine the effects of different organic manures on the dynamics of NH_4^+-N and NO_3^--N in surface soil; (2) to investigate the dynamics and distribution of NO_3^--N in soil profile after organic manure application; and (3) to assess the effect of different organic manures on N_2O emissions.

1 Materials and methods

1.1 Field experiment

The experiments were conducted at Yucheng Comprehensive Experimental Station, the Chinese Academy of Sciences(36°40'—37°12'N, 116°22'—116°45'E, an elevation of 28 m) during the maize growing season(June—October) of 2003. The station is located in the alluvial part of the North China Plain. The mean annual precipitation is 610 mm and the mean annual temperature is 13.1℃. The soil is aqua soil with sandy loam texture. The chemical properties of the soil are as follows: pH 8.46, organic matter 1.47 g/kg, total N 0.9 g/kg, total P (P_2O_5) 0.2% and total K(K_2O) 2.26%.

After organic manure application, the field was ploughed and leveled and subdivided into 24 plots(7 m × 6 m). The experiment was laid out in a randomized plots design with eight treatments, each with three replications. The eights treatments were: maize plantation without fertilizer(CK1), bare soil with no maize and no fertilizer(CK2), swine manure, poultry manure, cattle manure, each in two application levels (15 t/hm^2 and 30 t/hm^2). The chemical characteristics of these organic manures are shown in Table 1.

Table 1 Chemical properties of organic manure applied to the soil

Organic manure	N, %	P, P_2O_5%	K, K_2O%	pH	NO_3^--N, mg/kg	NH_4^+-N, mg/kg
Swine manure	0.76	0.42	0.71	8.55	169.49	962.42
Cattle manure	0.68	0.66	0.30	8.25	202.28	80.29
Poultry manure	0.92	0.93	0.89	8.55	671.37	1294.44

Maize was planted manually in 0.65 m wide rows on June 17 and harvested on October 5. There was no irrigation during the maize growing season.

1.2 Sample collection and analysis

Collection of gas samples was carried out by the close chamber technique. The chambers used here were made of stainless steel material. At the beginning of the experiment, stainless steel base were inserted 10 cm into the soil between the rows without including in maize and weed in each plot, without moving during the whole experiment. When gas samples were taken, the chamber was covered on the base with water used to prevent the air in the chamber from the outside. One chamber covered an area of 0.25 m^2 and had a volume of 125 L. Samples of enclosed air were withdrawn at 0, 10, 20, and 30 min after chamber was closed. Gas samples were analyzed within 24 h after sampling and injected in a gas chromatograph to simultaneously quantify

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CO_2, N_2O and CH_4 concentrations. Gas emission rate was computed from the linear change in gas concentrations over the period of measurement time.

Soil samples were taken from each plot from five depths: 0—15 cm, 15—30 cm, 30—50 cm, 50—70 cm, 70—90 cm and 90—110 cm in each plot, and analyzed colorimetrically for NH_4^+-N and NO_3^--N.

2 Results and discussion

2.1 Temporal change of NO_3^--N and NH_4^+-N in the surface soil after the organic manure application

Nitrogen transformation in soil after organic manure application has been documented in laboratory experiment. NH_4^+-N and NO_3^--N concentrations in soil were related to the nitrification and denitrification (Chantigny, 2002). After organic manure application, there was no significant difference in NH_4^+-N among all treatments and NH_4^+-N concentrations showed the same variation over time during the maize growing season (Fig.1). Due to high soil temperatures during the maize growing season, the nitrogen in organic manure was either nitrified quickly or immobilized, and little remained in the form of NH_4^+-N most time. The stability of NH_4^+-N in surface soil was due to its cation characteristic and tendency to be adsorbed by soil (Liu, 2001).

Fig.2 shows NO_3^--N great difference and temporal change during maize growing season after organic manure applications. The temporal change was partly due to precipitation. NO_3^--N with anion characteristic is not adsorbed by soil and increasing precipitation increased the tendency of NO_3^--N leaching from surface soil to subsoil (Zhang, 2002).

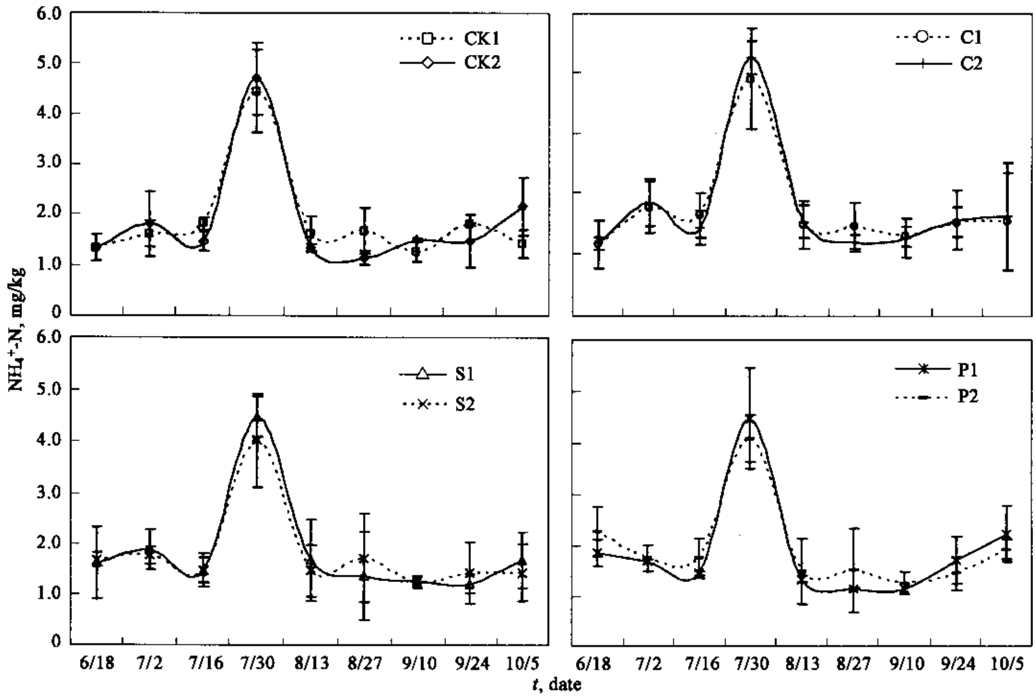
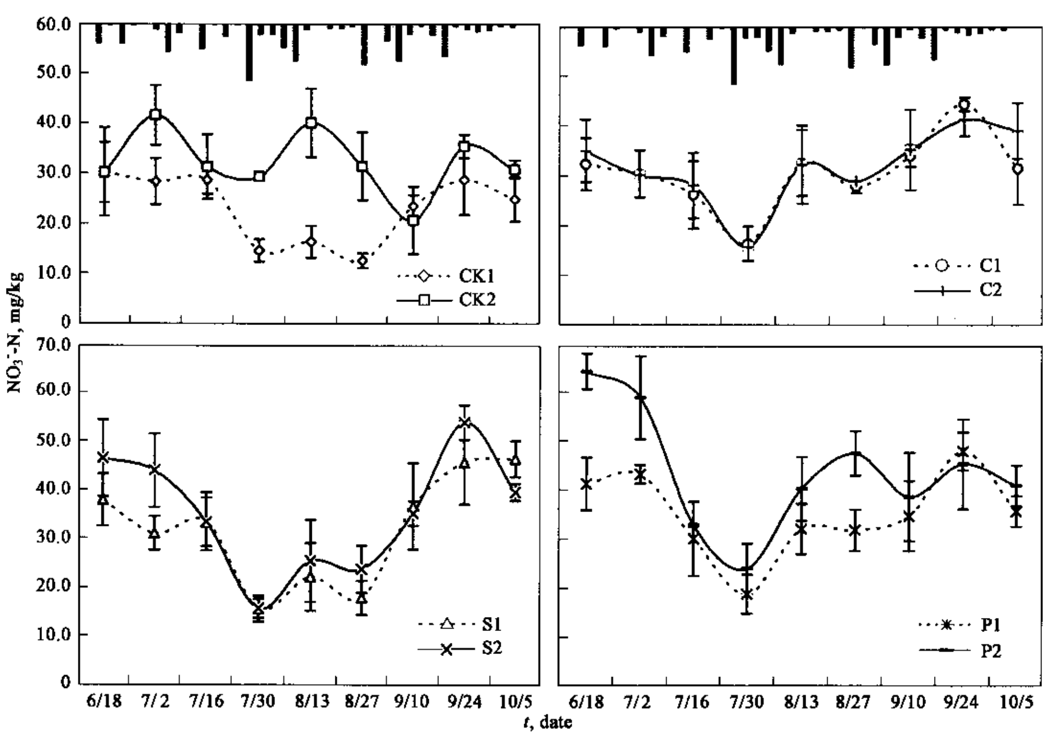


Fig.1 Temporal change of NH_4^+-N in the surface soil after the organic manure application



Besides, the leaching to subsoil, NO_3^--N was also assimilated by plant or denitrified as N_2O. Organic manure application increased NO_3^--N concentration in surface soil. The increasing effect was in the order of poultry manure, swine manure, and cattle manure. Increasing NO_3^--N concentration affected N_2O emission and leaching tendency of NO_3^--N.

2.2 Soil NO_3^--N dynamics and distribution in soil profile

The dynamics of NO_3^--N in soil was influenced by NO_3^--N concentration, soil water content and plantation (Maeda, 2003; Devienne-Barret, 2000). After organic manure application, soil NO_3^--N dynamics and distribution in soil profile are shown in Fig. 3. All treatments showed transformation of NO_3^--N from surface to subsoil with different dynamics. Compared with CK1, CK2 showed great changes and higher NO_3^--N concentration in soil profile. The results showed that maize plantation in summer could decrease NO_3^--N leaching due to the uptake of nitrogen by maize. Organic manure application increased the NO_3^--N concentration in soil, which increased leaching risk of NO_3^--N. The dynamics of NO_3^--N in soil profile was different due to different nitrogen content in the organic manure. The treatment with higher nitrogen amount such as poultry manure could increase the risk of NO_3^--N leaching. Some studies have pointed out that organic manure application could inhibit the NO_3^--N leaching compared with chemical fertilizer treatment. But organic manure could increase the accumulation of NO_3^--N and leaching to underground water (Guo, 2000; Yuan, 2000).

2.3 Effect of organic manure on N_2O flux

After the application of organic manure, N_2O flux showed the same temporal trends in organic manure treatments. The analysis of variance (ANOVA) showed that N_2O emission in organic manure treatments was significantly different form unfertilized control at the beginning of the growth period and emission peaks dates. There was no significant difference in N_2O emission among all treatments in the later period (Fig. 4). Cumulative N_2O emissions were from 0.41 to 1.33 gN_2O/m^2 per season in all treatments. Organic manure application increased the emission of N_2O. The effects were in the following order: P2 > S2 > C2 > P1 > S1 > C1. Bare soil showed lower N_2O emission than unfertilized maize soil, which is similar to the finding of Mahmood (Mahmood, 1997) that maize plants grown under field conditions always had the potential to increase denitrification.

N_2O emission from soil was due to nitrification and denitrification, which was influenced by the concentration of NO_3^--N and NH_4^+-N in soil (Abbasi, 2002; Skiba, 1998). Organic manure with rich organic carbon and easily mineralizable nitrogen increased N_2O emission by increasing the microbial biomass (Thornton, 1998). Organic manure input increased NO_3^--N concentration as shown in Fig. 2, which might have favored N_2O emission.

Fig.2 Temporal change of NO_3^--N(line) in surface soil after the organic manure application and the precipitation(bar) during the growth season

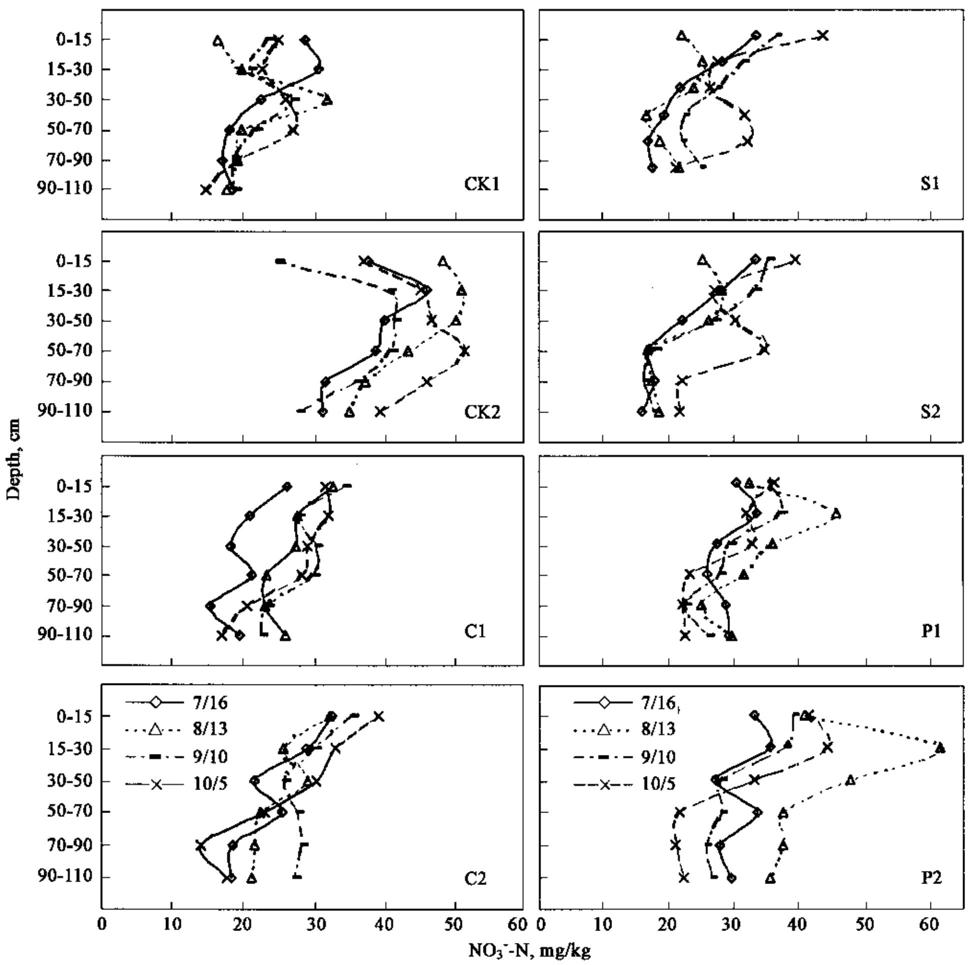


Fig.3 NO_3^--N concentrations in soil profile among all treatments at the different sampling times during the experimental period

3 Conclusions

The results of the experiment showed that after organic manure application, there were no significant differences in NH_4^+-N in surface soil among all treatments. But organic manure application increased NO_3^--N concentration in surface soil with large temporal changes. Maize plantation decreased the surface NO_3^--N concentration compared with bare soil. The trends of NH_4^+-N and NO_3^--N were related to nitrification and denitrification, and were also influenced by their electric charge and the absorption of soil.

Being affected by NO_3^--N concentration, the distribution of NO_3^--N in the soil profile in different time showed the different leaching tendency from surface soil to subsoil. Bare soil showed great NO_3^--N changes in soil profile. Organic manure application increased the NO_3^--N concentration in soil, which increased leaching risk of NO_3^--N. The treatment with higher nitrogen amount such as poultry manure could increase the risk of NO_3^--N leaching.

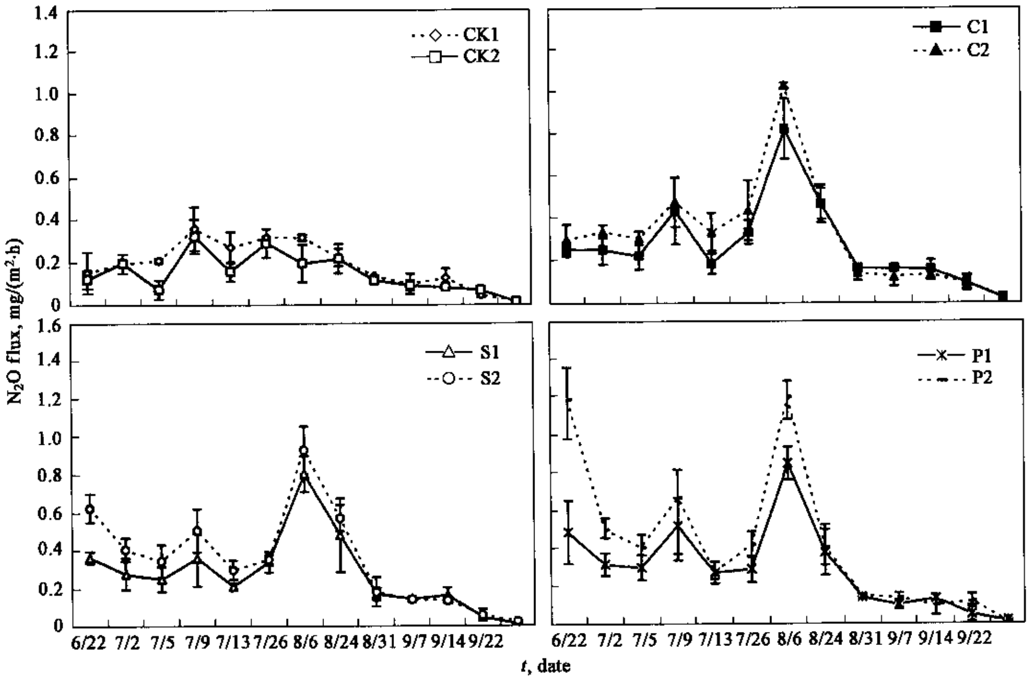


Fig.4 Soil N_2O fluxes from maize soil with time following application of organic manures

Application of organic manure increased N_2O fluxes from agricultural soil. The effects were in the order of poultry manure, swine manure, and cattle manure at low and high application amount. The differences were partly due to the different nitrogen content in organic manure.

The results indicated that in summer with high precipitation, excessive nitrogen from organic manure could cause NO_3^--N leaching. Application of organic manure with higher nitrogen content also increased N_2O emissions. So, management of organic manure in agriculture needs considering its effect on N_2O emission and NO_3^--N leaching.

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