Effects of Straw Return on Soil Nitrogen Leaching

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Nitrogen (N) is a major limiting factor for improvement in grain production. The return of straw to the soil (straw return) is regarded as a very effective option to develop sustainable agriculture. Soil N content could be increased by the straw return because straw itself contains some nitrogen. However, whether N retention could be increased by the straw return is worthy of further study. In the present study, a laboratory simulative incubation experiment was conducted to study the effects of straw addition on N leaching from soil. The experimental results showed that the pH values in soil with time were changed slightly with different straw application, there was no notable change in relative abundance of microbial taxa of different straw application in soil at domain level, and the EC of the soil did not show any clear trends after straw incorporation. The highest EC in the soil was 0.18 ds/m occurred with straw addition of 0.3%. Moreover, the N leaching amounts from soil with different straw application were decreased over time, the higher the amount of straw added in soil, the greater content of N leaching from the soil.

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INTRODUCTION

With rapid population growth and growing demand for food production, agricultural lands with intensive soil cultivation are becoming increasingly degraded. Nitrogen (N) is a major limiting factor for improvement in plant growth and food production (Sainju *et al.* 2009). The use of N-based fertilizer is an effective way to solve soil fertility decline, which is of great importance for sustainable agricultural development. The use of N-based fertilizer for promoting plant growth and food production has been increased in the past decades (Mader *et al.* 2002). However, the N use efficiency is low. Most of the loss of N from soil is caused by leaching, and the control of N retention plays an important role in the development of ecological and sustainable agriculture (Miao *et al.* 2011).

Crop straw is the most abundant agricultural by-product in China. Crop straw has been widely used as an energy source (Zeng *et al.* 2007), to enhance soil fertility (Wang *et al.* 2017), for bio-electricity (Lin and He 2017) and for industrial raw materials (Lu *et al.* 2015), *etc.* With the development of rural economy and the improvement of farmers' living standard, straw was usually burnt by farmers in China, especially in summer and autumn. Burning of crop straw not only causes a huge waste of biomass resources, but it also pollutes the ecological environment to a great extent and is forbidden by Chinese law (Qu *et al.* 2012; Zhang *et al.* 2014).

Incorporating straw into the soil is a widespread agricultural practice and is regarded as a very effective option to effectively manage this crop straw. Moreover, the effects of crop straw return on soil N retention are worthy of further study. Therefore, a laboratory simulative incubation experiment was conducted to study the effects of straw addition on N leaching from soil. Additionally, the effects of straw addition on electrical conductivity (EC), pH, and the microbial community of soil were also studied. The objective of this study was to investigate the possibility of control N leaching by straw return, The result will be helpful to elucidate the influence of straw return on N leaching, which are essential in the control of N retention for promoting plant growth and food production.

EXPERIMENTAL

Materials and Methods

Soil samples were collected from experimental sites (0 to 20 cm in depth) of Anhui Academy of Agricultural Sciences. The soil is eutric planosols, referring to the standard of HJ-T166-2004 (the National Environment Protection Bureau of People's Republic of China), which containing 15.5 g/kg organic matter, 1.21 g/kg total N, and pH 7.37. The soil samples were air dried for two weeks and mixed using sample quartering. About 3000 g soil (11.5% moisture) were gathered and subsequently filtered through 2 mm sieves after removal of debris. The rapeseed straw was collected from experimental sites, and it was cut into small pieces then incorporated into soil in series plastics boxes (5 L) with 3 different straw addition (w/w, %): The control was prepared with straw addition of 0%, straw addition of 0.3% and straw addition of 1%, respectively.

For the incubation experiments, the boxes (25 × 20 × 10 cm) were covered with distilled water. The tests were conducted in an incubator at constant temperature of 25 °C. The effects of different straw addition on N leaching were tested, where each treatment was independently replicated three times. Water samples were withdrawn from the boxes at specific intervals, and N content was determined by TOC-TN analysis meter (IL500, HACH, U.S.A). To measure EC and pH parameters in soil, 10 g of the soil sample was mixed with water at the ratio of 1: 2.5, which were centrifuged at 6000 rpm for 10 min. The supernatant was measured using a conductivity meter (DDS-307W, China). For the analysis of the diversity and structure of microbial communities, DNA was extracted from soil (3 g) using a PowerSoil™ DNA extraction kit (MoBio Laboratories Inc., Carlsbad, California, USA) according to the manufacturers' instructions. General Primer for the bacterial 16S rRNA genes amplification were (5'-AGAGTTTGATCMTGGCTCAG-3') and 1492R (5'-GGTTACCTTGTTACG ACT T-3'), primer for the fungi rDNA ITS1 amplification were ITS1F (5'-CTTGGTCATTTAGAGGAAGTAA-3') and TS1R (5'-GCTGCGTTCTTC ATCGATGC-3'). Reaction conditions of bacterial polymerase chain reaction (PCR) included an initial denaturation at 95 °C for 5 min, 94 °C for 30 s, 30 cycles of 57 °C for 30 s, 72 °C for 90 s, 72 °C for 10 min. Conditions of fungi PCR were 94 °C for 30 s, 55 °C for 30 s, 30 cycles of 72 °C for 30 s, and 72 °C for 5 min. Statistical analyses were carried out using Statistical Product and Service Solutions, 17.0.

RESULTS

The effects of straws return on N leaching from soil are shown in Fig. 1 (a, b, c). A similar trend was noticed that the content of N leaching from soil covered with distilled water decreased with time during the 60 days of incubation.

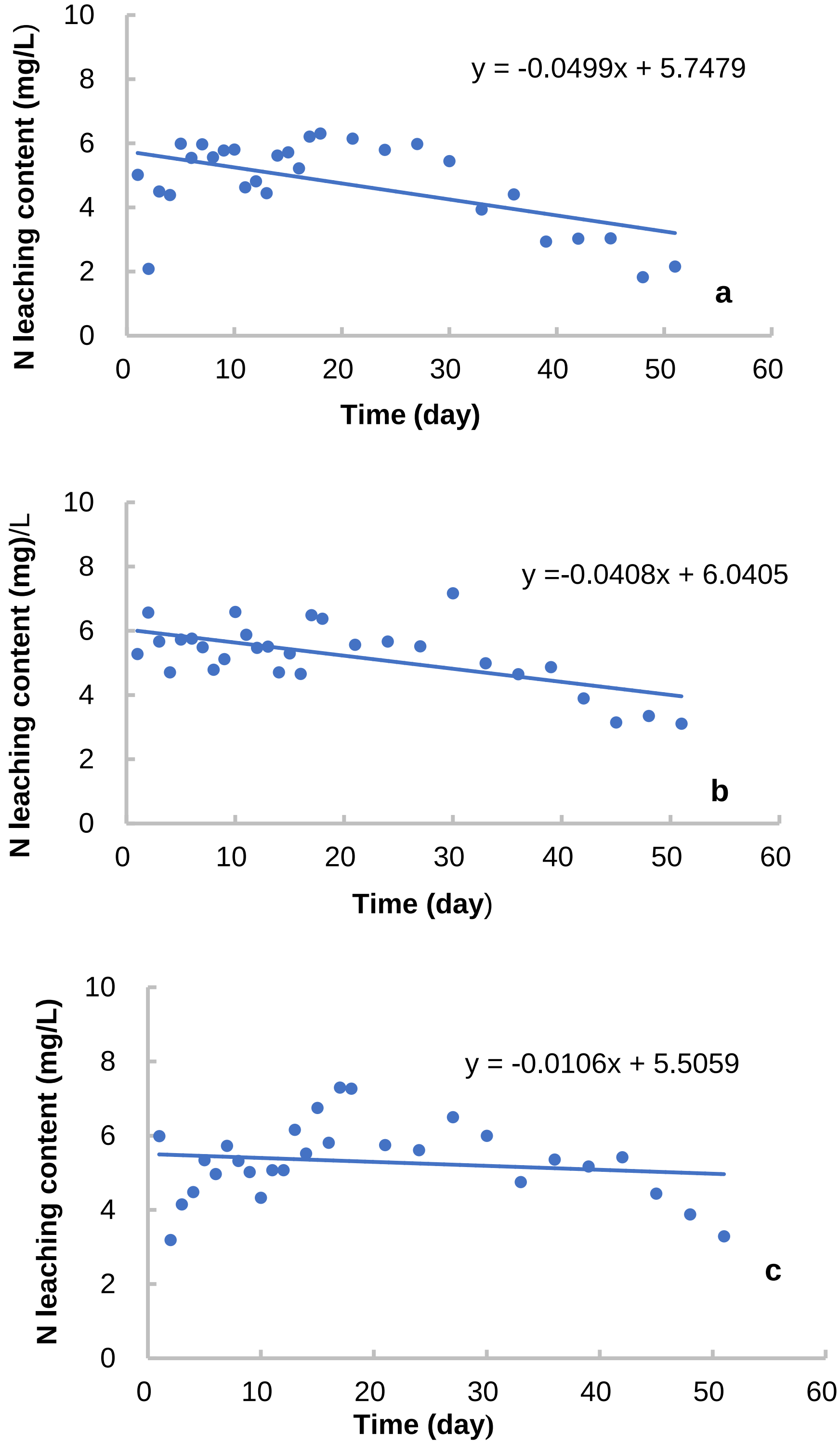

Fig. 1. N leaching from soil with straw addition of 0% (a), 0.3% (b) and (c) 1%

The trend line of N leaching with time corresponded to the linear equations $y = -0.0499x + 5.7479$, $y = -0.0408x + 6.0405$, and $y = -0.0106x + 5.509$ of control, straw addition of 0.3%, and straw addition of 1%, respectively. Interestingly, the content of N leaching from soil with different straw addition were decreased as incubation experimental progressed, the slope of the three trend lines was -0.0499, -0.0408, and -0.0106, respectively. These results mean that N leaching was increased with straw incorporated into soil. The higher the amount of straw added in soil, the greater content of N leaching loss.

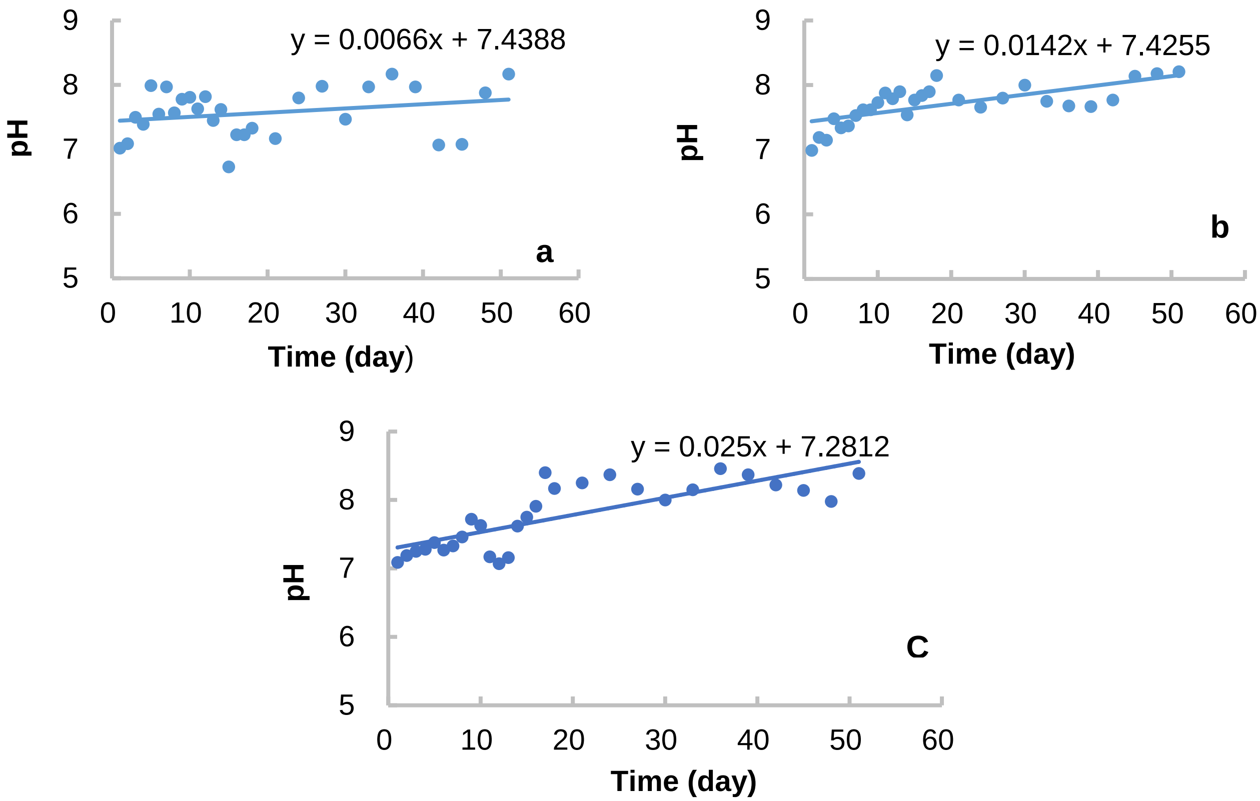

Fig. 2. Effect of straw addition of 0% (a), 0.3% (b) and (c) 1% on pH of soil

The effects of straw return on pH in soil are shown in Fig. 2 (a, b, c). Different trends were noticed. The value of pH in soil varied with time during the 60 days of incubation. The trend line of pH in soil with time followed the equations $y = 0.0066x + 7.4388$, $y = 0.0142x + 7.4255$, and $y = 0.025x + 7.2812$ of control, straw addition of 0.3% and straw addition of 1%, respectively. The pH in soil with different straw addition was changed slightly as conducted progressed. The slopes of the three trend lines were 0.0066, 0.0142, and 0.025, respectively, which means the higher the amount of straw added in soil, the faster rate of pH increased in soil.

The effects of straws return on EC of soil during the 60 days of incubation experimental are shown in Fig. 3, As can be seen, the EC of soil was in the range of 0.12 to 0.18, 0.13 to 0.2 and 0.13 to 0.16 (ds/m) with of control, straw addition 0.3%, and straw addition 1%, respectively. The EC of the soil did not show any clear trends after straw incorporation. The highest EC 0.18 ds/m was observed in the soil with straw addition 0.3%.

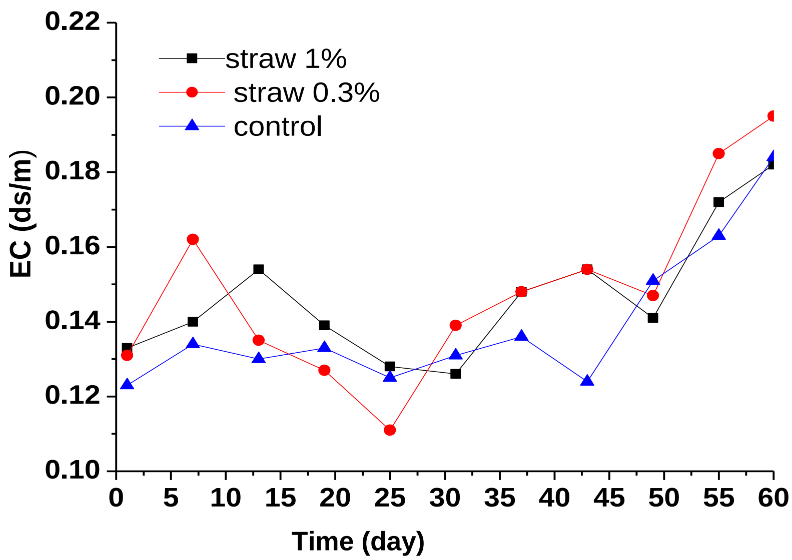

Fig. 3. Effect of straw addition on soil EC

DISCUSSION

N is an essential element for plant growth, and it is important to manage agricultural soil to reduce nitrification rates and soil N loss (Dalal *et al.* 2011). It was assumed that complex organic C input with C/N ratios >18 could enhance microbial N immobilization and reduce soil N loss (Cheng *et al.* 2017). Many studies have reported that straw return altered microbial community structure in soil (Burger and Jackson 2003; Shan and Yan 2013; Zhao *et al.* 2016). However, the present study demonstrated that no notable change in relative abundance of microbial taxa of different straw application in soil at domain level, bacteria (almost 96%) were dominated by microbial taxa. Table 1 shows the top 10 microbial taxa of different straw applications in soil at the phylum level.

Table 1. Abundance of Microbial Taxa of Soil with Different Straw Application at Phylum Level

Abundance of Microbial Taxa	Percentage of Top Ten Microbial Taxa with Different Straw Application (%)		
	Control	0.3%	1%
Bacteria_unclassified	38.8	34.7	37.7
Gemmatimonadetes	16.5	17.1	16.7
Actinobacteria	15.8	16.1	16.5
Proteobacteria	14.3	13.8	12.9
Nitrospirae	11.3	11.6	10.6
Deinococcus-Thermus	10.7	10.7	9.2
Cyanobacteria	7.9	7.2	7.7
Planctomycetes	3.5	4.1	5.3
Latescibacteria	2.1	1.9	1.4

The percentage of *bacteria_unclassified* was 38.8%, 34.7%, and 37.7% with straw application of 0, 0.3, and 1%, respectively. These findings meant that microbial growth and the immobilization of N were not enhanced by straw return in the present work. This might be due to the content of straw, which contained cellulose, lignin, hemicellulose, *etc*. The degradation of these large molecules was carried out by microorganisms (fungi and bacteria) with slow reaction rates, and variance of bacterial biodiversity were not obviously shown in the short term (Govaerts *et al.* 2009).

The soil EC has been confirmed to be a useful indicator of salinization, which would lead to loss in the productivity of the land (Mahajan and Tuteja 2005). A previous study showed that various environmental factors affect soil EC such as water content, physical properties of the soil, availability and mobility of ions, pH, temperature and so on (Feng *et al.* 2019). The present study demonstrated that the change of soil EC did not show any clear trends after straw incorporation (Fig. 3). A possible explanation for these findings was that the increase of EC was attributed to more ions being present (Dong *et al.* 2013), while the ions produced under the condition of straws return in short term was limited.

The organic carbon content of the rapeseed straw used in the present study was 48%, and the C/N ratio of the straw was 67. Thus, about 0.02 or 0.07 g of N per 1 kg of soil was introduced for the 0.3% or 1% addition level, respectively. The increasing of soil nitrogen retention due to straw return has been widely reported (Gollany *et al.* 2004; Yang *et al.* 2015). However, the present study demonstrated that N leaching was increased by rapeseed straw return, the higher amount of straw added in soil, the more N leaching loss (Fig. 1). A possible explanation for these findings was that physical, chemical, and biological components of soil are affected by straw application, and these components may play important roles in the N leaching from soil capability (Gentile *et al.* 2009). Pearson's correlation coefficients between straw return rate, pH, EC, and N leaching content revealed no significant correlations. Significance values (two-tailed) also indicated no significant relationship between straw return rate and N leaching content (Table 2).

Table 2. Correlation between Straw Return, pH, EC, and N Leaching content

Correlation Analysis		pH	EC	N Leaching Content	Straw Return Rate
Straw return rate	Pearson corr.	0.992	-0.682	0.988	
	Sig. (two-tailed)	0.81	0.522	0.1	
pH	Pearson corr.		-0.584	0.960	0.992
	Sig.(two-tailed)		0.603	0.181	0.081
EC	Pearson corr.	-0.584		-0.788	-0.682
	Sig. (two-tailed)	0.603		0.422	0.522
N leaching content	Pearson corr.	0.960	-0.788		0.988
	Sig.(two-tailed)	0.181	0.422		0.1

The leaching of nitrogen from the soil might be affected by impurities in water; thus, the effects of straw addition on soil N leaching loss were studied using distilled water in the present study. The effect of physical, chemical, and biological components of ordinary water on soil N leaching under the condition of straw return will be studied in the future.

CONCLUSIONS

1. N leaching was increased by straw incorporated into the soil. The higher the amount of straw added in soil, the greater content of N leaching from the soil.
2. The soil pH increased slightly with the addition of different rapeseed straw. The higher the amount of straw added in soil, the faster the rate of pH increase.
3. The rapeseed straw incorporated into the soil with different straw addition had no significant effect on electrical conductivity (EC) in the short term.

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