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Nitrous Oxide Emission and Urease Activity in Wheat

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Nitrous oxide (N_2O), as one of the main greenhouse gases, increases global warming and could cause damage to the Ozone layer by opto-chemical reaction with O_3 in the Ozone layer (IPCC 1992). Farmland ecosystems are the main source for the emission of N_2O, amounting to 60-70% of the artificial N_2O emission (IPCC 1994). The emission of N_2O in the soil mainly originates from nitrification and de-nitrification processes caused by microbes. These processes, largely influenced by climate and the bio-chemical properties of the soil, cause the variation in N_2O emissions (Williams et al. 1992). Changes in soil moisture and temperature, farming management practices and the soil's physical and chemical properties, all affect the fluctuation in emission of N_2O (Xu Wenbin et al. 2002, Bai Hongying et al. 2002), making it difficult to control N_2O emission. Therefore, it is vitally important to establish an indicator to reflect N_2O emission that is not influenced by other environmental factors. Urease in soil is essential for the biological recycling of carbon, nitrogen, phosphorus and other elements. It exists in many bacteria, fungi and higher level plants. The activity of urease in soil reflects the N level and is positively related to the amount of organic matter, total nitrogen and available nitrogen and to the numbers of microbes (Microbe Research Group, Nanjing Institute of Soil Science, 1985).

MATERIALS AND METHODS

The experiments were done to test urease activity and N_2O flux in wheat under different cultivation methods and fertilizer applications. The relationship between urease activity and N_2O emission was also studied to provide a basis for N_2O emission evaluation and the selection of emission reduction measures.

The experiments were carried out at a pilot station in the south of the Loess Plateau in China, located at 108°31′N, 350°42′E. The annual average temperature ranges from 11.0C° to 14.0C°. The annual average precipitation is

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415 to 630mm. The soils are typically orthic anthrosols with the following properties: density 1.10-1.37g/cm^3, water holding capacity 21%-23%, organic matter 11.5g/kg, total N 1.25g/kg, NO_3^--N 15.1mg /kg; NH_4^+-N 8.5mg/kg.

For each treatment, there were three replications. The 18 plots were as a randomized complete block. Each plot had an area of 20 m^2. The experiments were carried out over two successive wheat crops. Wheat was sowed around October 15 each year. The harvest was started around June 1 of the next year. N (150kg/ha) and P (40kg/ha) were applied as the basal fertilizer. The trial variety was Xiaoyan 503. No artificial irrigation was applied during the whole growth period. N_2O flux was tested at different growth stages. Soil samples were taken at depths of 0-5cm, 5-10cm, 10-20cm and 0-20cm to test urease and other physical and chemical properties.

The close chamber method was used to test for N_2O, with the removal of above ground crop parts to reduce the influence of N_2O emission from the wheat. A Variam GC 3800 (from the U.S) was used with ECD (^{63}Ni), with 80 - 100 Porapak Q, the carrier was high purity Nitrogen with a flow velocity of 10 mL/min, the standard gas (from Sweden) had a concentration of 328.2μL/L.

RESULTS AND DISCUSSION

Soil is a complex system. Its chemical and biological reactions are influenced by factors such as water, gas, heat and root systems of plants, as well as microbes and their secretions. The influence of wheat cultivation on N_2O emission using different cultivation methods with the same fertilizer application is shown in Figure 1.

It can be seen from Figure 1 that the average N_2O flux amount from the wheat under mulch (MW) was 1.32 times that from the fallow (MF), Under normal cultivation (NW) the average N_2O flux amount from wheat was 1.73 times that from fallow (NF). Compared with normal cultivation (NW), the increase in the N_2O flux was lower under mulch (MW). This may be due to the more stable conditions of water, gas and heat under the mulch. The un-mulched plots may be influenced by environmental factors, causing the N_2O emission fluctuation.

The general trend was that emission of N_2O from wheat was greater than that from fallow. According to Dang Tinghui et al. (2002), when urea was used as a basal fertilizer, its utilization rate by crops during the season was about 40%, and about 30% remained in the soil. Thus 29.5% to 32.52% had been lost. After winter, without N absorption by wheat, the accumulation of NH_4-N and NO_3-N in

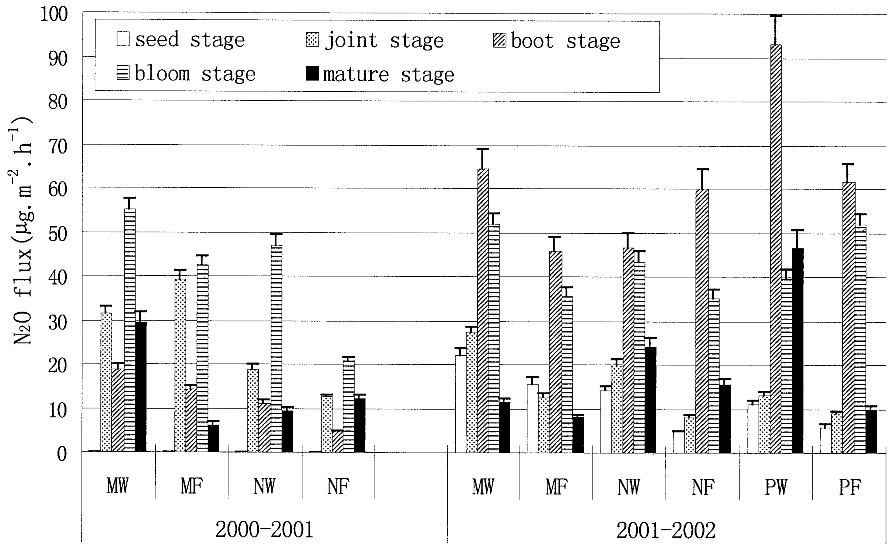

Figure 1. Influence of cultivations on N_2O flux ($\mu g.m^{-2}.h^{-1}$) in wheat.

the fallow land would be favorable for N_2O emission.. This may be due to the fact that large amounts of secretion from plant roots would favor the decomposition of urea in the soil and the absorption of nitrogen from soil: according to Dang Tinghui et al. (2002), about 1/3 of the nitrogen in soil is absorbed by wheat. On the other hand, the existence of the huge root system would make the NO_3^--N apt to convert into N_2O. In short, using any cultivation method, the cultivation will activate N_2O emission.

Table 1 shows the urease changes in soil layers 0-5cm, 5-10cm, 10-20cm and 0-20cm respectively. The urease activity in mulched wheat (MW) 0-5, 5-10cm decreased by 7.83% and 1.0% compared with mulched fallow (MF). The urease activity in cultivated wheat (NW) was 7.3 % and 3.8% higher than in cultivated fallow (NF). Overall, the urease activity 0-20cm was 1.6% to 10.8% higher in wheat (MW & NW) than in fallow (MF & NF) under both mulched and normal cultivation conditions, but the urease activity in shallow fallow 0-5cm and 5-10cm was higher than in wheat. This may be due to the fact that there was less competition from absorption by crops in shallow layers, and that large quantities of nitrogen and phosphorus may be favorable for the reproduction of microbes, thus stimulating urease activity. The distribution of the wheat's root system may stimulate the activity of urease in the surrounding area: thus, the urease activity in the soil at 10-20cm, and the average for the whole 0-20cm, was higher than that in the fallow.

Table 1. Influence of cultivation on urease activity in soil (NH_3-N μg/100g).

Year	Depth cm	Treatment ( )	Seed stage	Joint stage	Boot stage	Bloom stage	Mature stage	$\overline{X}$
2000 ~2001	0-5	MW	—	49.9	64.6	88.8	69.7	68.3
		MF	—	66.3	67.8	84.1	78.4	74.1
	5-10	MW	—	49.4	78.6	103.6	90.7	80.6
		MF	—	73.0	68.7	104.5	79.2	81.4
	10-20	MW	—	78.2	69.3	80.1	78.2	76.4
		MF	—	76.2	53.0	78.2	77.3	71.2
	0-5	NW	—	51.5	56.4	86.9	52.3	61.8
		NF	—	43.5	64.2	82.9	73.3	66.0
	5-10	NW	—	55.9	61.2	74.8	80.8	68.2
		NF	—	60.0	68.9	82.6	77.8	72.4
	10-20	NW	—	68.5	60.1	94.5	70.3	73.3
		NF	—	53.6	57.9	95.3	75.4	70.6
2001 ~2002	0-20	MW	29.6	88.3	130.9	82.9	36.1	73.6
		MF	25.6	82.5	130.4	89.8	33.8	72.4
		NW	29.1	79.1	77.8	60.6	34.8	56.3
		NF	24.8	52.8	73.8	70.9	31.5	50.8
		PW	27.3	87.1	121.8	88.6	29.1	70.8
		PF	24.7	80.4	109.4	85.2	28.8	65.7

N_2O emission varied with different cultivation methods. N_2O emission in wheat and fallow is shown in Figure 2. We can see that, in both wheat and fallow, N_2O emission from the mulched land (MW & MF) was 10.40% to 55.5% higher than that from normal cultivation (NW & NF). This is because the mulch made the soil temperature rise and reduced water evaporation. We observed that water content in the soil covered by mulch increased by 2% to 4% and the temperature increased by 1°C to 5°C. On the one hand, N_2O emissions have been shown to have a significant correlation with soil temperature and moisture (Xu Wenbin et al. 2002; Bai Hongying et al. 2002; Yan Xiaoyuan et al. 2000); on the other hand, the mulch may also have changed the oxygen concentration in parts of the soil, leading to anaerobic conditions and the denitrification reaction, thus causing the increase in N_2O emission (Shi Yi and Huang Guohong 1999).

Mulching increased urease activity in soil. The influence of mulched and normal cultivation on urease in fallow and wheat is shown in Figure 3. Urease activity in mulched wheat (MW) at depths of 0-5cm and 5-10cm was 10.52% and 18.18% respectively higher than that in normally cultivated wheat (NW). Urease activity in mulched fallow (MF) at depths of 0-5cm and 5-10cm was12.27% and 12.43% higher than that in normally cultivated fallow (NF). At

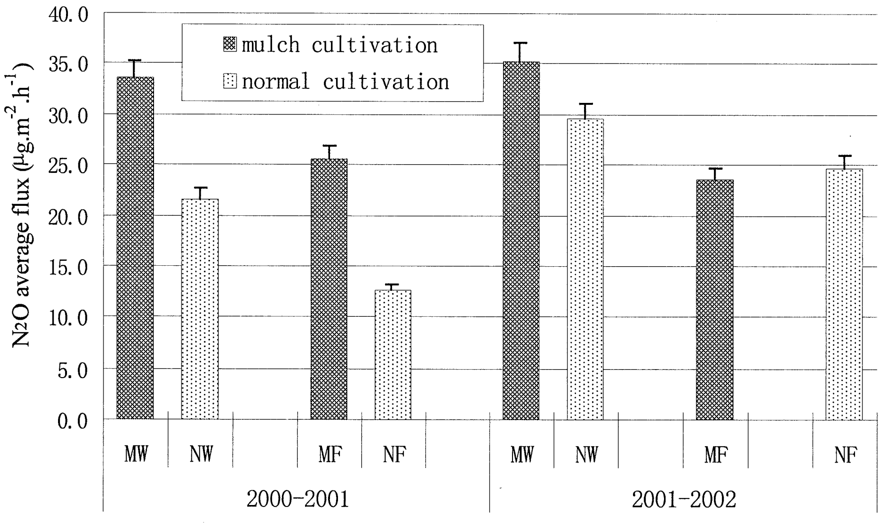

Figure 2. Influence of cultivation methods on N_2O flux ($\mu g.m^{-2}.h^{-1}$) in wheat.

10-20cm, urease activity in mulched wheat (MW) was 4.23% higher than that in normally cultivated wheat (NW), and in mulched fallow (MF) was 0.895% higher than that in normally cultivated fallow (NF). At 0-20cm, urease activity in MW and MF was 30.73% and 42.52% higher than NW and NF respectively. Analysis showed that the influence of the mulch treatment on urease activity (MW and MF) at depths of 0-5cm and 5-10cm was greater than at 10-20cm. This is because at 0-10cm the mulch increased soil temperature and water content. Higher temperature and moisture content favors the growth and reproduction of microbes in the soil and the root system, thus leading to an increase of urease activity in their secretions.

Urease is an important enzyme for the conversion of urea in soil, and it affects the decomposition, conversion, absorption and utilization of fertilizers infiltrated in soil (Zhou Likai 1984). Urease activity largely reflects not only the fixation of nitrogen, but also the nitrification function. Thus it is closely connected with the N_2O emission. The correlation between N_2O emission and urease activity is reflected in Table 2.

The analysis shows that, except at depth 5-10cm, urease activity in other layers had a significant orthodox relation to the amount of N_2O emission; and at a depth of 0-20cm, it showed an extremely significant orthodox relation. According Han Jiangang et al. (2002), N_2O in soil mainly comes from a layer at a depth of 10cm. However, the above analysis indicates that in every layer, especially in the layer

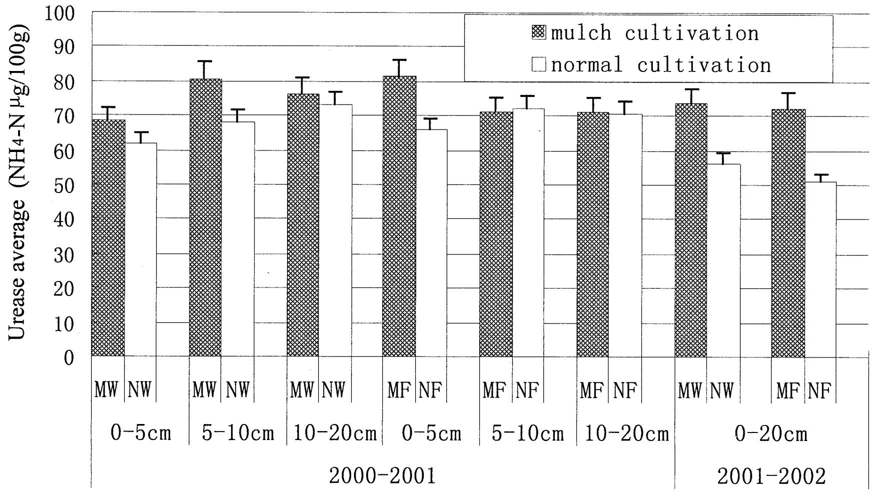

Figure 3. Influence of cultivation methods on average urease (NH_3-N μg/100g) in soil.

Table 2. Analysis of correlation between N_2O emission and urease.

Soil depth (cm)	Fitting equation	Correlation coefficient (r)	n
0-5	$Y_{N2O} = -16.2407 + 0.5858X_{urease}$	0.5828*	16
5-10	$Y_{N2O} = -12.3750 + 0.4722\ X_{urease}$	0.4672	16
10-20	$Y_{N2O} = -30.0381 + 0.7322\ X_{urease}$	0.5857*	16
0-20	$Y_{N2O} = 0.6686 + 0.4560\ X_{urease}$	0.6936**	30

5-10cm, the correlation between N_2O emission and urease activity is much less than that of the whole soil profile 0-20cm. This shows that urease activity in soil has comprehensive effects on the production, transmission and consumption of N_2O, and there exists a close relationship between urease and N_2O flux. Therefore the urease activity in the whole top 20cm of the soil should be chosen as a bio-indicator of N_2O emission.

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