

Management practices impact on soil nitrous oxide emission in the northern Great Plains, USA

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Abstract

Management practices may influence soil N₂O emission, a greenhouse gas responsible for global warming. The effects of irrigation, tillage, crop rotation, and N fertilization were evaluated on soil surface N₂O flux and soil temperature and water content at the 0- to 15-cm depth from April to November in 2008 and 2009 in eastern Montana, USA. Treatments were two irrigation practices (irrigated and non-irrigated) and five cropping systems [conventional-tilled barley with N fertilization (CTBFN), conventional-tilled barley with no N fertilization (CTBON), no-tilled barley-pea with N fertilization (NTB-PN), no-tilled barley with N fertilization (NTBFN), and no-tilled barley with no N fertilization (NTBON)]. The N₂O flux varied with changes in soil temperature and water content, peaking immediately following substantial precipitation and/or irrigation (>30 mm) over 7 d period. Cumulative N₂O flux from April to November was greater in non-irrigated than in irrigated practice in 2008 and greater in CTBFN than in CTBON, NTB-PN, and NTBON in 2009. The flux was greater with N fertilization than without in 2009 and greater in 2008 than 2009. Increase in N substrate availability due to N fertilization and soil water availability due to irrigation and precipitation probably increased soil microbial activity that increased soil N₂O emission.

Key Words

Crop rotation, irrigation, nitrogen fertilization, nitrous oxide, soil temperature, soil water, tillage.

Introduction

Nitrous oxide, although emitted in trace amount, is one of the most potent greenhouse gas responsible for global warming because it is 296 times more powerful than CO₂ in terms of global warming potential (IPCC 2001). Agriculture is the main source of anthropogenic N₂O emission due to N fertilization to crops, manure application, atmospheric N fixation, and soil organic matter mineralization (IPCC 2001). Although tillage and N fertilization influence soil N₂O emission (Dusenbury *et al.* 2008), little information is available about the effects of soil and crop management practices on N₂O emission in the northern Great Plains, USA. The objective of this study was to evaluate the individual and combined effects of irrigation, tillage, crop rotation, and N fertilization on soil surface N₂O flux from April to November in 2008 and 2009 in the northern Great Plains, USA.

Materials and methods

Soil surface N₂O flux was measured from 9 A.M. to 12 A.M. twice a week to once in every two weeks from April to November in 2008 and 2009 from a static chamber (Hutchinson and Mosier 1981). A chamber made of polyvinyl chloride, 20 cm diameter by 15 cm tall, was installed to a depth of 7.5 cm in the soil in each treatment. A cover, 20 cm diameter by 10 cm tall, was placed at the top of chamber, and gas samples were collected at 0, 20, and 40 min by injecting a needling in the chamber and transferring them in Extainers. The N₂O concentration in the gas sample was measured with a gas chromatograph in the laboratory. At the time of gas sampling, soil temperature at the 0-to 15-cm depth was measured with a temperature probe and soil water content was determined gravimetrically by collecting field-moist soil sample and oven drying at 105°C. The experiment was conducted in western North Dakota, USA in a sandy loam soil in 2008 and 2009. Treatments consisted of two irrigation practices (irrigated and non-irrigated) as main plot and five cropping systems [conventional-tilled barley with N fertilization (CTBFN), conventional-tilled barley with no N fertilization (CTBON), no-tilled barley-pea with N fertilization (NTB-PN), no-tilled barley with N fertilization (NTBFN), and no-tilled barley with no N fertilization (NTBON)] as split-plot treatments in a randomized block design with three replications. Malt barley and pea were planted in April and harvested in August. In NTB-PN, both malt barley and pea phases were present in every year. At planting, N fertilizer was applied at 67 kg N/ha to malt barley in both irrigated and non-irrigated practices. After 1 month, another N fertilizer at 67 kg N/ha was top dressed to malt barley in the irrigated practice. No N fertilizer was applied to pea. Both malt barley and pea received P fertilizer at 25 kg P/ha and K fertilizer at 21 kg K/ha at planting. After harvesting grains, biomass residue (stems + leaves) were returned to the soil.

Results and discussion

The N₂O flux varied with changes in precipitation and soil temperature and water content from April to November in 2008 and 2009 (Table 1, Figures 1-3). While the trend in N₂O flux generally followed to that of soil temperature, fluxes peaked immediately following substantial precipitation and/or irrigation (>30 mm) over a period of 7 d. During these periods, N₂O flux was greater in non-irrigated than in irrigated practice in 2008 but was variable between irrigation practices in 2009 (Figure 2). Similarly, the flux was greater in CTBFN and NTBFN than in other cropping systems in 2008 and 2009 (Figure 3). Cumulative N₂O flux from May to November was greater in non-irrigated than in irrigated practice in 2008 and greater in CTBFN than in CTBON, NTB-PN, and NTBON in 2009 (Table 1). Tillage and cropping system did not influence N₂O flux but N fertilization increased the flux compared with no N fertilization in 2009.

Table 1. Effect of irrigation and cropping system on cumulative soil surface N₂O flux from April to November and mean soil temperature and water content at the 0- to 15-cm depth in 2008 and 2009.

Irrigation	Cropping system†	N ₂ O flux (kg N/ha)		Soil temperature (°C)		Soil water (g/kg)	
		2008	2009	2008	2009	2008	2009
Irrigated		0.96b‡	0.44a	15.9a	15.2a	74.0a	90.8a
Non-irrigated		1.21a	0.41a	15.9a	15.8b	70.8a	86.4b
	CTBFN	1.06a	0.57a	15.6b	15.4bc	75.3a	91.6a
	CTBON	1.08a	0.37b	16.9a	16.1a	73.8a	83.1b
	NTB-PN	1.19a	0.43b	15.6b	15.3bc	74.8a	89.8a
	NTBFN	1.08a	0.46ab	15.5b	15.2c	69.9a	87.1ab
	NTBON	1.00a	0.32b	15.8b	15.7ab	68.3a	91.5a
<u>Contrast</u>							
Till vs. no-till		0.03	0.08	0.56*	0.25	5.4	-1.9
N fert. vs. no N fert.		0.02	0.17**	-0.79*	-0.61*	1.6	2.0
Cont. barley vs. barley pea in no-till		-0.15	-0.04	0.14	0.12	-5.7	-0.5

† Cropping systems are CTBFN, conventional-tilled malt barley with 67 to 134 kg N/ha; CTBON, conventional tilled malt barley with 0 kg N/ha; NTB-PN, no-tilled malt barley-pea rotation with 67 to 134 kg N/ha applied to malt barley; NTBFN, no-tilled malt barley with 67 to 134 kg N/ha; and NTBON, no-tilled malt barley with 0 kg N/ha.

‡ Numbers followed by different lower case letters within a column and upper case letter within a row in a set are significantly different at $P \leq 0.05$ by the least significant difference test.

* and ** Significant at $P \leq 0.05$ and 0.01 , respectively.

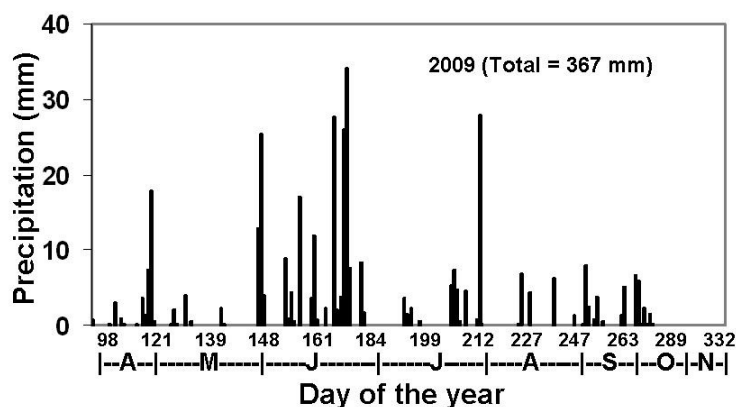


Figure 1. Daily precipitation from April to November in 2009 at the study site.

Sharp increases in N₂O flux following substantial precipitation during spring and summer suggests that precipitation increased soil microbial activities and organic matter mineralization during increased soil temperature due to greater soil water content. However, irrigation to an amount of 30 mm did not increase the flux, although it increased soil water content. Rather flux was lower in irrigated than in non-irrigated practice in 2008. In contrast, greater N₂O flux in CTBFN than in other cropping systems, except in NTBFN, suggests that tillage, followed by N fertilization probably increased the flux as a result of increased soil organic N mineralization and/or N substrate availability. Increased N₂O flux with increase in N fertilization rates have been reported by several researchers (Mosier *et al.* 2006; Dusenbury *et al.* 2008). Greater soil temperature but lower N₂O flux in CTBON indicates that soil temperature probably has minimal effect on

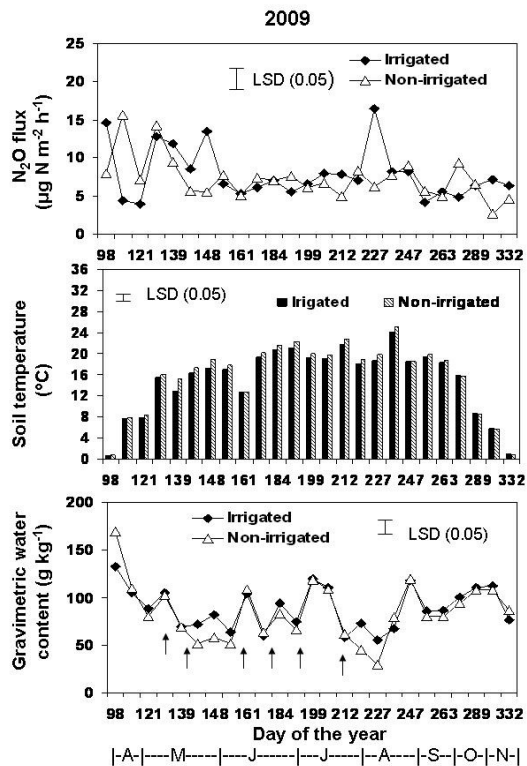


Figure 2. Effect of irrigation on soil surface N_2O flux and soil temperature and water content at the 0- to 15-cm depth from April to November in 2009. Arrows indicate time of irrigation. LSD (0.05) is the least significant difference between treatments at $P = 0.05$.

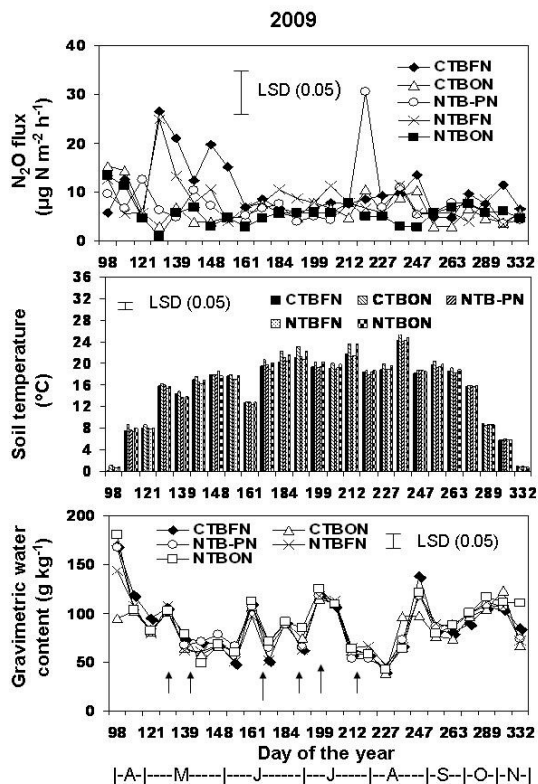


Figure 3. Effect of cropping system on soil surface N_2O flux and soil temperature and water content at the 0- to 15-cm depth from April to November in 2009. Arrows indicate time of irrigation. CTBFN denotes conventional-tilled malt barley with 67 to 134 kg N/ha; CTBON, conventional tilled malt barley with 0 kg N/ha; NTB-PN, no-tilled malt barley-pea rotation with 67 to 134 kg N/ha applied to malt barley; NTBFN, no-tilled malt barley with 67 to 134 kg N/ha; and NTBON, no-tilled malt barley with 0 kg N/ha. LSD (0.05) is the least significant difference between treatments at $P = 0.05$.

N₂O flux. The non-significant effect of crop rotation on the flux shows that inclusion of legumes, such as pea, in the crop rotation also has minimum effect on N₂O flux. Although total precipitation from May to November was greater in 2009 than in 2008, the reasons for greater N₂O flux in 2008 than in 2009 were not known but probably due to differences in soil NO₃-N content among years which was not measured in this study.

Conclusions

Soil N₂O flux usually increased following substantial rainfall over a period of 7 d due to increased soil water content. Irrigation <30 mm during dry period, however, did not increase the flux compared with no-irrigation, although it increased soil water content. Tillage, followed by N fertilization increased N₂O flux compared with other cropping systems probably due to increased soil organic matter mineralization and N substrate availability. For reducing N₂O emission, no-tilled continuous cropping with adequate N fertilization with or without irrigation can be used in the northern Great Plains, USA.

References

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