

Priming of Soil Microbial Communities for N₂O Emissions in a Long-Term Manure Agricultural System with a Change in Nitrogen Source

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Introduction

Nitrous oxide (N₂O) is a potent greenhouse gas, and its emissions from agricultural systems are strongly influenced by nitrogen (N) fertilization (Rochette et al., 2008). Moreover, there is evidence to suggest that fertilizer history may influence the capacity of the soil to produce N₂O. Indeed, the long-term application of manures and chemical fertilizers may induce changes to the abundance and genetic make-up of the soil microbial communities, which in turn can influence the production/consumption of N₂O in the soil.

The Dixon long-term manure plots were established in 1996 to investigate the agronomic and environmental benefits of manure application (Mooleki et al. 2002; 2004). During the early years (1997–2000), measurements of denitrification potential and nitrous oxide (N₂O) emissions lent support to the argument that the then-current IPCC emission factor (1.25%) did not accurately reflect N₂O losses from applied-N in Saskatchewan (where N₂O-N losses typically range between 0.2 and 0.8%), but did not address the issue of how long-term applications affect emission intensity. That is, do long-term manure applications “prime” the soil for increased N₂O production/emission? A subsequent study (conducted between 2009 and 2011) concluded that “long-term applications of manure-N can, at high application rates or following frequent manure applications, produce a ‘priming’ effect which may exacerbate N₂O emissions if a more available form of N (e.g., urea fertilizer) is applied to the soil”. These results have implications for the Nitrous Oxide Emission Reduction Protocol (NERP) aimed at reducing on-farm emissions of nitrous oxide and for 4R Nutrient Stewardship (Right Source @ Right Rate, Right Time, Right Place®).

The main objective of the present study is to assess the occurrence and duration of ‘priming effects’ on microbial communities for N₂O emissions in an agricultural field in Saskatchewan.

Materials and Methods:

Site Description

The research site is located in Dixon SK (off Highway 5 near Humboldt SK). The Dixon site has been used as a long-term research site with soils receiving fall applications of liquid swine manure (LSM), solid cattle manure (SCM), or urea from 1996 through 2010. The historical fertilizer treatments included manure and urea fertilizer applications at 1×, 2×, and 4× application rates, applied every year or every third year. The 1× application rate supplied approximately 100 kg total N ha⁻¹ (Stumborg et al., 2007). After the decommissioning of the long-term manure applications in 2010 a single yearly application of fertilizer (urea) was applied as a blanket treatment over all plots beginning in the spring of 2011. The site was cropped to barley in 2011 and canola in 2012.

Sampling Procedures

Gas sampling in the field was carried out using vented, non-steady state chambers (Corre et al., 1996; Farrell et al., 1999). The chambers were set into the plots and monitored from snowmelt through freeze-up. All gas samples were returned to the GHG analysis lab in the Department of Soil Science and N₂O concentrations determined using a Varian CP-3800 gas chromatograph equipped with a ⁶³Ni electron capture detector (ECD) and a Combi-Pal autosampler (CTC Analytics AG, Switzerland). Greenhouse gas fluxes were determined by fitting a linear or quadratic least-squares regression model to the gas concentration *vs.* time data (Yates et al. 2006) and then calculating the flux (F_{GHG}) as described by Rochette and Bertrand (2008).

Priming effects were assessed using a modified version of the denitrification enzyme activity (DEA) assay (Groffman et al., 1999). Soil samples were collected once each in May, July and September 2012, with the DEA assays conducted within 48-hours of sample collection.

Results and Discussion

The N₂O emission patterns observed in 2011 (Fig. 1) and 2012 (Fig. 2) were visually different. Indeed, N₂O emissions in 2012 were greater than those in 2011—reflecting the wetter conditions that prevailed during the 2012 season. Analysis of the N₂O data also indicated that emissions from the plots that had received long-term manure applications continued to produce greater N₂O emissions than either the unfertilized control plots or the plots that received yearly urea applications (data not shown).

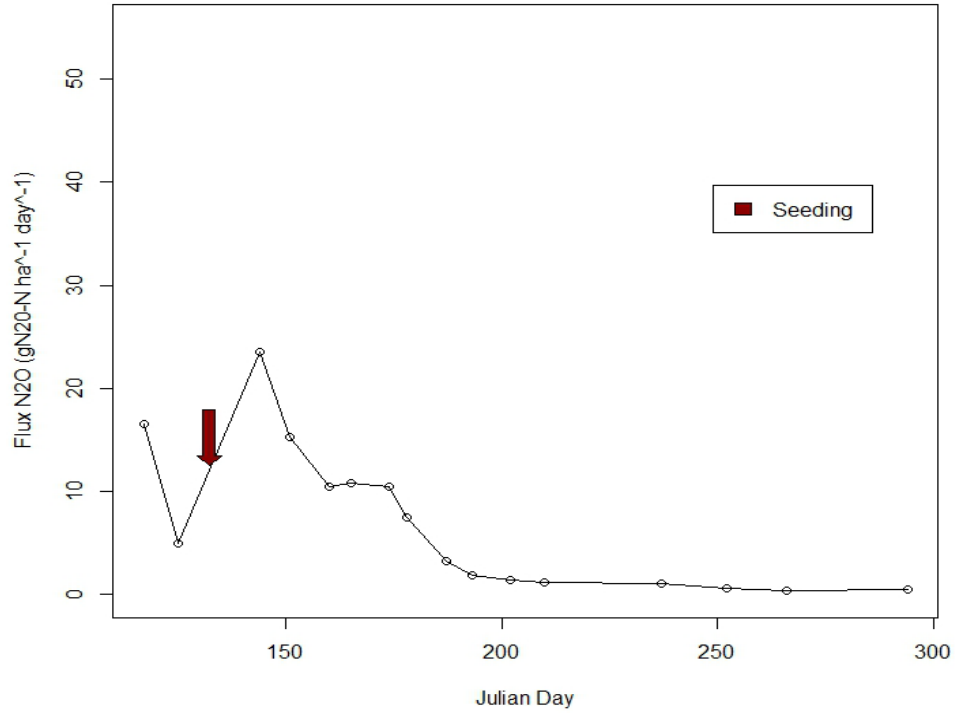


Figure 1. Preliminary results for the average N₂O flux per day for the 2011 growing season at the Dixon research site

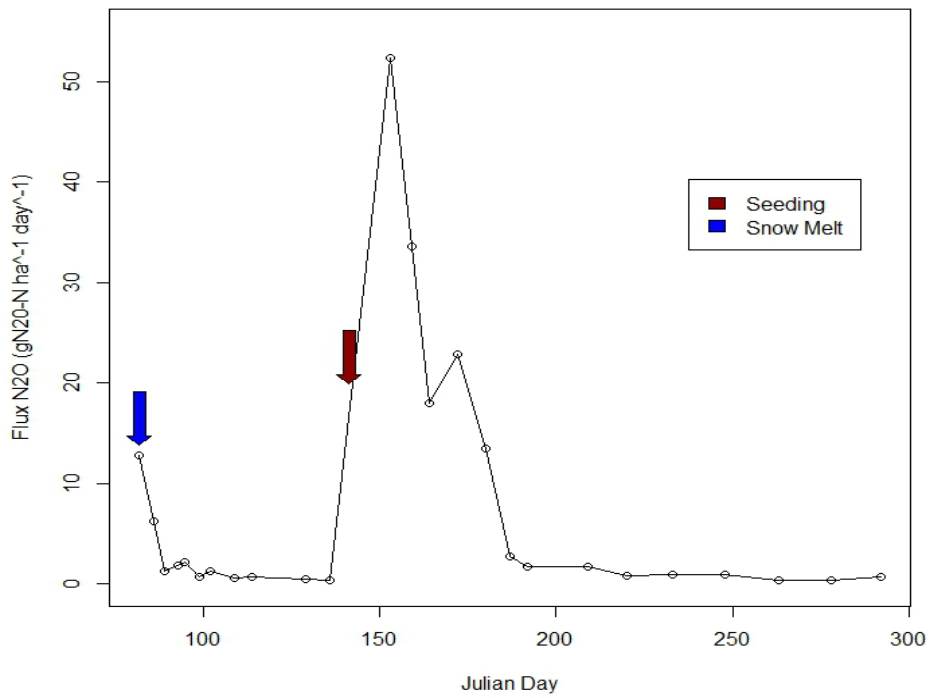


Figure 2. Preliminary results for the average N₂O flux per day for the 2012 growing season at the Dixon research site.

Denitrification enzyme activities also were greatest in the plots with a history of LSM or SCM applications, especially early in the growing season (Fig. 3). However, at harvest, the differences between treatments were muted, though the plots with a history of LSM applications continued to have DEAs that were significantly greater than those in the SCM, urea and control plots.

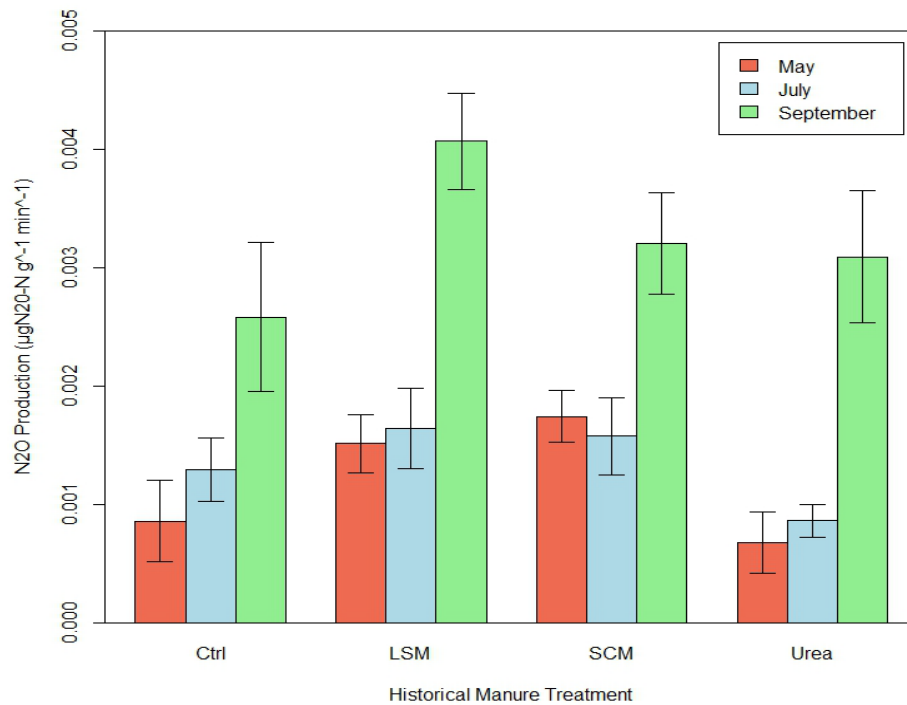


Figure 3. The 2012 DEA preliminary results for the May, July and September analyses broken up by historical long-term fertilizer amendment averaged across all application rates. Ctrl=no history of fertilizer application; LSM=Liquid swine manure; SCM=Solid cattle manure; Urea=Urea

Conclusions

The evidence to date, indicates that there is indeed a ‘priming’ effect associated with the long-term history of manure applications, especially with the long-term application of LSM. The magnitude of this effect appears to vary depending on soil conditions (e.g., it is greater under wet conditions than under dry conditions). Moreover, this effect does not appear to be transitory; i.e., it can last for at least two years after manure applications cease.

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