The influence of temperature on emissions of nitrous oxide and dinitrogen from soils

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<table>
<thead>
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<th>Description</th>
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<tbody>
<tr>
<td>µg</td>
<td>Microgram</td>
</tr>
<tr>
<td>$^{15}$N (%)</td>
<td>Labelling nitrogen (percentage of excess $^{15}$N atom)</td>
</tr>
<tr>
<td>ANOVA</td>
<td>Analysis of variance</td>
</tr>
<tr>
<td>AOA</td>
<td>Ammonia-oxidising archaea</td>
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<tr>
<td>AOB</td>
<td>Ammonium oxidising bacteria</td>
</tr>
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<td>BD</td>
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<tr>
<td>v/v</td>
<td>Volume per volume</td>
</tr>
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Abstract

Nitrification and denitrification are two major soil biological processes that release nitrous oxide (N$_2$O) from soils. N$_2$O production and reduction have been well-documented at temperatures below 35 °C, but are poorly understood at higher temperatures. N$_2$O production from nitrification was compared at a range of temperatures (10 °C to 45 °C) to mimic the typical temperatures encountered in soils from dairy pasture systems in Australia. Temperature was more important than soil type in controlling N$_2$O from nitrification, which was slow at 10 – 25 °C and peaked at 35 – 40 °C, suggesting a higher optimum temperature for N$_2$O production from nitrification than previous studies reported. Autotrophic nitrification produced N$_2$O predominantly below 35 °C, while heterotrophic nitrification, which used NH$_4^+$ for nitrifying, released N$_2$O principally between 35 °C and 40 °C. Total N$_2$O emissions measured at different temperatures were influenced by the climatic region from which the soils were sourced. The magnitudes of N$_2$O emissions in the tropical soil exceeded those in the temperate soil under experimental conditions, although N$_2$O/NO$_3^-$ from nitrification at different temperatures was independent of the climatic region from which soils were sourced. The N$_2$O/NO$_3^-$ ratio was positively correlated with increased temperature and was above 1.0% at 35 °C, regardless of climate.

Temperature interacted with soil moisture and NO$_3^-$ availability to regulate N$_2$O from denitrification, while the conversion of N$_2$O to N$_2$ was affected principally by temperature. The highest denitrification (N$_2$O + N$_2$) was found at 35 °C in the soils treated at 75% FC and N contents between 100 – 150 kg N ha$^{-1}$. Low N$_2$O/N$_2$ ratios at 40 – 45 °C was due to the enhancement of N$_2$ production at these temperatures, suggesting greater soil NO$_3^-$ loss as N$_2$ during summer, particularly in soils that are wet at that time.
Interestingly, high NH₄⁺ availability was observed at 45 ºC, which was hypothesised to relate to low nitrification rate and high rates of N mineralisation or dissimilatory nitrate reduction to ammonium at this temperature.

This work has improved the knowledge of N cycling processes at high temperatures. Soil moisture or NO₃⁻ content alone are poor predictors of N₂O and N₂ production, since these elements interacted with temperature to control denitrification. High soil NH₄⁺ availability at 45 ºC is a particularly interesting finding with potential to contribute to N losses. The findings confirm that management of soil moisture and NO₃⁻ availability, and a consideration of crop N demand are likely to reduce N losses as N₂O and N₂.
Declaration

I certify that this work contains no material which has been accepted for the award of any other degree or diploma in my name in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. In addition, I certify that no part of this work will, in the future, be used in a submission in my name for any other degree or diploma in any university or other tertiary institution without the prior approval of the University of Adelaide and where applicable, any partner institution responsible for the joint award of this degree.

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