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

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Acronyms and abbreviations

µg	Microgram
^{15}N (%)	Labelling nitrogen (percentage of excess ^{15}N atom)
ANOVA	Analysis of variance
AOA	Ammonia-oxidising archaea
AOB	Ammonium oxidising bacteria
BD	Bulk density
C_2H_2	Acetylene
CT	Constant temperature
DEA	Denitrification enzyme activity
DNRA	Dissimilatory nitrate reduction to ammonium
E_a	Activation energy
FC	Field capacity
FTP	Fluctuating temperature pattern
HSD	Honestly significant difference
mg	Milligram
MPN	Most probable number
N	Nitrogen
N_2	Dinitrogen
N_2O	Nitrous oxide
N_2OR	Nitrous oxide reduction
na	Not applicable
NH_2OH	Hydroxylamine
NH_4^+	Ammonium
NO	Nitric oxide
NO_2^-	Nitrite
NO_3^-	Nitrate
ns	Not significant
O_2	Oxygen
OC	Organic carbon
P_n	The proportion of N_2O to NO_3^- by nitrification
SE	Standard error
TEA	Terminal electron acceptor
T_{max}	Maximum monthly temperature
T_{min}	Minimum monthly temperature
T_{opt}	The optimum temperature
v/v	Volume per volume
WFPS	Water-filled pore space

Abstract

Nitrification and denitrification are two major soil biological processes that release nitrous oxide (N_2O) from soils. N_2O production and reduction have been well-documented at temperatures below 35 ºC, but are poorly understood at higher temperatures. N_2O production from nitrification was compared at a range of temperatures (10 ºC to 45 ºC) to mimic the typical temperatures encountered in soils from dairy pasture systems in Australia. Temperature was more important than soil type in controlling N_2O from nitrification, which was slow at 10 – 25 ºC and peaked at 35 – 40 ºC, suggesting a higher optimum temperature for N_2O production from nitrification than previous studies reported. Autotrophic nitrification produced N_2O predominantly below 35 ºC, while heterotrophic nitrification, which used NH_4^+ for nitrifying, released N_2O principally between 35 ºC and 40 ºC. Total N_2O emissions measured at different temperatures were influenced by the climatic region from which the soils were sourced. The magnitudes of N_2O emissions in the tropical soil exceeded those in the temperate soil under experimental conditions, although N_2O/NO_3^- from nitrification at different temperatures was independent of the climatic region from which soils were sourced. The N_2O/NO_3^- ratio was positively correlated with increased temperature and was above 1.0% at 35 ºC, regardless of climate.

Temperature interacted with soil moisture and NO_3^- availability to regulate N_2O from denitrification, while the conversion of N_2O to N_2 was affected principally by temperature. The highest denitrification ($N_2O + N_2$) was found at 35 ºC in the soils treated at 75% FC and N contents between 100 – 150 kg N ha^{-1}. Low N_2O/N_2 ratios at 40 – 45 ºC 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 NH_4^+ 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 NO_3^- content alone are poor predictors of N_2O and N_2 production, since these elements interacted with temperature to control denitrification. High soil NH_4^+ 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 NO_3^- availability, and a consideration of crop N demand are likely to reduce N losses as N_2O and N_2.

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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