Managing soil microbial communities to reduce N_2O emissions through pH management

WALSH SCHOLARSHIPS PROGRAMME

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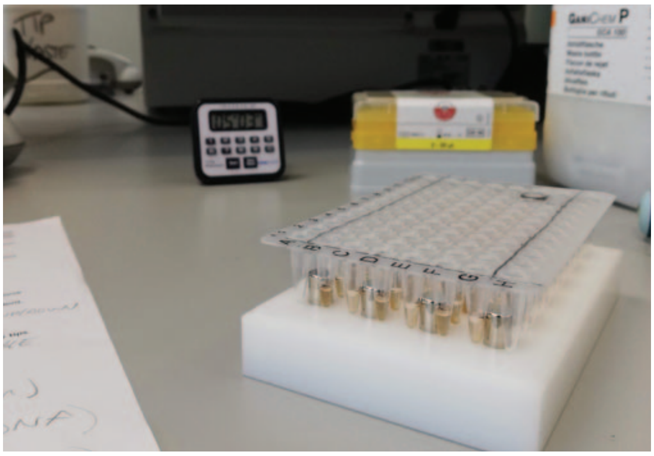
Nitrous oxide (N_2O) is a potent greenhouse gas with a global warming potential 298 times greater than carbon dioxide (CO_2). Agricultural soils are one of the main sources of N_2O emissions, with higher production rates of the gas induced by the application of nitrogen (N) fertiliser. The gases are primarily produced by microorganisms within soil that can transform plant-available N into gaseous forms. These emissions can be partly reduced by good agronomic practices; however, the project Mitigating Agricultural Greenhouse Gas Emissions by improved pH management (MAGGE-pH) aims to identify more efficient and specific approaches to decrease the production of N_2O. To do so, the project focuses on the microbial communities responsible for emitting and consuming N_2O in soils, and on the potential of soil pH management to control these emissions. pH has been shown in previous studies to play an important role in determining N_2O levels emitted from soils and is known to strongly affect soil microbial communities.

Impact of soil management

Microbial communities, like all living organisms, respond and adapt to their environment, and thus are strongly impacted by soil management. Microbes in the soil carry out a range of chemical transformations to obtain energy and essential nutrients. As part of the chemical transformation of N, N_2O can be produced, mainly through the denitrification process. This pathway is carried out by microbial denitrifiers when there are low levels of oxygen in the soil (anaerobic environments) and a ready supply of both available N and carbon. The application of N fertilisers leads to a supply of available N in soil that can be potentially transformed by microorganisms, leading to higher emissions of N_2O. Recent studies have shown that soil pH can dictate the N_2O losses, with acidic soils increasing the levels of N_2O emitted from soil. Laboratory studies report that increasing soil pH caused N_2O emissions to be reduced, providing a possibility of a more sustainable approach within agronomic practices.

The evidence of soil pH influencing the production of this greenhouse gas is predominantly restricted to laboratory studies. The MAGGE-pH project has brought together partners form across Europe and New Zealand to further explore the potential of soil pH management to reduce N_2O emissions under realistic field conditions. This collaboration has allowed this relationship to be tested over a wide range of soil types,



As part of the sequencing protocol, DNA samples are loaded into a 96-well plate, which is then placed on a magnetic stand. The magnet pulls the metal beads to the walls of each well allowing the sample to be cleaned.

liming strategies and geoclimatic conditions, as well as a wide pH gradient (4.1 to 7.4). This will enable us to assess how important soil pH is at regulating microbial communities involved in N_2O emissions across the globe.

PhD research

As part of the MAGGE-pH project, Meritxell's research is quantifying the abundance of microbes involved in the denitrification pathway, how their abundance changes across the international partners' experimental sites, and if their relationship with soil pH is maintained across them. This is achieved by using molecular techniques such as quantitative polymerase chain reaction (qPCR). Once DNA is extracted from soil, the samples are processed to quantify target genes known to be important in the denitrification process. These can be described as molecular labels that allow microbes capable of carrying out denitrification to be recognised. Their abundances can then be related to the pH range included in the study, allowing the identification of trends and patterns between the microbes and the soil property.

Soil pH could potentially turn into a key soil factor to manage and reduce the emissions of N_2O from soils. However, not only soil properties but also nutrient availability influence the microbial communities involved in different pathways. N availability is known to induce denitrification, but there are other nutrients that are less understood such as phosphorus (P). As part of Meritxell's PhD, the application and availability of P has been taken into consideration to establish any potential roles of the nutrient in relation to denitrification product rates. Using a long-term experimental trial with four P treatments as well as pH levels, potential N_2O production (laboratory-based experiment) and composition of microbial communities has also been studied to identify more specific approaches that can lead to the reduction of N_2O emissions from agricultural soils. Looking into the future, a target management of soil pH to benefit the microbial communities present in the soils may lead to a significant reduction of the production of N_2O from agricultural soils while improving agronomic practices and moving forward to a more sustainable management.

Molecular sampling set up in the pH x P field trial in Moorepark (Co. Cork). After soil samples are collected and mixed inside a plastic bag, a subset sample is collected inside a sterile tube and flash frozen in liquid nitrogen in the field.

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References

Forster, P.V., *et al.* (2007). 'Changes in atmospheric constituents and in radiative forcing'. In: *Climate Change*. (2007). 'The Physical Science Basis', 130-234.

Samad, M.D.S., Biswas, A., Bakken, L.R., Clough, T.J., De Klein, C.A.M., Richards, K.G., *et al.* (2016). 'Phylogenetic and functional potential links pH and N_2O emissions in pasture soils. *Scientific Reports*, 6: 35990.

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