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Effects of natural and NH4-charged zeolite amendments and their combination with 3,4-dimethylpyrazole phosphate (DMPP) on soil gross ammonification and nitrification rates

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The use of natural (NZ) and NH4-charged (CZ) zeolitites (rocks with > 50 wt% of zeolites) as soil amendments are valuable management practices to increase soil physico-chemical properties, agricultural sustainability and productivity. These minerals can be highly beneficial because of their capacity to reversibly exchange cations and water. However, little is known about their influence on soil nitrogen (N) transformation processes. Recently, NZ has been shown to have limited influence on soil microbial biomass activity in the short-term period, while CZ induced an immediate priming effect, stimulating net NO_3- production and NH4+ consumption. The high NO_3 concentrations induced by CZ suggests that the application together with a nitrification inhibitor would improve Nitrogen Use Efficiency (NUE) and reduce N losses.
Here we aim at identifying the mechanisms for different N availability after zeolite amendments, by measuring gross N transformation rates. This would provide a sharpened comprehension of their influence on soil N processes. Gross nitrification and mineralization rates were evaluated using the 15N pool dilution technique in soils amended with NZ and CZ with and without a commonly used synthetic nitrification inhibitor 3,4-dimethylpyrazole phosphate (DMPP).
The experiments were performed on a slightly alkaline soil with silty-clayey texture amended with 10 wt% of NZ and CZ in comparison to an unamended soil (control), with and without the addition of DMPP. Fertilizers were added at a ratio of 170 kg N ha-1 in the form of 15NH414NO_3 and 14NH415NO_3 at 10% atom 15N. At time 0 and after 24 h, we measured NH4+ and NO_3- and their concentration and N isotopic signature. Additionally, we determined the total evolved N2O during the incubation as well total DNA and functional genes involved in the N cycle (amoA, BamoA, nirS, nosZ) through qPCR.
Results show that gross NH4+ and NO_3- production and consumption was not different between NZ and control in samples that did not receive DMPP. However, DMPP application favored the preservation of the NH4+ pool and slowed the formation of NO_3- by ∼25% in both, NZ and the control. Compared to Control and NZ, the CZ amended soil showed a significantly higher gross NH4+ production as well as high N2O emissions. The latter were corroborated with a significantly lower content of nosZ and nirS in the CZ treatment. The lower expression of N2O reductase genes that converts N2O into N2 has likely resulted in the higher N2O emissions. High NH4+ availability in the CZ treatment has probably inhibited the second step in the nitrification reaction, as indicated by the reduced NO_3- production without consumption while fueling N2O production via nitrifier-denitrification.
The addition of DMPP to CZ amended soil, completely inhibited gross NO_3- production. Additionally, DMPP application reduced the total amount of evolved N2O in all the treatments by more than 90%.
These results suggest that the addition of DMPP to soils can mitigate N2O losses to a large degree, while the NUE for CZ amendments can be even strongly improved via reduced gross nitrification and can thus mitigate N losses to the water bodies.