Use of laser spectroscopy to evaluate the influence of soil storage on N_2O emission

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Introduction

The rapidly changing global climate is due to increased emission of anthropogenic greenhouse gases (GHGs). Among the key GHGs, nitrous oxide (N_2O) is 298 times more powerful than carbon dioxide (CO_2) in its global warming potential. N_2O emissions occur mostly through agricultural and other land-use activities and are associated with the intensification of agricultural and poor agricultural practices. The atmospheric concentration of N_2O has increased by more than 20% from ¬271 ppb to 331 ppb since the industrial era (ca. 1750) to 2018 (WMO 2019). To develop climate smart agricultural practices for mitigation of N_2O, isotopic technique of ^{15}N plays a key role in precise measurement as well as identifying its microbial processes that produce N_2O in soil. Incubation experiments using sieved soils under controlled environment are generally conducted to study microbial processes associated with N_2O emission. In some incubation studies, researchers have used stored soils which are likely to influences the N_2O production due to rewetting of soils. The objective of our study was to investigate the influence of soil storage on N_2O emission and N mineralization rates using ^{15}N technique.

Soil samples preparation

Seibersdorf Soil

- Soil was collected from the International Atomic Energy Agency Laboratories experimental fields in Seibersdorf, Austria (47°58’ N, 16°30’ E).
- Haplic Chernozem (IUSS-WRB, 2014), pH = 8.2, total N = 2.27 g kg^{-1} soil.
- Top soils from 0 to 10 cm were collected.
- Bulk density = 1.2 g cm^{-3}, soil porosity = 0.55%

Isotope

- ^{15}N labelled urea (1 atom%) at the rate of 50 mg N kg^{-1} soil, at room temperature (23°C).
- Urea was applied and the N_2O emission was measured on day 0, 1, 2, 3, 4, 7, 8, 9, 11, 14, 17, 21, 23, 25, 28, 30, 32, 35, 37, 39, 42, 44, 46, 49.

Soil storage/treatment (5 replicates of each treatment)

- **Soil stored at 4°C (ST):** Sieved to 2 mm; stored at 4°C at field moisture (0.123 g g^{-1} soil) in sealed plastic bags for 3 weeks.
- **Room temperature dried (PI):** Sieved to 2 mm; stored for 2 weeks dried at room temperature; revived for 2 weeks at 60% WFPS and room temperature.
- **Fresh sieved (FS):** Taken in the fourth week; sieved to 2 mm.
- **Fresh undisturbed (FU):** Taken in the fourth week; no treatment; N_2O measured at the same time as the other treatments.

The four treatments were all compacted to the same bulk density as FU and brought to a volumetric water content of 0.330 g cm^{-3} (60% WFPS) during the 49 days.

Treatment time axis

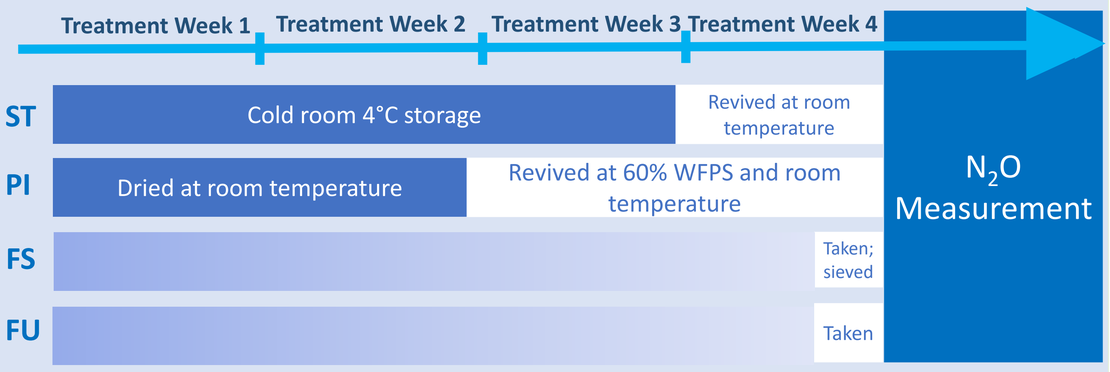

Fig. 1 revived at 60% WFPS

Fig. 2 soil compacted to desired bulk density

Fig. 3 soil at bulk density

Fig. 4 soil at 60% WFPS at room temperature

Fig. 5 applying ^{15}N labelled urea

Fig. 6 bulk density determination

N_2O measurement

- ^{15}N amended soil samples, comprised of different treatments, were incubated for 49 days.
- N_2O measurements were carried out for 49 days using a laser based N_2O analyser (off-axis integrated cavity output spectroscopy (OA-ICOS), Los Gatos Research, California, USA).

Fig. 7 sample incubated in a gas chamber

- N_2O fluxes were measured in closed loop mode for 12 min per sample, 3 min cleaning.
- Cumulative N_2O fluxes are expressed as the integrated area under the curves of the daily fluxes, using the trapezoidal rule.
- Keeling plot intercepts were calculated to identify the N_2O source

$$\delta^{15}N_s = \frac{\sum_{i=1}^{n}\left(\left(\frac{1}{N_i}-\left(\frac{1}{N}\right)_{av}\right)\left(\delta^{15}N_i-\delta^{15}N_{av}\right)\right)}{\sum_{i=1}^{n}\left(\frac{1}{N_i}-\left(\frac{1}{N}\right)_{av}\right)^2}$$

$\delta^{15}N_s$ = the intercept of the Keeling plot, the isotopic mixture of the sources;
N_i = measured N_2O ppm at time point i;
$(1/N)_{av}$ = the average value of $1/N_2O$ ppm over the measurement time;
$\delta^{15}N_i$ = the isotopic signature at time i;
$\delta^{15}N_{av}$ = the sources average isotopic signature.

- %Ndff and %Ndfs were calculated

$$\%Ndff = \frac{atom\%excessN_2O}{atom\%excessUrea} \times 100 \qquad \%Ndfs = \left(1-\frac{atom\%excessN_2O}{atom\%excessUrea}\right) \times 100$$

%Ndff = the percentage nitrogen derived from fertilizer; %Ndfs = the percentage nitrogen derived from soil; atom%excess N_2O = the N atom percent excess of the measured N_2O fluxes; atom%excess Urea = the N atom percent excess of urea (fertilizer).

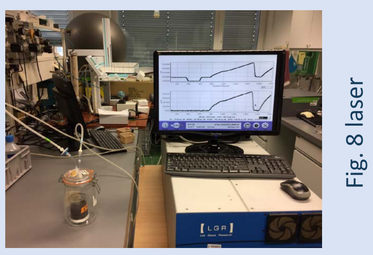

Fig. 8 laser analyser (LGR)

Fig. 9 soil samples, covered with parafilm to keep moisture constant

Results

- **Soil storage had a significant effect on N_2O emission.** Over the 7-week period, ST produced the highest cumulative N_2O emissions (2.70 µg N g^{-1} soil) and the largest amount of N derived from fertiliser (Ndff) (1.4 µg N g^{-1} soil).
- FU produced the lowest cumulative N_2O emissions (1.0 µg N g^{-1} soil) but the largest amount of N derived from soil (Ndfs) (0.6 µg N g^{-1} soil).
- The daily N_2O fluxes of FS and FU declined rapidly after day 8, PI and ST exhibited several peaks during the measurement.

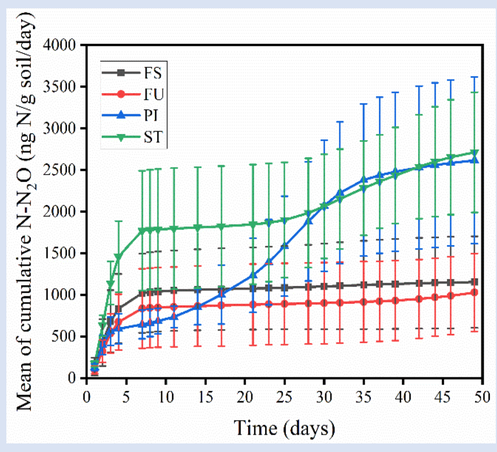

Fig. 10 effect of soil storage on N_2O emission

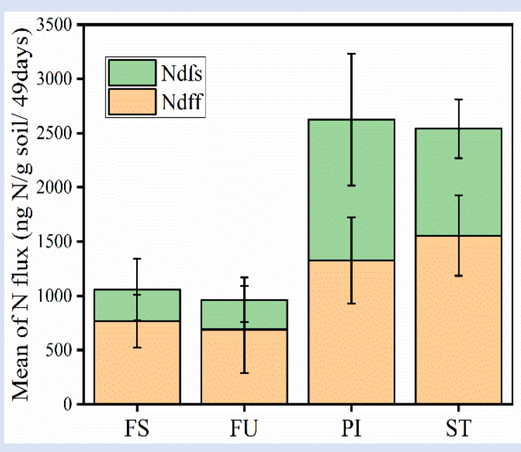

Fig. 11 N sources of N_2O emission for different soil storage

Fresh sieved (FS), Fresh undisturbed (FU), Room temperature dried (PI), and Soil stored at 4°C (ST)

Conclusions

These results indicate that soil storage affects microbial processes and therefore N_2O emissions. Our results suggest using fresh soil to avoid storage effects. If this is not possible, the effect of soil storage should be considered before the experiment.