

Determination of Sources of Soil Nitrate in a Long-Term Irrigated Rotation Using Ion Exchange Membranes and Isotope Ratio Measurements



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Objective

The objective was to test the potential use of Plant Root Simulator (PRS) probes for determining $\delta^{15}\text{N}$ and $\delta^{18}\text{O}$ values of soil nitrate in the laboratory and under field conditions.

Laboratory Experiment

Materials and methods

- 5 PRS probes were inserted in thirteen 1L-Nalgene bottles containing 1 kg dried sand and 200 ml KNO_3 solution (50 mg NO_3/L).
- PRS probes were removed periodically after 1 to 21 days.
- Adsorbed ions were removed from each PRS probe separately with 20 mL of 0.5N HCl.
- $\delta^{15}\text{N}$ and $\delta^{18}\text{O}$ values of nitrate were determined using the denitrifier technique and isotope ratio mass spectrometry at the Isotope Science Laboratory in the University of Calgary with a measurement uncertainty of 0.3 ‰ for $\delta^{15}\text{N}$ and 0.5 ‰ for $\delta^{18}\text{O}$.

Results

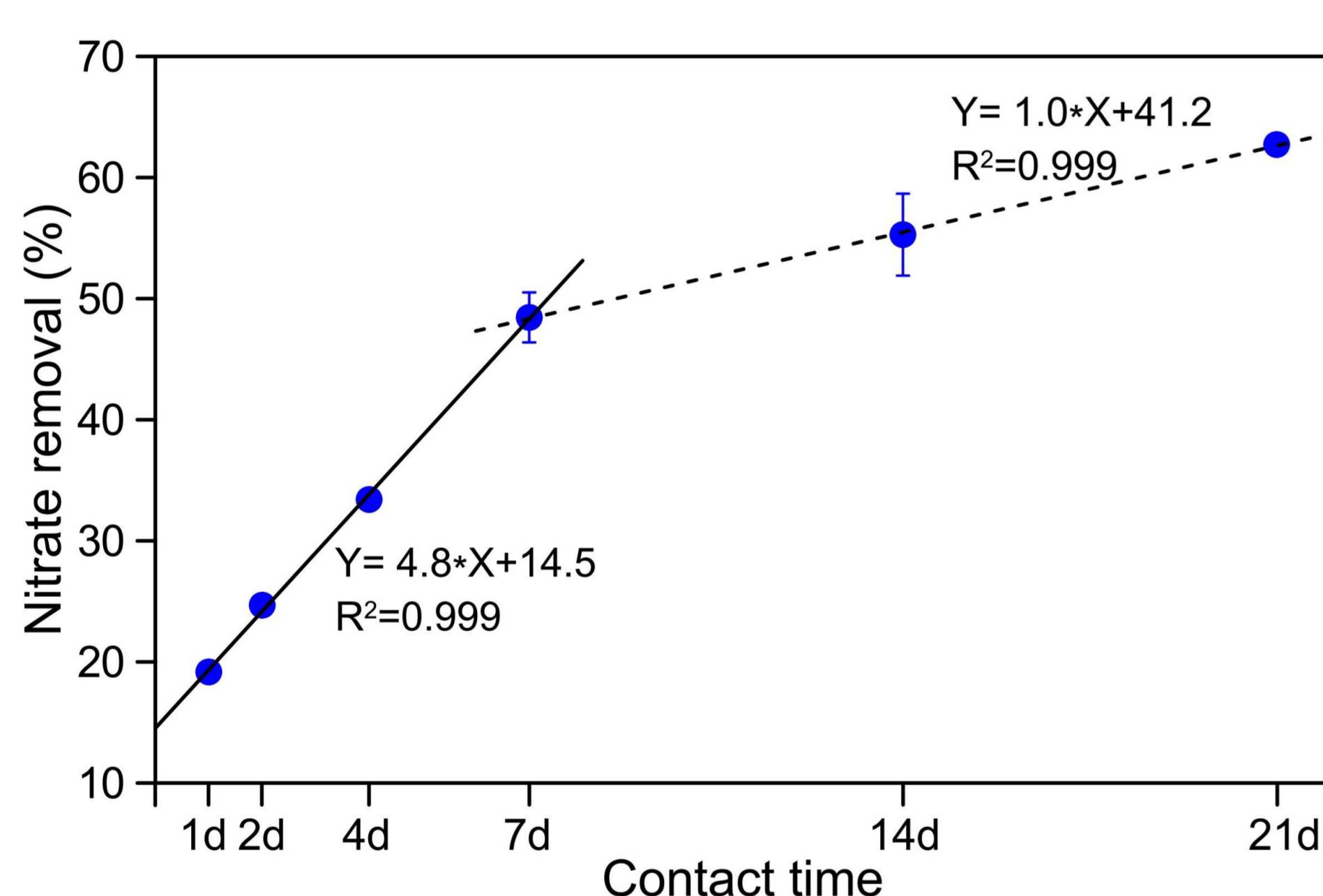


Fig. 1. Nitrate recovery on PRS probes with increasing contact time.

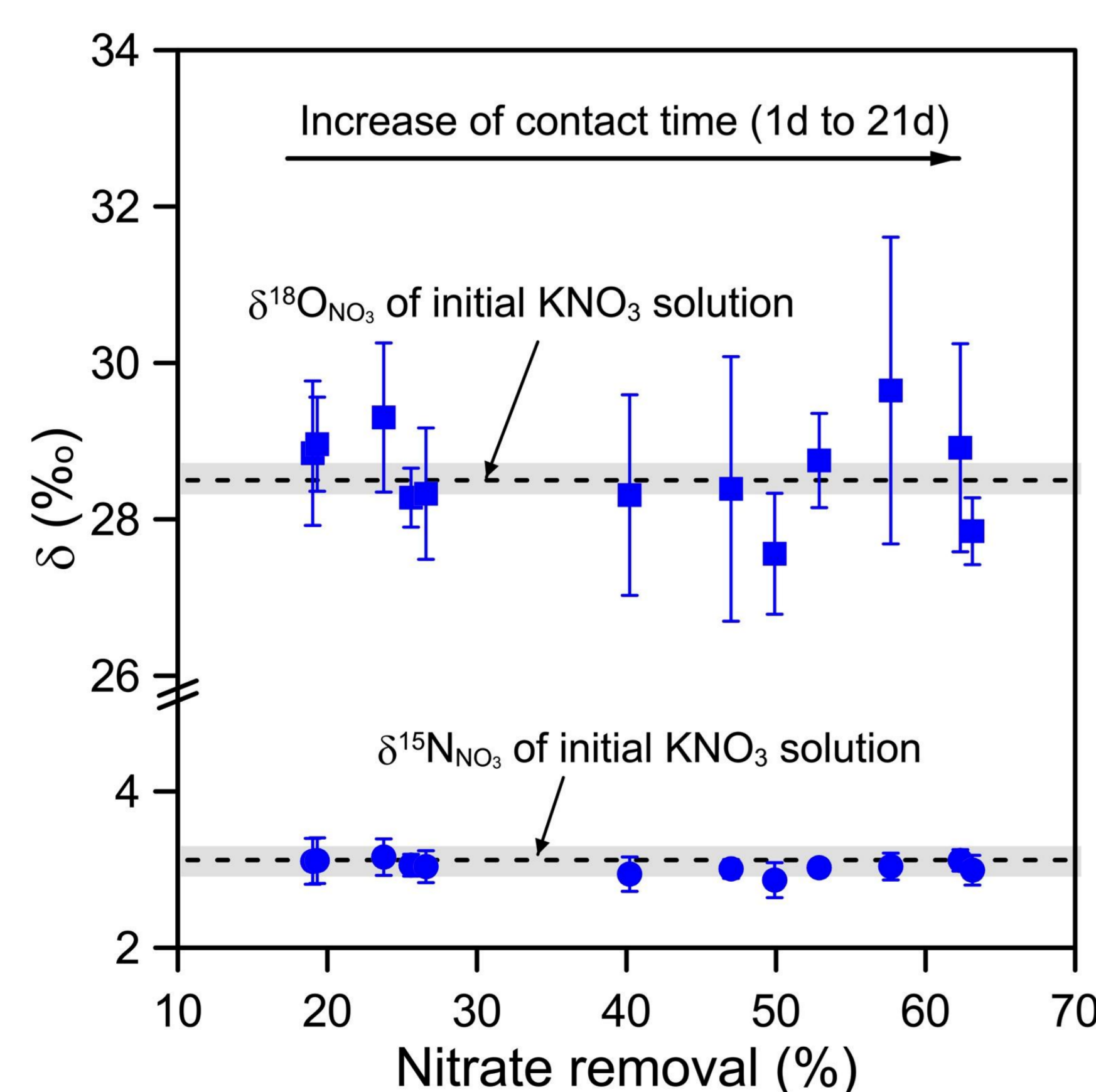


Fig. 2. $\delta^{15}\text{N}$ and $\delta^{18}\text{O}$ values of nitrate recovered from the PRS probes versus nitrate removal (in %).

- Nitrate adsorbed rapidly onto the PRS probes in the laboratory sand in the first week, with continued but slower nitrate adsorption in weeks 2 and 3 (Fig. 1).
- $\delta^{15}\text{N}$ values of nitrates adsorbed on PRS probes ranged from 2.9 to 3.1‰ and were identical to that of initial KNO_3 solution (3.0‰) irrespective of the extent of nitrate recovery (Fig. 2).
- $\delta^{18}\text{O}$ values of nitrate from the PRS probes were also identical (0.4 ± 0.2 ‰) with that of the KNO_3 solution within the measurement uncertainty (not shown).
- $\delta^{15}\text{N}$ and $\delta^{18}\text{O}$ values of nitrate eluted from PRS probes were accurate and precise regardless of the extent of nitrate recovered on the PRS probes.

Field Experiment

Materials and methods

- Long-term irrigated crop rotation at Lethbridge, AB
- Three rotations (A=alfalfa, W=wheat, B=barley, C=corn)
 - 1) AAWB
 - 2) CWCWBAAAB
 - 3) CWCWB+N (34.5-0-0, 100 kg N/ha/yr)
- Two fertility treatments
 - Manure: 33.5 wet t/ha once every four years (2009), +P
 - P_only: 0-45-0, 10 kg P/ha/yr
- PRS probes buried for 13 days in June 2012 (crop = wheat)

Results

- Nitrate adsorption was 60% higher in the N-fertilized rotation (33 vs. 20 $\mu\text{g NO}_3\text{-N}/\text{cm}^2/13\text{d}$, $P=0.04$), but not affected by other treatments (not shown).
- Manure treatment increased $\delta^{15}\text{N}$ values from 5.1 to 6.3‰ ($P=0.01$), but did not affect $\delta^{18}\text{O}$ values (Fig. 3).
- N-fertilized rotation (#3) increased $\delta^{15}\text{N}$ values from 5.1 to 7.1‰ ($P=0.01$) and $\delta^{18}\text{O}$ from -7.2 to 2.7‰ ($P=0.01$).

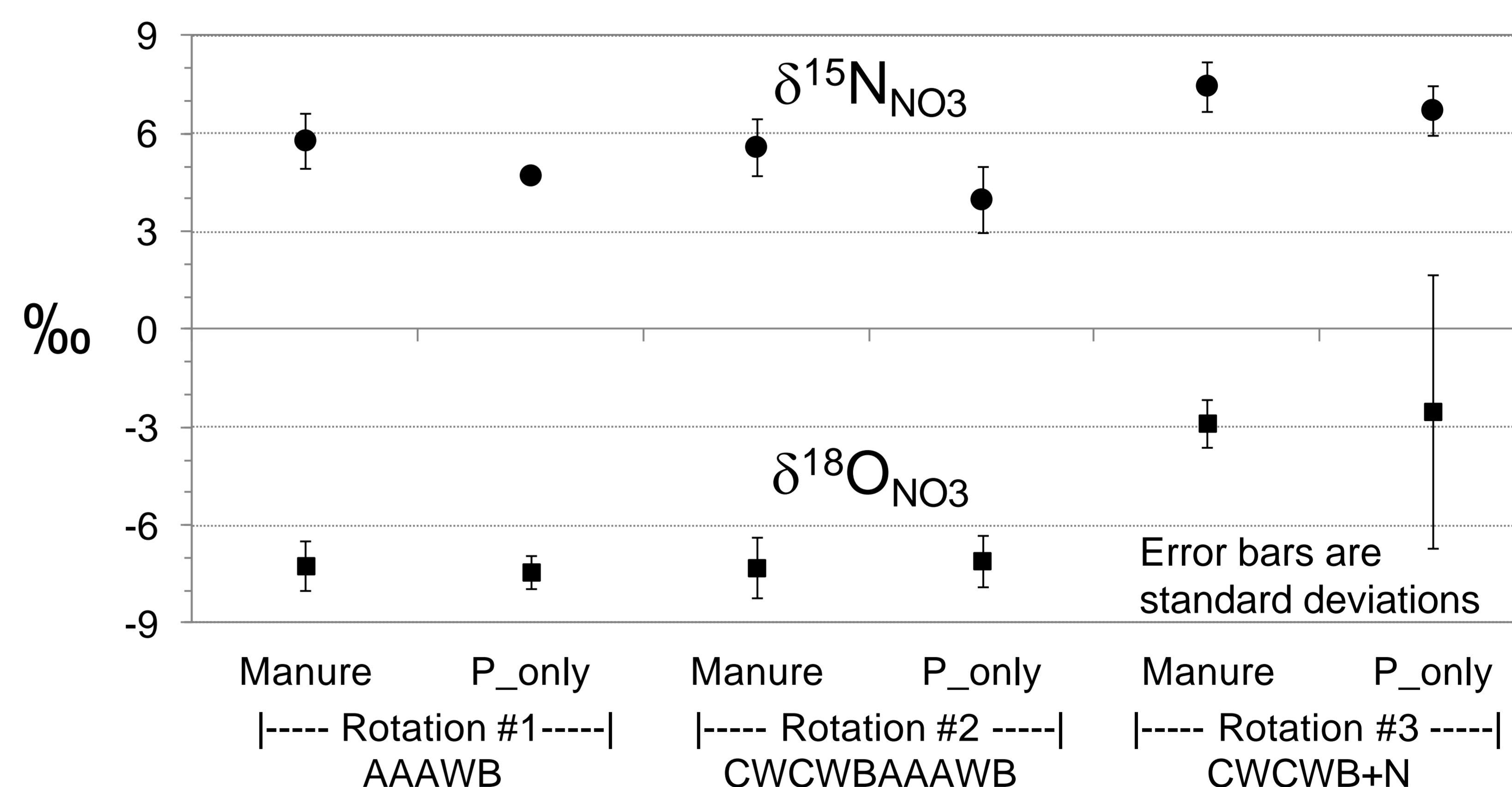


Fig. 3. Effect of crop rotation and fertility treatment on isotope ratios of soil nitrate collected by PRS probes in field study.

Conclusions

- Laboratory: soil nitrate adsorbed onto PRS probes in sufficient quantities for isotope analysis within days without significant nitrogen and oxygen isotope fractionation.
- Field: nitrogen and oxygen isotope ratios of nitrate were both affected by cropping treatments.
- PRS probes are an effective tool to collect soil nitrate for isotope analysis.