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Evidence of aerobic and anaerobic methane oxidation coupled to denitrification in agricultural soils

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Rationale
• Agricultural soils may act as either a source or a sink of atmospheric methane (CH₄).
• Its extent depends on soil type, aeration, water regimes, nutrient availability and environmental variables.
• Advancing research on the interactions between CH₄ oxidation and denitrification is a key concern for understanding global C and N cycles.
• This paper reviews recent progress in their functional relationships.

Relationship between CH₄ oxidation and denitrification
Isotope studies show that CH₄ production and oxidation takes place simultaneously in agricultural soils at water content above field capacity i.e. in presence of anaerobic microsites and aerobic-anaerobic interface (Fig. 1).

This results in either aerobic or anaerobic CH₄ oxidation coupled to the highest N₂O emissions, demonstrating a close relationship between CH₄ oxidation and denitrification processes.

Pathways of CH₄ oxidation coupled to denitrification
Methane is a low-cost electron donor for coexisting denitrifiers.

Denitrification is coupled to either aerobic CH₄ oxidation involving direct nitrate/nitrite reduction (partial denitrification, Fig. 2), or

anaerobic relating to nitrite/nitric oxide reduction (complete denitrification).

3CH₄ + 8NO₂⁻ + 8H⁺ — 3CO₂ + 4N₂ + 10H₂O
5CH₄ + 8NO₂⁻ — 5CO₂ + 4N₂ + 8OH⁻ + H₂O

Evidenced by microbial genomics and isotope study
A microbial consortium is involved in the interactive process. Recent research with microbiological techniques prove (Fig. 3):

(i) the occurrence of the coupled process by combining aerobic methanotrophs and denitrifiers, and

(ii) oxidation of ammonium and metabolic by-products, releasing N₂O as a terminal product.

However, the apparent anaerobic phenomenon lacks known genes for dinitrogen (N₂) production.

Isotope studies reveal that methanotrophs could bypass the denitrification intermediate N₂O to produce N₂ and O₂ that oxidizes CH₄ (Fig. 4)

What next?
• Further investigations using both advanced molecular microbiology and isotope tracing techniques are necessary to:
  • elucidate the nature of the processes,
  • better understand the mechanisms in agricultural soils and
  • develop biotechnological solutions to the issues concerning particularly to climate change.

References

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