

Rice Methane Innovation Accelerator

STATE OF SCIENCE

Methane-reducing Agents

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Carbon fixed by rice plants and made available through root exudates is converted to methane by soil microbes in the anaerobic conditions present in flooded paddy fields. Although actual methane synthesis is by a small set of methanogenic archaea, they require substrates produced by extensive communities of soil microbiota that process the root exudates¹. Therefore, manipulating the rice root microbiome, by either direct or indirect interventions, can mitigate CH₄ emissions.

Rice paddies harbour multiple methanogenic archaea². These include acetoclastic methanogens *Methanosarcina* and *Methanosaeta* that utilize acetate for methane production, and hydrogenotrophic methanogens *Methanocella* and *Methanobacteria* that instead use H₂ and CO₂. *Methanocella* has been presumed to be the main CH₄ source from rice plants³, but *Methanobacteria* might also have a major role⁴.

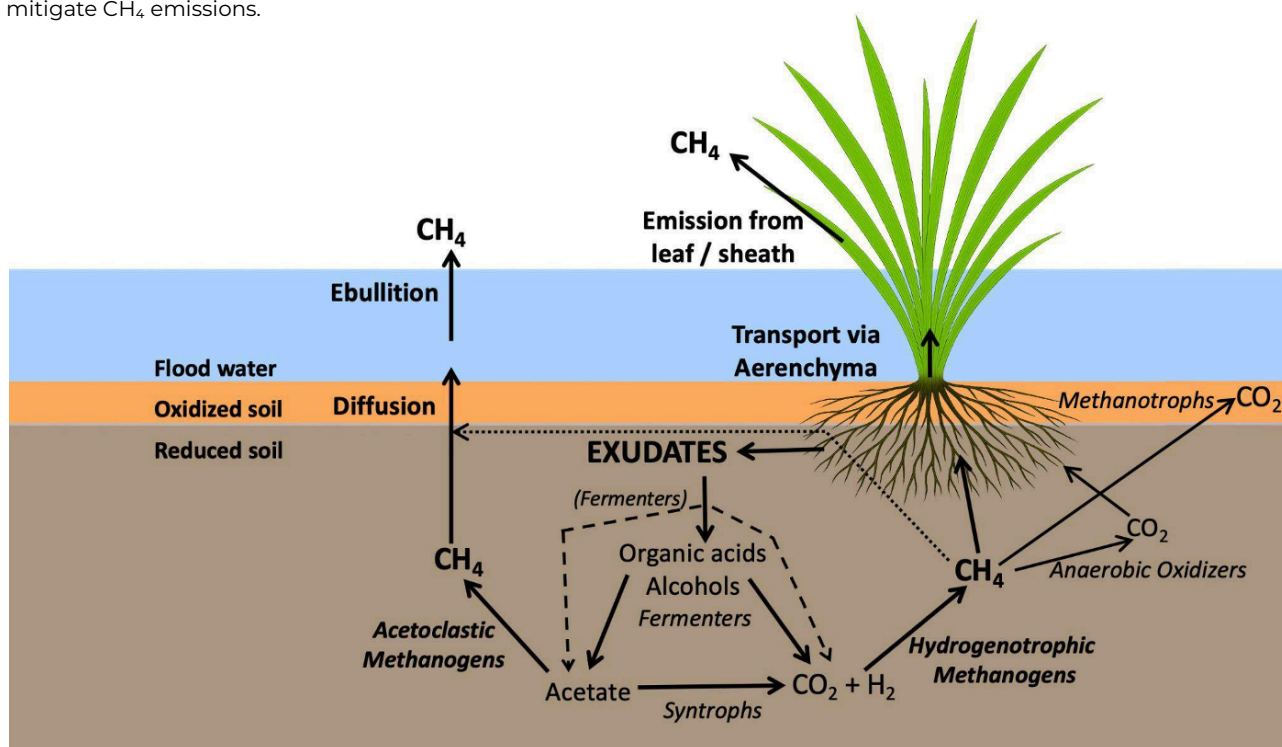


Figure 1: Microbial CH₄ cycling in flooded rice. Carbon from root exudates is converted by fermenters and syntrophic eubacteria into substrates for methanogenic archaea. CH₄ produced is emitted via aerenchyma, or directly released, or oxidized to CO₂ by methanotrophic eubacteria and anaerobic oxidizers. Dotted lines = possible alternate pathways. See text for details.

Methane cycling by microbial communities in the soil involves both the production of methane and its oxidation, carried out by different sets of microbial consortia. The possibility that applications of defined microbial strains to rice fields can be used to reduce emissions has been explored in many different studies over the past 20 years⁵. Several studies have reported impressive results in terms of reduction of methane emissions using this approach. Recent examples of field studies include the use of mixtures of methanotrophic eubacteria⁶, seed treatment using *Azoarcus*, a betaproteobacteria⁷, and different strains of cyanobacteria⁸. A remarkable reduction of CH₄ emissions by more than 90% was observed by the addition of cable bacteria, which promote the growth of sulfate-reducers that compete with methanogens for acetate and hydrogen⁹. However, this finding has not yet been extended to field conditions.

An alternative approach to microbial inoculants is to use chemical inhibitors of emissions. Several chemical inhibitors of methanogens have been described, some specific for methanogens (e.g. ethylene) and others that also affect non-methanogens¹⁰. Successful reduction of methane emissions has been reported in lab experiments by addition of ethephon, a solid which is converted to ethylene, that can be delivered using a biodegradable polymer¹¹. Restricting the soil microbial fermentation that supports methanogens can also be an effective strategy for methane reduction¹². Recently, the addition of inhibitors (oxantel and ethanol) that act by reducing fumarate production by upstream fermenters has been reported to lower emissions by 60% under field conditions⁴.

Despite the promising reports using microbial and chemical inoculants, they have not yet been translated into widespread usage in rice cultivation. Successful methane reduction under lab or greenhouse conditions often does not translate to field conditions. Externally applied microbes in fields have to compete with the large reservoir of existing soil microbes that are already well adapted to rice cultivation. Persistence of the applied microbes in field soil will require establishment within the pre-existing root-associated microbiomes throughout the plant life cycle, which might be facilitated by using microbial consortia instead of mono-inoculation. With both microbial and chemical agents, there is also a possibility of repeated applications resulting in lasting perturbations to the root and soil microbiomes. Detailed characterization and analysis will need to be incorporated into studies to avoid inadvertent negative effects, such as increased susceptibility to pathogenic microbes, changes to soil health and reduced biodiversity. Especially for chemical applicants, the potential for easy reversibility to the original state (e.g., as reported with ethephon¹¹) would be preferable to agents that might result in irreversible alterations to rice field soils and their ecology.

In summary, methane-reducing agents provide a highly promising approach that has been demonstrated to be effective on small scales and under limited conditions. If they can be combined with demonstration of scalability to field use, as well as lack of long-term negative effects, the implementation of such agents can be a major tool in global strategies for the reduction of emissions from rice fields.

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