Effects of arbuscular mycorrhizal symbiosis on plant water relations and greenhouse gas emissions under changing soil moisture regimes

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Belowground microbial-plant interactions

Plant roots: Nutrient cycling, C storage, Plant productivity, Plant diversity, Soil physical properties, Soil water regulation

Soil microorganisms:
Arbuscular mycorrhizal (AM) symbiosis

Present in 80% of the plant sps, different terrestrial ecosystems

Plant productivity

- Increased uptake and assimilation of N
- Higher absorptive area, higher access to soil nutrients: mycorrhizal network
- Preferential uptake of NH$_4^+$

Plant water relations

- Increased tolerance to water stress
- Higher access to soil water: mycorrhizal network
- Regulation of hormones (ABA)

Nutrient cycling

- Decrease the N available in the soil for immobilization, leaching or gas emissions
- Changes in soil moisture, effects on mineralization, nitrification and denitrification
Does AM colonization of plant roots influence soil greenhouse gas emissions?

i) AM symbiosis decreases N$_2$O and CO$_2$ emissions through modulation of plant nutrient uptake and direct impacts to N cycling

i) Effects to the GHG emissions are indirect through the modulation of plant water use
Experimental design

Tomato plant genotype

Mycorrhizal type: 76R MYC
Reduced mycorrhizal colonization: \textit{rmc}

- 20 reps per genotype
- Root in growth cylinders

- Soil: Organic farm
- Established AM fungi population (15-25\% colonization)
- High soil organic N pools
- Compost: 8 ton ha\textsuperscript{-1}
Experimental design

Soil moisture

- Two consecutive dry downs
- Simulate wet-dry cycles and patchy water availability typically occurring in the field
Experimental design

**Plant growth**
- Aerial, root biomass
- AM fungi colonization
- Shoot N, P, K

**Plant water relations**
- Photosynthetic rate, stomatal conductance
- Portable open flow infrared analyzer (IRGA)
- WUE: photosynthetic rate/stomatal conductance

**Greenhouse gas emissions**
- Static chamber
- \( \text{N}_2\text{O}, \text{CO}_2 \)
- Soil Moisture
- Soil temperature

**Inorganic N** (\( \text{NH}_4^+\text{-N}, \text{NO}_3^-\text{-N} \)), DON, microbial biomass C, DOC
Did AM symbiosis increase plant growth and nutrient uptake?

Colonization rates- 76R Mycorrhizal plants: 35%, *rmc*: 7%

**Root biomass**

Genotype * treatment: P=0.03

- *rmc* reduced colonization
- 76R mycorrhizal plants

No effects on shoot biomass or N, P, K content

Reduction of root biomass

*rmc*: higher susceptibility to water stress
Did AM symbiosis regulate plant water relations?

- AM plants - higher slopes - faster reaction to changes in soil moisture
- Higher transpiration and assimilation at high soil moisture
- Lower transpiration and assimilation at low moisture: tighter water control
Effects of AM symbiosis on soil biochemistry

10% lower soil WFPS over the first dry down (genotype * date: p = 0.04)

Lower N$_2$O emissions

Effects of AM plants on N$_2$O emissions depended on soil moisture

**N$_2$O emissions**

- **rmc** reduced colonization
- 76R mycorrhizal plants

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Effects of AM symbiosis on soil biochemistry

AM symbiosis: 10% lower soil WFPS over the first dry down (genotype * date: p = 0.04)

Lower N\textsubscript{2}O emissions

Effects of AM plants on N\textsubscript{2}O emissions depended on soil moisture

Plant genotype * WFPS: p = 0.01
Effects of AM symbiosis on soil biochemistry

AM symbiosis: 10% lower soil WFPS over the first dry down (genotype * date: p = 0.04)

- Lower N$_2$O emissions, depending on soil moisture
- Effects of AM plants on N$_2$O emissions depended on soil moisture
- No significant effects in soil CO$_2$, NH$_4$, NO$_3$, DON, MB-C between genotypes or water treatments
Conclusions

AM symbiosis improved the capacity of the tomato plants to respond to intermittent soil moisture regimes (modulation of photosynthetic rates and stomatal conductance)

Soil $N_2O$ emissions were reduced at high soil moisture with AM colonized plants

Reduction of $N_2O$ emissions related to a higher use of water by AM plants rather than a higher use of N

Soil management that enhances colonization of roots by AM fungi may contribute to a more efficient use of water under changing environmental conditions and the reduction of the GHG emissions from soil
Thank you for your attention!