Arbuscular mycorrhizae alter soil inorganic and plant nitrogen but have little effect on ammonia oxidizing community abundance in two agricultural soils

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Hypothesis

Arbuscular mycorrhizal fungal communities will reduce ammonia-oxidizer abundance in soil due to competition for ammonium, and this effect will be greater in a diversified, four-rotation agricultural soil with organic inputs compared to a conventional, two-rotation agricultural soil with inorganic fertilization.

Background

- Nitrate leachate from agricultural soils causes environmental damage[1]
- AMF have been shown to absorb N from organic material and can reduce N leaching from soils[2,3]
- AMF hyphae can alter nearby soil microbial communities[4]
- It is unclear if there is an inhibitory interaction between AMF and ammonia-oxidizing archaea and bacteria that convert ammonium to nitrate[5,6]

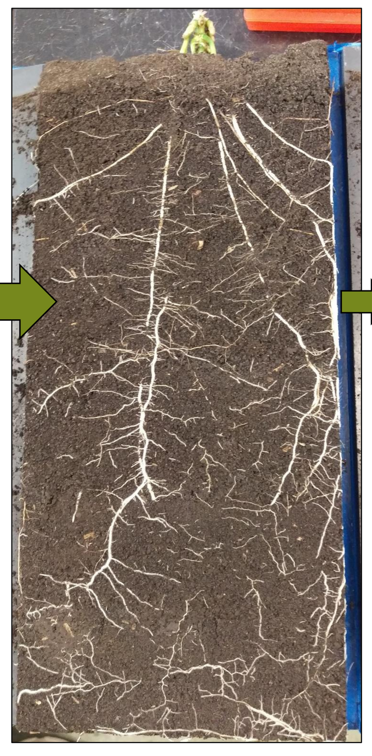
Approach

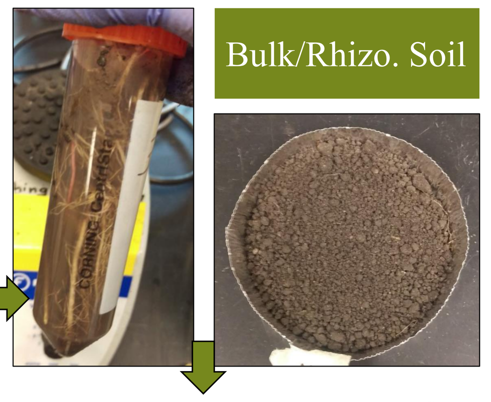
- AMF proficient and deficient (loss of function alleles in *dmi1* gene[7]) maize genotypes were compared

Methods

Key

AMF+	AMF proficient genotype
AMF-	AMF deficient genotype
Conv.	Conventional Cropping System
Div.	Diversified Cropping System
AOA/AOB	Ammonia-oxidizing archaea/bacteria





- Conv. soil: 2-yr rotation (corn-soy) with inorganic fertilizer
- Div. soil: 4-yr (corn-soy-oat-alfalfa) with composted manure
- Factorial design: genotype*soil, n =5

- SYBR Green qPCR of AOA/AOB amoA gene (functional marker gene)
- PLFA FAME 16:1ω5c (lipid marker for AMF)
- AMF root colonization
- Soil and plant nutrient analyses

AMF- genotype suppressed mycorrhizal colonization and biomass

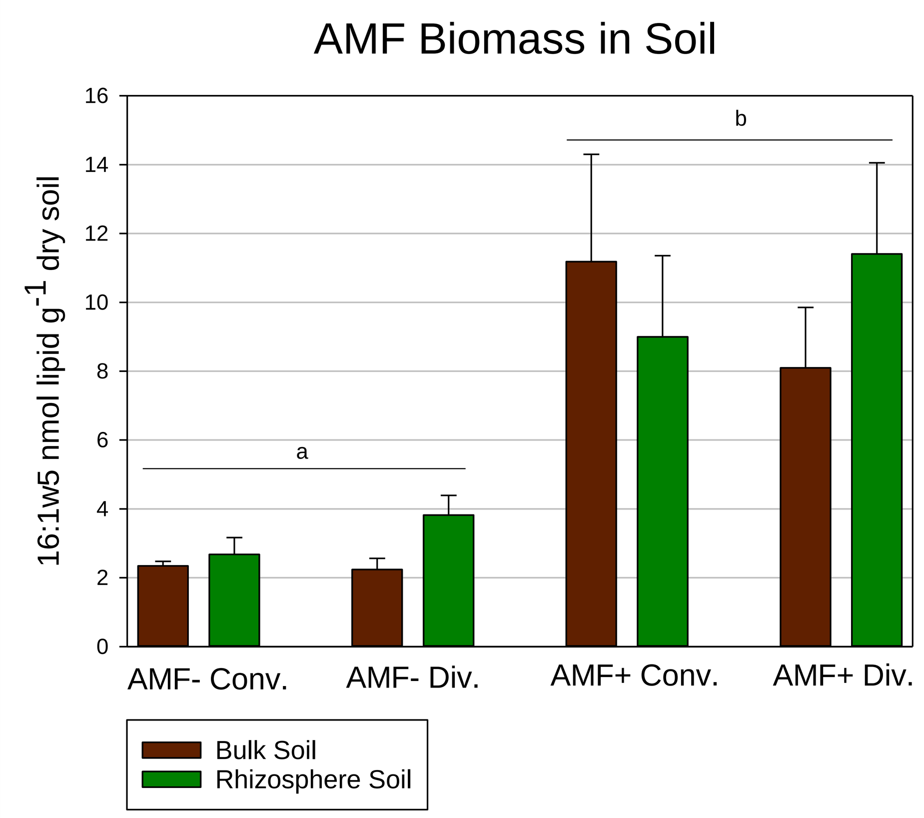


Figure 1. Effect of AMF treatment, soil type, and rhizosphere effect on AMF biomass in soil. Error bars show SE. Letters denote statistically significant groups of samples. Significance was determined with multi-way ANOVA type II SS, $P < 0.001$.

Table 1 | AMF Root Colonization

Treatment		
Mycorrhization	**Soil**	**Colonization (%)**
AMF-	Conventional	28.3[a]
AMF-	Diversified	22.7[a]
AMF+	Conventional	52.8[b]
AMF+	Diversified	51.8[b]

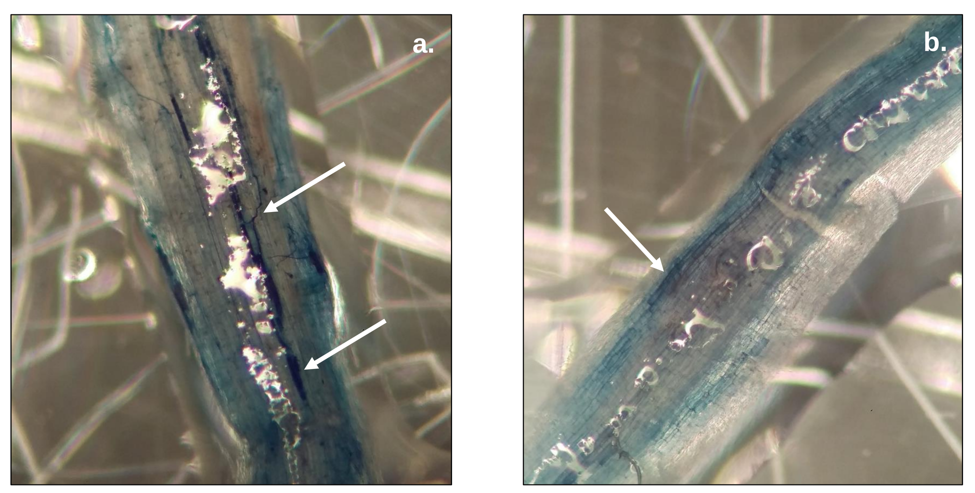


Figure 2. Images showing fungal colonization of maize roots. The images show examples of A) hyphal and vesicle/arbuscule colonization in AMF+ roots and B) mostly hyphal colonization in the AMF- roots. Images were taken at 40x magnification.

AMF affected plant biomass, nutrients, and soil nutrient levels

Table 2 | Plant Biomass and Nutrient Contents

Treatment		Dry Weight (g)		Shoot Nutrients	
Mycorrhization	**Soil**	**Shoot**	**Root**	**N (N%*g)**	**P (mg kg^{-1})**
AMF-	Conventional	2.1 ± 0.4[a]	0.3 ± 0.1[a]	4.8 ± 1.1[a]	1190 ± 300[a]
AMF-	Diversified	3.0 ± 1.1[a]	0.4 ± 0.1[a]	5.2 ± 1.7[a]	719 ± 63[b]
AMF+	Conventional	15.7 ± 1.8[b]	1.3 ± 0.2[b]	16.9 ±1.3[b]	1626 ± 174[a]
AMF+	Diversified	9.34 ± 3.4[c]	0.9 ± 0.1[b]	10.5 ± 1.4[a]	1662 ± 95[a]

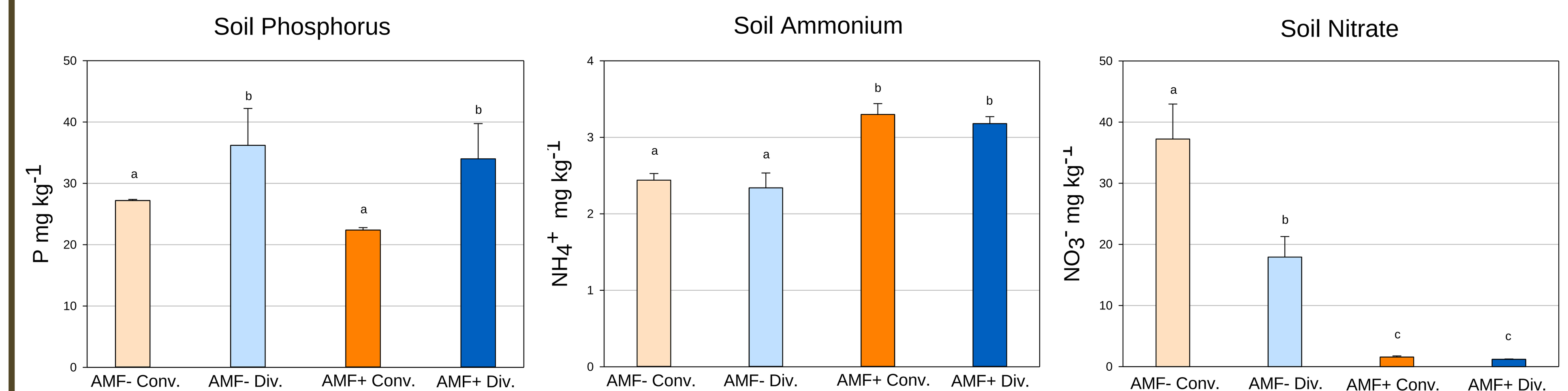


Figure 3. Effect of AMF and soil treatment on bulk soil concentrations of phosphorus, ammonium, and nitrate. Error bars show SE. Letters denote statistically significant differences at $P < 0.05$. Statistical significance was determined by multi-way ANOVA and Tukey's HSD.

AMF did not affect AOA/AOB abundance, but other treatments did

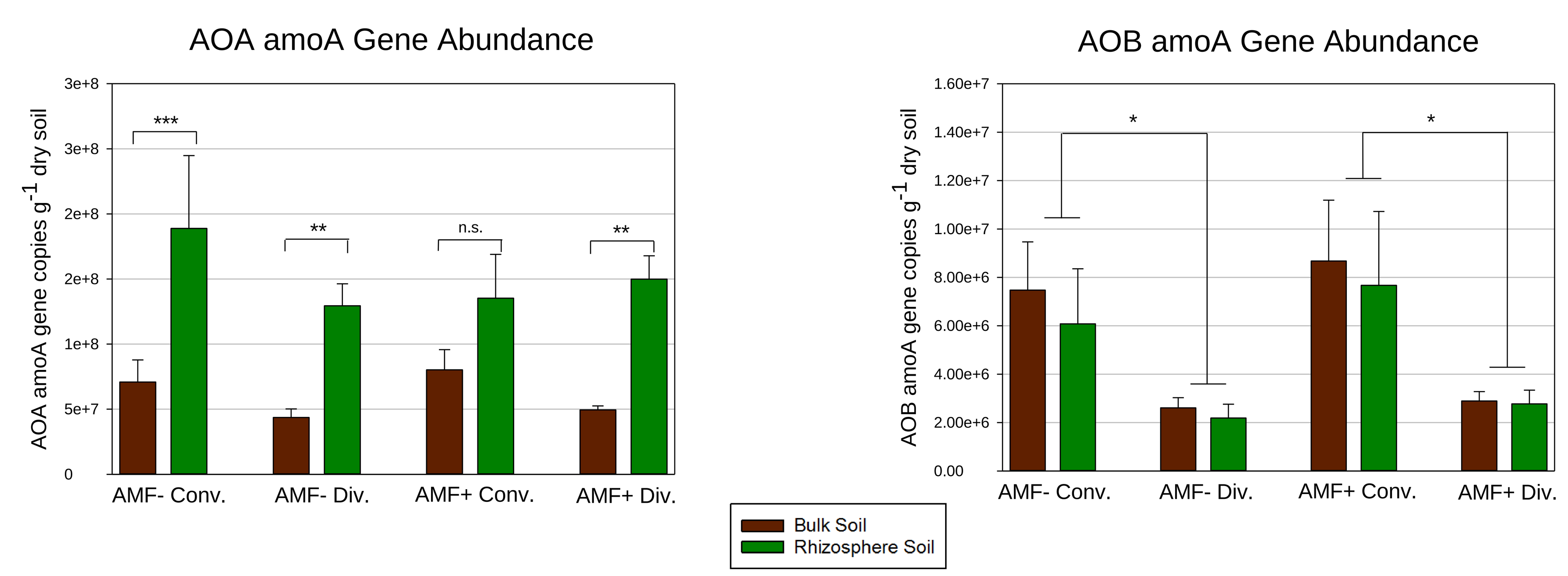


Fig. 4. Effect of AMF, soil type, and rhizosphere effect on AOA and AOB amoA gene abundances. Error bars show SE. Lines connect statistically significant groups as determined by pair-wise t-tests with Bonferroni correction on log transformed data. Lines connect groups that were tested for significance: * $P < 0.05$, ** $P < 0.01$, and *** $P < 0.001$.

Summary of Results

- AMF biomass in soil and root colonization was significantly reduced by the AMF- genotype independent of soil type (Fig. 1, 2, Table 1)
- Overall, N and P content and plant biomass were lower in the AMF- than the AMF+ plants (Table 2)
- Soil ammonium concentration was higher in the rhizotrons planted with AMF+ genotypes (Fig. 3)
- Inorganic nitrate concentration was elevated in the soil when AMF were not present (Fig. 3)
- AMF did not affect amoA gene abundances (Fig. 4)

Discussion and Conclusions

1. Decreased biomass and nutrient content of AMF- plants suggests that AMF have broad impacts on plant health
2. It is also possible that the DMI1 gene impacts root growth and N uptake
3. AMF may have contributed to nitrate rather than ammonium absorption from soil
4. AMF may contribute to soil ammonium production
5. We found no evidence that AMF influence AOA and AOB abundance in agricultural soils
6. AOB are highly sensitive to inorganic fertilizers
7. AOA may grow mixotrophically on root exudates[9]

Conclusions: AMF may aid the plant in nitrate uptake, but do not interfere with AOA or AOB populations in these nutrient-rich, agricultural soils. Future studies should investigate these interactions in N-limited soils.

References and Acknowledgements

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