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Determining if arbuscular mycorrhizal fungi inoculants increase yield and nutrient acquisition of sweet corn on Long Island, New York

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Arbuscular mycorrhizal fungi (AMF) are fungi that have a mutualistic relationship with most agricultural crops, including corn. These endomycorrhizal fungi grow within root cells and create arbuscules, where most soil plant nutrient exchange happens (Rillig 2004, Bona et al. 2016). The fungi also create an extraradical mycelium, which colonizes new areas in the soil to increase the absorption potential of the root system (Rillig 2004). In return, AMF receive photosynthates, sugar, from the plant. AMF are found naturally in soil, but recently commercial AMF products have become popular. However, studies have found mixed results of the ability of commercial AMF products to colonize plants and increase the biomass, yield, or nutrient absorption to help the producer. To determine the efficacy of AMF products used on Long Island, we tested the most common fungi species in sweet corn.

This study tested the efficacy of three commercial AMF products in sweet corn in field conditions with varying rates of fertilizer. We evaluated fungal colonization, nutrient absorption, and soil health improvement based on 1) fungal colonization of corn roots 2) foliar nutrient analysis and chlorophyll content 3) photosynthetic stress 4) soil aggregate stability. We hypothesized that all AMF products would result in root fungal colonization as well as increased nutrient absorption and cause plants to be less photosynthetically stressed. We hypothesized there will be no changes in soil health over a one-year period.

Methods

This trial took place at the Long Island Horticultural Research and Extension Center located in Riverhead, Suffolk County, NY in a Haven loam soil. The climate is maritime. One trial was established in spring 2023.

We used three commercial AMF products that represent the most common AMF. One contained the active ingredient *Rhizophagus irregularis*, the most prevalent AMF, which is present in 39% of commercial AMF fertilizers (Basiru et al. 2021). For this, we used PremierTech Agtiv Reach granular inoculant. Another product, JH Biotech Inc, MYCORMAX Biological Inoculum, which contains active ingredients *R. irregularis* and *Funneliformis mosseae* was used. *F. mosseae* is present in 21% of AMF products, always in conjunction with *R. irregularis* (Basiru et al. 2021). The final product contained a variety of active ingredients, specifically, *Rhizophagus aggregatus*, *R. irregularis*, *F. mosseae*, and *Claroideoglomus etunicatum*. *C. etunicatum* is present in 16% of commercial AMF products (Basiru et al. 2021).The final product contained a variety of active ingredients, specifically, *R. aggregatum*, *R. irregularis*, *F. mosseae*, and *C. etunicatum*. *C. etunicatum* is present in 16% of commercial AMF products (Basiru et al. 2021). For this we used USA MycoApply Endo-MAXX. Commercial AMF products were applied at recommended rates. While AMF products can generally be added to corn seed in the seeder, we were unable to apply AMF using this method because it would combine and contaminate our AMF treatments.

Instead, we combined the AMF products with field substrate and incorporated them above the corn seed directly after planting.

We also tested two rates of soluble N fertilizer, applied as urea at planting and sidedressed with 10-10-10 fertilizer. The Cornell recommended rate of soluble N fertilizer is 120-140 lbs per acre (Reiners et al. 2022). We had 2 nitrogen rates of 70 lbs/acre and 140 lbs/acre. For both, 50 lbs/acre were applied at planting and then the plots were sidedressed with 20 lbs/acre and 90 lbs/acre, respectively.

The field was arranged in a randomized complete block design. There were 4 blocks or replicates of each of the 8 AMF and fertilizer treatments. Plots, measured at 11.3 x 25 ft were comprised of 4 rows of corn, with 2 inner rows used for data collection and 2 outer rows as buffers. Rows were spaced 34" apart and corn was planted 9.1" apart within the row.

On April 5th, we sampled soil for mycorrhizal spore counts. For this, a representative sample of soil was taken from the plot prior to any AMF addition. This soil was mixed with greenhouse media and was used to grow sample corn in a greenhouse with a low phosphorus nutrient management plan, less than 40 ppm applied weekly. AMF colonization on the sample corn roots was measured to determine spore viability. We also measured baseline soil nutrient levels, and soil aggregate stability prior to planting. Prior to harvest, we sampled corn roots for percent mycorrhizal colonization, soil nutrient levels, and soil aggregate stability. We also collected foliar samples at two points in time on 7/17-21 and 8/16-17.

Photosynthetic stress response, measured as Fv/Fm, was measured twice, 7/25-7/26, 8/14-8/15. Chlorophyll content was measured three times 6/26, 7/25, and 8/14. Corn was harvested on 8/16-17 and yield was measured in number of ears, weight, length, diameter, and quantity of unmarketable ears. The results were analyzed in R statistics using two-way randomized block ANCOVAs (R team, 2023).

To monitor nitrate leaching, we also inserted resin bags 20 inches under the soil profile of the 8 treatments with 2 replications. The resin bags were filled with anion exchange resin beads that capture nitrate that leaches through the soil.

Picture of resin bags in hole in ground: resin bags are inserted 18 inches below the soil profile to capture nitrate leaching

Picture of resin bags on greenhouse bench: resin bags drying on a greenhouse bench after field extraction

Results

The percentage of mycorrhizal fungi root colonization did not differ significantly among the treatments and control, all mycorrhizal root colonization was <24% (Table 1). There was 57% AMF colonization on corn roots grown in soil taken from the plot prior to any AMF addition combined with a greenhouse media, grown in a greenhouse with a low phosphorus (less than 40 ppm) addition weekly. Photosynthetic stress response, measured as Fv/Fm did not differ significantly among the treatments (Table 1). Chlorophyll content, foliar nitrogen and changes in soil aggregate stability across the growing season did not differ significantly (Table 2). Corn yield weight did vary based on nitrogen rate, the higher nitrogen rate was correlated with greater corn yield weight ($p = 0.027$) (Table 1 and Figure 1). Nitrate leaching was also correlated with nitrogen application rate, where the plots with 140 lbs/acre N, leached more nitrate than plots with 70 lbs/acre N ($p = 0.024$) (Table 2 And Figure 2).

Active Ingredient	Treatment (AMF and N rate)	Yield weight	Yield count	AMF root colonization	July Fv/Fm	August Fv/Fm
R. irregularis and F. mosseae	Mycormax, 70	20.64	45.3	23.9	.775	0.793
R. irregularis	AgtivReach, 70	21.48	48.3	17.7	.772	0.786
R. aggregatum, R. irregularis, F. mosseae, and C. etunicatum	MycoApply, 70	22.82	52.3	23.6	.761	.781
Control/ NO AMF	Control, 70	25.84	57	13.1	.795	.798
R. irregularis and F. mosseae	Mycormax, 140	26.13	54	13.5	.783	.810
R. irregularis	Mycormax, 140	25.28	52.8	19.8	.762	.794
R. aggregatum, R. irregularis, F. mosseae, and C. etunicatum	Mycormax, 140	25.95	53	3.0	.779	.802
Control/ No AMF	Mycormax, 140	27.13	55.5	17.7	.779	.799

Table 1. Commercial AMF product and N application rates (lbs/acre), average sweet corn yield weight (lbs per subplot), yield count, AMF root colonization (%), and photosynthetic stress (Fv/Fm) in July and August 2023 across 4 replicates.

Active Ingredient	Treatment	June SPAD	July Foliar N	July SPAD	September foliar N	August SPAD	Nitrate in leachate
R. irregularis F. mosseae	Mycormax, 70	40	2.6	50	2.2	46	7.90
R. irregularis	AgtivReach, 70	40	3.1	49	2.0	46	9.69
R. aggregatum R. irregularis F. mosseae C. etunicatum	MycoApply, 70	40	2.9	49	2.3	44	5.52
Control/ NO AMF	Control, 70	40	3.0	50	2.3	47	24.71
R. irregularis F. mosseae	Mycormax, 140	41	3.2	52	2.6	49	52.36
R. irregularis	Mycormax, 140	40	2.6	50	2.3	47	13.71
R. aggregatum R. irregularis F. mosseae C. etunicatum	Mycormax, 140	40	3.2	52	2.6	49	16.90
Control/ N AMF	Mycormax, 140	41	3.0	50	2.3	49	25.48

Table 2. Commercial AMF product and N application rates (lbs/acre), chlorophyll content (SPAD) measured in June, July, and August 2023, foliar nitrogen measured in July and September 2023, nitrate in leachate (ppm).

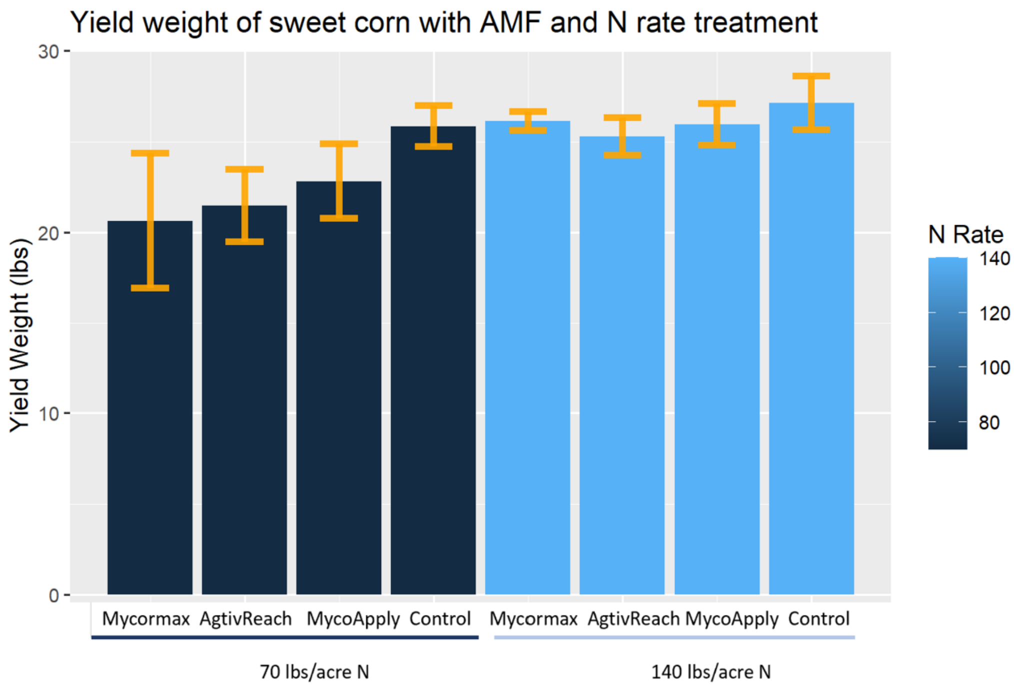

Figure 1: Yield weight of sweet corn with AMF and N rate treatments, error bars represent +/- 1 SE. Text only description for yield weight of sweet corn with AMD and N rate treatment (PDF).

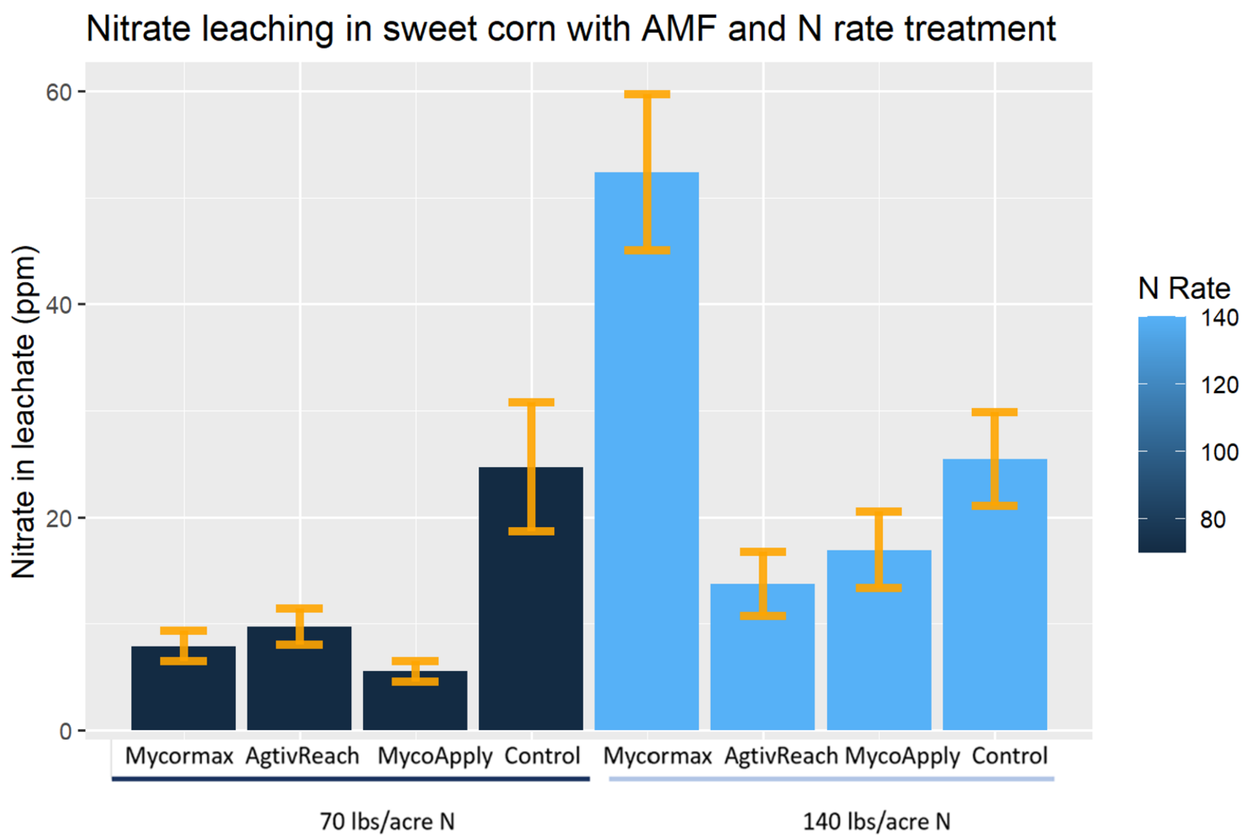

Figure 2: Nitrate leaching in sweet corn with AMF and N rate treatments, error bars represent +/- 1 SE. [Text only description for Nitrate leaching in sweet corn with AMF and N rate treatment (PDF)]

Discussion

The data from 2023 does not support the three commercial AMF products increasing nutrient acquisition, corn yield, or reducing photosynthetic stress in sweet corn grown in haven loam soil on Long Island. This could be due to high levels of phosphorus in the soil, 2638 lb/acre P as P_2O_5 prior to planting. High levels of phosphorus do not encourage mycorrhizal fungi colonization because the plant is not lacking in nutrients. Another reason may be that there is already a healthy population of AMF in the field soil. This is evidenced by the control treatments still containing AMF colonization on corn roots and a soil spore test taken prior to planting. Soil taken from the plot prior to any AMF addition was used to grow sample corn and those roots had 57% AMF colonization when grown in a greenhouse with a low phosphorus nutrient management plan. 57% AMF colonization is higher than the AMF colonization in any of our treatments. This could be due to AMF already existing in the soil or the low phosphorus substrate.

Another benefit of AMF is that they may improve soil health. While we did not capture this change in one growing season, over many years AMF may improve soil health. AMF produce glomalin, a glycoprotein, that coats the hyphae that extend from root systems (Rillig 2004, Wang et al. 2018). The glomalin coating contains metal ions and helps nutrients and water stick to hyphae (Rillig 2004). Once in the soil, the glomalin will act as a glue and attach to soil particles to increase soil aggregation and decrease erosion. There is a known positive correlation between AMF hyphal abundance and soil aggregation (Wright and Upadhyaya 1998, Wilson et al. 2009). The glomalin also increases soil organic matter and water holding capacity as it contains 30 to 40% carbon (Wright and Nichols 2002). It also acts as a carbon sink (Wright and Nichols 2002). The properties of AMF and the glomalin it produces have the potential to result in increased soil aggregation, water-holding capacity, reduced soil compaction and runoff, increased carbon sequestration, and improved drought tolerance.

This project only includes one year of data collection; results may change due to environmental conditions. Soil health improvements will take many years to quantity. We plan to conduct this research in 2024 as well to create a more robust set of data.

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References

Basiru, S., H. P. Mwanza, and M. Hijri. 2021. Analysis of Arbuscular Mycorrhizal Fungal Inoculant Benchmarks. Microorganisms **9**.

Bona, E., A. Scarafoni, F. Marsano, L. Boatti, A. Copetta, N. Massa, E. Gamalero, G. D'Agostino, P. Cesaro, M. Cavaletto, and G. Berta. 2016. Arbuscular mycorrhizal symbiosis affects the grain proteome of Zea mays: a field study. Scientific Reports **6**.

R Core Team, R: A Language and Environment for Statistical Computing, R Foundation for Statistical Computing, Vienna, Austria, 2023

Reiners, S., P. D. Curtis, M. Helms, M. T. McGrath, B .A. Nault, and A. Seaman. 2022. Cornell Integrated Crop and Pest Management Guidelines for Commercial Vegetable Production. Pesticide Management Education Program. Cornell University, Ithaca, NY.

Rillig, M. C. 2004. Arbuscular mycorrhizae, glomalin, and soil aggregation. Canadian Journal of Soil Science **84**:355-363.

Wang, X. X., X. J. Wang, Y. Sun, Y. Cheng, S. T. Liu, X. P. Chen, G. Feng, and T. W. Kuyper. 2018. Arbuscular Mycorrhizal Fungi Negatively Affect Nitrogen Acquisition and Grain Yield of Maize in a N Deficient Soil. Frontiers in Microbiology **9**.

Wilson, G. W. T., C. W. Rice, M. C. Rillig, A. Springer, and D. C. Hartnett. 2009. Soil aggregation and carbon sequestration are tightly correlated with the abundance of arbuscular mycorrhizal fungi: results from long-term field experiments. Ecology Letters **12**:452-461.

Wright, S. F., and A. Upadhyaya. 1998. A survey of soils for aggregate stability and glomalin, a glycoprotein produced by hyphae of arbuscular mycorrhizal fungi. Plant and Soil **198**:97-107.

Wright, S.F., K.A., Nichols. September 2002. Glomalin: Hiding Place for a Third of the World's Stored Soil Carbon. AgResearch Magazine, United States Department of Agriculture. https://agresearchmag.ars.usda.gov/2002/sep/soil