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Research Focus

Enhancing Vine Health with Commercial Arbuscular Mycorrhizal Inoculants

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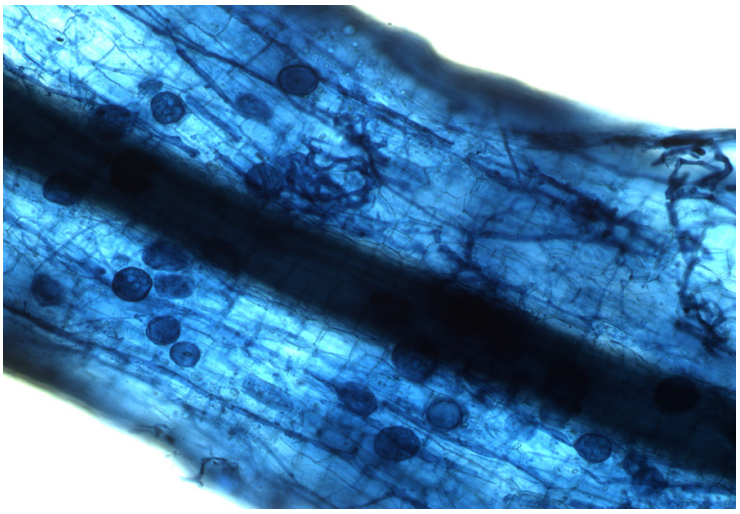

Figure 1. *Arbuscular mycorrhizae are fungi that form beneficial associations with roots, enhancing uptake of nutrients from the soil. Photo shows extensive arbuscular mycorrhizal fungi colonization in fine roots of Pinot noir. Samples were collected in November 2018, five months after inoculation at Sawmill Creek vineyards Hector, NY.*

Arbuscular mycorrhizal fungi (AMF) form beneficial associations with roots, and are widely distributed in soils. They increase functional root area, often enhancing uptake of nutrients from the soil.

In response to industry interest, our laboratory tested several commercial inoculants in replicated field and greenhouse studies, as well as in side-by-side comparisons in growers' vineyards. AMF inoculants increased colonization of roots and resulted in higher concentrations of some nutrients, particularly total leaf N, in field and greenhouse trials. Inoculation increased root diameter and length, and total dry weight of roots following inoculation. These effects are beneficial, but further work is needed to determine if the benefits to vineyards justify the cost of these products, which ranged from $138 to $476 per acre in our experiments.

Key Concepts

- Arbuscular mycorrhizal fungi (AMF) form beneficial symbiotic relationships with grapevine roots.
- They penetrate cortical cells of roots to facilitate nutrient exchange.
- Their hyphae outside the roots greatly increase the functional root area, enhancing nutrient uptake.
- In return, the vine supplies photosynthate, providing the mycorrhizal fungi with an energy source and carbon to fuel its growth.
- Several commercial inoculants are available. Five were tested in field and greenhouse trials by the Vanden Heuvel lab.
- In replicated field trials in commercial Riesling and Pinot noir vineyards, all products tested increased the number of vesicles, arbuscules, and hyphae on roots.
- In potted vines, two of the products doubled the size of the roots compared to an untreated control five months after inoculation.
- In side-by-side comparisons of inoculated and uninoculated vines in commercial vineyards, inoculation increased the presence of AMF in vine roots and total leaf nitrogen.
- In a field trial at one site some inoculants increased tissue content of other nutrients (P, K, Mg, B, Zn, Mn).
- Cost of products ranged from $138 to $478 per acre.

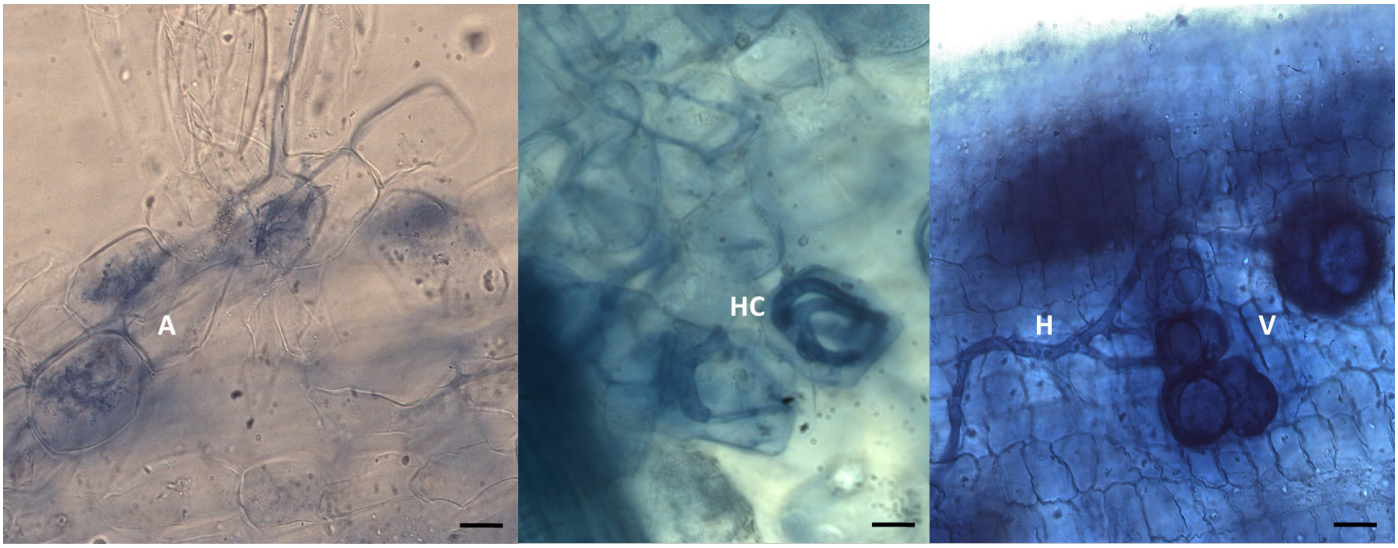

Figure 2. *The structural colonization of arbuscular mycorrhizal fungi in fine roots of Pinot noir at Sawmill Creek vineyards Hector, NY. A: Arbuscules. Scale Bar 12 µm, HC: Hyphal coils. Scale Bar 12 µm, H: Hyphae.Scale Bar 17 µm, V: Vesicles.Bar 26 µm. Magnification is 40x.*

Photo by Mariam Berdeja

Introduction

Grapevines benefit from a symbiotic relationship with arbuscular mycorrhizal fungi (AMF). Together the vine and the AMF form mycorrhizae, which play an important role in vine health, grapevine nutrition, and water relations. AMF are thought to improve nutrient uptake as well as the ability of vines to withstand stress from drought, disease, and insects.

AMF penetrate the cortical cells of roots to form arbuscules (Fig. 1 and Fig. 2) to aid nutrient exchange. The hyphal coils are long, branched portions of the fungus that act as a virtual root system for the vine, essentially increasing the functional root area. The hyphae enter the root and create vesicles for nutrient storage structures where nutrients are transferred between fungus and plant (arbuscules).

A range of products—generally referred to as soil microbial stimulators—are sold with the goal of encouraging the formation of mycorrhizae. While anecdotal reports from the grape and wine industry suggest these products can provide a benefit to the vine, none have been systematically tested in Northeast vineyards. With the help of many Finger Lakes growers as well as funding from the New York Farm Viability Institute, we tested these products in a series of fully replicated experiments as well as side-by-side trials in commercial vineyards.

Table 1. Inoculation products tested in fully replicated and grower side-by-side trials in the Finger Lakes

Product number	Inoculant name	Claimed species	Suggested application rates (from the label)	Cost/acre for one application
1	Big Foot Concentrate	4 sp. Endomycorrhizae N,P,K Humic acids, Softwood biochar Worm castings	2 tsp/gallon of water/6 plants Repeat every 2-3 weeks for 3 months	10 lb/acre $ 422
2	BioOrganics LLC	9 sp. Endomycorrhizae Clay	2-8 small holes/plant 2 tsp/hole Apply 1 time/year	13 lb/acre $ 418
3	MycoGrow® Soluble	7 sp. Endomycorrhizae 5 sp. Ectomycorrhizae Beneficial bacteria	1 oz/1 gallon of water/6 plants Apply 2 times/year	2 lb/acre $ 160
4	MycoApply Endo granular	4 sp. Endomycorrhizae clay	2-8 small holes/plant 2 tbs/hole 2 times per year Apply 1 time/year	54 lb/acre $ 354
5	MycoApply all Purpose granular	4 sp. Endomycorrhizae 5 sp. Ectomycorrhizae Beneficial bacteria N,P, K	2-8 small holes/plant 2 tbs/hole Apply 1 time/year	54 lb/acre $ 478

Methods

Table 1 lists the products we experimented with over a two-year period. There are a significant number of these types of products available commercially, but we specifically chose products that contained species of a fungal organism called *Glomus* as they've been proven in other crops to have a positive impact on mycorrhizal associations.

The instructions for application vary among all the products – but we did not usually follow the instructions for application as we needed to develop a more grower-friendly approach. Essentially, we either used a hoe and dug a roughly 1-inch deep trench that extended about 10 inches parallel to the vine row, about 10 inches out from the vine trunk and sprinkled in roughly a tablespoon of the powdered product per vine.

At other sites, if the product was soluble in water we approximated the concentration listed on the label, mixed it into water and sprayed it directly under the vines. At the grower sites, we only applied one application of a product, even if multiple applications were suggested. Additionally, we only applied the products in 2018 – so any 2019 results we've presented are due to the application of AMF in the previous year.

Results

Replicated trials. We completed three replicated studies at a commercial vineyard. In a Pinot noir/3309C block, we tested products 1, 2, 3, and 5 (see Table 1). In a Riesling/3309C block and a Riesling/SO4 block, we tested products 2, 3, and 5. All of the products improved the number of vesicles, arbuscules, and hyphae found on the roots. In the Pinot noir block, when we tested the leaves for nutrients there was a sizeable increase in the concentration of macro and micronutrients (Table 2). In the two Riesling blocks we only tested for leaf N, but again saw a sizeable increase. In the year after product application, N was 0.77% in the leaves of the product 5 vines, but only 0.62% in the leaves of the non-inoculated vines in the Riesling/3309C block.

Figure 3. *Root growth of 2 year old Cabernet Sauvignon/3309C inoculated with commercial AMF inoculant under greenhouse conditions. Roots were sampled after 5 months of inoculation.*

Photos by Mariam Berdeja.

We also tested some of these products in the greenhouse on potted vines to allow us to better quantify changes in root growth compared to in the vineyard. Figure 3 demonstrates the difference in size of root system for own-rooted Cabernet Sauvi-

Table 2. Leaf nutrient concentration of Pinot noir/3309C inoculated in May 2018 with 4 commercial biofertilizers containing arbuscular mycorrhizal fungi (AMF). Samples were collected at veraison in 2018.

Nutrients	Treatments				
	Control	Product 1	Product 2	Product 3	Product 5
Total N (%)	0.68 d	0.72 cd	0.79 ab	0.76 bc	0.84 a
Total P (%)	0.21 c	0.25 bc	0.30 ab	0.28 bc	0.37 a
Total K (%)	1.75 b	2.35 ab	2.72 ab	2.60 a	3.09 a
Total Mg (%)	0.66 d	0.70 cd	0.77 ab	0.73 bc	0.81 a
B ppm	28.75 d	32.00 c	37.00 b	33.75 c	40.75 a
Zn ppm	39.50 d	41.75 cd	49.25 ab	46.00 bc	52.50 a
Fe ppm	19.78 c	20.27 c	25.47 ab	22.30 c	25.93 a
Mn ppm	70.18 b	86.05 ab	102.70 a	81.82 ab	97.69 a
Cu ppm	5.60 c	6.26 bc	8.13 a	6.63 abc	7.56 b

Different letters within a row indicate a statistically significant difference in treatments.

gnon. After five months of growth, the inoculation products tested (products 2 and 4) had resulted in 2x the root growth as the control.

In the Riesling/3309C block, we collected sample cores five months after inoculation and quantified root diameter and root length. Product 5 resulted in a sizeable increase in root diameter, while all three products we applied increased root length in the cores (Table 3).

Grower comparisons. Table 4 provides the results from three of the grower side-by-side comparisons. The growers we worked with chose and purchased the product they were interested in and we helped them apply it. At all of the grower sites (which covered a range of cultivars, locations, and under-vine management) the products increased the vesicles, arbuscules, and hyphae on the roots. Some products provided more benefit than others, although those results were likely impacted by the single application of product that we used (as opposed to multiple applications, such as those suggested for Products 1 and 3). Total N in leaves was also increased at each of the grower sites.

Table 3. Root diameter and root length in soil cores collected from Riesling/3309C inoculated in May 2018 with three commercial products containing arbuscular mycorrhizal fungi (AMF). Root samples were collected in November 2019.

Treatment	Root diameter (mm)	Root length (cm)
Control	0.50 b	17.12 c
Product 2	0.58 ab	41.57 ab
Product 3	0.54 b	31.73 b
Product 5	0.66 a	51.00 a
P-value	0.0078	<.0001

Different letters within a column indicate a significant difference between the treatments.

Should I apply AMF in my vineyard?

While we were pleasantly surprised by the positive results in both the greenhouse and field studies, we don't yet have enough information to recommend commercial use of these products. It's important to note that some of these products contain nutrients or other additions that may also be impacting our results (such as product 5, which contains N, P, K). Our efforts focused on determining whether the AMF resulted in improved mycorrhizae formation of the roots – and the good news is that they did. When we studied root growth we found that at least some of the products increased root length, root diameter, and total root dry weight. Presumably, these increases in root growth are positive in that they'd allow for greater soil exploration by roots, resulting in access to additional water and/or nutrients. While we haven't studied the impact of these products on vine water status, we did note that leaves of inoculated vines had increased N content at all sites.

The next step is to determine whether these products are worth the cost and effort for grape growers, as these products can be expensive (Table 1). We hope to study the impact of AMF application on vine growth, fruit composition, and the ability of the vines to withstand stress (such as drought and disease). We will be applying for grants in the near future to take this next step in the required research.

Table 4 Impact of mycorrhizae inoculation in grower side-by-side comparisons. Vine roots were inoculated in Spring 2018.

Attribute Measured	Gruner veltliner/101-14 Keuka Lake		Chardonnay/ 3309C W. Seneca		Riesling/3309C E. Seneca	
	Non-inoculated	**Inoculated**	**Non-inoculated**	**Inoculated**	**Non-inoculated**	**Inoculated**
Vesicle colonization of roots (%), Fall 2018	20.0	49.9	14.6	19.7	31.5	60.5
Hyphal coils colonization of roots (%), Fall 2018	31.0	44.9	13.7	18.9	41.2	52.1
Arbuscule colonization of roots (%), Fall 2018	38.3	69.6	17.6	24.7	38.6	66.6
Vesicles colonization of roots (%), Fall 2019	23.3	44.3	16.9	26.5	17.4	45.2
Hyphal coils colonization of roots (%), Fall 2019	36.0	55.2	17.4	22.3	21.3	43.4
Arbuscule colonization of roots (%), Fall 2019	40.7	66.7	21.8	26.8	20.7	56.4
Petiole Total Nitrogen (%), Fall 2019	0.67	0.72	0.77	0.86	0.71	0.77

Questions?

If you have questions about this work, please contact me at Justine@cornell.edu.

Acknowledgements

Many thanks to Sawmill Creek for hosting the replicated studies, all of the growers who helped us out by testing these products, and Scott Osborn of Fox Run Vineyards who encouraged us to work on this topic. We also thank the New York Farm Viability Institute for funding to complete these field studies and the PA Wine Marketing and Research Board for funding for the greenhouse studies.

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