# Final report for FNE17-883

## Comparison of indigenous microorganism and commercial soil inoculant on crop yields and basil downy mildew disease resistance

https://projects.sare.org/project-reports/fne17-883/

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**Summary:**

A healthy population of soil microorganisms can increase crop yields and disease resistance by improving the release and transport of nutrients, producing soil stabilizing humic compounds, creating symbiotic relationships that can improve plants’ resistance to pathogens, and improving abiotic stress tolerance. However, it remains unclear how to utilize these microorganisms to best achieve these results on small polyculture farms. This experiment compared yields of five marketable crops (onion, fennel, ashwagandha, sweet basil, and parsley) under three treatment conditions at time of transplantation: untreated control seedlings, seedlings treated with commercial mycorrhizal inoculant, and seedlings treated with a simplified on-farm produced Indigenous Microorganism (IMO) inoculant. In addition to measuring crop yields, a similar treatment design was also used to measure resistance to downy mildew disease in sweet basil; basil downy mildew has become a significant disease in many New England organic farms leading to total crop loss. After data analysis, no crops in the IMO or commercial inoculant treatments had statistically significant improvements in crop yield compared to the control treatment. The researcher concluded the environment created in this field trial did not meet the conditions necessary to support the mycorrhizal fungi and ultimately the benefits to crops as measured by yield; however recommendations of ways to improve mycorrhizal symbiosis in agriculture is presented. The research did show a delay in infection with Basil Downy Mildew in Basil plants inoculated with the IMO treatment, which is a potentially promising finding worth further investigation. Outreach focused on submission of articles to five relevant periodicals, the information was made publically available on the farm website, five 1.5 hour talks were presented and three additional public talks were presented which included a brief summary of research.

**Project Objectives:**

My proposed solution was to design an on-farm research study using fungal inoculants to examine two concrete benefits to farmers: increased marketable crop yield and downy mildew disease resistance in sweet basil. The research used a block design method with five transplanted crops of commercial value (onions, sweet basil, ashwagandha, fennel, and parsley). The design compared yields of these five crops and basil downy mildew disease resistance using a simplified on-farm indigenous microorganism inoculant, compared with a commercial inoculant, compared with a control. These results were then shared with other Northeast farmers to allow them to decide whether to implement similar IMO or commercial inoculant practices.

All crops chosen were medicinal herbs currently grown by this farmer but also of potential interest to vegetable growers; all crops also have at least one prior study indicating a plant species/fungal symbiosis benefit. A simplified IMO protocol was also provided to other farmers to utilize if interested. This grant helped further knowledge of local farmers, gardeners and consumers on a sustainable production method that is potentially profitable, environmentally sound and beneficial to the wider community. This grant also offered guidance for on-farm practice changes, as well as recommendations on potential future research.

**Introduction:**

Mycorrhizal symbiosis is arguably the most important symbiosis on earth because of the high economic and ecological significance and application potential. “It hardly states the case to say that mycorrhizas are important to ecosystem function. It is much more accurate to say that mycorrhizas are ecosystem function.”(1)Yet current agricultural methods deplete native mycorrhizal species and disrupt related ecological cycles. Using fungal inoculants is in alignment with goals of sustainable agriculture: improve plant nutritional value, improve disease resistance, improve production under abiotic stressors such as drought, decrease soil erosion, decrease pesticide and artificial fertilizer inputs, and improve soil quality (2). These goals are also well regarded by medicinal herb consumers who tend to place a high value on organic, sustainable or constituent-dense products.

At a time of increasing demand for sustainably grown herb and vegetable crops, farmers in the Northeast are facing numerous challenges including drought and the emergence of new diseases. Fungal inoculants can provide tangible economic benefits of disease resistance and improved crop yield with a low tech, low cost method. Initially found in the Northeast in 2008, downy mildew (*Peronospora belbahrii*) is a devastating disease affecting sweet basil (*Ocimum basilicum*). Basil is the most commercially important annual culinary herb crop grown in the United States, and crop losses due to downy mildew can have a significant negative economic impact on small farms.

Research comparing commercial versus a simplified on-farm produced indigenous microorganism (IMO) inoculant can be especially helpful to small to medium sized polyculture farms by providing useful data on a variety of crops. Preliminary work shows possible benefits of IMO over commercial inoculates as: strongest improvement in plant growth, longer lasting benefits to fields, creating symbiotic relationships with plants when mycorrhizal fungi cannot, providing a multitude species that can act synergistically, and providing a diversity of species where some may flourish depending on specific field conditions. Literature indicates a need for: more field trials (as opposed to greenhouse conditions), on disease resistance, on a diversity of crops, and using indigenous microorganisms (as opposed to single species.) (3). A specific, clear IMO protocol on transplanted crops, and yield and disease resistant data, can better allow farmers to decide whether it is appropriate to incorporate fungal inoculants on their farms.

This grant builds on several previous SARE grants that utilized David Douds’ IMO method, but potentially offers an easier and more efficient method (production time of one month versus almost a year). There is growing interest in streamlined IMO protocol and benefits, as evidence by well attended lectures organized by Northeast Organic Farming Organization and Bionutrient Food Association, and anecdotally as Bryan O’Hara, a leader in the IMO movement, was named Organic Farmer of the Year for 2016 by NOFA.

Finally, there is increasing farmer interest in growing medicinal herbs, as evidenced by a standing-room only workshop led by this applicant at a recent NOFA conference, and by high attendance at other medicinal herb growing events. Medicinal herbs are a major market, constitute a multi-billion dollar industry, and have significant crop potential in the Northeast.

While a general literature review indicates that agricultural fungal inoculants are extremely promising, success remains mixed in part due to diversity of crops, and a variety of inoculants and application methods. In part because the majority of research has been done on single species plants or fungus, or in greenhouses, there is even less research providing application guidelines for farmers with polyculture field applications. SARE has provided several grants to farmers working on inoculation with mixed results; one of the most promising, Farm-Grown Microbial Soil Inoculants [on wheat] indicated: “only the on-farm inoculant produced measureable increases in nutrient update and crop growth, demonstrating that on-farm produced inoculants can be effective alternative to purchased, commercial inoculants, and may reduce the need for chemical fertilizer.”(4) While another SARE grant “On-Farm production of mycorrhizal fungus inocula” found some success, they note the difficulties of on-farm IMO production presented several limitations, “we have seen that even incorporating [Arbuscular mycorrhizal] fungus inoculum into greenhouse practice is a large step not fully accomplished within the 4 growing seasons of this project, so the consideration of the symbiosis in the whole of farm operations is likely far off.”(5) In my literature review, no field trials studying this particular method of IMO (based on a Korean Natural Farming method) have been found, nor focused on polyculture inoculation at time of transplantation.

Promising research on the benefits of fungal inoculants in disease resistance include: against soil-borne diseases, against nematodes, and some specific crops and diseases. Downy mildew control in sweet basil continues to be an area of research, but with limited success in finding organic control methods. Control of disease causing oomycetes (such as Peronospora belbahrii) with fungal inoculant has primarily been lab-based work, but holds promise “[this] opens up exciting possibilities for investigating the commonalities and differences between pathogenic and mutualistic lifestyles.”(6) Another conceivable benefit of this specific IMO protocol holds some promise, as the Arbuscular mycorrhizal fungi (AMF) associated mechanisms “might thus act in synergy with each other, with one mechanism becoming preponderant depending on the environmental conditions and the plant-cultivar pathogen/AM fungus strain studied.”(7)

Agricultural fungal inoculant research has been fairly narrowly focused on several species/families, especially fabaceae, with a need for work on a diversity of crops. Each of the five crops chosen shows promise of benefits with inoculation.

Sweet basil (Ocimum basilicum): AMF symbiosis may induce production of two important phytochemicals: rosmarinic and caffeic acids, “AMF potentially represents an alternative way of promoting growth of this important medicinal herb, as natural ways of growing such crops are currently highly sought after in the herbal industry.”(8) This grant builds on other SARE grants on downy mildew, including using modified assessment methodology established by Joan Allen. Notably, research has found that fungal endophytes in related Ocimum sanctum “hold great promise … as biocontrol agents against broad spectrum and economically significant phytopathogens.”(9)

Ashwagandha (Withania somnifera): may be unfamiliar to some vegetable growers, but is a prominent Ayurvedic medicinal herb, widely used for thousands of years. It can be readily grown in the Northeast, and has huge sales growth potential. Ashwagandha had the highest growth (40.9%) between 2014 and 2015 of any herb though natural channel sales.(10) AMF inoculation in field trials has shown benefits: enhanced shoot and root length, biomass, overall size, number of inflorescences and flower, seed production and net primary productivity.(11)

Onions (Allium cepa) are regarded as highly AMF responsive plants. Initial research indicates increases in nutrition and synergistic effect with dual microbial inoculation; one study showed nearly 100% increase in bulb fresh weight with Glomus sp. inoculum.(12) Onion is the third most consumed fresh vegetable in the United States, but also valued for medicinal qualities.

Fennel (Foeniculum vulgare): is a valuable crop both as vegetable, medicinal herb and for value-added products. Its cultivation area has increased four times during the past two decades and mycorrhizal inoculation has been shown to improve quantitative and qualitative yield, especially under drought conditions.(13)

And finally, Parsley (Petroselinum crispum): AMF inoculation of parsley has been shown to increase root and shoot biomass as well as improve chlorophyll content.(14) Parsley is also a familiar crop that is grown by vegetable and herb farmers alike.

[Endnotes with full citations](https://cdn.sare.org/wp-content/uploads/20190213115845/CA3AC690-5056-AE0A-BC40E16A116C99F41538_Melody-Wright-2016-SARE-Endnotes.pdf)

**Cooperators**

Maura Bozeman - Technical Advisor (Educator)

**Research**

Materials and methods:

**CROP YIELD PROTOCOL:**

1. In 2017 seeds were purchased from High Mowing and Simply Medicinals were started in greenhouse flats with commercial potting soil. 100 seedlings of each of the five crops are seeded. The original research design indicated that at the time of transplantation 60 seedlings were to be selected, with 10 seedlings each assigned one of three treatments, and each treatment duplicated (see attached design excel document). An additional 60 sweet basil seedlings are started with 40 selected for the disease resistance protocol (see below). Because of poor greenhouse germination rates, changes were made to the onion and fennel transplants, see specifics below.

Approximate seeding dates:

* Onion (*Allium cepa*, Yankee F1): Due to low germination rates of original seeding, onion sets were substituted on planting day
* Ashwagandha (*Withania somnifera)*: 3/19/17 (potted up 4/20/17)
* Parsley (*Petroselinum crispum,* Italian flat leaf): 3/19/17
* Fennel (*Foeniculum vulgare*, Finale): 4/13/17. Due to low germination rates, 7 instead of 10 plants were used in each treatment
* Sweet Basil (*Ocimum basilicum,* Genovese): 4/13/17

1. Eleven new beds were built (11’x4’). Research strongly suggests that this farm’s prior inoculation trials could have significant impact on yield and disease resistance findings, so new un-inoculated beds were essential. Beds were in close proximity with similar sun exposure, in a grass-lawn area not cropped in 2016, and bordered by rough sawn timber to prevent lateral migration of fungi between treatments.
2. A reference soil sample was sent to Logan Labs before inoculation. As low organic matter is expected, commercially purchased organic compost was added at the low rate of 2 cubic foot/bed. A low rate is used as research suggests excessive added nutrients likely would suppress fungal growth.
3. After last frost, on June 1, 2017 seedlings were transplanted in a block design identical for each treatment bed. Running from East to West: each bed was planted in order with Ashwagandha, Parsley, Basil, Fennel and Onions.

* T1: control with no treatment
* T2: MycoGrow purchased from Fungi Perfect, used according to instructions. 1 oz added per each gallon of water for root drenching at time of transplant. Contains *Glomus intraradices, Glomus mosseae, Glomus aggregatum* and *Glomus etunicatum*
* T3: On-farm produced Indigenous Microorganism inoculant (see below) is added to the soil just prior to seedling transplantation

1. At transplantation, all seedlings received a root drenching with a brief dip in separate buckets. T1 well water, T2 MycoGrow in well water, and T3 well water. All transplants were then mulched with commercially purchased straw and watered again with T1, T2, or T3 water. Mulching is important to keep the inoculants hydrated and alive.
2. In addition, because there were adequate seedlings leftover from some crops, a final bed was transplanted with the same block design. This bed then had an new batch of IMO added two weeks later, in results is noted as “Late IMO”.
3. Beds were hand weeded and watered equally with overhead irrigation as needed. Monthly rainfall data from NOAA is also recorded, for future reference if unusual precipitation trends occur. Due to heavy slug pressure, Sluggo was applied in even amounts around all plants, and hand slug picked was done periodically in all beds.
4. Each crop was harvested when mature, based on days to maturity (DTM), final visual assessment, and with CSA distribution schedule. For each crop, each plot within each bed (T1, T1, T2, T2, T3, T3, and Late IMO) is harvested, weighed and recorded independently.
   * Onion: Sept 22, 2017 bulb
   * Ashwagandha: Sept 24, 2017 roots only (tops discarded)
   * Fennel: August 16, 2017 shoot
   * Parsley: August 3, 2017 shoot
   * Sweet Basil: July 20, 2017 shoot

**BASIL DOWNY MILDEW PROCOTOL:**

1. Using the additional 40 sweet basil seedlings, five seedlings were assigned to T1,T1, T2, T2, T3, T3, T4, and T4, using the above protocols.
2. T4 is a repeat IMO application. For T4, the IMO inoculant was applied at transplant and additional side dressing to each plant (1/2 cup Stage 4 IMO) weekly.
3. Downy mildew disease pressure is expected from naturally occurring inoculum, typically July/August. Each sweet basil plant in this protocol was visually inspected weekly for downy mildew. Disease incidence is measured by counting the number of plants in each treatment protocol for downy mildew. Disease severity was rated using system adapted from SARE grant Allen, 2011.

0= no symptoms

1= symptoms noted with 1-10% leaf area with sporulation

2= symptoms noted with > 10% leaf area with sporulation

Statistical analysis of data was completed by Dr. Maura Bozeman, Academic Program Manager of Environmental Sciences at Post University.

Although a complex economic analysis is beyond the scope of this project, costs of commercial inoculant versus cost of producing on-farm IMO was shared with farmers at outreach.

**Research results and discussion:**

As each crop was harvested throughout the growing season, the yield was recorded from plants in each of the different treatments; crops were then included in the farm’s Medicinal Herb Community Support Agriculture (CSA) shares. After data analysis (analysis of variance with probability-value <0.05), no crops in the IMO or commercial inoculant treatments had statistically significant improvements in crop yield compared to the control treatment. Please see attached box and whisker graphs, which also indicate the median, quartiles and outlier values for each crop yield. We also looked at the total inter-species crop yield from each bed, to see if there was any possible benefit from the common mycorrhizal network. The CMN concept has shown that fungi will share nutrients between different species of plants, such as one study showing nutrient flow between a Douglas Fir, a Paper Birch and a Western Red Cedar. However, there was also no statistically significant increase in inter-species crop yield, please see attached graph.

Ultimately, this researcher concluded the environment created in the field trial did not meet the conditions necessary to support the mycorrhizal fungi and ultimately the benefits to crops as measured by yield. Regenerative agriculture theory presents us with three key components to have more effective sustainable agriculture systems: cover cropping, crop diversity and low or no-till practices, all of which have numerous benefits including the promotion of soil life. This particular field design only incorporated crop diversity, as there was no prior cover cropping and the design method incorporated significant prior soil disturbance. Other research strongly suggests that maximum benefits are achieved by the inoculation of plants at the time of seeding (germination) as opposed to at the time of transplantation, as done in this study. In addition, much of the peer reviewed and anecdotal evidence points to on-farm improvements being noted after three or more years of practice changes; this research only looked at crop yield in one year of inoculation. It is very possible that a multi-year research project could show significant differences than found in year one.

It is also very important to acknowledge that these findings are set within the specific conditions of one farm in one season, with numerous situational, geographic and weather related influences. Just one example would be the potential impact of precipitation in the month of July; July is historically the driest month in Connecticut but according to NOAA data, in July 2017, Connecticut had twice the monthly average rainfall. There is strong evidence from prior peer-reviewed research that the benefits of mycorrhizal symbiosis may be most prominent during mild to moderate drought conditions, the opposite of what this growing season presented. In addition, the farm experienced a significant hail event in June, which caused noticeable damage to broad-leaved plants. It is also significant to note that this research took place in beds that had extremely low initial soil fertility. Soil test results indicated the test beds had low organic matter at 4.17%, extremely deficient phosphorus, were low in calcium, and deficient in most micronutrients. As farmer and author Michael Phillips put succinctly, “Fungi and bacteria can access and move locked-up minerals around, but no critter makes missing elements from nothing.” Although organic compost was added to each research bed, it was likely insufficient to compensate for the deficiencies, and it is possible that a similar research project on soil with moderate organic matter and nutrients could have shown quite different results.

Finally, the researcher noted the worst slug infestation ever experience on the farm, which was especially problematic in the research beds. This could have had a significant impact on crop yield measurements especially in plants most attractive to slugs: basil and fennel. There were several plants in each bed that had significant slug damage despite control methods employed. Further data analysis was completed to see if crop yield benefits were noted once the plants with significant observable slug damage were removed from data sets; however no statistically significant difference was found with this analysis.

The unusual slug infestation noted in the research beds led to one of the most significant unexpected changes in research design- the use of regular slug hand-picking, use of shallow slug attracting beer trays in the beds, and the use of organic approved Sluggo around the research plants. All three slug reduction methods were used as evenly as possible among all the research beds. Ultimately there was noted to be significant slug damage in basil and fennel which may have impacted crop yield results; there is no way to determine if slug damage was preferential to certain beds or caused even damage across the research plots. There were several other minor changes to the original research design. Because of poor onion germination, instead of using homegrown onion seedlings, store-bought onion bulbs were used. In addition, although the intention was to have the farmer not aware of which treatment each bed received, ultimately due to logistics on the day of transplantation and inoculation, it was necessary for the farmer to know the treatment each bed received.

For the concurrent research on disease resistance, additional Sweet Basil plants in each treatment protocol were monitored weekly for signs of Basil Downy Mildew based on percentage of leaf area with sporulation. There was a delay in infection in Basil plants inoculated with the Indigenous Microorganisms treatment, which is a potentially promising finding worth further investigation, please see attached graph. While the delay in basil downy mildew infection rates was on the scale of days to weeks, even a week or two delay in basil downy mildew infection can have significant financial benefits by allowing increased sales.

Even more exciting were two Basil plants in the IMO treatment protocol that were infected with Basil Downy Mildew (which typically has 100% crop loss), but then made a significant recovery with new healthy leaf growth, please see attached photo. Though such a conclusion is beyond the scope of this study, this finding may be an indication of systemic acquired resistance. This resistance is when a plant is able to develop an immune response or resistance after exposure to a pathogen, in this case because of the benefits of mycorrhizal symbiosis. Plants growing as part of a healthy ecosystem that includes mycorrhizal fungi have improved access to the diversity of metabolites and are better equipped to combat pathogens. Remarkably, plants can down-grade their immune systems to allow for beneficial symbiotic relationships, which later can protect them from other pathogens. These findings of improved Basil Downy Mildew resistance were quite exciting, and certainly looking at the benefits of diverse soil microorganisms on plant disease resistance is worthy of more research.

Setting this research project within a larger body of knowledge, the author would offer the following conclusions to gardeners and polyculture farmers: One, by adding fungal inoculants at the time of seeding (as opposed to at time of transplanting), we improve the likelihood of seeing beneficial results. This could possibly be because of the increased time for the symbiotic relationship to develop and confer benefits to the plants. Two, exploring low cost, low tech methods of cultivating local indigenous microorganisms (IMO production method) may still offer benefits worth the effort, however short term gains from this method of fungal inoculation remain inconclusive. While there are some costs to farmers in terms of labor and materials, the simplified IMO production method detailed here is a relatively straightforward, low tech method that most farmers would likely be able to duplicate on the first or second attempt. Three, fungal inoculants are not “magic fairy dust” that one can sprinkle around the farm and expect miraculous results. Likely much more important is ultimately supporting growing conditions where soil microorganism can thrive, which can potentially help grow higher quality plants and produce increased crop yield, and offer significant environmental benefits. If used simultaneously, the three key tenets of regenerative agriculture: use of cover crops, crop diversity and low or no-till practices, potentially will create a habitat for the soil microorganisms to thrive, and allow for their associated benefits.

Besides general conclusion above offered to fellow farmers and gardeners, this research project had several specific benefits to the farm, as well as catalyzed several on farm changes. The research project had an unexpected benefit of improved neighbor relations. Most of the farm is out of sight from the road, however because the research design specified the breaking of new ground, the research project was completed in the front of the property, directly abutting on the road. There were many spontaneous positive conversations with neighbors who were walking, running, dog-walking and driving by. The project was also a strong reminder that there is rarely a “magic fairy dust” practice that can be used, and instead strengthened this farmer’s focus of looking at integrated holistic practices as tools for improvement. The research project also strengthened this farmer’s interest in the benefits of IMO and commercial inoculants. Moving forward the farmer plans has started to use inoculants at time of seeding and transplantation when applicable, not just at transplantation. The farmer has also increased use of inoculants and soil microorganism supporting habits, with a focus on crops that traditionally suffered severe disease pressures. The farmer is focusing on slowly incorporating on-farm changes that will better support the soil microorganisms, such as increased mulching, reduced tillage and increased cover cropping. The cost of the commercial inoculant was $66.71, while the cost of the homegrown inoculant was $209.07, with additional labor needed for the IMO production. This has led the farmer to be interested in exploring IMO processes that either use less expensive materials or incorporate on-farm waste products.

**Research conclusions:**

The goal of the research project was to look at two concrete potential benefits of using mycorrhizal inoculants: crop yield and disease resistance of Basil to Basil Downy Mildew. In addition, the goal was to provide guidance on a simplified method of Indigenous Microorganism inoculant production. The research did not show an improved crop yield benefits with either the IMO or commercial inoculant treatment. However the conclusions offer some specific challenges that may have impacted results, as well as set the findings within the larger body of knowledge, potentially helping guide future research and on-farm practice changes. The project did show improved disease resistance of basil to Basil Downy Mildew when treated with an IMO inoculant, which is a very promising finding worthy of additional research. This finding has also already changed on-farm practices. Finally, the outreach shared the project’s research, the relevant peer-reviewed research, and IMO directions to farmers and the larger gardening and medicinal herb interested community.

**Education/outreach description:**

Outreach included five presentations with PowerPoint, a question and answer session, and handouts. PowerPoint presentations were quiet detailed (58 slides) including a summary of prior research, detailed methods/data/results on each section of findings, and recommendations for changes to on-farm/garden practices and future research.

1. Presentation at the Winter CT NOFA Conference (March, 2018)
2. Bionutrient Food Association local chapter meeting, open to chapter members and the general public, at the Simsbury Public Library (April, 2018)
3. Presentation, open to the public and students, at Twin Star Herb School (May, 2018)
4. Presentation to farmers and farm apprentices at Sylvester Manor Farm (July, 2018)
5. Presentation at the Summer regional NOFA conference (August, 2018)

Three additional presentations were given to gardeners/general public on “Growing Medicinal and Culinary Herbs and Pollinator Friendly Plants”. The presentations including summary of research findings and recommendations, though at a more introductory level.

One journal article was published in the Journal of Medicinal Plant Conservation, spring 2018. One article was accepted, with publication pending, in the Holistic Management International journal “In Practice”. Three articles were submitted but publication declined by: UMass “Vegetable Notes” online newsletter, UConn extension online newsletter, and the UConn gardener online newsletter “LadyBug”. A future article focusing on basil downy mildew is planned but will not be completed prior to SARE grant completion.

Research findings, extensive bibliography, and IMO handout available free on the farm website: pleasantvalleybotanicals.com.

**Learning Outcomes**

Key areas in which farmers reported changes in knowledge, attitude, skills and/or awareness:

Farmers noted an increased in knowledge and skills:

* the role of mycorrhizal symbiosis as applicable to agriculture
* how to produce their own farm IMO product
* how to add commercial fungal inoculants on the farm
* potential benefits of fungal inoculation
* farm practices that help support soil organisms

Also, speaking with farm interns, they expressed that they benefited by learning about how to do on farm research, and about SARE program as a future research in their farming careers.

**Project Outcomes**

The specific changes of practices as a result of this research have already been detailed above, but include increased focus on low cost IMO production, a change in practice to include the use of commercial inoculant at time of seeding and transplantation, increased use of low/no till practices, increased use of cover crops and mulching, and increased focus on use of inoculants in crops that traditionally have high disease pressures. In addition, this grant led to an improved quality of life: improved relations with neighbors, pride in the on-farm changes being made as a result of the research, improved relations with local farmers and gardeners contributing to a strengthened sense of community. Inadvertently, this research has also led to a change in focus of the farm to a different method of sales, which I feel is in a positive direction both for quality of life and for improved profits.

As far as comments from outreach:

* “Thank you for teaching us all about the benefits of fungi! Your research was excellent and it was great to learn about grants and the whole (lengthy) process!”
* Another comment on what was most interesting/useful: “The ideas of improved yield, stress tolerance, disease resistance, nutrient density, [and] the relationship between plant and fungi.”
* Farmer commented on presentation, “you had come to the decisions you made based on data, rather than a gut instinct.  (Empirical evidence). The delivery of your report was good, and you were straightforward with your language (not a lot of flowery language/not too much jargon).”
* One farmer commented on the conclusion that adding inoculant alone did not make an impact in crop yield, and helped him think about the bigger picture: “I think that something is missing somewhere and very easily something beyond our current comprehension/understanding of soil.”
* Community feedback included: “I am the Leader of the Hartford Area CT Chapter of the Bionutrient Food Association.  In April of 2018 I co-hosted, along with the Simsbury Public Library, a presentation by Melody Wright on “The Role of Soil Fungi in Regenerative Agriculture: Soil Fungal Inoculants Impacts on Crop Yield, Nutrition and Basil Downy Mildew”.   The talk was well attended and the subject matter of much interest and importance.  The Bionutrient Food Association is an educational nonprofit that is working to increase quality in our food supply and much of what we talk about is the need for soil health…. Melody Wright’s research project gave great information about the documented results she got using scientific method.  She shared the successes, the failures, and the questions left unanswered which need further study which made it very realistic and actually inspired others to want to try some of these methods, such as purchased- or home-made seed inoculants, in their own garden systems.”
* Another wrote, as an “occasional farmhand, I found Melody’s research to be extremely informative and inspiring.  I felt encouraged to work with fungal inoculants to improve my own garden and I enjoyed discussing the possibility of using fungal inoculants with the local farmers for whom I worked.”

**Assessment of Project Approach and Areas of Further Study:**

In retrospect, the biggest change in methods would have been to inoculate seedlings at time germination/seeding in the greenhouse, as research indicates this likely has more benefits that just inoculating at time of transplantation. Although it would have added additional time/effort to keep seedlings separate in the greenhouse, the addition time for the plant/fungi symbiosis to occur could have potentially showed results. The biggest challenge which I do not believe could have been foreseen or negated was the potentially significant impact of slugs on the crops, and further research taking into account this potential confounding problem would be helpful. I feel I did answer the questions I set out to study, noting that it is important to highlight that the lack of crop yield results may be very particular to the specific conditions of this growing season.

I think there are two main areas for additional work on this topic. One, I would recommend a multi-year (minimum three) study to see how additional time for symbiosis to occur could potentially affected crop yield. Two, additional research on basil downy mildew could potentially have worthwhile findings, with larger scale trials or additional treatment methods utilized to duplicate and expand findings. In the future I hope to repeat the basil downy mildew research with slightly revised method, and larger sample size.

I feel that small polyculture farmers and gardeners in the Northeast are the population that would benefit most from the results of my research. I think the results are relevant for farmers who already have an interest in regenerative/sustainable methods, as well as farmers transitioning from more traditional methods who are seeking to learn which methods offer “more bang for their buck.” I also found a strong interest from gardeners, as inoculant and IMO methods are easily attempted to smaller scale gardens. And I also found interest from consumers who wanted to be better informed in their purchasing choices.