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Final Performance Report

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Project 1 (Final)
Bacterial Rots of Onions: Etiology and Control

Project Summary

This project had two related purposes that addressed the substantial losses from bacterial decay that New York commercial onion growers regularly sustain. These were to determine which bacteria were responsible for the rot and the etiology (factors that occur together that result in the development of disease) during the growing season. Secondly we sought to test possible materials and tactics that conceivably might reduce the development of bacterial rot under commercial onion growing conditions.

Our etiological studies necessarily required that we develop techniques to identify bacteria isolated from symptomatic and non-symptomatic onions collected from the field by growers, extension agents and ourselves. We chose to develop and use molecular biological techniques because these techniques generally provide unequivocal results, and once developed these techniques are generally applicable to our samples and those of other scientists faced with similar problems.

Because commercial onion growers lack any materials that are reliably effective in reducing bacterial decay, we sought one or more materials that conceivably might be effective. We arranged trials of each under actual commercial field conditions with collaboration with commercial growers. The materials tested were those known to be toxic to non-spore-forming bacteria, like all the bacteria that cause decay in onions based on our etiological studies. The outcome of the tests indicated that one material, sodium hypochlorite, showed promise for reducing bacterial rot. However, before sodium hypochlorite could be recommended for use by growers, it must be registered by the EPA and NYS DEC for application to growing onions. We are currently pursuing that goal.

This project did not build on a previously funded project with the SCBGP or SCBGP-FB.

Project Approach

EDIOLOGICAL STUDIES

These studies were based on sampling plants collected at various times during the growing season and analyzing them in the laboratory. Project partners (Cornell Cooperative Extension staff) alerted project personnel to bacterial rot problems and provided samples for analysis. First, samples were surface-disinfested by bathing in dilute solutions of sodium hypochlorite and then 70% ethanol. Then, outer leaves and roots were removed and the remining bulb-like sample was bisected length-wise, observed closely for symptoms of bacterial decay and then individuals were shaken separately in sterile water. Samples of the rinse water, and dilutions thereof, were plated on appropriate media in Petri plates. Sample colonies that developed were identified based on analysis of the gyrase B gene (Bonasera et al. 2014) or via amplification with highly specific PCR primers that we had developed for that purpose (Asselin et al. 2016). In addition, samples collected from the field of various ages were tested for susceptibility to several authentic onion pathogens by artificial inoculation. In addition, these studies resulted in several “new” bacteria associated with decayed onions. For example, lactic acid bacteria, were found associated with decayed onion bulbs. These were described, identified and their findings publicized (Bonasera et al. 2017).

CONTROL STUDIES

Control studies generally were begun in the laboratory to ascertain toxicity of the candidate materials to the bacterial pathogens that are problematic to onions in New York State. After arranging for field tests with collaborating commercial onion growers, we and the Cornell Cooperative Extension Educator (CCEE) working in the growers' area, plan the layout of the trial. The materials were then applied either by the CCCE or by the grower, as appropriate. At or following harvest, the trial is assessed by the grower, the CCEE and project personnel. Therefore, project partners assisted project personnel by conducting experimental treatments and they provided samples for analysis by project personnel.

The following materials were tested as indicated together with appropriate non-treated control strips:

1. Oxidate 2.0 applied as weekly sprays to strips of growing onions
2. Worm Power, vermicompost extract, applied as seed drench at planting or a transplant seedling dip.
3. Grower provided Chloropicrin fumigated plots performed the previous autumn aimed at achieving better control of weeds.
4. Seedling drench with TerraClean 5.0, a more concentrated preparation of the same active ingredients as Oxidate 2.0.
5. Sprays of dilute sodium hypochlorite, ("pool chlorine") applied every week to 2 weeks by growers together with whatever insecticides and/or fungicides the grower judged was needed at the time.

Generally, we pursued approaches to the etiological and control problems that we dealt with in greater detail in the two Annual Reports ending September 30, 2015 and September 30, 2016, submitted earlier. The experimental results also are described in the those reports. Thus, the reader is referred to those reports for more detail.

Goals and Outcomes Achieved

Etiological Studies - Year 1

Plants were collected, usually biweekly, during the latter two thirds of the growing season from one grower in each of the three major onion-growing areas of New York State. The plants were analyzed to determine the degree of bacterial infection, infestation and susceptibility to the three major bacterial pathogens of onion in our state. Very little infection was detected visually in bisected bulbs in any samples until the last two collections, a few weeks prior to harvest of the crop. Infestation of bulbs (presence of bacteria in symptom-less bulbs) varied depending on the pathogen and the location of the plants collected. Plants from Oswego County had a high proportion (about 30%) of infestation with *Enterobacter ludwigii* (formally *E. cloacae*) from the first two collections but fell off during subsequent collections. Few bulbs were infested with *Pantoea ananatis* or B*urkholderia cepacia* during the growing season, although occasionally *P. ananatis* was detected in bulb tissue near the end of the session. Generally, plants were susceptible to infection following inoculation by *P. ananatis* or *B. cepacia* at any age tested. However, many water-inoculated plants also became infected suggesting that the plants from the field were contaminated with pathogenic bacteria. This led to the suspension of inoculation tests, given that early results indicated that mature growing plants are not required to develop infection. Overall, the variable results were not sufficient to draw firm conclusions. Nevertheless, the results were useful for perfecting our procedures for further analyses during the 2016 season.

During the etiological studies, we developed further techniques for identification of onion-associated bacteria. Two of these molecular biological tests have proven quite useful in our studies. Each was described in a scientific manuscript that was submitted to peer-reviewed scientific journals (**Methods in Microbiology** and **Plant Disease**) and subsequently accepted for publication. Thus, the methods that we

developed have been key to the success of our etiological studies. In addition, the techniques, facilitated the identification of other bacteria from onion bulbs that may be important to losses sustained by growers.

In controlled inoculation and environmental studies, conducted in the laboratory, conditions were discovered that were conducive for the initiation and development of infection of growing onion plants that had reached the "bulbing" stage, when these plants were inoculated with pure cultures of *B. cepacia,* with and without conscious or specific wounding. The plants had been produced is a special controlled environment chamber programed to simulate the light and temperature conditions encountered during a typical onion-growing season in New York State.

Preliminary analyses of the voluminous data suggest the following relationships:

1. Small numbers of symptomatic infected plants were observed only towards the end of the growing season.

2. Generally, the percentage of plants with substantial endophytic populations of bacteria increased as the growing season progressed. Bacteria present in non-symptomatic tissues included known pathogens of onions and those not known as pathogens of onions.

3. Plants from the three plantings sampled differed in the percentage of plants with substantial populations of bacteria. It is unclear whether the basis for the differences depended on geographical location, an edaphic factor, weather conditions, grower management, a combination of factors or merely coincidental effects.

4. Known pathogens in New York were commonly detected as endophytes in plants collected from all three plantings. However, plants from one planting yielded a consistently increasing percentage (up to 24% of the sampled plants) of pathogens as the season progressed.

5. Strains of the *Burkholderia cepacia* complex or *B. gladioli* were the most prominent of the pathogenic endophytic strains isolated and identified from the sampled plants in the three plantings. Strains of *Enterobacter ludwigii* (formerly termed *E. cloacae*) were the second most common in two of the plantings, while strains of *Pantoea ananatis* were more common in the third.

6. Several of the identified bacteria, not known as onion pathogens in New York or elsewhere, caused various symptoms following introduction into healthy-appearing onion foliage or bulbs. These results raise the possibility that several "new" bacterial pathogens may have been problematic in New York onions in 2015.

Etiological Studies – Year 2

<u>Endophytic bacteria in growing onions</u>: Plants were collected usually biweekly during the latter two thirds of the 2015 growing season from one grower in each of the three major onion-growing areas of New York State. Very little infection was detected visually in bisected bulbs in any samples until the last two collections, a few weeks prior to harvest of the crop. However, we detected the presence of bacteria in the interior tissues of symptom-less bulbs (See histogram below). Many of the bacteria detected were onion-pathogenic bacteria, but the results varied with the time and location of the plants

collected. Plants from Oswego County had a high proportion (about 30%) of infestation with *Enterobacter ludwigii* (formally *E. cloacae*) from the first two collections but fell off during subsequent collections. Few bulbs were infested with *Pantoea ananatis* or B*urkholderia cepacia* during the growing season, although occasionally *P. ananatis* was detected in bulb tissue near the end of the session. Generally, plants were susceptible to infection following inoculation by *P. ananatis* or *B. cepacia* at any age tested. However, many water-inoculated plants also became infected suggesting that the plants from the field were contaminated with pathogenic bacteria. This led to the suspension of inoculation tests, given that early results indicated that mature growing plants are not required to develop infection. Overall, the variable results were not sufficient to draw firm conclusions. Nevertheless, the results were useful for perfecting our procedures for further analyses during the 2016 season.

<u>Several "new" Gram–positive bacteria identified from onions</u>. Very slow-growing bacteria had been isolated from symptomatic rotten bulbs from storage, growing symptomatic bulbs and non-symptomatic growing onions. These bacteria proved to be Gram-positive based on the KOH test. Based on the 16S ribosomal gene sequences, they belong to the Lactic Acid Bacteria (LAB) family. Several strains of LABs were isolated, identified by sequencing a portion of their *gyrB* genes as species of Leuconostoc, *Weissella* and *Pediococcus*, *Lactobacillus plantarum* and *Lactococcus lactis.* Many of the strains tested for pathogenicity by inoculation of healthy appearing bulbs and foliage of 6- to 8- leaf growing plants yielded positive results. Although a few strains caused symptoms following incubation at 18°C, others caused symptoms only following incubation at 28°C or 37°C. All the data were collated in a substantial manuscript submitted to and accepted for publication by **Plant Disease**.

Work continued on further characterizing multiple strains of Gram-negative bacteria that had been isolated from cull onions and several growing onions previously submitted to the Beer lab for identification of bacteria that were associated with the onions. Some of these bacteria appear to be closely related to *Rahnella aquatilis*. Because of our interest in *Rahnella* spp., we developed specific primer pairs useful for identification of these bacteria. Plant pathologists in Norway had contacted us because they became aware of our work with *Rahnella* spp. isolated from onions. We established a brief collaboration to investigate possible similarities among multiple *Rahnella* strains isolated from onions in New York and Norway. We exchanged bacterial strains and DNA isolated from suspect strains. Now, we are evaluating each other's strains based on their pathogenic capability and identification based on our primer pairs and other molecular biological properties.

In addition, during our studies we frequently encountered endophytic strains from onion that we identified as *Kosakonia cowanii.* This Gram-negative bacterium formerly was referred to as *Enterobacter cowanii.* In inoculation tests with onion bulbs, these strains occasionally caused mild discoloration of bulb scales.

Since 2011, the Beer Lab had isolated additional bacteria from cull onions and endophytes from non-symptomatic onion plants. Approximately 100 of these strains were tentatively identified as *Klebsiella* spp. Several species of *Klebsiella* are of clinical significance as important human and animal pathogens. Therefore, we initiated studies to better define the "Klebsiella" strains found in onions. The studies include robust testing of the pathogenic abilities of the strains to onions and identification based on sequencing portions of the *gyrB* gene and other genes to comprise a multilocus sequence analysis (MLSA). Completion of this study is likely to clarify the importance of this group of bacteria as pathogens of onions and may distinguish them from similar bacteria of bona fide clinical significance.

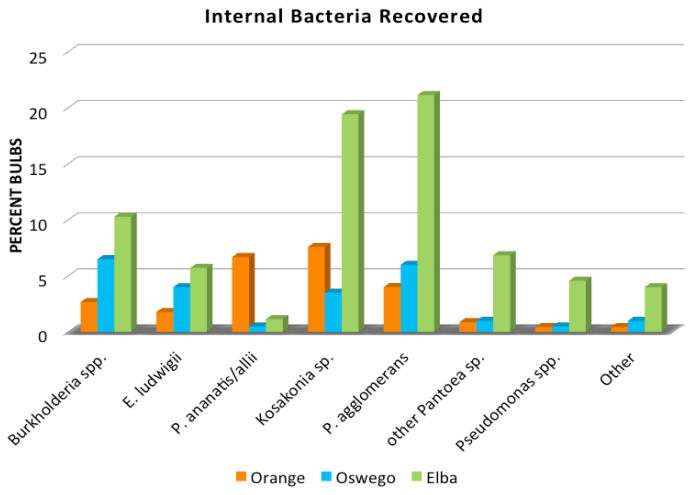

Figure 1: Composite percentages of bulbs collected from each of three major onion-growing areas of NYS [Orange County, Oswego County and the Elba Muck (Genesee and Orleans Counties)] yielding indicated bacteria from internal bulb tissues during the 2015 growing season.

Control Studies – Year 1

For the 2015 growing season, we evaluated four materials that were sprayed on onions that ***theoretically*** might reduce bacterial rot. None of the materials had been tested rigorously previously for the control of bacterial rot of onions. The materials were: a. Chloropicrin, applied by growers as a soil fumigant, aimed at weed control; b. Vermicompost extract, a microbe-rich product that has been found to have beneficial effects for the control of certain fungal and oomycete-induced diseases; c. TerraClear®5, a hydrogen-peroxide-containing product, similar to but more concentrated than OxiDate®2; d. "Pool Chlorine" (active ingredient sodium hypochlorite). Research plots were set up with growers and CCE educators in the three major onion-producing regions of NY.

The results of the rot control tests were judged by gathering and cutting of several thousand onions that were subjected to the four treatments, or not, as no-treatment controls. Project personnel depended on grower-cooperator schedules and our availability to gather bulbs for analysis. Cutting bulbs and examining the cut surfaces closely is the only sure means of assessing bulbs for rot. This was planned for the October and early November 2015. Thus, meaningful results of the control treatment will be available only during the first quarter of the second year of the project.

Control Studies – Year 2

Onion bulbs were harvested that had been treated or not treated with the four test materials in the 2015 season: TerraClean®5, Chloropicrin, Vermicompost Extract and "Pool Chlorine" (A.I. sodium hypochlorite). Treated bulbs and check bulbs were cut and rated for "rot" or "no rot".

Tests of two of the materials, vermicompost extract and sodium hypochlorite provided encouraging results. The "pool chlorine" which was applied by spraying biweekly in one trial, reduced rot incidence relative to control plots in the same field. Dipping onion transplant seedlings in vermicompost extract prior to transplanting resulted in less bacterial rot than similar transplants seedlings that had been dipped into water prior to transplanting. The results from testing these two materials seem to justify further and more extensive testing in 2016.

The hypochlorite treatment was particularly impressive. At harvest, based on cutting about 1,200 mature bulbs, those that had been treated with sodium hypochlorite had only 40% of the rot of those that were not treated. Sampling of plants during the growing season for bacteria and symptoms generally supported the reductions seen in the harvested samples. The grower estimated by counting sacks of harvested bulbs from the test and control plots that the sodium hypochlorite-treated onions yielded 22% more, before grading, than the onions from the control plots.

Thus, we made plans to work with growers in the several onion-growing areas of NY to test this treatment and the similar material, potassium hypochlorite in the 2016 season.

These materials were to be applied to growing onions on 7- to 14- day schedules together with the growers' regular insecticides and/or fungicides. Onions growing in the same field were treated with the same pesticides but without the added hypochlorite as "controls". We secured both products and delivered them to 13 cooperating growers with the help of Cornell Cooperative Extension personnel. Cooperating growers are located in all the important onion-growing regions of New York, including, Orange, Oswego, Wayne, Orleans and Genesee counties.

Just prior to harvest, we assessed rot from each spray treatment. Bacterial decay in bulbs was reduced in the 2016 season, due presumably to the severe drought that affected most NYS onion-growing regions. Nevertheless, most, but not all trials, had reduced rot from the hypochlorite sprays. The rough results from the several trials in Orange County are depicted in Figure 2. Similar results were gotten form the Elba area in Western NY and the Central NY area. Statistical analyses will be done when all spray records are received from the cooperating growers. Also, we are discussing registration of hypochlorites with the NYS DEC Pesticide Registration Chief, EPA and a major producer of the materials. The regulatory branches seem quite interested in facilitating an arrangement to allow for use of hypochlorites for reduction of bacterial rots in onions.

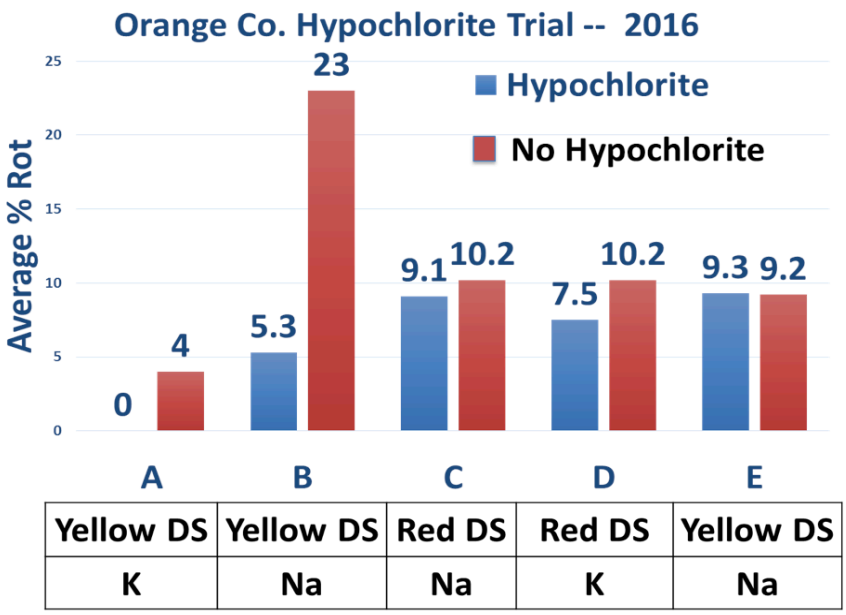

Figure 2: Effect of hypochlorite sprays on bacterial rot of onion bulbs at harvest on five onion farms (A through E in Orange County NY, 2016). The onion bulb color and mode of planting (direct seeded (DS) and type of hypochlorite, Potassium (K) or Sodium (Na) are indicated.

We feel that we have accomplished substantial progress in both sub-categories of goals.

We made progress in characterizing the bacteria associated with growing onions and discovering that many pathogenic bacteria often are present in non-symptomatic onion tissue before bacterial rot symptoms develop.

We have documented that sprays of hypochlorites on growing onions are effective in reducing the percentage of bacterial rots in onions, a definite plus for onion growers in New York.

As shown in the histograms ,hypochlorite shows promise in effectively reducing bacterial rot. In some trials rot was reduced > 20% and in others < 20%. Bear in mind that project staff dealt with small plots limited by use of unregistered experimental materials. Growers did not have large areas treated vs. those not treated. Only small plots assessed were measured, and project staff are not comfortable drawing overall conclusions that might be generally applicable, because of wide differences among growers in their practices and conditions. Further trials are needed. Results were reported, such as they were, to grower groups one to three times per year. Therefore, I feel SCBG funds were productively used.

More thorough analysis of the rot data from the several trials together with the detailed spray records await statistical analyses. Based on the nature of our field experimentation, involving only small plots by

a few commercial growers, the end results provided only indications that some of our trials were worth further testing. Also, prior to widespread use, effective materials must be registered by the New York State Department of Environmental Conservation and the Environmental Protection Agency. Therefore, during support by the SCBG, we could not draw State-wide conclusions.
[As an aside: In 2017, a sodium hypochlorite containing product, Surchlor, was duly registered for application to growing onions; many onion growers in the State used the material during the 2017 growing season.]

Publications released on the processes used and data obtained during this project can be found outlined in the "Additional Information" section below.

Beneficiaries

Our efforts have been made to directly benefit the 50 to 70 onion growers of New York State, who grow onions commercially on high-organic matter soil, generally called "Muck Soil". Other persons concerned with onions and those who advise growers or supply materials to onion growers also may benefit. Growers and scientists operating in other states or countries may also benefit. Growers will hopefully benefit from reduced rot and crop loss, as a result from treatment with products initially tested during this SCBG-support project.

Lessons Learned

We learned about the relationships between pathogenic bacteria and onion plants during the growing season. Surprisingly, the bacteria often become associated with growing plants as endophytes without eliciting symptoms of disease; this constitutes new knowledge that others may find useful.
Our evaluations of potential control material certainly constitute new knowledge useful to onion growers and their supporters and advisors in the industry. The effect of spraying dilute sodium hypochlorite on growing onions in the field to reduce bulb rot was particularly noteworthy.

Additional Information

Publications that appeared during the period of SCBG support:

Asselin, J., Bonasera, J., and Beer, S. 2017. When do onion-pathogenic bacteria become associated with growing onions? (Abstr.) Phytopathology 107:S2.5.

Asselin, J. E., Bonasera, J. M., and Beer, S. V. 2016. PCR Primers for detection of Pantoea ananatis, Burkholderia spp., and Enterobacter sp. from onion. Plant Disease. 100: 836-846.

Asselin, J., Bonasera, J., and Beer, S. 2016. Novel PCR primers for detecting bacterial rot pathogens of onion. (Abstr.) Phytopathology 106:S2.1.

Bonasera, J. Asselin, J, and Beer, S. 2017. Lactic acid bacteria cause a leaf blight and

bulb decay of onion (Allium cepa). Plant Disease. 101:29-33.

Bonasera, J. M., Asselin, J. E. and Beer, S. V., 2016. Grower trials of sodium/potassium hypochlorite sprays on growing onions to reduce bacterial rot in New York onions. Illustrated presentation made at the National Allium Research Conference and the National Onion Association Conference. December, 2016. Savannah, GA.

Bonasera, J. M., Asselin, J. E. and Beer, S. V., 2014. Identification of bacteria pathogenic to or associated with onion (*Allium cepa*) based on sequence differences in a portion of the conserved gyrase B gene. J. Microbiological Methods 103:138-143.

Zaid, A. M., Asselin, J. E., and Beer, S. V. (2016). "Detection of Burkholderia cepacia in onion planting materials and onion seeds." Chap. 22 in Detection of Plant-Pathogenic Bacteria in Seed and Other Planting Material, 2nd Ed. Fatmi, M., Walcott, R., and Schaad N., eds. APS Press: St. Paul, MN.

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Project 2 (Final)

Breeding Tomatoes with Improved Fruit as well as Late/Early Blight and Septoria Leaf Spot Resistances

Project summary

Tomato is an important crop in NY; fresh market tomato acreage in NY in 2009 was 2,700A with a value in excess of $32.7 million (USDA Statistics, 2009), with the majority of NYS fresh market tomato grown by diversified fresh market vegetable producers. This project targets three important defoliating diseases of NY tomato production: late blight (LB), early blight (EB) and Septoria leaf spot (SLS). Current varieties lacking genetic resistance require multiple fungicide applications to effectively control these diseases, particularly under favorable weather conditions.

Work funded in part by a prior Specialty Crop Block Grant (2010 to 2013) was very successful, creating the first tomato lines possessing strong LB and SLS resistances and EB tolerance, and created/trialed experimental hybrids possessing these traits, culminating in the 2013 release of the blight resistant commercial hybrid "Iron Lady". However additional work is needed: the introgression carrying the SLS resistance gene SLS-1 is extremely large and contains additional genes detrimentally affecting cluster form and fruit size. Although the negative genes are partially masked in hybrids, this problem could be fully resolved by targeted breeding.

This project addresses control of late blight, early blight and Septoria leaf spot on NY tomatoes, creating lines and hybrids that have genetic control of these diseases, producing higher quality, larger fruit on better clusters, and adapted to NYS conditions and growing practices.

The **GOALS** of this proposal were to 1. Generate new LB/EB/SLS lines with a small SLS-1 containing introgression, to eliminate negative genes and improve fruit and cluster traits. 2. Use the new LB/EB/SLS lines to create new experimental hybrids; 3. Test these new hybrids in conventional and organic trials on Cornell farms and farms of cooperating NYS growers. As **OUTCOMES** the tomato lines completed were to facilitate the productions of new hybrids with improved fruit quality that can be produced with fewer fungicide sprays, reduced potential for crop loss, at lower expense for conventional and organic growers in NYS; minimizing risks to the environment; and reducing fungicide residue on tomatoes for consumers.

Project Approach

Goal 1. *Reduce the size of the SLS-1 containing introgression to smallest size that possesses SLS-1 but eliminates the gene(s) causing problems with cluster formation and fruit size.*

Introgression size is reduced by chromosomal recombination that can occur every generation during the formation of the gametes (egg and pollen cells). This work was performed at Cornell University greenhouse and laboratory facilities in Ithaca NY by Mutschler and her staff. The initial size of the chromosome introgression carrying the SLS-1 gene and WILTY was very large, over 40 million base pairs of DNA (or 40 Mbp). As such we hoped that it would be possible to eliminate the portion of the introgression carrying the gene for WILTY, while maintaining the portion carrying the SLS-1 resistance genes. We performed 4 cycles of introgression reduction, selecting plants with a recombination somewhere within the introgression carrying the SLS-1 gene so that the introgression was reduced in size. For each recombinant plant, we selected selfed progeny that were homozygous for the shorter introgressions for seed production, then used the resulting seed to test the resulting lines for the presence of SLS-1 using disease screens, and for the presence of WILTY by growing the plants under stress in the

greenhouse.

Goal 2. Fruit/plant quality of new lines:

The work for this goal was to perform field trials of new lines with SLS-2 and also either different sized introgressions possessing SLS-1 or not possessing SLS-1 were performed, to test the improvement in fruit quality traits of the new lines, to determine if either reduction or elimination of the chromosome 1 introgression possessing SLS-1 reduces/eliminates the negative fruit trait observed in prior SLS-1/SLS-2 lines. This work was performed at Cornell Thompson Research Farm in Freeville NY by Mutschler and her staff.

Goal 3. Produce new LB/EB/SLS hybrids using the best of the new lines, and trial the new hybrids under organic and conventional settings.

As the best new LB/EB/SLS lines with improved fruit traits were determined, they were used as parents of two types of new hybrids: modern hybrids, in which both parents are modern lines, and so the hybrids should be analogous to the good commercial tomato cultivars, with the addition of the new disease resistances, and *half-heirloom hybrids* in which one parent is a new LB/EB/SLS line with improved fruit traits but the second parent was the heirloom Brandywine, which is renowned for its flavor, but which suffers severe fruit loss due to fruit defects such as severe cracking and blossom end scaring called "catface". The replicated trials of these hybrids were performed each year at the Cornell Thompson Research Farm in Freeville NY by Mutschler and her staff, at the Cornell Long Island station by McGrath and her staff, and at the Hudson Valley Farm Hub, by Teresa Rusinek and assistants. These trials provided the harvest yield and quality measures needed to determine the commercial potential of the hybrids.

Goals and Outcomes Achieved

Goal 1. *Reduce the size of the SLS-1 containing introgression to smallest size that possesses SLS-1 but eliminates the gene(s) causing problems with cluster formation and fruit size.*

Activities: Through the work in Goal 1 we produced plants with smaller and smaller introgressions, and identified a very small portion of chromosome 1 (less than 500,000 based of DNA, or 0.5Mbp) as containing the SLS-1 gene, but the same region also contains WILTY, which has been disappointing. Even though this region is very small, the annotated tomato genomic sequence shows that it contains at least 40 genes, so it is still possible that SLS-1 and WILTY are two separable genes. Although this funded project is terminating, we are currently performing another cycle of disease screens/tests for WILTY, on 16 selections that further restrict this small region containing SLS-1 and WILTY, in a last attempt to separate the genes controlling these two traits. That work will be completed by June 2017.

Goal 2. Fruit/plant quality of new lines:

Activities: During this program we evaluated the size and quality of the fruit produced by the new tomato lines possessing either both SLS-1 and SLS-2 genes (on chromosome 1 and chromosome 5, respectively), or only the SLS-2 gene in field trials performed at the Cornell Thompson Farm, Freeville, NY (Mutschler and staff). Since these new tomato lines are, for the most part, closely related and very similar plus and minus the SLS-1 containing region, we were able to make close comparisons of fruit/plant quality and the extent to which these traits are impacted by the introgression carrying SLS-1 gene.

The impact of the presence of the chromosome 1 introgression that contains SLS-1 was very striking for the plant abnormality we call WILTY. This trait is only found in lines possessing SLS-1, showing that this introgression contains a gene or genes responsible for the plant top die back characteristic of WILTY. What was interesting, and potentially useful, is that the degree to which different lines carrying the

introgression were negatively affected differs among lines carrying the region, suggesting that gene(s) on other chromosomes might ameliorate the expression, and problem, that is WILTY. Selections were made for the lines with reduced expression of this negative trait to allow reduction of the vine deficits. However the greatest reduction in the abnormality still resulted when the entirety of the chromosome 1 introgression was eliminated.

The fruit size comparisons showed a similar separation of the lines, with the lines carrying the chromosome 1 SLS-1 containing introgression also having, on average, smaller fruit. Again, the degree to which a line showed this impact varied among lines.

In addition, we produced hybrid seed from crosses of two lines that each possess SLS-2 but not SLS-1, to test the performance of the resulting hybrids not only for fruit size and productivity, but also Septoria leaf spot control. Based on the results of prior disease screens, plants homozygous for only SLS-2 could have equivalent disease control to plants heterozygous for both SLS-1 and SLS-2, but without the negative impact of being heterozygous for the chromosome 1 introgression.

The negative impacts of heterozygosity for SLS-1 are less than that in plants homozygous for SLS-1, but the new hybrids homozygous for SLS-2 which do not have SLS-1 should further improve plant type and fruit size. Although this project is terminating now, an observation trial of related hybrids that are all homozygous for SLS-2 (chromosome 5) but either heterozygous for or lacking SLS-1 will be grown and evaluated during the 2017 field season at the Cornell Thompson Farm, Freeville NY (Mutschler and staff).

Goal 3. Produce new LB/EB/SLS hybrids using the best of the new lines, and trial the new hybrids under organic and conventional settings: both new modern style hybrids and half-heirloom hybrids:

Four types of experimental hybrids and control hybrids were tested in one or more locations of three locations.

The types of hybrids were:

1. Hybrids similar to the commercial hybrid Iron Lady, and so homozygous for Ph2/Ph3 genes (late blight resistance), heterozygous for SLS-1 and SLS-2 (Septoria leaf spot resistance) and homozygous for early blight tolerance. Iron Lady was the control in the 2015 seasons, and Stellar was added to the trial in 2016
2. Hybrids similar to the commercial hybrid Mt. Merit, and so heterozygous for Ph2/Ph3 genes (late blight resistance), heterozygous for SLS-1 and SLS-2 (Septoria leaf spot resistance) and heterozygous for early blight tolerance. Mt. Merit was used as the control in both seasons
3. Hybrids heterozygous for the Tm2 gene providing resistance to tobacco mosaic virus (TMV), as well as being heterozygous for Ph2/Ph3 genes (late blight resistance), heterozygous for SLS-1 and SLS-2 (Septoria leaf spot resistance) and heterozygous for early blight tolerance. Iron Lady was the control in the 2015 seasons, and Stellar was added to the trial in 2016
4. Half-heirloom hybrids, for which the heirloom variety "Brandywine" was one parent. These hybrids were heterozygous for Ph2/Ph3 genes (late blight resistance), heterozygous for SLS-1 and SLS-2 (Septoria leaf spot resistance) and heterozygous for early blight tolerance. Brandywine was used as the heirloom control in both years.

The locations were:

1. Cornell Thompson Farm, Freeville NY (Mutschler and staff), where all 4 types of these hybrids were tested.
2. Hudson Valley Farm Hub (Rusinek and assistants), where hybrid types 1, some of 2, and 4 were tested.

3. Long Island Horticultural Research & Extension Center (McGrath and staff) where hybrid types 1, 2, and 4 were tested.

For the hybrids trials at each of the locations, fruit was harvested weekly for 3 to 4 weeks, depending on year and location. The harvested fruit were graded as being marketable vs. unmarketable. For each harvest, the number and weights of the marketable and unmarketable fruit were recorded, as well as the reasons for fruit being classified as unmarketable. Data were input and were analyzed. The major cause of fruit defects differed in the 2015 vs the 2016 field trials, which is understandable considering that 2015 had cooler wetter conditions than normal, and 2016 had hotter, dryer conditions than typical. However some of the hybrids were clearly superior to others. Data generated were very good to excellent.

Outcomes Achieved Across Goals

1. The location of the SLS-1 resistance gene has been identified as being within a very small region of chromosome 1 (<0.5 Mbp), and in the course of reducing the size of the introgressions, and mapping the SLS-1 gene, we developed several molecular markers that fall within this 0.5 Mbp. Those markers can be used by plant breeders as tools for marker based selection of SLS-1, and so are valuable for both private and public plant breeder, since use of marker based selection can reduce by half the number of generations needed for breeding, accelerating the development of improved lines.

2. The number of hybrids commercially available that possess genetic control of late blight/early blight/Septoria leaf spot will be expanded from one hybrid to three hybrids. Iron Lady was the first hybrid which used a line from the Cornell tomato program as a parent, and has combined genetic control for late blight, early blight and Septoria leaf spot. In 2016, seed of a second hybrid based on Cornell late blight/early blight/Septoria leaf spot resistant lines was also available commercially to growers. This new hybrid is named "Stellar", and was sold starting in 2016 by PanAmerican Seed Company. Stellar also had, as one parent, a Cornell line with genetic control for late blight, early blight and Septoria leaf spot. With both Iron Lady and Stellar being sold, there are now two hybrid tomato cultivars adapted to NE conditions with the same novel combination of foliar blight resistances. Based on the results of the trials from this project, and in regional trials which also included as entries the hybrids generated by this project, another new hybrid with genetic control for late blight, early blight and Septoria leaf spot will soon join the list of commercially available hybrids based on Cornell late blight/early blight/Septoria leaf spot resistant lines. One of the half heirloom tested by this project, as well as in trials run by other programs (such as the Organic Seed Alliance) to which we provided seed of the hybrid designated "Cornell 79" proved to be outstanding across locations. This hybrid was outstanding in our trials, multistate regional trials in a separately funded organic program, as well as in tests by executive chefs. This new hybrid will be the first of the fungal resistant hybrids that is a half-heirloom hybrid, noted for having the flavor of the favorite heirloom "Brandywine", but more moderate fruit size, with significantly less cracking and much higher marketable yield than Brandywine, in addition to the resistance to the foliar fungal diseases (late blight/early blight/Septoria leaf spot) and genetic control to resistances to the vascular fungal wilt diseases (Verticillum and Fusarium wilts) that is lacking in heirloom tomatoes. The combination of genetic control of all 5 fungal diseases will make production of marketable fruit of tomatoes with the flavor quality of Brandywine much more possible. A small NYS-based vegetable seed company has licensed the Cornell line needed to produce seed of the experimental half-heirloom hybrid "Cornell 79". The name under which this hybrid will be commercialized has not yet been decided. The announcement of the new hybrid is planned for fall of 2017, and the first seed sales for the new hybrid is planned for the 2018 growing season.

3. Wide distribution of results, bridging seed companies, growers, marketers

A number of venues were used in year 1, year 2 or both, as well as at the project end, to distribute the results of this project as widely as possible to seed companies, growers, and marketers

A. Cornell Garden-Based Learning Regional Training for CCE Educators and Master Gardener Volunteers in Middletown, NY, on Feb 18, 2015. McGrath gave a presentation on "Resistant Tomato Varieties for Managing Late Blight".

B. Annual Vegetable Breeding Institute Field Day, which is held in Freeville, NY, on the last Monday and Tuesday every August. At this event in both 2015 and 2016, the field trials testing the yields and fruit quality of the tomato hybrids being tested were displayed to representatives from 25 to 30 vegetable seed companies, and the progress on the project was described by Mutschler.

C. The annual report of the Vegetable Breeding Institute (association of vegetable breeders at Cornell University and University of Wisconsin- Madison) is distributed to over 50 national and international vegetable seed companies in January of each year. The tomato reports by Mutschler included in the annual reports released in Jan of 2016 and Jan of 2017 fully covered the results of the 2015 and 2016 growing season, respectively, concerning reduction of introgression length to attempt to eliminate WILTY syndrome, and the development and field trials of the new lines with genetic control of late blight, early blight, and Septoria leaf spot, and the performance of the blight resistant hybrids created using those lines. Seed companies request seed samples of the new tomato lines described in the reports to use as germplasm in their breeding program or as parent lines in hybrid creation and testing.

D. 2016 NJ Agricultural Convention and Trade Show in Atlantic City, NJ, on Feb 10, 2016. McGrath gave a presentation on "Update on Tomato Disease Management".

E. In both 2015 and 2016 a Grower Field day was held at the Hudson Valley Farm Hub showcasing the disease resistant lines, and included tomato fruit tastings and farmer evaluations.

F. Annual Plant Science Day, held at the Cornell University Long Island Horticultural Research & Extension Center in Riverhead, NY. Attendees tour research fields and learn about the projects being conducted. The event was held on July 15, 2015 and Sept 14, 2016. Tomato fruit were evaluated by attendees in 2016.

G. 2017 NYS Expo: Mutschler gave a presentation of on new tomato hybrids with genetic resistance to blights at the EXPO at the ONCENTER, in Syracuse, NY from Jan, 18, 2017.

H. Hudson Valley Commercial Vegetable Growers' School in Kingston, NY, on Feb 7, 2017. McGrath gave a presentation on "Minimizing Disease Risk Using Resistant Varieties and Seed Disinfestation".

I. RMA Organic Growers Winter Workshop in Plymouth, NH, on March 28, 2017. McGrath gave a presentation on "Update On New Diseases, Resistant Varieties, and Organic Disease Management".

J. The publication about this project, which was projected to be completed at the end of 2nd year has not yet been written due to other deadlines. However the three cooperators will be "meeting" on line to discuss analyses of the multiple trials, and develop the framework of a publication, so it can move forward this summer.

Beneficiaries

A. The tomato industry in NYS, and similar climatic regions in neighboring northeast and Mid-Atlantic coast states, is the target beneficiary here. Benefits will be realized as growers adopt and profit from the production of tomato varieties resistant to the three major blights, which unchecked cause major losses in fruit yield and quality. However tomato marketers, and consumers are downstream beneficiaries, as are home gardeners.

B. The tomato seed producing seed companies are also beneficiaries, since they can use the improved lines, the genetic markers developed, and can also use the information on the use of the resistant lines developed, with the potential benefits of such tomatoes for increased seed sales.

C. According to the 2016 USDA vegetable summary, in the 2015 season, 120 hundredweight of fresh-market tomatoes per acre were harvested from 2,800 acres. Including NY and also the mid-Atlantic coast areas (NY, PA, NJ, VA, TN, SC) 243 hundredweight of fresh-market tomatoes per acre were harvested from 21,700 acres.

Lessons Learned

A. When two genes (one positive and one negative) are both contained in one very large introgression, the probability is fairly high that the two genes are not located in close proximity on the chromosome, and that the negative gene can be eliminated through recombination. However this project demonstrated that in some unfortunate cases even though one starts with a large introgression, the two genes could be closely linked and prove very difficult to separate.

B. There can be more than one strategy for achieving a goal. In this case, we determined that similar levels of SLS resistance under field conditions were achieved by plants homozygous for only the SLS-2 gene (chromosome 5) and for plants heterozygous for both SLS-1 and SLS-2. Determining that this was the case allowed us to pursue a second strategy for achieving SLS control with larger fruit with better horticultural type.

C. Flavor is typically considered a complex multiple genic trait, so the extent to which the flavor of the half heirloom hybrids matched that of its Brandywine parent was remarkable. The decreased cracking and smoother fruit of these half heirloom hybrids, with substantially reduced catface, resulted in much higher marketable yields than that of the heirloom parents.

Additional Information

Two of the lines developed in this program were used to start the process of transferring genes for resistance to the important diseases bacterial speck and bacterial spot into fresh market tomato, with the goal of creating lines that combine resistance to both the fungal diseases (early blight, late blight and Septoria leaf spot) and the bacterial speck and bacterial spot, so that the lines could be grown either without or with very little use of both fungicide and copper sprays.

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Project 3 (Final)

Enhancing the Competitiveness of New York's Onion Industry with an IPM Program for Thrips

Project Summary

Onion thrips (*Thrips tabaci*) is a major insect pest of onion bulb crops throughout the world and is the most important insect pest of onion in New York. Onion thrips cause severe foliar-feeding damage and serious reductions in bulb yield. Onion thrips also transmit plant pathogens that can interfere with bulb quality. Substantial economic losses attributed to thrips and associated pathogens occur regularly for the onion industry. If costs for insecticides to control thrips are also considered, total economic losses attributed to thrips are even greater. Long-term management of onion thrips will require multiple strategies that ideally will be sustainable and eco-friendly.

Currently, there are no onion cultivars that offer high levels of resistance to onion thrips. Some cultivars offer "partial resistance" to thrips, and these cultivars sustain much lower levels of damage than susceptible cultivars and do not suffer bulb size reductions. Breeding efforts are underway to produce cultivars that are resistant to thrips, but these cultivars are years away from becoming commercialized. Until such highly resistant cultivars are available, partially resistant ones will offer growers a means in which to mitigate yield loss.

Reducing the amount of nitrogen applied to the crop is an effective cultural management tactic for decreasing onion thrips infestations. Thrips colonize onion fields later and populations build more slowly on onions that receive lower levels of nitrogen. In New York, onion thrips densities were reduced in onions that received 100 lbs of nitrogen per acre compared with those given 150 lbs of nitrogen per acre, without a loss in marketable yield. Reducing levels of nitrogen in onion crop production has additional economic, public health and environmental benefits by reducing fertilizer costs and risks of nitrates moving into ground and surface water.

Insecticide use is the principal tactic for controlling onion thrips. Until recently, thrips control was unpredictable because many populations developed resistance to commonly used insecticides. New insecticides belonging to novel classes of chemistry are now available and provide excellent control of onion thrips. Yet, many onion growers apply these new insecticides on an intensive weekly basis like they did for older products, increasing the risk of insecticide resistance. Optimizing insecticide use and applying insecticides in a manner that mitigates resistance development are critical for keeping these products viable to manage thrips. Action thresholds for the new insecticides have been developed, and sequences in which to use them have been recommended. Following these recommendations, the number of applications required to manage thrips infestations in several New York onion fields have been cut by as much as 50%.

This project was important and timely because individual tactics have been identified for thrips management, but have not been evaluated together in an IPM program. We proposed to evaluate and implement a novel IPM program for thrips that included cultivars partially resistant to thrips, a reduction in nitrogen use, and selective insecticides for optimally control thrips infestations. Results from this project will directly impact all onion-producing regions in New York and the approach will serve as a model for managing thrips in onion throughout the US. Adoption of this novel IPM program is expected to significantly increase marketable yield, reduce costs of inputs like fertilizer, pesticides and fuel, which will significantly increase profits for the onion industry, and also will improve environmental quality and human health.

This project did not build on a previously funded project with the SCBGP or SCBGP-FB

Project Approach

In a two-year field trial in New York, combinations of varying levels of nitrogen applied at planting (67, 101 and 140 kg ha^{-1}) and different insecticide programs (standard weekly insecticide program and action threshold-based insecticide program) were evaluated for onion thrips management in onion cultivars that had moderate resistance ('Avalon'), low resistance ('Delgado') and no resistance ('Bradley') to onion thrips. Results indicated that regardless of cultivar, nitrogen did not affect larval thrips densities, onion yields, Iris yellow spot disease or bacterial center rot. Across all cultivars, insecticide use (both programs) significantly reduced larval thrips densities and damage, Iris yellow spot severity and incidence, and increased onion yield. Insecticide use did not consistently affect the incidence of bacterial center rot. Both insecticide programs reduced onion thrips larval densities by 60–81% relative to the untreated control, but the action threshold-based application program used 2.8 fewer applications than the standard program. 'Avalon' had low thrips densities and Iris yellow spot disease, but required the same number of insecticide applications as 'Bradley'. Onion yields in both insecticide programs were statistically similar in both years, and bulb weights averaged 10–54% more than those in the untreated control. Our results indicated that growers can reduce nitrogen levels at planting and insecticide use without compromising control of either onion thrips or IYS disease or onion bulb yields.

Project partners included Ashley Leach, Steve Reiners, Matt Mortellaro and Christy Hoepting. Ashley is a Ph.D. student in my program and she conducted all of the field research, conducted the grower surveys and gave presentations about the results to stakeholders. Dr. Steve Reiners (Dept. of Horticulture) was extremely helpful in working with Ashley to ensure that the fertility aspect of the project was conducted properly. Matt Mortellaro (onion grower) permitted us to conduct research on his farm in 2015 and 2016. Not only did he provide us with the land, he helped by maintaining weed and disease control with pesticides. Christy Hoepting (CCE) helped disseminate information about our project to stakeholders. In 2016, she helped organize a field tour for the National Onion Industry and this enabled us to demonstrate our field research to onion growers in New York as well as other parts of the US and other countries. Christy also organized meetings in western New York in the summers of 2015-2017 so that we could discuss our results with growers. She also organized a session at the 2016 Empire State Producers EXPO and invited Ashley to discuss the initial year's results to the NY onion industry.

Goals and Outcomes Achieved

The principal goals of this project were for onion growers to learn about the novel IPM program for onion thrips, adopt it on their farms, and find it useful and profitable. We wanted to quantify the number of onion growers who have learned about this novel IPM program, those who use it on their farms, and how many find it useful and profitable. So, we surveyed onion growers in 2014 to identify how many are aware of the various management components that are included in the novel IPM program to establish a baseline level of knowledge. Initial survey results indicated that most implemented some level of integrated pest management (IPM) on their farm to control onion thrips populations. Approximately, 76% of growers implemented cultural pest management tactics to reduce onion thrips infestations by reducing nitrogen rates to reduce thrips colonization and reproduction, planting less thrips-susceptible onion cultivars, or removing volunteer onions that would support early-season populations. No growers responded that they used biological or physical controls to reduce onion thrips densities. Approximately 88% of growers either scouted their own onion fields or had a crop consultant scout their fields. Half of the growers (50%) claimed to use an action threshold to determine when to apply an insecticide. However, most growers (81%) responded that they made between seven and eight insecticide applications each growing season to control onion thrips populations, which is excessive. Most growers (94%) claimed to effectively rotate insecticides in a season-long sequence, and only made two sequential applications of one mode of action before rotating to a new insecticide. All growers surveyed stated that they began their

thrips management program with spirotetramat (Movento™) and concluded with applications of spinetoram (Radiant SC™) with a variety of other products in between.

Our target was for 75% of onion growers to know how each of the three tactics in the novel IPM strategy can be used to manage onion thrips. Similarly, 75% will use at least one tactic, 50% will use two of the three tactics, and 25% will use all 3 tactics of the IPM program on their farm. Seventy-five percent will find some aspect of this IPM program to be useful and profitable. We were pleasantly surprised that growers had been adopting many of our IPM suggestions even before we conducted research to validate our ideas. Consequently, because the initial survey results indicated that growers had already adopted reduced rates of nitrogen based on preliminary findings that we shared with them prior to this grant, that partially thrips resistant cultivars are still not ready to be grown commercially in New York, and that they were using the sequences of products to manage thrips effectively, we focused on trying to improve growers use of action thresholds to determine whether or not they should apply an insecticide. We knew that this change could make a big impact on insecticide use and insecticide resistance management. So, worked closely with 16-18 growers in all the major onion production regions in the state and provided them with weekly scouting and recommendations.

Results of the project have been shared with onion industry stakeholders at meetings across all of the onion-producing regions in New York (Empire State Producers EXPO, Orange County Onion School, Winter and Summer NYS Onion Industry Council Meetings, Oswego Onion Growers meeting and the Elba Muck Twilight Meeting) and beyond (Great Lakes Fruit and Vegetable EXPO, National Allium Research Conference, W-2008 Multi-State National Project that focuses on onion pest and disease management). Information also reached specialty crop growers via proceedings articles.

Another goal of this project was to share our results about the novel IPM program for onion thrips by including details about it on Cornell's vegetable program website. However, have not done this yet and are concerned that onion growers will not obtain information from this site. Therefore, we will continue to share information at meetings and in newsletters and magazine articles.

Beneficiaries

Onion growers were the main beneficiaries. However, professional crop consultants, agri-chemical company representatives, vegetable seed company representatives, University extension educators and faculty and the public also benefitted from information generated from this project. Efforts to transfer knowledge about our research focused primarily on verbal presentations at stakeholder-based meetings, extension educator-based workshops and on-farm visits.

We were highly successful in increasing grower adoption of action thresholds for insecticide applications by 60% (50% adoption rate in 2014 increased to 80% adoption rate in 2017). Consequently, onion growers who use action thresholds reduced the total number of applications on average by 2-4 per season and saved on average $42 per acre (range $20-64/acre). There are approximately 7,500 acres of onion in New York. We will continue to work with all onion growers and attempt to get the adoption rate of action thresholds to 80% for the entire state (6,000 acres). If successful, these growers should save $42/acre with an overall collective savings of $252,000 per year.

Lessons Learned

The most significant surprise to us was that low levels of nitrogen fertilizer applied at planting did not impact thrips populations, Iris yellow spot disease, bacterial disease or marketable bulb yield in our study. A positive implication of our findings is that growers can save money by lowering rates of nitrogen at

planting. A negative implication of these results is that we won't be successful reducing thrips infestations by reducing rates of nitrogen at planting.

Another surprise was that the partially thrips resistant cultivar, Avalon, suffered less thrips damage than the susceptible cultivars, but tended to have much greater levels of bacterial bulb rot than the other cultivars (not related to insecticide use or nitrogen use). So, the slight advantage gained by growing the partially thrips resistant cultivar for reducing thrips, was negated by the high levels of bacterial rot.

We were very pleased to learn that applying insecticides based on an action threshold rather than a weekly basis provided excellent thrips control using fewer applications. The implications of these results are that growers will save on their insecticide costs, less insecticide active ingredient will be applied to the environment, and hopefully the development of insecticide resistance in thrips populations will be mitigated.

Our decision to expand our study to focus on how to get onion growers to adopt action thresholds was interesting and overall successful. While the growers liked saving money on their pesticide bill, the main reason for cutting back their insecticide use was to mitigate insecticide resistance.

Additional Information

Peer-reviewed publication from this project:

Leach, A., S. Reiners, M. Fuchs and B. A. Nault. 2017. Evaluating integrated pest management tactics for onion thrips and pathogens they transmit to onion. Agriculture, Ecosystems and Environment 250: 89-101.

Photos of from this project below:

Adding fertilizer to spreader during planting of the 2015 field trial located in the Elba Muck in western NY.

Another photo of the 2015 field trial during the planting process.

Ashley and temporary summer employees who were taking data on thrips densities and other onion plant growth characteristics in the 2015 field study.

Photo of the 2016 field trial. This was a much drier season than the 2015 season.

Photo of Ashley Leach (PhD student) and me after we gave presentations about our SCBG-funded research to over 100 National Onion Association members and their families who were touring the Elba Muck area in 2015.

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Project 4 (FINAL)

Using Under-Vine Cover Crops to Reduce Management Costs in Hybrid Wine Grapes

Project Summary

Historically, grape production in New York vineyards focused on varieties and practices that maximized yield at acceptable levels of quality. Maintaining a weed-free zone directly beneath the vines through the use of herbicides would reduce competition so that vines could grow larger and produce more fruit. This practice has carried over to winegrape vineyards. The practice of maintaining a weed-free zone under the trellis results in herbicide migration into waterways (Martinson et al. 2009), soil erosion from bare strips (Martinson et al. 2009), as well as vigorous canopies where clusters are hidden by several layers of leaves resulting reduced flower bud initiation for the following season (Wolf, 2008). Herbicides are expensive to use (Yeh et al., 2014) and the high cost contributes to the estimates that grape growers are losing money producing most hybrid and vinifera grape cultivars (Gomez, 2014).

Planting annual groundcovers underneath the trellis rather than maintaining an herbicide strip may offer a potential method for reducing herbicide use, reducing erosion, reducing vine vigor through competition, and hence reducing production costs. The limited research on under-vine groundcovers to date has been conducted on vinifera vines which lack vigor compared to hybrids. Recommendations from those studies could not be carried over to hybrid winegrapes as the cover crops tested were not competitive enough to impact hybrid vines.

Prior to this project my research group had studied the impact of under-vine cover crops on Vitis vinifera winegrapes, but not hybrid wine grapes. These previous projects operated under grants funded by SCRI, SARE, and the Director Endowments at the NYSAES, and provided ample evidence of the ability of under-vine cover crops to improve the environmental and economic sustainability of vineyards. These projects were not previously funded by SCBGP or SCBGP-FB funds. Since hybrids are more vigorous we anticipated the results would differ. Since grape growers were operating in the red (Yeh et al., 2014), our primary motivation centered around reducing management costs. Current vineyard practices for maintaining an herbicide strip underneath the vines, for example, were $128 per acre per year (Yeh et al., 2014). In contrast, we estimated that establishing and managing a low-growing cover crop directly underneath the vine would be less than $50 per acre per year. The added potential benefits of reduced herbicide runoff into nearby bodies of water, reduced soil erosion, and reduced vine vigor resulting in increased yield are difficult to assign a value to. In short, we hypothesized that using under-vine groundcovers could result in considerable economic savings for winegrape growers, as well as the long-term environmental benefits. We estimated that if all of the hybrid acreage was eventually converted to use of under-vine groundcovers in the long-term, saving $78 per acre in production costs, the economic impact could be $312,000 per year in NY.

Project Approach

Experimental Setup

The trial was conducted at a commercial vineyard on the western side of Seneca Lake in Penn Yan, NY (42°38’03.0’’N, 76°56’52.0’’W, 247 m elevation) in 2015 and 2016. A randomized complete block design was replicated four times with 54 vines per replication – each experimental unit contained a data panel of three vines in between two guard panels the same size for a total of nine vines. Eight-year-old Noiret scions on 3309C rootstocks were trained to the Umbrella Kniffen system on 2 m spacing within the row and 2.7 m between rows. The soil was a shallow Kendaia loam and Lima silt loam, with depth ranging

from 0.6 – 0.9 m (U.S. Department of Agriculture, 2016). Row middles were resident vegetation (i.e. a mix of species).

In 2015, the cover crops were hand seeded on May 27th after rototilling with a Troy BLT Horse and hand hoeing the soil closest to vines and posts. Cover crops were seeded into the former herbicide strips at the following rates: 244.35 kg/ha of KY31 fescue (*Lolium arundinaceum*), 14.01 kg/ha of tillage radish *(Raphanus sativus*), 28.02 kg/ha of alfalfa vernal (*Medicago sativa),* 6.83 kg/ha of chicory Oasis (*Chichorium intybus*), and 168.13 kg/ha of mix (oat, pea, vetch, and fava bean). Glyphosate was applied on July 21st at a rate of 0.16 l/m^2. In 2016, chicory, fescue, and alfalfa reestablished themselves, small bald spots were selectively hand hoed and reseeded on May 27th. Fescue was mowed once to eliminate weed interference with the fruiting zone. The radish and mix treatments were cultivated and reseeded using the same methods and rates from 2015. Due to the persistent drought in 2016 (Figure 1), radish and mix failed to germinate by mid-June and were seeded at the above rates a second time. In an effort to save the treatments, radish and mix were irrigated on June 22nd at a rate equivalent to 1.3 cm of precipitation, yet they barely emerged. As a result, these treatments were not included in the 2016 data analysis. Glyphosate was applied on July 10th 2016.

Vines were shoot thinned to 20 shoots per linear meter of row during the first week of June in both years. 1-2 suckers per vine were preserved as future renewal trunks. In 2015, shoots were trained downwards with a rake wire which is typically necessary in an umbrella kniffen system. The rake wire was not used in 2016 due to the shortness of the shoots that year.

Climate data for both years was sourced from the Dundee (Weimer) weather station (42°34'12.00"N, 76°55'48.00"W, 214 m elevation) located 7.4 km from the experiment site. The station is managed by the Network for Environment and Weather Applications (www.newa.cornell.edu).

Shoot Lengths and Diameters

Following shoot thinning, four random shoots per data vine (twelve shoots per experimental unit) were designated for data collection and labeled A-D. Shoot lengths were measured from the base to the tip with a tape measure, and shoot diameters were measured above the first fully developed node near the base with electronic calipers (Hangzhou Maxwell Tools, model ME1002). An average of two diameter measurements - the greatest and least diameter – was calculated for each shoot to account for the oblong shape. Rate of shoot elongation was calculated by finding the difference of average length between two consecutive dates and dividing by the number of days between measurements.

Nutrient Analysis

One hundred petioles total were collected from both sides of the canopy in each experimental unit at veraison in 2015 and at bloom in 2016. Guard panels were included in the sampling to avoid excessive defoliation of the data vines. Samples were dried at 65°C for 48 hours then submitted to the Cornell Nutrient Analysis Laboratory for combustion analysis of C and N and dry ash extraction of macro and micronutrients.

Under-Vine Biomass

Cover crop and weed biomass was collected from each treatment at veraison in both years. A square frame equaling an area of 0.09 m^2 was randomly placed twice under each data panel, and the vegetation within it was cut at the base. The vegetation was dried at 65°C for 48 hours and then weighed. Weeds were removed from the cover crops to be weighed separately.

Harvest

Harvest occurred on October 6th 2015 and September 20th 2016 one to two days prior to when the

commercial grower planned to harvest the fruit. The number of clusters per vine were counted and the yield per vine was measured in lugs with a tared hanging scale (Hangzhou Maxwell Tools, model ME1002). Average cluster weight was calculated by dividing the number of clusters per vine by the yield per vine. Average berry weight was determined by collecting and weighing 100 berry samples from each treatment (Sartorius, model ELT103, Goettingen, Germany).

Pruning Weights

Pruning weights were collected in March 2016 and November 2016. Vines were pruned to four fruiting canes of ten buds each. The one-year-old wood from each data vine was weighed with a hanging scale (Salter Brecknell, model SA3N340). Crop load (Ravaz index) was calculated by dividing yield (kg) by pruning weight (kg).

Juice Analysis

Twenty clusters from each treatment were collected at harvest from each experimental unit and frozen until processing. Samples were thawed to room temperature and pressed by hand through cheese cloth. Soluble solids were measured using a digital refractometer (Misco, model PA203X, Cleveland, OH), pH was measured using a digital meter (Fisher Scientific, Accument Basic AB15, Hampton, NH), and titratable acidity was measured by auto-titrating 5 mL of juice with 0.10 M NaOH to a pH endpoint of 8.2 (Metrohm, 848 Titrino Plus, Switzerland). Samples were also tested for yeast assimilable nitrogen (YAN) by enzymatic analysis (Randox Monaco RX, model RS-232, United Kingdom).

Winemaking and Wine Analysis

In both years, wine was made from grapes in the glyphosate, chicory, and fescue treatments. In 2016, the entire experimental unit (guard panels plus data panels) had to be harvested in order to have enough fruit for winemaking. The Vinification and Brewing Lab at Cornell University's New York State Agricultural Experiment Station in Geneva, NY processed the fruit using conventional red winemaking techniques. Fruit was destemmed, crushed, treated with 50 mg/L of sulfur dioxide, and inoculated with ICV-GRE yeast (Lallemand). Diammonium phosphate (DAP(Scott Laboratories, CA)) was added to raise the YAN to 200 mg N/L. Fermentation and maceration was conducted in 114 L glycol jacketed stainless steel tanks (Vance, Geneva, NY). After fermentation to dryness (residual sugar <0.5%), skins were pressed, racked into 5 gallon glass carboys, and inoculated with "Alpha" malolactic bacteria (Lallemand). Upon completion of malolactic fermentation, the wines were cold stabilized and sulfur dioxide was added at a rate of 60 mg/L. Wine pH and titratable acidity was analyzed using the same methods as for juice chemistry, and an Oenofoss instrument ((Foss Oenofoss, Foss North America, Eden Prairie, MN) was used for malic acid, acetic acid, lactic acid, ethanol, glucose, and fructose.

Sensory Analysis

Fifty-three participants ranked 2015 wines and fifty participants ranked 2016 wines from three treatments (chicory, fescue, and glyphosate) in order of preference in exchange for $5 compensation (Berkey et al. 2011). Participants were required to be 21+ years of age and drink red wine more than once a month. Wines from the three treatments were presented to participants in all-purpose wine glasses with a plastic cap on top (to preserve aroma) and treatments were coded with random integers.

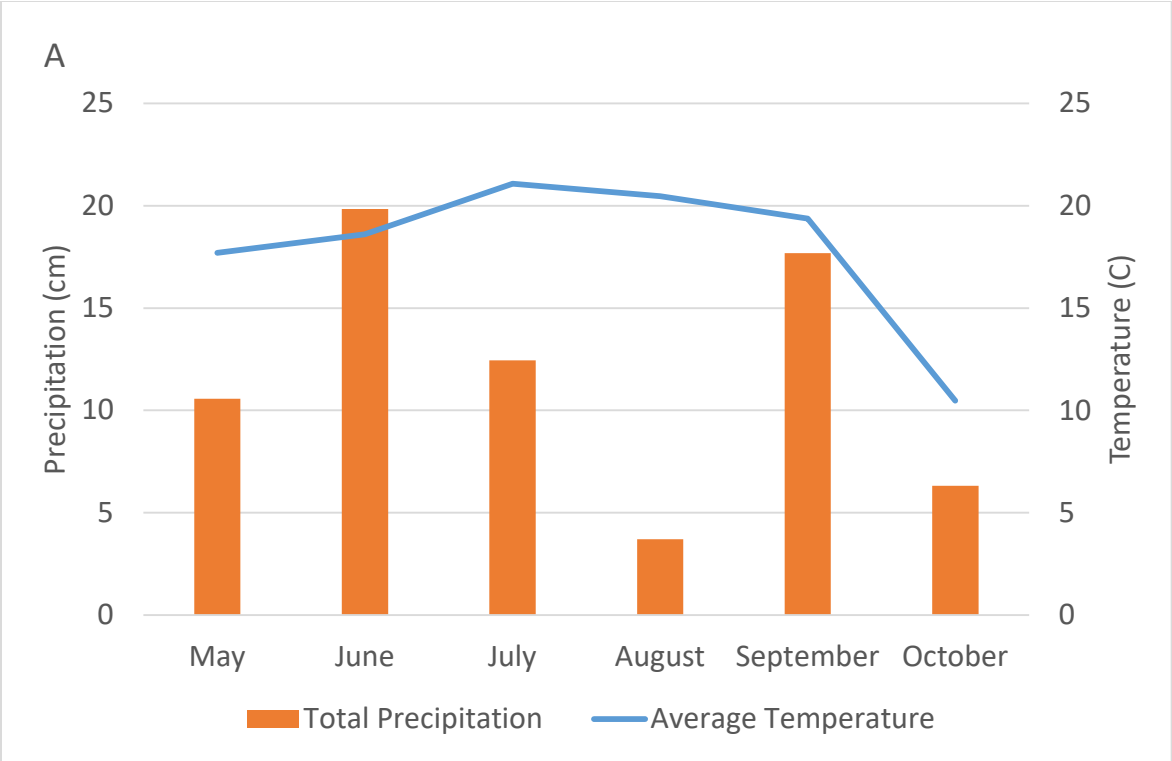
Statistical Analysis

JMP Pro version 12.0.1 (SAS Institute, Cary, NC). All data (with the exception of sensory data) was analyzed using a mixed model ANOVA with treatment as a fixed variable and replication and vine numbers nested as random effects. Values are an average of four field replications. A mixed model ANOVA was conducted and significance determined using the Tukey HSD test at $P < 0.05$. Data from the sensory study was analyzed using the Newell McFarlane test for rank sum differences (Newell and MacFarlane 1987) and the Dunn method for joint ranking at $P < 0.05$ (Dunn 1964).

RESULTS:

Weather

The 2016 growing season from May 1st to October 31st accumulated 3,067 (base 50 F) growing degree days and received 51.7 cm of precipitation – in comparison, 2015 was relatively cooler and wetter, at 2,851 GDD and 70.6 cm of precipitation (Figure 1). Between May 1st and harvest on September 20th 2016, the site received a total of 30 cm of precipitation. The Finger Lakes region experienced a Class 3 (severe) drought in 2016, according to the U.S. Drought Monitor.



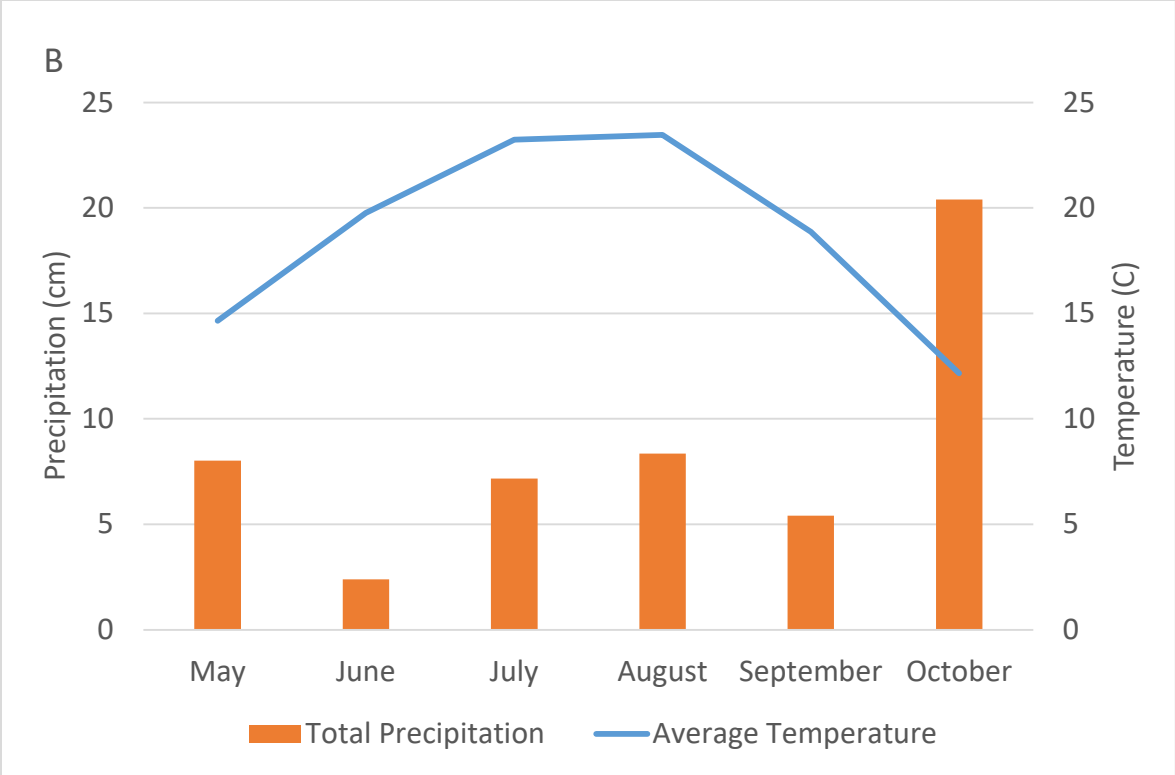


Figure 1 Monthly temperature and precipitation at Dundee (Weimer) Weather Station in 2015 (A) and 2016 (B). Station is 7 km from research site. Data accessed from New York State Environmental Applications (NYS IPM Program/Network for Environment and Weather Applications 2009).

Cover Crop Establishment

Chicory, fescue, and alfalfa successfully re-established in the second year. Data for mix and radish are presented for 2015 only, due to failed germination in 2016. Fescue had the lowest cover crop biomass on average (18.41 g) and chicory the highest (37.42 g) in 2016 (Figure 2). No significant differences were found for cover cop biomass or weed biomass among treatments in 2016.

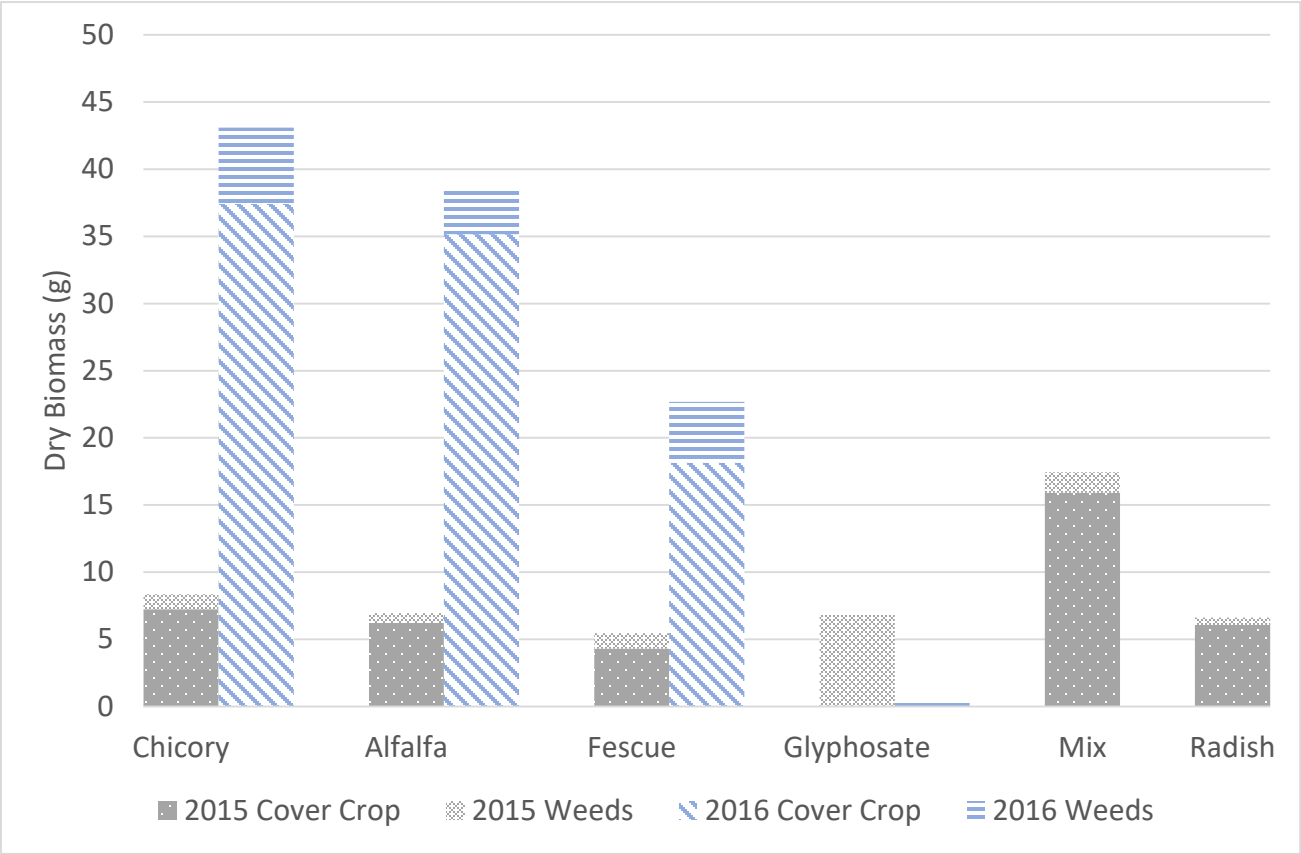


Figure 2 Biomass of cover crops and weeds at veraison in two years of an under-vine cover cropping experiment on Noiret grapevines in the Finger Lakes, NY.

Vegetative Growth

Under-vine cover crop treatments had no impact on shoot length or diameter in 2015 (Tables 1 and 2). In 2016, significant differences in length were observed at each data collection point throughout the season, and significant differences in diameter were observed at the last two measurements. Vines in the fescue treatment had the shortest shoots (60.6 cm) while vines in the glyphosate control had the longest shoots (97.4 cm) by the end of the summer. The shoot lengths of all treatments were significantly reduced compared to the control.

Table 1. Shoot lengths (cm) of Noiret grapevines during two consecutive growing seasons on a commercial vineyard in the Finger Lakes, NY.

Shoot Lengths 2015					
Under Vine Treatment	**15 June**	**24 June**	**10 July**	**22 July**	**7 Aug.**
Alfalfa	76.0 a	96.2 a	115.9 a	128.4 a	130.7 a

Chicory	75.0 a	94.5 a	108.9 a	119.6 a	120.7 a
Fescue	69.8 a	87.7 a	103.4 a	115.3 a	119.4 a
Glyphosate	67.4 a	86.8 a	104.8 a	111.6 a	119.2 a
Mix	71.6 a	91.4 a	110.8 a	121.2 a	123.6 a
Radish	73.9 a	92.8 a	117.4 a	130.25 a	135.9 a
P - Value	0.4068	0.5432	0.4005	0.4241	0.5329

Shoot Lengths 2016

	7 June	**17 June**	**June 29**	**July 12**	**July 26**
Alfalfa	43.6 ab	52.9 b	59.8 b	57.1 b	58.2 b
Chicory	43.9 ab	53.8 b	63.2 b	63.3 b	66.3 b
Fescue	40.8 b	51.4 b	61.4 b	59.6 b	60.6 b
Glyphosate	49.7 a	62.5 a	83.4 a	84.4 a	97.4 a
P - Value	0.0079	0.0021	<0.0001	0.0036	0.0003

Data was analyzed using a mixed model ANOVA, with treatment as a fixed variable and replication and vine numbers nested as random effects. Values are an average of four field replications. A mixed model ANOVA was conducted and significance determined using the Tukey HSD test at $P < 0.05$. Treatment means followed by different letters are significantly different.

Table 2. Shoot diameters (cm) of Noiret grapevines during two consecutive growing seasons on a commercial vineyard in the Finger Lakes, NY.

Shoot Diameters 2015					
Under Vine Treatment	**15 June**	**24 June**	**10 July**	**22 July**	**7 Aug.**
Alfalfa	7.5 a	8.1 a	8.9 a	8.9 a	8.8 a
Chicory	7.6 a	8.3 a	8.9 a	8.8 a	8.8 a
Fescue	7.2 a	7.7 a	8.2 a	8.3 a	8.4 a
Glyphosate	7.1 a	7.5 a	8.3 a	8.2 a	8.2 a
Mix	7.4 a	7.9 a	8.3 a	8.5 a	8.4 a
Radish	7.3 a	7.9 a	8.3 a	8.5 a	8.4 a
P - Value	0.4519	0.1714	0.3084	0.3281	0.4286
Shoot Diameters 2016					
	7 June	**17 June**	**June 29**	**July 12**	**July 26**
Alfalfa	6.1 a	6.7 a	6.8 b	6.7 b	6.9 b
Chicory	6.5 a	6.9 a	7.1 ab	7.2 ab	7.4 ab
Fescue	6.1 a	6.7 a	7.0 ab	6.9 ab	7.1 ab
Glyphosate	6.4 a	7.8 a	7.6 a	7.5 a	7.8 a
P - Value	0.1826	0.1172	0.0238	0.0337	0.0373

Data was analyzed using a mixed model ANOVA, with treatment as a fixed variable and replication and vine numbers nested as random effects. Values are an average of four field replications. A mixed model ANOVA was conducted and significance determined using the Tukey HSD test at P < 0.05. Treatment means followed by different letters are significantly different.

Vine Nutrient Status

Treatments had no impact on vine nutrient status as measured by petiole analysis at veraison in 2015 (Table 3). In 2016, petioles were sampled at bloom due to visual symptoms of nitrogen deficiency. Petiole analysis results confirmed nitrogen deficiency across all treatments and the control. Target values of 1.2 – 2.2% nitrogen at bloom are recommended for the Northeast (Wolf 2008), while means ranged from 0.55% (glyphosate) to 0.68% (alfalfa). Iron was slightly below recommended target values of 300 – 100 ppm in everything except fescue (31 ppm). The only significant difference among treatments was found in copper concentration: vines in the chicory treatment averaged 27.10 ppm, well above the recommended range of 5 – 15 ppm. Glyphosate, fescue, and alfalfa treatments were 42%, 44%, and 63% (respectively) lower in copper concentrations compared to chicory. Despite being in the toxicity range, no visual symptoms of copper toxicity were observed during the growing season. The cooperating grower confirmed that the site has not been sprayed with any copper fungicides in over 20 years.

Table 3. Analysis of petiole macronutrients (%) and micronutrients (ppm) from Noiret grapevines on a commercial vineyard in the Finger Lakes, NY. Nutrient concentration is dry weight at veraison in 2015 and at bloom in 2016.

Macronutrients

	N		**P**			**K**		**Ca**		**Mg**
Under Vine Treatment	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**
Alfalfa	0.59	0.68	0.30	0.24	1.80	1.74	1.96	2.24	0.52	0.35
Chicory	0.58	0.64	0.27	0.28	1.79	1.77	1.97	2.04	0.53	0.37
Fescue	0.57	0.59	0.26	0.26	1.52	1.63	1.98	2.27	0.52	0.43
Glyphosate	0.63	0.58	0.31	0.27	1.84	1.72	1.93	1.98	0.48	0.38
Mix	0.59	-	0.29	-	1.71	-	1.96	-	0.52	-
Radish	0.61	-	0.33	-	1.99	-	1.91	-	0.52	-
P - Value	0.7898	0.2147	0.1238	0.8407	0.1171	0.8121	0.9141	0.3963	0.7918	0.1405

Micronutrients

	B		**Cu**		**Fe**		**Mn**		**Zn**	
Under Vine Treatment	2015	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**
Alfalfa	37.08	35.84	6.37	9.93 b	61.58	29.19	-	108.87	-	38.73
Chicory	36.99	36.74	6.28	27.10 a	66.61	28.70	-	117.03	-	41.94
Fescue	36.49	39.25	7.19	15.08 b	64.25	31.11	-	119.67	-	39.56
Glyphosate	37.30	34.51	6.77	15.77 b	62.66	27.48	-	116.11	-	32.90
Mix	37.98	-	6.34	-	53.99	-	-	-	-	-
Radish	39.66	-	6.31	-	53.39	-	-	-	-	-
P - Value	0.3583	0.2263	0.3409	0.0013	0.6782	0.5131	-	0.6843	-	0.0781

Data was analyzed using a mixed model ANOVA, with treatment as a fixed variable and replication and vine numbers nested as random effects. Values are an average of four field replications. A mixed model ANOVA was conducted and significance determined using the Tukey HSD test at $P < 0.05$. Treatment means followed by different letters are significantly different.

Yield Components

Under-vine cover crop treatments had no impact on yield components in 2015 (Table 4). In 2016, yield per vine and average cluster weight were significantly decreased in all treatments compared to the control: glyphosate yielded highest at 4.3 kg/vine and alfalfa yielded lowest at 2.0 kg/vine. There was no difference in cluster number per vine in 2016. Crop size and cluster weight decreased from 2015 to 2016 across all treatments and the control.

Pruning weights were significantly different between the control and the fescue and alfalfa treatments in 2016. However, no differences were found in Ravaz indices (crop load), which ranged from 6.42 (alfalfa) to 7.42 (glyphosate).

Table 4. Yield components of Noiret grapevines on a commercial vineyard in the Finger Lakes, NY at harvest in 2015 and 2016.

Under Vine Treatment	Clusters per vine		Yield per vine (kg)		Cluster Weight (g)	
	2015	**2016**	**2015**	**2016**	**2015**	**2016**
Alfalfa	49.2	51.9	4.6	2.0 b	97.6	33.92 b
Chicory	61.3	50.0	5.9	2.5 b	97.4	51.18 b
Fescue	57.9	47.1	5.5	2.4 b	97.2	53.18 b
Glyphosate	57.9	52.1	5.2	4.3 a	90.9	82.17 a
Mix	63.6	-	6.1	-	97.5	-
Radish	58.5	-	6.0	-	103.0	-
P - Value	0.3512	0.8671	0.1255	0.0019	0.7303	0.0006

Under Vine Treatment	Berry Weight (g)		Pruning Weight (kg)		Ravaz Index (kg/kg)	
	2015	**2016**	**2015**	**2016**	**2015**	**2016**
Alfalfa	1.83	1.07	1.17	0.32 b	7.45	6.42
Chicory	1.83	1.13	1.16	0.41 ab	6.43	7.06
Fescue	1.90	1.14	0.99	0.36 b	6.56	6.77
Glyphosate	1.90	1.38	1.23	0.58 a	4.58	7.42
Mix	1.86	-	1.27	-	6.90	-
Radish	1.81	-	1.28	-	5.35	-
P - Value	0.3802	0.0981	0.6101	0.0091	0.6200	0.8913

Data was analyzed using a mixed model ANOVA, with treatment as a fixed variable and replication and vine numbers nested as random effects. Values are an average of four field replications. A mixed model ANOVA was conducted and significance determined using the Tukey HSD test at $P < 0.05$. Treatment means followed by different letters are significantly different.

Juice and Wine Chemistry

Treatments had no impact on juice and wine chemistry in 2015 (Tables 5 and 6). In 2016, significant differences were found in soluble solids between the treatments and the control; fescue had the highest soluble solids at 21.3 °Brix and glyphosate the lowest at 20.0 °Brix.

Table 5. Analysis of juice chemistry in harvested Noiret grapes from a commercial vineyard in the Finger Lakes, NY.

	Soluble Solids (°Brix)	Titratable Acidity (g/L)	pH	Yeast Assimilable Nitrogen (mg/L)

Under Vine Treatment	2015	2016	2015	2016	2015	2016	2015	2016
Alfalfa	18.9	20.8 ab	6.4	4.1	3.50	3.72	137.4	49.8
Chicory	19.6	20.5 bc	6.7	4.8	3.47	3.68	151.8	42.8
Fescue	19.8	21.3 a	6.4	4.3	3.46	3.65	110.6	45.6
Glyphosate	18.9	20.0 c	6.6	4.1	3.48	3.64	143.9	61.5
Mix	18.9	-	6.4	-	3.51	-	147.5	-
Radish	19.4	-	6.3	-	3.51	-	171.9	-
P-value	0.7317	0.0015	0.8370	0.5459	0.5708	0.8789	0.6494	0.4496

Table 6. Analysis of wine chemistry in finished Noiret wines.

	pH		Titratable Acidity (g/L)		Malic Acid (g/L)		Lactic Acid (g/L)	
Under Vine Treatment	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**
Chicory	3.40	3.46 b	8.35	7.66 a	2.35	-	0.80	1.80
Fescue	3.36	3.49 b	8.20	7.13 b	2.45	-	0.80	1.75
Glyphosate	3.38	3.55 a	8.30	7.17 b	2.60	-	0.65	1.75
Mix	3.41	-	8.15	-	2.55	-	0.80	-
P-value	0.0687	0.011	0.2280	0.0342	0.2887	-	0.0298	0.9000

	Acetic Acid (g/L)		Ethanol (%)		Glucose and Fructose (%)	
	2015	**2016**	**2015**	**2016**	**2015**	**2016**
Chicory	0.04	0.70	10.80	11.15	0.22	0.01
Fescue	0.08	0.70	10.70	11.15	0.24	0.01
Glyphosate	0.09	0.65	10.85	11.05	0.24	0.01
Mix	0.07	-	10.65	-	0.25	-
P-value	0.1939	0.4648	0.8135	0.7221	0.2795	0.9725

Data for Table 5 and 6 was analyzed using a mixed model ANOVA, with treatment as a fixed variable and replication and vine numbers nested as random effects. Values are an average of four field replications. A mixed model ANOVA was conducted and significance determined using the Tukey HSD test at P < 0.05. Treatment means followed by different letters are significantly different.

Sensory Analysis

In 2015 there was no difference in panelist preference for wines made from the glyphosate and fescue treatments (Tables 7 and 8). However, wines from both fescue and glyphosate were significantly preferred over wines made from the chicory treatment in that year. Rank sum differences using the Newell and MacFarlane test corroborate the results from the Dunn method – rank sum difference greater than 25 confirms P < 0.05 significance for preference for glyphosate and fescue over chicory. In 2016, the Newell and McFarlane test showed no significant difference in panelist preference for any of the wines, while the Dunn method indicated significant preference for glyphosate over chicory wines.

Table 7. Analysis of sensory data using nonparamteric comparisons for all pairs of Noiret wines from 2015.

Pair Comparisons	Score Mean		Standard Error Difference		p-Value	
	2015	2016	2015	2016	2015	2016
Glyphosate – Fescue	-18.98	-3.98	8.432907	8.192319	0.0732	1.000
Fescue – Chicory	-21.98	-15.98	8.432907	8.192319	0.0274	0.1533
Glyphosate - Chicory	-40.98	-19.98	8.432907	8.192319	<0.001	0.0442

Data was analyzed using the Dunn method for joint ranking at P < 0.05.

Table 8. Rank sum analysis for consumer preference of 2015 and 2016 Noiret wines produced from vines with under-vine cover crop treatments.

Treatment	Rank Sum	
	2015	2016
Glyphosate	86 a	92
Fescue	85 a	96
Chicory	127 b	109

Data was analyzed using the Newell and MacFarlane test. Treatment means followed by different letters are significantly different.

Economic analyses

Table 9. Summary of partial budget model variables used to determine revenue per hectare in under-vine management trial of Noiret.

Description	**Unit**	**Value ($)**	**Rate per Season**
Glyphosate Spray	$/ha	232	1
Glyphosate Spot Application	$/ha	84	1
Seed Spreading: Fescue, Alfalfa, and Chicory	$/ha	51	1 every other year
Seed Spreading: Radish, and Mix	$/ha	51	1
Fescue Seed	$/kg	2.20	244.35 kg/ha
Tillage Radish Seed	$/kg	18.34	14.01 kg/ha
Alfalfa Seed	$/kg	5.29	28.02 kg/ha
Chicory Seed	$/kg	29.63	6.83 kg/ha
Oat, Pea, Vetch, Fava Bean Seed Mix	$/kg	1.94	168.13 kg/ha
2015 Noiret Price	$/t	728	-
2016 Noiret Price	$/t	765	-

Table 10. Partial budget analysis comparing the impact of under-vine groundcover on yield and management cost for 2015 and 2016.				
	Cost of Under-vine Groundcover Maintenance ($/ha)	**Yield (t/ha)**	**Crop Value ($/ha)**	**Crop Value minus Cost of Under-vine Maintenance ($/ha)**
Treatment	**2015**			
Glyphosate	316.00	9.61	6997.45	6681.45 a
Fescue	563.07	10.17	7401.93	6838.86 a
Tillage Radish	307.94	10.91	7941.23	7633.29 a
Alfalfa	173.73	8.57	6242.43	6068.70 a
Chicory	227.87	11.00	8008.64	7780.77 a
Oat, Pea, Vetch, Fava Bean Mix	377.17	11.35	8264.81	7887.64 a
p-value	-	-	-	0.1401
	2016			
Glyphosate	316.00	7.9	6056.73	5740.73 a
Fescue	563.07	4.4	3364.85	2801.78 b
Alfalfa	173.73	4.6	3527.78	3354.05 b
Chicory	227.87	4.1	3102.75	2874.88 b
p-value	-	-	-	0.0028

The cost of maintaining the under-vine treatments differed based on the cover crop. Table 9 demonstrates that while maintaining glyphosate (herbicide) totaled $316/ha, planting tillage radish, alfalfa, and chicory were all cheaper. When net economic returns were calculated based on yield per hectare, there were no significant differences among treatments despite a roughly $1,200 increase in returns per hectare in the mixed cover crop and the chicory compared to the glyphosate.

2016 was a challenging year in the vineyard due to the significant drought (Fig. 1B). While it can be assumed that management costs were similar, all vines with cover crops produced significantly less fruit than those in the glyphosate treatment, resulting in decreases in net returns of almost $3,000 per hectare in the fescue and chicory treatments.

Prejean winery partnered with us for this project, providing the vineyard and donating the fruit. They made a considerable sacrifice in the 2016 growing season by allowing us to keep the experiment going despite the drought, which will have carry-over effects on the vines this year.
Steve Lerch worked tirelessly on the project, as did graduate students Taylor Mattus and Raquel Kallas.

Goals and Outcomes Achieved

OUTCOME

Reduce production costs in hybrid winegrapes by replacing herbicides with under-vine cover crops

GOAL

1. All NY hybrid growers gain the potential to reduce production costs by approximately $78 per acre by using under-vine cover crops instead of herbicides.

2. 120 hybrid winegrape growers complete our cover crops potential worksheet at BEV NY 2017 to learn how cover crops can help them reduce production costs

RELATED ACTIVITIES

1. Partial budgets for each treatment in study were calculated based on our two years of study at the site.

2. Results were presented in a handout to approximately 175 attendees at the BEV conference in 2017. We are still building the cover crop potential worksheet based on feedback from growers. While we've had to estimate costs of seeding since we don't have the cost of actual mechanical seeding, Hans Walter-Peterson of the Finger Lakes Grape Program has developed a seeder. Growers would like to see his numbers incorporated into the worksheet.

We achieved the goal with tillage radish, alfalfa, and chicory. The mix and fescue ended up costing more than the herbicide treatment!

With the exception of the cover crop potential worksheet (which is under development) we have met all goals.

Baseline and progress data toward achieving set targets are clearly laid out in Table 10.

Beneficiaries

The primary target group for this project was the approximately 250 NY winegrape growers and their vineyard managers who farm approximately 8,500 acres of winegrapes within NY, about 4,000 of which are hybrid cultivars (NASS, 2013). While NY's wine regions are gaining prominence for quality wine production, economic analyses (Yeh et al., 2014) suggest that at average yields vinifera grape growers in the Finger Lakes are operating at a net loss of $638-1,390 per acre, while hybrid winegrape growers are operating at a net loss of $377-1,391 per acre (Gomez, 2014).

Current vineyard practices for maintaining an herbicide strip underneath the vines are $128 per acre ($316 per hectare) per year (Yeh et al., 2014). In contrast, the cost of a cover crop was as low as $70 per acre per year (unfortunately $20 more per acre than we had hoped, but a savings of >$50 per acre

compared to herbicide). If all of the hybrid acreage was eventually converted to use of under-vine groundcovers in the long-term, saving $58 per acre in production costs, the economic impact could be $232,000 per year in NY.

Outside of NYS, there are approximately 650 acres of hybrids in PA, 500 acres in MI, 300 acres in IN, 500 acres in OH, 1060 acres in IL, 800 in MO, and about 1100 acres of cold hardy hybrids throughout other Midwestern states and the Northeast . Therefore total acreage of hybrids is about 8,000 acres in the USA, for a potential national impact of $464,000 per year. There is also the potential value of reduced soil erosion, reduced herbicide runoff, and potentially increased yield as a result of this practice yet these additional benefits could have tremendous economic impact in the long term.

Lessons Learned

The primary lesson we learned was that in a year of intense drought, under-vine cover crops may have to be terminated to reduce competition for water and nutrients. While this may seem intuitive, we've been working with under-vine cover crops on vinifera since 2010 and never had a problem, and hybrids tend to be more vigorous and therefore less susceptible to reductions in water availability!

The other important lesson is that the industry wants very precise information about costs. While we've estimated them to the best of our ability, the industry would like to see actual costs after mechanical seeding is developed (currently under development by the Finger Lakes Grape Program).

An unexpected outcome was that despite the intense drought of 2016, the wines were surprisingly palatable. This result provided hope that growers who use this practice will not see a large reduction in wine quality even in a drought.

Goals were achieved with the exception of the cover crop potential worksheet discussed above.

Additional Information

N/A

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Project 5 (FINAL)
Searching for the Oak Wilt Pathogen, Ceratocystis Fagacearum, in New York State

Project Summary

Ceratocystis fagacearum is an exotic pathogen that was first identified in the US in 1942. Over the years it built up a damage range from the central states of Wisconsin and Michigan over to western Pennsylvania and down through Texas. The host range includes all oak species (*Quercus* sp.) but researchers believe those belonging to the red oak group (northern red oak [*Q. rubra*], northern pin oak [*Q. ellipsoidalis*], black oak [*Q. velentina*]) are highly susceptible while oaks belonging to the white oak group are considered mostly resistant. Oak trees are important trees in NYS and across the United States because products from them are used to create furniture, cabinets and flooring; to dye leather and clothing; as common urban and landscape trees, by wildlife for shelter and nutrition and many other ways. The oak wilt pathogen was first identified in upstate New York in 2008 in a neighborhood in Schenectady County. This was surprising to many because the nearest known infection was approximately 180 miles to the southwest in Pennsylvania. An eradication effort by the New York State Department of Environmental Conservation (NYSDEC) working with the regulatory officials at the New York State Department of Agriculture and Markets (NYSDAM) was made by removing the symptomatic trees from the area. In 2013, a homeowner from the affected neighborhood observed wilting and leaf blight symptoms on a red oak that had appeared healthy in 2008 and therefore, was not removed during the eradication efforts. The diagnostician at the Cornell University, Plant Disease Diagnostic Clinic (CU-PDDC) isolated the oak wilt pathogen from the material submitted and advanced molecular procedures confirmed that *Ceratocystis fagacearum,* the oak wilt pathogen was found for a second time within the neighborhood in Schenectady County. Because this potentially devastating pathogen has been identified twice in upstate NY, we felt a broader investigation was needed and searching potentially favorable sites for the oak wilt pathogen would provide reassurance among green industry members in the state that are concerned of a potential spreading or reintroduction. This project would also help us get a better understanding of the general health of red oaks across the state. It would allow us to determine if the oak wilt infection in Schenectady County was a unique situation that had been contained or if the pathogen was in other locations throughout the state and additional eradication efforts are needed. Plant pathologists and other green industry specialists that work with tree health have learned through numerous case studies that the earlier an infection is found, the greater the chances are for successful eradication. If oak wilt was found in other locations in New York State, we would need to know that so an eradication effort could be made and other plant protection procedures could be implemented.

The primary purpose of this project was to protect oaks from damage caused by the oak wilt pathogen by identifying infected trees in other areas of New York State and by implementing additional molecular testing procedures. It created an opportunity for three agencies with the common goal of protecting NYS plants to work together. The NYSDEC personnel identified and collected quality, appropriate plant samples; the CU-PDDC clinic members analyzed the tissue, made isolation attempts for the pathogen and incorporated a molecular procedure for identification; and NYSDAM served as the funding agency providing support for this work.

This project was important and timely because the potential damage can be very serious and comparisons can be made to other diseases that have forever changed the landscape of urban and natural areas in New York State such as Dutch elm disease and chestnut blight. The second identification of the oak wilt pathogen in 2013 raised an alarm regarding its ability to survive and possibly spread into other areas. Specifically in the case in Schenectady County, the pathogen most likely spread through

root grafts established amongst the oak trees in the neighborhood. This is a common growth habit which often benefits trees during times of natural stresses such as drought conditions. The root graphs allow food and water to be shared by the tree community members and unfortunately, it also allows pathogens to move freely from tree to tree. The pathogen can also spread by insect vectors, most likely oak bark beetles and Nitidulid beetles that feed on the sap of the infected trees, pick up the fungal pathogen in their mouth parts, and introduce the pathogen to nearby, healthy trees. Trees are highly susceptible in the spring when pruning of trees causes mechanical wounds but infections can take place at any time.

Our goal was to find infections early in the process when eradication efforts are more likely to be successful and not as costly. Early identifications also reduce the loss of product values. Our project provided NYS green industry members with useful data based on surveying for the pathogen, finding it and actions taken by our collaborators to eradicate when found. The project was needed because oak wilt is a devastating pathogen that can cause significant damage and loss of trees if it becomes established. Receiving grant funds so personnel can focus on learning more about the distribution of oak wilt and implementing additional testing procedures has been a worthwhile investment.

This project did not build on a previously funded project with the SCBGP or SCBGP-FB

Project Approach

The CU-PDDC has a commitment to provide diagnostic analysis for New York State residents and green industry members; for the New York regulatory agencies, NYSDEC and NYSDAM; and for the federal plant pest and pathogen organizations. The Clinic has the facilities, equipment and knowledgeable personnel needed to perform various types of testing from basic isolation attempts and microscopy to the more advance serological testing and molecular procedures. The NYSDEC provided the collection site recommendations, performed the collections with PDDC staff assistance, and supplied tools and equipment needed to retrieve samples from very tall trees. Both organizations have a well-trained work force capable of performing the activities described. The PDDC is one of only four laboratories in the nation that has been granted NPDN STAR-D (System for True, Accurate, and Reliable Diagnostics) quality management system accreditation.

This project had three key objectives:

Objective 1: Collected visual observations of symptoms on oaks at potentially favorable sites for the establishment of oak wilt infections. NYSDEC personnel determined the best sites where oak wilt pockets might establish. The NYSDEC personnel identified symptomatic trees, recorded locations and collected samples, at times with the PDDC's field technician. They recorded observations such as percentage of red oak in the area (tree diversity can impact root grafting), percentage and extend of the damaged trees, and flagging and/or evidence of mycelial mat formation. They worked with the PDDC staff and learned that even more than with other pathogens, obtaining a quality sample is extremely important when working with suspect oak wilt samples and doing so can reduce the risk of false negatives due to improper sample handling. Submissions included wilted twigs, browning leaves, or trunk tissue. Samples brought back to the lab if the PDDC technician was part of the collection team or either dropped off at the Clinic or shipped by an overnight delivery service.

Additionally, marketing materials were created to inform other green industry members such as Cornell Cooperative Extension-County based personnel, arborists and growers of our project and asking them to

be on the lookout for symptoms of an oak wilt infections. A "BOLO" (Be On The Look Out) poster and postcards were created to help facilitate this objective. The green industry members were encouraged to share the materials with others that visit their offices for information. They were also provided details about the oak wilt pathogen, host plants, infection process, spreading capabilities, distribution and this Specialty Crop Block Project by the PDDC staff providing numerous lecture presentations using various outreach activities such as webinars, trainings, workshops, conferences and booth space at group meetings.

Objective 2: Determine if symptomatic samples contained the pathogen that causes oak wilt, *C. fagacearum*. The accepted method of processing suspect oak wilt samples is isolation and morphological identification. The fungus that causes oak wilt is believed to be the only member of that Genus pathogenic to oak and most diagnosticians in states that have oak wilt are confident with their morphological identification of the Genus level. The problem with this method is that it is a very time consuming process due to the slow growth rate of the fungus.

The PDDC staff examined the plant material submitted for analysis and selected material most likely to provide fungal growth from the tissue if the pathogen was present. The laboratory staff members made isolation attempts on APDA (Acidified Potato Dextrose Agar), an agarose medium conducive with hindering bacterial contamination while promoting fungal growth. The pathogen required a few weeks of development time to produce identifiable structures and obtain pure cultures. While selecting tissue for isolation attempts, the PDDC staff members also selected material to be used in the PCR analysis step.

Objective 3: Determine if newly developed PCR identification techniques will provided consistent results from pure cultures and directly from plant material. As mentioned in objective 2., the accepted method of processing suspect oak wilt samples is morphological identification. In addition to isolations being a very time consuming process due to the slow growth rate of the fungus, the accurate identification of the fungus relies on the ability of the diagnostician. Many diagnosticians have experience doing this and are confident with their abilities but those lacking experience may find this a difficult task. Therefore, the development of an additional method would be helpful for a few reasons; 1) It can confirm a result using a different type of test method, 2) the PCR testing would provide a much faster identification and 3) it may reduce the risk of false negatives by identifying the pathogen at much lower levels.

This objective of the project allowed us to determine if a PCR procedure gave consistent results to morphological identifications and if identifying the pathogen directly from plant tissue reduced the diagnostic time versus the amount of time needed for isolation attempts to develop. We performed the PCR using pure cultures (if available) and on all submissions using the plant material (twigs or bark with cambium tissue) submitted. As an additional confirmatory step with positive samples, the PCR product was submitted to the GenBank library to determine if our samples matched.

Samples were processed in two distinct ways:

1. DNA extracted from **branch tissue** and processed using the nested PCR, and
2. if fungal growth characteristic of the oak wilt pathogen was produced during the isolation attempts, DNA was extracted from the **fungal isolate** and processed using the nested PCR procedure.

The conventional PCR procedure used was published by the Juzwik laboratory and was being evaluated in the PDDC to determine if the procedure would meet our needs and perform as expected. The objective of using tissue directly versus a fungal isolate was one of our primary evaluation procedures to determine if this method was consistent and could be used with confidence for evaluating samples. The testing was performed in nested steps using primers that had been designed to be specific to *Ceratocystis fagacearum*, the fungus that causes oak wilt. Sequence analysis was done using the National Center for Biotechnology Information's (NCBI) online Basic Local Alignment Search Tool (BLAST).

For each sample tested, the samples proceeded through the steps of DNA extraction, conventional polymerase chain reaction (PCR) designed to be specific for *C. fagacearum*, and gel electrophoresis.

Significant Contributions and role of project partners in this project:

The project created an opportunity for representatives from three agencies with the common goal of protecting NYS plants to work together;

1. Karen Snover-Clift and Mary Ann Karp, the Cornell University Plant Disease Diagnostic Clinic (CU-PDDC),
2. Rob Cole and Jennifer Kotary, the New York State Department of Environmental Conservation (NYSDEC) and
3. Chris Logue and Inspectors, the New York State Department of Agriculture and Markets (NYSDAM)

In addition, the following individuals and organizations also contributed time to the project, sample collection and outreach education efforts for NYS members.

1. Mina Vescera, Cornell Cooperative Extension, Suffolk County, Extension Educator,
2. Russ Welser, Cornell Cooperative Extension, Ontario County, Extension Educator,
3. Margery Daughtrey, Long Island Horticulture, Research and Extension Center, Cornell University, Riverhead, Senior Extension Associate

The primary investigator from the Cornell University Plant Disease Diagnostic Clinic (CU-PDDC) developed the original grant proposal and the accepted grant work plan and budget. The clinic staff produced training materials that provided details of basic biology, symptoms and pathogen expression, spreading mechanisms, identification tools and contact information. This was done using Powerpoint presentations given physically at meetings and through a webinar format and with the production of "Be On the Look Out-BOLO" postcards and posters. The Clinic staff researched methods, purchased laboratory supplies, implemented laboratory techniques to include enhanced morphological identification and molecular procedures and processed sample submissions. Conducted many outreach presentations to report on the project accomplishments as well as inform others to be on the look-out. The primary role of the PDDC, was to evaluate and conduct the diagnostic testing methods. The CU-PDDC clinic members analyzed the tissue, made isolation attempts for the pathogen, incorporated and validated a molecular procedure for the identification

of the pathogen, provided training for NYSDEC staff on collecting and submitting a quality suspect oak wilt samples, cataloged images of submissions, organized sample results and reported results to appropriate officials. Additionally the laboratory provided numerous outreach activities, initially creating and distributing posters and postcards, providing webinars and trainings and informing green industry members of the project results.

The New York State Department of Environmental Conservation (NYSDEC) used their own funding for all aspects of their activities in this project. They committed staff time to education about the pathogen and hired additional staff to assist with the collection of appropriate diagnostic samples from suspect trees. Both of these activities were collaborations with the CU-PDDC staff. NYSDEC staff performed fly overs to gather images of trees from above, searching for damaged oak trees to include in collection efforts. The NYSDEC staff also performed the removal of trees that tested positive and performed follow-up visits to locations of previously positive trees that had been removed, collecting additional samples if symptoms were present.

The New York State Department of Agriculture and Markets (NYSDAM) administered the funding and participating in training events so their staff could also be on the look-out as they were conducting their business across New York State. Their inspectors also assisted NYSDEC staff with collections at times.

The other people associated with the project submitted samples, assisted in outreach efforts, worked with experts from the central states to learn more about the pathogen and were available to answer questions from residents when the announcements were made that oak wilt was found in their counties.

Goals and Outcomes Achieved

In 2015, 22 samples were submitted for analysis and one (1) produced a suspect positive that was re-collected 3 additional times in 2016. In 2016, 55 samples were submitted for analysis and fourteen (14) produced positive results. The 15 positive samples out of the 77 samples submitted is provided in a spreadsheet below. The site column groups positive sample from one area together. A key is also provided below.

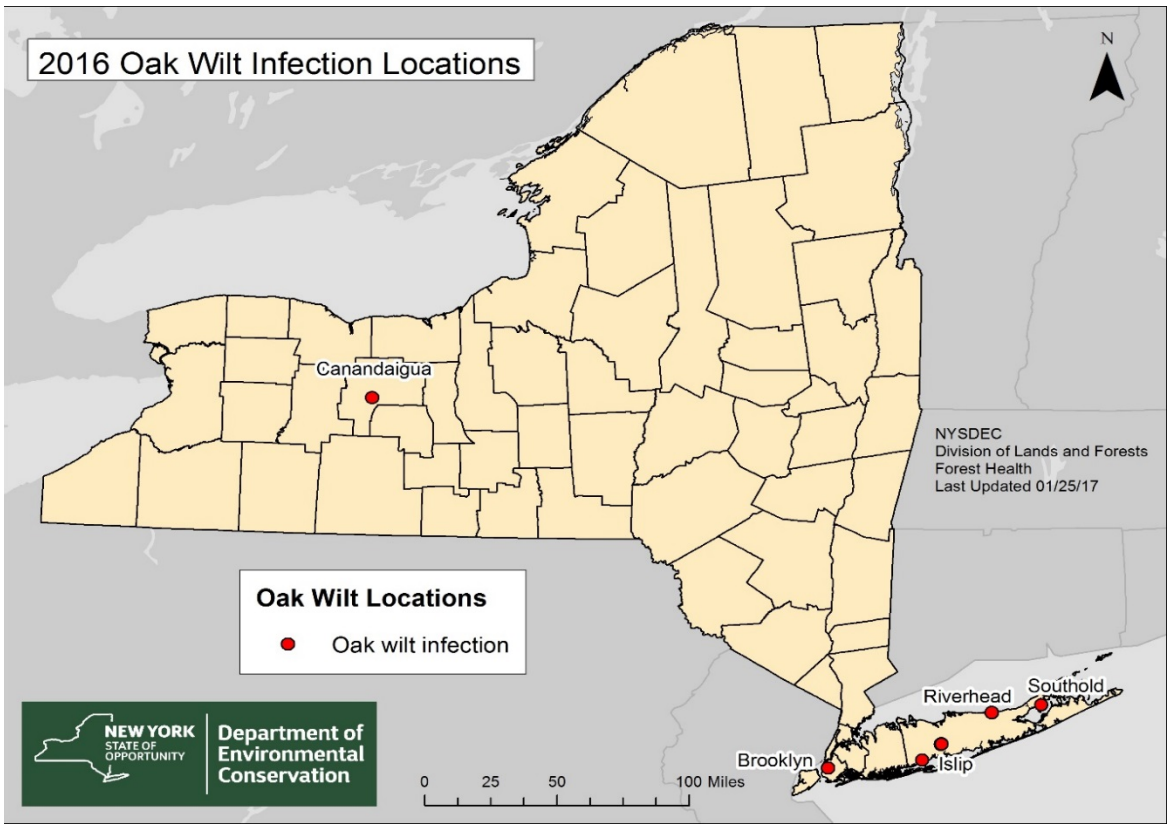
Lab Number	Plant	Site	Street	Field ID	Culture?	Tissue PCR	Isolation PCR	Sequencing	Overall result	Site:
OW15-00022	*Quercus rubra*	Central Islip	181 Allwood Ave.		negative	**POSITIVE**	n/a	*Ceratocystis fagacearum*	*C. fagacearum* identified	A
OW1600001	*Quercus rubra*	Central Islip	181 Allwood Ave.	DAM-001	negative	**POSITIVE**	n/a	*Ceratocystis fagacearum*	*C. fagacearum* identified	A
OW1600002	*Quercus rubra*	Central Islip	181 Allwood Ave.	DAM-002	negative	**POSITIVE**	n/a	*Ceratocystis fagacearum*	*C. fagacearum* identified	A
OW1600003	*Quercus rubra*	Central Islip	181 Allwood Ave.	DAM-003	negative	**POSITIVE**	n/a	*Ceratocystis fagacearum*	*C. fagacearum* identified	A
OW1600009	*Quercus rubra*	Central Islip	181 Allwood Ave.	DAM-001	mycelium	ngative	**POSITIVE**	*Ceratocystis fagacearum*	*C. fagacearum* identified	A
OW1600013	*Quercus velutina*	West Islip	78 Deforest Ave	20161804	negative	**POSITIVE**	n/a	*Ceratocystis fagacearum*	*C. fagacearum* identified	B
OW1600022	*Quercus rubra*	Little Hog Neck		20161820	negative	**POSITIVE**	n/a	*Ceratocystis fagacearum*	*C. fagacearum* identified	C
OW1600024	*Quercus rubra*	Little Hog Neck		20161823	negative	**POSITIVE**	n/a	*Ceratocystis fagacearum*	*C. fagacearum* identified	C
OW1600027	*Quercus rubra*	Brooklyn	GreenWood Cemetary	20161801	negative	**POSITIVE**	n/a	*Ceratocystis fagacearum*	*C. fagacearum* identified	D
16-00495	*Quercus rubra*	Canandaigua	6015 Ketchum Rd		**POSITIVE**	**POSITIVE**	**POSITIVE**	n/a	*C. fagacearum* identified	E
OW1600028	*Quercus rubra*	Canandaigua	6015 Ketchum Rd		**POSITIVE**	**POSITIVE**	**POSITIVE**	*Ceratocystis fagacearum*	*C. fagacearum* identified	E
OW1600032	*Quercus rubra*	Central Islip		20161900	negative	**POSITIVE**	n/a	*Ceratocystis fagacearum*	*C. fagacearum* identified	A1
OW1600033	*Quercus alba*	Central Islip	185 Alwood Av	20161898	negative	**POSITIVE**	n/a	*Ceratocystis fagacearum*	*C. fagacearum* identified	A2
OW1600035	*Quercus rubra*	Central Islip	48 Sportsmen St	20161901	negative	**POSITIVE**	n/a	*Ceratocystis fagacearum*	*C. fagacearum* identified	A3
OW1600036	*Quercus rubra*	Central Islip	48 Sportsmen St	20161902	negative	**POSITIVE**	n/a	*Ceratocystis fagacearum*	*C. fagacearum* identified	A3
OW1600037	*Quercus rubra*	Central Islip	48 Sportsmen St	20161903	negative	**POSITIVE**	n/a	*Ceratocystis fagacearum*	*C. fagacearum* identified	A3
OW1600038	*Quercus rubra*	Central Islip	123 Sportsmen St	20161904	negative	**POSITIVE**	n/a	*Ceratocystis fagacearum*	*C. fagacearum* identified	A4
OW1600039	*Quercus rubra*	Central Islip	123 Sportsmen St	20161905	negative	**POSITIVE**	n/a	*Ceratocystis fagacearum*	*C. fagacearum* identified	A4
OW1600040	*Quercus rubra*	Central Islip	123 Sportsmen St	20161906	negative	**POSITIVE**	n/a	*Ceratocystis fagacearum*	*C. fagacearum* identified	A4

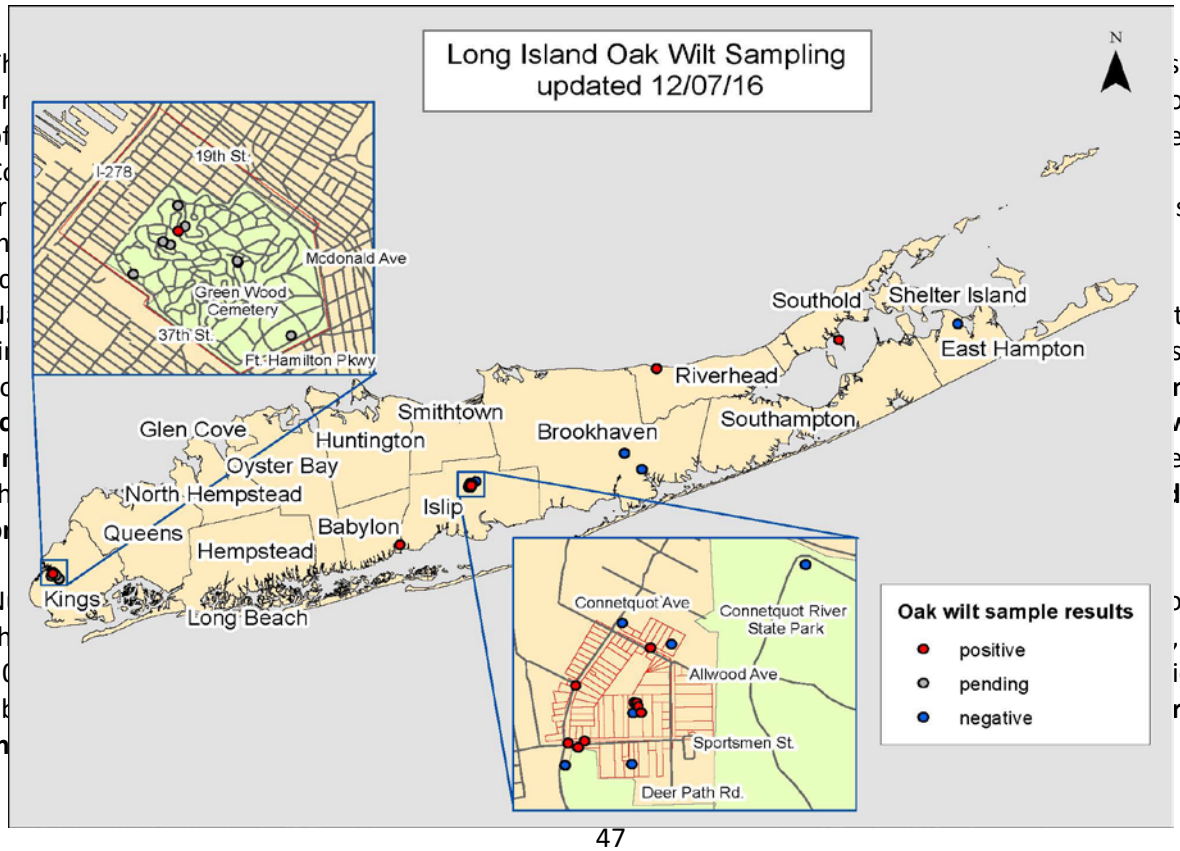
All projected goals were met for the project; 1) we surveyed numerous areas across New York State for the oak wilt pathogen and informed many residents and green industry members to be on the lookout for the disease, 2) we determined the presence of the pathogen in new locations using both morphological and molecular test methods, and 3) we believe we can use the PCR procedure directly from tissue which will reduce the diagnostic process time table.

Location code:	Description of location:
0	*Glenwood Neighborhood-Schenectady county*
A	*Original for Long Island-Central Islip*
A1	*Central Islip-*
A2	*Central Islip-48 Alwood Avenue*
A3	*Central Islip-48 Sportsman Street*
A4	*Central Islip-123 Sportsman Street*
B	*West Islip*
C	*Little Hog Neck*
D	*Brooklyn*
E	*Canandaigua*

The overall outcome achieved during this project was the positive identification of the oak wilt pathogen at numerous locations on Long Island and in Canandaigua, an additional upstate New York site. Fifteen (15) positive identifications were achieved because of this project. The positive results were located in five (5) new, unique locations on Long Island and one (1) in Canandaigua, in upstate NY. **These findings increase the total number of locations from one (1), the original site in Schenectady county, to seven (7) New York State locations where of the oak wilt pathogen has been identified.** This is a significant accomplishment that was made possible because of this grant. The diligent work of numerous staff members from three NYS institutions; NYSDAM, NYSDEC, and Cornell University, made this an extremely successful collaborative project and because of the SCBG system, we were able to find these new

locations and hopefully contain or eradicate the pathogen and reduce the risk of infecting even more New York State oak trees.





Beneficiaries

The purpose created an opportunity for three agencies with the common goal of protecting NYS plants to work together, NYSDEC, NYSDAM and the Cornell University Plant Disease Diagnostic Clinic. All of the collaborators and other green industry members of New York, such as arborists and nursery growers, benefitted from this project by learning more about the establishment of this harmful, exotic pathogen; by improving identification techniques; and by taking swift actions to remove any positively identified trees. The residents of New York were also beneficiaries as protection of plants affects their homes and land and natural areas were they may spend their recreation time.

The NYS nursery growers will be the primary beneficiaries of this project, and other members of the green industry will be positively affected as well. The wholesale nursery industry in New York (2007 figures) is comprised of 34,672 business establishments with $187 million in sales and $189 million in value added impact. The green industry in New York taken as a whole is worth $6.29 billion (http://www.fred.ifas.ufl.edu/economic-impact-analysis/pdf/US-green-industry-in-2007.pdf). Mature oak trees are extremely valuable for many reasons; they have a beautiful appearance with a broad, full canopy and they hold on to their fall color longer than any other species; they provides shade and a wind barrier; they attract birds and wildlife seeking shelter, a place to raise their young, and a source of nutritious food. Replacing a mature oak will take hundreds of years and generations in time and their value financially may be $1000s per tree. If you plant a seed today, you and your child may not get to enjoy the mature characteristics of that tree but your grandchildren might benefit from your planting. Removal of infected trees can be costly. Estimates for a single tree removal can range from $2000 up to $7000 depending on the site conditions and the labor force and type of equipment needed for removal. Protecting trees from the pathogen using fungicides is also costly and can range between $300 and $600 dollars per year per tree. If trenching is required, it may cost between $5 and $10 per linear foot. This can also add up quickly even if only a couple of trenches are needed in a backyard. If three, fifty-foot trenches are needed between four trees, it will cost a homeowner approximately $1000. Fees in communities or by state environmental conservation agencies can easily reach 100s of thousands of dollars if the pathogen is found to be established in an area. A case study of a single county in Minnesota with established oak wilt pockets, resulted in an estimated $2-6 million dollar annual expenditure for managing infected trees. Additionally property value losses need to be addressed as a significant issue. Property value losses due to sudden oak death (a similar, significant, non-native, forest, pathogen) in a county in California were estimated at $13 million dollars. Our findings will most likely not only impact NYS residents and businesses but other states where oak wilt is a problem.

Lessons Learned

A number of lessons were learned throughout this project.

1. The biggest lesson learned was the fact that the **oak wilt pathogen was present in locations we previously were not aware of**. Because of these discoveries, we are making sure that all of our outreach efforts include information about the possibility of an unknown pathogen being found by observant members of the green industry community. This was not a surprise to us but it did confirm that green industry members are often our eyes and ears in the field and we need to keep them informed.

2. Another lesson learned was the fact that **getting this organism in pure culture is extremely difficult**. It is a weak competitor and other more robust organism that may be secondary contaminants often outgrow the target pathogen in an artificial growth situation such as nutritive agarose plates. The pathogen can take from 3 to 6 weeks to develop the characteristics needed for a morphological identification. Margery Daughtrey, of our department and from the Long Island Horticulture Research & Extension Center in Riverhead and Snover-Clift both reached out to an expert from the United State Forest Service, Dr. Jennifer Juzwik. Dr. Juzwik explained that trying to isolate the pathogen from plant tissue collected during the months of November through March can be very difficult and they rarely attempt isolations during this time period of the year. She also suggested using a different culturing medium known as Barnett Oak Wilt Medium. We immediately ordered the supplies needed to make this much more specific medium so we could use it with future submissions. We did not have any additional success with the Barnett Oak Wilt Medium. In the future, we will not try to attempt isolations between November and April.

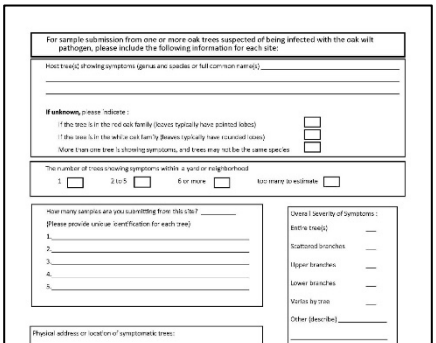
3. **Incorporating the molecular PCR procedure into our tools for identification worked in both situations we designed into this project**. It produced results directly from the tissue samples as well as from the isolates when they were available. As mentioned above, we had problems getting some of the samples isolated that produced positive PCR results. Therefore, the PCR procedure we evaluated for this project identified the pathogen more often than we could confirm with isolates.

4. We also learned that **having a second PCR procedure would be beneficial for confirmation purposes** when isolations are not productive. This would be helpful during the off season times when isolating is extremely difficult which is a significant time of year from November through early April. Also having this second method would help us provide testing service for trees that may have died the previous year and do not have living tissue available for isolation attempts. The DNA of the pathogen may remain in the stumps of the trees.

5. We also learned the sequencing is a valuable tools that we used during this project to confirm our PCR testing results. The source used for blasting the sequencing results was GenBank. GenBank a database of nucleotide sequences and the primary resource used by many scientists. The database contains over 300,000 organisms but only lists 12 sequences for comparison of our pathogen of interest, *Ceratocystis fagacearum*. **We would like to contribute to this database and submit the oak wilt pathogen sequences we produced as part of this project.**

Additional Information

For additional information, see examples of the marketing materials we produced to inform NYS residents and green industry members of the oak wilt pathogen. The Plant Disease Diagnostic Clinic webpage includes the oak wilt sample submission form and instructions, the Be On the Look Out (BOLO) Poster and Postcard, and other information is found at the following address:
http://plantclinic.cornell.edu/oakwiltpage.html


For sample submission from one or more oak trees suspected of being infected with the oak wilt pathogen, please include the following information for each site:

Host tree(s) showing symptoms (genus and species or full common name(s)): _____

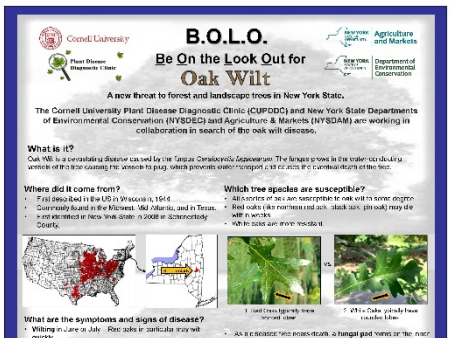
If unknown, please indicate:
- ☐ If the tree is in the red oak family (leaves typically have pointed lobes)
- ☐ If the tree is in the white oak family (leaves typically have rounded lobes)
- ☐ More than one tree is showing symptoms, and trees may not be the same species

The number of trees showing symptoms within a yard or neighborhood
1 ☐ 2 to 5 ☐ 6 or more ☐ too many to estimate ☐

How many samples are you submitting from this site? _____
(Please provide unique identification for each tree)
1. _____
2. _____
3. _____
4. _____
5. _____

Overall severity of symptoms:
- Entire tree(s): ___
- Scattered branches: ___
- Upper branches: ___
- Lower branches: ___
- Vertex by tree: ___
- Other (describe): _____

Physical address or location of symptomatic trees:



Contact

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Project 6 (FINAL)
Biology and Economic Impact of Red Blotch Disease in New York Vineyards

Project Summary

Red blotch disease is a new threat to the grapevine industry in New York. The causal agent of the disease is grapevine red blotch-associated virus (GRBaV). Preliminary surveys indicate the presence of this virus in vineyards of the Finger Lakes and Long Island in New York (and in many other vineyards across the US) but little information is available on GRBaV spread and its impact on vine health. Our project was designed to i) Determine the effect of GRBaV on vine vigor, fruit yield and fruit quality in local vineyards, ii) Characterize spread of GRBaV in New York vineyards, iii) Develop crop budgets to assess costs of red blotch disease management, and iv) Extend information to the local grape and wine industry to raise awareness on the disease and to promote profit-driven management options. The major aim of the research and education project was to fill gaps in our understanding of the ecology of red blotch disease and disseminate science-based disease management recommendations to stakeholders. The ultimate goal was to increase vineyard profitability, reduce production uncertainties and enhance the competitiveness of the New York grape and wine industry.

GRBaV is a recently identified virus that causes yield losses and fruit ripening issues, as documented in the late 2000s to early 2010s in California. More specifically the virus reduces fruit sugar content, increases titratable acidity, and lowers berry anthocyanin and skin tannins. No information is available on the effect of GRBaV on vine health in the East Coast, particularly in New York. Similarly, information on the economic impact of GRBaV is scarce. In addition, although the presence of GRBaV is documented in New York vineyards, limited information is available on its spread. Advancing our understanding of virus spread and economic impact was anticipated to help deliver up-to-date science-based outreach information to stakeholders for optimal disease management. Based on the novelty of GRBaV to the grape and vine industry, our research and extension project was timely to inform essential factors needed to assist stakeholders deal with the recently identified disease in terms of control.

This project did not build on a previously funded project with the SCBGP or SCBGP-FB

Project Approach

We determine the effect of GRBaV on vine vigor, fruit yield and fruit quality in local vineyards over two growing seasons. Our measurements revealed a negative impact of GRBaV on vigor (-6% in Merlot in 2015 and -5% in 2016 in Merlot), yield (-11% in Merlot and -13% in Chardonnay in 2014-2105), and fruit quality (up to -2.2 Brix; up to +1.0 pH unit, and up to +1.2 titratable acidity unit [g/L] in 2014-2015). These results confirmed observations made in California and are consistent with GRBaV affecting vine vigor and fruit ripening.
To characterize spread of GRBaV in New York vineyards, two vineyards were selected in the Finger Lakes region and one vineyard were selected on Long Island. These vineyards were selected based on disease

symptoms and documented presence of GRBaV in 2013. These vineyards were established with *Vitis vinifera* cvs. Pinot noir and Cabernet franc in the Finger Lakes and with *V. vinifera* cv. Merlot on Long Island. Leaf and dormant cane samples were collected from these vineyards in fall and winter 2014 and carried to the laboratory for verification of the presence of GRBaV by polymerase chain reaction (PCR) using specific primers. Test results confirmed the presence of GRBaV in some of the samples collected. The location of infected and clean adjoining vines was marked and vines were flagged. A comparative analysis of diagnostic results of leaf samples collected in a Pinot noir vineyard in the Finger Lakes and in a Merlot vineyard on Long Island indicated no change in the incidence of GRBaV in 2014 and 2015. In the Pinot noir vineyard in the Finger Lakes, 3 of 25 samples were positive for GRBaV in PCR in both years; the 2014 infected samples were found infected in 2015, and the 2014 healthy samples were found healthy in 2015. In the Cabernet franc vineyard in the Finger Lakes, 2 of 36 samples were positive for GRBaV in PCR in both years; the 2014 infected samples were found infected in 2015, and the 2014 healthy samples were found healthy in 2015. In the Merlot vineyard on Long Island, 45 of the 67 samples were positive for GRBaV in both years; the 2014 infected samples were found infected in 2015, and the 2014 healthy samples were found healthy in 2015. These results revealed no spread of GRBaV over two consecutive years in the two vineyards surveyed, suggesting that the planting material is the primary source of virus infection in New York. In 2016, 13 of the 23 leaf samples that were collected in the Merlot vineyard on Long Island tested positive for GRBaV in PCR. Among the 13 infected, two were newly infected vines. These test results were confirmed with re-samples, indicating an increase of infected vines and a decrease of healthy vines in the Merlot vineyard, thus revealing the occurrence of spread. This is the first documentation of an increased spatiotemporal incidence of GRBaV in a vineyard in New York and on the East Coast of the United States. Further work is needed to confirm this finding and assess the attributes of the spatiotemporal spread in the Merlot vineyard on Long Island.

Crop budgets to assess costs of red blotch disease management were developed. Surveys of grape growers and vineyard managers on Long Island were conducted at the Long Island Horticultural Research and Extension Station and at their winery in April 2015. Interview outputs were used as baseline information to determine the economic impact of red blotch over a 25-yr lifespan of a vineyard. Preliminary estimates indicated losses ranging from $5,468 per acre for a 5% initial infection and a 25% price penalty for poor fruit quality to $39,140.32 per acre when initial virus prevalence is 60% and managers face a 100% reduction. These baseline results were used to assess the economic feasibility of scenarios with disease control in order to highlight profitability issues and develop a matrix of net return scenarios. Rogueing (i.e. the elimination of individual diseased vines and their replacement with clean vines), replacing the entire diseased vineyard, or no control measure were options considered in this study. Rogueing was found economically attractive if virus incidence is less than 30% and price penalties are 50% or higher. Beyond a 30% initial incidence level and under a price penalty scenario of 50-100%, pursuing a total vineyard replant minimizes the economic losses imparted by GRBaV. When price penalties for infected grapes are lower i.e., closer to 25%, rogueing and replanting is the optimal strategy up until an initial infection level of ~7%. Beyond an initial disease incidence level of 7% and under such low price penalties (25% or less) it is economically preferable for Long Island vineyard managers to not control the disease. Only if the initial incidence is as high as 70% does replanting become a more economically favorable option to no management. Economic cost analyses have been

fine-tuned and disease management scenarios have been confronted to profit-making options, leading to a matrix of net return outcomes. Under scenarios incorporating a price penalty of 25%, the economic losses associated with late disease onset in years 8 and 10 are minimized when a strategy of 'no control' is pursued. This finding holds regardless of the initial disease prevalence level. When faced with a higher price penalty of 50%, rogueing and replanting becomes economically favorable to all other strategies when the initial incidence level ranges from 1 to approximately 20%, and 1 to approximately 15% for onset in year 8 and 10, respectively. If disease onset occurs in year 8 and the initial disease level exceeds 20%, full vineyard replacement is optimal. These data should help New York growers manage red blotch disease in infected vineyards.

We extended information on the project to the local grape and wine industry to raise awareness on the disease and to promote profit-driven management options. Results were presented and discussed at a Cornell Recent Advances in Viticulture and Enology Agriculture Conference during Food and Environmental Systems In-Service on November 4, 2015 (60 participants) and on November 2, 2016 (60 participants). Presentations were also made for representatives of the New York Wine and Grape Foundation, NY State Department of Agriculture and Markets and Governor's office in July 2016 (20 participants), and to a delegation of New York State Farm Bureau (30 participants) in October 2015. Updates were also delivered to New York grape growers and extension educators in Syracuse, NY (50 participants) in March 2015, in Riverhead, NY (20 participants) in March 2016 and in Rochester, NY (160 participants) in March 2016. In addition, presentations on the project were made during webinar seminar series in February 2016 (310 participants) and March 2016 (50 participants) as well as at the Estern Winery Exposition in March 2017 (100 participants) In summary, information pertaining to the project "Biology and Economic Impact of Red Blotch Disease in New York Vineyards" was delivered to over 800 people in 2015-2017.

Partners were essential to the success of the project. Cooperating growers in the Finger Lakes region and on Long Island of New York substantially contributed to the project by providing key information in terms of disease impact and management. This information was essential to develop economic models of red blotch disease management. Cooperating growers also provided regular and unrestricted access to vineyards of interest to determine the impact of GRBaV in vine vigor, fruit yield and fruit juice chemistry, as well as on virus spread. In addition to grower cooperators, Dr. Keith Perry contributed to determine the presence/absence of GRBaV in grapevine tissue; to inform spread. Dr. Tim Martinson contributed to assess the impact of GRBaV on fruit juice chemistry, determine virus incidence in Finger Lakes vineyards, and facilitate the dissemination of information; Dr. Miguel Gómez contributed the survey templates, the economic impact assessment of GRBaV and the development of economical viable disease management options; and Alice Wise contributed to determine the presence of GRBaV in Long Island vineyards, and to evaluate the impact of GRBaV on vine vigor, fruit yield and fruit juice chemistry.

Goals and Outcomes Achieved

- Supply the activities that were completed in order to achieve the performance goals and measurable outcomes for the project.
  The following activities were completed:
  - Determine the effect of GRBaV on vine vigor and fruit quality to document the negative impact of the virus in vine health.
  - Characterize GRBaV incidence over time in selected vineyards to document the occurrence of GRBaV spread on Long Island in New York State
  - Develop crop budgets to assess costs of red blotch disease management to develop profit-maximizing disease management recommendations
  - Extend information to the local grape and wine industry to raise awareness on the disease and to promote profit-driven management options

One of the goals of the project was for growers to adopt optimal disease management strategies. Some growers in the Finger Lakes and Long Island in New York as well as in California adopted our recommendations but continued efforts are needed to increase even more the level of adoption of the newly development management recommendations

Actual accomplishments are matching with the goals established for the reporting period. The table below provides a comparative analysis of initial goals and actual accomplishment.

Initial Goal	**Actual accomplishments**
Select vineyards in the Finger Lakes and Long Island where GRBaV is suspected based on symptomatology and previously documented presence of the virus	Monitored vineyards in the Finger Lakes and on Long Island for GRBaV and selected a Merlot vineyard on Long Island to determine impact on vine growth and fruit production
Create a survey template to interview vineyard managers and obtain information on disease pressure and management	A survey template was developed
Collect vine samples in vineyards of interest and test for GRBaV	Vine tissue was collected in Finger Lakes and Long Island vineyards for GRBaV testing
Flag GRBaV-infected and clean vines in four vineyards each in Finger Lakes and Long Island	GRBaV-infected and clean vines were flagged, especially in a Merlot vineyard on Long Island
Compare infected and healthy vines for fruit yield (number of clusters per vine and berry weight) and fruit juice	Comparative data were obtained for fruit yield and fruit juice chemistry

chemistry (sugar content and titratable acidity)	
Compare infected and healthy vines for vigor (pruning wood weight)	Comparative vigor information was obtained
Interview vineyard managers	Vineyard managers were interviewed in the Finger Lakes and on Long Island in New York
Extend information to the grape and wine industry	Information on the biology and ecology of red blotch disease was disseminated to the grape and wine industry
Compile survey results and develop cultural, harvest and overhead costs.	Survey results were analyzed and cost estimates were obtained
Monitor GRBaV incidence in selected vineyards in Finger Lakes and Long Island	GRBaV test results were analyzed and virus incidence levels were determined for vineyard surveyed
Compare baseline results to scenarios with disease control to highlight profitability issues and develop a matrix of net return scenarios	Different disease scenarios and disease management options were combined for the development of economically viable management recommendations
Compare infected and healthy vines for fruit yield and quality	Fruit yield and fruit juice chemistry data were analyzed
Compare infected and healthy vines for vigor (pruning wood weight)	Vigor data were analyzed
Reach out to stakeholders and publish extension articles in varied journals and web sites.	Information was disseminated to stakeholders primarily at winter meetings or webinar seminar series but no information was published in extension articles or web sites.
Develop costs of different management options	Economically viable disease management options were developed
Compile data on GRBaV incidence over time	GRBaV incidence data were complied over three growing seasons
Fine tune economic cost analyses	Economic cost analyses were optimized and validated by vineyard managers

Compile data on GRBaV effect on vine vigor, fruit yield and fruit quality	Data on the impact of GRBaV were compiled and analyzed
Incorporate new knowledge into integrated disease management recommendations	New knowledge on the biology and ecology of red blotch disease were taken into account for the development of management options
Change our knowledge of the effect of GRBaV on vine vigor, fruit yield and fruit quality and its economic impact. The target was to create knowledge on the effect of GRBaV on vine vigor, fruit yield and fruit quality and its economic impact	Experimental evidence was obtained on the negative impact of GRBaV on vine vigor (-5.5%), fruit yield (-12%) and fruit quality (-2.2 Brix; +1.0 pH unit, and +1.2 titratable acidity) and economic impact ($5,468 per acre for a 5% initial infection and a 25% price penalty for poor fruit quality to $39,140.32 per acre when initial virus prevalence is 60% and managers face a 100% reduction)
Increase the number of growers who are aware of red blotch and its impact; the target was to disseminate information to 400 grape growers.	Information on the project and research outcomes was disseminated at growers' meetings and conventions to 840 participants in 2014-2017
Increase the number of growers who will adopt profit-driven management options. The target was to have 10-20 growers adopt profit-driven management options.	A total of 14 growers, including eight in New York and six in Virginia have adopted our management options based on rogueing, if disease incidence is low or moderate (<30%), and removal of entire vineyards if disease incidence is high (>30%).

All the proposed research and extension activities were completed in order to achieve the performance goals and measurable outcomes for the project, as shown in the Table above.

Beneficiaries

Primary beneficiaries of the project are grape growers and vineyard managers in New York, the East Coast and the United States. Extension educators, farm advisors, grape nurseries and service providers are also indirect beneficiaries of the new knowledge gained through this project.

Growers adopting our disease management recommendations can save up to $8,352 per acre over a 25-year lifespan of a vineyard in New York. Savings can reach $27,752 per acre over a 25-year lifespan of a vineyard in California and $6,291 in Washington State.

Lessons Learned

A major lesson learned through the successful completion of this project is how critical it is for an interdisciplinary team to combine complementary expertise to tackle an emerging agricultural problem. Associating virologists, extension personnel, a viticulturist, and an ag economist was key to interact with growers, fill gaps in our limited knowledge of the ecology of the disease, and develop innovative disease management strategies.

Another major lesson learned is how critical it is to include researchers with extension responsibility in the team of investigator to facilitate interactions with growers, the implementation of the project, and the dissemination of information to a wide audience locally, regionally, nationally or even internationally.

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Fruits of GRBaV-infected (left) and healthy (right) Pinot noir.

Close-up of foliar symptoms of GRBaV on Pinot noir in a Finger Lakes vineyard of New York.

Foliar symptoms of GRBaV-3 on Chardonnay and Merlot on Long Island in New York.

Project partners (Keith Perry, Marc Fuchs and Alice Wise) collecting grapevine samples to characterize GRBaV incidence in a Merlot vineyard on Long Island in New York. Photo courtesy of Tim Martinson.

GRAPES

Cornell University

Integrated Pest Management

Grapevine Red Blotch Disease

Grapevine red blotch-associated virus

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Introduction

Grapevine red blotch disease (GRBD) is a recently recognized viral disease. It was first described on *Vitis vinifera* cv. Cabernet Sauvignon at the University of California Oakville Research Field Station in 2008, but the causative agent was not characterized until 2012. The disease, GRBD, is caused by a DNA virus named *Grapevine red blotch-associated virus* (GRBaV). Infected red wine grapevines exhibit symptoms similar to those associated with leafroll disease, with red blotches forming on leaves during the later summer months. Fruit ripening issues have been reported in grapevines diagnosed with GRBD. The symptom similarity to leafroll disease and abiotic factors such as nutrient deficiencies, insect damage, or physical injuries makes visual diagnosis difficult and explains the delay in recognition and characterization of the disease.

Causal Agent

The causal agent, *Grapevine red blotch-associated virus* (GRBaV), has a single-stranded circular DNA genome. The virus, GRBaV, is a member of a proposed new genus in the family *Geminiviridae*. It is one of only two geminiviruses currently known to infect woody perennial plants. Within GRBaV, two groups of genetic variants have been identified so far and are being studied to determine their relative virulence, symptomatology and modes of transmission so as to improve risk assessment and disease management.

Symptoms and Impact

Grapevine red blotch disease was first described in California in 2008, but the original source of GRBaV has yet to be determined. Grapevine red blotch-associated virus has since been identified across the United States and in Canada. States with documented infected vines include Arizona, Arkansas, California, Georgia, Idaho, Maryland, New Jersey, New York, North Carolina, Oregon, Pennsylvania, Texas, Virginia, and Washington. GRBaV has been found in red wine grapes, white wine grapes, table grapes, interspecific hybrids, and rootstocks.

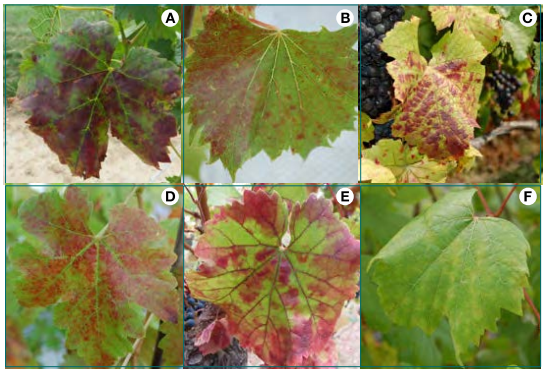

Figure 1. Foliar symptoms of red blotch on 'Cabernet franc' (A), 'Chambourcin' (B), 'Pinot noir' (C), 'Syrah' (D), 'Cabernet Sauvignon' (E) and 'Chardonnay' (F). Photos by M. Fuchs.

Figure 2. A GRBaV-infected 'Cabernet franc' vine exhibiting red blotch symptoms at the base of the canopy (left) and a healthy 'Cabernet franc' vine (right) in August-September. Photo by M. Fuchs.

As suggested by the disease name, red blotches and specks appear on leaves of infected red wine cultivars (Figure 1 A-E), sometimes accompanied by reddening of veins underneath the leaf blade or cupping. In white wine cultivars, foliar symptoms are more difficult to identify and generally involve irregular chlorotic areas sometimes accompanied by cupping (Figure 1F). Later in the season, regions of the leaf blade with severe chlorosis become necrotic. Foliar symptoms first appear on older leaves (Figure 2) at the base of the canopy in June and July and progressively move toward the top of the canopy in later months (Figure 3). Grapevine red blotch disease does not appear to substantially reduce fruit yield (Figure 4A and B, and Figure 5D and E) but does affect fruit quality by altering juice chemistry, and delaying ripening. Reductions in total soluble solids (1° to 6° Brix), and higher malic acid and titratable acidity are consistently reported in infected 'Cabernet franc', 'Chardonnay', and 'Cabernet Sauvignon' vines. In Cabernet cultivars, lower berry anthocyanin and skin tannin content have also been documented.

Transmission and Spread

Because GRBaV has been detected throughout almost all regions of the country in which wine grapes are grown, the likelihood of dissemination via propagation material is high. Although spread of GRBaV by a vector has not been confirmed, the grouping of infected vines in clusters within healthy vineyards adjacent to or near infected vineyards and the increase in number of diseased vines in healthy vineyards over time suggests that a vector is involved in disease spread. Extensive research efforts are ongoing to address spread of GRBaV.

Management

Like for other plant viral diseases, there is no cure for red blotch disease in vineyards. Selection of planting material derived from clean, virus-tested stocks is the best preventative strategy to limit the presence of GRBaV. Ongoing research developments on virus spread and transmission will likely lend insight into additional management options. So far, growers with confirmed, GRBaV-infected vines are culling them and replacing them with clean vines derived from virus-tested stocks.

Figure 3. Red blotch affected vines in a 'Cabernet Sauvignon' vineyard in October-November. Photo by M. Fuchs.

Foliar symptoms of GRBaV strongly resemble symptoms of leafroll disease, mite damage, or even magnesium or potassium deficiency. Symptom ambiguity makes visual diagnosis of infected vines difficult. Therefore, it is imperative to accurately diagnose symptomatic vines for GRBaV using a DNA-based assay to decide on the most appropriate management strategy. This is particularly true for white grape cultivars in which foliar symptoms are indistinct (Figure 1F and Figure 5 A-C) making them best candidates for DNA-based testing for the presence of GRBaV to facilitate management decisions.

Figure 4. Comparative fruit production on a (A) GRBaV-infected and (B) healthy 'Cabernet franc' vine. Photo by M. Fuchs.

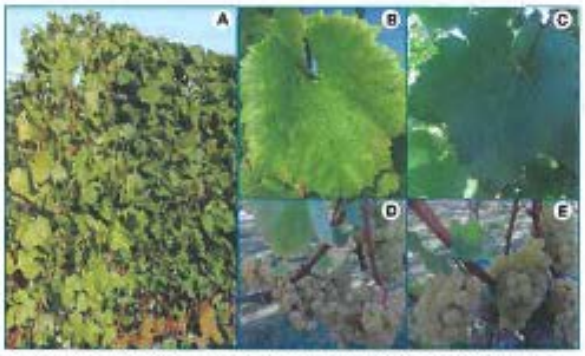

Figure 5. Red blotch disease on 'Chardonnay'. (A) Foliar symptoms on a diseased vine (left) in comparison to a healthy vine (right) (Photo by T. Martinson); close-up of a (B) diseased and a (C) healthy leaf; close-up of fruits from a (D) diseased and a (E) healthy vine. Photos by M. Fuchs.

Produced by the New York State Integrated Pest Management Program, which is funded through Cornell University, Cornell Cooperative Extension, the NYS Department of Agriculture and Markets, the NYS Department of Environmental Conservation, and USDA-NIFA. Design by Media Services, Cornell University. Layout by Karen English. New York State IPM Program. Cornell Cooperative Extension provides equal program and employment opportunities. © 2014 Cornell University and the New York State IPM Program. Posted 11/14 at www.nysipm.cornell.edu/factsheets/grapes/diseases/gv_red_blotch.pdf

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Project 7 (FINAL)

Addressing Diseases that Threaten the Developing New York Hop Industry

Project Summary

In the 1880s, New York was a vibrant center of US hop production. A succession of unusually wet years lead to extremely destructive outbreaks of two fungal diseases: powdery mildew and downy mildew. More than any other factor, the above diseases drove hop production to drier growing areas in the Pacific Northwest. The wet years in NY were followed by shortages of copper-based fungicides during WWI, and a decline in hop demand due to Prohibition. This was the death knell for the NY industry, and effectively ended local production of hops. Today, the hop industry is staging a comeback in response to a statewide resurgence of craft breweries. However, this resurgent industry was threatened by the same pathogens that destroyed plantings in the early 1900s. Moreover, the knowledge base that would allow us to effectively and efficiently address these diseases was sadly lacking. Through systematic investigation, our project established effective programs to protect hops from the threats posed by powdery and downy mildews, and established or communicated the following to NY stakeholders: (i) the quantitative susceptibility of major varieties to powdery and downy mildew under NY conditions; (ii) the essential details of pathogen survival, reproduction, and dissemination in NY; and (iii) an integrated and effective program to manage the foregoing diseases under NY conditions. Specifically, we have documented and communicated the following to the NY hop industry: (i) sources of infection and the temporal distribution of inoculum for powdery and downy mildew in NY; (ii) presence and threat posed by novel genotypes of powdery mildew able to overcome R6 resistance to powdery mildew and polygenic resistance to powdery mildew in the widely-planted cultivar Cascade; and (iii) an integrated program to effectively and simultaneously address both powdery and downy mildew under NY conditions, and to reduce erosion of the efficacy of this program through avoidance of fungicide resistance.

This project did not build on a previously funded project with the SCBGP or SCBGP-FB.

Project Approach

1. Locally collected overwintering structures (chasmothecia) were experimentally raised to maturity and then repeatedly tested for release of infectious spores (ascospores). The seasonal distribution of ascospore release was monitored and used to define the period for ascosporic infection for the powdery mildew pathogen. This model now serves an advisory purpose in disease management, and is used to predict a period of high risk for infection during which hopyards should be protected. Doing so markedly improves the efficacy of any disease management program.

2. Isolates of the powdery mildew pathogen were collected from hopyards throughout NY, DNA was extracted from the isolates, and the extracted DNA was analyzed by AmpSeq to identify genes associated with resistance to key families of fungicides, including DMIs such as

myclobutanil, strobilurins such as azoxystrobin, and SDHIs such as boscalid, and quinolines, such as quinoxifen. Results indicted a relatively high frequency of isolates with resistance to DMIs, but not other groups. This information can be used to guide programs to prevent spread of fungicide resistance isolates in NY.

3. NY hopyards in Watkins Glen and Wolcott NY were found to harbor severely infected plants that were putatively of the R6 resistant cultivar Nugget. The presence of severe powdery mildew on a R6 cultivar would indicate that a pathotype of the powdery mildew pathogen known only to the Pacific Norhtwest had been introduced on nursery stock to NY. This was a threat because the R6 form of host resistance is common among many hop cultivars, and it's loss due to importation of an exotic isolates would possibly require replanting of some hopyards to new varieties with alternative forms of resistance, in particular those under organic management practices. Isolates were reduced to clones and were tested for pathogenicity on known plants of Nugget without infection. This indicated that the reason the NY plants were mildewed was that they had been mis-identified as Nugget at the nursery, and therefore the isolates they bore were not able to overcome R6. The infected plants were furthermore traced to a single nursery in Michigan. Both the nursery and regulatory, university, and cooperative extension officials in NY and MI were notified of our findings.

4. Epidemics of powdery and downy mildew are presumed to be temperature-driven. All prior work has focused upon the assumption that mean daily temperatures or the number of hours during which temperature remain in an optimal range are the most significant determinants of disease severity. We discovered that rather than average temperature, that the number of cold-shock events was causing early season disease to "flat-line", and not increase, despite intervening protracted periods of favorable temperatures. This finding, coupled with information on the development of ontogenic (age-related) resistance was used to define the phenological and seasonal period during which hops are at the greatest risk of severe disease: from immediate prebloom until approximately 2 weeks postbloom. This period represents the time during which efficacy of fungicidal suppression must be near-perfect. By identifying and communicating this to growers, we greatly increased the efficacy of disease suppression, with no increase in the number of sprays applied.

Role of project partners in the project.

1. David M. Gadoury, Senior research associate, Cornell University: Project director and principal scientist. Responsibilities include experimental design, hiring and supervision of other project personnel, and writing and submission of project reports.

2. William Weldon, PhD student, Cornell University: Mr Weldon has adopted the epidemiology and management of hop powdery mildew as his thesis research project. He is responsible for the actual performance of experimental work, collection, analysis, and summarization of data, and reporting.

3. David Gent, Research Scientist, USDA, Corvallis Oregon. Dr. Gent is a member of W. Weldon's PhD advisory committee. He is also USDA's principal scientist tasked with research on hop disease, and an international authority on fungal diseases of hops. His lab provides advice on experiments and services the project, including the identification of pathotypes.

4. Steve Miller, Extension Educator, Cornell University. Mr Miller is a regional specialist for hops in NY, and assists with communication of project results to producers.

Goals and Outcomes Achieved

The objectives of the project were as follows:

1. Establish the quantitative susceptibility of major varieties to powdery and downy mildew under NY conditions.
2. Elucidate the essential details of pathogen survival, reproduction, and dissemination for hop powdery mildew and hop downy mildew in NY.
3. Develop an integrated an effective program to manage the foregoing diseases under NY conditions.

The activities that resulted in the fulfillment of each objective were:

1. Surveys of the pathogenic specialization of isolates growing on putatively resistant cultivars indicated that pathogenic races presently in NY do not include specific pathotypes able to overcome R6 resistance typified by Nugget, or polygenic resistance typified by Cascade. In both cases where importation an R6-virulent isolate was suspected, the putative R6 hop variety had been misidentified at the nursery. The same nursery was the source of plants in two separate NY outbreaks of powdery mildew. In the absence of hypervirulent strains or exotic isolates, the relative resistance observed for the various cultivars planted in NY should not deviate from other locales with similarly wild-type pathogen populations. Goal and Outcome achieved: Pathogen populations in NY were shown to be of the wild type, and exotic pathogen strains that would make otherwise resistant cultivars susceptible are not yet present at detectable levels in NY. Resistance of Cascade and hop varieties with R6-based resistance can be expected to make a meaningful contribution to disease suppression in NY.
2. Collection of pathogen samples and overwintering studies, as well as observations of disease progress and crop phenology under NY conditions resulted in development of temporal distribution of asocspore release, and guidelines to maximize fungicide efficiency based on risk of infection under NY conditions. Goal and outcome achieved: The period of greatest risk of primary infection, as defined by the period of powdery mildew ascospore release, was shown to occur between bud break and 1 wk postbloom in NY. This defines the 5 week window of opportunity to maximize the effect of fungicide sprays, and apply then at a time ideal for maximum disease suppression.

3. The distribution of ontogenic resistance of hops (target size and target susceptibility), plus the distribution of inoculum production (relative inoculum dose, were used to describe a critical period for fungicide application for maximum efficacy and efficiency of control. Goal and outcome achieved: Control recommendations statewide were revised to highlight the importance of increasing the intensity of

disease suppression actions during the period +/- one week of bloom to increase efficacy and reliability of IPM programs, and minimize risk of economic loss.

Beneficiaries

The groups and other operations that benefited from the completion of this project's accomplishments included all growers of hops in New York, as well as the associated value-added businesses, e.g., craft breweries. Secondary level stakeholders that benefit from downstream effects upon primary stakeholders include Finger Lakes, Western NY and Hudson Valley tourism, as well as added tourist traffic on the associated Wine Trail system of New York, much of which is co-located or coincident with craft brewing operations.

In the course of our project, we documented the total loss of crop in two NY hopyards due to powdery mildew. The first was in Watkins Glen in 2015 in a small start-up craft brewery growing approximately 2 acres, representing a direct loss of $8000 in yield, but approximately a 10-fold loss in value added product (beer and ale revenues that would have been otherwise produced). The second was on the cultivar CTZ in one of New York's largest hopyards (30 acres) in Wolcott NY, and represented proportionally larger losses. Implementation of disease management recommendations and intervention by our project personnel in both cases has prevented a recurrence of these losses, and served as instructional examples of effective UDSA-SCRI-BG research-based IPM programs presented at stakeholder conferences.

Lessons Learned

Stakeholder base is highly educated and enthusiastic, but relatively inexperienced. Educational materials must be specifically tailored to this clientel.

Industry is rapidly growing, and is sometime disconnected from supporting advisory and extension network. Additional effort is required to reach new growers with project results. You cannot depend upon them to *find you*.

Additional Information

The program has received funding for two additional projects dealing with NY hops production and IPM programs: (i) Washington State Univ./USDA SCRI #123535-G003383 - Reducing the Impact of Industry-Critical Insect & Disease Problems in Hops Through Development of Preventive & Predictive Strategies; and (ii) Engaged Cornell Grant entitled "Stakeholder Engagement: The Key to Preventing Catastrophic and Chronic Losses from Diseases that Threaten Sustainability of the NY Hop Industry". The former project can be accessed through the USDA Current Research Information System (CRIS) at https://cris.nifa.usda.gov/reports.html. The project website for the latter project is under construction.

The following abstract was presented at the 2017 Annual Meeting of the American Phytopathological Society, and was published in the December 2017 issue of the journal Phytopathology:

Cold induced disease resistance may explain unexpected stalling of foliar epidemics of hop powdery mildew (*Podosphaera macularis*). **WILLIAM WELDON (1)**, D.M. Gadoury (1), L. Cadle-Davidson (2). (1) Section of Plant Pathology and Plant-Microbe Biology, Cornell University; (2) USDA-ARS Grape Genetics Research Unit.

Epidemics of powdery mildew (*Podosphaera macularis*) on hop foliage are typified by an initial exponential increase of incidence, while severity, *i.e.,* size of mildew colonies, remains relatively constant, despite daytime temperatures optimal for pathogen growth. A similar pattern reported in grapevine powdery mildew (*Erysiphe necator*) was associated with cold-induced disease resistance (Phytopathology 100:1240-1249). We investigated the impact of both pre- and post-inoculation cold events on susceptibility of hop to *P. macularis*. Exposing young, ontogenically susceptible hop leaves to a brief (1-4 hour) cold event (4°C) 24 hours before inoculation reduced *P. macularis* hyphal density by 26.6% and colony formation success by 16.5%. A subsequent time course study involving acute cold events suggested that the magnitude of the effect of pre-inoculation cold events was maximized 36 hours after cold exposure. Sequential overnight acute cold events applied post-inoculation extended the latency period by approximately 20% and, 24 hours after initiation of sporulation, conidia production per colony was reduced by 72.8%. The discovery of a parallel induction of disease resistance by brief overnight cold events in both grapevine and hop powdery mildew pathosystems suggests that host responses to acute nighttime radiational cooling might not only explain stalling of powdery mildew epidemics in grapevine and hop, but also extend to powdery mildews of other crops.

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Project 8 (FINAL)
Sour Rot: Defining and Managing a Disease Threatening the Profitability of NYS Vineyards

Project Summary

Sour rot, a disease characterized by the breakdown of affected berries whose pulp smells of vinegar (acetic acid) and which often are associated with fruit flies (*Drosophia* spp.) in the vineyard, presents serious challenges for grape growers in New York State. Although it occurs somewhat sporadically in any given region, growers in at least one part of the state have suffered significant losses in virtually all of the past dozen years, with significant losses in 2 of the 3 years in which we conducted this project. Losses have been particularly severe on tight-clustered, high value wine grape varieties such as Pinot noir, Chardonnay, and Riesling, which are becoming increasingly important to the grape grower community due to a continuing increase in the demand for these wines produced from New York-grown grapes. However, with this increasing demand for supply has come an increasing demand for quality as well, and sour rot can have a devastating effect on both the quantity and quality of the harvested product. Unlike other important diseases that affect the crop in NYS, the organisms causing it were poorly defined when we initiated this project, and we knew so little about the disease that we had no basis for establishing rational control recommendations. Thus, the motivation for initiating this project was to define the cause of the disease; to use this information to propose and evaluate practical management programs for grape growers in NYS and beyond; and to convey these findings to growers and their advisors through a variety of oral and written communications approaches to enable them to be aware of and implement such programs.

This project did not build on a previously funded project with the SCBGP or SCBGP-FB.

Project Approach

The project had two major research foci and a related outreach focus, as described below:

Research focus 1: Determine the organisms responsible for causing sour rot.
Sour-rotted clusters were collected from 16 vineyards in the Finger Lakes region over two consecutive seasons. High levels of both ethanol and acetic acid were determined within them (averaging 1.14 and 1.58 g/L, respectively, across the two years of sampling). More than 1,300 individual microbial isolates were recovered by isolating onto specific agar media, with > 90% falling into four categories: two yeast species (strains of *Saccharomyces cerevisiae*) and two bacterial species, a *Gluconobacter* sp. (a known producer of acetic acid, i.e., a member of the acetic acid bacteria, or AAB), and a ubiquitous environmental bacterium (*Rahnella* sp.) not associated with acetic acid production nor considered a plant pathogen. Project partners who contributed to these efforts included (i) 12 commercial grape growers, who identified affected vineyard blocks and made them available to us for sampling; and (ii) Dr. Lance Cadle-Davidson, a USDA-ARS scientist who provided important technical consultancy on

methodologies for isolating and sequencing DNA from the recovered microorganisms, by which their identities were ascertained.

A series of experiments was conducted in the lab to determine whether the recovered microorganisms were, in fact, causing the disease. Berries of *V. vinifera* cultivars Cabernet Franc, Chardonnay and Red Globe were wounded and inoculated with 21 different individual yeast, mold fungi, bacteria or combinations thereof. One set of inoculated berries was exposed to fruit flies (*Drosophila melanogaster*), while a companion set was not. After eight days of incubation, berries were rated for rot and browning on a scale of 0-4, then macerated and the juice measured for ethanol and acetic acid content. Berries were determined to have sour rot if they had a visual disease rating of 3 or 4 and an acetic acid content of at least 0.83 g/L (based on the ranges detected in field samples).

Across all three cultivars, the only combinations of organisms that caused sour rot per our criteria were:

- *Aspergillus niger* (filamentous fungus) *x Gluconobacter oxydans* (AAB)
- *Hanseniaspora uvarum* (yeast) *x Acetobacter aceti* (AAB)
- *Hanseniaspora uvarum x Acetobacter aceti x Gluconobacter oxydans*
- *Pichia kluyveri* (yeast) *x Acetobacter aceti*
- *Pichia kluyveri x Gluconobacter oxydans*
- *Saccharomyces cerevisiae* (yeast) *x Acetobacter aceti*
- *Saccharomyces cerevisiae x Gluconobacter oxydans*
-

However, these we also found that these combinations produced sour rot symptoms only when berries were also exposed to *Drosophila* fruit flies after inoculation. When inoculated berries were not exposed to the flies, sour rot symptoms did not develop. In these initial experiments, we utilized a laboratory colony of *D. melanogaster*, which carry their own microbiota as they do in nature.
To determine whether the effect of the flies was due to microorganisms that they contributed or to some non-microbiological factor, colonies of axenic fruit flies were developed. These were reared in sterile media, rendering them devoid of gut and surface microbiota. In a series of similar inoculation experiments utilizing Red Globe grapes and multiple combinations of microbes plus axenic fruit flies (or not), only the following microbial combinations consistently caused sour rot symptoms, and only in the presence of axenic flies:

- *Saccharomyces cerevisiae x Acetobacter aceti*
- *Saccharomyces cerevisiae x Gluconobacter oxydans*
- *Pichia kluyveri x Acetobacter aceti*
- *Pichia kluyveri x Gluconobacter oxydans*

To further examine the role of the flies in development of the disease, we wounded berries and inoculated them with a combination of *S. cerevisiae* and *A. aceti,* then either exposed them or not to *D. melanogaster.* Ethanol and acetic acid evolution was monitored over each of 5 succeeding days. Samples inoculated with the yeast-bacteria suspension accumulated twice as much ethanol if they were not exposed to fruit flies as did as those berries that were exposed to flies . In contrast, the inoculated berries that were exposed to flies evolved more than 6 times as much acetic acid as those not exposed

to flies (Charts 1 & 2, Appendix). These results further indicate that fruit flies play a significant role in the conversion of ethanol to acetic acid in infected berries and the ultimate development of sour rot.

Collectively, these results collectively show that three interactive components are essential for sour rot development, none of which cause disease symptoms on their own: **Yeast,** which first produce ethanol from the juice of affected grapes; **Acetic acid bacteria,** which convert this ethanol to acetic acid; and ***Drosophila* fruit flies**, whose precise mechanistic role is yet to be determined. These results also suggest the possibility that sour rot can be managed via treatments that suppress the causal microorganisms and/or the fruit fly component of the disease.

Research focus 2: Developing and evaluating management strategies for sour rot; (a) Chemical components.

In a preliminary trial conducted in 2013, and two subsequent funded trials in 2015 and 2016, various treatments of antimicrobials and insecticide—both alone and in combination—were applied to a cv. Vignoles (tight-clustered interspecific hybrid variety) vineyard to test their effect on sour rot development.

In each trial, alternate vine rows were sprayed with an insecticide--Delegate (spinetoram) in 2013 or Mustang Maxx (zeta-cypermethrin) in 2015 and 2016--or left untreated. One- or two-panel plots were treated with antimicrobial materials (potassium metabisulfite, Kocide 3000 [copper hydroxide], OxiDate 2.0 [dihydrogen dioxide] or Fracture [BLAD polypeptide]) at various timings and rates (see treatment list in the manuscript entitled, "**Control of Sour Rot via Chemical and Canopy Management Techniques"**, provided at the end of the Appendix). Note that potassium metabisulfite (KMS), a common disinfectant in the winery, is *not* registered for use in the field but was included in these tests as a "proof of concept."

Insecticides were applied weekly when fruit reached 15.0° Brix, the stage where berries start to become susceptible to sour rot. The start of weekly antimicrobial treatments varied; their timing is listed in the table as: pre-symptoms–starting at 15° Brix; starting when sour rot symptoms were first visible; after the first rain following 15.0° Brix; following an increase in maximum daily dew point over 3 days; and no antimicrobial.

In 2013, antimicrobials and insecticide applied in combination provided significant control of sour rot with a reduction in disease severity (percent of cluster area diseased) of 30% to 54% compared to the unsprayed treatment**.** The vines treated solely with antimicrobial sprays did not experience a significant reduction in sour rot, nor did the treatment in which only insecticide was applied.
Significantly greater sour rot pressure developed in 2015, with nearly 30% of berries diseased on vines receiving no insecticide or antimicrobial, compared to 16% in 2013. In contrast to 2013, the insecticide alone provided significant control (57% reduction relative to untreated vines) without addition of an antimicrobial. Disease control increased significantly (73% to 84% reduction) in those panels where both antimicrobial and insecticide treatments were applied weekly starting before the onset of symptoms.

However, when addition of antimicrobials was delayed until symptoms appeared, the combination treatments did not provide significantly more control than the insecticide alone. Furthermore, even when applied on a preventive basis before symptoms appeared, antimicrobials applied alone were relatively ineffective and never provided the same level of control as insecticide applied alone.
Sour rot severity on untreated vines in 2016 was comparable to 2015. Significant control (40%) was provided when insecticide was applied without addition of an antimicrobial. Further control was achieved when any of three antimicrobials was combined with insecticide starting before the onset of symptoms, whereas delaying addition of an antimicrobial until symptom onset increased control for only one of the two materials tested.

Data from all 3 years are presented individually and cumulatively in the manuscript entitled, "**Control of Sour Rot via Chemical and Canopy Management Techniques"**, provided at the end of the Appendix. They demonstrate the importance of insecticide sprays in controlling sour rot, and the additional control that was provided when antimicrobial sprays were combined with and insecticide before the onset of symptoms. In all 3 years, applying KMS weekly beginning at 15° Brix (pre-symptoms) in conjunction with an insecticide achieved an average 65% control compared to the unsprayed treatment, and in the two years when OxiDate 2.0 was included in conjunction with Mustang Maxx on this schedule, an average 69% control was achieved. In the two years when Mustang Maxx was the insecticide used, it also provided significant control (48% average) when applied alone, whereas antimicrobials applied alone on this same pre-symptom schedule provided only 28% control when averaged for all materials across the three trial years. For growers deciding whether to apply only an insecticide or antimicrobial product, the insecticide appears to be the more important component of the mix.
Also noteworthy is that initiating antimicrobial sprays before the onset of symptoms was more effective than using a limited number of applications after symptoms appeared. The experimental design did not allow examination of the effect of insecticide applications alone if initiated after development of disease symptoms.

Research focus 2: Developing and evaluating management strategies for sour rot; (b) Cultural component.
In a commercial vineyard of *Vitis* interspecific hybrid cv. Vignoles in Branchport, NY, one block was divided into 14 vine rows trained in a vertical shoot position (VSP) system and 14 vine rows trained to a high-wire cordon (HW) system. Significant sour rot severity was observed in the vineyard block in previous years. Thus, our goal was to study whether or not the training system had a significant effect on disease development. Project partner, Mr. Jim Bedient (the vineyard owner) brought this vineyard to our attention and allowed us to use it for the studies described below.

In 2014-16, one vine was selected in each of 20 rows (10 in the VSP section and 10 in the HW section of the block). Following the first sighting of sour rot symptoms in the vineyard, disease ratings were made every 3 to 4 days until harvest.

In all 3 years of the study, there was significantly more sour rot at harvest in vines trained to the HW trellis system than the VSP system. In 2014, for example, sour rot severity increased from 21% to 35% in the HW system and from 13% to 18% in the VSP system in the final seven days before harvest **(**see Appendix for details on all 3 years).

Measurements of canopy density showed HW vines to have significantly greater density than VSP vines between the vineyard floor and fruiting zone (see Appendix), a result of the umbrella-like structure provided by their drooping shoots. This likely provided less ventilation and a more favorable microclimate for the disease than the VSP system, where vines were denser above the trellis wires due to upright growth of the shoots and their retention by catch wires. This aspect of the study served not only to examine the differences between training systems but also to document the rapid progression of disease severity as it increased steadily in both training systems over the final one to two weeks before harvest.

Outreach focus:
Outreach efforts were conducted by communicating the ongoing results of the research project and their related interpretations/recommendations through eight written publications and 13 oral presentations across its 3 years, as follows:
2015, written: (i) dedicated sections within the *2015 New York and Pennsylvania Pest Management Guidelines for Grapes* (Cornell Cooperative Extension); (ii) a dedicated section within *2015 Grape Disease Control*, a >70-pg. "newsletter" reference distributed through various local Cornell Cooperative Extension programs, those of other state Cooperative Extension programs to whom it is made available; and nationally online through these programs and those of selected consultants and nurseries.

2015, oral: Presentations in New York (Long Island, January; Finger Lakes, March and May; Capitol region, May), Michigan (May), and Arkansas (November). Local Cooperative Extension educators in each of these locations served as project partners through their efforts in organizing and promoting the individual meetings.

2016, written: (i) dedicated, updated sections within the *2016 New York and Pennsylvania Pest Management Guidelines for Grapes* (Cornell Cooperative Extension); (ii) a dedicated, updated section within *2016 Grape Disease Control*, a >70-pg. "newsletter" reference distributed through various local Cornell Cooperative Extension programs, those of other state Cooperative Extension programs to whom it is made available; and nationally online through these programs and those of selected consultants and nurseries.

2016, oral: Presentations in New York (Long Island, January; Finger Lakes, March), Pennsylvania (two separate presentations in March), and Virginia (December). Local Cooperative Extension educators and one private consultant (Virginia) in each of these locations served as project partners through their efforts in organizing and promoting the individual meetings.

2017, written: (i) dedicated, updated sections within the *2017 New York and Pennsylvania Pest Management Guidelines for Grapes* (Cornell Cooperative Extension); (ii) a dedicated, updated section within *2017 Grape Disease Control*, a >80-pg. "newsletter" reference distributed through various local Cornell Cooperative Extension programs, those of other state Cooperative Extension programs to whom it is made available; and nationally online through these programs and those of selected consultants and nurseries; (iii) an in-depth report on the project in *Appellation Cornell*, a CCE publication targeting the grape industry and distributed electronically throughout NY and nationally; and (iv) and in-depth report on the project prepared for *Practical Winery and Vineyard*, a "trade press" magazine distributed nationally.

2017, oral: Presentations in New York (Long Island, April; Finger Lakes, March and May) and New Jersey (March). Local Cooperative Extension educators in each of these locations served as project partners through their efforts in organizing and promoting the individual meetings.

GOALS AND OUTCOMES ACHIEVED

GOAL: Establish the microorganisms that cause sour rot in NY; determine their dynamics in the vineyard; determine their interactions with Drosophila spp. in disease development

Activities completed in order to achieve the performance goals included (i) the isolation and identification of microbes associated with sour rot both in NY vineyards, through our own isolation efforts, and in studies from other regions as reported in the literature; and (ii) assessing their ability to cause the disease, including their potential associations with *Drosophila* fruit flies. The methods used and data obtained have been supplied in the Project Approach section above, with additional details in the Appendix.

Additionally, to determine the source of these microorganisms and their dynamics in the vineyard, we characterized the phytobiome of sour rot-infected grapes from three diverse geographical areas across two years through DNA isolation, amplification, and sequencing. In 2015 and 2016, both healthy and sour-rot infected berries were collected from a research vineyard in Geneva, NY and in 2016, sour-rot infected grapes were collected from vineyards in Fredonia, NY, and Modesto, CA. We found the same predominate organisms on healthy berry surfaces that other researchers have documented in the literature, and those same organisms only increased in abundance when associated with sour rot symptoms. Representative data are presented in the Appendix Figures 3 and 4. For example, Finger Lakes grape berries collected in 2015 had similar bacterial and fungal microbiota, regardless of presence of sour rot symptoms (Fig. 3). However, more bacterial genera were detected on asymptomatic berries (20) than on symptomatic berries (12). While the relative mean frequency was non-significant for most genera represented, *Acetobacter* was 24-fold enriched on symptomatic versus asymptomatic berries ($p<0.001$; Appendix Fig. 3). For fungi, the only significant difference between the asymptomatic and symptomatic samples was the presence of *Taloromyces marneffei,* which was 3.7-fold enriched on

symptomatic versus asymptomatic berries ($p<0.01$; Appendix Fig. 4). *Saccharomyces cerevisiae* represented approximately 1% of the OTUs in both asymptomatic and symptomatic samples.

The shifts that occurred from asymptomatic berries to those symptomatic of the disease were primarily in the increased abundance of *Pichia* and *Acetobacter* species. This indicates that no new colonizers are necessary to bring on sour rot symptoms; instead it appears that disease symptoms could be caused by the endogenous yeast and bacteria, with the addition of *Drosophila* fruit flies.

We have conclusively shown that sour rot is caused by the interactions of various species of yeast and bacteria in concert with *Drosophila* fruit flies, a fact that was not previously known. Because of this, and our documentation of the microbial dynamics associated with the disease, we believe that we fully accomplished all goals within this section that we set for ourselves at the outset of the project.

GOAL: Develop a sour rot management program for recommendation to NY grape growers.

Activities completed in order to achieve the performance goals included three season-long control trials that examined multiple anti-microbial x insecticide treatments. The methods employed and data obtained have been summarized in the Project Approach section above and are provided in detailed form in the manuscript entitled, "**Control of Sour Rot via Chemical and Canopy Management Techniques"**, at the end of the Appendix.

Our goal of developing a spray program that would reduce disease severity by at least 60% was met. Our goal of conveying our results to the broad community of growers and advisors also was met, as detailed in the Project Approach section above. However, although numerous growers have successfully utilized both the insecticidal and antimicrobial aspects of our program to combat sour rot, we were not able to identify cooperative growers who were willing to leave portions of their vineyards unsprayed to use as a check treatment for on-farm control trials, forcing us to rely purely on our research farm trials.

BENEFICIARIES

The primary beneficiaries of this project have been the growers of interspecific hybrid and *Vitis vinifera* wine grapes who are now able to limit their losses from this disease; secondarily, premium wineries also have benefitted by having an increased supply of high-quality fruit available, from which they can produce more highly valued wines. Although a formal economic analysis was beyond the scope of this project, a rough estimate for the ANNUAL value of this information to New York agriculture could assume 800 acres affected (8% of approximately 10,000 acres of susceptible wine grapes) x 10% loss avoided x $5,000/A average farm gate crop value = $400,000 loss avoided. Assuming the cost of the control program at $125/A x 800A = $100,000, this provides an estimated NET benefit of $300,000 on a statewide basis in a moderately severe year for sour rot development (e.g., 2013, 2015, 2017).

LESSONS LEARNED

The senior project personnel have many years of experience working with grape growers to research practical problems and so were not particularly surprised by many specific operational aspects of the project as it unfolded. Nevertheless, our experiences were a reaffirmation of several important points that are worth remembering when conducting such work. These include the willingness of most growers to cooperate such projects when it does not entail a significant economic risk to them; their gratitude for whatever new knowledge is generated and shared with them, and their willingness to utilize it when it is presented to them within a practical context; and their hesitancy to put their crop at risk for experimental purposes.

Our greatest technical surprise was the pronounced influence that *Drosophila* flies have on sour rot development and, accordingly, the degree to which the disease can be managed simply by managing these insects. This is the single most important "takeaway" message from the entire project, and once that has been grasped readily by the industry already.

APPENDIX

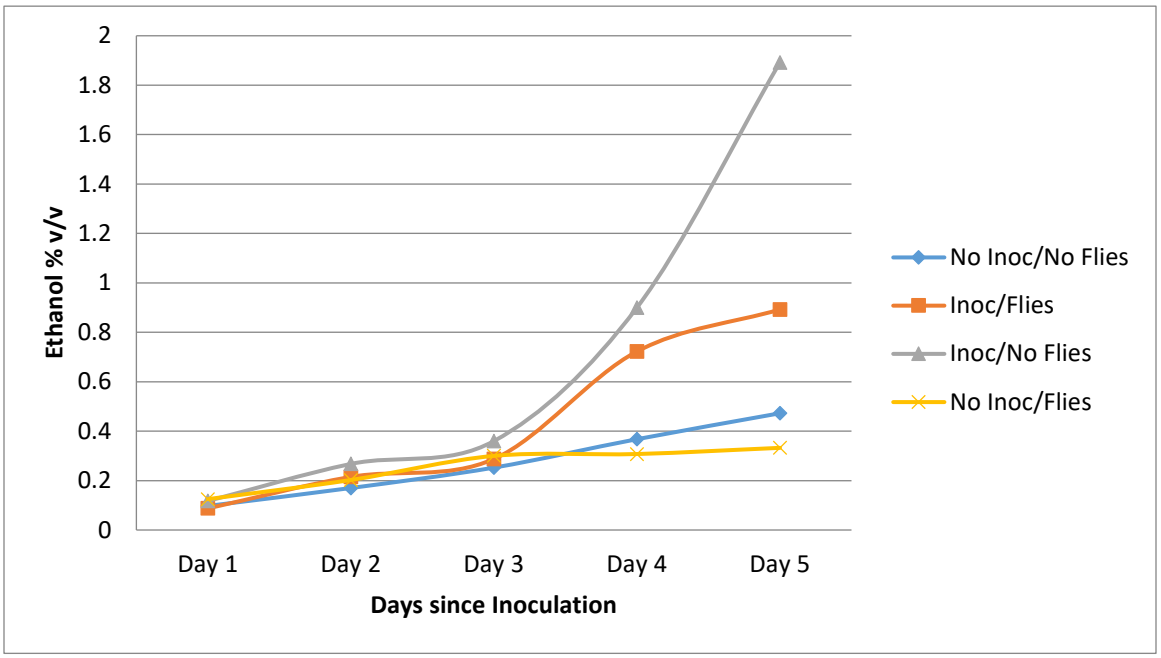

Figure 1. Mean daily ethanol accumulation (g/L) over 5 days in *Vitis vinifera* cv. Red Globe berries with and without inoculation on Day 0 with a suspension of *S. cerevisiae* plus *A. aceti* and exposure to wild-type *D. melanogaster*.

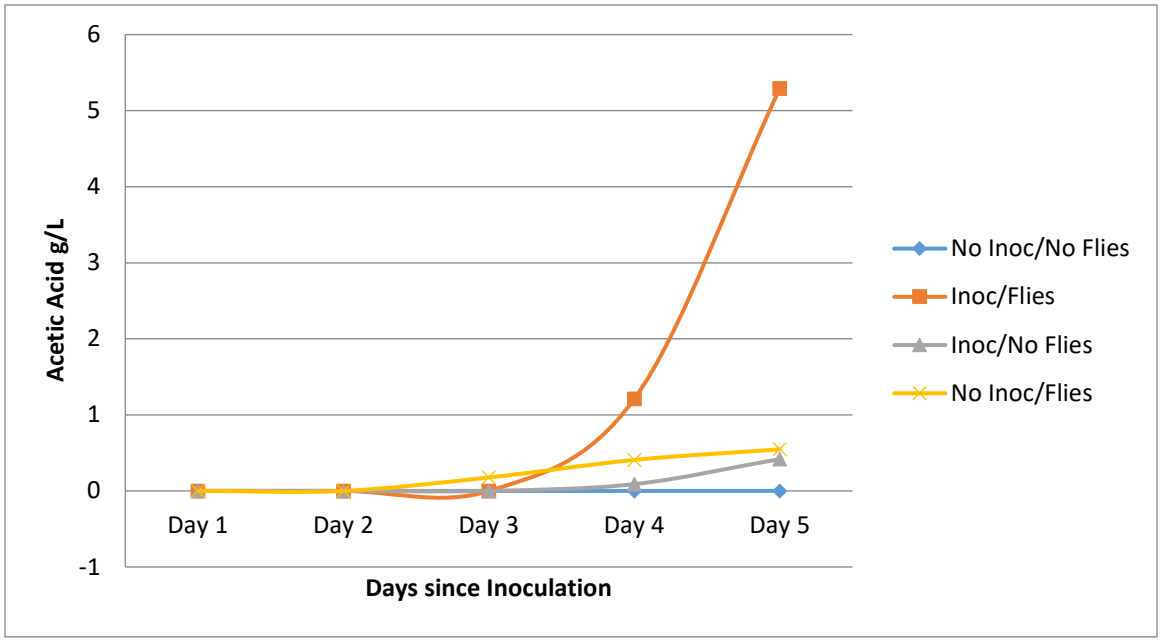

Figure 2. Mean daily ethanol accumulation (g/L) over 5 days in *Vitis vinifera* cv. Red Globe berries with and without inoculation on Day 0 with a suspension of *S. cerevisiae* plus *A. aceti* and exposure to wild-type *D. melanogaster*.

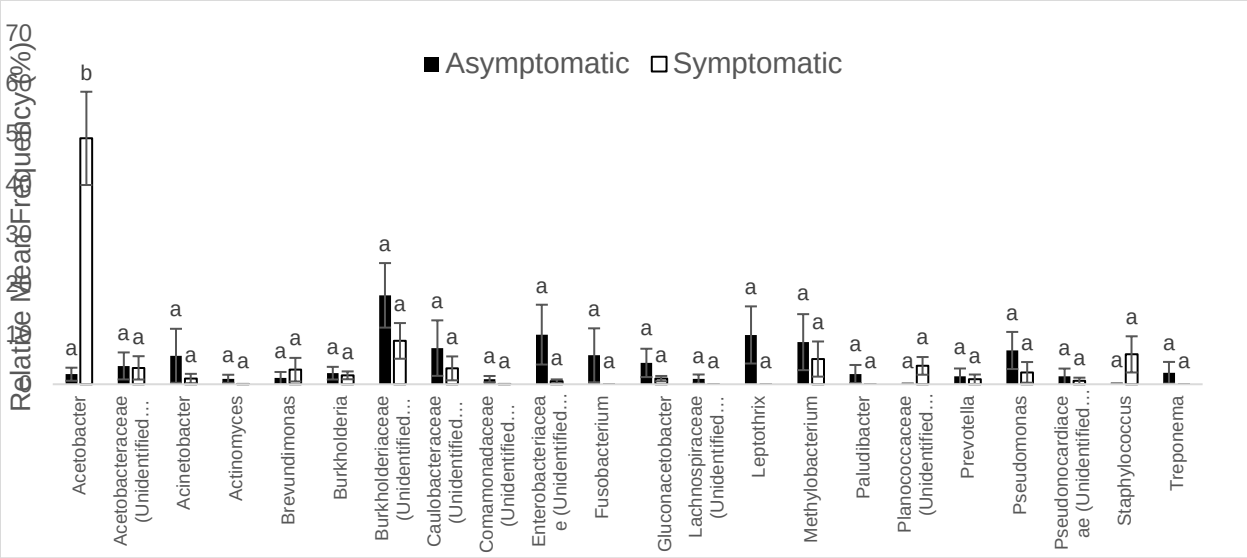

Figure 3. The relative mean frequency (%) of bacterial OTUs represented in 18 asymptomatic and 21 symptomatic sour rot samples from two commercial vineyards of *Vitis vinifera* cv. Riesling and Pinot Gris and one research vineyard of *Vitis* interspecific hybrid cv. Vignoles in the Finger Lakes region of New York in 2015. Differing letters indicate significance to p=0.05, as determined by a two-sided t-test.

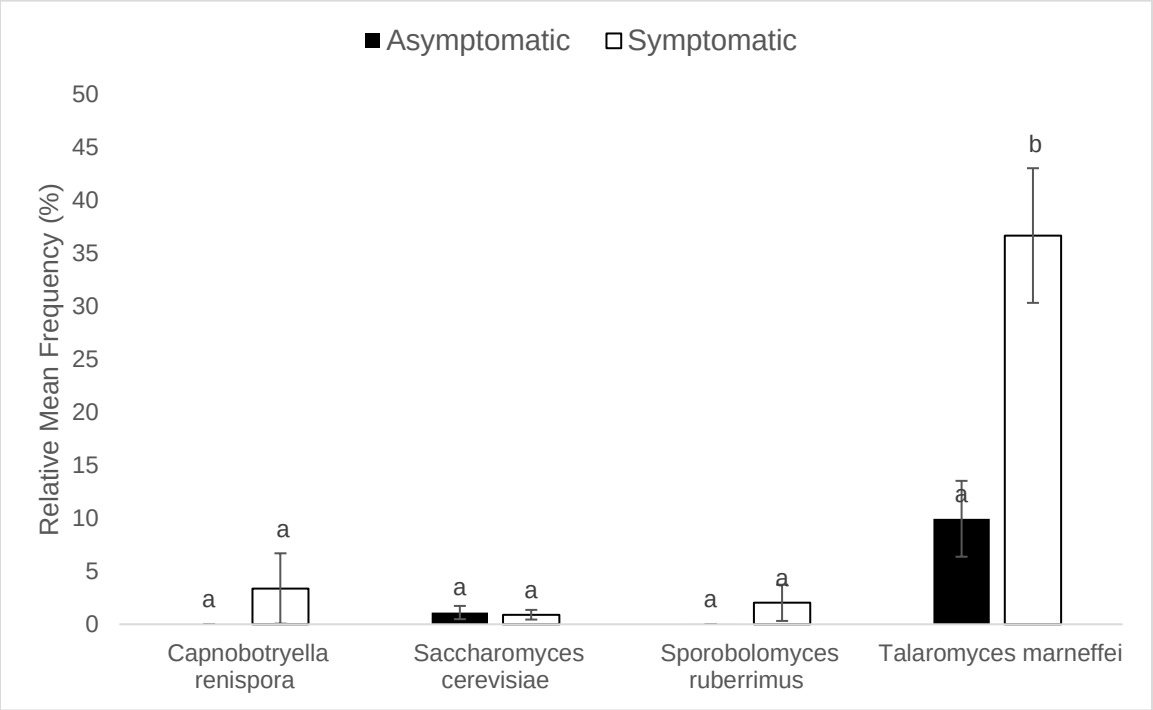

Figure 4. The relative mean frequency (%) of fungal OTUs represented in 22 asymptomatic and 29 symptomatic sour rot samples from two commercial vineyards of *Vitis vinifera* cv. Riesling and Pinot Gris

and one research vineyard of *Vitis* interspecific hybrid cv. Vignoles in the Finger Lakes region of New York in 2015. Differing letters indicate significance to p=0.05, as determined by a two-sided t-test.

Additional Information

MANUSCRIPT SUBMITTED TO AMERICAN JOURNAL OF ENOLOGY AND VITICULTURE

Control of Sour Rot via Chemical and Canopy Management Techniques

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Abstract

Sour rot is a disease complex characterized by rotting of the grape berry plus internal development of acetic acid, typically associated with an abundance of *Drosophila* fruit flies. Uncertainties regarding disease etiology and epidemiology have limited the development of reliable management practices. It is now known that yeast, acetic acid bacteria (AAB) and *Drosophila* spp. act together to cause the disease. Thus, we conducted three years of replicated field trials on the *Vitis* interspecific hybrid cv. Vignoles, in which we targeted these organisms through pre-harvest applications of various antimicrobial agents (potassium metabisulfite, copper hydroxide, BLAD polypeptide, and/or a mixture of hydrogen dioxide and peroxyacetic acid, depending on year) and an insecticide (spinetoram or zeta-cypermethrin, depending on year), both alone and in combination. Weekly applications of an antimicrobial plus insecticide provided an average 64% control relative to untreated vines across all three years of the trial when initiated preventively at 15°Brix, before the onset of symptoms; withholding addition of an antimicrobial to the insecticide application until symptoms appeared typically decreased the control level. Applying only an insecticide on the preventive schedule provided substantial control in two of the three years, whereas the antimicrobials were ineffective unless also applied with insecticide. Additionally, we studied disease development in a commercial vineyard of cv. Vignoles in which vines are trained to either a high wire cordon (HW) or vertical shoot position (VSP) system in groups of adjacent rows. In all three years of monitoring, disease severity was significantly higher on vines in the HW system where drooping shoots enclosed fruit within an umbrella-like canopy, whose density between the fruiting zone and vineyard floor was greater than for VSP vines.

Key words: sour rot, yeast, acetic acid bacteria, Drosophila, trellis systems, integrated pest management.

Introduction

Sour rot is a poorly-defined disease complex that is prevalent throughout temperate viticultural regions where pre-harvest rains occur. The skin of affected grapes turns a light brown color, in both red and white varieties, and then softens, releasing fermented grape pulp which smells of acetic acid (and occasionally, ethyl acetate) and drips onto other grapes within the cluster. Notably, fruit flies (*Drosophila* spp.) are commonly associated with the rotting clusters. Sour rot was originally thought to be the final and most destructive stage of gray mold, caused by *Botrytis cinerea* (Bisiach et al. 1982, 1986), and whereas this presumed scenario was later shown to be false, the term is sometimes applied

to a general decay syndrome that may involve various yeasts, bacteria, and/or filamentous fungi (McFadden-Smith and Gubler 2015).

The uncertainty regarding the disease's etiology and epidemiology has severely limited the development of specific, targeted management strategies that are generally agreed upon. For example, the labels for some fungicides currently registered for use on grapes in the United States list sour rot as a target disease while ascribing its cause to filamentous fungi such as *Cladosporium* spp. and *Aspergillus* spp. Some researchers claim that yeasts play an essential role in the development of sour rot (Barata et al. 2012, Bisiach et al. 1982, Guerzoni and Marchetti 1987). Many have noted the common association of acetic acid-producing bacteria (AAB) with the disease, such as species of *Gluconobacter* and *Acetobacter*, whereas Barata et al. (2012) concluded that AAB should be considered the etiological agents of sour rot. These latter authors also concluded that *Drosophila* spp. play a critical role as vectors of the yeasts and AAB involved in the development of sour rot, an opinion consistent with that of Bisiach et al. (1986) who similarly considered these insects to be important disease vectors.

In a separate series of experiments, we have determined that sour rot is the culmination of a process that begins with the fermentation of an injured berry's juice to ethanol by various yeasts (particularly *Saccharomyces* and *Pichia* species) and the subsequent oxidation of that ethanol to acetic acid by AAB, as proposed by Barata et al. (2012) (Hall et al. 2014, 2015, 2016, 2017). We have also found that *Drosophila* spp. play a crucial role in the development of sour rot beyond that of a vector (Hall et al. 2014, 2015, 2016, 2017). Accordingly, we initiated a series of field trials in which we examined various spray programs that employed general antimicrobial treatments likely to be effective against both yeasts and bacteria in conjunction with an insecticide treatment targeting *Drosophila* spp. Furthermore, because differential canopy management techniques have been shown to affect the development of sour rot (Zoecklein et al. 1992), we also examined the effect of two different training systems on the progress and severity of this disease.

Materials and Methods

Disease Control Trials. A series of control trials was established on different vines in each of four successive years in a vineyard of own-rooted *Vitis* interspecific hybrid 'Vignoles' in Geneva, New York (lat.: 42°52' 16", long.: -77°1' 59"), employing a split plot design with four replications. The vineyard was planted in 2004 and trained to a vertically shoot positioned (VSP) trellis system with a 3-m row spacing and 2-m vine spacing. Whole plots consisted of single rows that were either treated with insecticide or not, with the subplots consisting of various antimicrobial treatments applied to either one or two, four-vine panels depending on row length and individual vine characteristics. Antimicrobial treatments were assigned at random within each row. The insecticide treatment was applied to alternate rows in 2013, whereas the rows receiving insecticide sprays were randomized within the trial area in 2014-16. In 2013, the insecticide used against *Drosophila* spp. was spinetoram (Delegate WG; Dow AgroSciences, Indianapolis, IN) and in the subsequent years, zeta-cypermethrin (Mustang Maxx; FMC Corp., Philadelphia, PA) was used. The antimicrobial products included potassium metabisulfite (KMS; Cellar Science, Pittsburg, CA); copper hydroxide (Kocide 3000; E. I. DuPont de Nemours & Co. Inc., Wilmington, DE); banda de Lupinus albus doce (BLAD) polypeptide (Fracture; FMC Corp., Philadelphia, PA); and a mixture of hydrogen dioxide and peroxyacetic acid (OxiDate 2.0; Biosafe Systems, Hartford, CT). Antimicrobial treatments varied among years in terms of the material applied, rate, and application timing (Table 1); a control treatment receiving no antimicrobial material was also included each year. All materials were applied with a hooded-boom sprayer delivering a volume of 935 L/ha and operating at a pressure of 2069 kPa.

Symptoms of sour rot do not appear in nearby Ontario, Canada until berries reach a sugar level of 15°Brix, and inoculated berries are not susceptible to the disease until that time (McFadden-Smith and Gubler 2015). Hence, the insecticide sprays and our basic pre-symptom antimicrobial programs were initiated shortly after a random sample of 20 berries from each of three individual rows averaged 15°Brix with a refractometer. Antimicrobial treatments designated to begin only after symptoms appeared were applied when both visual and olfactory symptoms were detected in the vineyard. In 2016, two additional starting-point timings for antimicrobial sprays were added, based on environmental data measurements: (i) following the first rain after 15°Brix, since sour rot has long been associated with pre-harvest rains (McFadden-Smith and Gubler 2015, Oliva et al. 1999); and (ii) following a three-consecutive-day increase in maximum daily dew point (MDD), as determined by monitoring data produced daily by a weather station several hundred meters from the test site, beginning at 12°Brix. Unless otherwise noted, all treatment sprays were applied weekly upon initiation and were terminated during the final week before harvest. The Vignoles cultivar is relatively resistant to powdery mildew, downy mildew, and black rot, but mancozeb was applied three times per season to all vines (including the controls) to control these diseases and Phomopsis cane and leaf spot; Botrytis bunch rot was controlled with a rotational program utilizing fenhexamid, cyprodinil/fludioxonil, and fluopyram/tebuconazole applied at late bloom, bunch closure, veraison, and 2 weeks pre-harvest. A commercial formulation of *Bacillus thuringiensis* was applied as needed to control grape berry moth.

The harvest date for all years was determined when the fruit reached an average of 23 to 24°Brix as determined by a composite 20-berry sample collected from three rows, and was at least 2 days beyond the final spray application. At the time of harvest, 0.5 meters was measured from each post that defined the end of a treatment plot, and every cluster between those 0.5-m buffer zones was evaluated individually for sour rot severity based on a visual estimation of the percentage of the cluster showing typical necrosis and olfactory symptoms. A mixed effects model was used to analyze the mean severity ratings from each plot. The model includes the main effects of antimicrobial treatment, insecticide, an interaction effect between treatment and insecticide, and the random effect of replicate to account for variation between replications. Each year was analyzed separately, due to differences in treatments among years. Because there was a significant main effect of insecticide in each year, the effect of insecticide within each antimicrobial treatment was analyzed via a t-test. The effect of each individual treatment in comparison to the control treatment (no antimicrobial or insecticide) was analyzed via Dunnett's Method of Comparison. The trial data in 2014 could not be utilized due to the confounding effects of a hailstorm that severely damaged the grape clusters at the time of veraison.

Training system effects. The effect of training system on sour rot development was evaluated in a commercial vineyard of *Vitis* interspecific hybrid cv. Vignoles in Branchport, NY (lat.: 42°34' 51", long.: -77°9' 45"). One block of this vineyard is divided into 14 rows of vines trained in a vertical shoot position (VSP) system, with the 14 immediately adjacent rows trained to a high wire (HW) cordon system. The top wire in the HW system is positioned at 167 cm above the vineyard floor; in the VSP system, the fruiting and catch wires are positioned 111 cm and 190 cm above the vineyard floor, respectively. A random number generator was used to select both the row number for 10 rows per training system and single vines within each row, which were marked to facilitate repeated data collection. During the pre-harvest period, disease severity was determined for all clusters on the marked vines at 3- to 4-day intervals, as described above. For statistical analysis, a Mixed Effects Model was used, examining the main effects of time and training system and the interaction of time by training system. Vine was treated as a random effect because measurements were taken over time on the same vines at every sampling point. The VSP and HW sections of the vineyard were considered as treatments within a single

block. All vines were subjected to the same fertilization and pest management program standard for this region (Weigle and Muza 2016). No summer pruning or hedging was employed.

To examine potential differences in canopy density between the HW and VSP vines, we employed two different techniques during a period approximately 2 weeks before harvest. In the first, Enhanced Point Quadrat Analysis (EPQA) (Meyers and Vanden Heuvel 2008), data were focused on the metrics of cluster exposure layer (CEL), leaf exposure layer (LEL), and occlusion leaf number (OLN). To determine these measurements, a stiff metal rod was inserted into the canopy at the fruiting zone every 20 cm over the length of the vine, positioned parallel to the ground. As the rod was inserted into the canopy, the number of leaf and cluster contacts was recorded. Using this information, the number of leaf layers within the fruiting zone could be calculated in various fashions by determining the total number of shade-producing layers (OLN), the number of shade producing layers between a cluster and the outer edge of the canopy (CEL), and the number of shade-producing layers between leaves and the outer edge of the canopy (LEL). EPQA measurements were made on the same vines used for the disease ratings. For statistical analysis, a two-sided t-test was performed to analyze the significance of the differences in mean OLN, CEL and LEL values for the vines between the two training systems, in each of the 2 years of assessment.

To further measure potential differences in canopy density, we employed methods described by Palleja and Landers (2017). Four XLMaxSonar MB7092 ultrasound sensors (MaxBotix Inc., Brainerd, MN) were mounted on a utility vehicle at heights of 60, 100, 140, and 180 cm above the vineyard floor and driven down five rows each of the HW- and VSP-trained vines (all of which had been used for the aforementioned disease and canopy density assessments) at a rate of 4.8 km/h in each direction, so as to measure both sides of the canopy of each row. These sensors emit ultrasound wave pulses which propagate through the air, come in contact with a particular object and bounce back to the sensor, which records the returning waves (echoes). The energy and shape of these echoes, measured in volts, indicate distance from the sensor to the objects in front of it and their density. Thus, because we endeavored to keep the distance from the sensors to the outer canopy edge constant, variations among measurements for individual rows were attributable to differences in canopy density. For statistical analysis, a t-test was performed to determine the significance of the differences in these measures between the HW- and VSP-trained vines, at each ultrasound sensor height. This additional technique was employed only in the second of the 2 years of EPQA assessments.

Results

Disease control trials. In 2013, all four treatments in which both antimicrobial and insecticide treatments were applied provided highly significant ($P < 0.001$) levels of sour rot control, with disease severity reduced by 31 to 55% relative to the treatment receiving no antimicrobial or insecticide sprays. In contrast, applications of antimicrobials or insecticide (spinetoram) alone provided no significant control ($P = 0.27$ to 0.66). In conjunction with the insecticide sprays, OxiDate 2.0 applied at a rate of 1% (v/v) provided comparable control whether it was applied pre- or post-symptom (five and three sequential sprays, respectively) (Table 2, Figure 1). T-tests showed a moderately significant ($P = 0.08$) to highly significant ($P <0.001$) difference between antimicrobial treatments applied alone versus those applied in conjunction with an insecticide (Table 3).

In 2015, disease pressure was notably higher, with the measure of sour rot severity on untreated vines almost twice as great as in 2013 (Figures 1 and 2). Under these conditions, weekly applications of insecticide only (zeta-cypermethrin, a different material than used in 2013), beginning at 15°Brix before symptoms were visible, provided 66% control relative to the untreated vines ($P = 0.01$). When

insecticide-treated vines were also sprayed concurrently with one of the three antimicrobial materials used that year, control levels were increased to 79 to 87% compared with the untreated vines, whereas the same antimicrobial treatments applied to vines that did not receive insecticide provided less control than the insecticide-only treatment. Delaying these antimicrobial treatments until symptoms were visible in the block resulted in reduced levels of control relative to the preventive approach (three versus five total applications of each antimicrobial, respectively). Similarly, Fracture applied once at 15°Brix without insecticide provided no apparent control relative to the untreated vines and when applied with insecticide, control was comparable to the insecticide-only treatment (Table 2, Figure 2). Differences in mean disease severity between antimicrobial treatments applied alone versus those applied in conjunction with an insecticide were modestly to highly significant (P = 0.14 to <0.01) when the antimicrobial treatments began pre-symptom but were insignificant (P = 0.42 to 0.91) when antimicrobial sprays were not initiated until symptoms developed (Table 3).

In 2016, sour rot severity on untreated vines was similar to that in 2015 (Figures 2 and 3). Weekly applications of zeta-cypermethrin alone beginning at 15°Brix (pre-symptom) reduced disease severity by about half (P = 0.02), whereas applying these in conjunction with any of the three different antimicrobials reduced disease severity by approximately two-thirds relative to untreated vines (P <0.01 to <0.001). In the insecticide-treated plots, post-symptom applications of OxiDate 2.0 and Fracture were modestly less effective than the preventive approach with these materials, whereas delaying the initiation of OxiDate 2.0 sprays until either of the two climatic criteria had been satisfied did not improve control beyond that attained with insecticide sprays alone. With the exception of OxiDate 2.0 applied only after MDD increased over 3 consecutive days (the first three-consecutive-day increase in MDD occurred at 18°Brix, resulting in 2 weekly applications thereafter), none of the other six antimicrobial treatments provided significant control of sour rot in plots not also treated with the insecticide (P = 0.13 to 0.97) (Table 2, Figure 3). Direct comparisons showed that control was increased significantly (P = 0.03) when vines receiving sprays of OxiDate 2.0 beginning either pre- or post-symptom were also treated with insecticide, as was also the case with sprays of KMS initiated pre-symptom (P = 0.002). There was relatively little statistical significance (P = 0.16 to 0.78) to the effect of insecticide applications on disease severity in the pre- and post-symptom Fracture treatments or the two OxiDate 2.0 treatments initiated according to climatic criteria (Table 3).

Across all three years of control trials, treatments combining applications of an insecticide and an antimicrobial provided a weighted average of 64% control of disease severity relative to untreated vines when initiated at 15°Brix before symptoms appeared, and the difference for each of the nine total treatments relative to the appropriate untreated check was statistically significant (P = 0.03) to highly significant (P <0.001). When applications of a subset of these antimicrobials to insecticide-treated vines were delayed until sour rot symptoms developed, control was occasionally comparable to the pre-symptom regimen for the same material but typically decreased to a varying extent among the six individual treatment x year combinations in this category (P <0.01 to P = 0.34 in comparisons with the untreated check). In contrast, for the full range of antimicrobial treatments applied to vines that had not also been treated with insecticide, control averaged only 23 and 28% for pre- and post-symptom programs, respectively, across the three years with typically low degrees of statistical significance in comparisons with the untreated check (Table 2). These general observations are supported by the analysis of variance showing highly significant P-values for the main effect of insecticide in all three years of the trial, but for antimicrobials only in 2013. There also was a highly significant insecticide x antimicrobial interaction in both 2013 and 2015 (Table 4).

Training system effects. Over the final 7 days before harvest in 2014, sour rot severity increased in the HW system from 20.6 to 35.4% and in the VSP system from 12.7 to 18.1%. At all three data collection points, disease severity was significantly (*P* =0.05) higher in the HW versus the VSP system (Fig. 4). In 2015, sour rot severity was again significantly (*P* =0.05) greater in the HW- versus VSP-trained vines at each of the five assessment dates over the final 12 days before harvest. Six days before harvest, the vineyard owner applied a combination of KMS (10 g/L) and zeta-cypermethrin across the entire block, after which further disease development stopped in both training systems (Fig. 5), in stark contrast with the disease progress observed in both 2014 and 2016 (Fig. 6) when no treatment was applied for sour rot control and disease severity increased continuously up to the day of harvest. In 2016, severity ratings made 10 days prior to harvest were not significantly different (P = 0.05) in the two training systems yet they were by harvest, with severity in the HW-trained vines nearly 50% greater than those trained to the VSP system. The generally rapid pre-harvest increase in disease severity was reflected by the highly significant effect of sampling time provided by the mixed-effects model in all three years (Table 5). The main effect of training system also was highly significant in 2014 and 2015 (P <0.0001). In 2016, the main effect of training system was insignificant (P=0.69), reflecting the minor differences between the two during the first three evaluations; in contrast, the interaction between time and training system was highly significant (P=0.004), reflecting the substantial differences that had developed by harvest (Table 5).

Measures of OLN, CEL, and LEL, the EPQA parameters used to assess potential differences in canopy density, were virtually identical for vines in the two training systems in 2015 (*data not shown*). In 2016, measures for OLN and CEL were modestly but significantly (*P* = 0.05) higher for the HW-trained vines, indicating a denser fruit-zone canopy within this system, although the LEL values were once again virtually identical (Fig. 7). In 2016, the ultrasound sensor data indicated significant (*P* = 0.05) differences in canopy density between training systems at each sensor height, with VSP vines more dense at the two highest sensor levels and HW vines more dense at the two lowest levels. The VSP vines appeared least dense at the sensor level closest to the vineyard floor (60 cm height) and most dense at the 140-cm height, whereas the HW vines were least dense at the highest (180 cm) sensor level with density increasing progressively at each 40-cm increment toward the vineyard floor (Fig. 8).

Discussion

In all three years of the disease management trials, significant and consistent control was provided by applying antimicrobial and insecticide sprays in conjunction prior to the onset of sour rot symptoms, reducing disease severity by close to 70% over the untreated check. Insecticide sprays alone also provided significant control in the two years in which zeta-cypermethrin was utilized, whereas they did not in the one year in which spinetoram was the insecticide applied. However, we did not conduct a trial to compare these two materials directly, so cannot determine whether such differential control is likely due to differential efficacies of the two insecticides or to some other factor(s) that varied among the trial seasons. In contrast, with the exception of a single treatment in a single season, antimicrobial sprays alone never provided a statistically significant level of control. Nevertheless, applications of an antimicrobial in conjunction with an insecticide typically increased the level of control relative to the insecticide alone when the antimicrobial applications were initiated before disease was observed, but not after. Although these results might suggest that a preventive spray program is substantially more efficacious than one triggered by the first detection of disease, the potential for interplot interference in our trials must be recognized. That is, our sprayed plots represented a mere fraction of the vines within a 0.6-ha block of the same cultivar, which otherwise were not treated with products likely to affect yeasts, AAB, or *Drosophila* spp., and these unsprayed rows may have provided a continuous source of both insects and microbes as the disease progressed unimpeded within them. Thus, it is possible that

the degree of sour rot control provided by a post-symptom spray program could be more substantial in a vineyard in which an entire block is treated rather than just a few individual panels, and therefore, such an approach could be more effective than our trials demonstrated. This suggestion is supported by our observations in the commercial vineyard in Branchport in 2016, where an active sour rot epidemic did not progress further following a single application of KMS + zeta-cypermethrin, although the lack of unsprayed control panels in the vineyard block for comparison precludes our ability to draw conclusions from this observation. Furthermore, the experimental design of our spray trials did not allow us to examine the efficacy of delaying insecticide applications until symptom development. Thus, whereas we have clearly demonstrated the general utility of a pre-harvest spray program targeting both *Drosophila* spp. and the microbes responsible for causing sour rot, the most efficient timing for doing so while limiting chemical inputs remains to be determined. It should also be noted that although KMS is widely used as a general antimicrobial product in winemaking, it is not registered for vineyard applications in the United States; therefore, the control that it provided in our trials should be viewed as a proof of concept rather than an implied recommendation for use on vines except where allowed.
The significant control provided by insecticide sprays targeting *Drosophila* spp. in our experiments is consistent with the results of Barata et al. (2012a), who prevented sour rot development on wounded berries if they were physically excluded from these insects, and of Bisiach et al. (1986), who obtained control of the disease in some experiments with insecticide applications targeting the pests although they concluded that the importance of *Drosophila* control would require further investigation. *Drosophila* spp. carry both yeast and AAB in their guts and on their bodies (Broderick and Lemaitre 2012), so should serve as vectors of these causal organisms to and among wounded berries as suggested by both Barata et al. (2012a) and Bisiach et al. (1986), in addition to playing a critical non-microbial role in sour rot development as we have found for axenic *D. melanogaster* individuals (Hall et al. 2015a, 2015b, 2016c, 2017). Neither yeasts nor AAB are capable of infecting unwounded berries, and berry injury is typically required for sour rot development (McFadden-Smith and Gubler 2015). Thus, Bisiach et al. (1986) also emphasized the importance of controlling of wounding agents such as Botrytis, powdery mildew, and other insect larvae within an integrated program to control the disease. Therefore, we included control measures for these wounding agents in our trials, so that we could examine the effects of spray programs targeting *Drosphila* spp., yeasts, and AAB without the influence of additional confounding factors. Nevertheless, minimizing the possibility of wounds from various biotic and abiotic agents appears to be a key component of any sour rot management program. For example, McFadden-Smith (2009) showed that clusters whose compactness was reduced following applications of prohexidione calcium had significantly less sour rot than untreated, tighter clusters. With higher cluster compactness, berries press against one another, separating from the pedicel and creating wounds that facilitate entry of the organisms that cause sour rot but are otherwise unable to penetrate intact berries. Within this context, it should be noted that whereas there has been speculation about the potential role of the spotted wing Drosophila (*D. suzukii*) in sour rot development due to its ability to oviposit through the intact berry epidermis of some thin-skinned cultivars (Ioriatti et al. 2015), this species represents a minority of the fruit flies reared from decaying berries in New York vineyards (Loeb 2014), which is consistent with results reported from Oregon (Ioriatti et al. 2015).

In addition to the factors discussed above, we found that training system also had an effect on sour rot severity. In all three years of our monitoring, sour rot severity was significantly greater in HW-trained vines of cv. Vignoles than VSP-trained vines of the same cultivar. In an effort to quantify potential differences in canopy density between the training systems, we initially utilized EPQA measurements but were largely unable to distinguish between the two with respect to densities within the fruiting zone, the only portion of the canopy subject to EPQA assessments. However, the ultrasound technique that we utilized clearly illustrated the far greater density of leaves between the fruiting zone and the

vineyard floor in the HW system, which was visible to the naked eye owing to the umbrella-like canopy structure produced as the vigorous shoots first grew upwards from the top wire and then drooped down towards the vineyard floor as they increased in length. In contrast, there is no such area created in the VSP system where catch wires maintain the shoots in an upward position, thereby concentrating the canopy above the fruiting zone (particularly on vines not hedged during the growing season), as reflected by the relative ultrasound measurements that we obtained for the two systems. Thus, it is possible that the umbrella-like canopy structure produced by the HW system may have provided an environment more favorable for sour rot development due to factors such as reduced air circulation within the cluster region, although we did not measure environmental variables within the canopies. Interestingly, Zoeklein et al. (1992) also presented data showing substantially greater cluster rot severity on *V. vinifera* cultivars in a vineyard trained with a high cordon wire and drooping shoots versus another one with a low cordon wire and upright shoots when the same cultivars were evaluated, and although they demonstrated disease reduction through fruit zone leaf removal in both vineyards they were not able to compare the two training systems directly.

Collectively, our results and those of others indicate that an integrated program for managing sour rot ideally should consist of multiple techniques to the extent that they are practical and likely to be necessary based upon climate and individual vineyard factors, including previous history with the disease. These may include actions designed to increase sun exposure and ventilation within the fruiting zone, which also should improve the deposition of spray materials applied to protect the fruit from pests and diseases (Austin et al. 2011); reduce cluster compaction; protect against animal and microbial wounding agents; control the development of *Drosophila* spp. populations; and limit the development of the yeasts and AAB that serve as causal agents of sour rot.

Conclusions

Sour rot is a significant and challenging disease complex, caused by an interaction between yeast, acetic acid bacteria (AAB) and *Drosophila* fruit flies, that affects grape growers worldwide. In a series of replicated trials we found that a combination of antimicrobial plus insecticide sprays targeting these organisms consistently provided significant control of the disease when applied weekly after berry soluble solids content reached 15°Brix, before symptoms appeared. Insecticide sprays appeared to provide greater control than antimicrobials, although combining the two generally was most effective. Delaying antimicrobial applications until symptoms appeared usually was less effective than initiating them before symptom development and often provided no significant benefit. In a commercial vineyard of the interspecific hybrid cv. Vignoles where different vines were trained to either a high wire cordon (HW) or vertical shoot position (VSP) system and subjected to the same grower practices, sour rot severity was significantly greater on the HW vines in three consecutive years of evaluation. Measurements of canopy density utilizing an ultrasound sensor system showed HW vines to have greater density than VSP vines between the vineyard floor and the fruiting zone whereas the VSP vines were denser above the fruiting zone; expanded point quadrat analysis, which evaluated densities only within the fruiting zone, showed little difference between the two training systems in this portion of the canopy. An integrated control program for sour rot should utilize both canopy management and spray applications that target yeasts, AAB, and *Drosophila* spp., although the most efficient protocol for timing such spray applications has yet to be determined.

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Table 1. Antimicrobial treatments applied in disease control trials

Treatment, rate per L and timing[a]	**Years applied**
Untreated control	2013, 2015, 2016
KMS[b] 5 g, pre-symptoms	2013
KMS[b] 10 g, pre-symptoms	2013, 2015, 2016
Copper hydroxide 1.0 g, pre-symptoms	2013
KMS[b] 10 g, post-symptoms	2013, 2015
OxiDate 2.0[c] 10 mL, pre-symptoms	2015, 2016
Fracture[d] 2.5 mL, pre-symptoms	2015, 2016
Fracture[d] 2.5 mL, once at 15°Brix	2015
Fracture[d] 2.5 mL, post-symptoms	2015, 2016
OxiDate 2.0[c] 10 mL, post-symptoms	2015, 2016
OxiDate 2.0[c] 10 mL, following first rain after 15°Brix	2016
OxiDate 2.0[b] 10 mL, following 3-consecutive-day increase in maximum daily dew poi 15°Brix	2016

[a]Unless otherwise noted, all sprays were applied at weekly intervals upon initiation: pre-symptom sprays once a 20-berry sample indicated a soluble solids content of 15°Brix, post-symptom sprays once disease was observed in the trial plot, in a volume of 935 L/ha.
[b]KMS = potassium metabisulfite.
[c]OxiDate 2.0 = a commercial formulation consisting of 27% hydrogen dioxide + 2% peroxyacetic acid.
[d]Fracture = a commercial formulation containing 20% banda de Lupinus alba doce (BLAD) polypeptide.

Table 2. Mean percent disease control relative to the untreated check for each treatment in individual years and cumulatively across all years in which that treatment was administered

Antimicrobial treatment, rate/L and timing[a]	**Insecticide[e]**	**2013**		**2015**		**2016**		**Cumulative**
		% Disease control	p[f]	% Disease control	*p*	% Disease control	*p*	
None	No	--	--	--	--	--	--	--
	Yes	10.3	0.556	66.3	0.121	48.2	0.046	41.6
KMS[b] 5 g, pre-symptoms	No	12.3	0.362					12.3
	Yes	31.4	<0.001					31.4
KMS[b] 10 g, pre-symptoms	No	9.2	0.664	14.6	0.999	23.1	0.760	15.6
	Yes	47.1	<0.001	81.4	0.030	70.6	<0.001	66.4
Copper hydroxide 1.0 g, pre-symptoms	No	11.9	0.399					11.9
	Yes	55.2	<0.001					54.3
OxiDate[c] 2.0 10 mL, pre-symptoms	No			45.7	0.511	15.9	0.973	30.8
	Yes			87.0	0.017	61.1	<0.01	74.1
Fracture[d] 2.5 mL, pre-symptoms	No			32.2	0.873	41.1	0.128	36.7
	Yes			79	0.038	58.9	<0.01	69.5
KMS[b] 10 g, post-symptoms	No		0.269	47.6	0.453			30.6
	Yes		<0.001	57.6	0.239			55.2
OxiDate[c] 10 mL, post-symptoms	No			49.7	0.405	3.3	1	26.5
	Yes			52.4	0.341	59.7	0.006	56.1

Fracture[d] 2.5 mL, post-symptoms	No	45.8	0.505	23.6	0.601	39.7
	Yes	65.4	0.131	50.1	0.034	57.8
Fracture[d] 2.5 mL, once at 15°Brix	No	30.1	0.914			30.1
	Yes	66.7	0.116			66.7
OxiDate[c] 2.0 10 mL, following first rain after 15°Brix	No			36.8	0.223	36.8
	Yes			41.8	0.116	41.8
OxiDate[c] 2.0 10 mL, following 3-consecutive-day increase in maximum daily dew point after 15°Brix	No			54.5	0.017	54.5
	Yes			41.6	0.119	41.6

[a]Unless otherwise noted, all sprays were applied at weekly intervals upon initiation: pre-symptom sprays once a 20-berry sample indicated a soluble solids content of 15°Brix, post-symptom sprays once disease was observed in the trial plot. The spray volume was 935 L/ha for all applications.
[b]KMS = potassium metabisulfite.
[c]OxiDate 2.0 = a commercial formulation consisting of 27% hydrogen dioxide + 2% peroxyacetic acid
[d]Fracture = a commercial formulation containing 20% banda de Lupinus alba doce (BLAD) polypeptide.
[e]Insecticide sprays (spinetoram, 0.075 g/L in 2013; zeta-cypermethrin, 0.027 g/L in 2015 and 2016) were applied at weekly intervals once a 20-berry sample indicated a soluble solids content of 15°Brix, on the same days as relevant antimicrobial sprays were applied.
[f]P-values as calculated by Dunnett's test comparing percent disease severity of each treatment to the untreated control.

Table 3. Statistical significance of antimicrobial and insecticide treatments and their interaction with respect to sour rot severity in the three years of control trials, as determined by analysis of variance with the mixed-effects model

	Antimicrobial	**Insecticide**	**Antimicrobial*Insecticide**
	Disease severity[a]	**Disease severity[a]**	**Disease severity[a]**
	p	***p***	***p***
2013	<0.001	<0.001	0.008

2015	0.817	0.010	0.541
2016	0.214	0.016	0.017

[a] Mean % cluster area showing symptoms of sour rot, determined for all clusters per plot at the time of harvest for four replicate plots per treatment.

Table 4. Statistical significance[a] of the differences in mean sour rot severity between plots treated versus not treated with insecticide, for each of the antimicrobial treatments applied in each year of the trial

Antimicrobial treatment[b]	***2013***	***2015***	***2016***
None	0.205	0.020	0.042
KMS[c] 5 g, pre-symptoms	0.078		
KMS[c] 10 g, pre-symptoms	<0.001	0.125	0.002
Copper hydroxide 1.0 g, pre-symptoms	0.003		
KMS[c] 10 g, post-symptoms	0.001	0.776	
OxiDate[d] 2.0 10 mL, pre-symptoms		0.145	0.033
Fracture[e] 2.5 mL, pre-symptoms		0.007	0.514
Fracture[e] 2.5 mL, once at 15°Brix		0.349	
Fracture[e] 2.5 mL, post- symptoms		0.426	0.164
OxiDate[d] 10 mL, post-symptoms		0.912	0.0326*
OxiDate[d] 2.0 10 mL, following first rain after 15°Brix			0.7825

OxiDate[d] 2.0 10 mL, following 3-consecutive-day increase in maximum daily dew point after 15°Brix	0.4063

[a] P-values as calculated by two-sided t-tests.

[b]Unless otherwise noted, all sprays were applied at weekly intervals upon initiation: pre-symptom sprays once a 20-berry sample indicated a soluble solids content of 15°Brix, post-symptom sprays once disease was observed in the trial plot. The spray volume was 935 L/ha for all applications.

[c]KMS = potassium metabisulfite.

[d]OxiDate 2.0 = a commercial formulation consisting of 27% hydrogen dioxide + 2% peroxyacetic acid

[e]Fracture = a commercial formulation containing 20% banda de Lupinus alba doce (BLAD) polypeptide.

Table 5. Statistical significance of sampling time points, training system and their interaction with respect to sour rot severity in a commercial vineyard block of *Vitis* interspecific hybrid Vignoles, as determined by a mixed-effects model

	Sampling Time	**Training System**	**Sampling Time*Training System**
	Disease severity[a]	**Disease severity[a]**	**Disease severity[a]**
	p	***p***	***p***
2014	0.002	<0.001	0.15
2015	<0.001	<0.001	0.61
2016	<0.001	0.69	0.004

[a] Mean % cluster area showing symptoms of sour rot, determined for all clusters per plot at the sampling time.

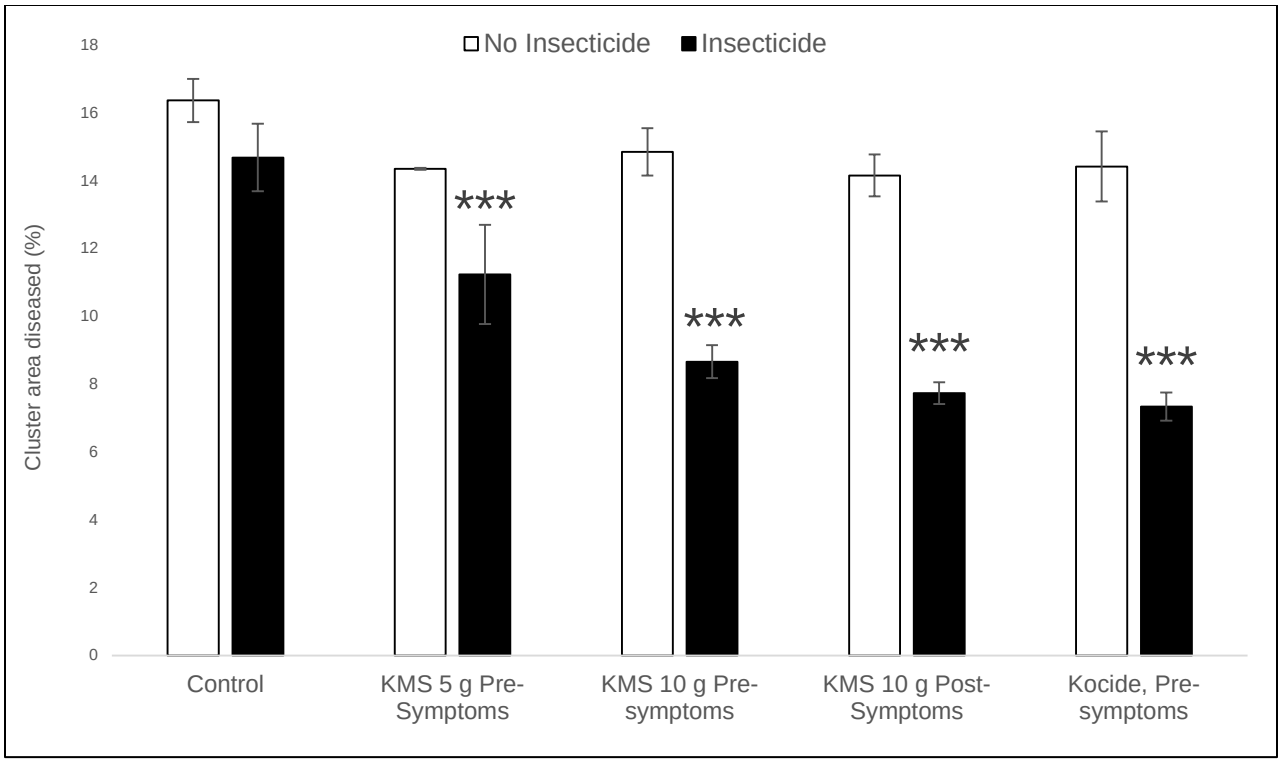

Figure 1. Sour rot severity in a vineyard block of *Vitis* interspecific hybrid cv. Vignoles in Geneva, NY in 2013 as a function of antimicrobial and insecticide treatments. Data represent the mean values across four replicate one- or two-panel plots per treatment, in which all clusters were rated. Asterisks (*) above a bar denote a significant difference relative to the treatment receiving no antimicrobial or insecticide sprays as determined by Dunnett's Method of Comparisons. *** = significant at *P*= 0.001.

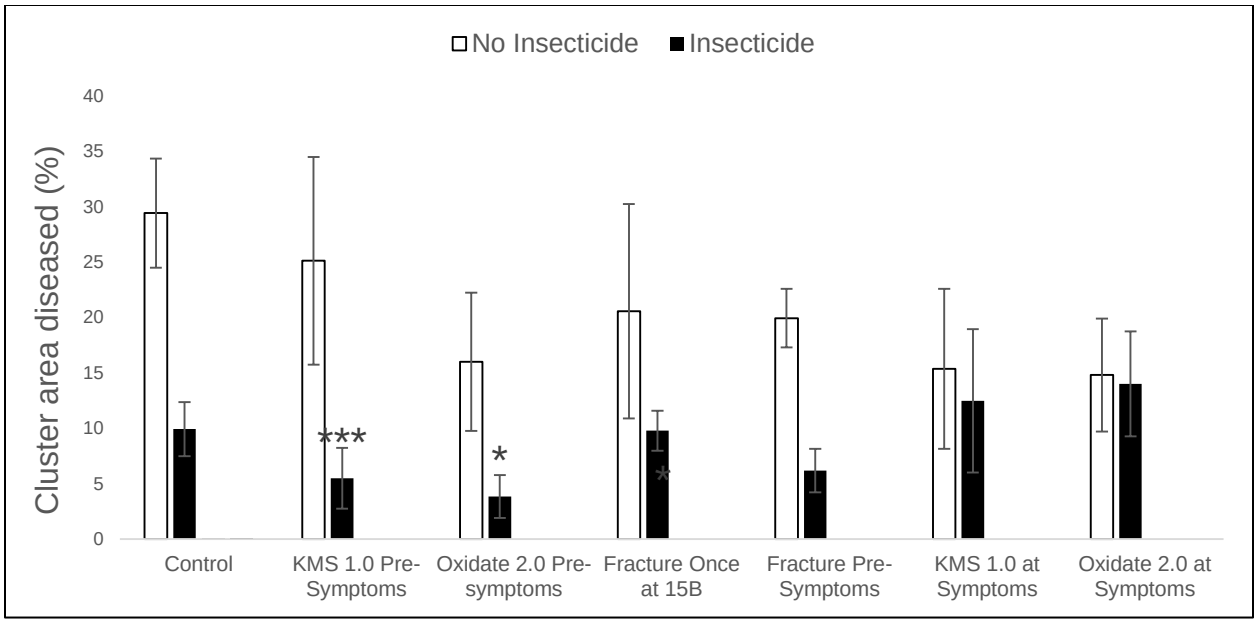

Figure 2. Sour rot severity in a vineyard block of *Vitis* interspecific hybrid cv. Vignoles in Geneva, NY in 2015 as a function of antimicrobial and insecticide treatments. Data represent the mean values across four replicate one- or two-panel plots per treatment, in which all clusters were rated. An asterisk (*) above a bar denotes a significant difference relative to the treatment receiving no antimicrobial or insecticide sprays as determined by Dunnett's Method of Comparisons. * = significant at $P = 0.05$.

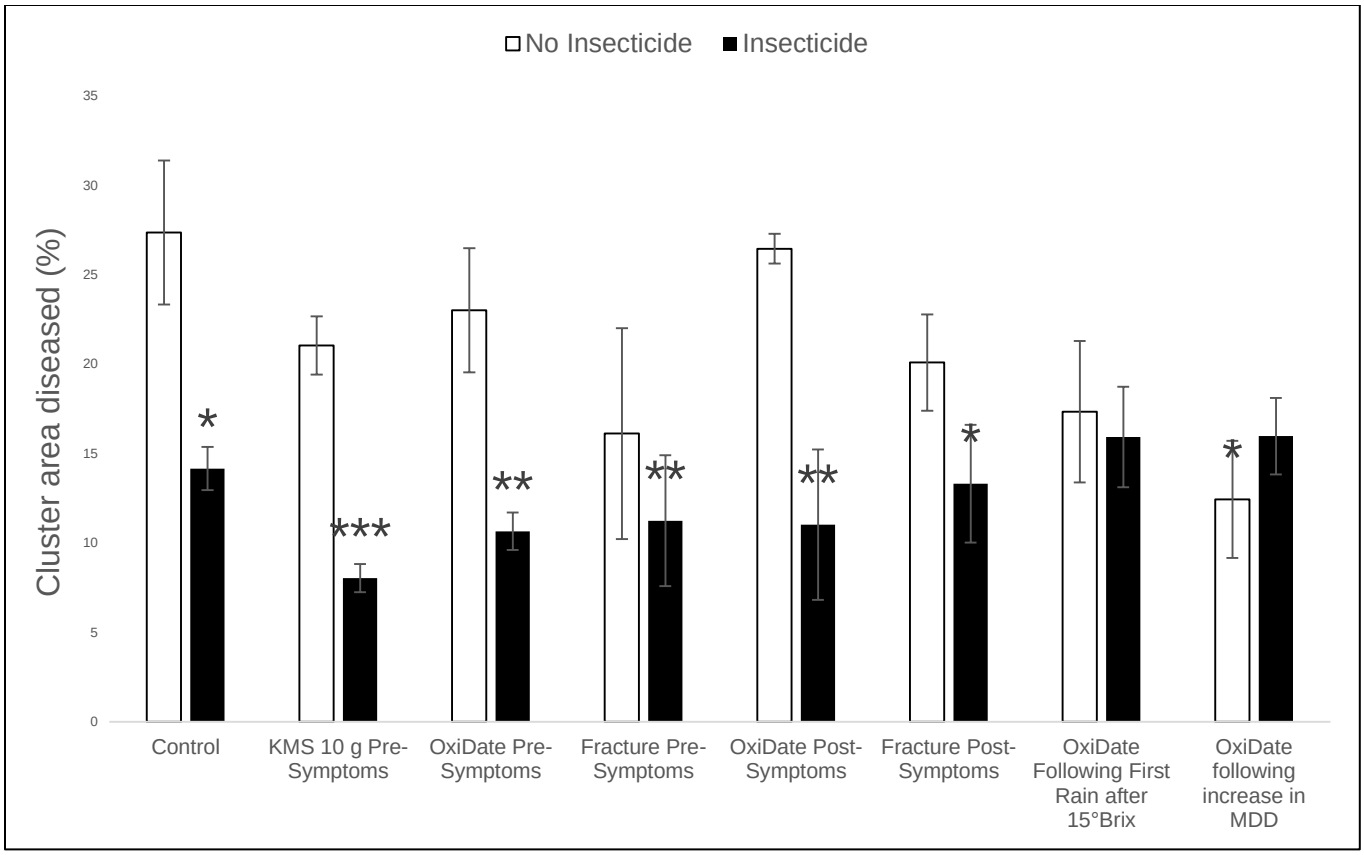

Figure 3. Sour rot severity in a vineyard block of *Vitis* interspecific hybrid cv. Vignoles in Geneva, NY in 2016 as a function of antimicrobial and insecticide treatments. Data represent the mean values across four replicate one- or two-panel plots per treatment, in which all clusters were rated. An asterisk (*) above a bar denotes a significant difference relative to the treatment receiving no antimicrobial or insecticide sprays as determined by Dunnett's Method of Comparisons. * = significant at $P = 0.05$, ** = significant at $P = 0.01$, *** = significant at $P = 0.001$.

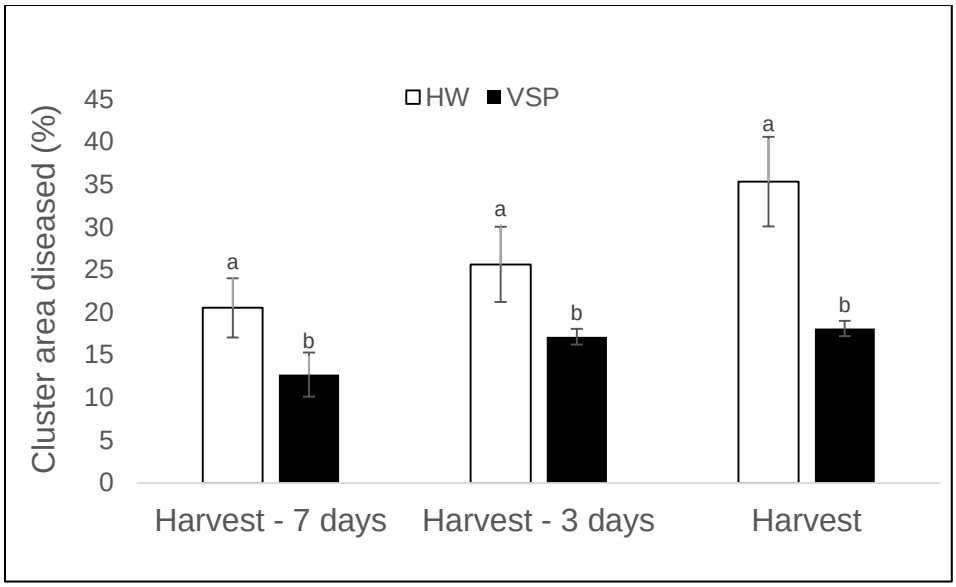

Figure 4. Progressions of sour rot severity in a commercial vineyard block of *Vitis* interspecific hybrid cv. Vignoles in Branchport, NY over the final 7 days before harvest in 2014 as a function of two training systems, High Wire Cordon (HW) and Vertical Shoot Positioning (VSP). Values represent the mean disease severities determined for all clusters on 10 vines in each of the two training systems. For each assessment date, means not labeled with a common letter are significantly different according to the Tukey-Kramer HSD test (p = 0.05).

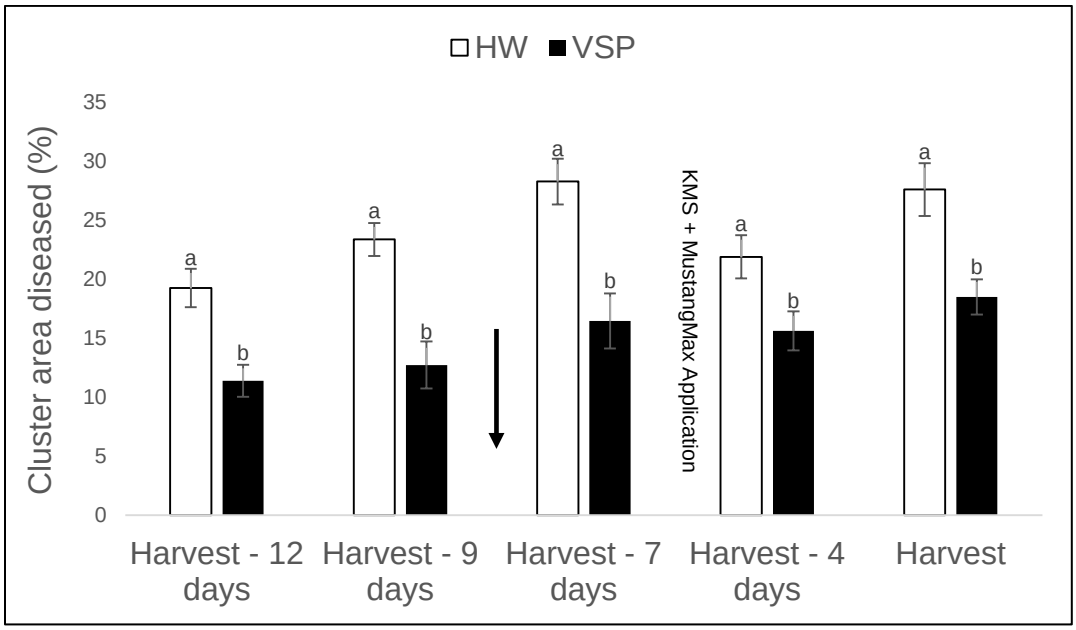

Figure 5. Progression of sour rot severity in a commercial vineyard block of *Vitis* interspecific hybrid cv. Vignoles in Branchport, NY over the final 12 days before harvest in 2015, as a function of two training systems, High Wire Cordon (HW) and Vertical Shoot Positioning (VSP). Following the 7-day-preharvest assessment, the growers applied a spray consisting of potassium metabisulfite and zeta-cypermethrin to all vines (arrow). Values represent the mean disease severities determined for all clusters on 10 vines in each of the two training systems. For each assessment date, means not labeled with a common letter are significantly different according to the Tukey-Kramer HSD test (p = 0.05).

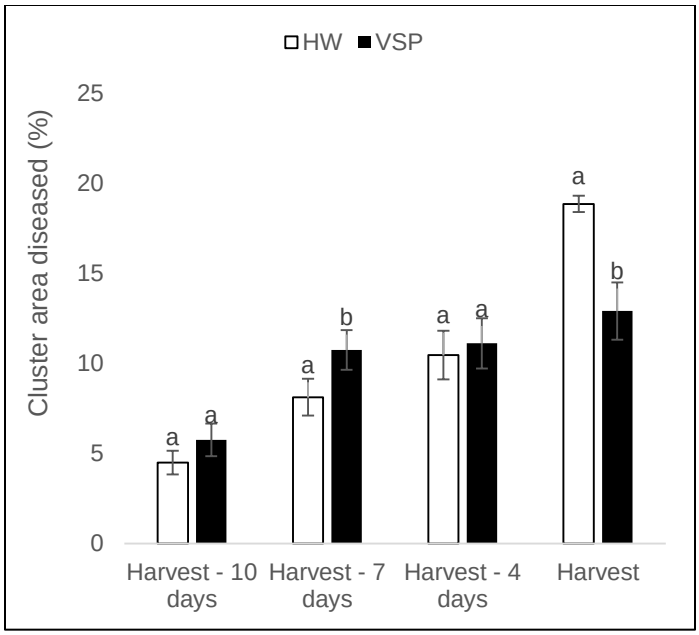

Figure 6. Progression of sour rot severity in a commercial vineyard block of *Vitis* interspecific hybrid cv. Vignoles in Branchport, NY over the final 10 days before harvest in 2016 as a function of two training systems, High Wire Cordon (HW) and Vertical Shoot Positioning (VSP). Values represent the mean disease severities determined for all clusters on 10 vines in each of the two training systems. For each assessment date, means not labeled with a common letter are significantly different according to the Tukey-Kramer HSD test (p = 0.05).

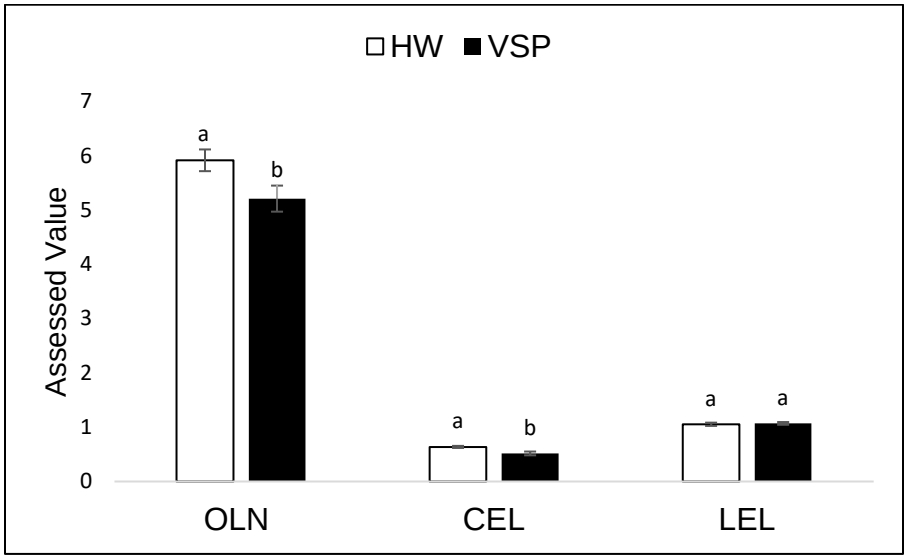

Figure 7. Enhanced Point Quadrat Analysis (EPQA) assessed in 2016 on vines of *Vitis* interspecific hybrid cv. Vignoles trained to two different systems, High Wire Cordon (HW) and Vertical Shoot Positioning (VSP), in a commercial vineyard in Branchport, NY. Occlusion layer number (OLN) represents the number of shade-producing contacts (leaves and clusters) per insertion; Cluster exposure layer (CEL) represents the number of shade layers between clusters and the nearest canopy boundary; Leaf exposure layer (LEL) represents the number of shading layers between leaves and the nearest canopy boundary. Values represent the mean assessments determined on 10 vines in each of the two training systems. For each parameter, means not labeled with a common letter are significantly different according to the Tukey-Kramer HSD test (p = 0.05).

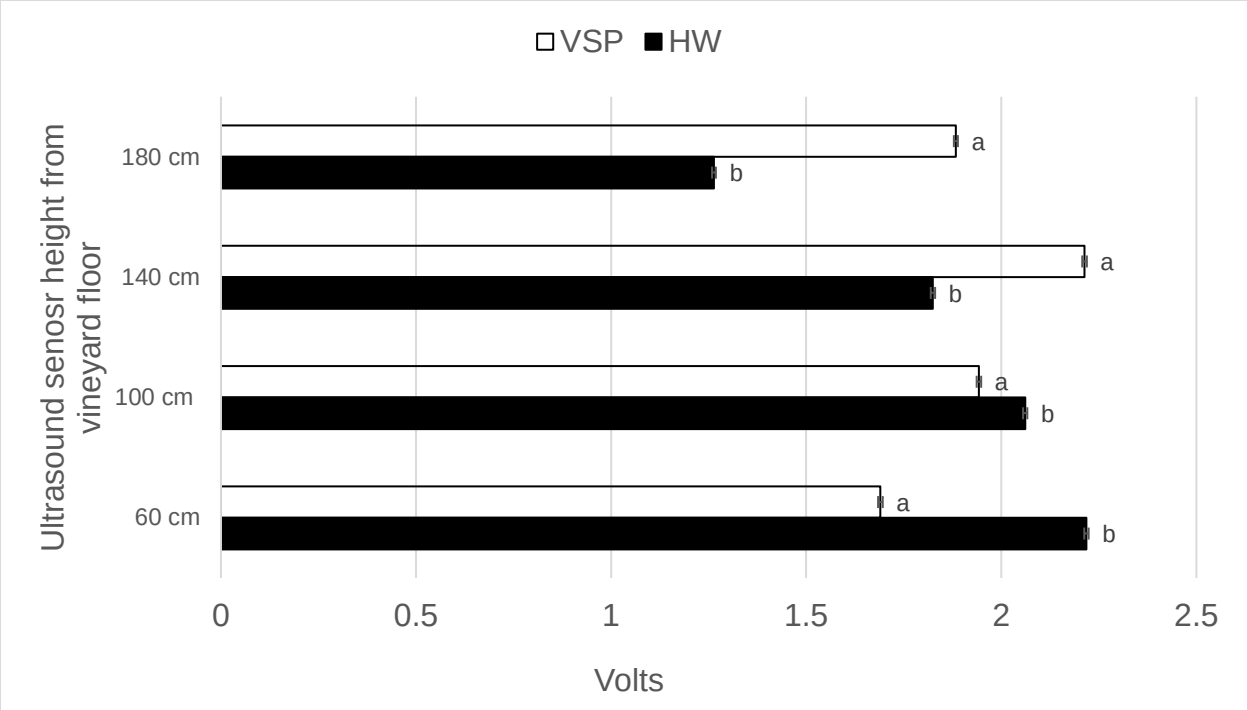

Figure 8. Ultrasound sensor canopy density measurements collected in late summer 2016 from vines of *Vitis* interspecific hybrid cv. Vignoles trained to two different systems, High Wire Cordon (HW) and Vertical Shoot Positioning (VSP), in a commercial vineyard in Branchport, NY. Four sensors were mounted on a utility vehicle at heights ranging from 60 to 180 cm above the vineyard floor and were driven down both sides of each of five rows of vines in each training system, for a total of 10 passes per training system. The data collected, expressed in volts, indicate the relative canopy densities at each given height, and are presented as mean values for the 10 replicate measures per training system at each height. For each height, means not followed by a common letter are significantly different according to the Tukey-Kramer HSD test (p = 0.05).

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Project 9 (FINAL)

Organic Seed Treatments for Sweet Corn for Enhanced Stand Establishment

Project Summary

When the proposal was submitted, the most recent agricultural census data listed New York as number two in organic sweet corn production in the US with 1,518 acres in 2011. Sweet corn seed fungal diseases, in particular those caused by species of the soil-borne pathogen *Pythium* causing pre- and post-emergence "damping-off" result in poor stand establishment or stand loss. Yield losses, as a result of stand loss, can be 40% or higher and 100% of NYS planted acres are at risk (Stivers, 1999). Yearly production costs for Wisconsin grown fresh market sweet corn were recently at over $2000 per acre (Center for Dairy Profitability, 2014). The University of Vermont Cooperative Extension reported an additional $750/acre cost for using transplants compared to direct seeding (Grubinger, 2010). Therefore, minimizing disease risks contributes to maintaining the market position for New York State organically grown sweet corn. Moreover, reducing the need for expensive transplants reduces grower costs in producing high quality, fresh market organic sweet corn.This project was focused on alleviating the yield risk due to damping-off fungi through the collaborative development of vermicompost-based seed treatments and field trials, within the two-year funding period.

The facilities and expertise of the Seed Science and Technology program at the Cornell University-NYS Agricultural Experiment Station, Geneva, NY (NYSAES), under the direction of Dr. Alan Taylor, were utilized throughout the study; Dr. Taylor's lab has the only University based program in the US with seed treatment and coating technologies. Additionally, staff at the New York State Seed Testing Laboratory, located at NYSAES, Geneva, NY (moved to Albany, NY on Dec. 31, 2016) had unique experience in seed testing and conducting the cold test on sweet corn, as well as facilities for testing temperature sensitivity and simulating alternating day/night temperatures; these facilities are now incorporated into Dr. Taylor's Seed Science and Technology Laboratory. Over the course of this study, twenty-two popular fresh market sweet corn varieties, identified by six companies, were initially received; all varieties were subjected to germination tests conducted under controlled laboratory conditions. Based on the results from these cold germination tests that simulate field conditions through seed-soil contact and sub-optimal temperatures, seeds supplied by Harris Seeds, Inc. (Rochester, NY), Seneca Vegetable Research, Inc. (Hall, NY), and Illinois Foundation Seeds, Inc. (Tolono, IL) were chosen for further testing and seed coating development. A NYS industry collaborator, Worm Power (RT Solutions, Inc., Avon, NY) supplied vermicompost used to develop seed treatments that are suppressive to the soil-borne pathogens *Pythium* spp. (Jack and Nelson, 2010) causing seedling damping-off. In addition to this combination of "in-house" expertise and facilities, there was active interest among growers to reduce stand loss due to damping-off. We were able to collaborate with a local wholesale organic and conventional vegetable and hop grower, Rick Pedersen, Pedersen Farms, Seneca Castle, NY; Rick was generous with his time and expertise and provided a transitional organic field for our 2016 planting. The overall goal desired by growers and stated in our proposal was to develop effective organic seed treatments that can be used for organic or conventional production to reduce production costs and provide consistent sweet corn stands.

There were no previously funded SCBGP or SCBGP-FB projects upon which this project was built.

Project Approach

The facilities and expertise of the Seed Science and Technology program at the Cornell University-NYS Agricultural Experiment Station, Geneva, NY (NYSAES), under the direction of Dr. Alan Taylor, were utilized throughout the study; Dr. Taylor's lab has the only University based program in the US with seed treatment and coating technologies. Additionally, staff at the New York State Seed Testing Laboratory, located at NYSAES, Geneva, NY (moved to Albany, NY on Dec. 31, 2016) had unique experience in seed testing and conducting the cold test on sweet corn, as well as facilities for testing temperature sensitivity and simulating alternating day/night temperatures; these facilities are now incorporated into Dr. Taylor's Seed Science and Technology Laboratory. Over the course of this study, twenty-two popular fresh market sweet corn varieties, identified by six companies, were initially received; all varieties were subjected to germination tests conducted under controlled laboratory conditions. Based on the results from these cold germination tests that simulate field conditions through seed-soil contact and sub-optimal temperatures, seeds supplied by Harris Seeds, Inc. (Rochester, NY), Seneca Vegetable Research, Inc. (Hall, NY), and Illinois Foundation Seeds, Inc. (Tolono, IL) were chosen for further testing and seed coating development. A NYS industry collaborator, Worm Power (RT Solutions, Inc., Avon, NY) supplied vermicompost used to develop seed treatments that are suppressive to the soil-borne pathogens *Pythium* spp. (Jack and Nelson, 2010) causing seedling damping-off. In addition to this combination of "in-house" expertise and facilities, there was active interest among growers to reduce stand loss due to damping-off. We were able to collaborate with a local wholesale organic and conventional vegetable and hop grower, Rick Pedersen, Pedersen Farms, Seneca Castle, NY; Rick was generous with his time and expertise and provided a transitional organic field for our 2016 planting. The overall goal desired by growers and stated in our proposal was to develop effective organic seed treatments that can be used for organic or conventional production to reduce production costs and provide consistent sweet corn stands.

The project objectives, as stated in the 2014 proposal, included:

1) research conducted with at least two sweet corn varieties, one each representing the popular fresh market "sugary enhanced (se) " and "supersweet (sh2)" genotypes;
2) FY1 development and application of at least two vermicompost-based seed treatments through controlled laboratory tests;
3) FY1 field test two vermicompost seed treatments compared to non-treated seeds and transplants;
4) further development of the most efficacious seed treatments based on laboratory germination results, cold tests, and FY1 field results;
5) characterization of the effect of soil temperature on seed treatment efficacy;
6) FY2 incorporation of the best selected seed treatment into field trials established at NYSAES, and

with grower and industry collaborators; and

7) FY2 publication of results through New York State Cornell Cooperative Extension and in peer-reviewed journals.

FY1 - Seed Coating with Vermicompost:

For FY1, Harris Seed Co., Rochester, NY donated two varieties of non-treated sweet corn that are popular choices for organic fresh market sweet corn production. Germination tests were conducted by the NYS Seed Testing Laboratory for two varieties: Luscious (homozygous "sugary enhanced" (se)) and Xtra-Tender (XT) 282A ("augmented supersweet", also known as "augmented shrunken" (sh2)). Warm germination test (7 days at 25°C) results for non-treated seed were close to those reported on the label: Luscious, 93% (label germination, 91%) and XT 282A, 92% (label germination, 89%). Germination of non-treated seeds under greenhouse conditions appeared normal.

RT Solutions, Worm Power, Avon NY provided their OMRI (Organic Materials Review Institute) approved vermicompost. Preliminary tests indicated that the 74µ particle size and smaller (≤74µ) micronized vermicompost (mVC) combined with a suitable binder would hold the vermicompost to the seed coat without sloughing off during handling; test results identified SOL053, an organic binder provided by Incotec, Inc. (Salinas, CA) and diluted to a 50% solution SOL053:distilled water (1:1, wt:wt) as the most effective binder. Binder-vermicompost combinations were developed and trialed in the Seed Science and Technology Laboratory and evaluated on percent buildup (based on seed dry weight) and retention during a mechanical shaking test (i.e., coating weight retained after shaking of coated seeds). Overall, the SOL053 binder applied at 10% of dry seed weight provided better retention for encrusted seed. To be consistent with the components used for encrustment, the film coating contained SOL053 binder plus mVC (≤74µ) as a slurry applied at 10% of the dry seed weight. Applications of coatings were done using a rotary pan (R6) seed coating equipment; the coating was applied either as a low volume slurry of mVC suspended in binder to produce "film coated" seed or as separate components, binder and pre-moistened mVC to produce "encrusted" seed. The procedure produced film coated seeds with 4% mVC based on dry seed weight. For encrustment, 150g of seed were coated using 50% SOL053 as the binder and pre-moistened mVC (≤74µ) as the filler; filler was applied at 20% of dry seed weight. Encrusted seed produced for *field* planting had 13% mVC (≤74µ) for Luscious and 16% mVC for XT 282A, based on dry seed weight.

FY1 - Field Trials:

Two field trials were planted, under the supervision of the field supervisor, James Ballerstein and the Co-Project Director, Dr. Stephen Reiners, on May 19, 2015 ("cool soil conditions") and June 24, 2015 ("warm soil" conditions), in a transitional organic field at the Research North Experimental Farm, NYSAES, Geneva, NY. A randomized complete block design was used for each variety on each planting date. Each planting included: transplants grown from non-treated seed (performance control); film coated seed; encrusted seed; and non-treated seed (disease control) for both varieties. As was commonly reported among many farmers in our region, for the 2015 growing season and in our FY1 annual report, both plantings sustained crop failure, due to sustained cold wet conditions with totally saturated soil within two weeks of the first field planting.

FY1 - Germination Tests:

With the crop failures in the 2015 season, additional cold tests were done using modified cold germination test conditions, in an attempt to identify seed susceptibility and varietal differences to cold, wet soil conditions. Initially, additional tests were conducted with the 2015 field planted

varieties. Warm germination test results, for Luscious and XT 282A were comparable to those reported by the supplier, 92% - 95%. An 11% and 12% drop in the average percent normal seedlings was recorded for Luscious and XT 282A, respectively, under cold test conditions *without* soil, indicating some susceptibility to cold germination conditions. The temperature regime for cold tests is 10˚C for 7 days (24hrs dark) and then transferred to 25˚C (16hrs dark, 8hrs light) for an additional 7 days. Under cold test conditions using *sterile* soil, the average percent normal seedlings fell further, 76% for Luscious (17% drop) and 78% for XT 282A (14% drop). However, a significant loss of germination was observed for both varieties when seeds were exposed to *non-sterile* soil. The average percent normal seedlings for Luscious was 1% and 3% for XT 282A, indicating an effectively lethal susceptibility to the soil borne pathogens present in the non-sterile soil.

The close of the 2014-2015 project year found considerable effort being expended on the testing and identification of candidates from the 12 "sugary enhanced" (se) varieties and ten "shrunken2" (sh2) varieties received from six seed industry donors. At the completion of the cold germination tests, the selected varieties, one from each genotype, were required to be of recognized high fresh market value and tolerant of cold, wet germination conditions common to the Geneva, NY growing season. Cold test germination results reported at year's end, for the 2014-2015 project year, identified one "sugary enhanced" (se) variety, CuppaJoe as showing a 32% reduction in average percent normal seedlings but greater than 50% average normal seedlings with exposure to non-sterile soil; this combination of moderate seed vigor lot (67% average normal seedlings) with obvious impact associated with exposure to non-sterile soil indicated a potential for benefit for CuppaJoe seed treated with biological seed coatings. Similarly, a moderate seed vigor lot (59% average normal seedlings) yet obvious impact (18% loss in average percent normal seedlings) was shown by Xtra-Tender 274A (XT 274A), a "shrunken2" (sh2) variety, with exposure to non-sterile soil. CuppaJoe (se) and XT 274A (sh2) were chosen for additional cold germination tests and seed coating trials, for FY2, the 2015-2016 project year.

FY2 - Seed Coating with Vermicompost:

In keeping with the project objectives, additional seed treatment formulations were tested and product sources identified. Vermicompost, provided by Worm Power (Avon, NY) was compared with BioWorks' RootShield® AG seed treatment (Victor, NY). To determine the suitability of various seed treatment formulations for the cold, wet field conditions common to early plantings typical to the Geneva, NY area, modified cold tests using non-sterile field soil mixed with mason's sand as a substrate were conducted under four temperature regimes; identification of seed coating formulations for future testing was based on the comparison of the average percent normal and abnormal seedlings between temperature regimes within a seed treatment, as well as the comparison of average percent normal and abnormal seedlings between treatment types within a temperature regime. For the lots tested, a reduced average percent normal seedlings was observed for both varieties using the 10°C/8days-25°C (8hrs light/16hrs dark)/4days temperature regime, compared to regimes using 15°C, 20°C, and 25°C as the initial temperature. Seed treated with one of the two biological seed treatments, micronized vermicompost (≤74µ particle size, encrustment) or Rootshield® AG Wettable Powder (WP) (*Trichoderma harzianum* Rifai strain T-22, guaranteed analysis of 85% ≤75µ particle size) had average percent normal seedlings that were less than the non-treated control of both sweet corn varieties, at the same initial

temperature. This reduction indicated negative impact of exposure to 10°C without an obvious associated benefit of either biological seed coating. At this point in our investigations, the lack of treatment benefit was suspected to be due to either loss of efficacy for the biological product and/or a negative seed lot x biological treatment batch effect.

With the change in management at our vermicompost supplier, Worm Power, Avon NY the micronized vermicompost (≤74µ particle size) was no longer available. The NYSAES Seed Science and Technology Laboratory, supervised by Dr. Alan Taylor assumed the responsibility for processing commercially available bagged product (Worm Power "All Purpose Organic Plant Food") to the particle sizes used for subsequent coating trials and cold germination tests. Trials with encrusted seed showed similar results for average percent normal seedlings within a variety, across vermicompost production dates. For the "large" size seed lots, the average percent normal seedlings for encrusted seed were consistently greater for XT 274A compared to CuppaJoe, regardless of the vermicompost production lot used, indicating varietal differences. However, lot-to-lot differences were apparent for XT 274A with the "large round" (LR) seed lot performing better than the "medium flat" (MF) seed lot of encrusted seed. Additionally, by comparison to the non-treated seed, the encrusted seed, regardless of the size class of the vermicompost particles, had lower average percent normal seedlings. Due to the lack of coating uniformity for the seed lots tested, coating fragility, and reduced percent average percent normal seedlings, encrustment was eliminated as a means of seed coating.

FY2 - Germination Tests:

Compared to the germination test results for encrusted seed, subsequent tests with film coating provided better coating uniformity and coat integrity, as well as greater average percent normal seedlings for both varieties. Commercially available Worm Power "All Purpose Organic Plant Food" vermicompost was processed to two different particle sizes and the average percent normal seedlings for each vermicompost treatment compared to the earlier results obtained for seed film coated with BioWorks Rootshield® AG provided by BioWorks, Inc., Victor, NY. Compared to encrusted seed, under the most rigorous testing, 10°C/8days followed by 25°C/4day, the average percent normal seedlings for the XT 274A (Lot 3517-6-401 MR, "medium round") seed *film* coated with Rootshield, 40% was similar to the XT 274A vermicompost (≤75µ particle size) encrusted seed, 32%. However, the average percent normal seedlings for the film coated Rootshield CuppaJoe (Lot 2407 LR) seed, 84% was far greater than the vermicompost encrusted CuppaJoe seed, 46%. Results from subsequent germination tests, using different seed lots with different seed sizes, indicated negligible benefit for the vermicompost *film coated* XT 274A MF seed (Lot 3517-6-401 MF), 11% compared to the XT 274A MF *encrusted* seed, 9%, indicating a poorly perfoming seed lot and/or poor seed lot x variety effect under the cold germination conditions used.

Vermicompost treatment differences appeared to be more noticeable for CuppaJoe "large flat" (LF) seed (Lot 2902 LF). Film coating using the ≤74µ vermicompost particle size was associated with a greater than two-fold increase in average percent normal seedlings for CuppaJoe LF seed, 49% compared to vermicompost encrusted CuppaJoe LF seed, 20%. The average percent normal seedlings for the

CuppaJoe LF vermicompost film coated seed is almost the same as the encrusted CuppaJoe LR seed, 46% but less than the CuppaJoe LR seed film coated with Rootshield, 84%. Because film coatings provided better overall coat integrity and coverage uniformity as well as greater average percent normal seedlings for vermicompost film coated CuppaJoe seed, film coating was selected as the method for coating the seeds to be used for the 2016 field planting. Large sized seed lots for both varieties, XT 274A, Lot# 3517-4-502 *LR* and CuppaJoe, Lot# 2902 *LF* were chosen for film coating and subsequent field planting.

Goals and Outcomes Achieved

Measurable outcomes, as stated in the proposal, were:

1) Decreasing production risk
   GOAL – The goal for this outcome is development of vermicompost-based sweet corn seed treatments with reduced crop mortality due to damping-off fungi.
   PERFORMANCE MEASURE – The quantifiable measures for performance of this goal include: percent stand losses caused by damping- off for treated and non-treated seed.
   BENCHMARK – Stand establishment from direct seeding will be compared to using transplants.
   TARGET – The target product for this project is to reduce stand loss to less than 10% with comparable fresh market quality.
   PERFORMANCE MONITORING – Percent seedling emergence recorded 1, 2, and 3 weeks after sowing, days to harvest, plant height, ear number, ear weight, ear length, ear width and tip fill.

2) Reduction of production costs
   GOAL – The goal for this outcome is development of vermicompost-based sweet corn seed treatments for less cost to the grower than transplants.
   PERFORMANCE MEASURE – The quantifiable measure for performance of this goal is the return on investment for the final market crop. – drought caused low yield => low ROI
   BENCHMARK – The baseline against which the use of sweet corn seed treatments will be measured will be the cost of non-coated seed and the cost of using transplants.
   TARGET – The target product for this project is to reduce stand loss to less than 10% with comparable fresh market quality.
   PERFORMANCE MONITORING – Costs associated with direct seeding (treated and non-treated) and transplanting, crop maintenance, and yield will be determined.

Activities Completed To Achieve Performance Goals

FY2 - Field Trials:
A one acre field at 2262 Carter Road, Geneva, NY 14456 (42.922823, −76.998113), leased by Rick Pedersen, owner/operator of Pedersen Farms, 1798 County Road 4, Seneca Castle, NY 14547, was made available to Cornell for the 2016 planting season. The field was clean and the field preparation and planting conditions were excellent for both planting dates. Field conditions for the early season

planting, 5/17/2016 were: ambient air temperature, 43°F (min) – 61°F (max); mean hourly soil temperature at 2 inches, 53°F and at 4 inches, 53°F; and mean hourly soil moisture at 2 inches, 21.8% and 4 inches 21.2%. For the mid-season planting, 6/6/2016, the field conditions were: ambient air temperature, 56°F (min) – 78°F (max); mean hourly soil temperature at 2 inches, 64°F and at 4 inches, 64°F; and mean hourly soil moisture at 2 inches, 15% and 4 inches 14.2% (NRCS-NWCC – Soil Climate Analysis Network (SCAN) Data & Products, Data for station 2011, Geneva, NY). Results from a bulk soil sample taken prior to field preparations showed optimal pH and gave the baseline data for N, P, and K used for determining the application rate of 2000lbs/acre of a 5-4-3 organic fertilizer. Based on this application rate, calculations indicated close to optimal nitrogen, as well as phosphorous and potassium exceeding the usual removal demands reported for sweet corn.

The *transitional organic* field used for the 2016 planting season was, geographically, the closest *certified organic* field (i.e., enrolled in the organic certification process) available. However, irrigation was not available on site. As the growing season progressed, precipitation fell markedly below normal; this contrasts to the 2015 growing season during which precipitation was sufficiently above normal to cause complete crop loss. The Geneva, NY (Ontario County) area was declared under a "drought watch", for severe drought conditions, on 7/15/2016 and a "drought warning" one level below "emergency", on 8/3/16. As an emergency measure, in order to alleviate the obvious drought stress in both the 5/17/2016 planting (Planting #1) and the 6/6/2016 planting (Planting #2), hand watering was done for the entire field on 7/5/2016; soil penetration did not exceed three inches at 12 hours after watering. On 7/11/2016, the field crew installed a tank truck supplied, gravity-fed irrigation system, 55 days after putting in Planting #1 and 34 days after putting in Planting #2. At 55 days after planting for Planting #1, the initiation of irrigation was well into pollen shed for both XT 274A and CuppaJoe. However, tassels had not yet emerged for either variety for Planting #2, when the piping was installed. Leaf roll and drooping were mitigated with the application of irrigated water.

FY2 – Stand Establishment:

Survival counts, recorded at 14 days after planting, showed less than 15% difference for the average row positions with plants ("row fill") for treated seed compared to non-treated seed in Planting #1 and Planting #2 (Table 1); with the exception of treatments 1 and 2 for XT 274A in Planting #2, none of the treated seed produced stands meeting the proposed targeted stand loss of 10% or less. For XT 274A, in Planting #1, 14 day transplants (treatment 3, 113/120 plants = 94%) had 9% and 10% more plants per replicate than seedlings grown from treatment 2, Rootshield film coated seed (85%) and treatment 1, vermicompost film coated seed (84%), respectively, and 12% more plants than non-treated seed, treatment 4 (82%) (Table 1). In a treatment by treatment comparison, average survival for CuppaJoe, in Planting #1, at 14 days, was 8% less for treatments 1 (76%), 2 (77%), and 4 (74%) and 16% less for treatment 3, transplants (78%) than the 14 day survival for XT 274A. Within variety comparisons, for Planting #2, show very similar average percent XT 274A survival for treatment 1, 91% and treatment 2, 92%; these percentages are slightly less than that for non-treated seed, treatment 4, 96% and less than that for transplants, 100%* (Table 1). Average 14 day survival for CuppaJoe seedlings for treatment 1, 78% was less than that for treatments 2 and 4 (non-treated seed), 86% and treatment 3 (transplants),

99% (Table 1). With the exception of treatment 1 for CuppaJoe, Planting #2, the 14 day survival percentages for treated seed are similar to those for non-treated seed (treatment 4), for both varieties but across treatment survival was greater for Planting #2. This similarity in 14 day survival between treatments 1, 2 and 4 within a variety indicates no apparent seed treatment associated survival benefit but the slightly greater overall survival for Planting #2 may indicate an environment-associated benefit (e.g., warmer ambient air and soil temperatures at time of planting and seed germination). Overall, during the first two weeks, survival for XT 274A, in both plantings, was greater than that for CuppaJoe; transplants had somewhat greater overall 14 day survival for both plantings, indicating a survival advantage associated with the established in-plug root system under progressively drying soil conditions. However, while the 14 day transplant survival may have been greater than direct seeded treatments and the non-treated control, drought, especially for Planting #2, was associated with the greatest amount of tip *not* filled for transplants for both varieties. This damage indicates the critical need for adequate moisture, typically one to one and half acre inches per week not only for the first three weeks of growth but through kernel development at 42-46 days after emergence.

FY2 – Harvest Data:

In spite of the lack of precipitation and late start to the field irrigation, plant establishment was maintained in sufficient numbers to provide harvest plots for all replicates of each treatment for both Planting #1 and #2 (Table 1); harvest plots were either 20 parallel feet of two rows or 40 feet from one row per replicate and centrally located in each replicate. Harvest data, per replicate, were collected for: number of plants in each harvest plot (maximum 60 plants); number of marketable ears per harvest plot; total harvest ear weight (lbs); 10 ear combined sub-sample/replicate green ear weight (with husk) and yellow ear weight (without husk) (lbs); 10 ear sub-sample per replicate for individual ear length (inches), ear diameter (inches) and percent of tip not filled; combined kernel weight (lbs) for a 10 ear sub-sample; and the percent moisture for each combined 10 ear sub-sample per replicate. Treatment data means for continuous variables of individual ear length, ear diameter, and inches of tip unfilled (sample size per treatment=40) were compared using Tukey's Honestly Significant Difference (HSD), as executed in JMP Pro 12, using alpha at 0.05 (i.e., 5% probability that a difference exists between means when it actually does not exist), for Planting #1 (Table 2) and Planting #2 (Table 3).

As discussed and illustrated in the 2016 Annual report, the lack of early season irrigation was associated with reduced plant height at harvest for all treatments for XT 274A and to a lesser degree, for CuppaJoe for Planting #1, compared to Planting #2. In addition, ear length for both varieties for all treatments for both plantings was less than the advertised average maximum ear length for both varieties. The reduction in ear length and ear diameter contributed to the markedly reduced number of marketable ears harvested from Planting #l, 27% (i.e., 16/60) - 37% of the maximum for XT 274A and 38% - 55% for CuppaJoe (Table 1). Drought associated effects for Planting #2 were not as severe for

Table 1. **Planting #1 and #2 *harvest* data**: **Planting #1**: Both varieties, XT 274A and CuppaJoe were harvested on 8/5/2016; **Planting #2**: XT 274A was harvested on 8/15/2016 and CuppaJoe harvested on 8/19/2016. Average survival rates at 14 days are calculated across 4 replicates, with a maximum of 60 plants per row and 120 plants per replicate plot per treatment. **N.B**.: ***Ear data received from the***

harvest crew gave individual ear data only for ear length, ear diameter, and tip fill (treatment n=40); all other data were given either as one sub-sample weight or percent number by replicate (treatment n=4) within a treatment. Harvest plots were either 20 parallel feet of two rows or 40 feet from one row per replicate and centrally located within the replicate with a maximum of 60 plants per harvest plot. **Treatment 1**: Film Coated with processed vermicompost (**VC**), applied as a slurry containing, by weight, 4g filler (≤74µ VC)/100 g seed suspended in 15g binder (SOL053:dH_2O (1:1, by wt) per 100g seed; **Treatment 2**: Film Coated with Rootshield® AG (**RS**) applied as a slurry containing 0.1875g RS/100g seed suspended in 4g binder (SOL053:dH_2O (1:1, by wt) per 100g seed; **Treatment 3**: Transplants (**T**) raised from non-treated seed (2 plants/plug); and **Treatment 4**: Non-treated field planted seed, control (**C**). Treatments 1, 2, and 4 were direct seeded in the field.

Variety	Planting #	Trt #	Trt Type	Ave Sur-vival per Repli-cate by Trt (max 120) at 14 days	Ave Sur-vival Per-cent/ Repli-cate (max 120 plants = 100%)	Ave # Plants per Repli-cate Harvest Plot (max 60/ plot)	Ave # Market-able Ears (max 60/ plot)	Ave Total Harvest Ear Wt (lb)	Ave Green Ear Wt (lbs) (Ave of 4 Reps: 10 Ear Sub-sample/Rep)	Ave Yellow Ear Wt (lbs) (Ave of 4 Reps: 10 Ear Sub-sample/Rep)	Ave Ear Length [1] (Ave of 4 Reps: 10 Ears/ Rep)	Ave Ear Dia [2] (Ave of 4 Reps: 10 Ears/ Rep)	Ave Tip Length NOT Filled (ins) (Ave of 4 Reps: 10 Ears/ Rep)	Ave Kernel Wt (lbs) (Ave of 4 Reps: 10 Ear Sub-sample/Rep)	Har-vest Index (Ave of 4 Reps: 10 Ear Sub-sample/ Rep)	Ave moisture %
274A	1	1	VC	101	84	54	20	12.93	6.75	4.61	6.7	1.3	0.025	2.371	4.3	78.8
274A	1	2	RS	102	85	53	16	9.77	6.10	4.17	6.5	1.1	0.000	2.034	4.1	79.4
274A	1	3	T	113	94	60	21	12.80	6.04	4.48	6.5	1.3	0.206	2.575	4.5	77.5
274A	1	4	C	98	82	54	22	14.73	6.79	4.89	6.8	1.2	0.000	2.375	4.3	78.6
CuppaJoe	*1*	*1*	*VC*	*91*	*76*	*53*	*33*	*16.45*	*5.03*	*3.42*	*6.5*	*1.4*	*0.094*	*1.624*	*5.1*	*74.8*
CuppaJoe	*1*	*2*	*RS*	*92*	*77*	*49*	*29*	*14.65*	*5.54*	*3.72*	*6.8*	*1.4*	*0.069*	*1.880*	*5.1*	*74.4*
CuppaJoe	*1*	*3*	*T*	*94*	*78*	*51*	*23*	*13.13*	*5.95*	*4.36*	*7.1*	*1.5*	*0.275*	*2.518*	*6.1*	*69.5*
CuppaJoe	*1*	*4*	*C*	*89*	*74*	*49*	*29*	*14.88*	*5.51*	*3.69*	*6.7*	*1.3*	*0.052*	*1.785*	*5.1*	*74.4*
274A	2	1	VC	109	91	59	40	22.05	5.48	4.13	7.3	1.7	0.719	1.970	4.3	78.4
274A	2	2	RS	110	92	61	42	24.23	5.65	4.27	7.3	1.7	0.825	2.041	4.3	78.6
274A	2	3	T	* 122	100	* 64	34	24.45	5.63	4.22	6.6	1.9	1.306	2.411	5.1	74.8
274A	2	4	C	115	96	* 62	39	20.85	5.29	4.01	7.2	1.7	0.906	1.713	4.4	78.1

CuppaJoe	***2***	***1***	***VC***	***94***	***78***	***55***	***35***	***16.13***	***5.09***	***3.82***	***7.4***	***1.5***	***0.400***	***1.730***	***4.8***	***76.0***
CuppaJoe	***2***	***2***	***RS***	***103***	***86***	***59***	***37***	***16.63***	***4.73***	***3.64***	***7.2***	***1.6***	***0.425***	***1.701***	***4.8***	***75.9***
CuppaJoe	***2***	***3***	***T***	***119***	***99***	**** 62***	***37***	***16.70***	***4.65***	***3.54***	***7.0***	***1.7***	***1.581***	***2.170***	***5.8***	***71.0***
CuppaJoe	***2***	***4***	***C***	***103***	***86***	***58***	***36***	***16.33***	***5.00***	***3.76***	***7.5***	***1.5***	***0.350***	***1.729***	***4.8***	***75.9***

* More than 60 plants per harvest plot or 120 plants per replicate is due to accidental double seeding with two plants surviving per row position.

1. Seed supplier advertised normal ear length for XT 274A is 8.0-9.0 inches (http://www.ifsi.com/sweet_corn) and 8.0-8.5 inches for CuppaJoe (http://fraserseeds.com/upload/doc/Seneca Veg Product Portfolio.pdf).
2. Seed supplier advertised normal ear width for CuppaJoe is 1.75 inches with 16 rows; information for ear width for XT 274A was not listed.

ear length and the number of marketable ears as reported for Planting # 1 (Table 1). While "tip fill" was markedly reduced (i.e., increased amount of tip *not* filled) across treatments for both varieties for Planting #2, the harvest crew reported an increase in the number of marketable ears compared to Planting #1, 57% - 70% for XT 274A and 58% - 62% for CuppaJoe.

Within variety comparison of treatment means, for Planting #1 (Table 2), showed statistically significant differences for CuppaJoe for ear length and ear diameter and for ear diameter for XT 274A.

Table 2. **Planting #1**, XT 274A and CuppaJoe, comparison of means for: ear length (inches, CuppaJoe* p-value 0.0008); ear diameter (inches, both varieties * p-value <0.0001); and length of ear tip *not* filled length (inches, no statistically significant difference for either variety). *Means not connected by the same letter are significantly different*. Data were analyzed using Tukey-Kramer HSD, alpha=0.05. Means are rounded to the number of significant digits as used for harvest collected data using means calculated by Tukey-Kramer HSD as executed in JMP Pro 12.

Treatment 1: Film Coated with processed vermicompost (**VC**), applied as a slurry containing, by weight, 4g filler (≤74µ VC)/100 g seed suspended in 15g binder (SOL053:dH_2O (1:1, by wt) per 100g seed;

Treatment 2: Film Coated with Rootshield® AG (**RS**) applied as a slurry containing 0.1875g RS/100g seed suspended in 4g binder (SOL053:dH_2O (1:1, by wt) per 100g seed;

Treatment 3: Transplants (**T**) raised from non-treated seed (2 plants/plug); and

Treatment 4: Non-treated field planted seed, control (**C**). Treatments 1, 2, and 4 were direct seeded in the field.

274A – Ear Length Means		**CuppaJoe – Ear Length Means**	
Treatment (Type)	Ear Length Mean (inches)	Treatment (Type)	Ear Length Mean (inches)
4 (C)	6.81 A	3 (T)	7.08 A *
1 (VC)	6.68 A	2 (RS)	6.79 AB
3 (T)	6.54 A	4 (C)	6.71 AB
2 (RS)	6.54 A	1 (VC)	6.51 B
274A – Ear Diameter Means		**CuppaJoe – Ear Diameter Means**	
Treatment (Type)	Ear Diameter Mean (inches)	Treatment (Type)	Ear Diameter Mean (inches)
3 (T)	1.57 A *	4 (C)	1.46 A *
1 (VC)	1.56 A *	2 (RS)	1.22 B
4 (C)	1.26 B	1 (VC)	1.15 B
2 (RS)	1.25 B	3 (T)	1.12 B
274A – Ear tip Unfilled Length Means		**CuppaJoe – Ear tip Unfilled Length Means**	
Treatment (Type)	Ear Tip Unfilled Length Mean (inches)	Treatment (Type)	Ear Tip Unfilled Length Mean (inches)
2 (RS)	0.15 A	2 (RS)	0.11 A
4 (C)	0.14 A	3 (T)	0.06 A
3 (T)	0.12 A	4 (C)	0.05 A
1 (VC)	0.08 A	1 (VC)	0.01 A

Comparison of mean ear length for CuppaJoe shows a significantly longer ear, on average for treatment 3 (transplants) when compared to all other treatments; ear length means for other treatments were not significantly different. There was no statistically significant difference between treatments for ear length for XT 274A. For CuppaJoe, treatment 4 (non-treated seed control) had significantly wider ears than all other treatments, while both treatment 3 (transplants) and 1 (vermicompost film coated seed) grouped within XT 274A as the widest ears. Treatment 2 (Rootshield® AG film coated seed) consistently grouped with the narrow ears, for both varieties. There was no statistically significant difference in Planting #1, for either variety, between treatments in the length of tip *not* filled.

Statistically significant differences existed between means for both varieties for Planting #2 (Table 3) for ear length, ear width, and tip fill. For both varieties, treatment 1 (vermicompost film coated seed) grouped with the longest ears and the narrowest ears as well as the ears with the best tip

Table 3. **Planting #2**, XT 274A and CuppaJoe, comparison of means for: ear length (inches, 274A * p-value <0.0001 and ** p-value 0.0002 and CuppaJoe * p-value 0.0053 and ** p-value 0.0117); ear

diameter (inches, 274A and CuppaJoe * p-value <0.0001); and length of tip *not* filled length (inches, 274A and CuppaJoe * p-value <0.0001). M*eans not connected by the same letter are significantly different*. Data were analyzed using Tukey-Kramer HSD, alpha=0.05. Means are rounded to the number of significant digits as used for harvest collected data using means calculated by Tukey-Kramer HSD as executed in JMP Pro 12.

Treatment 1: Film Coated with processed vermicompost (**VC**), applied as a slurry containing, by weight, 4g filler (≤74µ VC)/100 g seed suspended in 15g binder (SOL053:dH_2O (1:1, by wt) per 100g seed; **Treatment 2**: Film Coated with Rootshield® AG (**RS**) applied as a slurry containing 0.1875g RS/100g seed suspended in 4g binder (SOL053:dH_2O (1:1, by wt) per 100g seed; **Treatment 3**: Transplants (**T**) raised from non-treated seed (2 plants/plug); and **Treatment 4**: Non-treated field planted seed, control (**C**). Treatments 1, 2, and 4 were direct seeded in the field.

274A – Ear Length Means		**CuppaJoe – Ear Length Means**	
Treatment (Type)	Ear Length Mean (inches)	Treatment (Type)	Ear Length Mean (inches)
2 (RS)	7.29 A *	4 (C)	7.46 A *
1 (VC)	7.28 A *	1 (VC)	7.43 A **
4 (C)	7.17 A **	2 (RS)	7.22 AB
3 (T)	6.64 B	3 (T)	7.04 B
274A – Ear Diameter Means		**CuppaJoe – Ear Diameter Means**	
Treatment (Type)	Ear Diameter Mean (inches)	Treatment (Type)	Ear Diameter Mean (inches)
3 (T)	1.88 A *	3 (T)	1.66 A *
2 (RS)	1.70 B	2 (RS)	1.56 B
1 (VC)	1.68 B	1 (VC)	1.54 B
4 (C)	1.68 B	4 (C)	1.52 B
274A – Ear tip Unfilled Length Means		**CuppaJoe – Ear tip Unfilled Length Means**	
Treatment (Type)	Ear Tip Unfilled Length Mean (inches)	Treatment (Type)	Ear Tip Unfilled Length Mean (inches)
3 (T)	1.31 A *	3 (T)	1.58 A *
4 (C)	0.91 B	2 (RS)	0.43 B
2 (RS)	0.83 B	1 (VC)	0.40 B
1 (VC)	0.72 B	4 (C)	0.35 B

fill (i.e., least amount of tip *not* filled). Unlike Planting #1, treatment 3 (transplants) consistently produced the shortest ears and the widest ears, as well as the ears with the greatest amount of tip *not* filled, for both 274A and CuppaJoe. Within XT 274A, treatment 2 (Rootshield® AG film coated seed) had the longest ears and grouped with the treatments associated with narrow ears and better tip fill. However, within CuppaJoe, treatment 2 was within sampling variability with both the long ear and short

ear groups but grouped with the narrow ears and ears with better tip fill. For XT 274A, treatment 4 (non-treated seed control) grouped with treatments associated with long and narrow ears with better tip fill. Within CuppaJoe, treatment 4 had the longest ears with the best tip fill and grouped with long, narrow ears with better tip fill.

The moderate to severe drought conditions that existed for the entire growing season combined with the late application of irrigation and any possible irregularities in water dispersal during irrigation make identifying treatments that are significantly different statistically as well as biologically risky, at best. Results from treatment 1, vermicompost film coated seed from Planting #2 do appear to be associated with long ears, narrow ears, and better tip fill for both varieties. However, this significance was not observed for treatment 1 for Planting #1. Further, because of the possibly large contribution made by drought to reduce overall varietal performance, this apparent significance should not exclude consideration of the use of the other treatments under less stressful environmental conditions.

Decreasing Production Risk:

Overall, during the first two weeks, survival for XT 274A, in both plantings, was greater than that for CuppaJoe (Table 4); transplants had somewhat greater overall 14 day survival for both plantings, indicating a survival advantage associated with the established in-plug root system, under progressively drying soil conditions. However, while 14 day transplant survival may have been greater than direct seeded treatments, drought, especially for Planting #2, was associated with the greatest amount of tip *not filled* for transplants of both varieties. Consequently, while root establishment may have been initially enhanced for transplants, with subsequent 85% (CuppaJoe, Planting #1) to 100% (XT 274A, Plantings #1 and 2 and CuppaJoe Planting #2) live plants per harvest plot (Table 4) for Planting #1, the seedlings were developmentally advanced enough at planting that the progressively drying conditions of the drought effected greater kernel abortion in the tip of the ear for both varieties in Planting #2. This mid-season damage indicates the critical need for adequate moisture, typically one to one and half acre inches per week not only for the first three weeks of growth but through kernel development at 42-46 days after seedling emergence. Due to the increasingly severe drought conditions with consequent field-wide drought stress, absence of plants within a row due to damping off cannot be segregated apart from death due to drought.

For Planting #1, the average percent live plants per harvest plot from treatments 1 (90%) and 2 (88%) was 10% and 12% less, respectively, than that for XT 274A transplants (Table 4). Survival at harvest, for plants grown from vermicompost film coated CuppaJoe seed, 88% exceeded that for transplants by 3%, while that for Rootshield film coated seed, 82% was 3% less than that for transplants, 85%. However, the greater than 85% harvest plot survival was not translated into high yields for marketable ears, especially in Planting #1. For example, while XT 274A Planting #1 transplants had 100% harvest plot survival, only 35% of those plants produced marketable ears (Table 4); CuppaJoe transplants had 85% harvest plot survival but 45% of those plants produced marketable ears. In comparison to the transplants, treatment 1 plants grown from vermicompost film coated seed had a greater percent of

plants at harvest producing marketable ears for both plantings: XT 274A, Planting #1, 37%, compared to 35% for transplants; CuppaJoe, Planting #1, 62%, compared to 45% for transplants; XT 274A, Planting #2, 68% compared to 53% for transplants; and CuppaJoe, Planting #2, 64% compared to 60% for transplants (Table 4). With the exception of XT 274A, Planting #1, the average percent plants grown from Rootshield film coated seed producing marketable ears was within 1%-3% of the plants grown from vermicompost film coated seed and greater than that from transplants; for XT 274A, Planting #1, 30% of plants grown from Rootshield film coated seed produced marketable ears compared to that from transplants, 35%. The fact that a greater percent of harvest plot plants, on average, grown from the vermicompost film coated seed produced marketable ears indicates that there may be some benefit associated with ear development for this treatment. Similarly but to a slightly lesser extent, there may be some associated benefit for ear development in plants grown from Rootshield film coated seed, compared to transplants. However, as suggested above, the stand establishment for transplants may be less than expected due to drought killing the young roots and/or retarding development of the root system overall from the transplant plug and this may translated into fewer transplant grown plants producing marketable ears at harvest for both plantings.

Table 4. Average percent survival at 14 days after planting, average percent live plants/harvest plot producing marketable ears, marketable ears/harvest plot, and estimated yields/acre for XT 274A and CuppaJoe.

Treatment 1: Film Coated with processed vermicompost (**VC**), applied as a slurry containing, by weight, 4g filler (≤74µ VC)/100 g seed suspended in 15g binder (SOL053:dH_2O (1:1, by wt) per 100g seed;
Treatment 2: Film Coated with Rootshield® AG (**RS**) applied as a slurry containing 0.1875g RS/100g seed suspended in 4g binder (SOL053:dH_2O (1:1, by wt) per 100g seed;

Treatment 3: Transplants (**T**) raised from non-treated seed (2 plants/plug); and

Treatment 4: Non-treated field planted seed, control (**C**). Treatments 1, 2, and 4 were direct seeded in the field.

Variety	Planting #	Trt #	Trt Type	Average Percent[1] LIVE Plants per Harvest Plot at HARVEST	Average Percent LIVE Plants Producing MARKET-ABLE EARS at HARVEST	Average Percent MARKET-ABLE EARS per Replicate by Trt at HARVEST	Estimated Yield[2] Green Ears/Acre (Based on 15,000 Ear/Acre Average Published Yield[3])	Estimated Dozens of Green Ears/ Acre	Estimated Average Green CWT/ Acre[4]

274A	**1**	**1**	**VC**	**90**	**37**	**33**	**5,000**	**417**	**34**
274A	**1**	**2**	**RS**	**88**	**30**	**27**	**4,000**	**333**	**24**
274A	**1**	**3**	**T**	**100**	**35**	**35**	**5,250**	**438**	**32**
274A	**1**	**4**	**C**	**90**	**41**	**37**	**5,500**	**458**	**37**
CuppaJoe	***1***	***1***	***VC***	***88***	***62***	***55***	***8,250***	***688***	***41***
CuppaJoe	***1***	***2***	***RS***	***82***	***59***	***48***	***7,250***	***604***	***40***
CuppaJoe	***1***	***3***	***T***	***85***	***45***	***38***	***5,750***	***479***	***34***
CuppaJoe	***1***	***4***	***C***	***82***	***59***	***48***	***7,250***	***604***	***40***
274A	**2**	**1**	**VC**	**98**	**68**	**67**	**10,000**	**833**	**55**
274A	**2**	**2**	**RS**	**102 ***	**69**	**70**	**10,500**	**875**	**59**
274A	**2**	**3**	**T**	**107 ***	**53**	**57**	**8,500**	**708**	**48**
274A	**2**	**4**	**C**	**103 ***	**63**	**65**	**9,750**	**813**	**52**
CuppaJoe	***2***	***1***	***VC***	***92***	***64***	***58***	***8,750***	***729***	***45***
CuppaJoe	***2***	***2***	***RS***	***98***	***63***	***62***	***9,250***	***771***	***44***
CuppaJoe	***2***	***3***	***T***	***103 ****	***60***	***62***	***9,250***	***771***	***43***
CuppaJoe	***2***	***4***	***C***	***97***	***62***	***60***	***9,000***	***750***	***45***

1. More than 60 plants per harvest plot or 120 plants per replicate is due to accidental double seeding with two plants
   surviving per row position.
2. Estimated Yield: (((actual green ears/harvest plot)/(60, max ears/harvest plot)) x 15,000 average ears/acre); "green ears" have the husk on, typical for fresh market sales.
3. Penn State Extension – Agricultural Alternatives. 2015. Mid – to – Late Season Fresh Market Sweet Corn Budget. (http://extension.psu.edu/business/ag-alternatives/horticulture/files/budgets/sweet-corn-production/sample-sweet-corn-production-budget-fresh-market-mid-late-season) (*N.B.*: 1,250 doz/ac = 15,000 ears/ac average yield listed for early and mid to late season)
4. Estimated Average Green CWT/Acre is calculated as: (Estimated Ears/Acre/ (Green Ears/Cwt)); Green Ears/Cwt is calculated as: (100/Average Ear Weight in lbs), using actual ear weights collected by treatment for both varieties for each harvest.

When compared to plants grown from non-treated seed, with the exception of Rootshield film coated XT 274A seed, Planting #1, the average percent treated seed grown plants producing marketable ears was within 0% - 6%. Compared to plants grown from non-treated seed in Planting #1, 11% fewer plants from Rootshield film coated XT 274A seed produced marketable ears. Notably, while the average percent plants producing marketable ears ranged from 59% - 62% (Planting #1) to 60% - 64% (Planting #2) for CuppaJoe, an increase was observed for XT 274A from 30% - 41% in Planting #1 to 53% - 69% in Planting #2. As this increase is observed across all treatments for XT 274A in Planting #2, the apparent benefit is most likely associated with the warmer soil temperature at planting and indicates a greater soil temperature sensitivity for XT 274A.

Overall, across treatments for both varieties, while stand establishment was maintained across treatments, the number of marketable ears produced for Planting #1 was less than that produced for Planting #2; yield was calculated using a maximum yield of 60 ears/harvest plot. Planting #1 production was only 27% to 37% of the maximum yield for XT 274A and 38% to 55% of the maximum yield for CuppaJoe (Table 4). Using a published average yield of 1,250 dozen ears/acre (15,000 ears/acre, Penn State Extension, 2015; MOFGA, 2015) and the observed average percent yield by treatment for Plantings #1 and #2 for XT 274A and CuppaJoe, the yields for fresh market green ears (with the husk) per acre was calculated (Table 4).

For Planting #1, similar yields were observed for treatments 1, 2, and 4 for XT 274A but lesser yields were associated with plants grown from vermicompost film coated seed, treatment 1 than transplants, treatment 3: 5,000 ears/ac for XT 274A, treatment 1, compared to 5,250 ears/ac from transplants and unlike CuppaJoe producing 8,250 ears/ac for treatment 1, compared to 5,750 ears/ac from transplants. While the marketable XT 274A ear yield for plants grown from Rootshield film coated seed was 4,000 ears/ac compared to 5,250 ears/ac from transplants, the yield for CuppaJoe of the same treatment, 7,250 ears/ac was greater than from transplants, 5,750 ears/ac, for Planting #1 (Table 4). Compared to the yield from plants grown from non-treated seed, for Planting #1, only the yield from plants grown from vermicompost film coated CuppaJoe seed is greater, 8,250 ears/ac compared to 7,250 ears/acre, indicating a possible treatment x variety effect for CuppaJoe, treatment 1.

Treatment by treatment, across varieties, the calculated yield for green fresh market ears per acre was greater for Planting #2, compared to Planting #1 (Table 4). Similarly, due to this classification, the calculated hundred weight per acre (cwt/ac) based on average green ear weight (Table 1), was greater treatment by treatment across varieties for Planting #2 compared to Planting #1 (Table 4). However, average kernel weight for Planting #2 is either similar or less than that for Planting #1, as is average moisture percent and does not necessarily support the harvest crew's classification of marketable ears for Planting #2. Additionally, as stated above, while the harvest crew scored more ears as "marketable" for Planting #2, the amount of tip *not filled* was greater for both varieties for Planting #2, compared to Planting #1. As good ear and tip fill are usually considered necessary or desirable for purchase "by the dozen by the consumer, the harvest crew's classification of ears without good tip fill as "marketable" was an unexpected result. Examples of what a "marketable ear", albeit under sized, looked like for each treatment from Planting #1 were given in Figure 16 and 18 of the 2016 Annual Report for XT 274A and CuppaJoe, respectively; photos of representative "marketable ears" for Planting #2 are given in Figure 19 (XT 274A) and 20 (CuppaJoe). Examples of "cull ears" (i.e., ears with unfilled areas in the base, sides, and tip of the ear) were given in Figure 17 of the 2016 Annual Report.

Reduction of Production Costs:

Total on field costs, calculated on a per acre basis, for the 2016 organic production were greater than published per acre costs for conventional production (Table 5). Conventional costs are based on the most recently available published costs, "Mid- to Late-Season Fresh Market Sweet Corn Budget" published in 2014 as a Penn State Extension – Agricultural Alternatives Bulletin. Costs for the organic

Xtra-Tender 274A (XT 274A) and CuppaJoe are based on the "on field" costs for the experimental plot (0.31 acres) 'calculated up' for one acre; it must be understood that per acre organic costs are estimates calculated from the smaller plot costs. The only "fixed cost" (i.e., cost not changing with production level) is the land charge; the organic certification cost, another fixed cost, is not included here, as that varies with certification organization.

Difference in variable (i.e., not fixed) cost/ac for XT 274A compared to CuppaJoe is attributable to the greater cost for XT 274A seed $402.38/ac organic non-treated) compared to the CuppaJoe seed ($293.63/ac organic non-treated); the calculation of 21,750 seeds per acre is based on 36 inch spacing between rows. Cost for non-treated organic seed was two to almost three-fold greater than conventional non-treated seed, $144/ac. Coating the seed added the following costs: production of vermicompost at the 74 micron size and smaller (200 mesh), $1.75/lb; Rootshield, $90/lb; and custom seed coating, $0.20/lb, as quoted by Summit Seed Coatings, Caldwell, ID. Based on 21,750 seeds planted per acre; the weight of XT 274A (5.28 lbs/ac), CuppaJoe (12.17 lbs/ac), and conventional seed (18 lbs/ac, Penn State Cooperative Extension, 2014); and the film coating application rate used for vermicompost (4g/100g seed) and Rootshield (0.1875g/100g seed) on the 2016 field planted seed, calculations were made for cost per acre for each coating type for each variety. These costs/acre are listed in column 1, at the bottom of Table 5. For the benefit of any organic farmer, organic farming cooperative or seed company considering the development of an organic seed coating with a product of their own choosing, the initial coating cost will be greater; for this project our 'research & development' coating costs were calculated at approximately $200/acre.

In addition to the organic seed costs, the cost/ac for organic fertilizer was approximately 9 fold greater. Because the organic fertilizer product used in this study is no longer available, the cited fertilizer price is based on the most comparable currently available Harmony Ag Organic Fertilizer, 5-4-3 with 9% calcium at $18.80/50lbs (http://www.7springsfarm.com/harmony-ag-organic-fertilizer-w-9-calcium-5-4-3-50-lb/); if this product were available in bulk, this price should be significantly less. Finally, as with much organic production, "hand weeding" efforts were considerable for this study; the manhours (mnhrs) for weeding were calculated as follows: (actual 6.5 mnhrs/0.31ac) x 3 events and multiplied by 3.22 to obtain the per acre total, 62.79 mnhrs at $12/mnhr for a seasonal cost of $753.48/ac. By comparison, the 2015 conventional costs were: $120.56 for herbicide and $485.59 for insecticide, a total of $606.15.

As described in the proposal and currently practiced by most organic and conventional growers, transplants are used for sweet corn field planting (Grubinger, 2014). As this study covered less than an acre, transplants were hand planted. In a fresh market farm operation, transplants are machine planted. A typical organic farm operation, as described for Walker Farm, Dummerston, VT for their organic sweet corn production (MOFGA, 2015), will hand plant transplants in 128 plug trays (2 seeds/cell) in a greenhouse when greenhouse ambient temperatures are at least 62°F with 80°F during the daytime. The Walkers purchased a Mechanical 6000 Carousel transplanter for $3,200 for their field planting; this would be a fixed cost depreciated as "farm equipment" over the standard seven-year period unless a half-year option is used and this cost is not entered into the budget presented here. The Walkers report that the labor required to machine plant their sweet corn transplants was two men for

two hours planting 60 trays (36 inches between rows) per 0.5 ac; assuming the same planting rate per acre, this would be 8 mnhrs planting 120 trays/ac. The total average cost for producing and planting transplants has been reported at $750/acre (Grubinger, 2014); this cost was added to the costs for all transplants (Table 5). The cost of transplants adds 22% and 23%, respectively, to the total non-treated organic XT 274A and CuppaJoe costs; the same transplant cost would add 37% to the total conventional cost.

Estimated sales (Table 6) per dozen and per hundred weight (cwt) were calculated based on estimated yields per acre as calculated from the experimental yields (Table 4) and the published fresh

Table 5. On field organic production and hand harvested costs for the 2016 planting season compared to average 2015 per acre costs for conventional, hand harvested fresh market sweet corn.

Cost Item	ON FIELD Units Used	$ Cost/ Unit	Total $ Cost/ Ac	XT 274A $ Cost/ Ac	CuppaJoe $ Cost/Ac	Penn State Mid- to Late Season Conventional Hand Picked Sweet Corn (18 lbs seed/ac) -2015 Enterprise Budget	COST DIFFERENCE: Xtra-Tender 274A NYSAES - Conventional $ Cost/Ac	COST DIFFERENCE: CuppaJoe NYSAES - Conventional $ Cost/Ac
Fertilizer ((N-P-K only, no lime) (Non-organic price/ton for Conventional) per ton	2000 lbs	752	752.00	752.00	752.00	81.70	670.30	670.30
Drip Tape (17,517 linear ft/ac at 36 inch spacing between rows; Conventional=10,890ft)	5440 ft/ 0.31 ac	0.02/ ft	350.34	350.34	350.34	217.80	132.54	132.54
Sweet Corn Seed - (at 21,750 seeds/ac), NON-treated	21750	---	---	402.38	293.63	144.00	258.38	149.63
Irrigation Labor (Est: 2mhr setup tape+1 mnhr to empty tanks x 3 events=5mnhr $12/hr) (Conventional: 3.375mhrs)	5	12	60.00	60.00	60.00	40.50	19.50	19.50
Hand Weeding (Conventional:	62.79	12	753.48	753.48	753.48	120.56	632.93	632.93

Herbicide Cost+Sprayer)								
Insecticide (Conventional Only)	---	---	485.59	0.00	0.00	485.59	-485.59	-485.59
Hand Harvesting (mnhrs based on Conventional)	20	12	240.00	240.00	240.00	240.00	0.00	0.00
Grading (harvest crew manhours, NYSAES)	15	12	180.00	180.00	180.00	175.00	5.00	5.00
Operator/Supervisor ON FIELD Labor	4	15	60.00	60.00	60.00	49.55	10.45	10.45
Tractor, ON FIELD tractor hours with operator - Field Preparation	4	47.89	191.56	191.56	191.56	191.56	0.00	0.00
Tractor, ON FIELD tractor hours with operator - (Field Cultivation, 2 events at approx. 2 hrs each) (Conventional: Custom Operations Cost)	4	47.89	191.56	191.56	191.56	103.85	87.71	87.71
FIXED Cost: Land Charge (Rent/Acre)	1 acre	$200/ac/yr	200.00	200.00	200.00	200.00	0.00	0.00
TOTAL/ACRE cost using NON-TREATED SEED WITH direct seeding & hand harvesting				3381.32	3272.57	2050.11	1331.22	1222.47
TOTAL/ACRE cost using VERMICOMPOST FILM COATED seed, direct seeded & hand harvested (Coating Costs: XT 274A, $0.37/ac; CuppaJoe, $0.85/ac)				3381.69	3273.42	2051.37	1330.33	1222.06

TOTAL/ACRE cost using <u>ROOTSHIELD</u> FILM COATED seed, direct seeded & hand harvested (Coating Costs: XT 274A, $0.89/ac; CuppaJoe, $2.04/ac)				**3382.21**	**3274.61**	**2053.16**	**1329.06**	**1221.46**
Additional Estimated Transplant Cost				**750.00**	**750.00**	**750.00**		
TOTAL/ACRE cost using transplants & hand harvesting				***4131.32***	***4022.57***	***2800.11***	***1331.22***	***1222.47***

1. Penn State Extension – Agricultural Alternatives. 2015. Mid – to – Late Season Fresh Market Sweet Corn Budget. (http://extension.psu.edu/business/ag-alternatives/horticulture/files/budgets/sweet-corn-production/sample-sweet-corn-production-budget-fresh-market-mid-late-season) (*N.B.*: 1,250 doz/ac = 15,000 ears/ac average yield listed for early and mid to late season)

market prices recently received. The $8/doz price was received for premium conventional fresh market sweet corn in Washington State (Wheat, 2016) and for organic sweet corn in Massachusetts (MOFGA, 2014). However, in the Finger Lakes Region of New York State, the average 2016 fresh market green (husk on) price for organic sweet corn was $6.50/doz (Robert Hadad, Extension Vegetable Specialist, CCE Monroe County, Rochester, NY, 2017, personal communication) and $3.00/doz for conventional fresh market sweet corn, as observed in local stores and farm stands and published earlier by Penn State Cooperative Extension (2014). Conventional fresh market sweet corn yields are typically 1,250 doz/ac, gaining $3,750/ac in sales; average US fresh market sweet corn price received for 2016 was $28.20/cwt (YCharts, 2016); assuming 12 doz/cwt, the cwt price reflects a 22% drop in price/doz, compared to the $3/doz farm stand/market price.

The greater percent yield of marketable ears for Planting #2 compared to Planting #1, across treatments for both varieties, would result in greater sales for Planting #2 (Table 6). However,

Table 6. Estimated average sales/acre by treatment for XT 274A and CuppaJoe for Planting # 1 and #2.

<u>Treatment 1</u>: Film Coated with processed vermicompost (**VC**), applied as a slurry containing, by weight, 4g filler (≤74µ VC)/100 g seed suspended in 15g binder (SOL053:dH_2O (1:1, by wt) per 100g seed;

<u>Treatment 2</u>: Film Coated with Rootshield® AG (**RS**) applied as a slurry containing 0.1875g RS/100g seed suspended in 4g binder (SOL053:dH_2O (1:1, by wt) per 100g seed;

<u>Treatment 3</u>: Transplants (**T**) raised from non-treated seed (2 plants/plug); and

Treatment 4: Non-treated field planted seed, control (**C**).

Variety	Planting #	Trt #	Trt Type	Average Percent Market-able Ears per Harvest Plot Replicate by Trt at HARVEST	Estimated Fresh Market $ Sales/ Acre at Average Local Fresh Market Price of $8.00/Doz[1]	Estimated Fresh Market $ Sales/ Acre at Average Local Fresh Market Price of $6.50/Doz[2]	Estimated $ Sales by CWT/ Acre[3] (Based on Estimated ORGANIC CWT Price of $74.88/ cwt)	Estimated $ Sales by CWT/ Acre[3] (Based on Estimated ORGANIC CWT Price of $60.84/ cwt)
274A	1	1	VC	33	3,333	2,708	2,527	2,053
274A	1	2	RS	27	2,667	2,167	1,827	1,484
274A	1	3	T	35	3,500	2,844	2,374	1,929
274A	1	4	C	37	3,667	2,979	2,796	2,272
CuppaJoe	*1*	*1*	*VC*	*55*	*5,500*	*4,469*	*3,107*	*2,525*
CuppaJoe	*1*	*2*	*RS*	*48*	*4,833*	*3,927*	*3,008*	*2,444*
CuppaJoe	*1*	*3*	*T*	*38*	*3,833*	*3,115*	*2,562*	*2,081*
CuppaJoe	*1*	*4*	*C*	*48*	*4,833*	*3,927*	*2,991*	*2,430*
274A	2	1	VC	67	6,667	5,417	4,103	3,334
274A	2	2	RS	70	7,000	5,688	4,442	3,609
274A	2	3	T	57	5,667	4,604	3,583	2,911
274A	2	4	C	65	6,500	5,281	3,862	3,138
CuppaJoe	*2*	*1*	*VC*	*58*	*5,833*	*4,740*	*3,335*	*2,710*
CuppaJoe	*2*	*2*	*RS*	*62*	*6,167*	*5,010*	*3,276*	*2,662*
CuppaJoe	*2*	*3*	*T*	*62*	*6,167*	*5,010*	*3,221*	*2,617*
CuppaJoe	*2*	*4*	*C*	*60*	*6,000*	*4,875*	*3,370*	*2,738*

1. A premium price of $8.00/dozen was stated for conventional fresh market sweet corn raised by farmer Mark Kallstrom, Ephrata, WA selling in the western WA area with WA yields of 146 cwt/ac (Wheat, D. 2016. Grower pushes premium sweet corn. Capital Press – The West's Ag Website. Story at: http://www.capitalpress.com/Profit/20160729/grower-pushes-premium-sweet-corn); the 2014 organic sweet corn price received by Walker Farm, Dummerston, VT was $7.99/dozen, as reported on the MOFGA website

(http://www.mofga.org/Publications/MaineOrganicFarmerGardener/Spring2015/OrganicSweetCorn/tabid/2938/Default.aspx).

2. The price of $6.50/dozen was stated as the average 2015 fresh market sweet corn price available in the Finger Lakes Region of New York State by Robert Hadad, Extension Vegetable Specialist, CCE Monroe County, Rochester, NY (personal communication).
3. The price per hundred weight (cwt) reflects the 22% percent price drop for conventional fresh market sweet corn from the per dozen price to the cwt price ($3/doz (http://extension.psu.edu/business/ag-alternatives/horticulture/files/budgets/sweet-corn-production/sample-sweet-corn-production-budget-fresh-market-mid-late-season) to the 2016 $28.20/cwt (at 12 doz/cwt) price (https://ycharts.com/indicators/us_sweet_corn_fresh_market_price_received) for conventional fresh market sweet corn).

Compared to the $3/doz, $3,750/ac price for conventional fresh market sweet corn, none of the Planting #1 treatment yields for XT 274A were great enough, at either the $6.50/doz or $8/doz price, to have matched the conventional per dozen price per acre; all XT 274A Planting #2 fresh market "by the dozen" prices exceeded the conventional fresh market price of $3,750/ac. CuppaJoe Planting #1 yields from all treatments were great enough at the $8.00/doz to exceed the conventional price/ac and all but the transplant (treatment 3) yield, for Planting #1, exceeded the conventional price/ac. Across treatments for both varieties, all Planting #2 yields were great enough at either the $6.50/doz or $8/doz price to exceed the conventional per dozen price of $3,750/ac.

Conventional fresh market yield in New York State for sweet corn, in 2016, was 95 cwt/acre (USDA NASS, 2017), giving $2679.00/ac at $28.20/cwt received for 2016 (YCharts, 2016). Hundred weight prices for XT 274A and CuppaJoe were calculated using the 22% drop from the $3/doz conventional fresh market price to the $28.20/cwt price (at 12doz/cwt); ears/cwt were calculated for all treatments for both varieties in both plantings based on recorded average green ear weights (Table 1). Compared to the 2016 conventional cwt price/ac, neither the XT 274A nor the CuppaJoe Planting #1 *transplant* yields at $74.88/cwt were great enough to match this price, indicating overall inferior stand performance for these transplants (Table 6) compared to the nationwide conventional crop average. While cwt yields for XT 274A non-treated seed were sufficient to bring in a slightly greater price (4%) at $74.88/cwt (based on a $8/doz price) than conventional, CuppaJoe yields for treatments 1, 2, and 4 were adequate to exceed the conventional cwt price/ac. However, none of the yields from either variety for Planting #1 was sufficient at $60.84/cwt (based on a $6.50/doz price) to match the conventional cwt price/ac. This comparison of market values indicates that only the $74.88/cwt price for CuppaJoe treated seed and non-treated seed, that is, all direct seeded CuppaJoe stands from Planting #1 would have been sufficiently competitive in the hundred weight sales market and indicates a possible variety x treatment (direct seeded vs transplant) effect. With greater yields, in spite of lower average ear weight (Table 1), all treatments for Planting #2, for both varieties at $74.88/cwt exceed the conventional cwt/ac price (Table 6); low sales from transplants are associated with low average green cwt/acre (Table 4). Low green ear weight for transplants, in Planting #1 and #2, compared to the non-treated seed cwt averages indicates drought damage to root and shoot development as well as aborted/damaged kernel development sustained by the transplants prior to the application of irrigation.

Under the 2016 drought conditions, treatment x treatment effect cannot be segregated from treatment x environment effect.

The simple return on investment (ROI) is calculated as follows:

$$\text{Simple ROI} = \frac{\text{Gains} - \text{Investment Costs}}{\text{Investment Costs}}$$

A detailed introduction to return on investment can be found at: https://www.business-case-analysis.com/return-on-investment.html. A quick scan of Table 7 shows negative estimated ROIs for all Planting #1 hundred-weight (cwt) sales for both varieties at both ccwt prices, indicating debt (i.e., costs outweighing returns) associated with Planting #1 fresh market cwt sales. Estimated XT 274A Planting #1 fresh market "by the dozen" sales show negative ROI, except those for non-treated seed at $8/doz. With the exception of Planting #1 transplants for CuppaJoe, all ROI for fresh market "by the dozen" sales were positive. As expected, ROI drops with dropping returns and sales at $6.50/doz are insufficient, at the 2016 yields, to achieve profit for any of the XT 274A treatments. CuppaJoe Planting #1 yields were still sufficient, at $6.50/doz, for positive ROI for all sales but those from transplants (Table 7). In fact, transplant sales for both varieties from both plantings consistently showed the greatest or near to the greatest loss/lowest profitability (Table 7).

The estimated ROI for Planting #2 was positive, across treatments, for both varieties at both the $6.50/doz and $8/doz fresh market price. The estimated ROI for transplants showed the least profit, for both varieties in Planting #2 (Table 7). However, as stated previously, it is not known whether this is due to a treatment effect or, more likely, a treatment x environment effect due to the drought. Treatment 2 (Rootshield film coated seed) sales for Planting #2 had 10% greater ROI than treatment 1 (vermicompost film coated seed) for both XT 274A and CuppaJoe, at the $8/doz price (Table 7); the treatment 2 ROI was 8% greater than that for treatment 1 for both varieties at the $6.50/doz price.

Table 7. Average Return on Investment (ROI) for XT 274A and CuppaJoe for Plantings # 1 and #2 per based on two prices each for: fresh market price/ green ear dozen and hundred weight (cwt) price..

Treatment 1: Film Coated with processed vermicompost (**VC**), applied as a slurry containing, by weight, 4g filler (≤74µ VC)/100 g seed suspended in 15g binder (SOL053:dH_2O (1:1, by wt) per 100g seed;

Treatment 2: Film Coated with Rootshield® AG (**RS**) applied as a slurry containing 0.1875g RS/100g seed suspended in 4g binder (SOL053:dH_2O (1:1, by wt) per 100g seed;

Treatment 3: Transplants (**T**) raised from non-treated seed (2 plants/plug); and

Treatment 4: Non-treated field planted seed, control (**C**).

Variety	Planting #	Trt #	Trt Type	Average Percent Market-able Ears per Harvest Plot Replicate by Trt at HARVEST	Return on Investment (ROI)[1] Based on Estimated 2016 Yield/Ac and Cost/Acre for XT 274A[2] and CuppaJoe[3] at an Estimated Local Fresh Market Organic Product Price of $8.00/doz	Return on Investment (ROI)[1] Based on Estimated 2016 Yield/Ac and Cost/Acre for XT 274A[2] and CuppaJoe[3] at an Estimated Local Fresh Market Organic Product Price of $6.50/doz	Return on Investment (ROI)[1] Based on Estimated 2016 CWT Yield/Ac and Cost/Acre for XT 274A[2] and CuppaJoe[3] at an Estimated Price Organic CWT Price of $74.88/cwt (using average of 12 doz/cwt)	Return on Investment (ROI)[1] Based on Estimated 2016 CWT Yield/Ac and Cost/Acre for XT 274A[2] and CuppaJoe[3] at an Estimated Price Organic CWT Price of $60.84/cwt (using average of 12 doz/cwt)
274A	1	1	VC	33	-0.01	-0.20	-0.25	-0.39
274A	1	2	RS	27	-0.21	-0.36	-0.46	-0.56
274A	1	3	T	35	-0.15	-0.31	-0.43	-0.53
274A	1	4	C	37	0.08	-0.12	-0.17	-0.33
CuppaJoe	*1*	*1*	*VC*	*55*	*0.68*	*0.37*	*-0.05*	*-0.23*
CuppaJoe	*1*	*2*	*RS*	*48*	*0.48*	*0.20*	*-0.08*	*-0.25*
CuppaJoe	*1*	*3*	*T*	*38*	*-0.05*	*-0.23*	*-0.36*	*-0.48*
CuppaJoe	*1*	*4*	*C*	*48*	*0.48*	*0.20*	*-0.09*	*-0.26*
274A	2	1	VC	67	0.97	0.60	0.21	-0.01
274A	2	2	RS	70	1.07	0.68	0.31	0.07
274A	2	3	T	57	0.37	0.11	-0.13	-0.30
274A	2	4	C	65	0.92	0.56	0.14	-0.07
CuppaJoe	*2*	*1*	*VC*	*58*	*0.78*	*0.45*	*0.02*	*-0.17*
CuppaJoe	*2*	*2*	*RS*	*62*	*0.88*	*0.53*	*0.00*	*-0.19*
CuppaJoe	*2*	*3*	*T*	*62*	*0.53*	*0.25*	*-0.20*	*-0.35*
CuppaJoe	*2*	*4*	*C*	*60*	*0.83*	*0.49*	*0.03*	*-0.16*

1. Return on Investment (ROI) was calculated as follows: ((Gain from Investment – Cost of Investment) / Cost of Investment).
2. Calculated Xtra-Tender (XT) 274A Costs: non-treated direct seeded cost per acre: $3381; vermicompost film coated, direct seeded cost/ac: $3382; Rootshield film coated, direct seeded cost/ac, $3382; and XT 274A transplants from non-treated seed cost/ac: $4131.
3. Calcualted CuppaJoe Costs: non-treated, direct seeded cost per acre: $3273; vermicompost film coated, direct seeded cost/ac: $3273; Rootshield film coated, direct seed cost/ac, $3275; and CuppaJoe transplants form non-treated seed: $4023/Ac.

Based on just the comparison between treatments 1 and 2, treatment 2 appears to have a yield associated benefit for its ROI, across varieties. However, any 'across varieties' generalization breaks down somewhat for CuppaJoe when comparisons between the treated seed and the non-treated seed are included.

While the estimated XT 274A treatment 4 (non-treated seed) $8/doz ROI for Planting #2 was 5% less than treatment 1 and 15% less than treatment 2, the treatment 4 ROI for CuppaJoe was 5% greater than the treatment 1 ROI and 5% less than the treatment 2 ROI (Table 7), indicating variable treatment 2 associated benefit and a possible varietal or variety x environment difference. Under the prevailing drought with its probable damage to transplant roots and shoots without irrigation, XT 274A Rootshield film coated seed (treatment 2), for Planting #2, is associated with a 70% greater ROI than that of transplants; CuppaJoe treatment 2 is associated with a 35% greater ROI, compared to Planting #2 transplants (Table 7). While the Planting #2 $8/doz ROI for vermicompost film coated seed (treatment 1) sales, for both varieties, were estimated to be 10% less than the ROI for treatment 2 sales, the treatment 1 XT 274A ROI is 60% greater than that for transplants and the CuppaJoe treatment 1 ROI is 25% greater than that for transplants. However, this relationship is *not* seen across varieties in Planting #1 $8/doz ROI; XT 274A treatment 2 ROI is 6% less than that for transplants and the ROI for both treatments are negative. It is not known, at this time, if the application of irrigation *at the time of planting* and applied sufficiently to meet the usual one to one and half acre inch demand per week, would have reduced the difference between treated seed yields and/or between treated seed yields and transplant yields or reversed the relationship between the treated seed ROI and the transplant ROI. Given that most farmers now use transplants rather than direct seeding, there is a practical history indicating increased yields for transplants that are *adequately irrigated*, if irrigation is required.

Beneficiaries

According to the USDA National Agricultural Statistics Service 2014 Census of Agriculture - Organic Production Survey, there are 917 certified organic and exempt organic farms in New York that grow crops on 212,701 acres (USDA-NASS, 2014). Of these farms, New York State has 196 farms harvesting vegetables on 1,571 acres with $13,591, 231 in sales. Of these New York State farms, 24 farms harvested organic sweet corn from 103 acres with a total of 2,843 cwt and sales of $167,989. All harvested organic sweet corn was sold as organic sweet corn; no conventional sales were listed for organically grown New York State sweet corn. These numbers do not include growers who may grow organically, but are not certified. For the most part, the beneficiaries for this project would be the organic sweet corn growers in New York State but the use of organically coated conventional seed or organic seed would be applicable to conventional growers, should profit-bearing benefit be demonstrated by such treatments.

The impact of the 2015 field flooding conditions and the drought associated field problems described for 2016 existed for all New York State growers; indeed these problems were reported nationwide. Crop loss was wide spread for New York State in 2015 and appropriately applied irrigation was the only

method to reduce yield loss for 2016. Under environmental conditions that so negatively impact yield during this study, identification and quantification of treatment associated benefits to stand establishment and field yield loss reduction, as described, was confounded to a great degree by environmental effect. However, it is hoped that the knowledge gained from varietal selection, development of seed coatings, and germination of coated seed under a variety of controlled conditions can be shared based on results described in the 2015 and 2016 Annual Reports and this report. To date, this information has been shared on two dates: as a field visit with local growers and at an out of state workshop.

On August 11, 2016, just prior to the mid-season harvest, a field visit was held for local growers. In addition to project personnel, those attendance were: Rick Pedersen, owner/operator of Pedersen Farms, Seneca Castle, NY one of the largest fresh market sweet corn producers in the area; Timothy Whitwood, sweet corn breeder and global director of marketing and sales for Seneca Vegetable Research, Hall, NY; and Robert Hadad, Extension Vegetable Specialist, CCE Monroe County, Rochester, NY. The field trials and problems were discussed and a summary of seed coating development and early season yield results was handed out as a hard copy.

Earlier this year, on February 8, 2017 Dr. Alan Taylor led the Corn Seed Vigor Workshop sponsored and hosted by Syngenta Seed at Minnetonka, MN. While all attendees were Syngenta employees, three were sweet corn specialists, Hiromi Wilson, Mason Douglass, and Johan VanBosch. The information shared on sweet corn was primarily focused on varietal selection based on germination results under standard and modified test conditions.

Lessons Learned

Perhaps, one of the greatest lessons learned is the critical importance of variety selection to field performance. While this may seem an obvious point to consider, it was not until we tested 22 popular fresh market sweet corn varieties under standard germination test conditions as well as the modified cold test conditions that we were able to identify one “sugary enhanced” (se) and one “shrunken 2” (sh2, also known as “supersweet”) that tolerated both the cold, wet early season soil conditions typical for the Geneva, NY area and the resident soil pathogens for this area. This selection process was particularly important for the “Xtra-Tender”, sh2 variety, as this genotype usually needs warmer soil for good germination. Without a varietal selection that includes both a consideration of the planting environment *and* potential pathogen load, results for the development of potentially beneficial seed coatings will be confounded by environmental and pathogen effects. We would recommend that *all* organic fresh market sweet corn growers, as well as conventional fresh market growers have a reputable seed testing lab conduct a supplemental cold germination test using a field soil component in the test media. If possible, growers should have their soil tested for damping off and other soil borne pathogens. Such soil testing services are currently available for *Pythium* spp. and other fungi at AL&L Crop Solutions, Vacaville, CA (http://www.allcropsolutions.com). Portable kits for bacterial and viral pathogens and *Phytophthora* spp. are available (https://orders.agdia.com/pathogen-tests) but we have

not seen any *kits* advertised for *Pythium* spp. These pathogen tests should be done yearly, in addition to the yearly standard soil elemental and nutrition tests from soil collected *prior* to the first planting.

While the current study focused on the development and field-based benefits of organic seed coatings, it has become apparent that the supply and quality of the organic products used as the filler base for the coating can be quite variable. During this project, we had to assume the responsibility processing of the bagged "raw" product to the usable fraction size of 74 microns or less, when our supplier, Worm Power, Avon, NY no longer could provide this product. Additionally, as described in the 2016 Annual Report, we found 'batch-to-batch' variability associated with the germination of coated seeds from the same seed lot. Outside of this project, we have worked with vermicompost from over a dozen sources; elemental and nutritional tests have shown that some products had extremely low pH and/or a potentially plant damaging excess of one or more micronutrients. Seed companies planning to develop organic based seed coatings should confirm the supply reliability of the organic product provider's source of material as well as the *batch-to-batch conformity*, through standard soil tests, to the macro- and micronutrient concentrations appropriate to the plant species they are growing.

One of the greatest "unexpected outcomes", for this project, was the total crop failure for the 2015 planting season due to flooded field conditions. This lack of field data, eliminated the possibility for comparisons across planting seasons as well as all field data for encrustment type seed coatings. The persistence and magnitude of the drought during the following season of 2016 was unexpected, as well, and required additional manhours and supplies for the installation of irrigation tapes for each row for both plantings and the application of gravity fed distribution of water from a tanker through these tapes. As described in the 2016 Annual Report and summarized above, the effect of this drought eliminated our ability to segregate lack of seedling emergence due to damping off from that due to the drought effect, with the exception of treatments 1 and 2 for XT 274A in Planting #2, none of the treated seed produced stands meeting the proposed targeted stand loss of 10% or less. Clearly, the drought effect confounded our ability to identify any pathogen suppressive capability on the part of the seed coating. While the NYSAES field crew eventually was able to install irrigation, the installation date was late enough that ear size was reduced for both plantings and the amount of tip *not* filled for XT 274A expanded from less than 0.2 inches in Planting #1 to 0.7-1.31 inches in Planting #2 and from less than 0.11 inches for CuppaJoe in Planting #1 to 0.35-1.58 inches in Planting #2. For both varieties, in Planting #2, transplants had a statistically significantly greater amount of tip *not* filled, compared to all other treatments. The need to apply irrigation at the time of planting and whenever the water infiltration falls below 1.0-1.5 acre-inches per week was made especially obvious by the reduced yields in marketable ears from the transplants compared to both the seed treatments and the non-treated seed control. As discussed above, this reduction in marketable ears combined with the significantly greater increase in the amount of tip not filled indicates that the two week old transplant with its small root system was developmentally advanced enough to sustain root and shoot damage under the progressively drying soil conditions and continued as the kernels developed resulting in aborted (missing) kernels in the tip as well as on the sides and base of the ears. In considering these field conditions and the two extremely different environmental conditions during the course of this project, any farmer is well advised to expect

the same weather and prepare in advance by planting in well-drained soils and have on hand, as well, an adequate supply of water, irrigation tapes, and tubing!

Additional Information

There is no additional information to contribute, at this time.

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Project 10 (FINAL)
New York City Appleooza

Project Summary

The purpose of the project was to increase awareness about apples and their competitiveness both online and offline, as well as educate the public about apple agritourism through sampling at high-traffic markets and special events.

The importance and timeliness of the project coincides with a need for public nutritional education as obesity increases in New York City, as well as the need to bolster grower's revenue as a result of a decimated apple crop from previous years.

This project did not build on a previously funded project with the SCBGP or SCBGP-FB.

Project Approach

The project included market promotion, distribution of apples, online promotion, video promotion and lead collection. 5000 variety guides and 10,000 apples meeting original grant goals. 6 videos were produced and 25 growers were consulted with regarding their agritourism offerings. As a result of these efforts and all the positive feedback by both consumers and farmers, Greenmarket has asked EscapeMaker to continue apple promotion in their 80+ markets into 2016. Recommendations include communicating with apple growers on a more frequent basis to let them know of all the opportunities they have within the scope of the campaign.

- Present the significant contributions and role of project partners in the project:

EscapeMaker executed all original project goals in terms of marketing, promotion and distribution. Greenmarket provided access, equipment and promotion of all event dates in their markets. New York Apple Association provided printed variety guides and resources to distribute apple and apple products.

Goals and Outcomes Achieved

Goal: By increasing outreach at consumer events and farmers markets more consumers will be reached, providing them with a printed guide/ handouts with the nutritional benefits of eating apples, and information on apple-related agritourism destinations - thereby benefitting NY's entire apple industry.

Target: Distribute an additional 5000 guides at various high-visibility consumer events and at GrowNYC Greenmarkets, EscapeMaker.com and GrowNYC will report quarterly on the distribution number.

Actual Outcome: We coordinated 24 appearances in high-volume NYC Greenmarkets resulting in handing out an additional 5,000 guides resulting in a total of 10,000 guides resulting in a 200% increase over our original goal.

Goal: Sample different varieties of apples at consumer events, as well demonstrate the use in different recipes, educate, entertain and excite the public, thereby benefitting the entire industry.

Target: Provide an additional 5000 apple samples by the grant's expiration.

Actual Outcome: Project staff successfully accomplished handing out 5,000 apples plus an additional 5,000 apples resulting in a 200% increase. Furthermore, an additional 1700 apples were distributed at the 4th Local Food and Travel Expo at Brooklyn Bourghout Hall Expo, resulting in an additional increase of apples handed out by 17% resulting in an overall increase over goal of 217%.

Goal: A number of NY apple growers work with local bed & breakfasts, tourism bureaus and attractions to promote agritourism. We see apple agri-tourism as a potentially significant way to boost growers' and marketers' revenues. The project will increase the overall number and percentage of growers promoting agritourism.

Target: NY Apple Association staff identified over 250 of its members who currently package agritourism experiences or are direct marketers in New York and want to increase this percentage by 10%. EscapeMaker will include NY apple agritourism farm and market destinations in agritourism promotion stands it operates at selected high-traffic GrowNYC 92 Greenmarkets and work with NY apple industry direct marketers i.e. (farm markets, pick your own operations, cideries, etc.) to connect them to agritourism lodging partners and help them form viable bookable packages. Both EscapeMaker.com and GrowNYC will promote the packages online and report back to us quarterly on sales.

Acutal Outcome: EscapeMaker consulted with growers regarding "New York City Applepalooza" series and produced 6 videos. The film crew shot stock footage in the Greenmarkets on 5/16, 5/17 and 5/23 and traveled in New York State to film "apple experts" solicited by NYAA. Six 1-2 minute apple -themed agritourism videos were distributed over social media between late August and November 2015 on different topics. They consulted and corresponded with several growers about packaging. A survey was distributed to all 250 NYAA members and 25 (10%) were included in the agritourism info being distributed at non-Greenmarket events as well as at 80+ Greenmarket markets across the city - over 10,000 flyers were given out. We also added over 25 of their "apple-related" events to our database in September and October for agritourism ideas. We collected over 4500 contacts of qualified consumers to share with New York Apple Association and GowNYC as well as launching a robust social media campaign that connected Greenmarket and NYAA to the wider audience. We participated in 24 well-attended events that attracted over 141,500 attendees. (See below of dates participating and event venues and average number of attendance on each date.

3/21/2015	Union Square Market, Expo (Avg Market Attendance 10000)
3/28/2015	Ft. Greene Market Market, Expo (Avg Market Attendance 5000)

4/16/2015	Columbia University Market, Expo (Avg Market Attendance 5000)
4/25/2015	Tribeca Market, Expo (Avg Market Attendance 2000)
5/2/2015	EscapeMaker Local Food & Travel Expo (Attendance 6500)
5/16/2015	Ft. Greene Greenmarket (Avg Market Attendance 5000)
5/22/2015	Union Square (Avg Market Attendance 10000)
5/30/2015	Tribeca Greenmarket (Avg Market Attendance 2000)
6/13/2015	Greenpoint/McCarren Park (Avg Market Attendance 7000)
6/17/2015	Metro-North Getaway Day (Attendance 4000)
7/16/2015	Columbia Greenmarket (Avg Market Attendance 3000)
7/31/2015	Union Square, varieties (Avg Market Attendance 10000)
8/08/2015	Ft Greene Market, recipes (Avg Market Attendance 5000)
8/22/2015	Greenpoint/McCarren Park, recipes (Avg Market Attendance 7000)
8/27/2015	Columbia University, finding apples in the market apple picking, agritourism (Avg Market Attendanc
9/12/2015	Greenpoint/McCarren Park, apple picking (Avg Mkt Attendance 7000)
9/18/2015	Union Square - APPLE-PALOOZA (Attendance 7500)
9/26/2015	Grand Army Plaza, apple history (Avg Mkt Attendance 7000)
9/27/2015	Fulton Stall Market, apple picking (Avg Mkt Attendance 2000)
10/4/2015	Fulton Stall Mkt, apple picking CIDER WEEK (Avg Mkt Attendance 2000)
10/15/2015	Columbia Greenmarket (Avg Market Attendance 3000)
10/16/2015	Union Square - APPLE-PALOOZA (Attendance 7500)
10/17/2015	Grand Army Plaza, agritourism (Avg Mkt Attendance 7000)
11/14/2015	Grand Army Plaza, apples for the holidays (Avg Mkt Attendance 7000)
TOTAL	Approximate Market Attendance = 141500

EscapeMaker (Outcomes Achieved)-

- Coordinated 24 appearances in high-volume NYC Greenmarkets through 11/15
- 10,000 apples and accompanying 5000 NYAA brochures distributed at markets
- Fostered relationships with 8 different NYAA growers to purchase and coordinate delivery of apples at each market with great success
- Collected over 4500 contacts of qualified consumers to share with NYAA & GrowNYC with SPAM compliant policies for sharing
- Launched a robust social media campaign that connected Greenmarket and NYAA to the wider public. Market information was released several times a week promoting the apple growers and apple varieties distributed
- Hosted 4000+ visitors for the 4th Local Food & Travel Expo on 5/2 at Brooklyn Borough Hall
- Sponsor NYAA was given a prominent location in the main hall with heavy foot traffic
- NYAA President, Jim Allen kicked off the ribbon-cutting ceremony and press conference
- 1700 apples and NYAA brochures were distributed at the Expo
- 10 Eblasts went out about the Local Food & Travel Expo and the remaining were designed to coordinate with the Applepalooza videos in the Fall and Greenmarket tabling dates

EscapeMaker consulted with growers regarding "New York City Applepalooza" series and produced 6 videos.

The film crew shot stock footage in the Greenmarkets on 5/16, 5/17 and 5/23 and traveled in New York State to film "apple experts" solicited by NYAA. Six 1-2 minute apple -themed agritourism videos were distributed over social media between late August and November 2015 on different topics. They consulted and corresponded with several growers about packaging. A survey was distributed to all 250 NYAA members and 25 (10%) were included in the agritourism info being distributed at non-Greenmarket events as well as at 80+ Greenmarket markets across the city - over 10,000 flyers were given out. We also added over 25 of their "apple-related" events to our database in September and October for agritourism ideas.

All goals were accomplished. The only thing that changed was that EscapeMaker traveled to "Apple Experts" instead on them traveling to New York City.

All guide boxes and delivered apple crates were emptied. 5000 guides and 10,000 apples were distributed.

Beneficiaries

New York Apple Association and apple growers will benefit with increased visits to their websites and farms as a result of the agritourism promotion.

During events and online, Escapemaker collected over 4500 contacts of qualified consumers to share with NYAA to remarket to. The 25 apple growers that were featured as agritourism getaways and farmers featured on Heritage Radio saw increased traffic to their websites and farms as a result of the promotion.

Lessons Learned

There is a tremendous interest from the public in supporting farmers and apple growers through buying their apples and visiting their farms stores and farms for harvest festivals and events. The growers themselves need more resources to market the agritourism operations they currently have as well develop new ideas to increase revenue in order to adequately host these visitors.

A promotional campaign above and beyond the scope of the grant was launched through Heritage Radio Network to entice qualified visitors to EscapeMaker's Expo and also introduce consumers to apple growers in the region in the Fall with weekly radio interviews of different apple growers on the "Farm Report" segment. Heritage has offered to do this again on behalf of apple growers.

Additional Information

Go to http://www.facebook.com/EscapeMaker to see event photos and apple agritourism social media postings.

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Project 11 (FINAL)
Promoting Specialty Crops in the Capital Region

Project Summary

Background

The increasing importance of utilizing the web and mobile technology to market products is crucial as more and more people use smartphones to access information. According to a recent study by Pew Research Center, 77 percent of American adults have smartphones and use them as a primary means of online access at home. In addition 69% of U.S. adults are social media users. Social media is especially popular among younger adults, as 86% of 18- to 29-year-olds are social media users. In order to compete successfully in today's technology-centric world, specialty crops producers require access to resources that will enhance their ability to market and sell product, as well as better serve customers. This project enabled specialty crop producers in the Capital Region to promote their products via an optimized mobile website and social media, thereby increasing their internet and smartphone visibility.

Importance and Timeliness

The importance and timeliness of the direct sale of locally grown products is evident as indicated by a survey conducted by the National Agricultural Statistics Service in 2009. New York State has experienced significant growth in the number of farms marketing their products directly to consumers, retail stores, restaurants and institutions. According to the Direct Marketing Survey, 20 percent of all New York farms sold agricultural products directly to consumers, an increase of 10 percent since 2000. The average sales per farm selling direct increased 43 percent from 2000 to 2009. Statewide, the number of specialty crop producers selling direct was 5,671 generating direct sales of $256.6 million. Respondents of the survey indicated that the principle reason producers sold products directly to consumers was economic necessity.

As production costs continue to rise, producers can optimize their earnings through direct sales and niche markets. With consumers' increased demand for local product, producers have the opportunity to cash-in on the 'locally grown' movement. The Harvest Connection mobile friendly website and social media platforms enable more producers to market locally grown and increase their outreach to current and potential customers. The objectives of the Harvest Connection project were to:

1. Increase sales of specialty crops in the Capital Region with an optimized website and mobile website.
2. Increase the social media presence of specialty crop producers in the Capital Region with top media channels utilizing quality content and images.
3. Increase awareness of social media marketing with a how-to guide for New York State specialty crop producers.
4. Increase social media marketing educational opportunities for specialty crop producers, Cooperative Extension educators and agricultural service providers.
5. Foster partnerships amongst local growers that will encourage marketing from a regional perspective.

This project did not build on a previously funded project with the SCBGP or SCBGP-FB.

Project Approach

Activities and Tasks

The project leader started the project by creating a database including 355 specialty crop producers in a six county region. The producers were emailed and mailed information introducing the promotional project and explaining the objectives. As a result of the initial mailing, 30 specialty crop producers agreed to participate in the project. The project leader organized a meeting with interested participants and Spiral Design Studio to discuss the project, results of the farmer survey and provide an opportunity for farmers to provide input. The project leader organized a farm tour of three farms in Rensselaer County to meet with farm owners/operators and discuss the strategy to increase customer traffic with the newly developed website and social media platforms. Spiral Design Studio developed ideas for the project name and messaging. The project leader sent the title and tagline to farmers to rank. The title and tagline were chosen – Harvest Connection – Farm Fresh from the Capital Region. Spiral Design developed nine logos based on the title and tagline. The project leader and outreach coordinator reviewed the logos and approved the design.

Spiral Design Studio finalized the website design concept and the home and sub-pages design, Facebook best practice guide and Mail Chimp e-newsletter. They provided website Content Management System (CMS) training and development site access to the project leader and education and outreach coordinator. Spiral Design completed design of a brochure, print ads and a billboard to promote Harvest Connection.

The project leader contacted over 350 farms and farmers' markets to provide content and images for the website. The project leader recruited 120 farms and farmers' markets to participate in the project and entered content and images for the businesses into the CMS.

The education and outreach coordinator developed materials for four social media workshops held in March 2016 in four counties – Albany, Columbia, Rensselaer and Saratoga. The three-hour classes attracted 30 participants. The comments from the workshops were very positive and several producers mentioned how useful the presentations were to helping them feel more comfortable using the social media platforms.

The project partners are essential to the success of the project. Spiral Design Studio has been instrumental in creating a brand that is vital to the successful promotion of the project. They are integral to the development of the promotional tools that will attract the attention of shoppers interested in purchasing locally grown. Cornell Cooperative Extension also partnered on the project and provided social media outreach and education to both producers and consumers. CCE's digital literacy educator will continue to assist more producers in developing successful social media platforms that will drive more customers to farms, farmers' markets, CSA's, greenhouses, nurseries and honey and maple syrup operations.

Significant Results, Accomplishments, Conclusions and Recommendations

The project leader increased the number of specialty crop producers using the website and social media to promote their businesses by eighty percent. The website has attracted 6,032 visitors over the past six months and continues to demonstrate an increase in online usage with 1271 visitors in July with minimal advertising. As the website is advertised more extensively in phase 2 of the project, the project team anticipates an increase in online traffic.

Many of the farms participating in the project used websites and/or social media to promote their businesses, but some required assistance in utilizing social media to attract more customers. The project enabled farmers to further advance their digital media outreach by using tools to increase the number of people viewing their sites. In addition the creation of a regional brand and mobile friendly website provided an opportunity for farms and farmers' markets to further promote their specialty crop products. This resulted in an increase in the awareness of farms and farmers' markets selling specialty crop products in the Capital Region.

For any business interested in developing a local branding campaign, a good plan is essential to the success of the marketing effort. In addition, a clearly defined organizational structure, communications expertise, clear campaign policies and adequate financial and personnel resources are required to implement a successful plan. Farm businesses, farmers' markets or agricultural service organizations interested in online promotion should also include print and online advertising in their advertising budgets. In order to increase online traffic and build social media followers, advertisements including social media boosts engage more customers to find a farm or farmers' market to purchase locally grown products and result in an increase in the amount of product sold.

Significant Role of Project Partners

This project would not have been possible without the partnership with Spiral Design Studio and Cornell Cooperative Extension. Spiral Design Studio was instrumental in creating a mobile friendly website that allows for farms and farmers' markets to effectively promote their businesses. Their creative team of designers and website developers provided the support to create a brand and website that is appealing to a wide audience of users.

Cornell Cooperative Extension provided educational opportunities for specialty crop producers through their digital literacy program. 35 Farmers worked one-on-one with the digital literacy educator to develop their social media sites and also attended workshops to learn more about how to use social media to effectively promote their businesses. As a result, farmers made updates to their website and social media sites to attract more customers.

Goals and Outcomes Achieved

Activities Completed

The following activities were completed during the project period:

- Met with interested producers to discuss the website and social media activities.
- Organized advisory committee to oversee the project. Scheduled monthly meetings. Held first meeting to discuss project goals and work plan.
- Developed and sent out Request for Proposals for website development, social media, link building, SEO and content marketing strategy. Reviewed proposals. Selected contractor. Executed agreement.
- Met with media marketing contractor to review objectives and timeline. Scheduled follow-up meetings to discuss development of website, mobile website and social media sites.
- Developed and sent out Request for Proposals for farmer outreach and education. Reviewed proposals. Selected contractor. Executed agreement.
- Contacted 300 potential producers via email and mail to participate in project. Enlisted 30 producers to participate.
- Held conferences with the website/social media developer to discuss strategy and the project plan.
- Developed project name and messaging.
- Created website content outline, logo and website design.
- Recruited producers.
- Developed social media workshop presentation and materials.
- Held four social media workshops throughout the region
- Created and distributed Social Media QuickStart ebook.
- Reviewed and approved the subpages for the website and newsletter template.
- Provided outreach to farms, farmers' markets, nurseries and greenhouses for content and photos for the website.
- Populated website with content and photos of 85 farms and farmers' markets and content modules for FAQ's, Farm Specialties and Resources.
- Contacted 13 Christmas Tree Farms and 14 Maple Syrup producers.
- Signed up 17 new producers.
- Collected content and images from 15 farms and farmers' markets to include on the Harvest Connection website.
- Wrote and posted 2 news articles on the website.
- Launched website - http://www.harvestconnection-ny.com/.
- Taught 2 Social Media for Farmers Workshops.
- Hosted 4 Harvest Connection Orientations.
- Created print materials for onboarding sessions and project promotion.
- Designed curricula and prepared workshop materials.
- Created Twitter and Facebook pages.
- Created 15 news articles for the website.
- Updated 120 website farm pages.
- Organized and held 1 conference on Social Media for farmers who direct market.
- Visited 6 farms to meet with producers and take photographs.
- Created weekly FaceBook posts.
- Updated producer database.
- Created print and digital advertisements to promote the website.
- Placed print and digital magazine advertisement.

- Created report about the effectiveness of a regional branding campaign and website to promote specialty crop producers.

Comparison of Actual Accomplishments with Goals Established

The goals of the project were to increase the number of Capital Region Specialty Crop Producers marketing via a regional website and social media, i.e. Facebook, Twitter, and YouTube and to increase the sale of Capital Region specialty crop products.

The first goal was achieved by creating a website and social media to promote specialty crop farms in the Capital Region. 86 farms and 15 farmers' markets are now promoting their specialty crops online at www.harvestconnection-ny.com. The site provides an opportunity for specialty crop producers to showcase their products and build an online presence connecting them to their farm web and social media sites. The site was launched on December 16, 2016 and has been viewed by 6,065 users since the launch. Initial promotion of the site through a print and digital ad on June 26, 2017 increased page views by 77 percent over a 30 day period

It was difficult to quantify the increase in sales that were a result of the website and social media. Overall, sales have been down this season due to the weather and other factors. In order to accurately quantify the number of sales resulting from the website, every farm and farmers' market would need some type of tracking mechanism. Due to the number of participating producers, it was difficult to create an easy to use mechanism to accurately track sales.

Beneficiaries

The primary beneficiaries of the project are the 120 farms and farmers' markets that participated in the project. Other beneficiaries include the consumers who use the website to locate farms and farmers' markets in the Capital Region to find specialty crop products. The project team was unable to determine the number of consumers who purchase product as a result of the website and social media. During the project period, 6,065 potential customers viewed the website.

Lessons Learned

The creation of the Harvest Connection website provides an opportunity for specialty crop producers to further promote their businesses online. As a result of the online presence, the participating businesses increased their level of visibility with current and potential customers. This is especially true for new farmers and farmers' markets that did not have an online presence prior to the Harvest Connection website. The website allowed for these farms to participate regardless of their financial limitations and/or lack of resources.

Developing a new brand, website and social media outreach requires a significant amount time to build a large following. Due to the length of time required to create the brand and website, the number of users is lower than was anticipated. In order to build the user base, CCE of Rensselaer County secured a USDA Farmers' Market Promotion Program Grant to promote the website and build brand awareness. As more and more people discover the website, farms and farms and farmers' markets will generate greater online visibility that should result in an increase in sales.

Farms, farmers' markets or agricultural organizations interested in building a regional identity should be aware of the amount of time required to manage the website, social media and promotional efforts to establish a brand online. Many companies employ full time staff to execute their promotional campaigns realizing the importance of outreach to current and prospective clients in the digital age. The Harvest Connection Project did not have full time staff employed on the project, so worked with partners to keep the project on track. The key to any successful promotional campaign utilizing limited resources is to get the most bang for your buck. With continued outreach and education in the next phase of the project, the project team anticipates more farmer participation and an increase in the number of potential customers using the website to find farms and farmers' markets.

Initially, the idea of creating a tool for consumers to connect to farms appeared feasible with the allocated grant funding, but without additional resources it was difficult to promote the idea to the general public. The idea of Harvest Connection started with the creation of well thought out slogan, logo and website, but the project's future success will be dependent on the project team's ability to work effectively with the community by bringing together diverse and sometimes reluctant participants and partners. With the additional funding from the USDA FMPP grant, CCE will market Harvest Connection through print and digital advertisements and also provide more opportunities for farmers to utilize social media in their marketing efforts. Educating farmers and consumers about how to use digital media to locate farms will increase awareness about locally grown in the Capital Region and result in the additional sale of locally grown products.

Additional Information

N/A

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Project 12 (FINAL)
Let's Eat NY: A Farm-School-Grocery Partnership

Project Summary

The institutional food market is a largely untapped market for specialty crops produce growers with high potential for long-term, wholesale level, contracts. While many students, and families, would ultimately choose the local apple, tomato, pear or carrot, over their non-local counterpart based on taste, appearance and ease of consumption, competition for "brand recognition", or shelf space, is almost impossible for New York State specialty crops produce growers when compared to regional or national distributors of their competition. This project looked to increase sales of New York State specialty crops produce in the Broome-Tioga BOCES (BT BOCES) institutional food service lunch program through a targeted messaging and merchandising campaign combined with taste-testing and surveys with students; leading to ultimate recognition of, and preference for, New York State specialty crops produce such as apples, pears, tomatoes, carrots, and broccoli. This campaign was planned to take place simultaneously in a partner grocery store, Wegmans (store #73), located in Johnson City, NY. Success was to be evaluated through a variety of quantitative and qualitative measures, including raw sales data from school district procurement offices and Wegmans Produce Manager, tracked over the period of the project, results of taste-tests conducted by the BT BOCES Registered Dietitian, and surveys of students regarding the effect of the messaging and merchandising in their ultimate recognition of, and preference for, local produce.

Through a successful USDA Farm to School pilot project, great strides have been made by Broome-Tioga BOCES (BT BOCES) and Cornell Cooperative Extension of Broome County (CCE-BC) in connecting local farms with the school food market and educate students about New York State (NYS) produce. As well, the interested partner grocery store has made great efforts to highlight NYS specialty crops producers during the summer and fall months in their selection through signage, "meet & greets" and other means. In blind taste tests, the students have overwhelmingly chosen NYS apples and tomatoes over non-local produce. The *Healthy Hunger Free Kids Act*, and recently, the *Smart Snacks in Schools Nutrition Standards* have identified a growing demand for fresh, safe, local fruit and vegetable products at reasonable cost to schools.

However, specialty crop producers encounter several challenges when providing schools and grocery stores with their produce. The biggest challenge is that districts, and produce managers, are accustomed to working with large national distributors/suppliers with aggressive marketing strategies already in place. Local efforts to compete with these established brands often fail, even if the local produce tastes better and is less expensive when transportation and other costs are included. Local producers interested in working with these markets must resort to more direct, hands-on approaches, such as conducting taste tests and offering free samples.

Let's Eat New York! is aimed at putting specialty crops producers on a more equal footing with their competition by designing targeted messaging and marketing materials that Food Service Directors (FSD) and store produce managers can use to increase demand for local specialty crops.

This project is not building on a previously funded Specialty Crops Block Grant Program project.

Project Approach

Marketing & Merchandising Campaign:

- A variety of marketing and merchandising methods were used during the project. These included point of purchase materials (aprons, buttons, window clings and produce labels for value-added items such as dehydrated apple chips) used in the school cafeterias, both on the lunch line as well as worn by food service workers and in the produce section at the partner grocery store. The messaging was focused on eating NYS Specialty Crops. All were launched during "NY Harvest Week" to coincide with the greatest amount of NYS items on the menus. These got great reception from the students in encouraging them to try and choose the NYS Specialty Crop over it's non-local competition.

- Fantastic Foodies: A social media marketing campaign was also designed using a cast of 7 local youth ages 8-12. A set of short videos were created with messaging about eating healthy and local. These youth also participated in a local youth cooking contest and got great reception from their peers and the local media. Their videos have been viewed thousands of times on youtube. Due to the interest we were approached by our local public television affiliate to repurpose them for showing between afternoon programming, but we did not have the available funds to repackage them for their purposes (they needed much shorter pieces) but we will look at perhaps pursuing this in the future.

Taste Tests & Classroom Education:

- Taste tests were conducted both in partnership with the Broome-Tioga BOCES Registered Dietician, as well as by Cornell Cooperative Extension of Broome County staff, when done in conjunction with the in-classroom education – which took the form of skits (for elementary students) and a food miles activity (for middle school students). The taste tests included carrot coins (NYS versus California), pears (NYS versus Washington), blueberries (NYS versus Michigan), and apples (NYS versus Washington). The taste tests were extremely helpful in showing how important taste is in student's preference. The carrot coins from NYS were sliced too thin so they were dry; the pears were bosc pears so an unfamiliar variety. But blueberries and apples from NYS won hands down in the taste tests. What we took away from this is that variety is important, how the item is processed is important – but most important is taste palate. More work needs to be done on exposing youth to the different varieties of produce that are grown here in NYS, as well as working with processors on perfecting their processes. Through these taste tests and skits we reached over 4000 students in the two counties.
- The in classroom education pieces were equally as important in showing the value of NYS Specialty Crops. These educated children from Pre-K to 8th grade about what is grown locally, why it's important to choose a local fruit or vegetable over it's non-local counterpart related to taste, food miles, supporting the local farm, etc… We got great feedback from students and teachers on these activities and believe that paired with the taste tests that they positively impacted student preference.

Producer Education and Outreach:

- Producer education and outreach took several forms. We worked with interested farms to walk them through the procurement process so they could successfully win a bid to sell produce to Broome-Tioga BOCES. (Two additional farms were awarded bids to sell produce to schools). We also held several trainings related to GAPs so farmers could pursue that certification and be eligible to sell to the partner grocery store. (We had 20 farms from across the region attend these trainings and four are currently working towards GAPs certification and writing their food safety plan). Additionally, we worked with our partner grocery store to identify additional farms that the schools could contact regarding sales of produce because they would also already have GAPs, which is required by the schools to purchase. Finally, we presented at the Empire State Fruit & Vegetable Growers Expo about the opportunities with Farm to School. We have been excited about the interest from farmers in this market opportunity as traditionally there has been pushback.

RVSA Advertising: Our advertising firm did all the work on creating creative content, and creating, taping and editing all the social media pieces. They went above and beyond the value of their contract to provide a quality product.

Broome-Tioga BOCES: Their Registered Dietician coordinated and implemented the carrot and pear taste tests, as well as worked with Food Service Directors on integrating NYS Specialty Crops into the monthly menus.

Wegmans, Store 079: Their Produce Manager was helpful in identification of farms who would be a good fit for the schools in terms of the types of produce they were looking to source. They also allowed one of the social media spots to be shot in their produce section to showcase their partnership and dedication to NYS Specialty Crops. Our original intention was to use all the marketing and merchandising materials in the store as well as the school cafeterias. But due to their space and existing signage we were unable to do so.

Goals and Outcomes Achieved

Our original purchasing/procurement goals for the school districts was a 15% increase in NYS Specialty Crops. In the first year we saw a 40% increase due to the great apple production we had that year! However, in the year following the percentage decreased significantly for the NYS Specialty Crops farms due to the terrible apple production we experienced across the state. However, we also were able to help the schools increase the number of farms who are participating in their bid process so they have a larger number of options for NYS Specialty Crops.

Baseline purchases (2014-2015): 5,912.5lbs of NYS apples in the 2014-2015 school year with a value of $4314.84 to the farm. This equals 148 cases.
In fall/winter (2015/2016): 14,716lbs of apples were purchased with a value of $11,478.48 to the farm! (40% increase in purchases) = 368 cases
In fall/winter (2016/2017): 1060 cases of apples were purchased with a value of $17,967 to the farm (tripled in number of cases from the previous year) → BUT this was from a PA farm just over the border as the apple season was terrible due to a late frost. But it does show the demand for local as for many schools in the Southern Tier of NYS, a farm from Pennsylvania is closer than one in NYS.

If the schools had been able to purchase the apples from a NYS farm in the fall/winter 2016/2017 it would have been an increase of seven times from the baseline start of the grant! This is much more than we dreamed and is due to our holistic approach of marketing and merchandising, the taste tests and in-classroom education to provide the education and experiences to impact student preference in the lunch line!

Beneficiaries

30,000 students in the K-12 participated/benefited from this project through increased access to NYS Specialty Crops in the lunch line. Additional beneficiaries were the farmers who got increased sales. To see the economic impact to local farms please see #4 above. As part of a sister project, more taste testing is being conducted in Broome-Tioga BOCES schools focused on NYS root vegetables and cabbage (in a coleslaw and salad) to focus their taste palate and then those products will start to be sourced from NYS farms which will increase the economic impact.

Lessons Learned

We learned several very important lessons during this project. First, we need to work on building farmer capacity for institutional level procurement because the demand already exists and grows every year. This takes time, perhaps even two growing seasons to completely achieve the successful GAPs audit. Additionally, packaging is very important and can often be a stumbling block for farmers so working on options which can satisfy GAPs and aren't cost prohibitive needs more research. Second, that procurement of a specific product cannot rely on one farmer – due to the nature of farming and heavy reliance on weather. We saw this specific to apples but it is similar across all types of NYS Specialty Crops which are produce. Third, that marketing and merchandising does have an impact on student preference for NYS Specialty Crops. We know the impact would have been even larger if we could have worked with our local public television station and if we find additional funds in the future we will work on leveraging the spots already created by the Fantastic Foodies to continue the peer-to-peer marketing.

Additional Information

Nothing at this time. All has been sent with previous reports.

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Project 13 (FINAL)

Providing New York's Organic and Transitioning Producers with Pest Management Recommendations for Specialty Crops

Project Summary

New York State has seen continued growth in the number of certified organic farms in the State in the last decade. In 2003, certifiers reported 281 certified organic producers in NYS. In 2007, there were 723 certified organic producers, and in 2016, National Agricultural Statistics Service reported 935 certified organic producers are currently operating in NYS. This steady growth has been in all production sectors. New York State organic producers need the most recent and up-to-date information on cultural practices and pest management. The project's purpose was to provide this information for producers. The project's specific objectives were to update the pest management cultural and product recommendations for 12 organic production manuals for specialty crops, including carrots, cole crops, cucurbits, lettuce, peas, potato, snap beans, spinach, blueberries, grapes, strawberries and storage for organic fruits and vegetables.

The project is important because pesticides for certified organic growers are being developed and registered by the US Environmental Protection Agency. Some work; some don't. Some are registered for use in New York State, some are not. The revised manuals compile all the new registration information, any pertinent research on actual pesticide or cultural practice efficacy and provide it to growers on a crop by crop basis. When a new product is registered, growers should not be asked to simply believe manufacturer's claims, but should also have access to independent efficacy trials by researchers and others.

This project did not build on a previously funded project with the SCBGP or SCBGP-FB.

Project Approach

For each of the two years of updates:

Research was conducted to ascertain whether any new production recommendations were in order for each of the vegetable and fruit guides. This work was commenced at the start of the grant funding cycle and continued through the winter months. It entails reviewing journals and publications where research on organic methods and practices is published, having specific Cornell faculty crop experts review the work, if they are unfamiliar with the research, and then making a determination as to whether the research results impact current production recommendations in each guide.

The Organic Materials Review Institute listings were reviewed for new products and uses that have been added since mid-2015, as well as products that have been removed from their lists, and products were added and removed from the guides as needed. This institute provides an important bridge between regulators and manufacturers because it will confirm product ingredients are allowable as per the USDA National Organic Program regulations while maintaining manufacturer confidentiality.

Every pesticide included in each guide was also reviewed for both US Environmental Protection Agency changes to labels, as well as NYS Department of Environmental Conservation pesticide label registrations, a requirement for the use of any pesticide in New York State.

In the second round of updates, all pesticide/crop/pest combinations, along with efficacy data when available, were entered into a database created and administered by Cornell University's Pesticide Management and Education Program (PMEP). Tables included in the guides indicating products labeled for specific crop/pest combinations can be generated from the database. Having this information in the database will streamline future updates of the guides. The efficacy data collected over previous funding cycles was also reorganized to facilitate future updates.

Grant funding provided for a technical writer, who conducts literature searches, interacts with faculty, coordinates those responses and, as directed, incorporates responses into the updated guides. Another technical staff person employed by PMEP, who conducts the pesticide regulatory review, was also funded by the grant.

Goals and Outcomes Achieved

In both 2015 and 2016 updated guides were posted either on the NYS IPM web site (2015) or on Cornell's eCommons site in the NYS IPM Program publication section (2016) in May as pdf files available as free downloads (https://nysipm.cornell.edu/environment/organic).

Download statistics
Oct 1, 2014 – September 30, 2015 - 3,744
Oct 1, 2015 – September 30, 2016 - 7,003
Oct 1, 2016 – March 1, 2017 – 8,490

Goals:

- Increase producer knowledge of the most up-to-date, legally allowed IPM protocols for certified organic producers of specialty crops.

Outcome:

- Download numbers have increased substantially during the funding cycle, reflecting the usefulness, and possibly improved user awareness, of the guides. The increased numbers indicate that users are downloading annual updates and accessing the most up-to-date IPM protocols and legally allowed pesticides for certified organic production. From 2014 to 2015, downloads nearly doubled and a 21% increase in the following 6 months.

Goal

- Get producers to refer annually to the production manuals, to ensure that they are using organic pesticides as per the federal and state regulations that control their use, and ensure that they are aware of and understand new organic IPM protocols.

Outcome:

- The goal of conducting email surveys of growers each year before and after releasing the updated guides was not accomplished. Staff responsible for this performance measure retired before it could be completed.

Beneficiaries

Beneficiaries of the guides include approximately 1,300 (based on statistics from the 2016 NASS Organic Survey) organic fruit and vegetable producers in the Northeast, (NY, PA, and the New England states) an unknown number of conventional producers contemplating transitioning land to organic production (no statistics available on number of conventional producers contemplating transition), and approximately 25 Extension educators and consultants working with organic growers, throughout the Northeast.

Lessons Learned

Part of the project (updating and posting the guides) was contracted to Cornell University, but the surveys were to be conducted in-house by NYSDAM staff who have since retired, so there was a mismatch between proposal writing and the scope of work promised and reported on in the subcontract. Project staff learned it was tougher to measure project impacts than anticipated. Producing the guides was a worthwhile endeavor, however with staff changes the follow-up with users was an issue. Evidence that the guides were downloaded and utilized by an increasing number of users over the course of the project shows that specialty crop growers benefitted from access to greater knowledge of best practices in organic pesticide use.

Additional Information

N/A

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Project 14 (FINAL)
Expanding First Time GAP Audits and Preparing Producers for Food Safety Regulations

Project Summary:

Fresh and minimally processed, ready-to-eat fruit and vegetable production is a multi-billion dollar industry in the United States. In recent years, food safety has become a major concern in the production of fresh produce in the United States and globally. Many major international and domestic retailers, wholesale buyers, foodservice companies, restaurants and schools now require their suppliers to provide certification from a third-party to verify adherence to Good Agricultural Practices (GAP); and/or Good Handling Practices (GHP). In order to assist New York's specialty crop producers and handlers of fresh produce address these growing demands and remain competitive in the marketplace, the New York State Department of Agriculture & Markets (NYSDAM), using funds from the 2014 Specialty Crop Block Grant Program-Farm Bill (SCBGP-FB), implemented a multi-faceted food safety program to educate growers about GAP/GHP requirements as well as to assist growers, producers and handlers in paying the costs associated with first time audits, informational assessments and costs of water testing to comply with GAP/GHP.

GAP education and certification-reimbursement programs have been funded by New York's Specialty Crop Block Grant allocation prior to the 2014 award cycle. Prior to 2014, New York funded a "GAP Certification Assistance Program" using 2011 SCBG funds. Due to overwhelming feedback from farmers on the importance of providing this financial assistance, the project was once again funded in 2014. Producer response to the current program indicates the decision to continue previous efforts was worthwhile. Participation of growers, packers and handlers in GAP & GHP audits in New York has increased during this project as compared to the previous project. In the previous project, funded with 2011 SCBG funds, NYSDAM had conducted 532 audits in total, while at the conclusion of the current project, NYSDAM conducted 665 audits, with 204 of them receiving reimbursement for certification.

Project Approach:

NYSDAM developed a *Good Agricultural Practices Certification Assistance Program* whereby growers and handlers could receive financial assistance in paying up to $750 of costs associated with third party GAP/GHP audits. This reimbursement approach was taken in order to provide a significant incentive for producers who were not familiar with the GAP/GHP certification process and may therefore be hesitant to have an audit performed or could otherwise not afford it. The audits were performed by NYSDAM or private companies and funds were distributed on a first-come, first-served basis. An informational brochure, marketing materials and associated program applications/forms were developed and made accessible both in hard copy and on the Department's website.

In order to effectively and efficiently target producers/growers/handlers, outreach and education was conducted at venues throughout the State including farm/trade shows, county fairs, food safety conferences, etc. In addition, Cornell Cooperative Extensions (CCEs) conducted twelve GAP workshops throughout the State in partnership with Cornell University staff and NYSDAM. During these two-day GAP workshops, CCE staff put on presentations for farmers to inform on GAP requirements and were provided assistance in developing their food safety plans.

In order to meet the increased need and demand for certifications, SCBG funds were used for training auditors and to maintain necessary certification of USDA auditor qualifications.

Furthermore, in partnership with Cornell University and the New York State Food Laboratory, a portion of the SCBGP-FB funds were used to create a water quality database to minimize microbial food safety hazards to fresh and minimally processed fruits and vegetables posed by surface water irrigation. These commodities often are irrigated with surface water throughout the U.S. (1). While there is concern with all sources of water for pre-harvest use, relative to food safety, surface water is more likely to be exposed to fecal contamination than ground water and is expected to pose a greater risk to human health than irrigation with water from deep aquifers with properly constructed and protected wells. In most cases, the sanitary quality of surface water used for irrigation is not known because it is not regularly tested.

Previous studies of irrigation waters have been concerned primarily with chemical rather than microbiological water-quality parameters (2). As a result, there is a nationwide knowledge gap regarding sanitary quality of irrigation waters. Public attention to recent outbreaks of food borne illness has led the industry sectors to self-mandate irrigation water sampling and set quality standards based on the United States Environmental Protection Agency's Bacterial Water Quality Standards (USEPABWQS) for fresh water (3). Recreational-water criteria may not be appropriate for direct application to irrigation water; however, in the absence of a publicly available database based on water testing, this standard has been adopted. In addition to industry adoption of standards, in December 2009, the United States Food and Drug Administration publicly announced their intention to develop a Produce Safety Regulation for fresh produce.

Preliminary research data gathered prior to the beginning of this project from surface water sources used to overhead irrigate fresh produce crops indicated that if growers were forced to adopt the USEPABWQS, they would either have to discontinue use of some of their water sources or implement mitigation strategies to reduce the microbiological load because surface water quality can vary over the season (Bihn, unpublished data). These mitigation strategies could represent a significant financial investment and directly impact farm viability. Both food safety and the importance of water as a natural resource are being managed on the farm and understanding current water quality will allow farmers to make informed decisions about surface water use.

Goals and Outcomes Achieved:

Grower/packers/handlers participation in GAP & GHP audits in New York has increased during this project as compared to the previous project. In the previous project, funded with 2011 Specialty Crop Block Grant funds, NYSDAM had conducted 532 audits in total, while at the conclusion of the current project, NYSDAM conducted 665 audits, with 204 of them receiving reimbursement for certification.

NYSDAM provided and/or participated in 25 outreach and educational venues over the course of the project, directly reaching more than 2,500 growers/packers/handlers. This included 13 venues in 2014-15 reaching more than 1000 individuals, 6 venues in 2015-16 reaching more than 1400 individuals, and 6 venues in 2016-17 reaching more than 100 individuals.

During all three years of the project, all NYS auditors attended 20 hours of mandatory training, each year, to meet continued professional education requirement of the auditor license. Six auditors attended new auditor training. Currently, NY State has 13 USDA licensed GAP auditors.

Grower outreach and education was conducted at the following venues:

Date	Event-Location	No. of Attendees
12/3, 12/4/114	Cornell GAP Workshop, Middletown	23
1/12 – 1/13/15	Cornell GAP Workshop, Geneva	21
1/20, 21, 22/2015	Empire State F&V Expo, Syracuse	500
1/30/15	Wegmans GAP Workshop, Rochester	80
2/5, 2/6/15	Cornell GAP Workshop, Canajoharie	20
2/10, 2/11/15	Cornell GAP Workshop, Riverhead	30
2/26, 2/27/15	Cornell GAP Workshop, Kingston	12
3/9, 3/10/15	Cornell GAP Workshop, Milbrook	10
3/17, 3/18/15	Cornell GAP Workshop, Arcade	30
8/13/15	Empire Farm Day, Seneca Falls	300
1/19, 1/20, 1/21/16	Empire State F&V Expo, Syracuse	300
2/17/16	Cornell GAP Workshop, Riverhead	40
2/22/16	Cornell GAP Workshop, Geneva	50
3/7, 3/8/16	Cornell GAP Workshop, Aurora	35
8/9, 8/10, 8/11/16	Empire Farm day, Seneca Falls	1,000
9/22/16	NY Association of Food Protection, Syracuse	20
12/6 & 12/7/16	Cornell GAP Workshop, Binghamton	10
1/7/17	On-Center, Syracuse	20
2/8/17	Cornell GAP Workshop, Watertown	10
2/27 & 2/28/17	Cornell GAP Workshop, Liberty	25
3/21 & 3/22/17	Cornell GAP Workshop, Riverhead	20
4/6/17	Cornell GAP Workshop, Batavia	4

Project Activity	Who performed the work?	When was the activity accomplished?
GAP Workshops: The two day GAP workshops to be organized in cooperation with Cornell Cooperative extension. On first day growers will be given information and will be shown presentations about GAP requirements and on 2nd day growers will be helped to develop their food safety plans.	Joscelyn Moseley Steven Smith Michael Santoro Tom Tubbs Victoria Costa Ethan Freeman Matthew Arno	12/6/16, 12/7/16, 2/8/17, 2/27/17, 3/21/17, 4/6/17
Empire Expo, Empire Farm Day : Direct interaction with growers to provide them information about GAP audits and reimbursement program, and to answer their concerns and questions about checklist questions.	Marty Farrell Linda Wason	1/17/17
Auditor Training: Auditors receive annual mandatory training as a requirement of USDA continued professional education, to keep the auditor license.	Michael Santoro Thomas Tubbs George Spohn Matt Arno Emily Wallace Aaron Finley Victoria Costa Ethan Freeman Joscelyn Moseley Wendy Ingersoll Steven Smith Steven Schirmer Marty Farrell Linda Wason	Various dates
New Auditor Training: New auditors receive various 'New Auditor Training' sessions, offered by USDA, to become licensed GAP auditors.	Nathan Hance Linda Reiter Linda Wason	*5/1/17 to 5/5/17* *6/6/17 to 6/12/17*
GAP – Lead Auditor Training: ISO-9001 Lead auditor training course to qualify as GAP evaluator, to evaluate other auditors – as a requirement of USDA audits program.	Linda Wason	*9/18/17 to 9/22/17*

GAP promotional activities

To bolster the program's success, promotional video was shot, edited and production was completed through the assistance and funding provided by another NYS agency known as Empire State Development (ESD). As ESD provided this financial assistance toward promotion, SCBG project funds were better aimed at outreach, trainings and additional GAP certification reimbursements.

The ESD-funded video was released when the NYSDAM GAP website was launched in February 2016, along with a new brochure, which has the same look and feel as the website. The decision was made to launch and release simultaneously during the off season, which appears to have had a significant impact on this project in the subsequent 2016 growing season. During 2016, the greatest number of GAP reimbursement requests occurred for this project (151), likely due to the timing of the video release and website launch. Below are links to the promotional materials that helped to facilitate the many

Link to the brochure:

https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKEwjoqdvyv5vYAhVBQCYKHaH9BMAQFggpMAA&url=https%3A%2F%2Fwww.agriculture.ny.gov%2Fgap%2Fwp-content%2Fuploads%2F2016%2F11%2FNYSGC-GAP-Brochure-final_20161116.pdf&usg=AOvVaw2Llk_lfJQyfE8XrFr5mGPf

Link to the NYSDAM GAP website:

https://www.agriculture.ny.gov/gap/

Link to video:

https://www.agriculture.ny.gov/gap/overview-video/

Beneficiaries:

Direct beneficiaries were the numerous New York State growers and handlers that participated in the various workshops and educational outreach sessions, and/or had a GAP/GHP audit performed for their operation. More than 2,500 growers, packers and handlers directly benefitted from the events outlined above, which informed farmers on GAP requirements and the potential for certification reimbursement through this program. Included were: 13 venues in 2014-15 reaching more than 1000 individuals; 6 venues in 2015-16 reaching more than 1400 individuals; and 6 venues in 2016-17 reaching more than 100 individuals. NYSDAM performed 665 GAP audits during this project timeframe and reimbursed 204 individual farms for their GAP certification costs.

A secondary group of beneficiaries were the various levels of major international and domestic retailers, wholesale buyers, foodservice companies, restaurants and schools that participated in

educational outreach venues and/or had their produce suppliers participate in this program and became more aware of the benefits of GAP/GHP.

A third group of beneficiaries are the millions of consumers of locally produced fresh fruits and vegetables who benefitted from improved food safety practices on farms and at handling facilities.

Lessons Learned:

This project demonstrated that providing financial assistance to growers/handlers for first-time third party GAP/GHP certification is an effective way to encourage participation in implementing and documenting effective food safety practices. Coupling that assistance with broad-based educational outreach and comprehensive technical assistance throughout the certification process significantly extended the impact of the grant funds and resulted in grower/handler implementation and satisfaction.

Many producers who participated in this program realized that they were already implementing many of the recommended food safety practices, but just weren't documenting it within the context of a food safety plan. As a result, the perceived costs associated with potential changes to improve food safety practices were not as significant as some growers/handlers feared. At the same time, this project demonstrated that as producers/growers/handlers become more aware of food safety issues and incorporate changes in their practices into a farm food safety plan, the benefits of GAP certification become increasingly recognized throughout the industry.

Another lesson learned is that the diversity of the fresh and minimally processed produce industry needs to be considered on many levels throughout the development of a food safety education and implementation program. New York State's specialty crop industry is particularly diverse and complex, consisting of farms with a wide range of commodities, sizes and shapes. As a result, developing a program, educating the industry and implementing GAP procedures on individual farms is challenging and requires cooperation and working partnerships among various segments of the industry, including farmers, buyers, commodity organizations, educators, and government agencies.

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Additional Information:

New York water testing laboratory information collected as part of this project is posted at the National GAPs Program website at www.gaps.cornell.edu.

Citations

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3. United States Environmental Protection Agency Bacterial Water Quality Standards for Recreational Waters (Freshwater and Marine Waters), Status Report. June 2003. http://www.epa.gov/waterscience/beaches/local/statrept.pdf