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## Project Title: Reducing the Impact of Phytophthora Blight on Vegetables In New York

### Project Summary

Phytophthora blight is a devastating disease of vegetables caused by the pathogen *Phytophthora capsici*. In New York, it has caused losses in bell pepper, hot pepper, tomato, eggplant, cantaloupe, cucumber, melon, pumpkin, squash, zucchini and snap bean crops. While many states have battled this disease for decades, the pathogen had not been a significant problem in upstate New York until relatively recently. Over the past five-ten years both incidence and severity of the disease have increased, and vegetable producers are now searching for effective control strategies. The objectives of this project were to 1) aggressively extend to growers the information that we have on how to prevent contamination of clean fields and how to manage fields contaminated with *P. capsici*, 2) identify breeding lines and continue development of plant varieties that have tolerance to the pathogen, and 3) to demonstrate to growers cultural control strategies (mulches, bed height, cover crops) that would reduce disease severity.

### Project Approach

A brief summary of activities performed for each objective are included below.

Objective 1: Aggressively extend to growers the information that we have on how to prevent contamination of clean fields and how to manage fields contaminated with *P. capsici*.

Task/Project activities and completion date for each activity are listed below.

1. Grower surveys – Completed in 2010.
  - a. Vegetable growers (both organic and conventional) were surveyed as to the presence of Phytophthora blight on their farm, and site visits to validate the presence of the pathogen have been made. We surveyed 117 growers (at three different meetings), and 81 were returned. Twelve (12) of them indicated that they did not have Phytophthora blight on their farm, and that we could survey their field in 2011 to determine if the pathogen had spread to their farm. In 2011, we surveyed (by visiting) 12 farms that said they did not have Phytophthora blight in 2010. None of these farms had Phytophthora blight in 2011. We did survey the cultural practices adopted at these 12 farms. The original survey identified tolerant varieties grown (90% of growers that grew tolerant varieties grew Paladin). The surveys also asked about types of resistant crops that would be most useful to NY growers, sources of irrigation, and fungicide use.
  - b. These data have been shared among all team members. Mazourek is using the survey data to expand the pepper breeding program to varieties growers would like to grow.
2. Develop comprehensive website with downloadable fact sheets – Completed Jan 2011, but **new information is added when available**.
  - a. Fact sheets are available in print and electronic forms. A general Phytophthora blight fact sheet and a specific disease alert for Phytophthora blight on snap beans are available.
  - b. Comprehensive Phytophthora blight website is on-line, and can be found at <http://phytophthora.pppmb.cals.cornell.edu/> The site now contains:
    - i. **recently added** links to three webinars held in the fall of **2012**

- ii. information on weed hosts, susceptible hosts, results of variety trials and information on research projects
  - iii. downloadable fact sheets
  - iv. locations in NY where fungicide resistant strains have been identified
  - v. images of the pathogen on various crop hosts
  - vi. images of the pathogen taken under the microscope
  - vii. management and control strategies
  - viii. powerpoint presentations given by Smart and Dillard
- 3. Grower twilight meetings, demonstrations, and annual field days were successful.
  - a. Four activities were held **2012**, during the months of August and September (listed in appendix A, page 8).
  - b. Five activities (plus multiple visits to individual farms) were held in **2011**.
  - c. Six such activities were held in **2010**.
- 4. Develop and implement a quick assay for fungicide resistance
  - a. The Fry lab completed the lab testing portion of the rapid metalaxyl/mefenoxam sensitivity assay that was developed as part of this grant. The assay is based on leaf tissue and can be completed within 4 days (which is significantly quicker than the current 10 day assay). They tested 35 isolates, comparing the traditional agar assay with the new leaf tissue assay, and found the new assay to be reliable.
  - b. The rapid system was used during the **2011** and **2012** growing seasons on samples collected in the Albany area following major flooding (due to hurricanes Irene and Lee). Unfortunately, most isolates were found to be mefenoxam resistant.
- 5. Presentations at annual winter meetings such as the Vegetable Expo in Syracuse
  - a. Six talks were presented **2012** (listed in appendix A).
  - b. Eight talks at winter meetings were presented by the PIs in **2011**.
  - c. Two additional talks were presented to growers by Graduate students working on the Phytophthora blight project in **2011** (listed in appendix A).
  - d. Three talks at winter meetings were presented in **2010** (listed in appendix A).
  - e. Six talks at University department seminars were also given in **2010** and **2011** by the PIs (at North Carolina State, Ohio State, Rutgers and three at Cornell).
  - f. Fry has presented information on Phytophthora blight and fungicide resistance (using this project as an example) to his introductory Plant Pathology course at Cornell (PIPa 3010) in **Fall 2009, Fall 2010, and Fall 2012**. Because Fry was unavailable, Smart presented the information in the **Fall of 2011**.

Objective 2: Identify breeding lines and continue development of plant varieties that have tolerance to the pathogen.

- 1. Both private and public breeding lines were tested at the blight farm during the summers of 2010, 2011 and 2012.
  - a. New trials were completed at the farm in **2012**. Mazourek had new lines that Smart tested, along with breeding lines from private companies. These data are consistent with those obtained in 2011, and the tolerance levels in Mazourek's lines are excellent.
  - b. We had over 5,000 pepper plants at the farm in **2011**, including breeding lines of Mazourek. The data are presented in appendix B (page 12). The tolerance levels in Mazourek's lines are excellent!
  - c. We observed severe disease symptoms in **2010**, and some of the breeding lines held up well to a high level of Phytophthora blight inoculum.

2. Mazourek has used the data from the survey to identify pepper types he will include in his Phytophthora resistance breeding program.
  - a. Mazourek, Smart and Reiners compared horticultural traits of the new pepper varieties to commercially available Phytophthora blight tolerant peppers. This experiment occurred at 3 research sites, and the data are presented in appendix B.
  - b. In **2011** growers evaluated the new varieties developed by Mazourek, and we have visited farms to receive valuable feedback. Growers felt that under high disease pressure, fruit blight was observed however it was no worse (and perhaps better) than commercially available lines. The growers also felt the fruit were a bit small.
3. Dillard had a large snap bean trial at the farm in 2010, and an even larger trial in 2011.
  - a. Significant differences between commercially available snap bean varieties have been observed, and Dillard is now able to make variety recommendations to growers.
  - b. The data from the **2011** season were similar to those from 2010.
4. Additional breeding companies tested their varieties in NY (at the blight farm) in **2011 and 2012**. Some lines look very promising. Because of the broad scope of this project, we have been asked by several breeding companies to conduct disease tolerance tests on many sweet and hot pepper varieties, as well as some squash varieties. This is excellent news for NY vegetable growers because we have the opportunity to see how these varieties perform in New York.

Objective 3: Demonstrate to growers cultural control strategies (mulches, bed height, cover crops) that would reduce disease severity.

1. Smart and Reiners have completed projects to study cultural control strategies including green manure cover crops (Smart) and living mulches (Reiners). Reiners gave a talk about this work at the NY fruit and veg expo in **2012** and growers were very enthusiastic. Smart has included data on the green manure trials in several talks, and has had many inquiries from growers trying to improve soil health.
2. In **2011**, Reiners conducted a horticultural variety trial/demonstration using Phytophthora blight tolerant pepper varieties. This demonstration was showcased at two field day events in August 2011.
3. An on-farm trial using mixed species cover crops was planted (Oct 2011), for the **2012** growing season. The crops were tilled under in May and tomatoes were planted in June. Disease ratings and plant vigor data was collected in **2012** and we found that different cover crop mixtures did not alter plant vigor or disease, however cover crops (and the addition of beneficial bacteria) did improve plant height.

#### *Favorable or Unusual Developments*

- Grower enthusiasm for the project was, and remains, excellent. Six growers tested Mazourek's pepper lines and provided valuable feedback.
- Variety trials using commercially available pepper varieties and Mazourek's breeding lines went exceptionally well, and a publication is expected to be submitted soon.
- All data from the project were presented at multiple meetings from 2010-2012.

### *Significant Contributions and Role of Project Partners*

Christine Smart – Responsible for project oversight, web development, outreach and education at grower meetings and at the Phytophthora blight farm. Smart also coordinated and spoke at many of the outreach events, and coordinated on-farm trials of pepper breeding lines.

Helene Dillard – Responsible for web development along with Smart (including fact sheets), outreach and education at grower meetings and at the Phytophthora blight farm. Dillard performed disease tolerance and product efficacy trials for snap bean, and reported the data at multiple grower events.

William Fry – Responsible for the development and implementation of a metalaxyl/mefenoxam sensitivity test. The test is complete, and was used in 2011 and 2012 to assess mefenoxam sensitivity.

Michael Mazourek – Responsible for the development of pepper varieties with tolerance to Phytophthora blight. Mazourek had also identified cucurbit germplasm to be tested for potential tolerance to the pathogen. New additional advanced breeding lines were developed during the winter of 2012 and were tested by Smart at the blight farm during the summer of 2012. These varieties had excellent tolerance to Phytophthora blight and will be tested in on-farm trials in the future.

Stephen Reiners – Responsible for identifying and testing cultural practices that have the potential to reduce Phytophthora blight. He has reported these findings at grower meetings, and had a graduate student working on this project complete his MS degree in 2012.

### **Goals and Outcomes Achieved**

Objective 1: Aggressively extend to growers the information that we have on how to prevent contamination of clean fields and how to manage fields contaminated with *P. capsici*.

1. The website is now operational, and will continue to be updated. The website has had 2,319 hits to date.
2. Grower twilight meetings, demonstrations, annual field day at the Phytophthora blight farm were conducted from 2010 - 2012. A total of 15 such meetings were held, these were specific to Phytophthora blight. Additional talks that covered many topics (including Phytophthora blight) were also given. Growers are very supportive of work on Phytophthora blight.
3. The assay for fungicide resistance developed by the Fry lab will be used on field samples in 2011, and 2012. In 2011, about 20 samples from the greater Albany area were tested for fungicide resistance, and all but 1 sample was found to be resistant to the most commonly used fungicide (mefenoxam). Additionally, 10 samples from the Eden Valley were tested and one was found to be resistant. This was the first report of fungicide resistance in the Western part of NY. In 2012, 27 isolates from the Albany area were tested and 25 of the 27 were found to be resistant to the fungicide.
4. Twenty two presentations (2010-2012) were given at annual winter meetings are listed in appendix A.

Objective 2: Identify breeding lines and continue development of plant varieties that have tolerance to the pathogen.

1. Newly developed pepper breeding lines were tested at the blight farm during the summers of 2010 - 2012.
2. Mazourek will continue to develop tolerant pepper varieties in his Phytophthora resistance breeding program. They look very promising in both winter greenhouse screening as well as summer field trials.
3. Dillard tested additional snap and dry bean varieties for tolerance in 2011. Results were consistent with those collected in 2010.
4. Reiners has tested potentially tolerant varieties for horticultural characteristics at multiple locations in 2011. These data have been presented at multiple meetings and are currently being written up for publication.

Objective 3: Demonstrate to growers cultural control strategies (mulches, cover crops) that would reduce disease severity.

1. Smart has completed a 2 year cover crop trial at the blight farm, and an on-farm trial that was just completed in the fall of 2012. An increase in soil organic matter seems to improve overall plant health. Results from these studies are promising, as there was some increase in plant height.
2. Reiners is reporting results from the living-mulch trials to growers, and analyzing the final data from this project. The living mulches appear to reduce splashing between rows, and decrease fruit blight.

We surveyed 25 growers (by visiting their farms in 2011 to determine if they were disease free and only 1 of the 25 had diseases spread to a new field. Additional, there were two growers identified that did not previously have the disease and had disease spread due to flooding caused by Hurricanes Lee and Irene. Of the 25 growers surveyed, 13 had mefenoxam resistant isolates on their farm. Of those 13, twelve had stopped using mefenoxam. Of the 25 growers, 100% had adopted a new practice.

**Table 1. Comparison of actual accomplishments with goals established for the reporting period.**

<b>Task/Project Activity</b>	<b>Personnel Responsible</b>	<b>Timeframe</b>	<b>Actual Accomplishments</b>
<b>Objective 1</b>			
Development of a comprehensive web site with downloadable fact sheets	Smart, Dillard	November 2009- January 2010	Growers were surveyed to identify needs (2009-2010). Website is up and running (Jan 2011); fact sheets complete and on web, updated frequently (Jan 2011-present).
Grower twilight meetings, demonstrations, field days at the Phytophthora blight farm	Dillard, Smart, Reiners, Fry, Mazourek	August, September 2010, 2011, 2012	Had 6 such interactions with growers in 2010, and an additional 5 in 2011, and 4 in 2012.
Develop and implement a quick assay for fungicide resistance	Fry	January 2010- September 2010	Assay development done, and was used on isolates collected in Albany and W. NY in 2011.
Presentations at annual winter meetings such as the Vegetable Expo in Syracuse	Smart, Dillard, Reiners, Fry, Mazourek	Winter 2010, 2011, 2012	Five presentations were given 2012, ten in 2011, and seven in 2010.
<b>Objective 2</b>			
Identify and evaluate breeding lines	Mazourek, Smart, Dillard	November 2009- October 2012	Growers have tested new pepper lines. Mazourek continues to improve these lines. We have evaluated both private and public breeding lines of pepper, snap bean, and some cucurbits.
<b>Objective 3</b>			
Evaluate and demonstrate utility of cultural practices including mulches, bed height, green manure, and cover crops	Reiners, Smart	Summer 2010, 2011, 2012	Smart and Reiners have completed these experiments, and performed an on-farm trial in 2012. Both have given talks about the value of cultural practices.

## Beneficiaries

This project has benefited all New York vegetable producers of susceptible crops. Phytophthora blight is particularly menacing for New York growers, because many of the vegetable crops grown in New York are susceptible to *P. capsici*, including tomato, pepper, eggplant, pumpkin, cucumber, winter squash, summer squash, melon and snap bean. Combined, these vegetables are produced by over 1,400 growers in NY and have a farm gate value of over \$200 million, rendering an important farm economy at risk. The research performed for this project has economic benefit to vegetable producers through reduced crop loss (due to earlier recognition of the disease, cultural practices and resistant varieties), reduced expenditures associated with fungicide applications for disease management (because we can now quickly identify resistant isolates), and sustained reputation among buyers for high quality disease free produce. New York is the fifth largest vegetable production state in the US, and provides fresh produce to large markets including New York City, Boston and Philadelphia.

Through our outreach programs, we estimate that we have reached over 60% of the pepper and cucurbit growers, and 40% of the snap bean growers. These growers are now informed on how to manage Phytophthora blight on their farms. Through personal interactions with growers, we estimate that over 80% of pepper growers that have had problems with Phytophthora blight are now using at least one commercially available resistant variety. Additionally, we have interacted with 100% of the vegetable Cornell Cooperative Extension educators and they know where to find information, and understand the best management practices for farms that have the Phytophthora blight pathogen, and for farms that do not yet have the pathogen.

## Lessons Learned

- Grower enthusiasm for the project is excellent. It is very easy to identify grower cooperators when working on Phytophthora blight, since so many farms are being devastated by this disease.
- Variety trials using commercially available pepper varieties and Mazoruek's breeding lines went exceptionally well. We were surprised by the enthusiasm with which private companies wanted to have their breeding lines tested as part of our program. They were happy to pay for the opportunity to have their lines tested. We will continue this work as it is extremely valuable for NY growers to have some knowledge of how varieties that will be released soon grow in New York.
- We were surprised at the diversity in tolerance to Phytophthora blight in snap bean. A commonly grown snap bean variety was very susceptible, which is critical for growers to know.

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## Additional Information

### Appendix A: Listing (by year) of presentations at grower field meetings and annual winter meetings.

#### Grower twilight meetings, demonstrations, and annual field days (2012)

- a. Twilight meeting in Eden Valley (Western NY) Eden Valley Twilight Meeting August 27, 2012, Eden Valley NY. *Diseases of the 2012 Growing Season*. 1 hour talk to 30 growers and educators.
- b. Meeting with several growers in the Albany area August 17, 2012. Had excellent discussions with growers that are now facing Phytophthora blight due to flooding in the fall of 2011.
- c. Vegetable Breeders field day, August 28, 2012. Mazourek and Smart discussed results from Phytophthora blight trials with breeders from around the country.
- d. Smart and Mazourek were involved in three 1 hour webinars covering Phytophthora blight (Sept 27, October 25, and November 15, 2012).

#### Presentations at annual winter grower meetings (2012)

- a. Capital District Winter Vegetable Meeting February 29, 2012, Albany NY. *Dealing with Tomato Diseases and Phytophthora Blight in Bell Pepper*. 30 minute talk to 100 growers and educators.
- b. Empire State Fruit and Vegetable Expo. January 25, 2012. *Update on Phytophthora capsici Resistant Pepper Breeding at Cornell*. Mazourek presented this 30 minute talk to 100 growers and educators.
- c. Empire State Fruit and Vegetable Expo. January 25, 2012. *Cover Crops Between Rows of Plastic Mulch May Reduce Phytophthora Splashing*. Reiners presented this 30 minute talk to 100 growers and educators.
- d. Empire State Fruit and Vegetable Expo. January 25, 2012. *Comparing Yield and Disease Incidence in Phytophthora-Tolerant Sweet Peppers*. One of Smart's graduate students presented this 30 minute talk to 100 growers and educators.
- e. Science Night, Geneva NY March 14, 2012. An event put on by the Geneva City School District. Over 50 different booths with a science theme. Smart and Reiners presented *Plants get sick to*, a K-12 outreach event focusing on plant disease and specifically Phytophthora blight, since it attacks pumpkins (which are very familiar to kids). We used an interactive display with *P. capsici* and a microscope connected to a monitor so kids could see the swimming spores of the microscopic plant pathogen. 450 people attended the event, which lasted for 2 hours.
- f. In addition to presentations, an alert article was sent out by Smart and her student Dunn, when fungicide resistance isolates were identified in Western NY. Dunn, A.R. and Smart, C.D. (2012) *Fungicide resistance found in Phytophthora blight isolates from Western New York*. Veg Edge newsletter April 2012.

#### Grower twilight meetings, demonstrations, and annual field days (2011)

- a. Reiners held a processing vegetable field day on August 18, 2011 in Geneva NY. He showcased snap bean varieties, and also had a demonstration of pepper varieties with tolerance to Phytophthora blight.
- b. Pepper varieties with tolerance to Phytophthora blight were also a highlight of an organic vegetable meeting conducted by Smart, Reiners and their labs on August 24, 2011.
- c. Smart, Mazourek and Reiners held meetings and examined field trials of Mazourek's peppers at two farms in the Eden Valley (on August 26, 2011).

- d. Smart also visited several farms and had meetings with growers in the Capital District on September 27, 2011. This region was hit hard by flooding caused by hurricanes Irene and Lee. Many vegetable growers had flood waters on their farms, and several farms now have Phytophthora blight because the flood water brought the pathogen to their farm. Smart also visited the farm where Mazourek's Phytophthora blight tolerant peppers were grown.
- e. The entire Phytophthora blight team (Smart, Dillard, Reiners, Mazourek and Fry) held a field day for breeders and other visitors on August 30, 2011.

#### **Presentations at annual winter grower meetings (2011)**

- a. Smart presented a seminar entitled *Using genomics to solve applied problems in plant pathology: Are we there yet?* Discussing the latest advances Phytophthora blight work in NY at NC State University on October 17, 2011.
- b. Capital District Fruit and Veg Program Winter Meeting – Albany NY Feb 15 2011. *Phytophthora capsici and other plant pathogens in surface irrigation water*. The Smart lab presented a 30 minute talk to 75 people.
- c. Cornell Vegetable Program Winter Meeting – Lockport NY. March 7, 2011. *Phytophthora blight and other diseases to prepare for in 2011*. Smart presented a 60 minute talk to 40 people.
- d. Science Night, Geneva NY March 2, 2011. An event put on by the Geneva City School District. Over 50 different booths with a science theme. Smart presented *Plants get sick to*, a K-12 outreach event focusing on plant disease and specifically Phytophthora blight, since it attacks pumpkin. Smart used an interactive display with *P. capsici* and a microscope connected to a monitor so kids could see the swimming spores of the microscopic plant pathogen. 450 people attended the event, which lasted for 2 hours.
- e. NYSAES Advisory Council Meeting, Geneva NY. February 4, 2011. *Solutions to Disease Challenges Facing Vegetable Growers in New York*. 20 minute talk to 40 people. Smart presented information on Phytophthora blight, and why it is such a major problem for NY vegetable growers.
- f. Mid-Atlantic Fruit and Vegetable Convention, Hershey PA February 1, 2011. *Management Strategies for Phytophthora Blight*. Smart presented a 45 minute talk to 100 growers and educators.
- g. Empire State Fruit and Vegetable Expo. January 27, 2011 Syracuse NY. *Phytophthora Blight: A New Disease of Snap Beans in NY*. Dillard and Smart gave a joint presentation (35 minutes) to 90 growers and educators.
- h. Empire State Fruit and Vegetable Expo. January 26, 2011 Syracuse NY. *Tomato Diseases: What do I Have?* Smart presented 35 minute talk to 135 growers and educators, including a comparison of Phytophthora blight symptoms to symptoms caused by other pathogens.
- i. Empire State Fruit and Vegetable Expo. January 26, 2011 Syracuse NY. Each of two graduate students from the Smart lab presented 30 minutes talks (to 135 growers) on different aspects of Phytophthora blight. The first (Amara Dunn) presented information on the population biology and distribution of the pathogen in New York. The second (Lisa Jones) presented information on her work detecting Phytophthora and other plant pathogens in surface irrigation water in NY.
- j. Mazourek presented a seminar to the Horticulture Department (Cornell, Ithaca NY) entitled *Major genes affecting vegetable quality traits via phenylpropanoid-derived metabolites* March 28, 2011.

### **Grower twilight meetings, demonstrations, and annual field days (2010)**

- a. Reiners held a processing vegetable field day on August 19, 2010 in Geneva New York. He showcased snap bean varieties, discussing which varieties were most susceptible to *Phytophthora* blight, and importantly, which were least likely to have *Phytophthora* blight attack the pods.
- b. Mazourek was involved with the Organic field day at the Freeville Organic Farm in Freeville NY (August 5, 2010). He demonstrated the use of immunostrips as an economical way for growers to detect and identify pathogens (including *Phytophthora capsici*) and how early detection can be used to restrict the introduction of the pathogen onto a farm. 25 people attended.
- c. The *Phytophthora* blight project team held a field day at the blight farm in Geneva NY on August 31, 2010. About 20 breeders and others visited the farm and saw the variety and cultural practice trials (both conventional and organic). Smart, Dillard and Mazourek gave talks about their work.
- d. The Dillard lab was involved with a soil health team twilight meeting at Lynn Fish's farm on August 18. Lynn's farm has had severe problems with *Phytophthora* blight since 2006.
- e. Mazourek took 45 Cornell students that plan on careers in agriculture on a trip to his breeding and germplasm fields (September 22 and 24). They toured the *Capsicum baccatum* (pepper) species collection that will be screened for resistance to *Phytophthora capsici*, and also toured his *Cucurbita pepo* (squash) collection of nearly 800 accessions that will be used as a source of seed that may have resistance to *Phytophthora capsici*.
- f. Mazourek also had *Phytophthora capsici* resistant bell peppers growing in a field in East Ithaca to perform field evaluation of pepper type and quality.

### **Presentations at annual winter grower meetings (2010)**

- a. Dillard gave a presentation with information on *Phytophthora* blight on Snap beans at the NY State Fruit and Vegetable Expo (Jan 26, 2010) to 120 snap bean growers.
- b. Smart gave a presentation including information on *Phytophthora* blight at the Ontario Fruit and Vegetable Convention (February 25, 2010) to 50 organic and conventional vegetable growers (some from Canada, some from Western NY)
- c. Smart gave seminars on the *Phytophthora* blight situation in New York at Ohio State University and Rutgers University in New Jersey (about 75 people at each of the two presentations).
- d. Both Smart and Mazourek gave seminars in department seminar series at Cornell (about 50 people at each of the two presentations). These talks (points c and d) are critical to increase interaction between researchers in many states and also within NY.
- e. Smart and Dillard held a two hour session for New York State Cooperative Extension Educators on *Phytophthora* blight. November 18, 2010.
- f. Mazourek gave a talk at the Cornell Seed Conference *Pepper, squash, cucumber, watermelon and snap pea breeding at the CUAES in Ithaca*. December 2, 2010.

## Project Title: Developing Strategy to Reduce Fire Blight Infection of Apple Rootstocks

### Project Summary

The death of young apple trees due to fire blight infection of their rootstocks, just as they are entering their productive bearing years, is a devastating loss to New York growers. The most popular rootstock, M.9, is extremely susceptible to fire blight infection. Since infection of the rootstock is usually fatal, measures must be taken to minimize infection. To design such preventive measures intelligently, a better knowledge of the factors favoring rootstock infection is urgently needed. From anecdotal evidence and preliminary research it is thought that the timing of infection of blossoms and shoots has a major influence on rootstock. Also borer damage to rootstocks is suspected to play a role in initiating rootstock infection. The water status of trees also appears to influence how vulnerable they are to rootstock infection.

The main issue is the widespread occurrence of infection of the rootstocks of young apple trees, and the lack of effective recommendations to control it. This infection afflicts the most popular rootstock M.9, and annually causes losses of thousands of valuable trees in New York. Although resistant rootstocks are being developed commercially, at present they are not yet widely available, and the problem on M.9 must be addressed now.

The specific objectives of the project were:

- a) Determine the role of early and late season scion infections on the development of rootstock infection.
- b) Determine the role of direct infection of rootstocks via borer injury
- c) Determine the effect of water status of trees on susceptibility to rootstock infection

Besides these factors, it is well known that root suckers of susceptible rootstocks can provide an avenue for entry fire blight into the rootstock. Control of suckers will be an integral part of recommendations for reducing rootstock blight.

### Project Approach

Task/Project Activity	Personnel Responsible	Timeframe
Experiment on influence of timing of scion infection on incidence of subsequent rootstock infection	Technician and summer student supervised by H. Aldwinckle	May-September 2010-2011
Experiment on influence of simulated borer damage on incidence of rootstock infection	Technician and summer student supervised by H. Aldwinckle	May-September 2010-2011
Experiment on influence of water status of trees on incidence of rootstock infection	Technician and summer student supervised by H. Aldwinckle	May-September 2010-2011
Analysis of results and preparation of reports	H. Aldwinckle	Oct-Dec 2010-2011
Writing of recommendations for reduction of incidence of rootstock infection	H. Aldwinckle	Nov-Dec 2011

## Goals and Outcomes Achieved

Experiments on influence of timing of scion infection on incidence of subsequent rootstock infection and on influence of simulated borer damage on incidence of rootstock infection were carried out three times, in 2010, 2011 and 2012. The proposed experiment on influence of water status of trees on incidence of rootstock infection proved impractical to carry out because springtime rains made it impossible to provide trees with a water deficit.

The experiments on influence of timing of scion infection on incidence of subsequent rootstock infection and on influence of simulated borer damage on incidence of rootstock infection gave generally similar results. Results from the timing experiment confirmed that the earlier inoculation of flowers in May with the fire blight bacterium resulted in more infection of rootstocks than inoculation of shoots approximately one month later. These results applied to trees grafted with Golden Delicious, as well as Gala.

Inoculation of simulated borer wounds on rootstock shanks, made with an electric drill, produced a high frequency of rootstock infection, whereas spraying of non-wounded shanks with inoculum produced little infection. Controls did not become infected. These results applied to trees grafted with Golden Delicious, as well as Gala.

Data from all 3 years' experiments will be analyzed. As an example of the results from the 3 years, the results from 2012 are provided in detail below.

Recommendations based on these results to reduce the incidence of rootstock infection will be prepared and presented to growers at field days and the Fruit Expo.

- IFTA Summer tour, Cornell Fruit Field Day, July 29, 2010 – Factors affecting fire blight infection of apple rootstocks. Herb Aldwinckle presented the preliminary results early in the life of the project to 400 participants from NY and across the country concurrent with the International Fruit Tree Association summer tour.
- 2011 EXPO, Preventing Fire Blight in New Plantings, Herb Aldwinckle & Deborah Breth – presented the management recommendations for preventing fire blight and tree losses in new orchards to 125 participants at the Jan. 27 Tree Fruit Session.

The final results will be published in the Fruit Quarterly and reported at the NY Expo for a grower audience. The impact of the recommendations will be assessed based on grower surveys of rootstock infection done early in the project compared with surveys done after the new recommendations are published.

## Surveys Conducted by Cornell Cooperative Extension Specialist (Debbie Breth)

- **Baseline survey by Extension (October 2009)**  
Extension ran fire blight model blossom blight prediction models to help growers plan timely protective sprays of antibiotics. They were introduced to the possibility of using cell phone text messages to receive special alerts. In 2009, growers needed to apply 3-4

streptomycin for blossom blight and several hail storms. Because growers followed recommendations for blossom blight control, they did not suffer severe losses to fire blight due to rootstock blight. Fourteen growers reported tree losses due to rootstock fire blight ranging from 10 – 100% tree loss in acreage ranging from 1 to 3 acres. Tree ages ranged from 1 to 5 years old. Growers tried to save trees if planted on B9, a less susceptible rootstock. Growers began to switch from M9 (a very susceptible rootstock) to B9 to prevent whole tree losses due to fire blight. But the tree structure left from cutting out severe fire blight results in a tree that is not very profitable.

- **Extension survey after 3 growing seasons (2012)**

After 3 growing seasons a few growers still reported tree losses due to rootstock blight, especially on Gingergold/M9 and Lady Apple/M9. One grower had 48% tree loss, and another had 53% each of 3 acre blocks. One of those growers had other difficulty in managing fire blight due to the development of resistance to streptomycin. No streptomycin resistance was detected on the second farm. These growers removed the remainder of the orchards because it was not economical to continue to maintain these orchards with so many missing trees.

### **Reduced losses of trees due to rootstock infection**

The claim can be made that there was a reduction in the number of farms that have lost trees due to rootstock infection because they have managed blossom blight more accurately, and they have adopted fire blight resistant rootstocks in their plantings. But this has not resolved tree losses completely because of the poor tree structure remaining after removing fire blight from the susceptible scion.

### **2012 Results**

Experiment 1. Influence of timing of scion infection on incidence of subsequent rootstock infection

A block of Royal Gala/M.9 trees was planted in 2005, with the objective of determining the period of greatest susceptibility to rootstock infection of young bearing trees suffering infection of the scion at bloom or later in the season. To determine the period of greatest vulnerability to development of rootstock infection, scions were inoculated with fire blight at two times during the growing season. In May the open flowers of selected trees were be sprayed with a suspension of *Erwinia amylovora* strain Ea4001a. Similar trees were inoculated by cutting the two terminal leaves of more or less vigorously growing shoots with the same strain in mid-June. Symptoms of rootstock blight were observed in the weeks following inoculation.

Experiment 2. Influence of simulated borer damage on incidence of rootstock infection

A block of Golden Delicious/M.9 trees was planted in 2005, with the objective of determining the role of borer damage to the rootstock shank on the incidence of rootstock infection by fire blight. Borer damage was mimicked by drilling holes of the same diameter as borer insect holes into the

rootstock, and then fire blight bacteria were introduced into the drill holes using a pipettor. Checks were drilled/non-inoculated, non-drilled inoculated, and non-drilled non-inoculated. Symptoms of rootstock blight were observed in the weeks following inoculation.

The layout of Experiments 1 and 2, and symptoms observed on individual trees are shown in Fig 1 below.

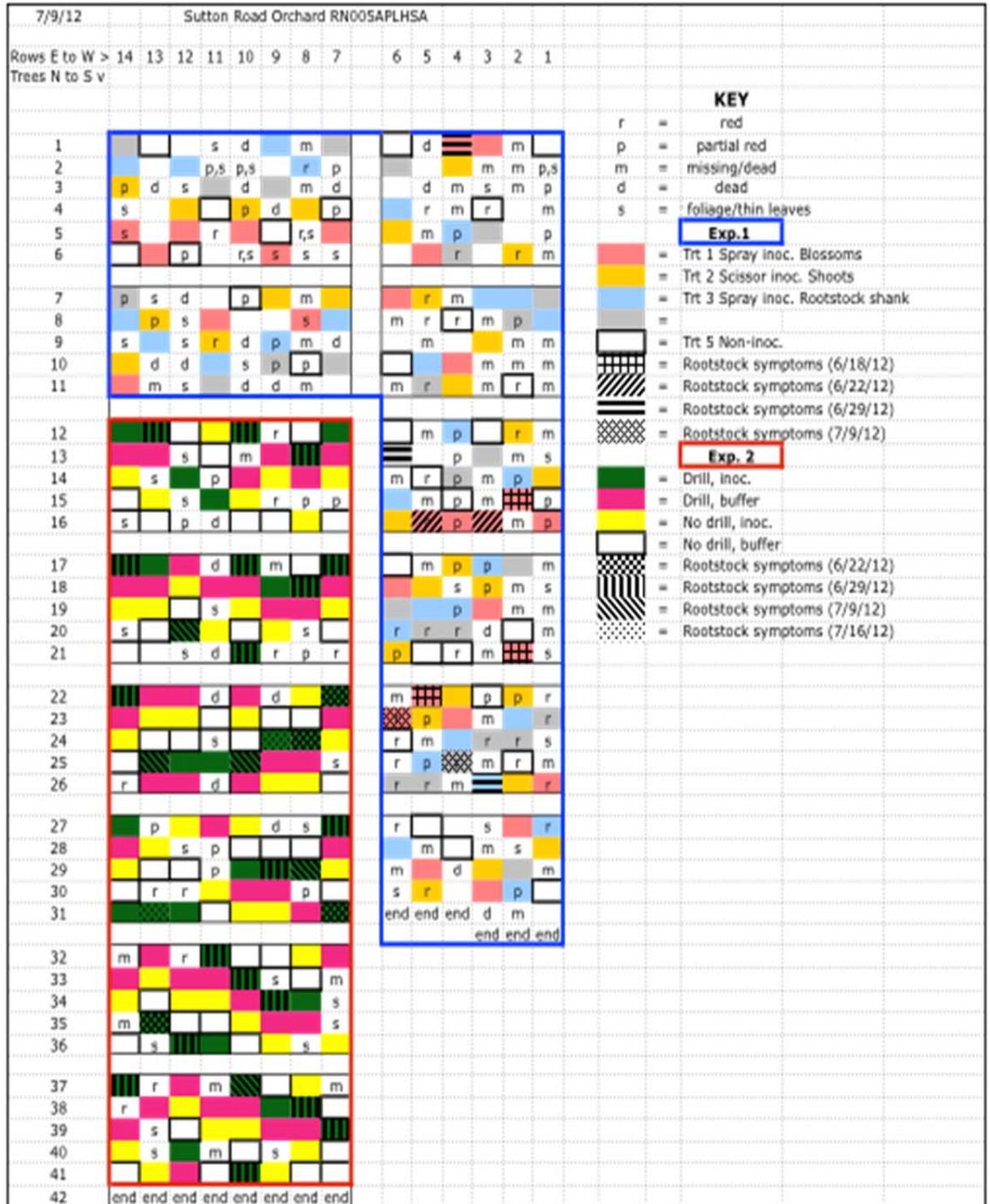
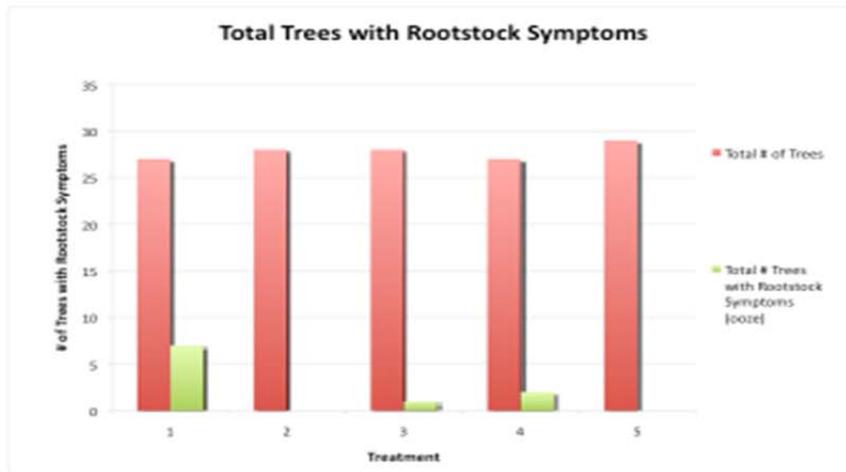
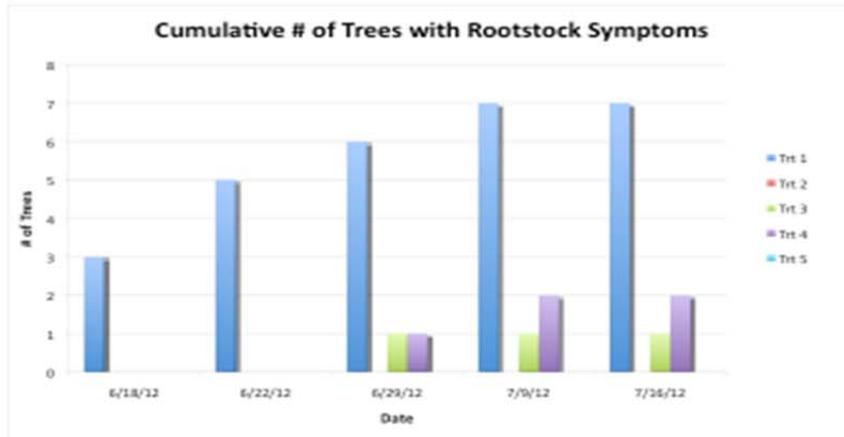


Fig. 1. Layout of 2012 Experiments 1 and 2, and symptoms observed.

**Experiment 1**

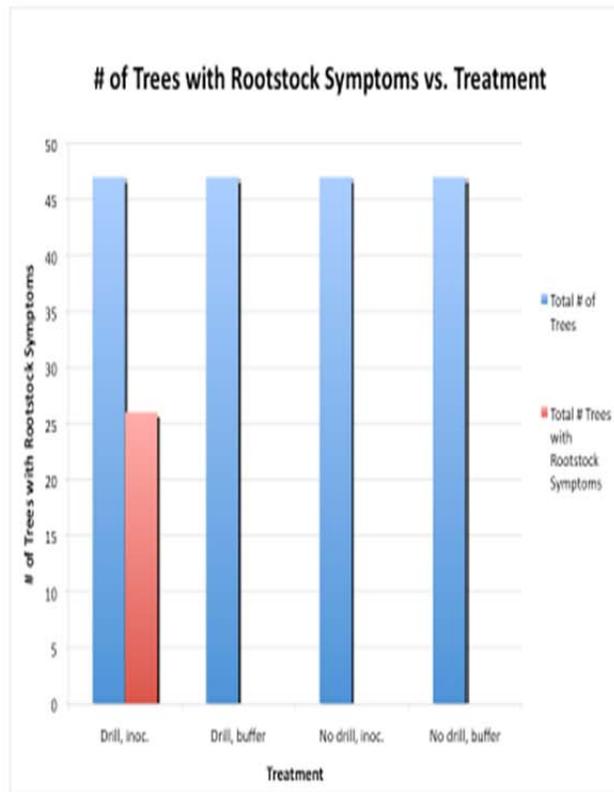
Treatment		Date	Total # of Trees	Total # Trees with Rootstock Symptoms (ooze)	Cumulative # Trees with Symptoms including Ooze				
					6/18/12	6/22/12	6/29/12	7/9/12	7/16/12
1	Spray inoc. Blossoms	5/7/12	27	7	3	5	6	7	7
2	Scissor inoc. Shoots	6/7/12	28	0	0	0	0	0	0
3	Spray inoc. Rootstock Shank	5/7/12	28	1	0	0	1	1	1
4	Spray inoc. Rootstock Shank	6/7/12	27	2	0	0	1	2	2
5	Non-inoculated		29	0	0	0	0	0	0



Results of Experiment 1, 2012.

**Experiment 2**

Treatment	Total # of Trees	Total # Trees with Rootstock Symptoms	Cumulative # Trees with Rootstock Symptoms			
			6/22/12	6/29/12	7/9/12	7/16/12
Drill, inoc.	47	26	4	19	24	26
Drill, buffer	47	0	0	0	0	0
No drill, inoc.	47	0	0	0	0	0
No drill, buffer	47	0	0	0	0	0



Results of Experiment 2, 2012.

## Beneficiaries

All New York growers planting new apple orchards will benefit from the results of the project. The recommendations coming out of the project should help reduce their tree losses due to fire blight infection of the rootstock. It is estimated that several hundred NY apple growers will eventually benefit from the project.

Loss of young bearing trees is especially costly to growers. They have already made the considerable investment in the nursery trees, trellis, land preparation, and maintenance. They lose not only the trees, but also the production for the next several years before replacement trees can be established. The loss per acre can amount to several thousand dollars. Better recommendations to reduce rootstock blight incidence would prevent a large proportion of these losses. The economic benefit to NY growers could be more than \$1 million in bad fire blight years.

## Lessons Learned

The weather before and after the infection of apple trees by fire blight has a great influence on whether rootstocks become infected by *Erwinia amylovora*. Therefore the experiments have to be repeated over two or more years in order to understand the effects of the timing of initial infection and the part of the tree in which it takes place. Also the amount of blossoms varies from year to year which has an effect on infection of the rootstock. Lastly the effect of soil water status on susceptibility of the rootstocks to infection proved impossible to study, because in all three years there were episodes of excess soil water before and during the bloom period.

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## Additional Information

Recommendations based on these results to reduce the incidence of rootstock infection will be prepared and presented to growers at field days and the Fruit Expo. The final results will be published in the Fruit Quarterly and reported at the NY Expo for a grower audience.

## Project Title: Improved Forecasting and Management of Strawberry Powdery Mildew

### Project Summary

Strawberry is New York's most valuable small fruit crop and powdery mildew, caused by the fungus *Podosphaera macularis*, is a worldwide threat to commercial strawberry production. Research on this disease has largely stagnated over the last 40 years, with little advancement in our knowledge of pathogen biology and ecology, perhaps because very effective fungicides have been available. Meanwhile, the pathogen has become resistant to nearly all available compounds, and few replacement materials are in the "research pipeline". The disease is especially destructive in high tunnel production systems, and is the primary factor limiting adoption of this otherwise highly-profitable technology. To better manage strawberry powdery mildew with a dwindling arsenal of fungicides will require a more complete understanding of the disease than we presently possess. Such fundamental questions as (i) how does the pathogen survive winter, and (ii) how and when does infection occur, remain largely unanswered. Our long-term goal is to reduce loss due to strawberry powdery mildew through the development of practical forecasting models based upon a comprehensive investigation of pathogen biology, ecology, and epidemiology.

### Project Approach

A collection of four clonal isolates of *Podosphaera aphanis* was heterothallic and was composed of two mutually exclusive mating types. Cleistothecial initials  $\approx 20$  to  $30 \mu\text{m}$  in diameter were observed within 7 to 14 days after pairing of compatible isolates and developed into morphologically mature ascocarps within 4 weeks after initiation on both potted plants maintained in isolation and in field plantings in New York State and southern Norway. Ascospores progressed through a lengthy maturation process over winter, during which (i) the conspicuous eiplasm of the ascus was absorbed; (ii) the osmotic potential of the ascospore cytoplasm increased, resulting in bursting of prematurely freed spores in water; and, finally, (iii) resulting in the development of physiologically mature, germinable, and infectious ascospores. Release of overwintered ascospores from field collections was coincident with renewed plant growth in spring. Overwintered cleistothecia readily dehisced when wetted and released ascospores onto glass slides, detached strawberry leaves, and leaves of potted plants. Plant material exposed to discharged ascospores developed macroscopically visible mildew colonies within 7 to 10 days while noninoculated controls remained mildew free. Scanning electron and light microscopy revealed that cleistothecia of *P. aphanis* were enmeshed within a dense mat of hyphae on the persistent leaves of fieldgrown strawberry plants and were highly resistant to removal by rain while these leaves remained alive. In contrast, morphologically mature cleistothecia on leaves of nine deciduous perennial plant species were readily detached by simulated rain and seemed adapted for passive dispersal by rain to other substrates. Contrary to many previous reports, cleistothecia appear to be a functional source of primary inoculum for strawberry powdery mildew. Furthermore, they differ substantially from cleistothecia of powdery mildews of many deciduous perennial plants in their propensity to remain attached to the persistent leaves of their host during the intercrop period.

The formation of cleistothecia by the strawberry powdery mildew pathogen (*Podosphaera aphanis*) is widespread, but often sporadic throughout the range of strawberry cultivation. In some production regions, notably in warmer climates, they are reportedly rare. We confirmed the presence of a bipolar heterothallic mating system in *P. aphanis*. We have also demonstrated that initiation is not only dependent upon the presence of both mating types, but that ascocarp initiation is largely suppressed at temperatures above  $13^{\circ}\text{C}$ . Nightly exposure to  $13^{\circ}\text{C}$  for 1 h was sufficient to stimulate ascocarp formation at an otherwise constant temperature of  $25^{\circ}\text{C}$ . Progressively more ascocarps were

initiated as the duration of the cold period was increased to 4 h per 24 h cycle. At lower temperatures, the shifts to production of cleistothecia resulted in a decline, but not total cessation of conidial production. Number of cleistothecia (14 days after inoculation) per cm<sup>2</sup> of leaf area was 2.2, 5.7, and 15.5-fold higher on pairs incubated at 13°C continuously than the same pairs incubated at 13°C in the diurnal cycle for 4, 1, and 0 h respectively. We developed mating types markers specific to *P. aphanis* and used these to confirm the presence of both mating types in populations that had not yet initiated cleistothecia. The geographic discontinuity of ascocarp production, and the sporadic and seemingly unpredictable appearance of ascocarps in *P. aphanis* is possibly due to the combined influence of heterothallism and suppression of ascocarp formation by high temperatures, and may confer some selective advantage in delaying production of an overwintering stage until an environmental cue (decreasing temperature) indicates impending winter.

Susceptibility of the leaves and fruit of four strawberry cultivars to powdery mildew (*Podosphaera aphanis*) declined exponentially with age. Receptacle tissue of berries inoculated at four phenological stages from bloom to ripe fruit became nearly immune to infection approximately 10 to 15 days after bloom, as fruit transitioned from the early green to the late green or early white stage of berry development, although the achenes remained susceptible for a longer period. Leaves also acquired ontogenic resistance early in their development, and were highly resistant shortly after they unfolded, and before the upper surface was fully exposed. No significant difference was found in the susceptibility of the adaxial vs abaxial surfaces. The predominance of powdery mildew colonies on the abaxial surfaces of leaf may reflect leaf folding during the most susceptible stages of development, and consequent escape from infection. The rapid acquisition of ontogenic resistance by leaves and fruits revealed a narrow window of susceptibility to which management programs might be advantageously adapted.

### ***Production and maintenance of clonal isolates and crossing of isolates.***

Strawberry leaves bearing young, sporulating colonies of *P. aphanis* were obtained from colonized strawberry leaves in plantings at Hamar, Ringsaker, Larvik, and Sola, Norway. After collection, leaves were placed in petri dishes to allow resporulation. To obtain clonal isolates, single conidial chains were transferred from the above leaves to mildew-free leaves in petri dishes as described by Pearson and Gadoury. Colonies that developed were subcultured in the same manner onto mildew-free leaves to ensure that clonal isolates were obtained. Once reduced to clonal lines, the isolates were maintained on surface-sterilized (5% sodium hypochlorite plus 0.05% Tween 20, followed by three sterile distilled water rinses) detached strawberry leaves on water agar. Four clonal lines were obtained. Isolates were transferred as necessary to new leaflets as conidial chains using a human hair affixed to a Pasteur pipette as described by Gadoury and Pearson. Isolates to be crossed were placed on opposite sides of the midvein of a leaflet and the leaflets were incubated at 13 to 15°C with 12 h of light. Establishment of each isolate transferred was confirmed 4 to 6 days after inoculation before results were taken on the outcome of each pairing 14 to 28 days after inoculation. The isolates were crossed in all possible combinations, with each pairing replicated three times on separate disease-free leaflets maintained on water agar, and the experiment was repeated twice. Pairings were scored as compatible if one or more replicates in both runs of the experiment produced mature cleistothecia with the full complement of ascospores.

### ***Scanning electron and light microscopy studies of initiation and development of ascocarps.***

Leaves bearing cleistothecia in various stages of development were collected from research plantings of cv. Earliglow at the New York State Agricultural Experiment Station (NYSAES) in Geneva, NY. Several disks  $\approx$ 2 mm in diameter bearing mildew colonies supporting developing ascocarps were cut from the leaves. Disks intended for scanning electron microscopy were immediately fixed in 4% glutaraldehyde buffered with 0.05 M KPO<sub>4</sub> at pH 6.5 for 2 h. The samples were rinsed six times in 0.05 M KPO<sub>4</sub> at 10-min intervals, rinsed twice in distilled water, and subsequently postfixed in OsO<sub>4</sub> for 1.5 to 2 h. The leaf pieces were then rinsed in distilled water six times at 10-min intervals, dehydrated in a seven-step acetone series, critical point dried, mounted, and sputter coated with gold before examination and photography. Disks intended for sectioning and viewing under light microscopy were immediately fixed in formalin/acetic acid/alcohol, dehydrated in a tertiary butyl alcohol series, infiltrated with paraffin, and serially sectioned at 10 to 15  $\mu$ m. The sections were adhered to glass microscope slides, dewaxed in HistoClear, and subsequently stained with 1% safranin O in 50% ethanol followed by counterstaining in 0.1% fast green in clove oil as described by Johansen. Developmental studies were repeated on cv. Elan.

### ***Maturation of ascocarps, ascospore discharge, ascospore germination, and infection of strawberry leaves.***

Detached mildewed leaves bearing cleistothecia were collected in October in years 1 to 3 of the study; encased in envelopes made from fiberglass window screen; and stored overwinter on the ground at NYSAES. In each seasonal repetition of the experiment, at monthly intervals from January to March and at 2-week intervals thereafter, 2-cm disks bearing at least 20 to 50 ascocarps were cut from the leaves, attached to a 9-cm disk of filter paper wetted with distilled water, and suspended above mildew-free strawberry seedlings (cv. Elan) or above detached leaves (cv. Earliglow) for 24 h at 20 to 22°C. During these experiments, the Elan seedlings were enclosed within clear polycarbonate drinking cups covered with a double layer of tissue to exclude conidia of *P. aphanis*. Detached leaves of Earliglow were enclosed in 9-cm polystyrene petri dishes. Treatments were replicated 10 times in year 1 and 5 times in year 2 and 3. All tissues were incubated at 20 to 22°C for 14 days after exposure to cleistothecia and were then examined at  $\times$ 20 magnification for the presence of mildew colonies. An equal number of disks were placed on wet filter paper in the lid of a petri dish and suspended above a glass microscope slide within the dish for 24 h at 20 to 22°C in each year of the study. Detached leaves of 'Korona' were also inoculated ( $\approx$ 2 weeks before bloom) as above using cleistothecia borne on leaves overwintered at Egge, Norway. The water potential of ascospore cytoplasm was determined as previously described by mounting 10 arbitrarily selected ascocarps on glass microscope slides in distilled water or 0.2, 0.4, 0.6, 0.8, and 1.0 M NaCl at monthly intervals from October to May of year 1 and from October until May at NYSAES in year 2. The water potentials generated by the NaCl solutions were 0, -670, -1,262, -1,838, -2,411, and -2,990 kPa. The ascocarps were crushed on the slides and observed under phase contrast illumination. The molarity at which incipient plasmolysis was observed in the freed ascospores was recorded. The percentage of cleistothecia that contained viable ascospores was assessed by mounting 20 to 25 arbitrarily selected ascocarps from each collection date on glass microscope slides (five ascocarps per slide) in a 0.5% (wt/vol) aqueous solution of fluorescein diacetate (FDA). The cleistothecia were fractured under a cover glass, allowed to absorb the stain for 5 min, and then observed under bright-field microscopy at  $\times$ 200 and immediately afterward under fluorescence microscopy (325- to 500-nm excitation filter and transmission filter  $>$ 530 nm) at  $\times$ 200 magnification. The percentage of cleistothecia containing viable (fluorescing) spores was estimated based upon comparison of the bright-field and fluorescence views. The total number of ascospores per ascus was also recorded for each ascocarp containing viable spores, and the presence or absence of fluorescent

epiplasm in the ascus was noted. Parallel assessments of ascocarp and ascospore development and viability using FDA were made as above at approximately monthly intervals, beginning in fall, and continuing until June of the following years, at Ås, Norway, utilizing cleistothecia borne on Korona leaves.

### ***Comparative studies of ascocarp retention and removal from leaves.***

Leaves bearing powdery mildew colonies with abundant cleistothecia were collected in September of year 1 in Geneva, NY from strawberry plants (*Fragaria* °—*ananassa* with *P. aphanis*) and nine woody deciduous perennial hosts: grapevine (*Vitis vinifera* with *Erysiphe necator*, syn. *Uncinula necator*), English hawthorne (*Crataegus laevigata* with *P. clandestina*), white ash (*Fraxinus americana* with *Phyllactinia guttata*), Norway maple (*Acer platanoides* with *E. circinata*, syn. *U. circinata*), American hazelnut (*Corylus americana* with *E. alni*, syn. *Microsphaera alni*), sycamore (*Platanus occidentalis* with *E. penicillata*, syn. *M. penicillata*), chestnut oak (*Quercus prinus* with *E. extensa*, syn. *M. extensa*), lilac (*Syringa vulgaris* with *E. syringaejaponica*, syn. *M. penicillata*), and sweet cherry (*Prunus avium* with *Podosphaera clandestina*). The experiment was repeated in Norway in October, when leaves were collected as above from strawberry, ash (*F. excelsior* with *Phyllactinia guttata*), oak (*Q. robur* with *E. alphitoides*), and lilac (*S. vulgaris* with *E. syringae-japonica*). The potential for cleistothecia to be removed from the above leaves and thereafter dispersed by rain events was assessed using a technique modified from Gadoury and Pearson. Three leaves bearing abundant cleistothecia were selected for each of the above host species, and a 1-cm disk was cut from each leaf. The disks were examined under a dissecting microscope at °—25 magnification, the number of cleistothecia on each disk was recorded, the disks were shaken in an Erlenmeyer flask in distilled water for 1 min, and the number of cleistothecia remaining on each disk was again determined at °—25 magnification. The percentage of cleistothecia removed from each disk by agitation in water was calculated and recorded.

### ***Collection and maintenance of additional P. aphanis isolates.***

Immature trifoliolate leaves (light green, leaflets slightly separated from each other, lamina unfolded approximately 5 degrees) of strawberry cv. Korona were used for maintenance of isolates and experimental work. To keep plants free of powdery mildew prior to inoculation, plants were treated daily with sulfur for 3 to 4 h at night from a sulfur burner (BBK Veksthus, Tønsberg, Norway). Absence of powdery mildew immediately prior to inoculation was confirmed by examining leaves under a dissection microscope.

Trifoliolate leaves were surface sterilized in sodium hypochlorite (0.5%) and rinsed in distilled water three times, then the water was allowed to dry from the leaf surface by placing the leaves in a blotting paper. After drying, the petiole was removed, the lamina were divided to single leaflets, unfolded gently, and placed into Petri dishes containing water agar (0.5% agar and amended with 0.03% benzimidazole), with the adaxial (upper) surface of the leaflets facing the agar surface. Leaflets were randomized among the Petri dishes to randomize effects of leaf age variation among treatments. Thus, Petri dishes contained three leaflets originating from three different leaves.

Monoconidial isolates of *P. aphanis* were prepared as follows. Leaves bearing mildew colonies were collected from commercial plantings at eight different locations in southern Norway in June and July. Conidia were transferred to detached leaflets of cv. Korona as described above, and incubated to stimulate conidiation. Once sporulation had occurred, single conidia were transferred to new leaflets from each source using an eyelash or thin copper wire as described by Gadoury and Pearson. Each selected conidium was placed on a leaflet in a separate Petri dish and incubated at 20°C, 80% RH for

seven days. Thereafter, a leaflet bearing a sporulating colony was selected for each collection site, and subculturing as above was repeated to insure that it was clonal. Monoconidial isolates were transferred to new leaves every 8 to 10 days by gently touching the leaflet bearing the monconidial isolate to the abaxial (lower) leaf surface of cv. Korona. Leaves were incubated at 20°C, with relative humidity 80%, and 16 h light period.

### ***Compatibility of isolates and production of cleistothecia among compatible pairs.***

Monoconidial isolates were paired in all 36 possible combinations to determine mating type. On each inoculated leaflet, isolates were paired on opposite sides of the midvein, approximately 5 mm apart, and were incubated at 13°C, 80% RH, 16h day light. Beginning 1 wk after inoculation, leaflets were observed for the formation of ascocarps. Presence or absence of cleistothecia was assessed using a dissecting microscope. For all pairings in which cleistothecia were found, the percentage of the leaflets bearing ascocarps was recorded. For 15 pairings forming cleistothecia, the number formed on each leaflet 3 wk after inoculation was assessed using a dissecting microscope. Cleistothecia density per leaflet area was estimated from field of view of the microscope covered by a certain magnification. There were three replicates for each pair of isolates (three leaflets per replicate), and the experiment was conducted twice.

### ***Effects of temperature on initiation of cleistothecia.***

Two isolate pairings (isolates 1 + 3 or isolates 1 + 5) that produced abundant cleistothecia in the above experiment were selected to determine the effects of temperature on initiation of ascocarps. Detached leaflets on water agar in Petri dishes were inoculated with paired isolates as above, and then incubated at 13, 15, 20 and 25°C, 80% RH, 16 h light period. The different developmental stages of the cleistothecia (white, brown and black) were distinguished and counted under a dissecting microscope as described above. There were three replication for each isolate pairing and treatment (three leaflets per replicate), and the experiment was conducted twice.

The experiment was repeated on potted strawberry plants, with the following modifications. Forty-eight plants of the cv. Korona, which had become naturally infected by *P. aphanis* were incubated at 9, 12, 15 and 18°C, 80% RH, 12 h day/night on 10 August 2009 in a phytotron. On 15 September, 30 mildewed leaves were removed from plants at each temperature, and presence of cleistothecia was determined under a dissecting microscope. Each treatment had three replication (four plants per replicate), and the experiment was conducted once.

### ***Effect of duration of low temperature exposure in the diurnal cycle on cleistothecia formation.***

The following experiments were conducted at Cornell University's Agricultural Experiment Station in Geneva, New York from August to October 2010. Two sexually compatible monoconidial isolates were established as described above from local sources in New York, and were maintained in isolation using detached leaves of the cv. Earliglow and Elan on water agar in Petri dishes. The isolates were paired as before on opposite side of the midvein of detached cv. Earliglow leaflets on water agar, and were subjected to one of the following treatments: (i) constant day and night temperature at 25°C; (ii) constant day and night temperature at 13°C; (iii) alternate high and low temperatures of 25°C for 23 h and 13 °C for 1 h during the night; and (iv) alternate high and low temperatures of 25°C for 20 h and 13°C for 4 h during the night. The number of cleistothecia produced per leaflet was assessed as before at 3 weeks after inoculation. The treatments were replicated five times (three leaflets per replicate), and the experiment was conducted twice.

### ***Cleistothecia formation versus conidiation.***

The above two compatible monoconidial isolates were grown separately and as paired isolates to determine the impact of ascocarp initiation and development upon asexual reproduction and productivity of conidiation. Detached leaflets of cv. Earliglow placed on water agar were inoculated with either monoconidial isolate, or with both isolates, on opposite sides of the leaflet midvein as above. Leaflets were incubated for 24 h at 18°C to allow uniform germination and colonization, and then incubated at 13°C to promote ascocarp initiation. When ascocarp initials observed on leaflets inoculated with both isolates, leaflets inoculated with each of the single isolate and their pair were moved to 18°C to promote further conidiation. Once cleistothecial initials were observed on leaflets inoculated with the paired isolates, conidia were removed by washing the leaflets in 20 ml sterile water plus 0.05% Tween 20<sup>®</sup>, collecting the rinse water, and counting the number of conidia contained in a 5 µl sample on a glass microscope slide at ×100 magnification, and the total number of conidia produced per leaflet was calculated. Surface water was allowed to evaporate from the leaflets, which were then returned to their respective Petri dishes and further incubated at 18°C to promote re-sporulation. Two days later, the number of conidiophores at the densest area of colonization bearing one or more conidia per 35× field of view was recorded under a dissecting microscope. Each leaflet was then washed again as above in 20 ml distilled water and plus 0.05% Tween 20<sup>®</sup>, and the number of conidia produced per leaflet was again determined as described above. Surface water was again allowed to evaporate, the leaflets were incubated for another four days at 18°C, and the forgoing assessments of conidiophores and conidiation were repeated. Treatments were replicated five times.

### ***Determination of mating type phenotype and mating type genes.***

Seven monoconidial isolates obtained from local sources in New York, designated isolates A, B, C, D, E, F, and G were paired with an eighth isolate, designated isolate H to determine their sexual compatibility. Six of isolates (four of one mating type and two of the other) were selected for genotyping. Genomic DNA was extracted from these isolates as described for *E. necator*, with the following modifications. Briefly, isolates were propagated on detached leaves of cv. Earliglow on water agar for 8 to 10 days at 18°C, and then conidia, conidiophores and mycelium were collected by touching 1 to 2 cm pieces of scotch tape to the colony multiple times, until the tape was coated with a layer of fungal biomass. The tape was placed in 1.5 ml microcentrifuge tube, stored at -20°C overnight, and then 150 µl of 5% chelex 100 and 10 mg of glass beads were added to each microcentrifuge tube and each tube was vortexed for 20 s. The tubes were then opened, and the tape was submerged beneath the surface of the chelex 100 solution with a sterile wooden stick, vortexed for an additional 20 s, centrifuged briefly, incubated at 95°C for 15 min in a heat block, vortexed for 10 s, and incubated (at 95°C) for another 15 min. The tube was allowed to cool for 30 min at room temperature, and the supernatant was removed and used as the DNA template for PCR.

To amplify the alpha box region, we designed primers based on the *Podosphaera xanthii* sequence. The primers were Palpha-10f (AATTCATGGATTGGCTTCAGA) forward primer and Palpha-156r (GGATCACGGTTCCACAATTT) reverse primer. The HMG domain was amplified by degenerate primers pmHMGdF (CCTCCSAAYTCTTGGATTTTATAKCG) and pmHMGdR (CGTTTAACTTCRGAAGRYTCCGTGG).

Polymerase Chain Reaction (PCR) and thermal cycler conditions were as previously described. PCR was carried out in a 25 µl volume containing: 2.5 µl of 10× PCR buffer, 2.5 µl dNTPs, 1.25 µl of 10 µM forward and 1.25 µl of 10 µM reverse primers, 0.75 U ExTaq (Takara Bio, Inc., Otsu, Japan), 1 µl DNA template, and 15.75 µl double distilled water. Thermal cycler conditions were: initial denaturation at

95°C for 2 min, followed by 3 cycles of 95°C for 1 min, 42°C for 1 min, 72°C for 30 s, followed by 35 cycles of 95°C for 1 min, 52°C for 1 min, 72°C for 30 s, followed by a final extension at 72°C for 5 min. The PCR products were separated by electrophoresis in a 1% agarose gel. The DNA band of the expected length was excised and directly sequenced at the Cornell University Life Sciences Core Laboratories Center.

#### ***Development of multiplex PCR-based mating type markers.***

Multiplex PCR was carried out in a 10 µl volume containing: 1 µl of 10× PCR buffer, 1 µl dNTPs, 0.5 µl of 10 µM forward and 0.5 µl of 10 µM reverse HMG primers, 0.5 µl of 10 µM forward and 0.5 µl of 10 µM reverse alpha primers, 0.07 µl ExTaq (Takara Bio, Inc., Otsu, Japan), 1 µl DNA template, and 4.93 µl double distilled water. Thermal cycler conditions were: initial denaturation at 95°C for 2 min, followed by 95°C for 30 s, 55°C for 30 s, 72°C for 30 s, followed by 35 cycles of 95°C for 30 s, 55°C for 30 s, 72°C for 30 s followed by a final extension at 72°C for 5 min. The PCR products were separated by electrophoresis in a 2% agarose gel.

All data were transformed using  $\log(x+1)$  when there was a deviation from the assumption of normal distribution of variances. Significant differences among treatments were determined using analysis of variance, followed by Tukey's test when treatments were observed to have significant effect ( $p \leq 0.05$ ).

#### ***Ontogenic resistance on strawberry fruit.***

Short-day (June-bearing) strawberry cvs. Frida, Inga and Korona were propagated from runners, and the day-neutral cv. Elan was grown from seed. Rooted plug plants were planted into individual pots with a commercial soil (P-jord, L.O.G As, Norway) mixed with Perlite (4:1 v/v) and were grown in a greenhouse at 18 °C, with a 16 h daylength. Natural daylight was supplemented as necessary with high-pressure sodium (HPS) lighting delivering 150 micro mol of daylight-balanced light. Frida, Inga, and Korona plants were sprayed at planting, and Elan plants at emergence of the first true leaf, with penconazole (Topas 100 EC, Syngenta Crop Protection) at a rate of 0.25 ml per liter. Plants were thereafter exposed to vaporized sulfur for 3 to 4 h every evening until flower initiation, whereupon sulfur use was discontinued. The plants were hand-pollinated using a paintbrush to insure uniform fertilization and fruit initiation. Approximately 4 weeks elapsed between the penconazole treatments and the earliest inoculations.

Inoculum production was as previously described. Briefly, emergent mildew-free Korona leaves were collected and soaked in 0.5% sodium hypochlorite for 5 min, rinsed three times in distilled water for 2 min, and then air dried for 1-2 min under a laminar flow hood. The petioles were removed from leaves and they were placed within 9 cm petri dishes containing 0.5% water agar amended with 0.03% benzimidazole. The leaves were then inoculated by touching them lightly with a leaf bearing a sporulating mildew colony, and were then incubated in a growth chamber (20°C, 16L:8D h photoperiod, 80% RH) for eight to ten days until abundant sporulation occurred.

Fruit of all cultivars were inoculated at the following developmental stages: flowering, green fruit, white fruit, and pink fruit. Flowers were tagged and labeled with the date on which they first opened to allow the age of later-inoculated organs to be expressed both as the forgoing developmental stages and days after bloom. For each developmental stage to be inoculated, four plants of each cultivar, each bearing at least five tagged flowers or fruits of a specific developmental stage, were randomly selected. Thus, a replicate consisted of at least five inoculated flowers or fruits of the same age on a single plant of each cultivar. Treatments were replicated four times in a completely

randomized design. Flowers and fruit on uninoculated plants served as controls. The entire experiment was conducted twice on each of the four cultivars.

Berries and leaves of plants were examined for presence of powdery mildew before inoculation. Flowers or fruit were inoculated by transferring conidia from infected leaflets using a fine artist's paintbrush. For inoculation of flowers, the conidia were applied to the receptacle tissue only, not the corolla. The density of conidia applied to inoculated tissue was estimated by transferring conidia using the same methods to a glass microscope slide. The slide was examined under bright field microscopy, the conidia were counted, and their density per cm<sup>2</sup> was calculated.

Inoculated plants were incubated in a greenhouse at 18°C and 80% RH, under a 16 h day with HPS lights to deliver a minimum of 150 micro mol of daylight-balanced light. The incidence (percentage of fruits diseased) and severity (percentage of fruit surface colonized by *P. aphanis*) were recorded at harvest. Severity was assessed using a dissecting microscope. For all four cultivars, disease incidence and severity was assessed on a total of 868 fruits.

### ***Ontogenic resistance on strawberry leaves, effects of leaf folding, and differential susceptibility of the abaxial and adaxial leaf surfaces.***

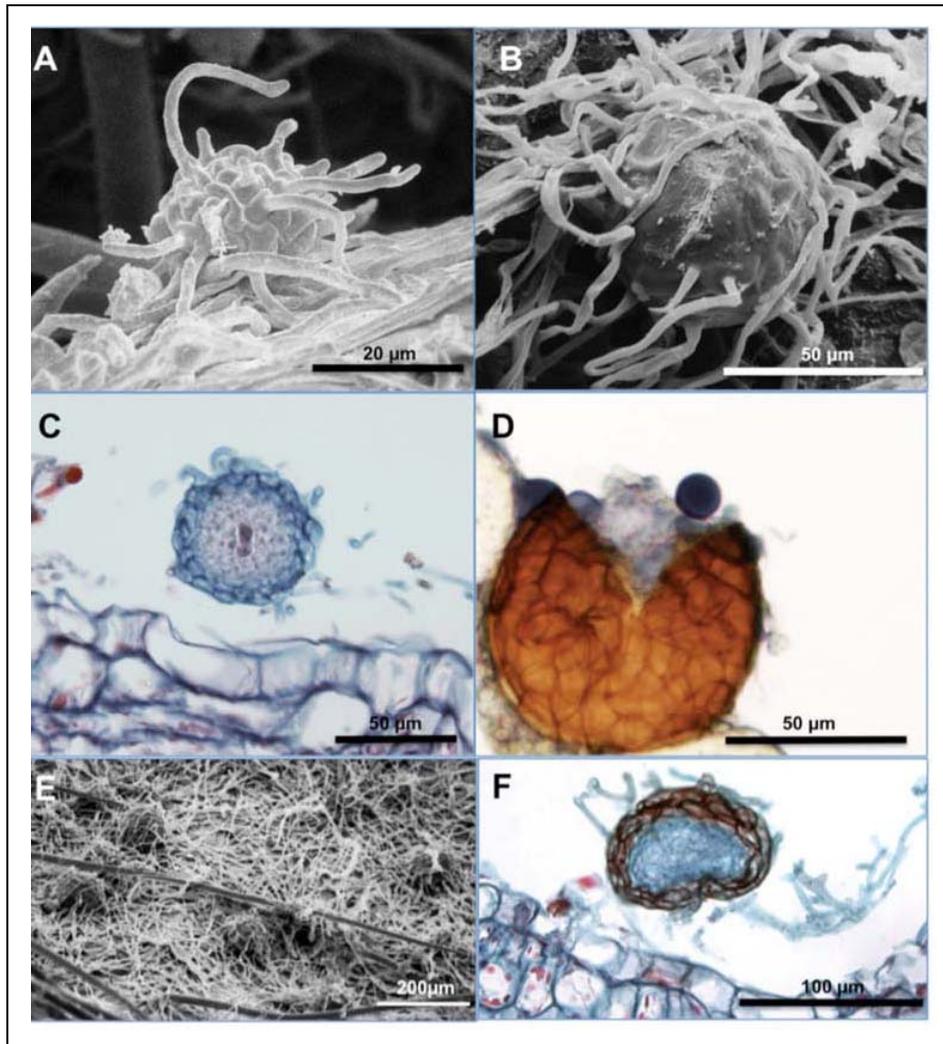
Development of ontogenic resistance was assessed on strawberry leaves of the short day cultivar Earliglow and the day-neutral F<sub>1</sub> hybrid cultivar Elan at New York State Agricultural Experimental Station (NYSAES), Geneva, NY, USA. Earliglow plants were propagated from dormant rooted crowns, while Elan plants were raised from seed as previously described. Mildew-free potted plants were inoculated using 7-day old cultures of *P. aphanis*. Leaves were inoculated at seven developmental stages ranging from the youngest emergent leaf to fully expanded leaves as depicted in Fig. 2, and are further described as: (i) stage 1 - leaves light green, leaflets not separated, leaf lamina highly folded, leaf vertical, blades not reflexed from petiole; (ii) stage 2 - leaves light green, leaflets partially separated, lamina unfolded approximately 5 degrees, blades not reflexed from petiole; (iii) stage 3 - leaves light green, most leaflets separated, lamina unfolded 15 to 30 degrees, blades not reflexed from petiole; (iv) stage 4 - leaves light green, leaflets separated, lamina unfolded 30 to 60 degrees, blades slightly reflexed from petiole; (v) stage 5 - leaves light green, completely separated, lamina unfolded more than 60 degrees, blades reflexed up to 45 degrees from petiole; (vi) stage 6 - similar to stage 5, but leaf blades reflexed 90 degrees from petiole; and (vii) stage 7 - similar to stage 6 but leaves dark green.

Leaves of the various stages were tagged (one stage per plant). Plants to be inoculated were placed within a laminar flow hood. Leaflets were inoculated by transferring chains of conidia from newly-sporulating colonies on detached leaves maintained in Petri dishes. The transfer was accomplished using a fine artist's camelhair paintbrush trimmed to retain approximately 5 hairs. The tip of the brush was lightly touched to the mildew colony, and then gently brushed across either the adaxial or abaxial leaflet surface. To access the adaxial surface of the highly folded leaflets in stages 1, 2, and 3, the leaflet surfaces were separated using fine-point forceps and the artist's brush was inserted, and lightly touched to the separated surfaces. Three leaflets of four plants were inoculated for each phenological stage for each of the two cultivars. The plants were then transferred to growth chambers maintained at 20 °C and 70 to 80% RH for 10 days before they were examined for signs of colonization and sporulation. Sporulation (conidia per mm<sup>2</sup> of colonized tissue) was assessed by pressing a 22 mm square cover glass to the sporulating surface of the colony, counting the number of conidia in three

microscopic fields of the cover glass at 100 to 800x using bright field microscopy, and correcting for the area examined. Non-inoculated plants served as experimental controls. The experiment was repeated a total of three times on cv. Earliglow and three times on cv. Elan.

Development of ontogenic resistance was similarly assessed at the Norwegian University of Life Sciences (UMB) in Ås, Norway on cvs. Frida, Inga, Korona, and Senga Sengana with the following modifications: (i) all the old leaves were trimmed and the plants were kept in a clean room until the plant has five or more leaves. Five leaf stages were tagged on the same plant corresponding to stages 2, 3, 5, 6 and 7, where a plant did not contain all the five stages, the required leaf stages were tagged on other plants; (ii) there were four replication, and a replicate contains five plants (fifteen leaflets of each phenological stage) for all cultivars with the exception of cv. Inga in experiment 2 where four plants (12 leaflets of each phenological stage) were used per replication; (iii) only the abaxial surfaces of the leaflets were inoculated; (iv) For all four cultivars, disease incidence and severity was assessed (on a total of 2340 leaflets, experiment 1 and 2 combined) 21 days after inoculation under a dissecting microscope; (v) sporulation was assessed as the percentage of the colonized area bearing conidiophores; (vi) the experiment was conducted in a greenhouse maintained at 18°C, 80% RH and 16 h light period with a minimum of 150 micro mol of daylight-balanced light supplied by HPS lamps as necessary; and (vii) the experiment was conducted twice on each of the four cultivars.

For each cultivar at both NYSAES and UMB, the number of days required to advance through the leaf developmental stages was recorded for ten leaves. Both severity and incidence data were  $\log_{10}(x+1)$  transformed to fulfill the assumptions of equal variance. Following one-way analysis of variance procedure, means were compared using Tukey's test with  $P = 0.05$  (Minitab version 14.0, Minitab Inc. State College, PA USA), or were described by linear regression of the transformed values. Seven potted Earliglow plants, each bearing two previously tagged trifoliate leaves in one of the above stages of development were placed in a wind tunnel approximately 3 m downwind of a fan generating a wind speed within the tunnel of approximately 8 km/h. Three heavily mildewed Earliglow plants were placed immediately in front of the fan for 5 min as a source of airborne inoculum for the downwind plants. Three 24 X 50 mm microscope coverglasses were placed next to each set of downwind plants to determine the intensity of inoculation to which leaves were exposed. These coverglasses were placed in Petri dishes containing moist filter paper and were incubated at 22°C for 24 hrs before they were examined under brightfield microscopy at 100X, and the number of germinated and ungerminated conidia per coverglass was recorded. The first downwind set of plants was then removed and replaced by a second set, likewise exposed for 5 minutes and removed, and then a third set of plants was placed in the tunnel for 5 minutes, and were then removed. Thus, treatments (leaf developmental stages) were replicated upon three plants, each bearing two trifoliate leaves at one of the developmental stages shown in Fig. 2. Inoculated plants were placed in a plant growth chamber at 20°C for 7 days with a 16 h day length. Seven days after inoculation, the severity of powdery mildew was recorded on the abaxial and adaxial surface of five trifoliate leaves of each developmental stage. The experiment was conducted twice as above, and then repeated twice more with the following modifications: (i) inoculated plants were of the cultivar Elan, and (ii) inoculated plants were incubated for 10 days before severity of infection was assessed.



*Significant results*

**Fig. 1.** Stages in the development of cleistothecia of *Podosphaera aphanis*. **A**, Ascocarp initial with early hyphal outgrowths from ascocarp wall and **B**, ascocarp at "yellow sphere" stage, ≈10 days after initiation. Hyphal outgrowths have now become intertwined in the pannose mycelium of the mildew colony. **C**, Cross section of ascocarp at ≈14 days after initiation showing uninucleate ascus mother cell and binucleate ascus initial; **D**, crush mount of 4-week-old ascocarp mounted in Sudan Black B showing dark staining of lipid droplets; **E**, mature cleistothecia in pannose mycelium on persistent green leaf collected in September 2008; and **F**, mature ascocarp in cross section showing basal concavity and persistent pannose mycelium on leaf collected in Autumn.

It's easy enough to find an assumption stated as a fact, in many sources, that the pathogen survives winter on strawberry plants as hyphae. Some sources state that the surviving hyphae are deep within the crown of the plant. Other sources state that hyphae survive on senescent green leaves that persist through winter. The trouble is that when you try to find conclusive experimental evidence for this in the literature, it's not there. So, we ran a number of experiments where we stripped dormant crowns of all of their leaves and then forced individual plants to regrow in isolation chambers. When we removed the senescent leaves, the plants remained mildew free. When we did not remove those senescent, but persistent leaves, a small percentage of the plants developed mildew on the new leaves as they emerged. So, we can't prove that the fungus never survives in the crown, only that we cannot detect it. However, these senescent, persistent leaves appear to be quite suitable for carrying the pathogen through the period between crops, or through winter. In cold-climate strawberry plantings, these leaves would be well-protected under layers of mulch or fleece, and possibly snow.

**Vegetative overwintering of Pathogen?**

- Survival of hyphae in the crown of strawberry plants?
- Survival on senescent/persistent leaves of strawberry plants?
- **Plants stripped of persistent leaves did not develop disease.**
- **About 3 to 5% of plants not stripped developed powdery mildew.**



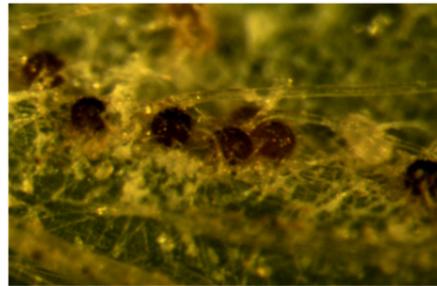
**Before dormancy**      **Stripped of persistent leaves**      **Regrowth in isolation**

Heterothallism might explain some of the discontinuity in the distribution of cleistothecia, but it turns out there's another factor involved. Our research revealed that temperatures above 13C will strongly suppress ascocarp initiation. After all, from an evolutionary standpoint, why form an overwintering stage before there is any evidence of the approach of winter. So, ascocarp formation would be suppressed for much of the year in the major US production areas like California and Florida. Add to this the fact that many of the plants actually grown in the southern US come from nurseries near the Canadian border, and we have production system that is purpose-built to produce variation and discontinuity in the appearance of cleistothecia.

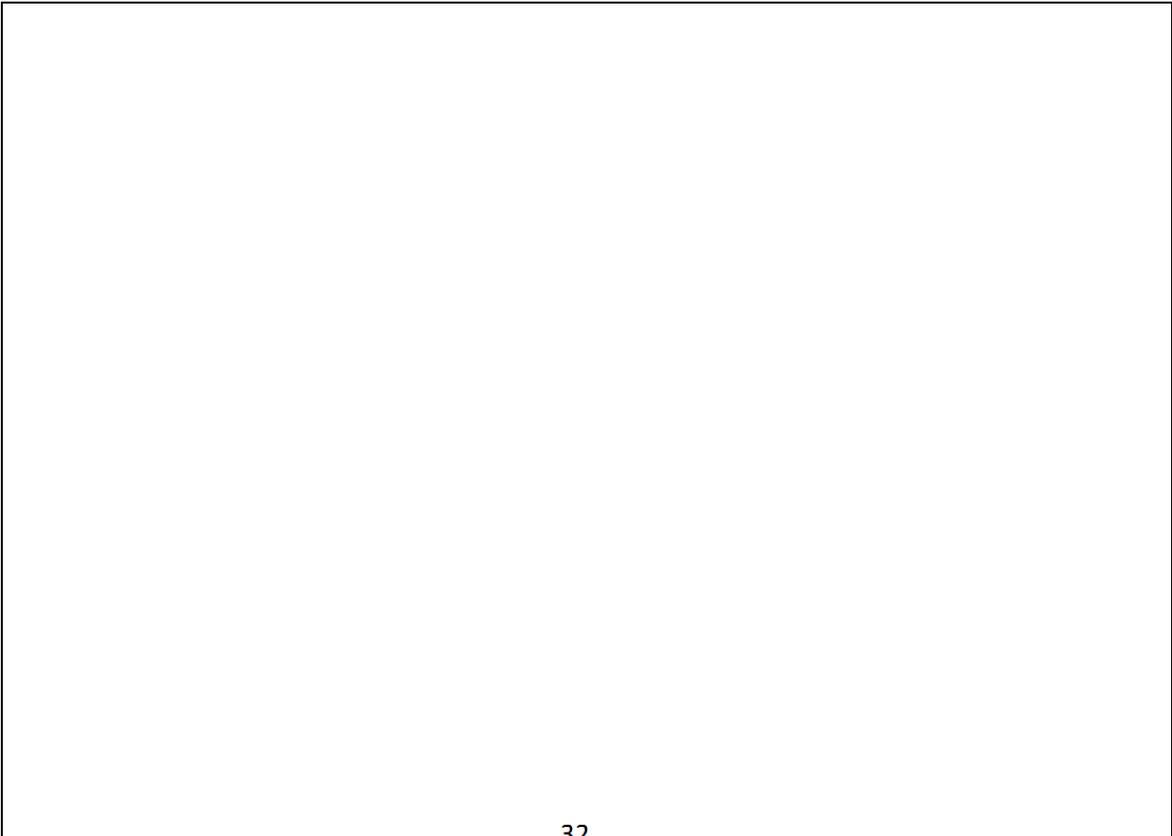
## ***Discontinuity in distribution of cleistothecia?***

**Cleistothecia are initiated when both mating types are present AND temperatures fall below 13 C (55F).**

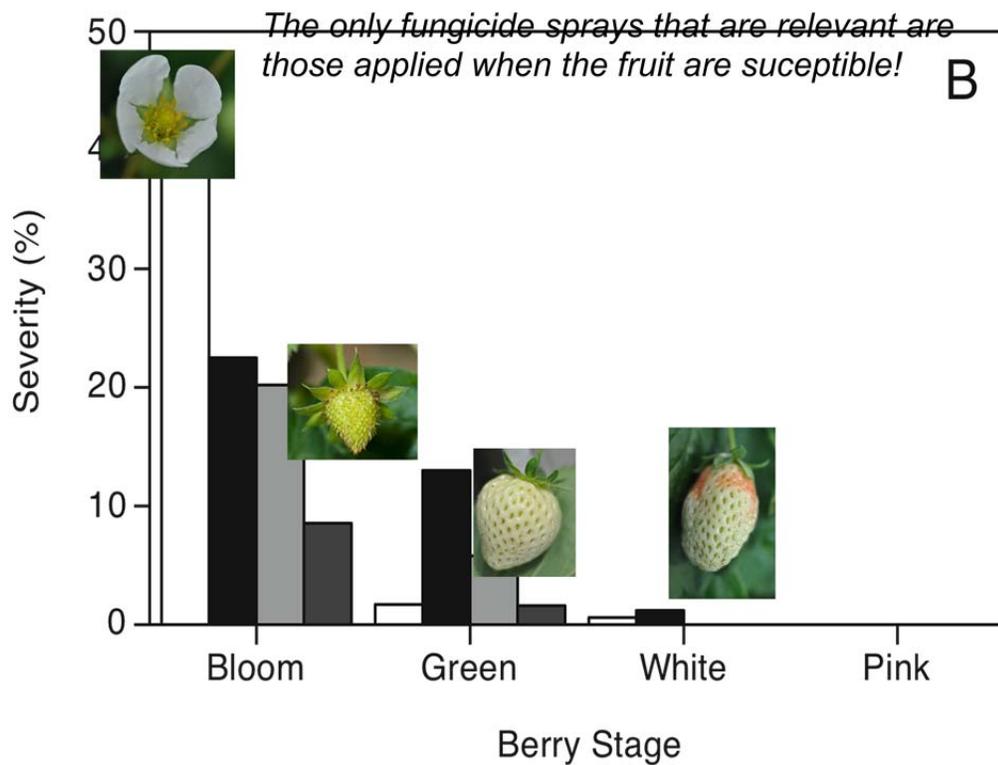
Why worry about winter when it's warm?



One of the first experiments we conducted was to examine the relative susceptibility of the upper and lower leaf surfaces across the various stages of leaf development. This plate from one of our papers shows the seven leaf stages that we used in the inoculation studies. And it turns out that it's really not all that easy to inoculate the upper surface of young strawberry leaves. They are highly folded, and you have to pry the surfaces apart with forceps to insert the inoculum. And the results from those inoculations showed that there was no significant difference between the upper and lower surfaces in their susceptibility. However, there was a very rapid decline in susceptibility of both surfaces as the leaves aged, and this was coincident with unfolding and leaf expansion. In fact, by the time the leaves are completely unfolded at stage 4, they are nearly immune to infection. We conducted parallel studies on the development of ontogenic resistance in berries. And again, when we looked at severity of berry infection across several varieties, we found a similar narrow window of susceptibility in the fruit. Again, this runs contrary to much of what's in the literature regarding susceptibility of fruit at different stages of development. Powdery mildew has always been mistakenly treated as a late-season disease. Now, while we might be accustomed to seeing the symptoms of powdery mildew on older fruit, those infections can only be initiated at bloom or the green fruit stage, and that's the only time they can be prevented. So, this has immediate application to management programs, because not spraying berries when they are susceptible, allowing them to become diseased, and then spraying them after they've become resistant to further infection, is wasting time and money.



## Berries also have a narrow window of susceptibility



The net impact of this has been a shift in focus from late-season suppression of visible disease, to a much more intensive and focused effort aimed at early season prevention. We're now better able to align management practices with aspects of host and pathogen development to maximize their impact on preventing epidemics. My seminar title had to do with recent advances in pathogen ecology and epidemiology. Ultimately we're seeking discoveries that will improve management programs. So, the research is directed towards gaps in our knowledge that prevent those improvements. In the past, strawberry powdery mildew has been treated as a late-season disease, but what we've found is that the stage is really set for an epidemic quite early in the growing season. We've more precisely identified the tissues that are most at risk, and exactly when they are at the greatest risk. And finally, while we've had a lot of fun identifying cleistothecia as a previously ignored source of infection, if we can better align our management practices with host and pathogen development, we can greatly reduce the likelihood that cleistothecia will ever have a chance to form.

## Goals and Outcomes Achieved

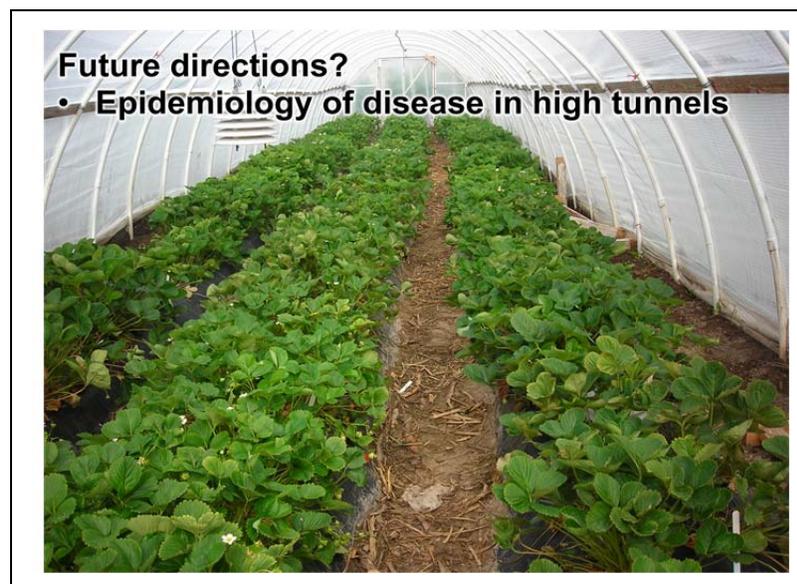
### *Impact on today's management programs*

- Change of focus to intensive early season prevention
- Alignment of management with host and pathogen development
- Improved control makes formation of cleistothecia unlikely

The net impact of our work has been a shift in focus from late-season suppression of visible disease, to a much more intensive and focused effort aimed at early season prevention. We're now better able to align management practices with aspects of host and pathogen development to maximize their impact on preventing epidemics. Ultimately we were seeking discoveries that will improve management programs. So, the research is directed towards gaps in our knowledge that prevent those improvements. In the past, strawberry powdery mildew has been treated as a late-season disease, but what we've found is that the stage is really set for an epidemic quite early in the growing season. We've more precisely identified the tissues that are most at risk, and exactly when they are at the greatest risk. And finally, if we can better align our management practices with host and pathogen development, we can greatly reduce the likelihood that cleistothecia will ever have a chance to form.

### *Future directions*

- Epidemiology of disease in high tunnels
- Distribution of resistant isolates by nurseries.
- Prior selection for resistance at nursery.
- Risk is greatly elevated when coupled with high tunnel production systems.



There are two areas of immediate concern for the future. First, is the movement of strawberry production in many parts of the world into high tunnel growing systems. These are really the best thing that has ever happened to anyone interested in working on powdery mildews, because nearly all powdery mildews are much more severe when the crop is moved into a tunnel production system. The assumptions are that powdery mildews become more severe due to ventilation and humidity issues. Our most recent work on how light quality affects

sporulation and sensitivity to UV radiation suggests there's much more going on here than a simple temperature or humidity effect, and that the increased disease severity may be related to the wavelengths that are selectively screened out by the tunnel covering.

A second area of concern relates to the spread of fungicide-resistant isolates through the nursery trade. There's always a premium placed on the production of nursery stock that appears to be free of powdery mildew. That's a driving force behind intense fungicide use in nurseries, and also pushes nurseries towards using the most effective, but ironically the most resistance-prone materials. Coupled with high-tunnel production systems, this has the potential to be a particularly destructive combination. First, planting material entering the system appears disease-free, but it is probably not so. Secondly, whatever isolates that are harbored on the planting material may have undergone intensive prior selection for resistance to a broad swath of the best available fungicides. Lastly, there will be additional pressure towards the use of the at-risk fungicides in the high tunnel systems once powdery mildew appears

## Beneficiaries

The beneficiaries of our research are anyone who grows strawberries in New York. As previously stated, strawberries are the most widely-planted and economically valuable small fruit crop in the state. They are one of the few fruit crops that are not limited by our winters, and they are grown in virtually all NY counties. They are increasingly grown as highly-valuable cash crops in vegetable production, in small farm pick-your-own systems. In addition to direct producers, our research would benefit other stakeholders, including County Cooperative Extension educators and advisory personnel, private crop consultants, and faculty and staff of the New York State Integrated Pest Management Program.

There are over 400 commercial strawberry growers in NY. In addition to growers whose primary crop is strawberries, there are nearly an equal number of diversified farms that produce strawberries as part of the overall farm operation. Indeed, in a 2007 survey of NY berry growers, 55% were growing strawberries on 3 acres or less of their operation. Note that even this small acreage represents a substantial return, as net income from a single acre can be valued at \$5,100 to \$7,500.

Our means of communicating the project results have depended upon the multiplier effect of communicating with extension personnel and applied scientists who are the primary contacts with the industry, and to publish the results in sources referenced by these stakeholders. In the course of our research, we have discovered a new functional source of infection for one of the major diseases of strawberry. This is highly relevant to control of the disease. This discovery has been published in a series of peer-reviewed papers in the leading scientific journal of our profession, specifically:

Gadoury, D.M., Aslaf, B., Heidenreich, M.C., Herrero, M.L., Welser, M.J., Seem, R.C., Tronsmo, A.M., and Stensvand, A. 2010. Initiation, development, and survival of cleistothecia of *Podosphaera aphanis* and their role in the epidemiology of strawberry powdery mildew. *Phytopathology* 100:246-251.

Aslaf, B., Gadoury, D.M., Tronsmo, A.M., Seem, R.C., Cadle-Davidson, L., Brewer, M.T., and Stensvand, A. 2013. Temperature regulates the initiation of chasmothecia in powdery mildew of strawberry. *Phytopathology*. 103 (in press).

In addition, the results of the research was presented at national meetings of the American Phytopathological Society in 2012 (approximate attendance 100 per session), at sessions attended by the state extension specialists in fruit production, specifically:

Asalf, B., Stensvand, A., **Gadoury, D.M.**, Seem, R.C., Cadle-Davidson, L., Peres, N.A., and Tronsmo, A.M. 2012. Temperature functions as a repressor of ascocarp formation in strawberry powdery mildew *Podosphaera aphanis*. *Phytopathology* 102:0000 (in press).

Asalf, B., **Gadoury, D.M.**, Seem, R.C., Tronsmo, A.M., and Stensvand, A. 2012. Early-season cryptic development of powdery mildew (*Podosphaera aphanis*) in June bearing strawberries. *Phytopathology* 102:0000 (in press).

Bekoscke, K., Asalf, B., Stensvand, A., Tronsmo, A.M., Seem, R.C., Peres, N., Cadle-Davidson, L., Brewer, M.T., and Gadoury, D.M. 2013. Geographic and climatic discontinuity in production of cleistothecia in *Podosphaera aphanis*. *Phytopathology* 103 (in press).

The research was also presented at the annual meeting of the North American Strawberry Growers in Tampa, Florida; with approximately 300 grower and extension personnel in attendance.

The results of the research, specifically the discovery of a new source of inoculum, are now reflected in disease management guides nationwide, including those published by Cornell for NY growers.

We have communicated with the lead pathologist for Driscolls Strawberries, the largest processor of strawberries in the US. The project results, in turn, were communicated to Driscoll growers nationwide.

A final report on the project is also in preparation for an extension newsletter distributed electronically statewide to strawberry growers in NY.

A website for the project, intended to generate the samples directly from growers, received over 20,000 "hits" in 2012. We have received leaf samples from growers in 11 states: NY, CA, FL, MA, NC, OH, TX, OR, WA, PA, and MI; allowing us to map the distribution of the new source of inoculum on a nationwide scale. This mapping is the subject matter of the above presentation by Bekoscke et al, to be made at a national meeting of research and extension personnel in Austin Texas in August of 2013. Attendance at this meeting is expected to be approximately 1500 registrants.

New York presently ranks 6<sup>th</sup> in US strawberry production. In 2007, there were at least 1,500 acres planted in NY, with a value of utilized production of \$7.6 million dollars. The cost of a single fungicide spray applied to New York's strawberry acreage is approximately \$100,000, and up to four such applications may be directed against powdery mildew. The most popular and therefore profitable strawberry varieties are susceptible to the disease, thus varietal resistance is generally not a consideration in commercial production. Economic benefits of our research were gained from two principal avenues: reduced fungicide use (perhaps as much as a 50% reduction is feasible based upon our preliminary data), and reduced crop loss (even a 10% crop loss amounts to \$760,000 at current

production levels). Given the misalignment of fungicide applications that existed prior to our work, savings of one or more fungicide sprays coupled with greatly improved control are conservatively estimated direct benefits of this work. Furthermore, both values would be inflated by a switch to high-tunnel production systems, where yields, disease potential, and fungicide inputs are higher than in open field production.

### Lessons Learned

- Despite the importance of the crop, and the number of scientists working on strawberry powdery mildew, there were several fundamental flaws in our understanding of the basic biology and epidemiology of this disease. A significant degree of skepticism is helpful in reviewing the state of our knowledge to separate what is truly known from what is long-held speculation.

### Contact Information

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### Additional Information: *Publications from the research*

Gadoury, D.M., Aslaf, B., Heidenreich, M.C., Herrero, M.L., Welser, M.J., Seem, R.C., Tronsmo, A.M., and Stensvand, A. 2010. Initiation, development, and survival of cleistothecia of *Podosphaera aphanis* and their role in the epidemiology of strawberry powdery mildew. *Phytopathology* 100:246-251.

Gadoury, D.M., Aslaf, B., Heidenreich, M.C., Herrero, M.L., Welser, M.J., Seem, R.C., Tronsmo, A.M. & Stensvand, A. 2009. Development of cleistothecia of *Podosphaera aphanis* and their role in the epidemiology of strawberry powdery mildew. *NJF Report* 5 (9):19.

Aslaf, B., Eikemo, H., Dobson, A., Hagen, C., Tronsmo, A.M., Gadoury, D.M., Seem, R.C. & Stensvand, A. 2009. Evaluation of fungicides and alternative non-chemical agents to control strawberry powdery mildew. *NJF Report* 5 (9):20.

Aslaf, B., Stensvand, A., Gadoury, D.M., Seem, R.C., Dobson, A. & Tronsmo, A.M. 2009. Ontogenic resistance to powdery mildew in fruits of four strawberry cultivars. *NJF Report* 5 (9):31.

Stensvand, A., Gadoury, D.M., Eikemo, H., Dobson, A., Heidenreich, M.C. & Seem, R.C. 2009. Strawberry powdery mildew epidemics are affected by initial disease level. *NJF Report* 5 (9):32.

Aslaf, B., Gadoury, D.M., Tronsmo, A.M., Seem, R.C., Dobson, A., and Stensvand, A. 2012. Ontogenic

Resistance of Leaves and Fruit, Leaf Folding and Distribution of the Pathogen on Strawberry Plants Colonized by *Podosphaera aphanis*. Plant Dis. 96:0000-0000 (in press).

Aslaf, B., Gadoury, D.M., Tronsmo, A.M., Seem, R.C., Cadle-Davidson, L., Brewer, M.T., and Stensvand, A. 2012. Temperature regulates the initiation of cleistothecia in the heterothallic powdery mildew of strawberry (*Podosphaera aphanis*). Phytopathology. 102:0000-0000.

## **Project Title: Improving the Competitiveness of the Snap Bean Industry in New York Through Resistance to Aphid-Transmitted Viruses**

### **Project Summary**

Devastating yield losses in snap beans in NY have been associated with aphid-transmitted viruses (largely associated with the Asian soybean aphid which first appeared at this time). The primary virus linked to these yield-losses is Cucumber mosaic virus (CMV), which causes flower reduction and distortion when vectored to snap bean fields pre-bloom. Additionally, BYMV and CYVV have been detected at high levels in the majority of infected snap bean regions causing further yield losses, pod distortion and quality reduction through interior pod necrosis. As the aphid-vectors do not complete their life cycle on snap beans, it is not possible to control the spread of the viruses using insecticides. The only effective solution is virus resistant snap bean varieties, and there are none available commercially at this time. The development of snap beans with resistance to aphid-transmitted viruses could significantly reduce these losses in snap bean production by improving yields and quality in infected regions. Breeding efforts were initiated for resistance to CMV by Griffiths at Cornell NYSAES. Considerable breeding efforts have resulted in advanced snap bean breeding lines that appear to prevent the flower loss and distortion that results in yield losses. This resistance is controlled by multiple genes, and is difficult and highly labor intensive to select into marketable snap beans. Advanced lines are now being developed for commercial type and marketable appearance.

The success of these varieties would be complemented and enhanced by combining resistance sources to BYMV and CYVV into the CMV resistant background, as preliminary work indicates that cross-resistance occurs among these viruses. Efforts were also initiated to develop snap beans resistant to BYMV from the Cornell black bean breeding line 'B-21', and resistance to CYVV from the navy bean variety 'Clipper'. Advanced snap bean breeding lines have now been selected for resistance to all three of these viruses. The combination of resistance to these viruses promises to not only enable superior snap bean varieties able to withstand a wider range of challenges, but also to enhance resistance to the primary virus associated with yield loss, CMV, and potentially enhance the durability of resistant varieties.

The pyramiding of resistance genes to these aphid-transmitted viruses combined with evaluation of the mechanisms and interactions of the resistance genes will enable better understanding of how the virus damage occurs in snap bean production areas and how the resistance sources can be combined in a snap bean variety to protect against the yield losses following infection. Snap bean production is an important, profitable and increasing industry in NY State, along with other affiliated industries associated with seed sales and processing. To maintain and increase the market share in the state, it is critical to develop varieties that are able to withstand the damage caused by aphid-transmitted viruses. Pyramiding and development of snap beans combining resistance to these viruses will benefit hundreds of snap bean producers throughout NY State in both the processing and fresh-market industries.

Despite the importance and prospective contribution this work will have on the NY snap bean industry, it is extremely difficult to get support from federal sources.

## **Project Approach**

The project had three objectives:

[1] The selection and advancement of breeding lines for resistance to multiple aphid-transmitted viruses by advancing breeding lines combining the resistance to CMV, BYMV, CYVV and evaluating for performance following infection in greenhouse tests and including selection for type. Lines showing high levels of cross-resistance were selected for advancement. New advanced breeding lines were developed through this approach by combining resistance sources in a commercial type for field-testing.

[2] The study of levels and distribution of virus in plants and the interaction of resistance from the combined sources on floral and plant morphology. Advanced breeding lines were compared to susceptible varieties to study virus levels in the tissues and how this effects yield and quality issues in harvested pods based on infection time and plant resistance. Plants were evaluated comparing and combining resistance genes to CMV, BYMV and CYVV. Studies included 3-D imaging of floral development following infection with CMV.

[3] Outreach activities of project activities through dissemination of results at the New York State Vegetable Research Council/Association meeting, the NY State Vegetable Expo, extension grower meetings as outlined in quarterly and annual reports.

This combined effort led to significant steps forward in the understanding of resistance to viruses in snap beans, the interactions and complementation of genes, the responses of plants and the introgression of resistance into market types. Dissemination of the results has been made through multiple outreach activities presenting the results not just to academic and grower audiences but also to major corporations with influence in NY State and nationally. These activities have resulted in partnership with 'Seneca Foods' the major vegetable processor in NY State to advance the breeding lines to field-testing and cultivar development. The work supported during the course of this project is likely to make a major impact if the materials are advanced to commercial cultivars, potentially in the \$10 millions. The ability to achieve this will be dependent of continued resources that are allocated to this work to enable optimal gene combinations to be combined in advanced breeding lines through an accelerated introgression approach.

## **Goals and Outcomes Achieved**

Breeding efforts were focused on the advancement of virus resistant snap beans from multiple sources and lineages. This included resistance to and evaluation of responses of flowers on plants of many processed snap bean cultivars that distort causing yield reduction (Fig. 1). Research undertaken as part of this project has shown that the flower distortion following CMV infection appears to be much higher in cultivars that have the initial severe blistering response such as 'Hystyle' and 'Titan', and also appears to be influenced by environmental conditions and density stress – higher levels of flower and pistil distortion are typically observed when high temperature conditions are present, or when plants are grown in smaller pots. There is likely an inoculation timing effect on the incidence of this, as plants

silence the initial severe foliar responses to CMV likely making the duration between infection and bloom the most critical time. Initial 3-D imaging undertaken has indicated that this might be caused by a morphological deformation of the growing anthers in a developing flower, physically preventing pollination of the pistil in these flowers (Fig. 2).

The ability for deformed flowers to set a fertilized pod appears to be an all or nothing event, consistent with the physical separation of the anthers from the pistil in distorted flowers, which can prevent pollination in a large proportion of these; however, it appears that distorted flowers are able to set pods at a low rate. These observations indicate that the resistance response and yield losses associated with CMV infection are not caused by a gene-for-gene interaction, but the extent and deformation of flowers which varies among genotypes and is influenced by genes that either reduce the overall response to CMV infection or the consequent number of flowers deformed. The responses have interactions with environmental stress effects including high temperatures, plant density and plant growth rate. Timing of infection is also important. Genotypes including 'Hystyle' and 'Titan' can recover from severe blistering at the seedling stage to have close to normal pod sets and very few or no distorted flowers, especially if they are in larger pots, or have a slower growth rate (perhaps a result of a longer time to silence CMV and reduce titer) such as during lower light conditions during wintertime. The high level of CMV in seedlings of genotypes exhibiting severe blistering following infection, likely results in higher yield losses under field conditions especially when combined with environmental stress. This is based on results that indicate much higher levels of virus titer in the early trifoliates of severe blistering types, even though the total titer can level off as the plant approaches flowering (Fig. 3). Selection of breeding lines exhibiting the non-blistering (NB) or very low blistering response at the seedling stage is therefore critical in the development of CMV resistant cultivars.

The severe seedling blistering response is more of an exception than the rule, a screen of snap bean genotypes detected this response in approximately 10% of the snap bean cultivars evaluated in differential screens. In an initial screen of 104 cultivars there were 14 exhibiting the severe blistering response ('Hystyle', 'Titan', 'Hercules', 'Nicelo', 'Spartacus', 'TrueBlue', 'Goldmine', 'Daytona', 'Zeus', 'Slenderette', 'Crest', 'Bluecrop', 'BBL156' and 'BBL274') and 10-15 exhibiting an intermediate response including 'Labrador', 'Venture', 'Brio', 'Cadillac'. Dry bean cultivars infected with CMV do not exhibit the severe blistering response, and have also not experienced the yield reductions of snap bean growers – this is likely also effected by the more vigorous growth of dry beans and the longer flower flush. Snap bean cultivars not showing the severe seedling blistering response, typically show some response to CMV including some leaf distortion, leaf epinasty and plant stunting.

Previous efforts initiated to add Bean yellow mosaic virus (BYMV) and Clover yellow vein virus (CIYVV) resistance to the research efforts as these viruses were being detected at high levels in bean fields throughout NY (frequently 40%+). Initial sources used were 'Black Knight' (black bean) 'Clipper' (navy bean) and 'Kentwood' (navy bean) for CIYVV resistance, and the black beans 'B-21' and 'SP-17B' for BYMV resistance. The multiple BYMV gene transfer from 'B-21' and 'SP-17B' retrospectively involved the transfer of genes interacting with and complementing *By-2* that are present in dry beans but not the recurrent parent 'Hystyle'. Additional materials were incorporated into the project to transfer the *bc-3* gene, which is a recessive Bean common mosaic necrosis virus (BCMNV) resistance gene that also gives resistance to CIYVV. These were crossed with the snap bean cultivars 'Hystyle' and 'Bronco' and have subsequently been backcrossed to 'Hystyle' as the recurrent parent. As multiple virus resistance gene transfer was undertaken, screens of materials with differential cultivars were also initiated.

It has become evident that the resistance to CMV is not only connected to resistance genes to BYMV and BCMV, but that resistant lines could more easily be identified and selected from the BYMV material being worked on than the scarlet runner bean interspecific sources being introgressed. BYMV breeding lineages being selected have cross-resistance providing not only resistance to the CIYVV potyvirus, but also resistance to CMV especially from the 'B16', 'B18' and 'B28' lineages. Sister lines of an F<sub>3</sub> 'B18' breeding lineage showed a 3:1 segregation of non-blistering in seedlings (NB) to severe blistering (B) indicating that a major dominant gene prevented blistering. The sister lines from this source did not show any stunting indicating that a second CMV gene was likely fixed in these lines. Further population studies have confirmed 3:1 segregations of NB:B although there are indications that two different genes might confer this major gene resistance response, one of which may be linked to BYMV resistance, and one which does not appear linked based on differential snap bean cultivar screens where the NB response is identified with BYMV susceptibility. The cultivar 'Huntington' that has been widely deployed in NY processed snap bean acreage has a NB response to CMV, and also appears to contain a weak BYMV resistance gene or allele that prevents plant death but still causes a stunting and mosaic following BYMV infection. In 'Hystyle' a severe stunting and deformation response is observed, early responses of which are shown (fig. 4). As the genetic control and interactions of different genes are identified, it is becoming clear that multiple virus resistance genes are involved with resistance to the differentials some of which are allelic and homologs. For CIYVV resistance, the recessive gene introgressed from 'Clipper' is one of three homologs of the eIF4E gene, the other two alleles are present and identified in 'Black Knight' introgressed from 'GN 1140' and *bc-3* introgressed derived from IVT 7214 supposedly derived from PI 181954 (however this introduction was accessed and that source is not resistant adding some confusion to the original source).

The *bc-3* gene is the most effective of these as it provides resistance to CIYVV and BCMNV when complemented with the dominant *I*-gene present in the majority of snap bean cultivars. As *bc-3* is effective against BCMV/BCMNV when combined with the *I*-gene it will be important for seed production regions, it will also provide resistance to CIYVV which can be present in snap bean production regions (CIYVV was associated with 50% yield losses in central Pennsylvania in 2010, where CMV was not detected). The BYMV lineages contain all genes necessary for resistance to the differentials as indicated in Fig. 5, which would be enhanced by pyramiding the *bc-3* allele to provide additional protection to CIYVV improving durability of released cultivars and providing resistance to BCMV/BCMNV

The gene(s) for NB need to be included with BYMV resistance for an optimal combination against CMV in cultivars, these are also present in the BYMV lineages and are currently being investigated through the development of differential cultivars to be discussed as part of the current population development. Current populations show that the NB response can be selected separately from BYMV resistance; however, in other differential lines being developed there are indications that there is a separate dominant gene controlling the NB response that is associated with or linked to BYMV resistance.

This project has resulted in significant steps forward in the ability to develop virus resistant snap bean cultivars for NY by going beyond the outlined project objectives to secure an understanding of gene interactions and combinations that are required for resistance in snap bean cultivars while introgressing the resistance into advanced breeding lines. Introgressing, combining and field-testing of these resistance genes into snap bean cultivars would have a major impact for NY processed vegetable production. The ability to achieve this will be dependent on the availability of resources necessary to undertake the labor-intensive population development and selection work.

Cumulative activities of the project were presented at the NYSVRA/C on Dec 11<sup>th</sup> 2012 where over 50 people were present including major snap bean growers throughout the state of NY and representatives of the two vegetable processing companies in NY: Seneca Foods (3 in attendance) and Farm Fresh First (5 in attendance). The work has led to a follow on partnership for field-testing materials with the vegetable processor responsible for canning products from over 10,000 acres of snap beans in NY and 40,000 acres in the NE. Results of this work were disseminated through multiple outreach activities which are listed below.

- 12/14/12** - Breeding varieties for NYS. Dry Bean Advisory Council Meeting  
LeRoy Country Club, LeRoy, NY (40 in attendance)
- 12/11/12** - Breeding snap beans for host plant resistance. New York State Vegetable Research  
Association/Council meeting (50 in attendance)
- 8/27/12** - Cornell Vegetable Breeding Institute Field Day  
Ithaca NY (70 in attendance)
- 8/28/12** - Cornell Vegetable Breeding Institute Field Day  
Geneva NY (50 in attendance)
- 8/10/12** - Meeting with Seneca Foods research director and breeder  
Geneva NY (3 in attendance)
- 9/18/12** - 2012 Dry Bean Field Day  
Avon NY (60 in attendance)
- 3/19/12** - 2012 NYS Dry Bean Meeting  
LeRoy Country Club, LeRoy (40 in attendance)
- 10/26/11** - Discussion of progress with meeting of Seneca Foods CEO Kraig Kayser (15 in  
attendance)
- 9/17/11** - Field day hosting PNBR 4160 plant breeding students, international exchange visitors  
discussing importance and future of project (25 in attendance).
- 11/02/11** - Presentation of research at Bean Improvement Cooperative conference in San Juan,  
Puerto Rico to regional multi-state project leaders (30 in attendance).
- 8/30/11** - Field days hosting of seed company breeders and representatives Geneva NY/Ithaca NY  
(45 in attendance).
- 12/2/10** - Presentation of virus project, status, direction etc. to NY Growers, Extension personnel  
at NYSVRC/A meeting Canandaigua NY (40 in attendance)
- 12/10/10** - Presentation of virus project and efforts to NYS Dry Bean Council in Mendon NY (30 in  
attendance).
- 9/19/09** - Field day hosting PNBR 4160 plant breeding students, international exchange visitors  
discussing importance and future of project (30 in attendance).
- 9/24/09** - Field day hosting two master gardener groups, tying in the research to the fresh market  
production of snap beans (60 in attendance)
- 9/27/09** - Presentation of research at Bean Improvement Cooperative conference in Fort Collins  
Colorado to regional multi-state project leaders (25 in attendance).
- 11/05/09** - Bean Virus meeting with several state extension personnel and Cornell researchers to  
discuss problems, solutions and research Barton Hall, NYSAES (15 in attendance).
- 12/2/09** - Presentation of virus project, status, direction etc. to NY Growers, Extension personnel  
at NYSVRC/A meeting Canandaigua NY (45 in attendance).
- 12/10/09** - Presentation of virus project and efforts to NYS Dry Bean Council in Mendon NY (25 in  
attendance)

- 1/20/10 -** Virus meeting with other researchers, Hedrick Hall, NYSAES Geneva to discuss project goals directions and co-ordination (15 in attendance).
- 2/2/10 -** Presentation of virus project status and direction to Pennsylvania snap bean growers at Hershey, Pa (30 in attendance).
- 3/2/10 -** Presentation of virus project to NYS dry bean growers Mendon NY (50 in attendance).
- 7/10/10 -** Discussion of virus project and grower participation/visit directors office Geneva NY (5 in attendance).
- 8/24/10 -** Hosting of NY growers and processors including tours of greenhouse and field plots for virus project and discussions of progress/status at Geneva NY (15 in attendance).
- 8/31/10 -** Field days hosting of seed company breeders and representatives Geneva NY/Ithaca NY (55 in attendance).
- 9/9/10 -** Field day for home garden seed association (seed distributors throughout US) presenting virus project Geneva NY (50 in attendance).

### **Beneficiaries**

There will be many beneficiaries of this work undertaken if resources are available to move the optimal combinations through to the commercial cultivar stage. When cultivars are completed this work will benefit over 100 growers throughout NY State but will also benefit growers throughout the NE region and the world (NY processed vegetable growers, NY fresh-market growers, growers in the wider region). The work will also benefit processed vegetable companies present in NY such as 'Seneca Foods', and commercial seed companies with presence in NY State or nationally. Development and implementation of this resistance into cultivars would have considerable contributions on many levels, from an environmental standpoint by reducing the need for pesticides to a yield stability and enhanced profit margin for all sectors associated with snap bean production in NY.

### **Lessons Learned**

The goals and objectives of the project were not only attained for the most part but largely surpassed. The knowledge generated through this project provides a platform for moving the entire industry to the next level through the development of virus resistant cultivars. While the time to achieve commercial type cultivars based on the complexities of genetic interactions, linkage drag and determination of optimal gene combinations, the materials to achieve this now appear to be in place. Using this information to create advanced breeding lines with optimal combinations for selection of commercial cultivars will be necessary to achieve this, and will require the resources for the necessary breeding work. If this is achieved, the impact and economic contribution to the NY vegetable industry will be significant.

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**Additional Information Provided:** Additional information has been provided through pictures/figures below and referenced to previously:

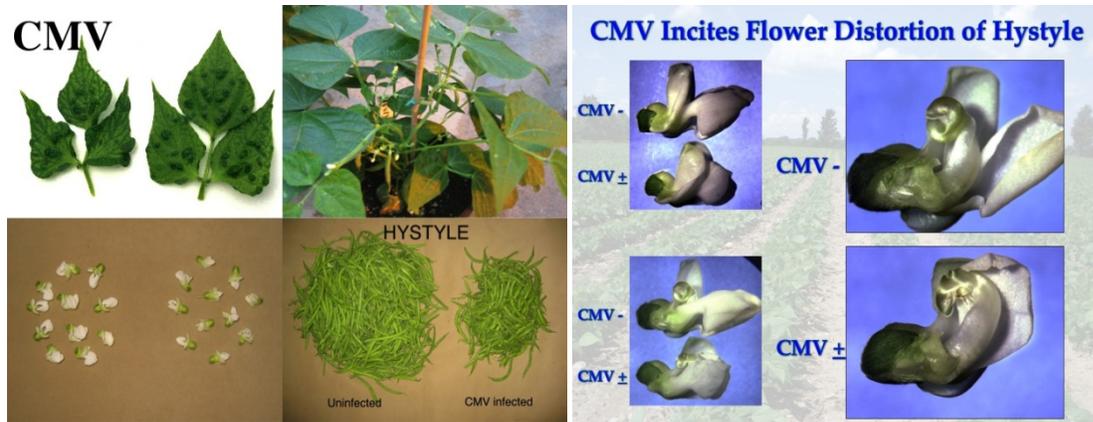


Fig. 1: Flower distortion and failure to set pods following CMV inoculation of 'Hystyle' seedlings.

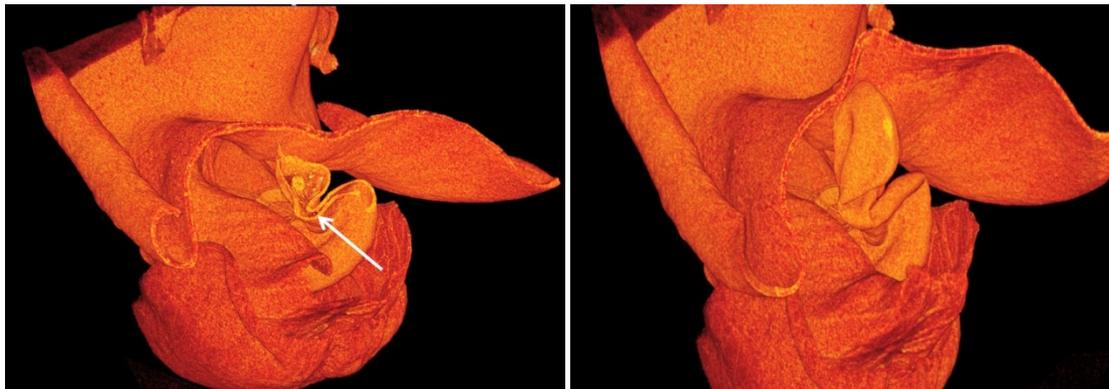


Fig. 2: CT-Scan (X-Ray Computed Tomography) of developing distorted flower (the fold typical of a distorted flower marked by an arrow) allows visualization of internal structures.

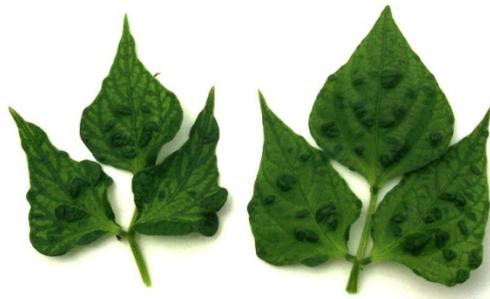
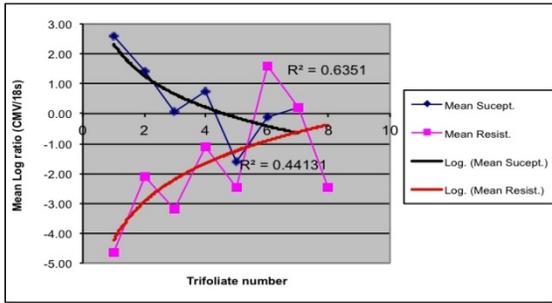


Fig. 3: qRT-PCR/qPCR of the severe seedling blistering genotype shows high virus titer in early trifoliolates which becomes silenced as the plant matures.

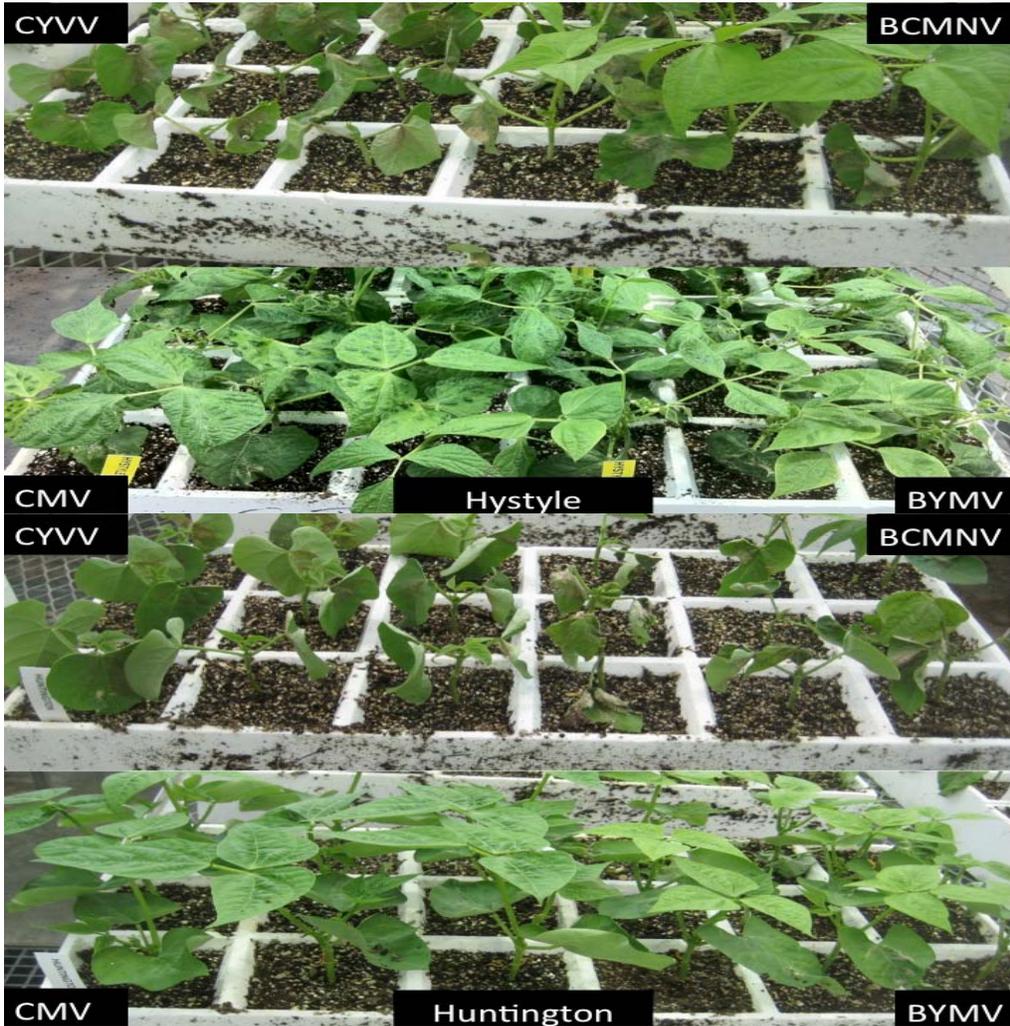


Fig. 4: Responses to differential screens of 'Hystyle' and 'Huntington' with CMV, BYMV, CYVV and BCMNV NL-3.

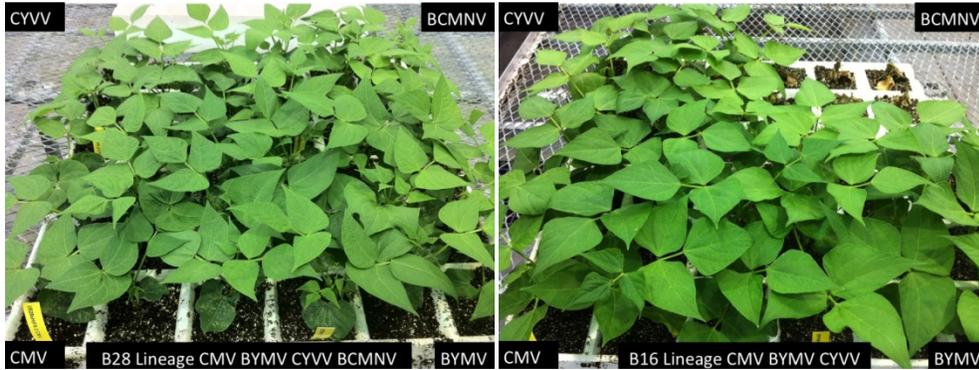


Fig. 5: Response of B28 and B16 BYMV lineages to CMV, BYMV, CYVV and BCMV NL-3 (B16 does not contain the gene delaying susceptibility to NL-3).

## **Project Title: Increasing Utilization of IPM Tools in the New York State Christmas Tree Industry**

### **Project Summary**

Integrated pest management (IPM) combines information on pest presence and identification with the available methods of control to determine the most effective, economical, and environmentally appropriate method of managing pests in a crop. IPM is considered a best management practice and is part of a sustainable production system.

Most NYS Christmas tree growers use some aspects of Integrated Pest Management (IPM) in their production, but in a 2007 survey over 50% of the 155 respondents said they would like additional training in IPM practices and pest identification. We have also seen an increase in the use of IPM techniques, and the need for information on them, based on interactions with growers through the Christmas Tree Farmers' Association of NY (CTFANY) educational programs and other grower programs, such as the annual Hudson Valley Christmas Tree Twilight meeting sponsored by the local Cooperative Extension offices.

Demonstration of practices on-farm combined with a comparison of current and improved practices is one of the best ways to expand use of IPM to a wider audience of Christmas tree growers. On-farm projects also provide a way of collecting real world data on potential economic and environmental benefits of improving pest management through the increased use of IPM tools.

### **Project Objective**

The long-term objective of this project is to increase the use of available IPM tools by Christmas tree growers in NYS based on current NYS Christmas tree growers' use of IPM and knowledge gained while working with them to expand their level of adoption. Using knowledge gained from 12 growers and at on-farm Open Houses, we want to create a plan for the development of educational materials and how to extend them to continue the expansion of IPM and the production of quality trees by NYS growers in the future.

### **Project Approach**

#### Activities and Tasks

1. Identification of Cornell Cooperative Extension Educators interested in participating in the project.

Seven educators had indicated an interest in the project at the time the grant was written: Stephanie Mallozzi Radin (Dutchess County), Walt Nelson (Monroe County), Crystal Stewart and Chuck Schmitt (Fulton/Montgomery Counties), Alexis Alvey and Nora Catlin (Suffolk County), Laurel Gailor (Warren County), Bret Chedzoy and Roger Ort (Schuyler County) and Carl Albers and Stephanie Mehlenbacker (Steuben County). During the project, several changes in personnel occurred because of retirements or changes in job status. All counties remained active in the project with the exception of Warren County.

2. Identification of growers to participate in the project.

We had intended to have one grower per educator but additional growers were interested, so we had a final total of 12 grower participants. These growers are diverse in region, size of operation, years in business, educational and employment background, and previous use of integrated pest management in their operations.

Dutchess County: Abel Tree Farm (Verbank) and Plains View Farm (Lagrangeville)  
Fulton County: Goderie's Tree Farm (Johnstown)  
Monroe County: Woody Acres (Penfield), Morgan Hill Christmas Tree Farm (Scottsville)  
Onondaga County: Three B's Tree Farm (Jordan)  
Ontario County: Darling's Tree Farm (Clifton Springs)  
Saratoga County: Ellms Christmas Trees (Ballston Spa)  
Schuyler County: Buttonwood Tree Farm (Reading), West Hill Tree Farms (Montour)  
Steuben County: Stephens Tree Farm (Andover)  
Suffolk County: Elwood Pumpkin and Christmas Tree Farm (Huntington)

### *3. Creation of survey and scouting/training materials*

Personnel of the NYS IPM program had already created the Elements for Christmas Tree Integrated Pest Management in New York State. Elements of IPM are lists of procedures that could be used by growers who use IPM to produce their crops. They are specific to a production system and are intended to cover a broad range of activities that can be adapted by each grower to fit their own situation. In some cases, for example vegetable crops, point values are assigned to each activity and the totals are used to determine whether a grower's crops qualify as 'grown with IPM'. In the case of Christmas trees, there is no official use of the Elements, but they can be used as a grower self-evaluation or education tool.

We used the Elements for Christmas Tree IPM as a baseline and final survey to gather information about the project growers in specific and as a group representing the Christmas tree growers of NY, and to evaluate change in practice over the course of the grant.

No scouting or training materials were created specifically for this project. CCE Educators were already well skilled in working with growers on scouting and the growers' needs were quite variable. As needed, information was collected or created and provided to the educators or growers. The Cornell Pest Management Guide for the Production of Trees and Shrubs and the Branching Out scouting newsletter were provided to each grower as part of these scouting and training materials.

### *4. Site visits throughout grant period*

Educators visited farms throughout the grant period as needed. In many cases, the educators would assist the growers with their scouting on a regular basis during the primary growing season. PIs visited the farms once each year with the educator to discuss progress and needs of the growers.

### *5. On-farm Open Houses*

The intent was to hold an Open House at each farm or at least in each county during the second year. In order to have more results to demonstrate, it was decided to hold the Open Houses in 2012. However, the logistics of holding 9 Open Houses in the spring and summer of 2012, so as not to compete with each other or the CTFANY summer meeting for participants, lead us to decide to hold some of the Open Houses after the grant period had ended.

In addition to the official grant supported Open Houses, information gathered during the grant was provided to Christmas tree growers at other programs, as noted below.

**Open Houses**

Location	Date	Number attending	Grant partners participating	CCE participating
Red Barn Christmas Tree Farm Brainardsville, NY	October 12	35	Rob and Cathy Jo Brown	E Lamb
Goderie's Tree Farm, Johnstown	September 22	25	Pete Goderie	E Lamb B Eshenaur C Schmitt
Shamrock Christmas Tree Farm Mattituck	July 10	30	Lee Itzler	E Lamb A Alvey
Abel's Trees, Verbank	June 27	35	Steve Abel Glenn Wade	E Lamb B Eshenaur S Radin

**Other public events with Christmas tree IPM information presented, based on information from baseline data and grower experiences**

Location	Date	Number attending	Relevant topics	Event	Grant participants
Stokoe's Christmas Tree Farm, Scottsville	September 6	40	Weed id and management  Disease and insect management	NY Farm Viability grant program – B Eshenaur	B Eshenaur E Lamb
Empire Evergreens, Painted Post	July 20-21	100	Weed management  IPM for new growers	Christmas Tree Farmers' Association of NY summer meeting	E Lamb
Cornell Cooperative Extension of Steuben County Bath	March 20	25	Disease and insect identification and management	Southern Tier Christmas Tree Growers annual meeting	E Lamb C Albers

### Open Houses planned for 2013

*March or later* – with the Southern Tier Christmas Tree Growers group and cooperatively with Steuben and Schuyler County Cooperative Extension (Stephanie Mehlenbacher and Roger Ort)

*June* – Darling’s Tree Farm, Clifton Springs NY

*Late summer* – Monroe County

*Fall* – North Country with Rob Brown hosting

### 6. Pre and post surveys of primary growers and Open House participants

The Elements of IPM survey was completed by each grower at the first visit with the PI and the CCE Educator. Of the 11 growers still available at the end of the grant period, 6 redid the survey as a method of evaluating change in practice. The remaining 5 will be surveyed in early 2013 when their schedules permit, either in person or by phone. The results of these surveys are described in the following section.

While the intent was to survey Open House participants, these surveys were not completed. A wider survey of Christmas tree growers will be completed during 2013 and this will include questions on participation in Open Houses and other IPM programs and what practices have been adopted as a result of the educational programs.

### Significant results and conclusions

#### 1a. Initial survey results

Values based on 12 responses unless otherwise noted in parentheses. Non-responses may be due to non-applicability of question to grower, or slight change in questionnaire during surveying

### PRE-PLANT IPM CONSIDERATIONS

Activity	Percent growers responding yes
Match appropriate Christmas tree species to the site conditions, especially considering soil drainage characteristics.	75
Inspect plants upon arrival and quarantine those with signs of infection or insect infestation or poor vigor/root system.	75
Determine tree spacing to allow good air movement and to allow enough room for equipment.	100
Map areas that will be planted within the next year paying particular attention to weed species that will be difficult or impossible to control after planting	27 (11)
Plan plantings so blocks of land will be open to rotation and do intensive weed management.	27 (11)

## PRE-GROWING SEASON IPM CONSIDERATIONS

Activity	Percent growers responding yes
Calibrate pesticide application equipment	54 (11)
Inspect and clean pesticide storage and mixing areas	91 (11)
Maintain an inventory of pesticides	72 (11)
Ensure all personal protective equipment is clean and stored properly	72 (11)
Remove trees with (chronic/severe/untreatable) pest problems that are likely to infect/infest other trees	100

## CROP MANAGEMENT

Activity	Percent growers responding yes
Keep complete records of soil test results and fertilizer frequency	41
Use soil analysis, to determine appropriate fertilizer programs	27 (11)
Record dates of budding, and significant weather events	8
Use growing degree days in your pest management	27 (11)
Test water source(s) used for irrigation and pesticide spray mixtures for pH level and alkalinity	8
Adjust tree species grown as pest pressures dictate	92

## GENERAL PEST MANAGEMENT

Activity	Percent growers responding yes
Develop a plan for pest management based on time of season, pest thresholds, and available management options	75
Scout regularly for insect, and disease problems, using a plan that covers all tree species and planting areas.	67
When scouting, inspect trees thoroughly, including the interior needles and lower branches.	83
Identify all insect, weed and disease problems	66
Maintain scouting and pest control records in order to predict pest problems	8

## IN-SEASON INSECT MANAGEMENT

Activity	Percent growers responding yes

When possible, remove infested plant parts prior to insect emergence. Examples: Removing white pine weevil blighted shoots before mid-July and removing galled tips containing the spruce gall adelgids before the galls open in late July	72 (11)
Choose insecticide products carefully so beneficial insects are not killed when pests are being controlled, if at all possible	60 (10)
Use insecticides only when pest populations reach potential to damage crop	70 (10)

## IN SEASON DISEASE MANAGEMENT

Activity	Percent growers responding yes
Maintain adequate spacing between plants for good air circulation	92
Remove individual trees severely damaged by diseases such as needlecasts	100
If records indicate there is a potential for disease development, apply fungicides at the appropriate time and frequency based on environmental conditions	100 (9)

## IN SEASON WEED MANAGEMENT

Activity	Percent growers responding yes
Scout fields for weeds, and identify weed species, especially those that are difficult to control	58
Use groundcover management techniques that will reduce soil erosion, nutrient runoff and herbicide use	66
Control weeds in vacant fields and land bordering production area to reduce weed, and disease movement into Christmas trees	64 (11)
Clean equipment before moving to a new location to prevent movement of weed seeds or vegetative portions to new field	36 (11)
Use mowing and/or effective herbicides at the recommended time of year for dominant or difficult to control weeds	100

## NUISANCE WILDLIFE MANAGEMENT

Activity	Percent growers responding yes
Practice good groundcover management since moles, rabbits, and groundhogs are more problematic where vegetation is thick	77 (9)
Follow all wildlife management laws, get appropriate permits	100 (9)
Use control measures other than pesticide baits for groundhogs, mice, moles, rabbits, and voles	63 (8)
If deer pressure is high enough consider fencing options	30 (3)

## GROWER IPM EDUCATION

Activity	Percent growers responding yes
Train employees in IPM practices	81 (11)
Learn to recognize beneficial insects and/or predators/parasitoids that naturally control pests and protect these natural enemies of tree pests	25
Have a current year's copy of Pest Management Guide for Commercial Production and Maintenance of Trees and Shrubs	67
Attend one or more university extension programs or industry conferences per year	92

## SUPPLEMENTAL QUESTIONS

	Percent growers responding yes
If you come upon a problem you don't recognize do you identify the pest?	100
How?	100% said Cornell Cooperative Extension
Do you have a map(s) with – soil drainage patterns, particular weeds, tree species, etc.	25

## What IPM project would you like to work on with us?

This question was included to help us better tailor the work the educator would do with the grower to the situation. Growers were allowed to make as many suggestions as they wished.

	Percent requesting
Scouting	42
Soil testing and fertility	33
Record keeping	33
Weed id and management	25
Insect and disease id and management	25
Groundcover management	17
Mapping	17
Sprayer calibration	8
Use of growing degree days (GDD) to schedule pesticide applications	8
Pesticide schedule management	8
Assessment of planting stock	8

### 1b. Discussion

The 12 growers included in the grant may be considered a random sample of NYS Christmas tree growers, although they may have self selected for an interest in, or understanding of, IPM.

The responses in the survey are those given by the growers. Often there are nuances that come out during the survey that are difficult to include in table format, in part because of the complexity of some of the Element statements. For ease of presentation, 'sort of' as an answer was included as a 'No' answer as it usually indicated that the grower followed part of but not all of the practice. Therefore, the percentages may be somewhat conservative. Using the Elements as a survey has given us good background for improving the Elements as a teaching tool, an unexpected benefit.

However, there are some clear results.

1. All Christmas tree growers use some practices that are consistent with IPM but all growers could increase their use of IPM.

- The concept of spacing for air movement and equipment usage is well understood.
- Most growers remove trees seriously damaged by insects or disease to reduce spread.
- In general, insecticides, fungicides and herbicides are used appropriately, although there are improvements to be made.

- Disease management IPM activities are more common than insect and weed management IPM activities.
- Changing to tree species with fewer pest problems is very common.
- Growers will ask for assistance in identifying a new pest.

Some activities are rarely done for reasons other than IPM

- Planning new plantings for rotation is often limited by the lack of available land
- Deer fencing is often too expensive to consider as an option

There are some clear indications of the need for additional education

- Identification and understanding of beneficial insects
- Methods for making mapping of farms easier
- Calibration of pesticide equipment
- Methods for making record keeping easier
- Methods for planning pesticide timing, including using growing degree days
- The importance of cleaning equipment to prevent moving weed seeds and diseases or insects

The growers’ suggested projects give us a good indication of where they feel they need additional information and/or assistance. We thought scouting might be the primary request because of the time needed to do scouting and its perceived difficulty. We were impressed that growers already had good ideas as to what aspects of IPM could be improved on their farms.

2a. Final survey results

The same survey questions were used for the final survey. Initial and final results were compared for each of the 6 growers for which we had both surveys at the end of the grant period. Very rarely did results change from a Yes answer to a No answer, which is to be expected. Results are tabulated here as growers who showed a change from not using a procedure at the beginning of the project to using it at the end of the project.

Changes in survey results based on final survey

(Activities are listed in the same order as the Elements in the initial survey above. If an activity is not listed, there was no change in the number of growers answering Yes)

Activity	Increase in growers using this procedure
Match appropriate Christmas tree species to the site conditions, especially considering soil drainage characteristics.	1
Map areas that will be planted within the next year paying particular attention to weed species that will be difficult or impossible to control after planting	3

Plan plantings so blocks of land will be open to rotation and do intensive weed management	1
Calibrate pesticide application equipment	1
Maintain an inventory of pesticides	1
Ensure all personal protective equipment is clean and stored properly	3
Keep complete records of soil test results and fertilizer frequency	2
Use soil analysis, to determine appropriate fertilizer programs	3
Record dates of budding, and significant weather event	2
Use growing degree days in your pest management	2
Adjust tree species grown as pest pressures dictate	1
Scout regularly for insect, and disease problems, using a plan that covers all tree species and planting areas.	1
When scouting, inspect trees thoroughly, including the interior needles and lower branches.	2
Identify all insect, weed and disease problems	2
Maintain scouting and pest control records in order to predict pest problems	2
When possible, remove infested plant parts prior to insect emergence. Examples: Removing white pine weevil blighted shoots before mid-July and removing galled tips containing the spruce gall adelgids before the galls open in late July	1
Choose insecticide products carefully so beneficial insects are not killed when pests are being controlled, if at all possible	1
Use insecticides only when pest populations reach potential to damage crop	2
Scout fields for weeds, and identify weed species, especially those that are difficult to control	2
Use groundcover management techniques that will reduce soil erosion, nutrient runoff and herbicide use	1
Control weeds in vacant fields and land bordering production area to reduce weed, and disease movement into Christmas trees	3
Clean equipment before moving to a new location to prevent movement of weed seeds or vegetative portions to new field	1
Train employees in IPM practices	1
Learn to recognize beneficial insects and/or predators/parasitoids that naturally control pests and protect these natural enemies of tree pests	1

## 2b. Discussion

Responses were not always what we expected based on the activities emphasized by the educators. For example, cleaning of personal protective equipment was not a specific request by any grower, yet 3 more growers included that in the final survey. On the other hand, scouting was specifically requested as a project goal by 4 growers, and actively done or discussed by all the educators, yet only 1 additional grower included it for diseases and insects and 2 for weeds.

The number of different activities included, plus the percentage of surveyed growers adding them was greater than expected. Often with a project such as this, there is little immediate measurable change. The increases in mapping and the use of soil tests for fertility decisions are encouraging. Once the remaining surveys are completed, we will redo this table.

### 3a. Grower reactions to the project

A series of open-ended questions were included with the final survey in order to gauge the effects of the project.

#### What did you learn from the project?

		Number giving this answer
Scouting	Starting earlier	1
	More often	2
	Improved method	4
	Use for evaluating effectiveness of treatments	1
Pest identification	Insect	3
	Disease	2
	Weed	1
Less spraying		1
Soil testing		1
Liming and fertilization practices		1
Air flow for disease management		1
Ground cover management		1
Disease management		1
Link between tree species/plant health and environment/location		1

#### What new procedures are you planning on or have already implemented on your farm?

Each farmer listed at least 1 and as many as 3 procedures.

Improved scouting
Improved weed management through timing of herbicides
Removal of insect infested trees to reduce spread

Groundcover management techniques (2 growers)
Using blocks of the same species of trees to make pest management easier and reduce amount of pesticides
Choice of tree species with fewer pest problems
Record keeping, in particular noting effect of pesticide treatments
Tagging trees with issues to keep track of them
Trialing new techniques, species and products (on a small area of the farm)

**Did this project reduce unnecessary pesticide applications?**

While this is not a primary goal of the project, it is a primary goal of IPM and of interest for that reason.

Yes, used more oil
Yes
Yes, sprayed only herbicides in 2012
Oh, yeah! And we changed the chemicals we are using to more appropriate ones

3b. Discussion

We would expect the initial project choice list and the 'what did you learn' list to be similar at least, and scouting and pest identification are high in both. The differences in the two lists support the continuing need for education mentioned previously, on topics such as record keeping, calibration, and use of GDD, for example. Specific tools for those topics need to be developed in order to see a change in practice.

We would also expect the procedures that have been implemented or those they intend to implement to mirror the differences seen in the initial and final surveys. In some cases, they did but the implemented practices list is more specific, being in the growers' own words. The breadth of changes is encouraging, from a relatively short-term project.

While the indicated reduction in pesticide use is not quantified, it is encouraging and suggests that in the future, we could work with these growers to measure actual changes in pesticide use.

Accomplishments

The project activities were designed to help us gain a better understanding of the current level of adoption of IPM by NYS Christmas tree growers, their specified needs for educational information and tools, and how we might work with them to increase their use of IPM. Based on the work of the educators and the growers, we have progressed a long way to understanding those 3 essential elements, as can be seen in the results discussed above. While the ultimate project goals are longer term than the grant period, these accomplishments give us a good basis for continuing to work with NYS Christmas tree growers to help them produce better trees with fewer pest issues.

Some of the other accomplishments are less tangible and more difficult to measure. One in particular is the interaction between CCE educators and PIs that was provided for by the project. While many of us work together in other areas, this project expanded the network by which we will all succeed. Also, it provided the potential for face-to-face and out-in-the-field interactions between growers and Extension that can lead to a continuing educational relationship.

### Significant contributions and role of project partners

Without both the CCE educators and the participating growers – and their close cooperation, this project would not have been possible. Their activities and contributions are detailed in the previous section. We are extremely grateful to the growers for their free donation of time and experience and to the CCE Educators for their dedication to the project.

### **Goals and Outcomes Achieved**

The long-term objective of this project is to increase the use of available IPM tools by Christmas tree growers in NYS based on current NYS Christmas tree growers' use of IPM and knowledge gained while working with them to expand their level of adoption. Using knowledge gained from 12 growers and at on-farm Open Houses, we want to create a plan for the development of educational materials and how to extend them to continue the expansion of IPM and the production of quality trees by NYS growers in the future.

#### 1. Activities completed (additional information in Project Approach section)

Twelve growers were identified to be part of the project. CCE educators worked with each grower to evaluate their IPM practices and incorporate new practices throughout the grant period. A comparison of initial and final IPM usage surveys indicated that all 6 of the growers for whom such information has been gathered indicated that they had learned new IPM practices and added at least one IPM practices to their production methods.

Four on-farm Open Houses were held with the assistance of the participating growers. These were in the Hudson Valley, Long Island, Johnstown and the North Country. At each, growers presented information on their IPM practices, supported by CCE educators and PIs. Information gathered from project growers was also presented at 3 additional educational programs.

Baseline and final data for these activities, and for the achievement of long-term goals are illustrated in the Project Approach section.

#### 2. Progress toward achievement of long-term goals

The baseline data from the initial grower survey, and the information learned from growers during field visits provides the backbone of identifying IPM topics for which tools and educational materials need to be created to reach the long-term objective of this project. In addition, working with the project growers, which we expect to continue past the grant period, and through the Open Houses gives us the experience, and the sounding board, we need to ensure that these tools and materials are properly designed to be practical and adoptable by NYS Christmas tree growers and will result in the adoption of IPM practices.

### 3. Comparison of actual accomplishments and established goals

While there are some activities that have not yet been completed, the intended results of the project are largely fulfilled. We intend to complete the following activities to provide additional support and information for the long-term goal and to expand upon the knowledge gained during the project.

- a. Complete the final surveys for the remaining 5 growers
- b. Hold at least 4 additional Open Houses in the regions that have not yet been covered
- c. Do evaluations of knowledge gained by the participants of the 2013 Open Houses
- d. Survey NYS Christmas tree growers on their previous participation in IPM programs, knowledge gained and implementation of IPM practices in their production systems

#### **Beneficiaries**

There are approximately 700 Christmas tree farmers in New York State with at least 3 acres in trees and they farm in nearly every county in the state (Darling, Christmas Tree Farmers of New York, personal communication). The USDA Nursery Crops 2006 Summary (SP Cr 6-3(07)) states that the 129 NYS growers surveyed farmed approximately 8,000 acres, and sold 245,000 trees with approximately \$7 million in gross sales.

The most direct beneficiaries of this project are the 12 growers who participated in the on-farm aspects of the project with the CCE educators. All of growers surveyed increased their use of IPM by at least 1 activity and several by as many as 3, and indicated that they learned new information, and generally reduced pesticide use. The approximately 120 growers who participated in 2012 Open Houses, the approximately 165 growers who participated in other educational programs that benefitted from information gleaned during this project, and the growers who will attend the Open Houses planned for 2013 all learned IPM tactics with potential benefits for their own operations.

As we continue to develop educational tools based on lessons learned in this grant, we will also expand the audiences that we educate and the number of NYS Christmas tree growers who benefit.

#### **Lessons Learned**

There were 2 primary lessons learned as part of this project:

##### 1) Methods for achieving improvements in adoption of IPM

The intersection of knowledge and experience of the growers, the CCE educators, and the PI was the crux of this project. The direct contact with the field as a classroom is a very persuasive situation. This applies to teaching new techniques to the individual growers who participated in the project as well as to the on-farm Open Houses where participating growers can explain what they have learned and put in practice to other growers. "Nothing teaches like experience" should flavor as many of our teaching opportunities as possible.

##### 2) Topics and techniques for which educational tools and materials are needed

The initial and final surveys provide a good overview of where the gaps in education are. The procedures that were adopted by the project growers indicated which others require additional support to encourage adoption.

### 3) Lessons from outcomes yet to be achieved

There are additional lessons to be learned from the aspects of the project that will continue after the project period. Surveys of growers who have and have not yet attended educational programs intended to promote the use of IPM will give us a better understanding of what topics and techniques can be encouraged through oral presentations alone and which require a more hands-on approach. We will evaluate some of the new educational tools developed at the Open Houses planned for 2013 to determine if they are effective and adopted.

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#### **Additional Information**

Photographs of the Johnstown and Brainardsville Open Houses are included in the Quarter 12 report (October 2012).

Shamrock Tree Farm, Mattituck Open House



Abel's Trees, Verbank Open House



## **Project Title: New York Peaches and Apricots: More than Just Tasty Fruits**

### **Project Summary**

Over two harvest seasons – 2009 and 2010 – 12 peach and 7 apricot commercial varieties grown in New York were assessed on the basis of their physical, chemical and nutritional properties. The intended outcomes were to obtain information about healthful benefits the fruits offer in order to increase marketability, and to develop all-natural, value-added products rich in fruit content.

All peach and apricot varieties studied were found to be significant sources of phenolic, antioxidant and carotenoid compounds. For peaches, PF 23 and PF 22007 had the highest phenolic content and antioxidant capacity and Baby Gold 5 the highest carotenoids; Hargrand apricot ranked highest in all three categories. Apricots had twice the amount of phenolic and antioxidant content as peaches and up to ten times the carotenoid content, providing up to 30% of RDI for vitamin A per serving. Catechin, chlorogenic acid, neochlorogenic acid and cyanidin-3-glucoside were the major polyphenolic compounds present in both fruits while  $\beta$ -carotene was the main carotenoid. Antioxidant capacity in both fruits was due primarily to hydrophilic compounds, with the lipophilic fraction contributing marginally.

Maturity at harvest and processing procedures were also studied for their influence on nutritional content of fruit and fruit products. Typically, phenolic and antioxidant content decreased and carotenoid content increased with maturity while nutritional changes in processed products varied considerably with treatment type.

Production processes were optimized and all natural, value-added products with high fruit content were developed from both fruits including nectars, dried fruit, jam and canned fruit. Complete production procedures that can be implemented by farmers and processors were developed and are included in this report.

The qualitative and quantitative data obtained from this study provides relevant information about the nutritive value and commercial opportunities of New York peaches and apricots. The nutritional information obtained will be available to NY farmers and processors and is being published in scientific and trade publications to disseminate the findings, thus the relevant facts can be incorporated into Nutrition Panels in labels and in promotional materials.

### **Project Approach**

The peach (*Prunus persica*) and apricot (*Prunus armeniaca*) are two of the most consumed stone fruits worldwide. New York (NY) peaches and apricots have however not enjoyed the same scale of cultivation and commercialization relative to other production areas (e.g. California) and local fruits (e.g. NY apples) due to significant environmental and socio-economic challenges involved in their cultivation in this region<sup>1-3</sup>. The best argument for public attention to these fruits is the ever-increasing evidence of the various health benefits of fruit and vegetables<sup>4-6</sup>. Both fruits are nutrient-rich reserves of healthful compounds, primarily antioxidants, polyphenolics and carotenoids, as well as vitamin C, iron, fibre and potassium<sup>7-9</sup>.

Polyphenolics are widely distributed in plant tissue and play a role in fruit colour and taste. Major phenolic compounds in both fruits include catechin, epicatechin, chlorogenic acid and derivatives of cyanidin and quercetin<sup>10-14</sup>. Carotenoids are regarded as the most widespread pigments in nature and are responsible for colours ranging from yellow to orange and red. Predominant carotenoids in these fruits are  $\beta$ -carotene,  $\alpha$ -carotene, zeaxanthin, lutein,  $\beta$ -cryptoxanthin and lycopene<sup>8,15-18</sup>.

The main health benefits of peaches and apricots are attributed to their antioxidant content. Antioxidants are compounds effective against free radical species that damage DNA, proteins and lipids. Research thus far indicates that these compounds work against the incidence of cardiovascular diseases, cancers and aging<sup>19,20</sup>. Antioxidant capacity in these fruits is derived from both hydrophilic (phenolic) and lipophilic (carotenoid) compounds, with the former being the primary contributor<sup>21-23</sup>. Notably, chlorogenic and neochlorogenic acid have been found to be chemopreventive against breast cancer while  $\beta$ -carotene has been suggested to have a preventive effect against lung and colorectal cancer<sup>24,25</sup>.

Peaches and apricots are also sources of vitamin A precursors, namely carotenoids  $\beta$ -carotene,  $\alpha$ -carotene and  $\beta$ -cryptoxanthin. Vitamin A deficiency can lead to xerophthalmia, blindness and premature death; it remains a leading cause of child mortality in developing countries. Zeaxanthin and lutein, although lacking provitamin A abilities, accumulate in the macular of the eye and protect against age-related macular degeneration<sup>25</sup>.

In both fruits, further research is required to identify and quantify the antioxidant and provitamin A activity of phenolic and carotenoid compounds and also assess the effects of growing, harvesting, handling and processing conditions on the concentration and availability of these nutrients<sup>25,26</sup>. This report details the findings of our study to develop physical, chemical and nutritional profiles for 12 peach and 7 apricot varieties commercially available in NY, and investigate the effects of production practices and processing procedures on these.

With current trends of increased consumption of fruits and vegetables, and greater awareness about health complications and diseases linked to poor diet choices, consumers are looking for good quality products with proven health benefits. The primary aim of this project was to provide information about NY peach and apricot varieties and increase knowledge about the health benefits of local varieties by assessing their nutritive value (polyphenolics, antioxidants and carotenoids) in fresh or processed form. Qualitative and quantitative data obtained is being disseminated through conference presentations, and trade and peer reviewed publications, thus enabling their utilization in labeling and promotional information, with the overall goal of contributing to the appeal and marketability of NY varieties and corresponding value-added products.

### **1.1 Activities performed**

The first phase of the study, conducted in 2009, was a screening process in which as many varieties as possible were sourced; a total of twelve peach and seven apricot varieties were procured from local orchards. In 2010, ten peach and five apricot varieties were re-assessed.

#### **a. Physical and chemical characterization**

Analysis was performed in triplicate, allotting 5 fruit per replicate (Figure 1). L, a and b colour values were measured with a HunterLab UltraScan XE (Hunter Associates Laboratory Inc., Reston, VA);

two measurements each were taken of skin and flesh. Two firmness reading were taken per fruit using an 8 mm plunger from a McCormick Fruit Tester, model FT 327 (McCormick Fruit Tech., Yakima, WA) in 2009 and one measurement per fruit with a TA-XT2 Texture Analyzer (Texture Technologies Corp., Scarsdale, NY) in 2010. Brix (Leica Auto ABBE refractometer; Leica Inc., Buffalo, NY), pH (Accumet Basic AB15 pH meter; Fisher Scientific, Waltham, MA) and titratable acidity in malic acid equivalents (manual titration and Mettler Toledo 20 compact titrator; Mettler-Toledo Inc., Columbus OH) were measured from juice extracted using a food processor. Moisture content values were obtained from the weight difference before and after lyophilisation.

b. Phenolic, antioxidant and carotenoid profiling

In both years, fruit and fruit products underwent qualitative and quantitative nutritional profiling (Figure 1). Total phenolic content was assessed by a colorimetric assay using the Folin-Ciocalteu (FC) reagent and expressed as mg gallic acid equivalents (mg GAE)<sup>27,28</sup>. Additionally, in 2010, individual phenolic compounds were identified via high performance liquid chromatography (HPLC)<sup>29,30</sup>. 2009 carotenoids were measured via an assay of hexane extractable compounds and expressed as µg beta carotene equivalents (µg BCE)<sup>31</sup>. In 2010, carotenoid profiles were developed by HPLC and reported as µg/ 100 g<sup>32-34</sup>.

In 2009, hydrophilic and lipophilic antioxidant capacity were obtained using a modification of the fluorometric oxygen radical absorbance capacity (ORAC) procedure to partition hexane and aqueous-extractable compounds and expressed as µmol trolox equivalents (µmol TE/100 g)<sup>35,36</sup>. Building on information from that year – particularly that the lipophilic component was only 2-3% of total antioxidant capacity – in 2010 total antioxidant capacity was directly assessed using another modification of the ORAC procedure<sup>36,37</sup>.

c. Effect of fruit maturity at harvest

Information from the 2009 harvest was used to identify three peach and three apricot varieties of nutritional or commercial importance. In 2010, these were selectively harvested at two points – commercial maturity and full maturity, the latter occurring 6-10 days after the former depending on variety – in line with farmers' schedules and established indicators of maturity. Fruit from commercial maturity was stored and analysed as a third treatment – storage.

d. Processing and development of value-added products

The six selected varieties were processed to investigate the effects of selected processing procedures on nutritional content. Canning and drying were performed with fruit of commercial maturity while jam and nectar were obtained using pureed fruits at full maturity. For each processing type, two frequently used treatments were employed and optimized, and their effect on nutritional components compared (Figure 2).

e. Statistical Analysis

Tests were conducted in duplicate or triplicate as required and analyzed with JMP 9.0 Statistical Software (SAS Institute Inc, Cary, NC). Data was subjected to analysis of variance (ANOVA) and means compared with the Tukey Significant Difference test at 95% confidence interval. Nutritional data was reported per 100 g edible portion (flesh and skin) of fresh fruit.

## 1.2 Significant results, conclusion and recommendations

### Fruit and varietal characterization

Notable differences between the 2009 to the 2010 harvest seasons (Tables 1-3) include a significant increase in soluble solids with an equally significant decrease in moisture content. This was in line with expectations due to differences in rainfall patterns between the two years resulting in an accumulated 30.11 inches for 2009 and 14.35 inches for 2010<sup>38</sup>. Total phenolic content (TP) increased in peaches and sugar-to acid ratio in apricots. A change was also observed in titratable acidity, with an increase in peaches and a decrease in apricots. Visually, the fruits of 2010, particularly apricots, appeared smaller than those of 2009. Parameters such as carotenoid concentration (CC) and antioxidant capacity (AOX) could not be effectively compared from one year to the next as assays were modified; qualitative AOX rankings however remained similar from one year to the next.

In 2009, average peach TP was 45.2 mg GAE and average AOX was 746.2  $\mu\text{mol TE}$  with PF 23 highest in both categories. John Boy 2 had the highest CC, greater than two times the overall average of 714.0  $\mu\text{g BCE}$ . In 2010, PF 22007 had the highest TP and AOX and averages for both parameters were 57.5 mg GAE and 1992.8  $\mu\text{mol TE}$ , respectively. Baby Gold 5 showed highest CC with the average being 487.8  $\mu\text{g BC}$ .

For 2009 apricots, Hargrand showed impressively high TP and AOX values while the average across apricot varieties was 124.9 mg GAE and 1804.5  $\mu\text{mol TE}$ , respectively. Mascot had the highest CC, with fruit average at 886.1  $\mu\text{g BCE}$ . In 2010, Hargrand again had highest TP and AOX with average values for both parameters being 167.4 mg GAE and 4097.3  $\mu\text{mol TE}$ , respectively. Hargrand also showed highest CC with average apricot CC 4027.9  $\mu\text{g BC}$ .

In both years, TP and AOX content for apricot were more than double that of peaches. For CC, however, apricot concentrations appeared only slightly higher than those for peaches in 2009, but about 10-fold higher in 2010. This discrepancy was attributed to differences in sensitivity of the two methods employed. Results in 2010 were considered more representative as they were obtained via an optimized high performance liquid chromatography method.

In peaches, the predominant phenolic compounds identified were catechin and chlorogenic acid. In apricots, the predominant phenolic compound was catechin, with significant amounts of epigallocatechin, neochlorogenic acid, chlorogenic acid, rutin and epicatechin. Beta-carotene was the main carotenoid in both fruit types with other identified compounds being beta-cryptoxanthin, lutein and zeaxanthin.

Hargrand apricot proved very rich in phenolic and antioxidant content. High values of catechin were observed in this variety and theorized to be the main factor behind its outstanding TP and AOX values. It could well provide the incentive required to drive the NY apricot market. PF 23 peach ranked highest in sensory evaluation and, together with its high phenolic and antioxidant content, could be promoted for fresh consumption.

### Effect of maturity at harvest and storage

In 2010, the influence of fruit maturity at harvest as well as storage was studied. Fruits harvested at commercial maturity (CM) were compared to those harvested at full maturity (FM) to investigate changes occurring during on-tree ripening and storage. In apricots, a storage study was conducted only on Hargrand as the other varieties did not store well under experimental conditions.

In both fruits, maturity was marked by an increase in brix, pH, sugar-to-acid ratio and a decrease in titratable acidity, similar to previously observed trends<sup>39</sup>; moisture content patterns were variety dependent. In peaches, AOX remained stable, TP decreased and CC increased from CM to FM. Nutritive components remained relatively stable under cold storage and thus ST was observed to have higher TP but lower CC than FM. Similar trends were observed in apricots, except that CC increased during storage for the single variety studied. CC increase with on-tree ripening was particularly pronounced in apricots, showing as much as a three-fold increase from CM to FM.

In general, these findings are in agreement with earlier studies<sup>40</sup> and could inform decisions concerning harvesting schedules, depending on the intended use or proposed promotion niche of fruit products.

#### Effect of processing on nutritional content

As mentioned, selected varieties underwent processing to study effects on nutrient content and retention. Products were manufactured using standard processing techniques and nutritionally compared per 100 g serving. In some cases, optimized production processes were developed the following year.

Canned products were processed with and without skin to investigate the nutritional implications of the latter, which is the preferred processing method due to visual appeal (Figure 3). Peaches and apricots canned with skin had higher TP, AOX and CC than those canned without (Table 4). The removal of skin resulted in significant losses of pertinent compounds, particularly cyanidin-3-glucoside in peaches, quercetin-3-glucoside in apricots and catechin in both. These observations point to the need for better information about the distribution of nutritional compounds within the fruit and how these are therefore influenced by routine processing treatments. The syrup in which fruit was canned was found to possess 60% TP and 85% AOX antioxidant equivalent to that of the fruit it contained; suggestions on secondary uses of syrup would aid in gaining optimum nutritional benefit from canned products. The procedure was modified in 2011 in an attempt to reduce nutrient loss (Figure 4).

For dried fruit, the objective was to find a viable alternative for sulfite-dried products in response to concerns about sulfite sensitivity as well as the push for more natural products. After initial trials – including the use of ascorbic acid, sucrose and stevia dips – a treatment using a sucrose solution soak with pasteurization was selected, with a sulfite treatment as control (Figure 5). In dried peaches, the sucrose+SO<sub>2</sub> drying treatment had higher TP, AOX and CC than the sucrose+pasteurization treatment. In apricots, the sucrose+pasteurization drying treatment had overall higher TP and AOX but lower CC than the sucrose+SO<sub>2</sub> treatment (Table 5). This was however due mainly to the strong influence of Harlayne; Hargrand and Harogem showed higher nutritional values across board for the sucrose+SO<sub>2</sub> treatment. Visually, however, products from the sucrose+pasteurization treatment did not match up to those of the control. In 2011, this process was optimized by increasing final water activity, addressing possible shelf life concerns by vacuum packing end products (Figure 6). Additionally, two new treatments were developed based on proposed antibrowning properties of rhubarb juice due to its oxalic acid content<sup>41</sup>. The sucrose and rhubarb juice treatments, which included a pasteurization component, yielded visually appealing products and hold promise as viable commercial options.

Jam and nectar were prepared from fruit puree (Figure 7). In both instances, nutritional implications of the production of standard or reduced sucrose versions of fruit products were examined.

Standard jam was made to 65-70 °Brix and the reduced sucrose product 55-60 °Brix (Figure 8). The greater fruit content of reduced sucrose jam resulted in higher TP, AOX and CC than standard jam (Table 6). Compared to other products, however, jam had overall low nutritional content. In 2011, therefore, an optimized process was formulated to increase fruit content, with technical challenges being the maintenance of texture. This was accomplished by capitalizing on the known properties of available varieties. Harlayne apricot was chosen for its high brix content (20°Brix), allowing for fruit content of up to 70% while ensuring good set and texture (Figure 9).

Nectar was produced following specifications outlined in the USDA Commercial Item Description database (Figure 10)<sup>42</sup>. Standard nectars had a Brix value of 16 and reduced sucrose products 14, obtained by replacing 30% of sucrose from the standard product with a natural, high intensity sweetener, stevia (Rebaudioside-A 97%; PureCircle, Oak Brook, IL). The tartness of both fruits, particularly apricots, served to sufficiently mask the aftertaste associated with sugar substitutes. Differences between standard and reduced sucrose nectar were not significant, primarily due to equal fruit content – 70%. In peaches, standard nectar had higher TP and AOX but lower CC than reduced sucrose nectar. For apricots, TP was higher in reduced nectar while AOX and CC were higher in standard nectar.

In 2011, the same protocol was used to formulate 100 calorie fruit beverages, using either peach or apricot, with fruit content ranging from 50% (Harlayne apricot) to 90% (Red Haven peach), depending on fruit and varietal characteristics. The high sugar-to-acid ratio of peach allowed for the manufacture of a peach beverage with no added sugar, while stevia (Rebaudioside-A 99%; Good&Sweet Stevia, Life Concepts Inc., Rancho Santa Margarita, CA) was used in preparation of the apricot beverage, allowing for an acceptable level of sweetness while maintaining low sugar and caloric content.

Figures 11 and 12 provide images of the fresh and processed peach apricot products. Overall nutrient retention, determined on dry fruit solid content basis, was in the order dried fruit>canned fruit>nectar>jam. Generally, in peach products, Red Haven had the noticeably high post-processing values, while Hargrand had the highest for apricots. While results for Hargrand were anticipated, those for Red Haven were unexpected – as the variety was often of average or low relative nutritional value when fresh. This outcome points at differences in the stability or availability of nutritive compounds among varieties, influencing their response to processing treatments and conditions. Such information, coupled with Red Haven’s low ranking in sensory evaluation (8<sup>th</sup>) suggests that this variety may be better suited for processing as opposed to fresh consumption.

### **Goals and Outcomes Achieved**

The project completed all the established objectives:

- Perform physical, chemical and nutritional characterization of NY peaches and apricots.
- Evaluate the nutritional value of and nutrient retention in peach and apricot processed products.
- Develop high fruit content, value-added products with high appeal to consumers.
- Obtain quantitative data which can be used in the promotion and labeling of local products.

The study achieved the primary aims of evaluating and providing information on a substantial and commercially important number of local peach and apricot varieties, and developing value-added peach and apricot shelf-stable products that can be produced locally. Our target was to evaluate at

least 10 peach and 4 apricot varieties and to develop at least 3 value-added products containing at least 60% fruit. We surpassed our goal by studying 12 peach and 7 apricot varieties and by developing 4 categories of shelf-stable products with at least 2 viable options within each category with full analysis and complete processing diagrams. Findings have been presented at the Institute of Food Technologist (IFT) Annual Meetings in 2010, 2011 and 2012, where they were met with genuine interest, since such research had until now been the purview of high-producing states, particularly California, and little information was available on Northeast varieties. The discovery of exceptional New York varieties like Hargrand could contribute to a renewed patronage of these fruits.

Apricots, which generally receive considerably less attention than peaches, have proven to have higher concentrations of bioactive compounds, possessing twice as much phenolic and antioxidant compounds and up to ten times the carotenoid content as peaches within this study. On a 100 g weight basis, phenolic and antioxidant capacity of apricots and antioxidant capacity of peaches were equivalent to those reported for grapes, with Hargrand having more than doubled the average TP and AOX of grapes<sup>43</sup>. Considering the additional provision of carotenoids, these fruits are more nutritionally diverse than either apples or grapes. Following current guidelines, apricots can be classified as good sources of vitamin A, providing on average 30% of the recommended daily intake for vitamin A<sup>44, 45</sup>.

On a scientific basis, this project has provided a means of testing a number of hypotheses, allowing for an assessment of the influences of intrinsic and extrinsic factors on the overall nutritional values of these fruit and laying the foundation for future research. Findings will be submitted for publication in peer-reviewed journals and one paper has been already published in the New York Fruit Quarterly, acknowledging funding sources. Appropriate summaries will be available to New York farmers and processors interested in implementing our findings.

The included Appendix presents a summary of all results pertinent to the project.

## **Beneficiaries**

This project has a direct impact on all fresh peach and apricot producers in NY. This is the first report that worked specifically in NY and Northeast varieties since the 1980's, which only covered traditional quality parameters. Based on USDA NASS, there are more than 500 peach and apricot farms in the state. We expect that the results from this project will improve the competitiveness of fresh producers due to the quantitative information that is now available (ORAC values, phenolic and carotenoid content), which will help differentiate the NY fruit from out of state and imports. Consumers are more likely to buy a local high quality product that has proven benefits.

The project also provides information that allows the farmers to select fruit for fresh market or processed utilization based on overall quality, nutritional value and performance after processing. In addition, the fresh fruit business will be leveraged with value-added products, which will decrease losses (fruit not fit for fresh market due to size or appearance), extend season and increase awareness of NY products. Consumers are very familiar with the drawbacks of foods with "chemicals", therefore offering a quality-natural-local-nutrient rich NY fruit product with extended shelf-life will most likely create consumer loyalty and expanded markets. There is the added convenience factor of shelf-stable fruit products: easy to carry, no fruit waste, in many cases appropriate as children's snacks. Collaboration between peach and apricot producers and processors is also expected if the value-added products develop fit the processors capabilities. For farm-based producers, a complete blue-print

design has been developed to facilitate implementation of the processing stages into their packing house or to build a processing area.

### **Lessons Learned**

Working with stone fruits proved to be challenging due to the lack of information and uniformity regarding harvest time and post-harvest handling. Due to weather conditions from one year to another, some varieties were not available in consecutive years, thus disrupting the collection of data to validate findings from the first year.

Local farmers were very receptive to this project because of the apparent benefits that would be derived from the results, and the fact that the new information would help their specific crops without being a competitive advantage to a particular producer.

Overall, this was a very rewarding project that became a doctorate research for one Cornell student, thus giving the student the opportunity to work with farmers and real life situations.

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### **Additional Information**

All pertinent detailed information is presented in the Appendix.

Publications to date:

Campbell, O. E., Padilla-Zakour, O. I. (2012). *Alternative methods for the production of all natural dried peaches and apricots*. Las Vegas, NV, USA: 2012 IFT Annual Meeting. Estimated number of stakeholders that attended this poster presentation: 60.

Campbell, O. E., Merwin, I. A., Padilla-Zakour, O. I. (2011). *Nutritional Quality of New York Peaches and Apricots* (ed., vol. 19, pp. 12-16). Geneva, NY, USA: New York Fruit Quarterly. This is a publication that reached most US Fruit growers. It is available in print and electronic forms.

Campbell, O. E., Merwin, I. A., Padilla-Zakour, O. I. (2011). *Effects of harvest, storage, and processing on antioxidant, phenolic, and carotenoid content of selected Northeast peaches and apricots*. New Orleans, LA, USA: 2011 IFT Annual Meeting. Estimated number of stakeholders that attended this poster presentation: 35.

Campbell, O.E., Padilla-Zakour, O.I. and Merwin I. 2010. Antioxidant, phenolic and carotenoid content of selected Northeast peaches and apricots. Institute of Food Technologists Annual Meeting & Food Expo, Chicago, IL. Abstract 190-10. Estimated number of stakeholders that attended this poster presentation: 25.

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## Appendix

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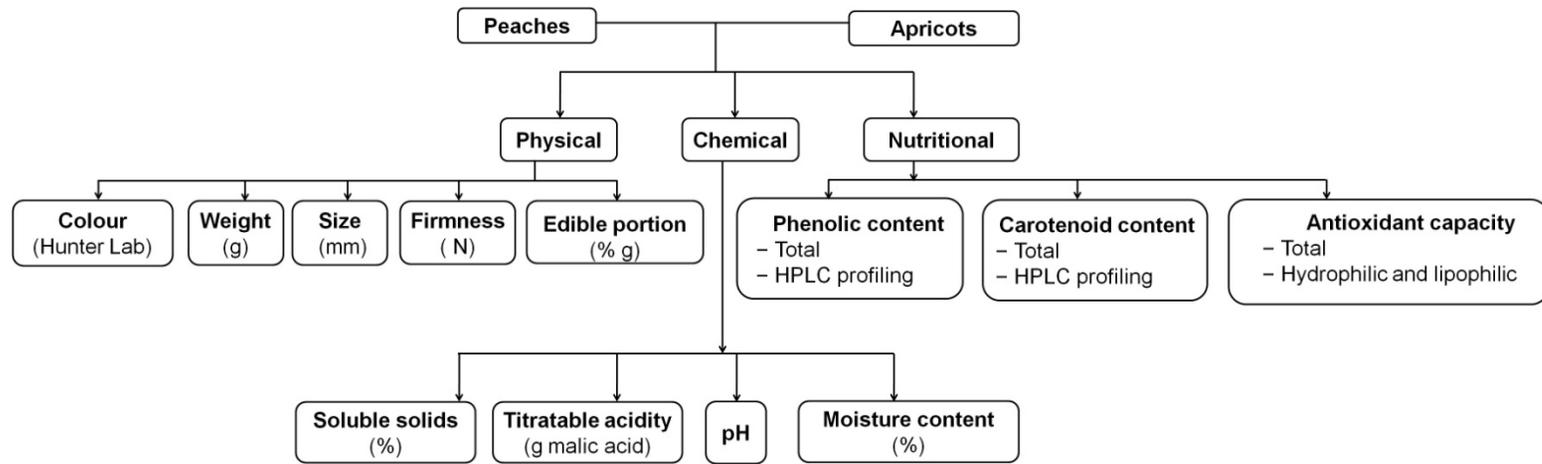


Figure 1. Physical, chemical and nutritional analyses of fresh and processed products.

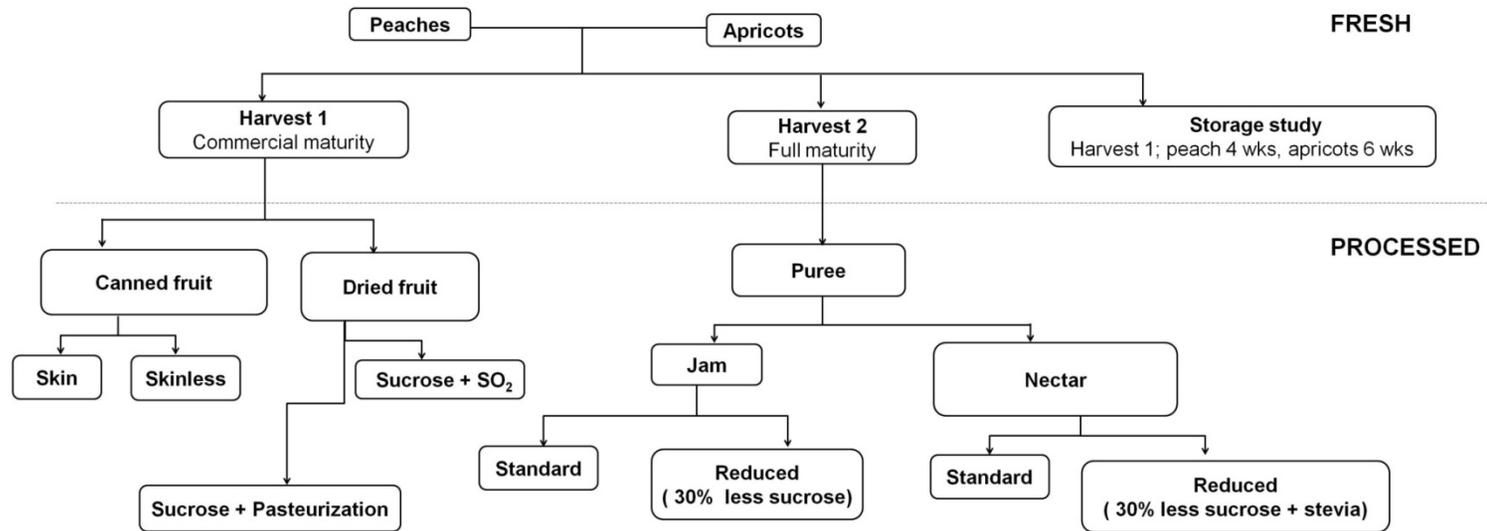
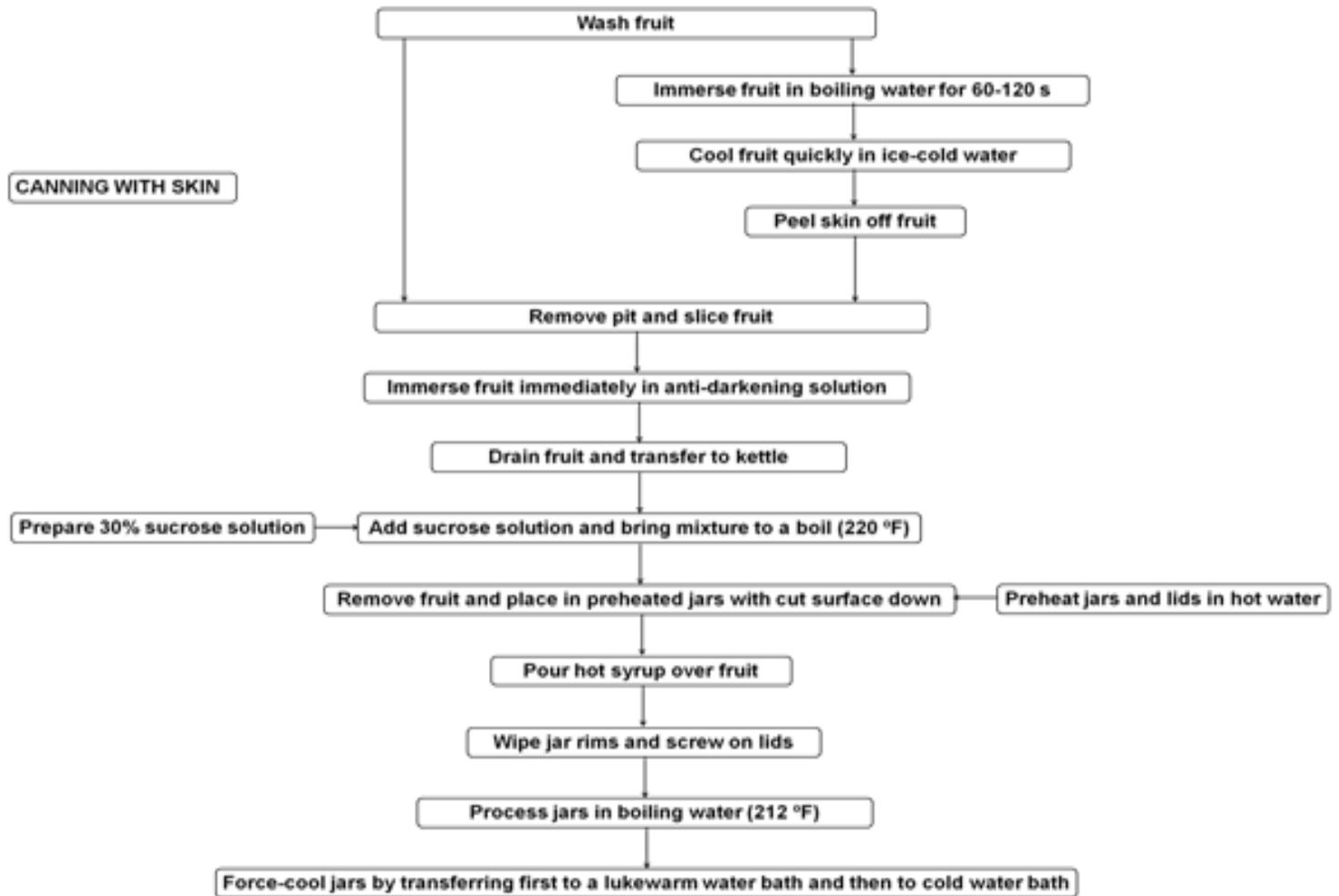


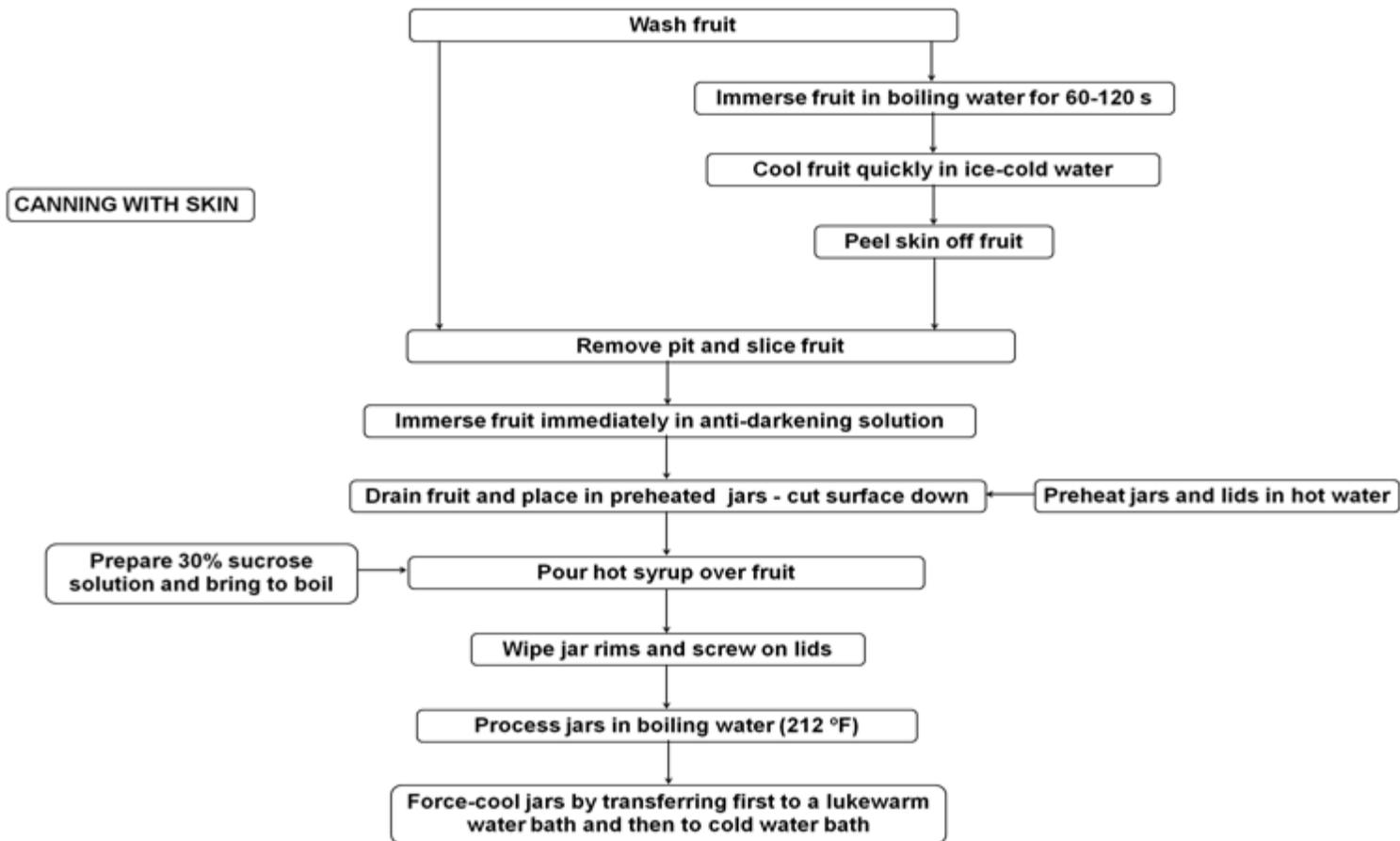
Figure 2. Experimental design for harvest, storage and processing of peaches and apricots.



**Notes:**

- Anti-darkening solution = 50.4 g citric acid, 25.2 g calcium chloride and 8.4 g ascorbic acid made up to 1 gallon (3.7875 kg or 8.35 lb) with water.
- For a load of 8 half-pint jars, heat penetration studies gave effective processing specifications as 15 min for peach and 17 min for apricot, where product ratio was 60% fruit to 40% syrup.

Figure 3. Flow chart for the manufacture of canned peaches and apricots



**Notes:**

- *Anti-darkening solution = 50.4 g citric acid, 25.2 g calcium chloride and 8.4 g ascorbic acid made up to 1 gallon (3.7875 kg or 8.35 lb) with water.*
- *For a load of 8 half-pint jars, heat penetration studies gave effective processing specifications as 15 min for peach and 17 min for apricot, where product ration was 60% fruit to 40% syrup.*

Figure 4. Flow chart for the optimized manufacture of canned peaches and apricots

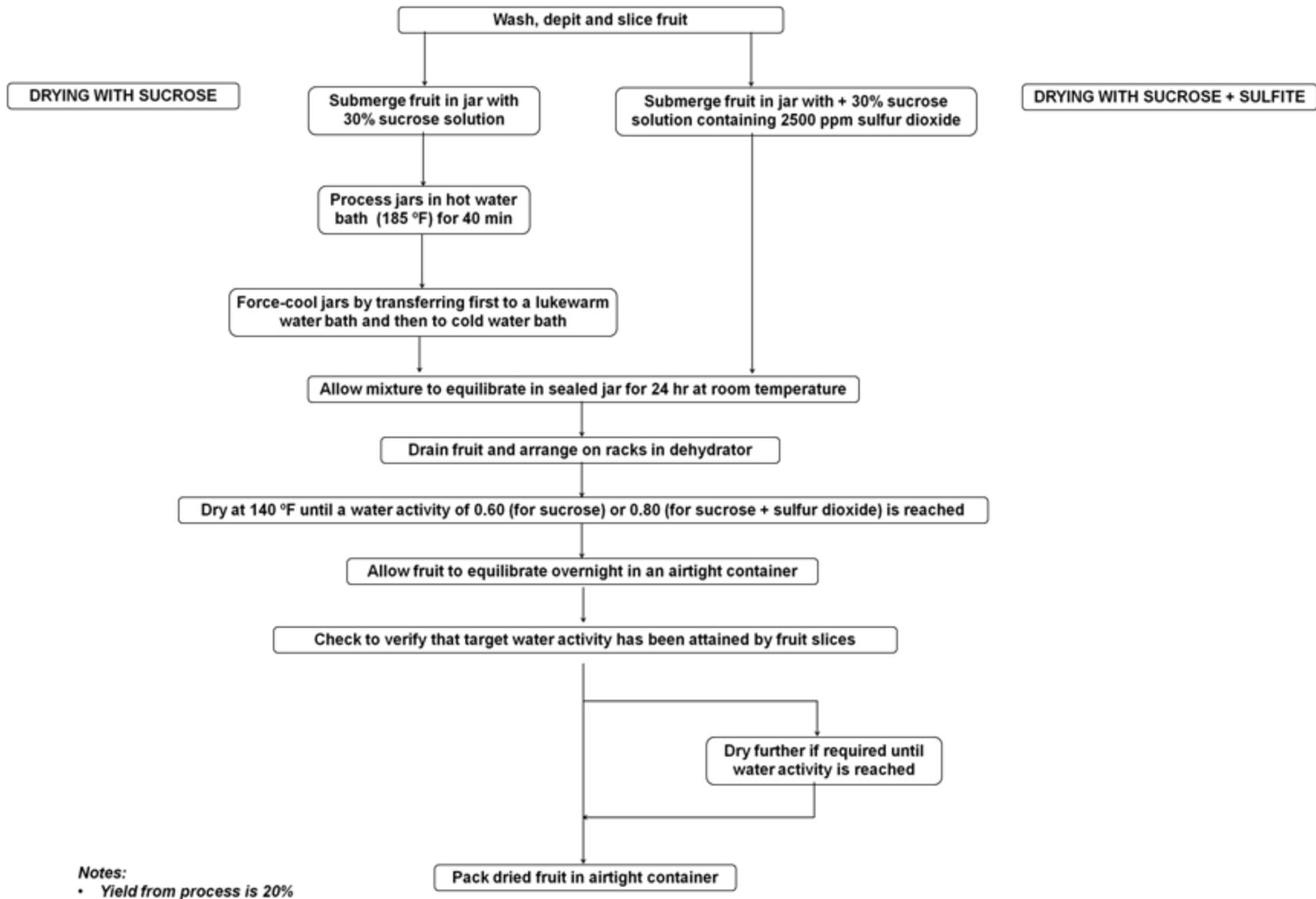
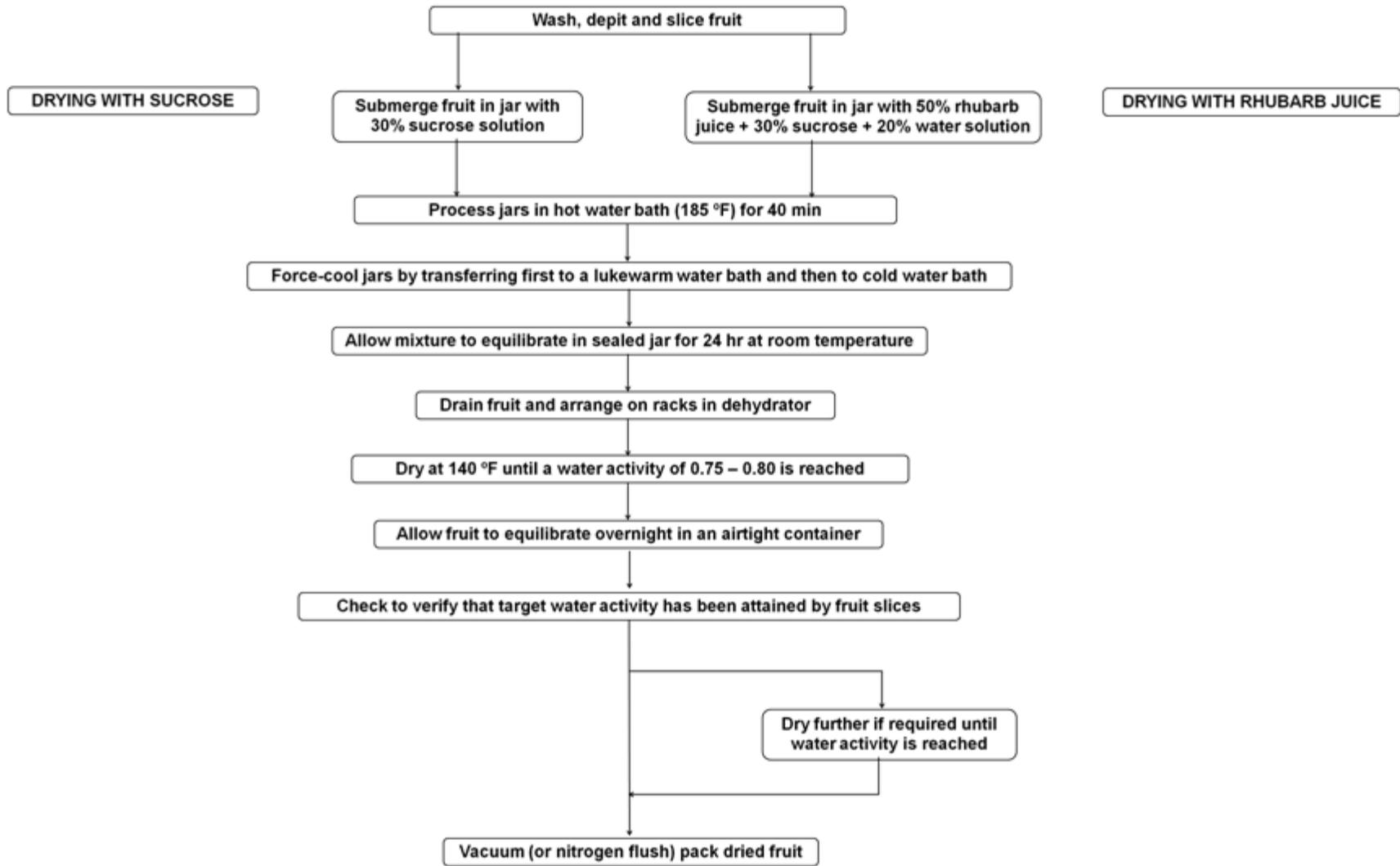


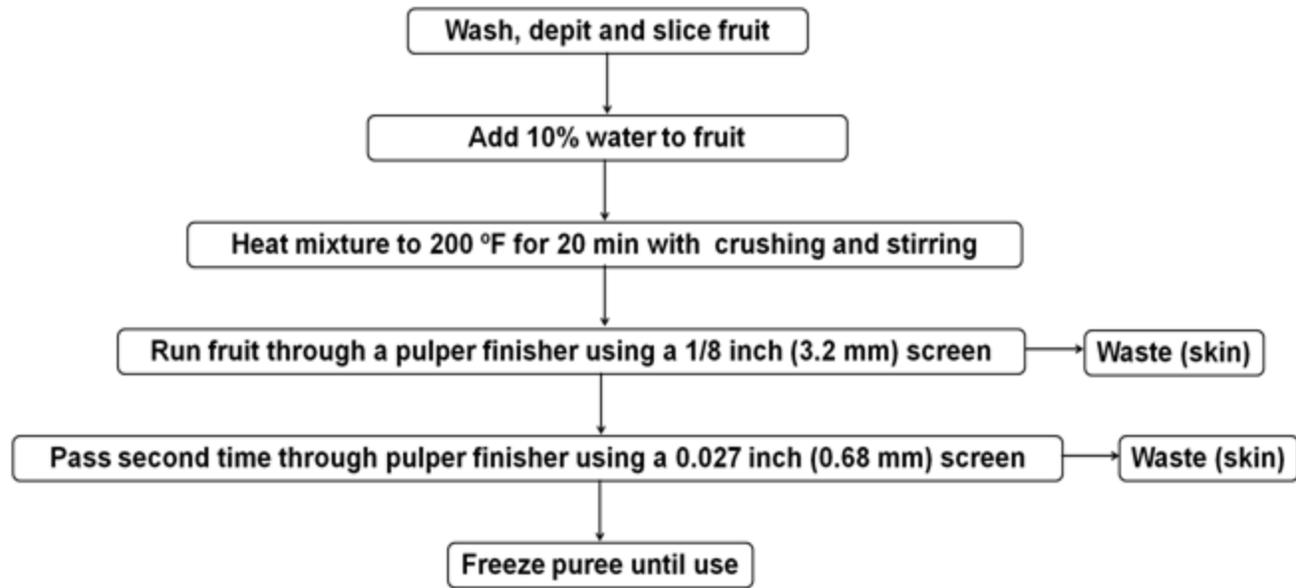
Figure 5. Flow chart for manufacture of dried peaches and apricots



**Notes:**

- Yield from process is 20%

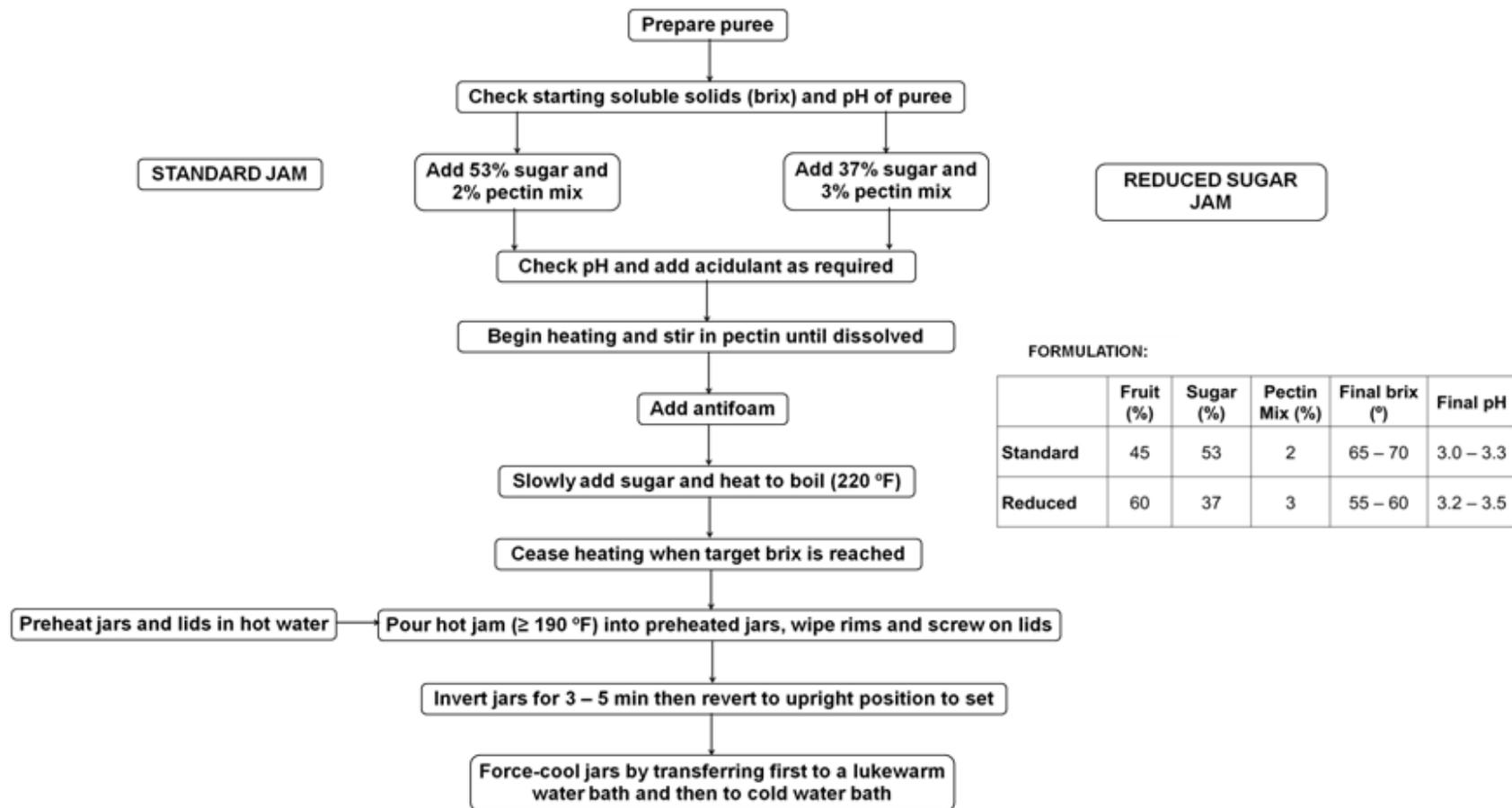
Figure 6. Flow chart for optimized manufacture of dried peaches and apricots



**Notes:**

- Yield from process is 60%

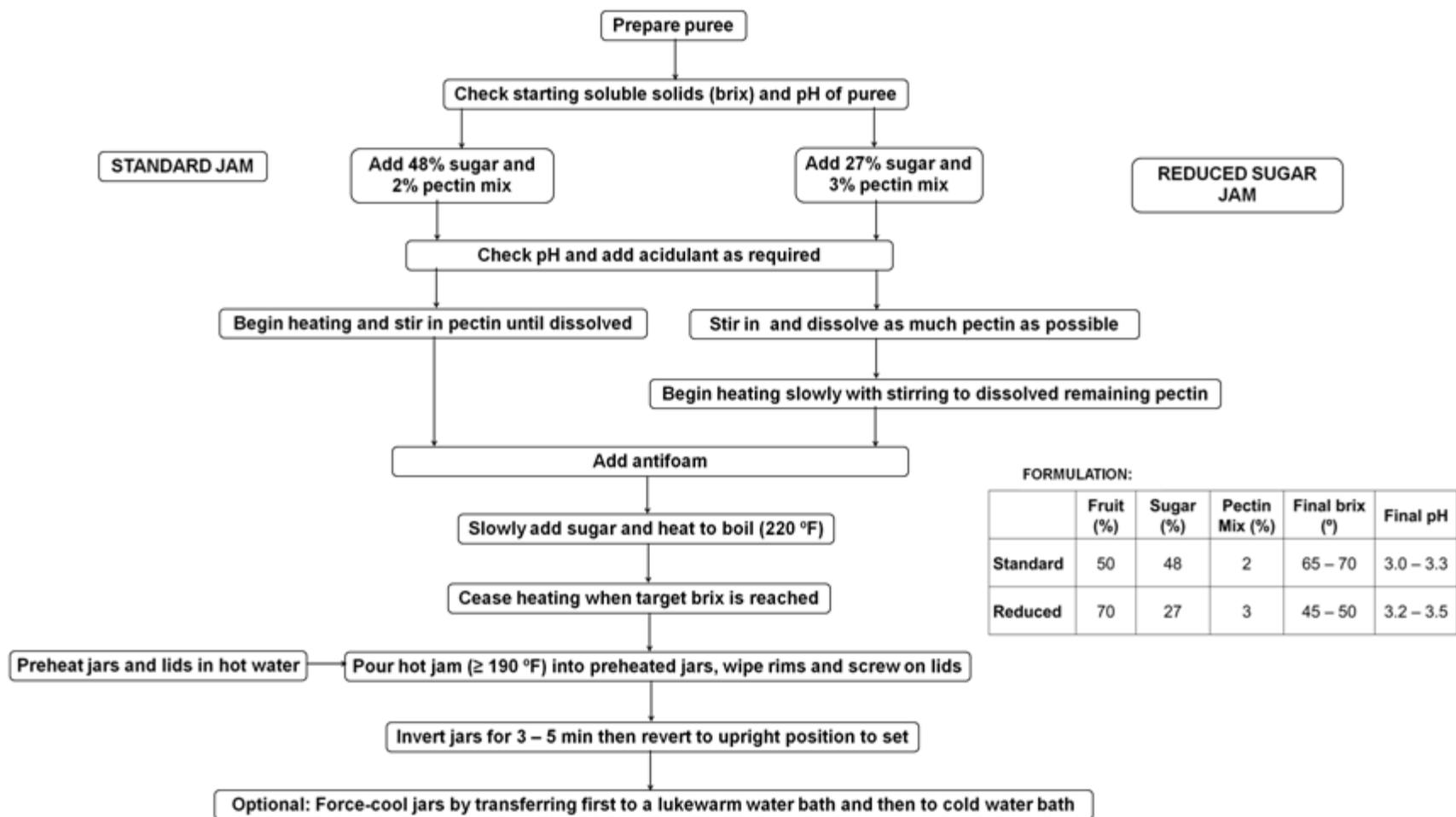
Figure 7. Flow chart for manufacture of peach and apricot puree



**Notes:**

- Pacific pectin mix was used for standard jam and Pacific LM-3 pectin for reduced sugar jam (Pacific pectin, Oakhurst, CA)
- Approximately 3 drops of Pacific Pectin double strength antifoam were used per kg jam

Figure 8. Flow chart for manufacture of peach and apricot jam



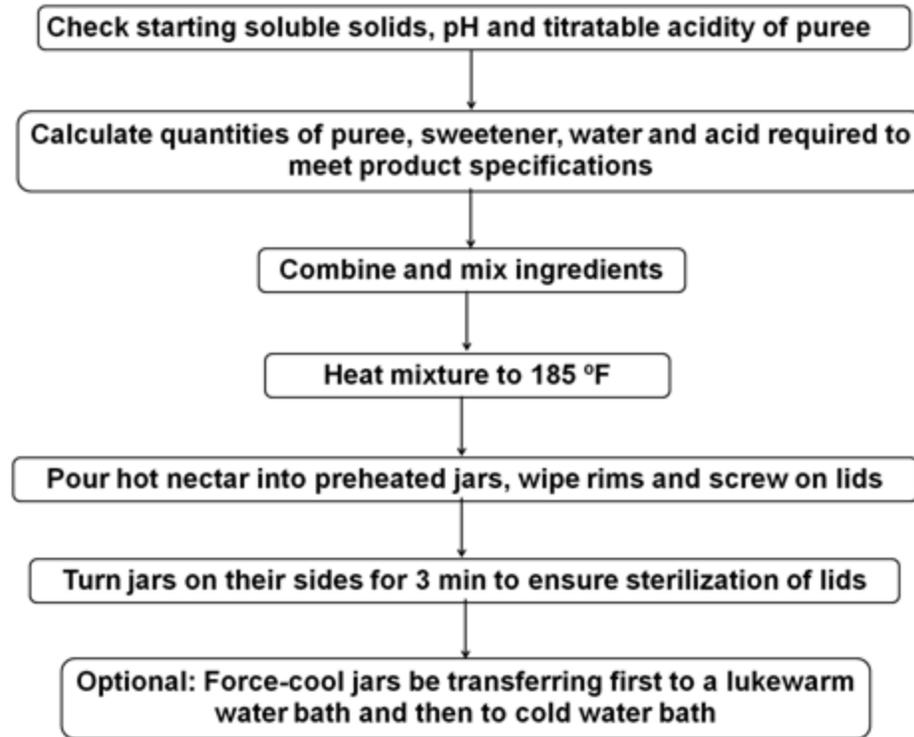
FORMULATION:

	Fruit (%)	Sugar (%)	Pectin Mix (%)	Final brix (°)	Final pH
Standard	50	48	2	65 – 70	3.0 – 3.3
Reduced	70	27	3	45 – 50	3.2 – 3.5

**Notes:**

- Fruit content for reduced sugar jam is variety-dependant. For better texture for varieties with lower starting brix, fruit content may be reduced to 65%
- Pacific pectin mix was used for standard jam and Pacific LM-3 pectin for reduced sugar jam (Pacific pectin, Oakhurst, CA)
- Approximately 3 drops of Pacific Pectin double strength antifoam were used per kg jam

Figure 9. Flow chart for optimized manufacture of peach and apricot jam



**FORMULATION OF 100 CALORIE BEVERAGES:**

<b>Fruit</b>	<b>Puree (%)</b>	<b>Water (%)</b>	<b>Sucrose (%)</b>	<b>Stevia (%)</b>	<b>Final brix (°)</b>	<b>Final sugar-to-acid ratio</b>
<b>Peach (Red Haven)</b>	90	7.23	2.77	-	11	18
<b>Apricot (Harlayne)</b>	50	49.60	0.20	0.20	11	28

Figure 10. Flow chart for manufacture of peach and apricot nectar



Baby Gold 5



Bounty



Harrow Beauty



John Boy



John Boy II



PF 22007



PF 23



PF Lucky 13



Red Haven



Vivid



Hargrand



Harogem



Harlayne



Vivagold

**Figure 11. Peach and apricot varieties**



Canned peaches with and without skin



Apricots dried with sucrose+SO<sub>2</sub>, sucrose+pasteurization and rhubarb juice+pasteurization



Peach and apricot jam



Peach and apricot nectar

*Notes:*

*For jam and nectar, significant visual differences existed between peach and apricot products but not between standard and reduced sugar products.*

**Figure 12. Processed peach and apricot products.**

**Table 1. Chemical characteristics of selected New York peaches and apricots**

Variety	Soluble solids (%)		pH		Titratable acidity (g malic acid/100 ml)		Sugar-to-acid ratio		Moisture content (%)	
	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
<b>PEACH</b>	<i>p</i> <0.0001	<i>p</i> <0.0001	<i>p</i> <0.0001	<i>p</i> <0.0001	<i>p</i> <0.0001	<i>p</i> =0.0007	<i>p</i> <0.0001	<i>p</i> =0.0358	<i>p</i> <0.0001	<i>p</i> <0.0001
Baby Gold 5	9.70 ± 0.42 <sup>def</sup>	11.77 ± 0.45 <sup>ab</sup>	3.87 ± 0.08 <sup>a</sup>	3.96 ± 0.06 <sup>a</sup>	0.48 ± 0.03 <sup>e</sup>	NA	20.44 ± 0.41 <sup>ab</sup>	NA	88.47 ± 0.12 <sup>de</sup>	85.36 ± 0.11 <sup>c</sup>
Bounty	8.56 ± 0.18 <sup>e</sup>	12.03 ± 0.58 <sup>a</sup>	3.79 ± 0.03 <sup>a</sup>	3.75 ± 0.02 <sup>b</sup>	0.48 ± 0.03 <sup>e</sup>	0.74 ± 0.07 <sup>a</sup>	17.78 ± 1.14 <sup>bc</sup>	16.30 ± 1.69 <sup>a</sup>	89.86 ± 0.50 <sup>ab</sup>	86.65 ± 0.48 <sup>bc</sup>
Clings	10.11 ± 0.16 <sup>bcd</sup>	NA	3.84 ± 0.05 <sup>a</sup>	NA	0.51 ± 0.04 <sup>de</sup>	NA	20.03 ± 1.81 <sup>ab</sup>	NA	88.58 ± 0.09 <sup>cd</sup>	NA
Glo Haven	9.03 ± 0.28 <sup>efg</sup>	NA	3.61 ± 0.04 <sup>cde</sup>	NA	0.65 ± 0.01 <sup>b</sup>	NA	13.83 ± 0.42 <sup>de</sup>	NA	90.65 ± 0.35 <sup>a</sup>	NA
Harrow Beauty	9.78 ± 0.10 <sup>cdef</sup>	10.23 ± 0.57 <sup>bcd</sup>	3.53 ± 0.02 <sup>def</sup>	3.66 ± 0.03 <sup>bc</sup>	0.61 ± 0.02 <sup>bcd</sup>	0.67 ± 0.05 <sup>abc</sup>	15.92 ± 0.59 <sup>cd</sup>	15.39 ± 1.67 <sup>a</sup>	88.31 ± 0.24 <sup>de</sup>	88.23 ± 0.41 <sup>ab</sup>
John Boy	10.31 ± 0.20 <sup>bcd</sup>	10.83 ± 0.32 <sup>abcd</sup>	3.65 ± 0.05 <sup>bcd</sup>	3.64 ± 0.02 <sup>bc</sup>	0.47 ± 0.02 <sup>e</sup>	0.71 ± 0.04 <sup>ab</sup>	22.15 ± 1.13 <sup>a</sup>	15.28 ± 0.70 <sup>a</sup>	88.37 ± 0.31 <sup>de</sup>	87.99 ± 0.60 <sup>ab</sup>
John Boy II	12.17 ± 0.61 <sup>a</sup>	10.03 ± 0.78 <sup>cd</sup>	3.45 ± 0.05 <sup>bcd</sup>	3.57 ± 0.04 <sup>cd</sup>	0.65 ± 0.05 <sup>b</sup>	0.51 ± 0.04 <sup>bc</sup>	18.79 ± 1.68 <sup>abc</sup>	19.81 ± 0.68 <sup>a</sup>	86.45 ± 0.21 <sup>g</sup>	88.70 ± 0.75 <sup>a</sup>
PF 22007	10.92 ± 0.22 <sup>b</sup>	11.93 ± 0.49 <sup>ab</sup>	3.52 ± 0.06 <sup>def</sup>	3.48 ± 0.07 <sup>de</sup>	0.61 ± 0.05 <sup>bcd</sup>	0.66 ± 0.03 <sup>abc</sup>	17.96 ± 1.45 <sup>bc</sup>	18.13 ± 1.07 <sup>a</sup>	87.29 ± 0.27 <sup>fg</sup>	86.12 ± 0.46 <sup>bc</sup>
PF 23	10.85 ± 0.30 <sup>bc</sup>	12.47 ± 0.76 <sup>a</sup>	3.51 ± 0.04 <sup>ef</sup>	3.58 ± 0.07 <sup>cd</sup>	0.70 ± 0.03 <sup>ab</sup>	0.76 ± 0.14 <sup>a</sup>	15.43 ± 1.11 <sup>cd</sup>	16.93 ± 4.14 <sup>a</sup>	87.64 ± 0.18 <sup>ef</sup>	86.93 ± 0.37 <sup>c</sup>
PF Lucky 13	8.91 ± 0.48 <sup>fg</sup>	11.07 ± 0.40 <sup>abc</sup>	3.56 ± 0.02 <sup>def</sup>	3.50 ± 0.03 <sup>de</sup>	0.54 ± 0.02 <sup>cde</sup>	0.55 ± 0.11 <sup>abc</sup>	16.49 ± 0.49 <sup>cd</sup>	20.78 ± 4.88 <sup>a</sup>	89.67 ± 0.03 <sup>b</sup>	88.10 ± 0.60 <sup>ab</sup>
Red Haven*	8.85 ± 0.49 <sup>fg</sup>	9.24 ± 0.89 <sup>d</sup>	3.77 ± 0.03 <sup>ab</sup>	3.64 ± 0.05 <sup>bc</sup>	0.62 ± 0.06 <sup>bc</sup>	0.44 ± 0.11 <sup>c</sup>	14.35 ± 1.59 <sup>de</sup>	21.98 ± 5.14 <sup>a</sup>	90.65 ± 0.21 <sup>a</sup>	89.42 ± 1.02 <sup>a</sup>
Red Haven JB*	8.75 ± 0.19 <sup>fg</sup>	NA	3.74 ± 0.04 <sup>abc</sup>	NA	0.79 ± 0.04 <sup>a</sup>	NA	11.05 ± 0.77 <sup>e</sup>	NA	89.44 ± 0.45 <sup>bc</sup>	NA
Vivid	9.74 ± 0.64 <sup>def</sup>	10.04 ± 0.35 <sup>cd</sup>	3.59 ± 0.04 <sup>de</sup>	3.42 ± 0.03 <sup>e</sup>	0.60 ± 0.02 <sup>bcd</sup>	0.74 ± 0.05 <sup>ab</sup>	16.13 ± 1.00 <sup>cd</sup>	13.65 ± 1.25 <sup>a</sup>	89.21 ± 0.51 <sup>bcd</sup>	89.06 ± 0.45 <sup>a</sup>
<b>Mean</b>	<b>9.82 ± 1.05</b>	<b>10.96 ± 1.07</b>	<b>3.65 ± 0.14</b>	<b>3.62 ± 0.15</b>	<b>0.59 ± 0.10</b>	<b>0.64 ± 0.12</b>	<b>16.95 ± 3.02</b>	<b>17.58 ± 2.79</b>	<b>88.81 ± 1.26</b>	<b>87.66 ± 1.33</b>
<b>APRICOT</b>	<i>p</i> =0.0005	<i>p</i> <0.0001	<i>p</i> <0.0001	<i>p</i> <0.0001	<i>p</i> <0.0001	<i>p</i> <0.0001	<i>p</i> <0.0001	<i>p</i> <0.0001	<i>p</i> <0.0001	<i>p</i> <0.0001
Harcot	12.39 ± 0.41 <sup>ab</sup>	NA	3.12 ± 0.04 <sup>cd</sup>	NA	2.36 ± 0.5 <sup>a</sup>	NA	5.24 ± 0.09 <sup>c</sup>	NA	85.68 ± 0.14 <sup>c</sup>	NA
Hargrand	13.23 ± 0.44 <sup>a</sup>	14.27 ± 0.34 <sup>a</sup>	3.08 ± 0.04 <sup>d</sup>	3.68 ± 0.06 <sup>ab</sup>	2.46 ± 0.15 <sup>a</sup>	1.82 ± 0.21 <sup>a</sup>	5.41 ± 0.50 <sup>c</sup>	7.91 ± 0.72 <sup>b</sup>	84.78 ± 0.16 <sup>d</sup>	80.87 ± 0.44 <sup>d</sup>
Harlayne	11.51 ± 1.09 <sup>ab</sup>	14.74 ± 0.27 <sup>a</sup>	3.46 ± 0.03 <sup>a</sup>	3.67 ± 0.04 <sup>b</sup>	1.65 ± 0.05 <sup>bc</sup>	1.14 ± 0.04 <sup>b</sup>	6.98 ± 0.70 <sup>ab</sup>	12.988 ± 0.21 <sup>a</sup>	87.03 ± 0.15 <sup>b</sup>	83.92 ± 0.16 <sup>c</sup>
Harogem	12.89 ± 0.66 <sup>a</sup>	14.53 ± 0.40 <sup>a</sup>	3.18 ± 0.01 <sup>c</sup>	3.69 ± 0.04 <sup>ab</sup>	1.56 ± 0.02 <sup>c</sup>	1.01 ± 0.07 <sup>b</sup>	8.26 ± 0.52 <sup>a</sup>	14.48 ± 1.00 <sup>a</sup>	85.61 ± 0.10 <sup>c</sup>	84.73 ± 0.41 <sup>c</sup>
Mascot	10.98 ± 0.25 <sup>b</sup>	NA	3.32 ± 0.04 <sup>b</sup>	NA	1.50 ± 0.13 <sup>c</sup>	NA	7.35 ± 0.63 <sup>ab</sup>	NA	87.84 ± 0.17 <sup>a</sup>	NA
Tomcot	10.54 ± 0.53 <sup>b</sup>	11.22 ± 0.59 <sup>b</sup>	3.40 ± 0.02 <sup>ab</sup>	3.48 ± 0.03 <sup>c</sup>	1.81 ± 0.05 <sup>b</sup>	1.70 ± 0.07 <sup>a</sup>	5.83 ± 0.33 <sup>bc</sup>	6.64 ± 0.61 <sup>b</sup>	87.88 ± 0.32 <sup>a</sup>	87.79 ± 0.54 <sup>a</sup>
Vivagold	10.57 ± 0.86 <sup>b</sup>	14.07 ± 0.11 <sup>a</sup>	3.35 ± 0.03 <sup>b</sup>	3.77 ± 0.01 <sup>a</sup>	1.61 ± 0.08 <sup>bc</sup>	NA	6.60 ± 0.82 <sup>bc</sup>	NA	88.20 ± 0.01 <sup>a</sup>	86.31 ± 0.10 <sup>b</sup>
<b>Mean</b>	<b>11.73 ± 1.18</b>	<b>13.77 ± 1.33</b>	<b>3.27 ± 0.14</b>	<b>3.66 ± 0.10</b>	<b>1.85 ± 0.38</b>	<b>1.41 ± 0.36</b>	<b>6.52 ± 1.15</b>	<b>10.50 ± 3.35</b>	<b>86.72 ± 1.29</b>	<b>84.73 ± 2.36</b>

NA: Not analyzed in 2010 \*\* Two samples of this variety were obtained from two different orchards to study site/geographic influence.

**Table 2. Physical characteristics of selected New York peaches and apricots**

Variety	Firmness (g)		Unit weight (g)	Cross-sectional diameter (mm)	Edible portion (%)	Hue angle (skin)		Hue angle (flesh)	
	2009*	2010**	2010	2010	2010	2009	2010	2009	2010
<b>PEACH</b>	<i>p</i> <0.0001	<i>p</i> =0.0100	<i>p</i> <0.0001	<i>p</i> <0.0001	<i>p</i> <0.0001	<i>p</i> =0.0679	<i>p</i> <0.0001	<i>p</i> <0.0001	<i>p</i> =0.0010
Baby Gold 5	2461.67 ± 154.30 <sup>cde</sup>	4765.58 ± 417.67 <sup>ab</sup>	220.53 ± 10.72 <sup>b</sup>	73.34 ± 1.40 <sup>b</sup>	93.21 ± 0.56 <sup>d</sup>	45.03 ± 3.02 <sup>a</sup>	56.89 ± 3.90 <sup>a</sup>	79.17 ± 0.70 <sup>abc</sup>	77.94 ± 0.83 <sup>a</sup>
Bounty	1126.67 ± 495.41 <sup>efg</sup>	2510.28 ± 84.47 <sup>b</sup>	179.47 ± 10.09 <sup>c</sup>	68.98 ± 0.30 <sup>c</sup>	94.94 ± 0.42 <sup>bc</sup>	54.23 ± 2.90 <sup>a</sup>	45.28 ± 1.30 <sup>bcd</sup>	80.21 ± 0.27 <sup>ab</sup>	77.55 ± 0.33 <sup>a</sup>
Clings	3123.33 ± 458.84 <sup>bc</sup>	NA	NA	NA	NA	42.79 ± 5.67 <sup>a</sup>	NA	78.64 ± 0.35 <sup>bcd</sup>	NA
Glo Haven	411.67 ± 41.93 <sup>g</sup>	NA	NA	NA	NA	50.56 ± 5.34 <sup>a</sup>	NA	81.63 ± 0.64 <sup>ab</sup>	NA
Harrow Beauty	4673.33 ± 686.46 <sup>a</sup>	5048.78 ± 1472.91 <sup>a</sup>	95.87 ± 7.11 <sup>d</sup>	56.49 ± 2.28 <sup>e</sup>	94.85 ± 0.37 <sup>c</sup>	47.64 ± 3.10 <sup>a</sup>	38.14 ± 1.64 <sup>ef</sup>	78.79 ± 0.33 <sup>bcd</sup>	77.24 ± 2.54 <sup>ab</sup>
John Boy	803.33 ± 431.58 <sup>fg</sup>	4609.60 ± 409.36 <sup>ab</sup>	189.13 ± 4.88 <sup>c</sup>	71.47 ± 0.68 <sup>bc</sup>	95.77 ± 0.24 <sup>abc</sup>	44.08 ± 2.86 <sup>a</sup>	35.51 ± 0.67 <sup>f</sup>	73.58 ± 2.34 <sup>e</sup>	72.97 ± 1.03 <sup>bc</sup>
John Boy II	2801.67 ± 653.08 <sup>cd</sup>	3501.79 ± 155.30 <sup>ab</sup>	174.73 ± 0.28 <sup>c</sup>	70.49 ± 1.09 <sup>bc</sup>	95.68 ± 0.22 <sup>abc</sup>	47.85 ± 4.89 <sup>a</sup>	41.90 ± 2.18 <sup>cde</sup>	75.65 ± 1.51 <sup>de</sup>	72.49 ± 1.65 <sup>c</sup>
PF 22007	2156.67 ± 907.89 <sup>cdef</sup>	5242.06 ± 1648.07 <sup>a</sup>	296.40 ± 4.42 <sup>a</sup>	83.32 ± 1.51 <sup>a</sup>	96.58 ± 0.06 <sup>a</sup>	46.42 ± 10.53 <sup>a</sup>	38.23 ± 1.50 <sup>ef</sup>	80.82 ± 1.80 <sup>ab</sup>	76.71 ± 2.05 <sup>abc</sup>
PF 23	4351.67 ± 260.21 <sup>ab</sup>	3152.58 ± 500.28 <sup>ab</sup>	184.20 ± 6.25 <sup>c</sup>	70.23 ± 1.16 <sup>bc</sup>	95.34 ± 0.68 <sup>bc</sup>	43.48 ± 6.52 <sup>a</sup>	40.90 ± 2.07 <sup>cdef</sup>	78.41 ± 0.39 <sup>bcd</sup>	74.85 ± 1.48 <sup>abc</sup>
PF Lucky 13	1818.33 ± 772.31 <sup>cdefg</sup>	4146.40 ± 942.92 <sup>ab</sup>	198.47 ± 2.30 <sup>bc</sup>	72.62 ± 0.71 <sup>bc</sup>	96.07 ± 0.23 <sup>ab</sup>	44.97 ± 2.36 <sup>a</sup>	40.20 ± 2.46 <sup>def</sup>	75.99 ± 2.00 <sup>cde</sup>	75.34 ± 2.05 <sup>abc</sup>
Red Haven	401.67 ± 111.84 <sup>g</sup>	4096.76 ± 553.85 <sup>ab</sup>	121.27 ± 0.86 <sup>d</sup>	61.86 ± 1.53 <sup>d</sup>	93.63 ± 0.12 <sup>d</sup>	47.82 ± 4.44 <sup>a</sup>	46.44 ± 0.85 <sup>bc</sup>	82.28 ± 0.27 <sup>a</sup>	78.27 ± 0.81 <sup>a</sup>
Red Haven JB	3101.67 ± 269.00 <sup>bc</sup>	NA	NA	NA	NA	56.96 ± 2.70 <sup>a</sup>	NA	80.23 ± 0.89 <sup>ab</sup>	NA
Vivid	1300.00 ± 499.17 <sup>defg</sup>	5007.68 ± 651.11 <sup>a</sup>	186.93 ± 9.32 <sup>c</sup>	72.33 ± 1.83 <sup>bc</sup>	95.06 ± 0.54 <sup>bc</sup>	48.68 ± 5.79 <sup>a</sup>	48.59 ± 1.47 <sup>b</sup>	80.60 ± 0.81 <sup>ab</sup>	76.84 ± 1.26 <sup>abc</sup>
<b>Mean</b>	<b>2194.75 ± 1394.49</b>	<b>4208.15 ± 906.70</b>	<b>184.70 ± 53.77</b>	<b>70.11 ± 7.10</b>	<b>95.11 ± 1.04</b>	<b>47.73 ± 4.17</b>	<b>43.21 ± 6.30</b>	<b>78.92 ± 2.53</b>	<b>76.02 ± 2.03</b>
<b>APRICOT</b>	<i>p</i> <0.0001	<i>p</i> <0.0001	<i>p</i> <0.0001	<i>p</i> <0.0001	<i>p</i> <0.0001	<i>p</i> =0.0050	<i>p</i> =0.0002	<i>p</i> <0.0001	<i>p</i> <0.0001
Harcot	3750.00 ± 240.68 <sup>a</sup>	NA	NA	NA	NA	54.18 ± 7.05 <sup>ab</sup>	NA	62.87 ± 0.47 <sup>b</sup>	NA
Hargrand	2730.00 ± 558.86 <sup>ab</sup>	680.53 ± 162.22 <sup>c</sup>	48.93 ± 1.81 <sup>a</sup>	43.18 ± 1.15 <sup>bc</sup>	94.21 ± 0.26 <sup>a</sup>	64.37 ± 1.13 <sup>a</sup>	60.04 ± 3.83 <sup>a</sup>	64.09 ± 0.51 <sup>a</sup>	56.32 ± 0.76 <sup>c</sup>
Harlayne	1643.33 ± 575.70 <sup>bc</sup>	1207.51 ± 219.08 <sup>b</sup>	49.60 ± 1.56 <sup>a</sup>	45.05 ± 0.71 <sup>b</sup>	94.36 ± 0.05 <sup>a</sup>	54.23 ± 5.51 <sup>ab</sup>	55.97 ± 1.39 <sup>ab</sup>	63.96 ± 0.45 <sup>a</sup>	62.48 ± 1.04 <sup>ab</sup>
Harogem	2058.33 ± 470.01 <sup>bc</sup>	1069.29 ± 22.68 <sup>bc</sup>	48.20 ± 2.82 <sup>a</sup>	47.77 ± 0.46 <sup>a</sup>	94.30 ± 0.30 <sup>a</sup>	52.93 ± 6.75 <sup>ab</sup>	48.48 ± 0.55 <sup>c</sup>	62.63 ± 0.27 <sup>bc</sup>	63.69 ± 1.09 <sup>a</sup>
Mascot	750.00 ± 176.92 <sup>c</sup>	NA	NA	NA	NA	46.03 ± 4.51 <sup>b</sup>	NA	61.66 ± 0.48 <sup>b</sup>	NA
Tomcot	2378.33 ± 215.77 <sup>b</sup>	1180.31 ± 186.40 <sup>b</sup>	24.40 ± 2.62 <sup>b</sup>	35.08 ± 1.64 <sup>d</sup>	91.78 ± 0.61 <sup>b</sup>	59.70 ± 2.05 <sup>a</sup>	59.19 ± 1.92 <sup>a</sup>	62.19 ± 0.19 <sup>bc</sup>	61.16 ± 0.49 <sup>b</sup>
Vivagold	2896.67 ± 794.31 <sup>ab</sup>	1803.45 ± 191.64 <sup>a</sup>	48.87 ± 3.44 <sup>a</sup>	41.77 ± 0.32 <sup>c</sup>	91.55 ± 0.17 <sup>b</sup>	61.92 ± 2.02 <sup>a</sup>	52.72 ± 0.61 <sup>bc</sup>	61.59 ± 0.08 <sup>a</sup>	58.41 ± 0.19 <sup>c</sup>
<b>Mean</b>	<b>2315.24 ± 960.91</b>	<b>1188.22 ± 403.37</b>	<b>44 ± 10.97</b>	<b>42.57 ± 4.75</b>	<b>93.24 ± 1.44</b>	<b>56.20 ± 6.24</b>	<b>55.28 ± 4.59</b>	<b>62.71 ± 1.01</b>	<b>60.41 ± 2.87</b>

\* and \*\* indicate that parameter was measured using different methods in the two years.

**Table 2 cont. Physical characteristics of selected New York peaches and apricots**

Variety	Skin colour (L)		Skin colour (a)		Skin colour (b)		Flesh Colour (L)		Flesh colour (a)		Flesh colour (b)	
	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
<b>PEACH</b>	<i>p</i> =0.1073	<i>p</i> <0.0001	<i>p</i> =0.0007	<i>p</i> =0.0063	<i>p</i> =0.0529	<i>p</i> <0.0001	<i>p</i> <0.0001	<i>p</i> =0.0004	<i>p</i> <0.0001	<i>p</i> =0.0004	<i>p</i> <0.0001	<i>p</i> <0.0001
Baby Gold 5	49.12 ± 3.00 <sup>a</sup>	56.45 ± 2.12 <sup>a</sup>	24.05 ± 4.83 <sup>bc</sup>	19.90 ± 2.34 <sup>b</sup>	26.97 ± 4.82 <sup>a</sup>	34.22 ± 3.30 <sup>a</sup>	68.88 ± 0.94 <sup>abc</sup>	63.27 ± 0.76 <sup>abcd</sup>	9.08 ± 0.73 <sup>bc</sup>	10.12 ± 0.67 <sup>bc</sup>	47.15 ± 0.93 <sup>a</sup>	47.16 ± 0.67 <sup>ab</sup>
Bounty	53.56 ± 3.13 <sup>a</sup>	47.47 ± 1.15 <sup>bcd</sup>	23.99 ± 1.45 <sup>bc</sup>	20.04 ± 0.56 <sup>b</sup>	35.44 ± 2.81 <sup>a</sup>	24.48 ± 1.28 <sup>cd</sup>	67.94 ± 1.10 <sup>bc</sup>	62.72 ± 1.55 <sup>abcd</sup>	7.83 ± 0.23 <sup>cd</sup>	10.99 ± 0.49 <sup>abc</sup>	45.08 ± 0.49 <sup>ab</sup>	49.97 ± 0.78 <sup>a</sup>
Clings	47.61 ± 5.13 <sup>a</sup>	NA	25.46 ± 2.53 <sup>abc</sup>	NA	26.08 ± 5.28 <sup>a</sup>	NA	69.00 ± 0.90 <sup>abc</sup>	NA	9.54 ± 0.54 <sup>abc</sup>	NA	46.88 ± 1.13 <sup>a</sup>	NA
Glo Haven	56.35 ± 4.92 <sup>a</sup>	NA	25.19 ± 0.62 <sup>abc</sup>	NA	31.91 ± 4.75 <sup>a</sup>	NA	70.96 ± 0.78 <sup>ab</sup>	NA	6.25 ± 0.51 <sup>d</sup>	NA	42.40 ± 0.69 <sup>c</sup>	NA
Harrow Beauty	51.17 ± 3.07 <sup>a</sup>	43.84 ± 0.85 <sup>de</sup>	31.85 ± 1.13 <sup>a</sup>	23.77 ± 0.38 <sup>ab</sup>	35.73 ± 2.58 <sup>a</sup>	20.44 ± 1.67 <sup>d</sup>	73.06 ± 1.58 <sup>a</sup>	64.78 ± 4.41 <sup>abc</sup>	8.56 ± 0.34 <sup>cd</sup>	9.83 ± 1.26 <sup>c</sup>	42.95 ± 0.96 <sup>bc</sup>	45.47 ± 1.74 <sup>bc</sup>
John Boy	48.89 ± 2.41 <sup>a</sup>	43.94 ± 0.54 <sup>de</sup>	30.55 ± 1.24 <sup>ab</sup>	25.47 ± 2.47 <sup>ab</sup>	30.46 ± 2.09 <sup>a</sup>	18.91 ± 1.94 <sup>d</sup>	62.79 ± 3.68 <sup>d</sup>	59.55 ± 2.42 <sup>cd</sup>	11.92 ± 1.69 <sup>a</sup>	12.83 ± 0.81 <sup>a</sup>	40.69 ± 0.50 <sup>cd</sup>	42.57 ± 1.21 <sup>c</sup>
John Boy II	50.94 ± 4.84 <sup>a</sup>	44.65 ± 1.82 <sup>de</sup>	28.62 ± 1.98 <sup>abc</sup>	21.05 ± 1.36 <sup>ab</sup>	33.12 ± 3.66 <sup>a</sup>	20.10 ± 0.46 <sup>d</sup>	65.87 ± 0.46 <sup>cd</sup>	57.17 ± 0.95 <sup>d</sup>	11.63 ± 1.15 <sup>ab</sup>	12.94 ± 0.75 <sup>a</sup>	46.09 ± 0.39 <sup>a</sup>	42.97 ± 1.01 <sup>bc</sup>
PF 22007	50.74 ± 6.21 <sup>a</sup>	46.06 ± 1.20 <sup>cde</sup>	29.96 ± 4.18 <sup>ab</sup>	27.12 ± 4.23 <sup>a</sup>	33.02 ± 7.53 <sup>a</sup>	23.67 ± 1.32 <sup>cd</sup>	68.97 ± 0.30 <sup>abc</sup>	63.54 ± 2.46 <sup>abc</sup>	6.22 ± 1.29 <sup>d</sup>	10.01 ± 1.05 <sup>bc</sup>	38.68 ± 0.22 <sup>d</sup>	42.39 ± 2.01 <sup>c</sup>
PF 23	46.40 ± 2.47 <sup>a</sup>	42.60 ± 0.65 <sup>e</sup>	27.01 ± 0.92 <sup>abc</sup>	20.88 ± 3.34 <sup>ab</sup>	27.97 ± 4.93 <sup>a</sup>	19.39 ± 1.88 <sup>d</sup>	68.72 ± 0.57 <sup>abc</sup>	59.52 ± 0.69 <sup>cd</sup>	9.25 ± 0.10 <sup>bc</sup>	12.64 ± 1.40 <sup>ab</sup>	45.31 ± 0.96 <sup>ab</sup>	46.45 ± 0.69 <sup>abc</sup>
PF Lucky 13	49.94 ± 2.47 <sup>a</sup>	44.95 ± 1.94 <sup>cde</sup>	29.42 ± 1.76 <sup>abc</sup>	24.07 ± 1.20 <sup>ab</sup>	30.32 ± 1.28 <sup>a</sup>	23.29 ± 2.19 <sup>cd</sup>	67.79 ± 2.03 <sup>bc</sup>	60.20 ± 2.28 <sup>bcd</sup>	9.95 ± 1.13 <sup>abc</sup>	10.85 ± 0.54 <sup>abc</sup>	40.47 ± 1.16 <sup>cd</sup>	43.32 ± 2.96 <sup>bc</sup>
Red Haven	55.50 ± 2.72 <sup>a</sup>	49.23 ± 2.48 <sup>bc</sup>	25.33 ± 2.91 <sup>abc</sup>	24.24 ± 2.18 <sup>ab</sup>	28.79 ± 1.73 <sup>a</sup>	28.01 ± 2.79 <sup>bc</sup>	71.05 ± 0.92 <sup>ab</sup>	65.96 ± 2.50 <sup>ab</sup>	6.16 ± 0.39 <sup>d</sup>	9.56 ± 0.71 <sup>c</sup>	45.45 ± 1.14 <sup>ab</sup>	46.25 ± 1.86 <sup>abc</sup>
Red Haven JB	58.35 ± 3.73 <sup>a</sup>	NA	22.49 ± 0.59 <sup>c</sup>	NA	36.18 ± 1.75 <sup>a</sup>	NA	68.93 ± 1.08 <sup>abc</sup>	NA	7.83 ± 0.76 <sup>cd</sup>	NA	45.95 ± 0.72 <sup>a</sup>	NA
Vivid	52.47 ± 4.07 <sup>a</sup>	51.24 ± 0.25 <sup>b</sup>	28.31 ± 2.31 <sup>abc</sup>	25.13 ± 1.18 <sup>ab</sup>	33.33 ± 3.68 <sup>a</sup>	31.37 ± 1.17 <sup>ab</sup>	67.52 ± 1.47 <sup>bc</sup>	66.57 ± 0.60 <sup>a</sup>	7.64 ± 0.80 <sup>cd</sup>	11.82 ± 1.08 <sup>abc</sup>	45.99 ± 1.01 <sup>a</sup>	50.40 ± 0.51 <sup>a</sup>
<b>Mean</b>	<b>51.62 ± 3.52</b>	<b>47.04 ± 4.24</b>	<b>27.10 ± 2.91</b>	<b>23.17 ± 2.52</b>	<b>31.49 ± 3.36</b>	<b>24.39 ± 5.26</b>	<b>68.57 ± 2.51</b>	<b>62.33 ± 3.10</b>	<b>8.60 ± 1.89</b>	<b>11.16 ± 1.31</b>	<b>44.08 ± 2.75</b>	<b>45.70 ± 2.93</b>
<b>APRICOT</b>	<i>p</i> =0.0200	<i>p</i> =0.0079	<i>p</i> =0.0013	<i>p</i> <0.0001	<i>p</i> =0.0004	<i>p</i> =0.0035	<i>p</i> <0.0001	<i>p</i> =0.0003	<i>p</i> <0.0001	<i>p</i> =0.0006	<i>p</i> <0.0001	<i>p</i> =0.0008
Harcot	54.00 ± 5.55 <sup>ab</sup>	NA	25.87 ± 3.90 <sup>ab</sup>	NA	35.79 ± 3.97 <sup>b</sup>	NA	57.07 ± 0.82 <sup>cd</sup>	NA	20.64 ± 0.89 <sup>bc</sup>	NA	40.18 ± 1.41 <sup>bc</sup>	NA
Hargrand	56.17 ± 0.05 <sup>ab</sup>	53.07 ± 1.76 <sup>ab</sup>	20.32 ± 1.55 <sup>b</sup>	20.18 ± 2.26 <sup>d</sup>	41.93 ± 2.23 <sup>ab</sup>	35.38 ± 1.94 <sup>bc</sup>	54.56 ± 1.15 <sup>d</sup>	42.82 ± 1.80 <sup>c</sup>	18.65 ± 1.33 <sup>c</sup>	21.01 ± 0.58 <sup>b</sup>	38.08 ± 2.36 <sup>c</sup>	31.60 ± 1.74 <sup>c</sup>
Harlayne	54.97 ± 3.68 <sup>ab</sup>	53.42 ± 2.06 <sup>ab</sup>	28.84 ± 2.95 <sup>a</sup>	26.74 ± 0.87 <sup>bc</sup>	40.77 ± 4.07 <sup>ab</sup>	39.87 ± 2.19 <sup>ab</sup>	61.85 ± 0.53 <sup>a</sup>	51.72 ± 3.49 <sup>ab</sup>	22.69 ± 0.52 <sup>ab</sup>	19.60 ± 1.98 <sup>b</sup>	46.43 ± 0.85 <sup>a</sup>	37.33 ± 2.98 <sup>abc</sup>
Harogem	53.49 ± 4.45 <sup>ab</sup>	50.77 ± 0.34 <sup>b</sup>	31.25 ± 3.26 <sup>a</sup>	28.65 ± 0.90 <sup>ab</sup>	43.08 ± 5.24 <sup>ab</sup>	34.42 ± 0.24 <sup>c</sup>	59.90 ± 0.60 <sup>ab</sup>	56.18 ± 1.75 <sup>ab</sup>	23.72 ± 0.40 <sup>a</sup>	20.24 ± 1.63 <sup>b</sup>	45.78 ± 0.32 <sup>a</sup>	40.51 ± 1.22 <sup>ab</sup>
Mascot	49.52 ± 3.34 <sup>b</sup>	NA	33.13 ± 2.32 <sup>a</sup>	NA	35.78 ± 3.42 <sup>b</sup>	NA	56.29 ± 0.27 <sup>cd</sup>	NA	23.54 ± 0.75	NA	43.50 ± 0.68 <sup>ab</sup>	NA
Tomcot	58.09 ± 1.15 <sup>ab</sup>	56.45 ± 3.75 <sup>a</sup>	29.13 ± 1.89 <sup>a</sup>	24.73 ± 0.22 <sup>c</sup>	49.95 ± 0.74 <sup>a</sup>	41.71 ± 3.15 <sup>a</sup>	61.60 ± 1.26 <sup>a</sup>	49.28 ± 3.79 <sup>bc</sup>	23.05 ± 0.33 <sup>a</sup>	20.13 ± 1.50 <sup>b</sup>	43.62 ± 0.99 <sup>ab</sup>	36.56 ± 3.01 <sup>bc</sup>

Vivagold	61.21 ± 0.54 <sup>a</sup>	58.61 ± 0.75 <sup>a</sup>	26.44 ± 2.40 <sup>ab</sup>	30.66 ± 0.84 <sup>a</sup>	49.47 ± 1.28 <sup>a</sup>	40.38 ± 0.92 <sup>ab</sup>	58.40 ± 1.30 <sup>bc</sup>	56.82 ± 0.68 <sup>a</sup>	23.70 ± 0.88 <sup>a</sup>	26.48 ± 0.38 <sup>a</sup>	43.73 ± 1.62 <sup>ab</sup>	42.94 ± 0.92 <sup>a</sup>
<b>Mean</b>	<b>55.35 ± 3.70</b>	<b>54.46 ± 3.24</b>	<b>27.85 ± 4.18</b>	<b>26.19 ± 3.73</b>	<b>42.39 ± 5.74</b>	<b>38.35 ± 3.31</b>	<b>58.52 ± 2.75</b>	<b>51.36 ± 5.53</b>	<b>22.28 ± 1.93</b>	<b>21.49 ± 2.77</b>	<b>43.05 ± 2.97</b>	<b>37.79 ± 4.23</b>

## **Project Title: Testing New Botrytis Leaf Blight Onion Lines & Hybrids to Develop the Best Strategies for Disease Control on Conventional and Organic Farms**

New York is the 6<sup>th</sup> ranked onion producing state, with production in Orange, Oswego, Orleans, Yates, Genesee, Madison, Wayne & Steuben counties. Current onion cultivars are susceptible to the pathogen *Botrytis squamosa* the causal agent of Botrytis leaf blight (BLB). This pathogen is endemic in NY onion fields and BLB outbreaks occur yearly, with disease severity dependant climate conditions. BLB is frequently cited as a top priority by NY onion producers. Since BLB can reduce yield by 75% in untreated onion fields, this disease can severely affect grower profits and even farm survival. In the absence of BLB resistant cultivars, control of BLB is chiefly achieved through use of an intensive preventive fungicide spray program that typically begins in mid-June and continues on a weekly schedule until harvest. This significantly increases operating expenses and unnecessary release of pesticides into the environment.

This project targets Botrytis leaf blight (BLB), an important disease for NY onion production. Lacking resistant varieties, onion BLB is primarily controlled by multiple preventative fungicide applications. The Cornell breeding program produced onion lines with BLB resistance or BLB tolerance. Our goal is to determine how to utilize varieties with BLB resistance within a revised IPM framework to control BLB in traditional and organic onion production. Multisite trials in conventional and organic fields were used to determine levels of BLB control in BLB resistant lines/hybrids, and whether other fungal diseases develop. Lab tests of the pathogen (*B. squamosa*) samples from diverse locations were used to determine relative control on susceptible, resistant and tolerant plants. Results of the lab and multi site field trials will be used to create an IPM strategy for use with BLB tolerant and resistant onions for effective disease control in organic and conventional onions. The ultimate goal is to reduce crop loss, reduce fungicide sprays and expense for conventional & organic onion growers in NYS, minimize risks to human health and the environment, and reduce risk of residuals in onion for consumers.

### **Project Approach**

This is best described in 4 subsections, A through D, as follows:

3A. *To determine if there are differential responses B. squamosa isolates from around NYS to BLB resistant or tolerant onions*

This involved collection of isolates around NY, purification of isolates, then use isolates in chamber /greenhouse screens in Ithaca on susceptible and resistant onions. This work was done in Ithaca in cooperation by staff in Mutschler and Lorbeer programs. Results were measured by lesion size & degree of disease.

The outcomes fulfilled all expectations for this goal. DNA analysis of 5 *B. squamosa* isolates collected from different onion growing regions of NYS was performed using UP PCR primers. Combining the data from 4 primers was sufficient to demonstrate that these showed that they were

genetically different, not clonal. Therefore there was potential that the different isolates could have different pathogenicities.

Mist chamber tests were used to test the different *B. squamosa* isolates collected from different counties in NYS. One of these was isolate MD16, which has been used by the Cornell breeding program over the years to select for BLB resistance, and so has been in culture for many years. The other 4 new isolates tested were selected from different growing regions in NYS in 2009, and were shown by the DNA analysis to be genetically different. The results of the mist table screens clearly show that similar results were obtained when each isolate was used to inoculate the different onion genotype. In each case, the onion cultivar Candy showed the worst disease symptoms, followed by the susceptible female parent GAL-cms, the GAL-cms x BLB-R line 07-801 F1 hybrid, with the least symptoms on the BLB-R line 07-07-801. In some cases, the heterozygous F1 had significantly greater disease than that of the BLB-R line 07-801. In other cases the difference in disease on the BLB homozygous resistant line was not significantly greater than that on the BLB heterozygous resistant F1 hybrid. A similar pattern is seen when data are combined and analyzed across isolates. Overall, the tests to date do not indicate differential pathogenicity among isolates, and the MD16 isolate which has been used by the breeding program is no less pathogenic than the new isolates collected in 2009, and most importantly, none of the isolates tested to date could overcome the BLB resistance. If field tests also show no indication of the presence of *B. squamosa* that are different in their pathogenicity, the usefulness of the BLB resistance in current lines is supported

*3B. Determine the effect of heterozygous vs. homozygous BLB resistance or BLB tolerance on degree of control across locations and production systems*

Onion lines and hybrids homozygous and heterozygous, respectively, were included in the chamber tests described in 1. above. The results did not show conclusive evidence that the resistance in the homozygous resistant lines was greater than that in the heterozygous resistant hybrids. This suggests that use commercial hybrids with heterozygous BLB resistance would be sufficient to control this disease.

The activities for this goal also included regional field miniplots established and examined in multiple sites in the three major onion growing regions in NYS. Susceptible onions, and onion lines and hybrids homozygous and heterozygous, respectively, were also tested in replicated mini-plot trials performed yearly. These trials were located in Elba, Oswego, and Orange County, with the work performed by Hoepfing, Schell, and Ullrich, respectively in cooperation with Mutschler's staff. The multi-site field trials were located in onion fields in plots provided by host growers and included trials in conventional & organic production systems.

The major obstacle to these trials was the adverse weather conditions. Most of the summers included in the period of this project were notable for the hot dry weather condition for considerable stretches of time during June and/or July, the critical periods for observing BLB. Such

conditions do not favor BLB disease development. Therefore the levels of disease on the susceptible controls were often lower than anticipated. This stress limited level of disease and so might have limited our ability to detect differences in disease level.

One of the better sets of BLB data was collected from 5 of the 9 trials established in Orange County in 2010. Results from the 5 successful trials showed moderate levels of disease in the susceptible control Festival. The male sterile female parent used in the hybrid production was also susceptible, but had somewhat lower symptoms than Candy and Festival perhaps due to its smaller size (the result of inbreeding depression). The least disease was observed in the homozygous BLB resistant lines. Their disease level was significantly lower than that of the susceptible control, and two of the three fixed lines had significantly lower disease than their heterozygous BLB resistant F<sub>1</sub> hybrids (the third line did not include an F<sub>1</sub>).

Under the conditions present these years, the results show that reduced disease in the homozygous BLB resistant lines than in the susceptible controls, but diseases levels were not sufficient to provide conclusive evidence whether the resistance in the homozygous resistant lines was greater than that in the heterozygous resistant hybrids. It is possible that under conditions extremely favorable to BLB disease development that it might be possible to distinguish disease level on plants homozygous vs. heterozygous. Since no significant differences were seen as yet BLB development in heterozygous vs. homozygous resistant plants, it is likely that the heterozygous resistance will suffice for control of this disease in hybrids onions.

### *3C. Determine risk from other foliar diseases in traditional & organic production as sprays are reduced*

During the first season in this project, the miniplots were observed not only for levels of BLB, but also for entrance of secondary pathogens that typically appear later in the season, such as purple blotch. Then in the last two seasons of this project, the miniplot trials described in 2 above were doubled in size at some locations, so that half of the trial could be supplemented with fungicidal spray later in season should other diseases such as purple blotch, be seen in the fields. This performed in Elba and Orange County by Hoepting and Ullrich. Unfortunately, the later two seasons were particularly hot and dry. With little BLB or other disease noted even in susceptible control onions, it was not possible to test for reduction in disease when the plots were supplemented with mild sprays. The hot dry conditions generally suppressed development of other secondary diseases as well. Therefore despite setting out multiple trials in each of three counties, we were not able to generate the data needed to test efficacy of supplemental sprays to control secondary diseases in these plots, and to make evidence based recommendations regarding supplemental sprays to control other diseases in BLB resistant onions.

### *3D. To combine the results from the first three objectives to create a comprehensive IPM disease control strategy*

The most important information that this project was to generate was an evaluation of the potential utility of the BLB resistance, and of the current onion lines that possess this resistance. This has two components: the utility of the resistance to control BLB, and the quality of the onion lines that currently carry the BLB resistance. As described above, the utility of the BLB resistance was supported by the results obtained. This resistance could be used, at least initially, in the heterozygous condition in hybrids, perhaps in time homozygous in hybrids as well. The second aspect of the question involves the horticultural type of the current BLB resistant lines, as measured by the horticultural type of the hybrids generated by crossing these lines onto a standard female (male sterile) onion line. This was examined in all years by considering the bulbs produced by the hybrids compared to the standard onion control hybrid. The bulb sizes of the hybrids generated by crossing different BLB lines onto the same female parent varied from significantly smaller to not significantly different from that of the commercial hybrids used as the controls. General type (neck thickness, bulb shape, etc) was also approaching that of commercial hybrids. Therefore some of the BLB resistant lines are approaching the type needed for generation of commercial hybrids. The lines were released non-exclusively under MTA to all interested seed companies (ones with onion breeding programs). The companies are currently using the lines for production of experimental hybrids, and also as germplasm to move the BLB resistance gene into their proprietary lines. This is needed to generate as many BLB resistant commercial hybrids, to give onion growers a range of hybrids from which to select.

The final aspect of the work is dissemination of the information produced by the project. During the course of this project, this involved release of yearly reports, of presentations at yearly grower meetings, or reports to the seed industry, and of training materials for extension agents and growers. This was performed by all members of the interactive team. Reports were provided yearly at different venues as follows:

- To onion industry at twilight meetings (Hoepting, Mutschler). There were 30 to 40 in attendance at the NYS OIC meetings each mid July (usually July 11<sup>th</sup>) in 2010, 2011, and 2012.
- To onion industry at onion schools (Ullrich, Mutschler). Held each year in Orange County, generally in February, organized by Ullrich, with Mutschler as one of the presenters.
- At the onion section of the annual EXPO each January, Ullrich, Hoepting, and Mutschler all presented. Attendance in 2012 was 70 (of which 8 were female and 1 African American, one Asian and 2 "other"). The 2012 onion expo overall was rated as above average (excellent or good) by 98% of respondents, with Hoepting rated above average by 86% for content and 94% for delivery, and Mutschler rated above average by 87% for content and 93% for delivery. The 2010 onion expo overall was rated as above average (excellent or good) by 98% of respondents, with Hoepting rated above average by 100% for content and 100% for delivery, and Mutschler rated above average by 100% for content and 94% for delivery. Individual comments in 2011 included statements that growers were "eager to see BLB onions available" to them.
- To the NYS onion council by an oral annual report (Mutschler). There are generally 20 to 25 in attendance at these meetings, which are held every January. This meeting centers more on discussion of industry needs and issues, and is not subject to rating surveys. However in a 2011 survey of New York onion producers developed by New York State Onion Industry Council and Cornell Cooperative Extension

- *Botrytis squamosa* ranked 3<sup>rd</sup> in terms of important diseases and developing resistance to diseases and insects ranked first in terms of grower importance in breeding programs.
- To seed companies at the annual field day presentations (Mutschler). This meeting, held the last Monday of each August, provides seed companies information on ongoing work, and advanced notice of new lines for release. There are generally 30 to 40 in attendance at these meeting, representing seed national and international seed companies. This meeting is not subject to rating surveys. This meeting is followed by the annual report provided to the seed companies each January, with extensive information on progress, and listing new lines available each year. This is the mechanism through which the onion lines were released to seed companies.

Information was also provided to extension staff in-service training days held each November. In addition, a publication summarizing the work and its results is currently under review among the participants, for submission early Jan. 2013.

### **Goals and Outcomes Achieved**

Through both lab tests and regional trials, we failed to find pathogen isolates capable of overcoming BLB resistance. This is very favorable indication of the potential value of this resistance in new onion cultivars, and for reduction of use of and reliance upon fungicides to control BLB if BLB resistance onion cultivars are used by growers.

We showed that plants with heterozygous and homozygous BLB resistance showed similar reduced levels of BLB disease, at least under the conditions prevalent during this project.

We have released to seed companies the BLB resistant lines with the best horticultural type, and information regarding the utility of this resistance, to encourage use of the resistance in new onion hybrids.

We have disseminated this information to all target groups.

### **Beneficiaries**

BLB resistant onion lines have been released to industry by Mutschler's onion breeding program. Nearly all major seed companies with active onion breeding programs have obtained this germplasm, under MTA, and are using it in their breeding programs. Information regarding strength of the resistance under heterozygous vs. homozygous condition was provided to all of these seed companies, to help guide use of this resistance in their new hybrids. This will enable the seed companies to most rapidly develop and release new onion hybrids that are BLB resistant

The onion growers are also beneficiaries of this work. When the seed companies release new BLB resistant cultivars, the onion growers will be able to use them to reduce risk of loss of crop, and reduce reliance upon fungicides for preventative control this disease.

When growers are able to reduce use of fungicides, there is downstream benefit to consumers and the environment associated with reduced used of fungicides.

### **Lessons Learned**

- All field work is reliant on weather conditions. By increasing the number of plots, we increased likelihood that some would have adequate disease to generate the desired data. We were able to produce some additional data by having a miniplot each year in Ithaca, at a location where we could inoculate (ensuring presence of pathogen) and mist the plot at night (providing a microenvironment more conducive to disease development).
- The BLB resistance of the new onion lines has considerable potential as a genetic control of BLB that will reduce use of and reliance upon preventative fungicidal sprays.

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## **Project Title: Advancing Adoption of Reduced Tillage Systems in Conventional and Organic Vegetable Production in New York**

### **Project Summary**

Our goal for this project was to advance the use of RT systems to more vegetable farms in New York State. Conventional and organic farming systems have traditionally utilized intensive tillage at the time of planting. Despite its historical popularity, this management practice has contributed to plow pans and soil organic matter losses. Although organic systems often rely upon intensive tillage to a greater extent than conventional agriculture systems, the adverse effects can occur in both systems, such as increased fertility costs, losses from water borne pathogens and poor soil health. Reducing tillage could provide substantial gains to both systems while supporting a more efficient and conservative land use.

The benefits of tillage include an increased nutrient mineralization from incorporated crop residues and weed control (Trewavas, 2004). However, interest in conservation tillage methods is expanding in response to concerns over soil quality and environmental health (Peigne, 2007). Conservation tillage refers to systems that minimize soil disturbance and maintain at least 30% residue cover (SSSA, 2005). These tillage systems can reduce soil and wind erosion, overcome compaction challenges typical of vegetable soils, conserve organic matter and improve overall soil health. In addition, research with conventional vegetable growers has demonstrated a reduction in fuel use and equipment wear as well as an improvement in labor efficiency (Rangarajan, unpublished results). Deep zone tillage is one method that minimizes the width of soil disturbance to the planting row while providing sufficient soil disturbance to increase drainage and aeration and decrease compaction (Raper, 2007; Karunatilake and van Es, 2002). This disturbance results in improved conditions for seed germination compared to no-tillage systems which may not be feasible in the finer soils of the Northeast due to cooler soil temperatures and high moisture (Cox, 1992). Reducing tillage frequency and intensity is of interest to organic and conventional vegetable growers across the U.S.

Our outreach focus has been on creating on-farm demonstrations in diverse locations around New York and on cropping systems that represent a wide variety of vegetable production practices. With the increased appearance of extreme weather events, whether droughts or heavy rainfalls, the necessity for growers to adopt soil conservation methods is ever increasing. Our field days reflected our research trials' pursuit to combine reduced tillage methods with cover cropping strategies. The goal of these cover crop strategies are aimed at conserving soil moisture in the face of droughts, preventing erosion and improving drainage in the event of heavy rainfalls and also providing soil nutrients and promoting ecological diversity and cycling to create a healthier soil.

Synergies between reduced tillage and cover cropping practices have been shown to enhance the performance of both and further the goals of building soil health. Cover crops are an important tool to enhance soil health, and have been shown to reduce soil erosion, promote better nutrient cycling, improve soil physical properties, improve soil fertility and suppress weeds (Blevins et al., 1971; Dinnes et al., 2002; Doran and Smith, 1991; Kaspar et al., 2001; Munawar et al., 1990; Nagabhushana et al., 2001; Reeves, 1994). As such, integration of cover crops in a reduced tillage system serves to further improve the whole system's ability to build soil quality and accrue environmental benefits. The organic

matter from decaying cover crop residue can help improve the ability of plant roots to penetrate the soil when tillage is avoided. Winter cover crop root system decay over the summer crop season created biopores that allowed movement of air and water and easier vegetable root penetration in a compacted sandy loam (Stirzaker & White 1995).

Cover crops in reduced tillage systems can provide a surface mulch that is not present in conventionally tilled fields. This mulch can help conserve water, suppress weeds, and protect the soil from washout due to pounding rains or wind. Cover crop mulch (especially cereal-legume mixtures) has been found to be effective for in-row weed suppression (Teasdale, 2004). Efficacy of weed suppression depends upon the quantity of mulch, which is determined by cover crop seeding rate and date (Turk, 2003; Pineiro, 2002). If insufficient mulch is present, weed emergence can be stimulated by trapped moisture (Teasdale, 1993). Rye, which has allelopathic properties, has been found to suppress weeds effectively when three times the amount that can be grown in a specific area is applied (Teasdale, 2000).

Additionally, legume cover crops are invaluable in organic systems for their nitrogen contributions. A hairy vetch mulch can increase vegetable yield; this is thought to be due to increased mineralizable N and improved soil structure after growing the cover crop (Abdul-Baki, 1996; Decker, 1994). In cover crop mixtures, leguminous cover crops fix nitrogen while non-leguminous cover crops scavenge nitrogen, resulting in reduced leaching (Fageria, 2005). Rye-vetch mixtures can reduce leaching prior to crop N-assimilation and produce higher biomass yields than either cover crop grown alone (Clark, 1994; Rosecrance, 2000; Jimenez, 1989). Both cover crops are winter-hardy and can be killed effectively in an organic system with flail mowing if done at the heading stage (Creamer and Bennett, 1997; Creamer et al., 1995).

Our NY RT team of growers, CCE educators and faculty have actively engaged in research and education such that we now lead the nation in development of RT systems for vegetables. We found that zone tillage with deep ripping supports similar yields to conventional tillage for sweet corn, dry beans, cabbage, squash and pumpkins. While cost savings are significant, growers reported that the most important benefit of RT is the greater flexibility afforded early in the season. By speeding up primary tillage and field preparation, reducing labor hours and reducing fuel costs, growers were timelier with planting, efficient with labor, and improved early season cash flow. In some cases, RT systems have allowed growers to expand acreage with more efficient labor. All of these factors have had significant impact on farm profit.

## **Project Approach**

### *Outreach*

To increase the number of vegetable growers using reduced tillage on their farms, we integrated the use of presentations, in-depth workshops, farmer networking, on-farm demonstrations, and research trials to encourage more growers try reduced tillage on their farms. A barrier in the past involved having units available for growers to experiment with on their farm. We developed a network of equipment dealers in Western NY, Central NY, Eastern NY and Long Island willing to rent Unverferth Deep Zone Tillage units to vegetable farmers, plus provided units from our various research projects around the state (LI, Capital District, and Ithaca). Reduced Tillage growers were also recruited through

field days at research stations throughout the state, advertising in periodicals distributing to growers, announcements during conferences and expos for both organic and conventional growers, and from word of mouth.

Conference presentations were used to highlight benefits of reduced tillage (RT) in vegetables, outline challenges and share opportunities to engage in trials with loaner deep zone tillage equipment. In 2010-2012, we hosted sessions at the Empire State Fruit and Vegetable Expo and Direct Marketing Conference. This gathering is sponsored by the New York State Vegetable Growers Association, Empire State Potato Growers, New York State Berry Growers Association, New York State Farmers' Direct Marketing Association, New York State Horticultural Society, Cornell University and Cornell Cooperative Extension. This is the primary winter educational meeting for NYS conventional vegetable growers. Full day sessions were held jointly for Reduced Tillage and Soil Health at the Empire State Vegetable Expo in 2010 and 2011, each reaching about 150 growers.

In 2012, we eliminated the single Reduced Tillage session at the Expo in favor of presentations in multiple sessions, to reach more farmers on the use of RT in different vegetable crops. Our reduced tillage team gave presentations and announcements in the Cabbage and Cole Crops, Phytophthora Blight; Tomato, Peppers and Eggplants; Cover Crops and Soil Health; Sweet Corn and Vine Crops sessions. Approximately 300 total growers and researchers were present. We made announcements regarding our reduced tillage program in every vegetable crop session, discussing the SCRI funding available to support grower RT equipment rentals. We included information about the opportunities for growers to adopt zone tillage trials on their farm through our project with little risk or cost to their operation. Ten growers expressed interest in adopting reduced tillage in their operations in the 2012 growing season. Half of these growers own and manage small acreage organic farms with low horsepower tractors.

On February 11, 2011, we also hosted a videoconference with four participating locations, titled "Planning the Transition to Reduced Tillage Systems: Equipment, Fertility and Weed Control." Following the videoconference, we hosted planter clinics in three regions of NY. Former Extension Field Crops and Reduced Till Specialist Jim Capron led the clinics focused on optimizing planter function. In both years, we also hosted twilight meetings at the Cornell Organic Research Farm in Freeville, NY, to highlight strategies for applying RT in organic vegetable systems. We demonstrated two of our loaner RT units for growers in attendance.

We also published articles in regional vegetable newsletters highlighting the project and availability of technical support for transitioning to RT systems. It is estimated that 200 farmers participated in the conference presentations and 60 attend our field days. From these events, we had identified 10 new growers for trials in 2012, 4 of which are organic producers. Four growers who hosted trials in 2011 also intended to continue their trials in 2012.

The RT team and the Project PI and Coordinator provided logistical support for locating equipment, recommending strategies and adjustments for varying soil types, crops and weather and documented RT grower trials through interviews, conference calls, field observations and biomass collections, and formal evaluations.

## Research

Our research trials provided opportunities for growers to learn strategies to advance the use of RT in vegetables. The trials included evaluation of innovative cover crop planting in RT (organic and conventional), RT equipment comparisons (organic), deep placed nitrogen (conventional), alternative fertility sources (organic) and variety selection for RT systems. These experiments were replicated each year. All trials implemented deep zone tillage, where a narrow slot is ripped deep enough to cut through compacted soil layers --often 9 to 12" deep in vegetable soils, but sometimes extending 15 to 18". This vertical tillage is followed by fluted coulters (similar to discs) that shallowly (4-5 inches deep) disturb a soil zone about 8" wide, centered over the slot. This is where the crop is planted. Finally, a rolling basket or cultipacker helps to break up soil clumps and smooth the seedbed.

A major challenge for integration of cover crops into RT systems is interference of the cover crop residue with weed control. To overcome this limitation, we tested a strategy of strip planting of winter-killed with overwintering cover crops to improve weed management and crop yields in both organic and conventional RT systems. The cover crops were planted the preceding fall in alternating in-row (planting row) and between-row mixes of cereal rye and hairy vetch or forage oats and winter peas. The treatments combinations included: 1) no cover crop (control); 2) cereal rye/hairy vetch between rows with no cover crop in row; 3) rye/vetch between and in rows; 4) oats/peas between and in rows; 5) rye/vetch between and oat/peas in row; or 6) winter peas/oats between and rye/vetch in row. Broccoli was the test crop. Weed, crop and cover crop biomass, soil temperature and weather data were collected during the season. Soil samples were taken at regular intervals for analysis of soil nitrogen.

Past experiments with sweet corn indicated that the full fertilizer requirement for the crop could be placed 8-10 inches deep in the zone tilled slot without any loss in yields. Growers were interested in knowing if this practice could be used with other RT crops. We evaluated fertilizer rates, type and placement in a cabbage field, using both conventional and deep zone tillage. The standard practice was with dry fertilizer, providing an N rate of 0, 120, 180 lb/A. Deep placed nitrogen was achieved using liquid N source (UAN) to deliver 100 lb/a N at the beginning of the season. Sidedressing with additional N during the season helped achieve different fertilizer rates. Two varieties of cabbage were grown: a long season variety and a short season variety. At planting, all plots were given starter fertilizer applied to the zone tilled trench underneath the transplants.

## Goals and Outcomes Achieved

Over the course of the project timeline, we completed our objective of identifying and assisting thirty-six growers to test reduced tillage strategies in their vegetable production operations. Recruitment was established on the basis that RT strategies would improve soil health and profitability on their farms, reducing the fuel and labor costs of tillage. At least two organic trials were conducted each year of the project timeline.

## 2011 Reduced Tillage Education and Information Sessions

The Reduced Tillage session at the 2011 Empire State Fruit and Vegetable Expo focused on sharing the experiences and innovations of growers who have transitioned to this soil preparation method. The session was opened by Anu Rangarajan (Project PI) who has been doing research and outreach on reducing tillage in all kinds of vegetables – both conventional and organic – for a number of years. Rangarajan reported on the successes with reduced tillage in a wide variety of large seeded and transplanted vegetable crops. She also shared how growers could apply for cost share funds available via the SCRI grant to rent the equipment they need to give reduced tillage systems a try.

The highlight of the session was a farmer panel about transitioning to reduced tilled vegetables. A Western NY grower moderated the session. This grower has been a strong proponent of this method and is recognized as a grower expert. The five other grower panelists focused their presentations on one or two of the more unique crops they were growing in zone till, or modifications of the system that have been successful. These crops included squash, sweet corn, lettuce, carrots on raised beds, cabbage, cauliflower, broccoli, kale, garlic, pumpkins and snap beans. There was particular interest in cabbage, a valuable crop in NY. Crops that have been challenging under the system include small seeded crops, especially root crops like carrots.

Seventy-five growers were in attendance at the session. Most (80%) of the growers reported having tried or were planning to try a reduced tillage system with one of their vegetable crops. In a post session survey, responding growers indicated that their knowledge had improved on the economic, environmental and labor management benefits as well as the challenges of reduced tillage systems. Because the panelists shared their innovations with this system, most growers did not feel they had gained much more knowledge of strategies to transition to this type of tillage. All were more aware of the availability of demo equipment to do on-farm trials. Respondents also indicated that they were more likely to try this system with vegetables on their farm. Many wanted to attend more field days or to visit with experienced growers or educators prior to committing to on-farm trials with the system.

A videoconference titled, "Making Reduced Tillage Work on Your Farm," was held on February 11, 2011 from 9am to 2:30pm. Sixteen growers attended the Videoconference, which also included cooperative extension and educators from New York State and Massachusetts. Topics included grower evaluations of Deep Zone Tillage equipment, weed and cover crop management challenges and grower experiences with fertility management.

Five sites were included in the video conference: Central NY, Western NY, Long Island, Northern NY and Eastern NY. Forty five growers participated as well as eight extension educators, and five researcher collaborators. Overall the evaluations indicated that participation in the video conference increased grower knowledge and confidence about trying reduced tillage by at least 25%. The discussion facilitated by the videoconference allowed growers from across the state to ask each other and the team questions about adapting equipment, testing new fertility practices, managing cover crop and past crop residue, and fine tuning weed management. All of these areas are essential for success in any reduced tillage system. From the video conference, 25% of growers stated they were interested in trying reduced tillage on their farms in the coming 2011 season. Several had access to equipment and others asked to borrow the team's loaner units. Several experienced growers were the focus of case studies for the project.

Our field days in the summer and fall of 2011 were well attended by vegetable growers, with almost 80 collective participants at our meetings. The Summer Organic Twilight Field Day was promoted by NOFA-NY and attended by both conventional and organic vegetable growers. The Organic Research plots at LIHREC on Long Island were showcased as part of the Organic Field Day Vegetable Tour on August 23, 2011, and the Plant Science Day on September 8, 2011.

The Summer Organic Twilight Field Day was held at the Organic Research plots of Cornell University's Homer C. Thompson Research Farm on August 4, 2011. The event was well attended, with roughly 60 growers, gardeners and those with an agricultural interest in attendance. Approximately three quarters of the participants in the Organic Field Day attended the reduced tillage presentation. Forty of the growers at the Field Day were given our 'Guidelines for Deep Zone Tillage in Vegetable Production' publication. The pamphlet highlights key equipment, field preparation, fertility management and planter setup issues that should be considered when starting a successful deep zone tillage program for vegetables. Many of the growers had only a limited knowledge of cover cropping techniques while others had experience with cover crop monocultures and had not used mixes. None had considered strip planting of cover crops to facilitate management. Of those that attended the presentation, five growers demonstrated an explicit interest in conducting on farm deep zone tillage trials and in borrowing deep zone tillage equipment.

As part of this project, we have been interested in helping smaller scaled growers implement reduced tillage on their farms. This required design of alternative, scale appropriate, DZT equipment appropriate for tractors with 45 to 70 HP. We identified several farm built designs as well as some lower cost commercial options. One unit we developed uses specialized shanks from the Yeoman's plow. This plow was developed in New Zealand for improving water management and drainage in pastures. We have constructed a small, lightweight tool bar to hold two of these Yeoman's shanks, and are building finishing units to be attached to the back that will allow for development of clean tilled areas (8-12" wide) over the vertical slots created by the shanks. This unit will be available for smaller scaled growers to test zone tillage in 2011. We especially hope to have this unit used by organic farmers in NY.

The organic growers who confirmed their interest in testing RT were small farm owners and managers, representing Tompkins, Delaware and Niagara Counties. Due to their limitations of tractor size and the small area of their plots, they expressed interest in borrowing our Yeoman's zone builder, which has been specially built for tractors with lower horsepower.

#### 2012 Reduced Tillage Education and Information Sessions

Anu Rangarajan (PI) presented the most recent innovations and developments in organic reduced tillage at the NOFA NY Organic Winter Conference in January 2012. Research discussions focused around zone and deep zone tillage and the goals of enhancing soil quality through minimizing soil disturbance, with applicable case studies mentioned. Organic strategies for weed suppression in a reduced tillage

system were discussed on an annual and multi-year basis, describing the merits of permanent raised beds, mulching techniques and crop rotations. The soil disturbance profile was outlined for zone versus deep zone tillage with descriptions of successful vegetable crops grown in both systems. The other portion of the presentation elucidated equipment innovations, including zone builders constructed for low horsepower tractors for use on small acreage plots, as well as the most recent innovations in DZT units built to form raised beds for a permanent bed system. The experimental results discussed demonstrated fertility and weed management compromises for different strip planted cover crop treatments. Our long-term pepper and cabbage experiments showed similar yields between conventional and DZT for years 3 and 4. Rye/Vetch cover crop residue was challenging to manage and interfered with mechanical cultivation. Though mulch reduced weed pressure it also reduced yields in cabbage 2 of the 4 years conducted and peppers 3 of 4 years. Perennial weed pressure becomes problematic after 2 years and may warrant a conventional plowing after the 3rd year.

In the winter of 2012, a meeting of Cornell Professors, Graduate Students and Researchers in the fields of Horticulture, Plant Pathology and Soil Health was arranged with a select group of organic growers who have developed long-term, effective reduced tillage practices to their vegetable production operations to discuss and compare a number of reduced tillage systems. The meeting was set with the mindset of evaluating effectiveness and assessing the possible areas of growth and development, or attributes that could be applied to other forms of reduced tillage. The reduced tillage systems that were represented by the panel of growers included ridge-till, no-till and variations on the deep zone tillage system. Crop rotations, weed suppression and disease management were discussed in relation to cover crop strategies for each RT strategy. The meeting included 6 growers and 15 Cornell and Faculty members.

Our reduced tillage team organized a conference call with all growers participating in on-farm trials in 2012, as well as growers with previous experience conducting RT trials. The conference was meant to assist our research team in developing future direction for the projects and education initiatives. The growers with past experience served as our advisory panel, to help us both evaluate our findings and plan useful extension and other outreach events. The insights shared during our conference call have helped shape the project. During the call, and afterwards in a follow-up email, we invited growers to participate in the DACUM (Develop A CURriculum) project, which we have begun to use to identify the tasks and duties expert organic growers use in thinking about how to reduce tillage on their farms. Growers who participated in our last DACUM, focused on organic vegetable crop rotation planning, reported it as a very rewarding and an intellectually stimulating experience that deepened their own knowledge while strengthening their connections to other farmers in the region. The Peer-to-Peer focus of this process will help us define and refine the management skills needed to be successful in adapting a reduced tillage organic practice. The DACUM results will also influence the research design for the future years of the project.

We hosted a meeting in 2012 with Cornell Cooperative Extension agents and researchers from Northern New York to locate farmers in the region that would be interested in participating in next year's on-farm trials and setting up a comparison between conventional/existing practices and zone building. While we had tried to host some demonstrations in 2012 summer, most growers were hesitant after the difficult fall in 2011. Both organic and non-organic farms will be targeted in 2013 to build more RT support and grower outreach in Northern NY. Ideal fields would include a killed cover crop or no cover crop for the first year. We would adjust our zone builder to run just under most compaction layers at a depth of about 14 inches, with sweet corn or transplants being planted at a 30" to 36" row spacing.

The Twilight Organic Field Day this year was held on August 15, 2012 at the Organic Research plots of Cornell University's Homer C. Thompson Research Farm in Freeville, NY. The event showcased the continuation of our reduced tillage and strip-planted cover crop experiment in organic broccoli as well as our more recent nutrient meal/zone builder comparison experiment in organic broccoli. The event was well attended, with roughly 55 growers, gardeners and those with an agricultural interest in attendance. Nearly all of the participants in the Organic Field Day attended the reduced tillage presentation. Of those that attended the presentation, six growers demonstrated an explicit interest in conducting on-farm deep zone tillage trials and in borrowing deep zone tillage equipment. The growers who confirmed their interest were small farm owners and managers, representing Tompkins, Delaware, Onondaga and Niagara Counties. Due to their limitations of tractor size, they expressed interest in borrowing our Yeoman's zone builder. Twenty-seven of the growers at the Field Day were given our 'Guidelines for Deep Zone Tillage in Vegetable Production' publication.

During this year's field day, many of the growers were interested in differentiating the effects of deep zone building as it applies to different soil types. Next year we will include a more in-depth discussion of how the inversion and aeration caused by traditional plowing reduces soil organic matter accumulations and what kind of tillage can be applied to especially weedy fields to prepare them for a deep zone tillage system the following year.

The LIHREC Twilight Field Day was held on August 22, 2012. The tour began with a demonstration of the deep zone tillage equipment with a side-by-side comparison demonstrating the function of rolling basket and cultipacker attachments as planting bed shapers. Two local farms, where deep zone tillage trials were conducted, were also included in the tour. These farms implemented the equipment for production of sweet corn, pumpkin, sunflower and crucifers. The field day was conducted and moderated by Cornell Extension and was attended by 30 growers.

#### *Research Trials*

Both the Unverferth and Yeoman's Plow zone builders found to perform similarly in terms of crop yields (Table 1). This result was important in that it demonstrated that the smaller Yeoman's Plow built specifically for small acreage growers performed as well as the larger Unverferth unit.

Organic systems often depend upon early season tillage to stimulate soil microbial mineralization of N. In RT systems that lack this soil disturbance, we have been concerned that fertility might be limiting. We found that fish meal applied as a sidedress 3 weeks after planting broccoli supported higher yields than poultry compost or no added fertilizer (Table 1). Soybean meal provided intermediate results. This was the first examination of nutrient sources for organic RT.

Our organic research trials evaluating strip-planted cover crop techniques in 2011 demonstrated that the treatments with some combination of Oats/Peas produced the best yields, similar to the bare ground control (Table 2). In 2012, our results showed no significant

differences among the cover crop treatments repeated from the previous year. The conventional strip-planted cover crop trials showed no significant differences amongst treatments in 2012 and 2011.

Our fertility rate and placement experiment with early and long season cabbage varieties showed that the deep zone tillage and conventional tillage methods produced similar yields (no significant differences) in 2011. The long season variety produced higher yields than the shorter season. The 120 lbs/A fertilizer rate tended to perform the best. No difference was observed amongst application methods (dry or liquid, or deep placed).

Table 1. Average Head Weight of Broccoli at Final Harvest in Freeville, NY during 2012 season.

Treatment	Mean (g)
<i>RT Plow (RTP)<sup>z</sup></i>	
Unverferth (U)	245
Yeoman's Plow (Y)	248
<i>Org. Fert. (OFS)<sup>y</sup></i>	
Fish Meal	359 a <sup>x</sup>
Soybean Meal	263 a b
Kreher's Compost	202 b
No amendment	162 b
<i>Statistical significance</i>	
RTP	ns
OFS	.0002
RTP*OFS	ns

<sup>z</sup> Both tillage treatments conducted on same, 2 days before transplanting.

<sup>y</sup> Applied in-row at rates of 105 kg N/ha-1

<sup>x</sup> Means followed by different letters are significantly different at  $P < 0.05$ .

Table 2. Average Head Weight (g) and Marketable Yield (kg/ha) of Organic Broccoli, grown in Freeville, NY during the 2011 season.

Treatment	Average Head Wt (g) <sup>y</sup>	Marketable Head Wt (kg/ha) <sup>1</sup>	Percent Marketable Heads (%)
<i>CC<sup>z</sup></i>			
BG	352 b	11,172 a	98
OP (bet/in)	423 a	12,803 a	98
RV/OP	351 b	10,742 a b	95
OP/RV	313 b c	10,251 a b	97
RV/BG	292 c	8,206 b c	88
RV (bet/in)	300 b c	7,338 c	85
<i>Statistical significance</i>			
CC	.002	.034	ns

<sup>z</sup> BG – bare ground, RV – rye vetch mix, OP – oats peas mix. Mix on left represents strip planting between row and mix on right represents strip planting in row.

<sup>y</sup> Means followed by different letters are significantly different at  $P < 0.05$ .

## Beneficiaries

### 2011 Grower Trials (6 LI, 5 CNY, 2 WNY - 13 total):

#### Long Island trials (6)

One grower borrowed a Cornell-owned Unverferth zone builder to grow snap beans. Another grower started to grow sunflowers for cut flowers at his farm stand using reduced tillage. He has observed no obvious difference in growth compared to sunflowers produced with conventional tillage.

Six growers produced sweet corn with reduced tillage in 2011. Five of these growers own their own equipment purchased within the past few years, and one other used the Cornell Unverferth zone builder to prepare ground for planting sweet corn. Some comments were obtained from growers during summer farm visits. Growers have been satisfied with sweet corn crops grown with reduced tillage.

Six growers on Long Island produced pumpkins using reduced tillage in 2011. Five of these growers have had *Phytophthora capsici* occur in pumpkins on their farms. Two of these growers have a few years of experience with reduced tillage and now only grow pumpkins under this system; it was not possible to conduct a comparison of pumpkins produced with deep zone and conventional tillage on their farms.

Effectively managing weeds with herbicides continues to be a major constraint to producing pumpkins with reduced tillage, and often with conventionally-produced pumpkins as well. The main herbicide, Strategy, needs water to be activated. Many growers rely on rainfall because they are not set up to irrigate entire fields at one time. When a cover crop mulch is present on the soil surface in the RT system, more water is needed to move the herbicide through straw residue to the soil. High residue cultivator could be a valuable tool for these growers.

#### Upstate NY On-Farm trials (5)

A grower in Baldwinsville, NY planted tomatoes, squash and peppers using the Cornell Yeoman's plow and 2-row Unverferth. He used these tools for primary soil tillage prior to shaping raised, plastic mulch covered beds. Soil under the DZT plastic was lumpy and uneven as compared with the conventional, which had more uniform soil. The plastic and drip tape laid well in both treatments. He reported that DZT cost him 1/3 the amount of labor and approximately 1/2 the fuel usage.

While we had established side by side conventional versus deep zone tilled comparison in three fields, different tomato and squash varieties were planted, preventing any yield comparisons from two fields. In the pepper field, 2 beds were prepared using with the Yeoman's and 1 bed with the Unverferth. Two rows of peppers were planted on each bed. A cover crop was grown in the alleyways, but was killed by the tractor field activities. The grower saw an increase in grass pressure in the DZT areas, though it did not become a problem until the fourth harvest, 2 months after planting. This grower has *Phytophthora capsici* present in all of his soil but finds that it is only really a problem late in the season when zucchini and squash are picked from the end of the vines (no longer resting on the plastic). He observed no differences in disease pressure between *Phytophthora* susceptible plants in

DZT and conventional. There were also no observed drainage differences between DZT and conventional plots.

He wants to conduct trials again in 2012. He said that one of the main reasons he signed on to do a Yeoman's and Unverferth trial was because he was allowed enough time to adjust the machines at his leisure and was able to wait until the ideal day to conduct DZT. He states that both the Yeoman's and the Unverferth have potential for RT and laying plastic, with the Unverferth capable of tilling multiple rows with more efficiency. He is planning on growing peppers, squash, tomatoes and maybe cucumbers. Instead of moldboard plowing and two passes of disking, grower 9 is thinking of taking his deep ripper and tilling all ground but with one pass leaving the between rows bare, stating that growing a cover crop in the bare ground between rows was foolish considering the area was driven over 6 times, killing a cover crop that was there and compacting the soil. He wants to break up that compaction later with deep ripping shanks. He also wants to build three beds at once, saving fuel and improving carbonization because the ground is only stirred once.

A grower in King Ferry NY implemented DZT using his own Blue-jet 16 row deep zone tiller with a 250-300 horsepower tractor. He deep zone tilled 600 acres of some sweet corn, soy beans, sunflowers, vine crops and field corn his first year and increased the number to 1000 acres in 2011. He conducted DZT on sweet corn but felt like the highly variable weather may have affected trials. The strip-tilled plots were much more variable than the conventional plots and did not yield as well. He added that the crops that were mature on time lacked uniformity, and sometimes only half of the yield was marketable. The conventionally tilled plots were substantially better.

The fields in which we had established side by side comparison were accidentally plowed, so no yield data was collected, however the grower reported that there was definitely a smaller percentage yield (~10% lower) in the DZT plots. He generally fall plows and then disks twice in the spring before planting. He would also disk once or twice before strip tilling in order to be able to plant in the soil. In terms of weed pressure, he reported no observable differences as he was able to use the same herbicide program on both conventional and DZT and disk before strip tilling. He feels that DZT limits his options for planting. He has to often make changes to plots and move crops around once the time to plant arrives. He will not participating in a trial in 2012.

A grower in Trumansburg, NY (Organic) borrowed the Yeoman's plow, which is best suited for his 68 horsepower, 4-wheel drive tractor, and left the setup with two straight leg shanks for deep ripping. Typically, he would chisel plow then disk and shape raised beds before planting.

The zone tillage did not work this year as he was attempting plow in a rye cover crop that had been chopped when it was tall, resulting in a heavy residue. The rollers on the Yeoman's kept binding up on the flailed rye. He wants to try the DZT system again in the 2012 season on small plots of fall Brassicas, Broccoli and Cabbage, and hopes to mow the cover crop when it is smaller. Phytophthora is present on the farm, with more incidence after the heavy rains this season. He feels that Botrytis is a larger problem on his farm and he does not have drainage issues. He hopes to implement DZT to reduce labor and fuel costs and improve overall soil health.

A grower in Marcy NY borrowed our Unverferth Zone Tillage Unit for deep ripping with his 100 horsepower tractor. He reported that the crop fared better than the conventional areas. He conducted a zone tillage trial this year on sweet corn, cabbage, brussel sprouts, other cole crops, pumpkins and winter squash. He implemented deep zone tillage on half of his pumpkin and winter squash acreage (about 3 acres); the other half was conventionally plowed. He sprayed roundup to manage weeds and

oats stubble. He found that he had issues with weed management, but that it was equally distributed across the conventional and deep zone tilled plots. His farm was hit by Hurricane Irene before he was able to harvest, but he said that the DZT plots produced a good crop and he could see no difference between it and the conventional plots. He noted that all crops with DZT produced similar yields as the conventional. He would like to purchase a 4 row zone tilling unit but is unsure whether it would be financially viable at this time. He has looked into outfitting an older unit.

A grower in Rome, NY conducted his first trials with DZT in 2010. He was very pleased with the outcome of that test and wanted to repeat the trial in 2011. He borrowed our zone builder in the spring for a mix of vegetable crops. In the fall, he was supposed to receive our Unverferth Unit from another grower but did not due to a miscommunication.

#### Western NY (2)

Two growers conducted deep zone tillage in Western NY. One set up a side by side comparison of zone building cabbage in a conventional plot. Another purchased a Gladiator Zone Tiller and first planted sweet corn and field corn in the zone tilled plots, then added soybeans and winter squash with a side by side comparison for the squash against conventional tillage. Both were highly satisfied with the performance of their crops in RT and intended to continue trials in 2012.

#### **2012 Grower Trials (4 CNY, 10 ENY, 5 LI – 19 total)**

#### Central NY (4)

In 2012, deep zone tillage equipment was provided to local growers who demonstrated an interest in adopting reduced tillage practices to their existing vegetable production operations. Four farms in Central NY borrowed our zone builder constructed for small farm use. One Seneca county grower conducted deep zone tillage as the only field preparation for large-seeded vegetables and transplants, while also conducting the deep zone tillage in conjunction with a shallow rototilling for some small-seeded crops. An Onondaga county grower signed up to borrow our Yeoman's plow, which fit his tractor rating, but later decided to purchase a unit himself after learning more about the benefits of deep zone tillage. In our later follow-up discussion the grower stated that his primary challenges with his zone builder was its inability to handle heavy residue and pull effectively through variations in the field. He was happy with its results on level ground and has discussed making alterations to the setup for next year including redesigning the rear "roller crumbler" such that it is on a resistance type setup that can float and follow the soil surface versus the current adjustable, but fixed position, set up that he has. On the implement itself, he thinks he can make some adjustments in terms of finding a better residue cutter and row cleaner. Furthermore he had opposite hilling discs this past season and thinks offsetting them front to back would help a great deal as the opposite discs were getting clogged with residue and rocks. Two growers, one in Schuyler and the other in Seneca County borrowed equipment for late summer field preparations for the 2013.

#### Eastern NY (10)

One grower sprayed an alfalfa sod, but it was not adequately killed. Prior to zone building, he made an additional application. He borrowed a Cornell ripper. He reported that transplanting into the slot was the easiest planting he had ever done. He also sprayed twice with Sandea/Dual postplanting and placed his nitrogen deep in the slot.

A grower in Sharon Springs, NY had a nice stand of rye that he killed and then ripped and applied Nitro deep in the slot. He transplanted pumpkins, and was very happy with the results.

A grower in Kinderhook, NY worked closely with a neighbor, sharing the ripper, tractor and corn picker. They tried to use the ripper to renovate their strawberries. They purchased a quick hitch to allow them to offset the unit, to better accommodate their row spacings.

Another grower started experimenting with RT strawberries and is very happy with the response. He might also invest in a quick hitch for the same reason as above.

Six additional growers put some acreage in RT vegetables. These growers manage conventional operations and have total acreages ranging from 60 to 100, with most on the upper side of the range.

#### Long Island (5)

Five growers utilizing reduced tillage for a portion of their vegetable production plots. Two of these growers were featured in the LIHREC summer field day this past August. They provided a tour of their sweet corn, pumpkin, sunflower, and crucifer plots. Two of the growers have been conducting deep zone tillage for upwards of three years.

### **Lessons Learned**

Our research trials addressed questions and challenges put forth by RT growers. Our goal was to advance the systems with new strategies. We found that we could produce similar yields of early and late season cabbage with nitrogen placed deep in the zone till slot. Yields were also similar to the conventional treatments. In addition, an analysis of our soil moisture probes at a 6 inch depth showed that the DZT plots had significantly higher soil moisture levels than the conventional plots. The 9 inch depth probes displayed that the DZT plots had lower moisture levels but greater stability than the conventional.

Cover crop mulch did reduce yields of organic broccoli. Winter killed oat/peas, which has little residue in the spring, had similar marketable head weights (kg/ha) to the bare ground control. This was true if oats/peas were sown through the whole area or alternated with rye/vetch either in or between the planting row. The treatments with just the rye/vetch mix showed reduced yields compared with those containing some combination of oats/peas. In a repeat of the experiment, we found no difference among the treatments, thus year to year variability remains a challenge.

Our Zone Builder comparison trial showed that there were no significant differences in crop performance between the Yeoman's Plow and the Unverferth Unit. This information is promising as it demonstrates that smaller acreage growers who do not have the tractor rating or horsepower to pull a unit the size of the Unverferth can attain similar results with the Yeoman's Plow, which we built specially for small acreage growers.

Weed management continues to be an issue for deep zone tillage in organic production. After three to four years of conducting deep zone tillage in organic plots we see a shift from annual to perennial weeds. Though overwintering cover crops, once flail chopped become a good mulch, but this coverage and weed control is limited to beginning of the growing season as in-row cultivation tends to

dislodge the between row mulch and move it around causing gaps in the cover. We have experimented with a number of configurations and types of cultivation units to circumvent this outcome but have not come up with a viable solution yet.

Management of the cover crops also poses a potential threat if the overwintering rye/vetch is not killed properly. We've found that the best time to control these cover crops is when the vetch is flowering and the rye is beginning to bolt. At this stage the plant is shifting a great deal of its energy to the top of the plant, which allows for mowing, flailing or flail chopping to be more effective. With the mild winter we had this past year we also saw oats overwintering that had to be flailed in the spring.

Our grower trials have been successful for the most part. We have found that transplanting into the zone built planting rows or direct seeding large-seeded vegetables has been the most effect strategy for vegetable production. However, we have some growers who have experimented with direct seeding small-seeded crops into zone built areas after doing a very light rototilling that extends a few inches over the deep zone tillage. Official reports and interviews from these growers are still pending.

We believe that grower engagement and recruiting for trials has been more successful given changes to our marketing strategy. In order to convince growers to adopt RT methods we've had to demonstrate that DZT can be an effective tool for making their operation more economically efficient. We've learned that many growers believe that the long term goals of increased soil health are not enough to warrant them conducting deep zone tillage, if their yields will be smaller in the short term. To counteract this, we actively remind growers that despite some yield loss in the first two years of DZT, they will save money through reduced time commitment and labor costs, lower fuel costs resulting from fewer tractor passes and increased flexibility of tillage time. This has proved an effective tool for convincing growers that the short term losses do not necessarily outweigh the gains from implementing DZT in the short and long term.

We have also found that many tractors that are rated high enough to pull the Yeoman's plow may be insufficient due to the size and weight distribution of the tractor. The unit, when the bed shaping disks and rolling baskets are attached to the back extends behind the tractor for a distance that alters the tractor's center of gravity. Growers need both sufficient weight in the front and in the back near the tires to keep the unit from becoming bogged down. We've also found that the units function best when run slightly off level with the straight leg shanks angled slightly upward.

The 2011 growing season was a challenging year to implement and test reduced tillage for some growers. Rainy weather in June affected planting and herbicide treatments. Conditions in July were very dry which led to soil crusting that affected emergence and soil drainage. Several unusually intense rain events beginning in mid-August provided ideal conditions for development of *Phytophthora* blight, resulting in the worst outbreak of this disease on Long Island. In addition, the heavy rains brought on by Hurricane Irene did a great deal of damage to some areas of Central New York, with others remaining relatively untouched. One participating grower had to plow a field because of the adverse soil conditions after the rain. Another grower lost a significant portion of his crop due to flooding. One grower who participated the first year did not participate in the project again; the heavy precipitation this spring put him behind schedule for planting his crops, making it difficult to focus on any projects. The level of *Phytophthora capsici* on his farm appeared to be unmanageable.

The majority of farms participating in our on-farm trials that began in 2010 either expand their DZT in 2011 or kept it the same as the previous year with the exception of one. The grower whose field had to be plowed due to adverse soil conditions will no longer be conducting DZT as he believes it will limit his ability to be flexible with changing plantings and low risk management. He observed that the strip tilled plots were much more variable than the conventional plots and did not yield as well. He added that the crops that were mature on time weren't as desirable because of a lack of uniformity. The grower whose fields were lost reported that before the flood the crops with DZT produced similar if not the same yields as the conventional. He started with DZT in 2010 on sweet corn and reported that the crop fared better than the conventional areas. Another farm was hit by Hurricane Irene before he was able to harvest, but he said that the DZT plots produced a good crop and could see no difference between it and the conventional plots. He would like to purchase a 4 row zone tilling unit but is unsure whether it would be financially viable at this time. He has looked into retrofitting an older unit.

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**Additional Information**

Cornell Reduced Tillage in Vegetables website: <http://www.vegetables.cornell.edu/reducedtillage/>

## **Project Title: A Demonstration of the Feasibility of Northeast-Based Honeybee Production Industry While Meeting the Challenge of the Newest Disease to Hit New York State Honeybees**

### **Project Summary**

Commercial non-migratory beekeeping in the Northeast United States is difficult at best. Beekeepers who do not move their bees to warmer climates sustain substantial overwintering losses every year. Restocking their hives is a considerable cost that comes in the spring, a time of year when many operators have little or no income from their bees. The vast majority of bees and queen bees used to restock hives come from either the southern United States, California, or Hawaii. Even nucleus hives sold by some New York beekeepers may have bees from New York colonies but actually have queens that are purchased from out-of-state. These southern bees are not adapted to our northeast climate and are more prone to overwintering losses than bees that were raised here.

Beekeeping has received a great deal of publicity as of late because of Colony Collapse Disorder (CCD). CCD is characterized by a dwindling of the beehive's population so that not enough bees are left to sustain the beehive's continued survival. This symptom has historically been observed before. In earlier days it was most commonly called disappearing disease; in another case it was called fall collapse. This malady can be caused by a number of different factors including poor nutrition, exposure to pesticides, and infectious organisms. One possible factor that is not publicized much is the application of pesticides by beekeepers to their beehives for the control of the parasitic mite, *Varroa destructor*. These miticides can build up in the wax of the hive, making it a less hospitable home over time.

New York beekeepers have sustained substantial losses due to the appearance of the two exotic parasites of the honeybees: tracheal mite and varroa mite. Ultimately, the best solution to these diseases is the use of resistant stock that does not require the use of chemicals for the control of these diseases. Mite resistant stock has been developed and is available. Unfortunately, a new disease is currently spreading through the honeybees of New York: *Nosema ceranae*. *Nosema ceranae* is a mid-gut parasite caused by a fungus that can live in the digestive system of honeybees. It is displacing *Nosema apis*, a dysentery that mainly afflicted honeybee colonies during the winter months. The symptoms of *Nosema ceranae* are more severe and can affect honeybee colonies during all twelve months of the year. An effort to develop *Nosema ceranae* resistant honeybees seems like a good approach though it is not entirely clear whether this approach will succeed or whether we will need to use medications for a more indefinite period of time.

Mr. Michael Johnston, owner of Johnston's Honeybee Farm was the project administrator. He has been a beekeeper for over 33 years and has done business with the beekeepers that have purchased bees from him in the past. Hives at Johnston's Honeybee Farm were tested for *Nosema ceranae* by the NYS Bee Inspectors in August of 2007 and then again in August of 2009. In 2007, the bees were found to be free of this disease and in 2009, they tested positive for the disease.

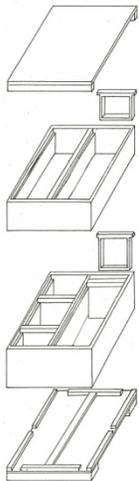
An important part of the project was distribution of mite resistant stock to beekeepers in the Northeast. Beekeepers were reimbursed for half of the cost of the bees they purchased from Johnston's Honeybee Farm. All bees were sold to the beekeepers at cost and therefore no program income was generated through the sale of bees on this project. Of the \$28,485.62 spent, \$13,614 was distributed to 79 participating beekeepers in the form of cost-share towards the cost of purchasing bees from Johnston's Honeybee Farm. Fourteen beekeepers participated twice; two beekeepers participated all three years. In return, they cooperated in the inspection of their bees for mites and nosema and also collected data that compared those bees with other honeybee genetic stock that is being utilized in New York State.

**Project Approach:**

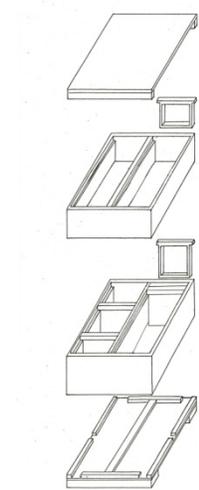
The project developed a system whereby Northeast beekeepers could produce their own bees for restocking hives. Two specialized hives were employed that produced nucleus hives and queen bees respectively. The goal was to maximize the production of each kind of hive.

The project demonstrated that nucleus hives (nucs) and queen bees could be commercially produced in a northern location through the use of two innovative beehives. The Two Colony Hive (two colonies of bees occupy a single bee hive) was produced so that each colony had a separate entrance and the two clusters were separated by division boards in the center of the bee boxes. The two colony hive was well suited to producing bees and repopulated quickly after requeening.

**Two Colony Hive**



## Combination Queen and Comb Honey Hive



The Combination Queen Rearing Nucleus and Comb Honey Hive produced the queens. It was divided into six compartments in the spring and when the queen production was over, it allowed for the hive to be converted to a two compartment hive for honey production. The Combination Queen Rearing Nucleus and Comb Honey Hive was more intensive and involved additional woodworking and to produce the equipment was much more involved but resulted in being a major improvement over other queen rearing equipment currently being used in the bee industry today. This hive solved the problem of how to overwinter baby nuc frames while utilizing the same principles employed in the two colony hive to produce a productive hive. Other queen rearing equipment consists of single compartment baby nucs, multiple compartments hives with standard frames, or a 4 compartment hive with baby nuc frames. With the other hives, the bees either get killed at the end of the season or the frames get stacked up in single compartment hives.

This project put 50 combination hives with six compartments into production during the course of the project.

### **Production of Bees in 2010**

In 2010 a total of 131 nucs were distributed to participating beekeepers. Of those, 74 nucs were “early nucs” with one year old queens and 57 nucs were “late nucs” with queens raised during the current season. A total of 81 caged queens were sold.

Overwintering losses during the winter of 2010/2011 were very high. The bees responded by having the strongest swarm season that was ever observed. The results of the hives with the young

queens was that the standard hives had an overwintering success of 59% (13 live /22 hives), and the two colony hives had an overwintering success rate of 58% (45 live clusters/78 possible hives). Overall, the young queens had an overwintering success rate of 58% (58/100 possible).

The results of the hives with the old queens was that the standard hives with 2 year old queens had an overwintering success rate of 27% (15 live /56 hives), and the two colony hives with 2 year old queens had an overwintering success rate of 58% (11 live /19 hives). Overall, the 2 year old queens had an overwintering success rate of 35% (26 live / 75 hives). The total overwintering success for the operation was an overwintering rate of 48% (84 live /175 hives).

The wintering losses from participating beekeepers for nucs and queens in 2010 were: early nucs with 2 year old queens: an 18% overwintering success (7 live /40 possible). The late nucs and 2010 queens had a 42% overwintering success (23 live /55 possible). The total overwintering success for nucs was 32% (30 live/ 95 hives).

### **Production of Bees in 2011**

A total of 172 nucs were sold to 41 beekeepers in 2011. In our original proposal, it was expected that we could produce 150 nucs by utilizing 50 two colony hives that sustained 75% overwintering success (100 clusters of bees x 75% overwintering = 75 clusters); 2 nucs would be produced from each surviving cluster. As it turned out, in the spring of 2011, we had 84 clusters of bees in both standard and two colony hives and we sold 172 nucs. This is a ratio of 2.05 nucs per cluster of bees. In the process of restocking our own hives, we actually produced another 128 clusters of bees. If you add this number to the 172 nucs, you can come up with  $(172 + 128 / 84 = 3.57)$  3.6 new bee clusters produced per cluster of overwintered bees.

A total of 68 queens were sold to 17 beekeepers. Our original projection was to sell 600 queens by utilizing 50 Combination Queen Rearing Nucleus and Comb Honey Hives. We actually had 30 queen production hives in various configurations.

### **Overwintering of Bees for 2011/2011 Winter**

The winter of 2011/2012 was unusually mild for Central New York and almost no hives were lost. Going into the winter, there were 145 clusters of bees in two colony equipment and 63 clusters of bees in standard equipment. A total of 6 clusters were lost from two colony equipment ( $139/145 = 96\%$  overwintering success) and 5 clusters were lost from standard equipment ( $58/63 = 92\%$  overwintering success). Standard equipment had a greater percentage of two year old queens that did two colony equipment so the overwintering success of the two kinds of equipment is not directly comparable. Part of the overwintering success can be attributed to the ability to visit bee yards and feed light hives with granulates sugar; in most winters, hives in Central New York would be buried in snow. Some

overwintering success can also be attributed to the use of Apriguard in October of 2011. Participating beekeepers reported an overwintering success rate of 60/95 equaling 63%.

### **Production of Bees in 2012**

The summer of 2012 saw drought conditions from most of the United States including Central New York. A total of 212 nucs were sold to 42 beekeepers. These 212 nucs were produced using 197 clusters of bees. This is a ratio of 1.08 nucs produced per cluster of overwintered bees. As it turned out, many of the hives swarmed that would not have been swarmed.

A total of 239 queens were sold to 66 beekeepers. The sales of these 239 queens were done by utilizing 26 queen rearing hives in 6 compartment configurations. Another 12 of the hives were configured into 2 compartments but were not used for raising queens. Though it was originally planned to bring 50 queen rearing hives into production, this number has not been needed so far. We have been able to fill all of the orders for queens that were requested by the participating beekeepers. Going into the winter, most of the 6 compartment hives were changed over to two compartment hives by selling off queens and removing divider boards.

### **Total Production of Bees in 2012**

Coming out of the winter of 2011 to the spring of 2012, there were 139 clusters of bees in two colony equipment and 58 clusters in standard equipment for a total of 197 clusters of bees. After an inventory of the bee yards in November and December of 2012, it was found that there were 245 clusters of bees in two colony equipment and 104 clusters of bees in standard equipment for a total of 349 clusters. (this does not include bees in special queen rearing hives.) Therefore, during the 2012 season the number of clusters was increased by 152. Each cluster is equivalent to another nuc that could have been sold. So the production of bees in 2012 was 212 nucs plus 152 additional clusters for a total of 364. By dividing 364 by 197 clusters there were 1.85 clusters of bees produced per available cluster of bees.

During July 2012, samples from 16 hives with 2 year old queens were submitted to the Beltsville Bee Lab for Nosema disease diagnosis. (Greater than 1.0 million spore count per sample is considered high). These spore count results ranged from 0-3.0 million spores. The average spore count was 0.72 million. Of the 16 samples, 7 will be considered for breeder queens if they make it through the winter. Two hives had 0 spore counts, one hive had a 0.05 million spore count, two hives had a 0.15 million spore count, and two hives had a 0.20 million spore count.

## Mite Resistant Queens

A total of 65 queens were purchased in 2012 for testing versus queens that were produced at Johnston's Honey Bee Farm. Of the 65, 25 were Minnesota Hygienic (from Mississippi), 20 were Varroa Sensitive Hygienic (from North Carolina), and 20 were New World Carniolan. These queens were used to start new hives in different locations of Johnston's Honeybee Farm. Samples were taken from some of each of these types of hives in September-October and tested for Varroa counts and Nosema spore counts. As the time this report was submitted, the Varroa spore testing results were not available. In October, Nosema samples were taken; 4 were from Minnesota Hygienic hives and 12 were from Johnston's Honeybee Farm hives. The Minnesota Hygienic Hives were all negative for Nosema. Seven of the Johnston's hives were negative for Nosema, the other 5 samples were at low levels. Results of mite sampling are as follows: Four New World Carniolan hives averaged 24 mites per 200 bee sample. Four Minnesota Hygienic hives average 16 mites per 300 bee sample. Two Varroa Sensitive Hygienic hives averaged 11.5 mites per 300 bee sample. Eighteen Johnston's Honeybee Farm raised hives averaged 23 mites per 300 bee sample.

The production of the hives assisted in laying the groundwork for producing Nosema resistant bee. During the project many of the bees were tested for Nosema spores and the results were highly variable with some hives possessing high Nosema levels and some having low Nosema levels. Under this project, queens with alleged varroa resistance were purchased from three different queen breeders. Four hives with New World Carniolan queens and five hives with Minnesota Hygienic queens were tested and came back with 0 spore counts even though the brood used to start these queens came from infected hives. Two hives with Varroa Sensitive Hygienic queens came back with relatively high Nosema spore counts. Different methods are used for selecting Minnesota Hygienic Bees and Glenn Apiary's Varroa Sensitive Hygienic Bees. New World Carniolan bees were started using artificial insemination techniques to produce a fairly pure strain of Carniolan.

		Mite Count Per 300 bee sample	Nosema Spore count Greater than 1 million is high
Johnston B13 #1	Berry Yard	50 mites	0 Spores
Johnston B13 #2	Berry Yard	No Mite count Drone laying queen	0 Spores
Johnston B13 #3	Berry Yard	25 mites	0 Spores

Johnston B13 #4	Berry Yard	32 mites	0.70 Million Spores
Johnston B13 #5	Berry Yard	35 mites	0 Spores
Johnston B13 #6	Heim Yard	9 mites	0 Spores
Johnston B15 #1	Davis Yard	10 mites	0 Spores
Johnston B15 #2	Davis Yard	27 mites	0 Spores
Johnston B15 #3	Berry Yard	20 mites	0.50 million spores
Johnston B15 #4	Berry Yard	45 mites	0.25 million spores
Johnston B2a	Swiazek Yard	20 mites	0 Spores
Johnston B24	Heim Yard???	18 mites	0 Spores
Johnston S1	Sodun Yard	11 mites	0.50 million spores
Johnston S2	Sodun Yard	8 mites	0 Spores
Johnston W1	Wittwer Yard	7 mites	0.05 million spores
Johnston B211	Pierce Yard	20 mites (9/30/12)	1.65 million spores (8/6/12)
Johnston B222	Pierce Yard	11 mites (9/30/12)	0 spores (8/6/12)

Johnston B223	Pierce Yard	25 mites (9/30/12)	1.35 million spores (8/6/12)
Minnesota Hygienic #1	Swiazek Yard	16 mites	0 Spores
Minnesota Hygienic #2	Wittwer Yard	18 mites	0 spores
Minnesota Hygienic #3	Wittwer Yard	16 mites	0 spores
Minnesota Hygienic #4 - weak hive	Wittwer Yard	3 mites	0 spores
Minnesota Hygienic #5	Heim Yard	15 mites	0 spores
New World Carniolan #2	Swiazek Yard	10 mites	0 Spores
New World Carniolan #2	Swiazek Yard	20 mites	0 Spores
New World Carniolan #3	Swiazek Yard	25 mites	0 Spores
New World Carniolan #4	Davis Yard	40 mites	0 Spores
Varroa Sensitive Hygienic #1	Davis yard	15 mites	0.45 million spores
Varroa Sensitive Hygienic #2	Davis Yard	8 mites	1.10 million spores

## Workshops

As part of this grant, three workshops were to be conducted. In February of 2011, it was decided to drop Central New York Resource Conservation and Development (RC&D) from the project.

Federal funding for RC&D was being zeroed out and CNY RC&D was no longer going to have full-time staff. The role of RC&D was to take registration, promote the event, and do printing. A new deal was negotiated with Madison County Cornell Cooperative Extension (CCE) Agricultural Economic Development (AED) to handle the registration, do some promotion through their existing network of Extension offices, and do printing for three workshops.

#### Nosema Workshop

The first workshop was held on June 9, 2011, at Morrisville State College. The workshop was on *Nosema ceranae*. A total of 16 beekeepers attended. Grant recipient Michael Johnston spoke on the project, NYS Chief Bee Inspector Paul Cappy spoke on the results of extensive sampling for *Nosema* done over the past several years by the Apiary Inspector Program. Peter Borst, President of the Finger Lakes Beekeepers Association and a former bee inspector, gave an overview of different forms of *Nosema* disease in a number of organisms. Peter subsequently wrote an article for the American Bee Journal's August 2011 issue that was similar to his talk at the workshop. Janet Tam of the Ontario (Canada) Beekeepers Technology Transfer Program gave a power point presentation on testing for *Nosema*, IPM and treatment for the disease.

#### Overwintering Workshop

The second workshop was held on October 22, 2011, at Morrisville State College and was attended by 77 beekeepers. The workshop was entitled *Overwintering Honeybees in the Northern Climate*. This seemed to be a timely topic that would assist beekeepers in reducing overwintering losses. Whereas, migratory beekeepers have suffered great losses from CCD in recent years, the greatest losses occur to our local beekeepers in New York from overwintering losses. The winter of 2010/2011 was particularly bad for the great majority of our non-migratory beekeepers in New York. The workshop combined indoor presentations and presentations in a local bee yard. Paul Cappy, the NYS Chief Bee Inspector, spoke on recent overwintering losses and recent developments in disease treatment. Janet Tam of the Ontario (Canada) Beekeepers Technology Transfer Program gave an overview of the causes and prevention of overwintering losses. Two New York Beekeepers that have had 90% overwintering success gave presentations on their methods. Sam Hall, a member of the Ontario Finger Lakes Bee Club, spoke on D-E hives that employ an extensive ventilation system. Sam has managed to have a very good overwintering success in spite of the fact that he does not treat for disease. Joe Marcinkowski, a member of the Mid-York Beekeepers Association, spoke on his methods of wrapping hives and gave the dimensions of the materials used. Peter Borst, President of the Finger Lakes Beekeepers Association, gave a presentation about recent research on the connection between *Varroa* and honeybee viruses. Michael Johnson spoke on the project as well as bee diseases and medications, young queens versus old queens in overwintering, and two colony hives versus standard hives in overwintering.

#### Queen Bee and Nucleus Hive Production in the Northeast

The third workshop was held at Morrisville State College on June 2, 2012. Presentations were made by Janet Tam, Ontario(Canada) Beekeepers Technology Transfer Program; Mike Palmer, French Hill Apiaries in Vermont; Peter Borst, American Bee Journal contributor; Ken Boyce, President of the Mid-York Beekeepers Association; Bill Crowell, retired NYS Bee Inspector and Michael Johnston. A total of 80

people attended the program. Topics included Queens & Drones Quick Biology, Advantages (and Disadvantages) of Locally Raised Northern Queens and Nucs, History of Honeybee Breeding – Advances in Methods, Influence of the Different Strains of Honeybees – Role of Diseases – Selecting Breeder Queens/Stock Selection Criteria – Grafting – Cell Builder Hives, Different Systems – Case Method of Raising Queens, Other Queen Rearing Methods, Two Days Later – We Have Queen Cells, Now What Do We Do? – Different Hives Using Baby Nuc Frames – Different Nucs Using Full Size Frames, Making Splits Using Queens, Queen Cells, Making Splits by Letting Hives Raise Natural Queens, Requeening Hives, Producing Mid-Summer Nucs and Overwintering Them, and The Future of Bee Breeding. The indoor presentations were followed by outdoor demonstrations of beehives on campus behind the greenhouses.

### **Goals and Outcomes Achieved**

The longevity of queens being produced by all sources is not good. This is a fairly recent phenomenon that is commonly acknowledged by commercial and non-commercial beekeepers. The primary cause of this shortened lifespan is called a syndrome called Nosema Induced Supersedure. This is a difficult syndrome to solve because not only do your breeder queens and queen cell builder hives need to be free of Nosema, but also the nucs that receive the queen cells since the queens can become infected after hatching. At this time, it is unknown whether laying queens free of Nosema provided to other beekeepers and placed in infected hives can also have a shortened lifespan because of this supersedure problem. Most of the cooperating beekeepers do not have queens from multiple sources.

- One beekeeper (Steve Burton) reported that he observed 50% supersedure of 18 queens from the B13 breeder but no supersedure among six B15 queens and six B29 queens.
- Another beekeeper (Walt Heinrich) purchased 7 nuc and 3 queens in 2011. Two queens were lost before the end of 2011. Five out of the eight remaining hives overwintered and four of those hive swarmed in the spring. Mr. Heinrich purchased 5 nucs and 4 queens in 2012. All 4 of the queens failed for him and 2 of the 5 nucs swarmed.
- Another beekeeper (Tim McGarry) purchased 14 queens in 2012 and had 11 of those 14 queens at the end of the season. Of the three that did not succeed, one failed because there was already another queen cell in the hive. Mr. McGarry's queens were produced later in the season and the B13 breeder was no longer in use. He then purchased 4 queens from Purvis Brothers in 2012 and only had one left by the end of the season.
- Keelan Darling purchased 10 queens in 2010 and 25 nucs in 2012. She had 5 of the 2011 queens left in 2012 but two of the queens died because the lids blew off the beehives during the winter.

- G & S Orchard had 8 of 11 nucs come through the winter of 2011/2012. They purchased 11 hives from a beekeeper in Penn Yan and had 3 make it through the winter of 2011/2012.
- Clyde Goodrich purchased 5 queens and 5 nucs in 2011 and had 8 of those queens come through the winter.
- Mike Healey purchased 3 nucs in 2011 and all made it through the first winter and all three swarmed during 2012.
- Dick McConnell purchased 12 nucs from Johnston's Honeybee Farm in 2011 and 10 Kutik Nucs in 2011. There was 75% survival from the Johnston's nucs and a 50% survival from Kutik nucs.

Below is a chart that compares the production of New York State raised bees to other bee stock and pounds of honey per hive.

G & S Orchard	Year 2010 Johnston Bees 12 nucs with old queens	17 lb average
	Year 2010 Other bees 7 splits or swarms	4 lb average
Ted Howard	Year 2010 Johnston Bees 3 nucs with young queens	15 lb average
	Year 2010 Other bees 3 Italian Hives Natures Way Apiary	17 lb average
McConnell	2011 – 12 Johnston nucs	13 lb average
	2011 – 10 Kutik nucs (3 weeks ahead)	63 lb average
Darling	Year 2011 Johnston bees 10 young caged queens	40 lb average
	Year 2011 Georgia Bees 5 Italian Hives, young queens	98 lb average
Darling	Year 2012-Johnston bees 5 hives from 2011 queens	84 lb average
	Year 2012 – other bees 18 hives	55 lb average
	2012 – 2012 Johnston bees 25 nucs young queens	24 lb average
Burton	Year 2012 - Johnston bees 30 nucs young queens	30 lb average
	Year 2012 – Burton bees 100 nucs young queens	30 lb average

	Year 2012 – Burton bees from cut-outs 20 hives old queens	80 lb average

Below is a chart that compares the winter survival of New York State raised bees to other bee stock and the % overwintering.

G & S Orchard	Year 2010 Johnston bees 12 nucs with old queens	2/12 - 17% overwintering
	Year 2011 Johnston bees 11 nucs with young queens	8/11 – 73% overwintering
	Year 2011 PennYan bees 11 hives with old queens	3/11 – 27% overwintering
DeConnick	Year 2010 Johnston Bees 5 nucs	0/5 – 0% overwintering
	Year 2010 Other bees 19 hives	6/19 – 32% overwintering
Griggs	Year 2010 Johnston Bees 10 nucs with old queens	4/10 – 40% overwintering
	Year 2010 Grigg stock 24 hives with young queens	18/24 – 75% overwintering
Norray	Year 2010 Johnston Bees 10 nucs with old queens	1/10 – 10% overwintering
	Year 2010 Johnston Bees 15 nucs with young queens	11/15 – 73% overwintering
	Year 2010 Johnston Bees 5 young caged queens	0/5 – 0% Overwintering
	Year 2010 Other Bees 8 hives	3/8 – 38% overwintering
Riedman	Year 2010 Johnston Bees 5 young caged queens	4/5 – 80% overwintering
	Year 2010 Other bees number not specified	40% overwintering
Ted Howard	Year 2010 Johnston Bees 3 nucs young queens	2/3 – 67% survival
	Year 2010 Nature’s Way Apiary 3 nucs	2/3 – 67% survival

	Year 2011 Other bees 2 hives	2/2 – 100% overwintering
Neil Boerman	Year 2010 Johnston Bees 2 nucs old queens	0/2 – 0% survival
	Year 2010 Johnston Bees 3 young caged queens	0/3 – 0% survival
	Year 2010 1 Kutik Nuc & 1 Swarm	2/2 – 100% survival
Jones	Year 2011 Johnston Bees 4 nucs young queens	4/4 – 100% survival
	Year 2011 Other Bees 2 hives	2/2 – 100% overwintering
Mc Connell	Year 2011 Johnston Bees 12 nucs young queens	9/12 – 75% overwintering
	Year 2011 Kutik Bees 10 nucs young queens	6/10 – 60% survival

### **Disease Testing**

Samples from breeder queens were sent to the USDA Bee Research Laboratory, Beltsville MD, in July and October of 2011. In July, Varroa mite levels were low and Nosema spore count ranged between 0 to 5.4 million spores. In October, Varroa mite levels ranged between 0 to 4 mites per 25 bee sample and Nosema spore counts ranged between 0 to 4.35 million spores. For Nosema, spore counts above 1.0 million are considered high. Significantly, the same hives that had either 0 or low spore counts in July also had 0 or low spore counts in October. It is significant to note that in the October samples, the hives with the highest Varroa counts also had the highest levels of Nosema. At this time it was thought that Colony Collapse Disorder (CCD) was caused by a combination of Varroa, viruses transmitted by Varroa, and Nosema ceranae.

### **Breeder Queen Selection**

In 2011, 26 samples were sent to Beltsville Bee Lab for testing. Three breeder queens with low Nosema spore counts were identified; these were the only queens used for grafting queen cells in 2012. These queens also had low Varroa mite counts as determined by the Beltsville Lab and had excellent brood patterns. The spore count ranged from 0-5.4 million. The average spore count was 1.08 million. Below is a photo of a frame of brood from one of our breeder queens; the queen is two years old.



### **Beneficiaries**

There are 2,000 beekeepers in New York State and approximately 70,000 colonies. Beekeepers across the United States are normally losing 30% of their colony every year for the past six out of seven years. The potential of having to replace 20,000 colonies is staggering (figures obtained from NYS Bee Inspection Services). The *Northeast-Based Honeybee Production Industry While Meeting the Challenge of the Newest Disease to Hit New York State Honeybees* project resulted in the development of a system for 30 commercial and 65 sideliner beekeepers so that they can produce their own queens and replacement nucs to potentially eliminate the yearly loss that normally occurs in their operation. As a result of beekeepers participating in the project and the educational workshops, these beekeepers now have the ability to produce extra queens and nucs to sell to hobby beekeepers. Most hobby beekeepers would not go to that extent themselves to use this system, but buy nucs and queens from beekeepers using this two colony hive system. Commercial and sideliner beekeepers would potentially keep themselves in business so they have a better chance to be self supporting. In addition the beekeepers now have the ability to produce the nucs and queens at a much lower cost for a potential savings to the New York beekeeping industry up to \$2.0 million. As additional beekeepers begin to either use the 2-colony hive system or purchase from beekeepers who do, more beekeepers can become more profitable in their operation.

## **Distribution of Mite Resistant Bees**

An important part of the project was distribution of mite resistant stock to beekeepers in the Northeast. Of the \$28,485.62 spent, \$13,614 was distributed to 79 participating beekeepers in the form of cost-share towards the cost of purchasing bees from Johnston's Honeybee Farm. Fourteen beekeepers participated twice; two beekeepers participated all three years. The cost-share amounted to \$35 towards the \$80 cost of a 4 frame nuc and \$10 towards the \$20 cost of a queen. In return for the cost share, participating beekeepers signed an agreement and agreed to share pertinent information about bees purchased under the program. Data collection sheets were sent to all participating beekeepers.

In 2010, 24 beekeepers signed cost share agreements on the purchase of 115 nucs and 27 queens. The following winter for 2010/ 2011 started early and ended late. Overwintering success for two year old queens purchased by participants was 18% while it was 35% for Johnston's Honeybee Farm. Overwintering success for 2010 produced queens was 42% for participating beekeepers while it was 58% for Johnston's Honeybee Farm. Overall, overwintering for bees purchased was 32% and for Johnston's Honeybee Farm was 48%. Some participating beekeepers treated for Varroa mites and some did not. No treatments were used by Johnston's Honeybee Farm.

For 2011, there were 26 agreements that cover 91 nucs and 36 queens. Overwintering success reported from bees purchased was 63%. Only queens raised in that season were sold in 2011. Participating beekeepers used a variety of treatments or none at all to control mites. The year 2011 was a very good growing season. Some overwintering failure can be attributed to swarming that was reported by some participants in the latter portion of the growing season. Some participants may have had this happen and not realized it. Overwintering success for Johnston's Honeybee Farm this past winter was 95%. This was a mixture of young queens and older queens. Overwintering success was a little better for young queens. Johnston's Honeybee Farm used one round of Apiguard in October of 2011 to control mites. This was the first time any treatment was used since the year 2003.

In 2012, there were 47 agreements that cover 147 four frame nucs and 63 queens. Data collection sheets are still being submitted by participants and so far 22 beekeepers have submitted information about their bees. While one beekeeper reported that 50% of his 30 nucs purchased had supercedure of queens, another beekeeper reported that 25% of his 4 nucs purchased had supercedure. Two beekeepers reported swarming by hives from nucs purchased in 2012. Surplus honey production varied from 0 pounds to as much as 80 pounds.

## **Demonstration of Bee Production as a Benefit to Bee Industry**

Half of this project was a demonstration of the use of two beehives that were developed. These hives are very good at producing bees for the restocking of hives lost during overwintering. It takes 18.2 board feet of lumber to produce a two colony hive while it takes 14.3 board feet of lumber to produce a standard Langstroth hive. So there is 27% more lumber in a two colony hive than in a standard hive. It has been observed that overwintering success is slightly better in two colony equipment than standard equipment. Usually, two colony hives will bring a little more than twice as

many clusters through the winter than standard hives. These clusters of bees can be used to restock dead out standard hives. Each side of the nuked-out two colony hives can be restarted with one frame of brood along with a frame of honey and a queen cell. Alternatively, two colony hives for honey production has been used while removing only enough brood to reduce swarm pressure, and two colony hives have produced a surplus of 350 pounds of honey and wax by weighing honey supers before and after extracting. The average honey surplus per hive in New York State is 60 pounds. The world record for honey production is 404 pounds by Ormond Aebib in California in 1974.

### **Development of Nosema-resistant stock as a Benefit to the Bee Industry**

Because of the grant, Johnston's Honeybee Farm started testing bees for Nosema and mite levels for the beekeeping industry. Breeder queens were chosen based on testing results. The particular queens that were used as breeder queens would not have been chosen otherwise. The queens were slightly more defensive than usually chosen as breeder queens but were good honey producers, had excellent brood patterns, and overwintered well. Feedback received from participating beekeepers was that there has been as much as 50% supercedure of the queens that were sold. This phenomenon is probably due to a phenomena called Nosema-induced supersedure (see below in Lessons Learned). In the short term, we can possibly reduce the incidence of this supercedure by reducing the number of queen cells produced in our cell builder hives thus providing better nutrition for each queen cell. This will produce stronger queens less predisposed to disease. In the long term, the ultimate solution to problems caused by Nosema ceranae is the development of bees that are more resistant to this disease. From past experience, it took ten years from the advent of Varroa to the time when bees bred by Johnston's Honeybee Farm could survive without mite medication. So breeding for resistance will take longer than the term of this grant. Johnston's Honeybee Farm is located in a good area for developing disease resistant bees. With open mating, we cannot select the drones with which our queens will mate and a queen will mate with up to 20 drones before settling down to head the hive. Johnston's Honeybee Farm is the largest non-migratory operation within the area contributing drones for possible mating with our queens. Migratory operations do not arrive here until after blueberry pollination is over around July 1. Prior to July 1, available drones are from overwintered hives, the majority of which belong to Johnston's Honeybee Farm.

### **Lessons Learned**

Losses were also very high with the queen rearing hives. In the winter of 2009/2010, the hives were fed sugar syrup made from table sugar. In the winter of 2010/2011, the hives were fed with high fructose corn syrup. These hives did not do well on high fructose corn syrup and the losses were much greater. High fructose corn syrup is less expensive and is already in liquid form, thereby saving money and labor. For unknown reasons, the bees did not do well on this materials so it wasn't used again. Therefore raising queen cells was discontinued and concentration was placed on preparing queen rearing hives for the winter.

The winter of 2010/2011 started early and ended late in Central New York. Because of this long winter, the presence of Nosema ceranae, and the continued presence of Varroa destructor, losses were

very high. Therefore, starting later in the Spring and having less bees to work with meant that less data would be collected by the participating beekeepers because they were not able to order them.

### **Producing Nucs**

The original planned method for producing nucs was abandoned after the first year of the grant as a result of the delay in the execution of the contract. Originally, it was planned to remove a four frame nuc from each side of a two colony hive along with the overwintered queen then requeening each side with a queen cell and selling an additional four frame nuc once the new queen started laying. The two colony hive would then be requeened with a queen cell a final time and allowed to build and enter the following winter. In this manner, Johnston's Honeybee Farm would be selling "early nucs" with 1 year old queens and "late nucs" with young queens. Most of the nuc buyers wanted "early nucs" because they would be available earlier in the season and there was a better chance of producing a honey crop. This method was employed during the Spring of 2010. This system did not work for because Johnston's Honeybee Farm was trying to get too much out of the hives. After the "late" second nuc was sold, the hive was basically exhausted and brood would need to be obtained to restock the hive from other parts of the operation. Additionally, the early nucs that were being sold were prone to swarming and did not overwinter well during the subsequent winter because they contained older queens. It was concluded that it was better to use overwintered hives to produce brood and only sell "late nucs". This method was employed during the Spring of 2011 and 2012.

### **Queen Supersedure Problems**

Because of the relationship with participating beekeepers, we became aware of queen supersedure problems. Some of the cooperating beekeepers have reported up to 50% supersedure of queens in the nucs that were sold. Apparently, this is a common problem throughout the bee industry that has just developed over the past several years. A December, 2010 article in the Journal of Invertebrate Pathology entitled *Pathological effects of the microsporidium Nosema ceranae on honey bee queen physiology (Apis mellifera)* explains the probable cause of this supersedure problem. As far back as 1962, a phenomena entitled Nosema-induced supersedure has been observed. According to the article, queens infected with Nosema produce larger amounts of queen mandibular pheromones (QMP). Weak or sick or poorly mated queens produce elevated levels of QMP; queens with lower amount of QMP are more attractive and better groomed by worker bees. Since Nosema-induced supersedure was first observed prior to the advent of Nosema ceranae, it was not a major problem until just recently. The occurrence of high levels of supersedure is just another reason why the development of Nosema-resistant bees will be of benefit to the bee industry.

### **Timing of Taking Samples for Bee Disease Diagnosis**

The summer of 2012 was quite dry in Central New York; moderate drought conditions were experienced. Bee Disease diagnosis levels for Nosema spores sampled late in the season were generally low with 0 spore counts reported for many samples. In the future, it will be better to take samples in

early spring when Nosema levels are at their seasonally highest levels. At that time of year, there should be greater separation in Nosema spore counts between resistant bees and hives susceptible to disease. In the past, samples were not taken in early spring because it is a busy time for restocking dead hives, making splits, raising queens, and moving bees to pollination. In order to get the best possible results, sampling will have to be just another task to fit into the schedule.

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## **Project Title: Reducing Production Costs and Improving Wine Quality Through Root Zone Management**

### **Project Summary**

Production of high-quality wine grapes is a particular challenge in cool climates such as Upstate NY due to rich soils and variable yearly precipitation. These conditions often result in excessive vigorous vines with clusters hidden by several layers of leaves resulting in poor development of wine flavors and aromas and an increased disease pressure within canopy and on fruit. Currently, the wine and grape industry has several options for remediation of such problem canopies, such as leaf removal and hedging; however these practices are only band-aid solutions to vine vigor and can be expensive to implement. Development of new economically and environmentally sustainable methods to control vine vigor, improve vine balance and potentially increase wine quality is critical for to the advancement of the Finger Lakes winegrape region.

Another option for reducing excessive vine vigor is by root zone management (RZM). Reducing the supply of water e/o nutrient to the canopy, either by severing portions of the root system or by planting cover crops beneath the row to cause direct competition with the grapevine roots, may be a potential tool for reducing excessive vine vegetative growth, improving fruit composition and hence wine quality and bottle price. Limited research on RZM practices has been conducted in warmer climates (Tesic et al., 2007; Hatch et al., 2011); optimal strategies for their use need to be established for the cooler climates and shorter growing season of Upstate NY. Furthermore, cover crops used in warmer climates under the vine can generally not be used in cooler climates due to the need to “hill up” the graft union in NY wine grape vineyards, necessitating the use of an annual crop with an ephemeral root system to allow for freedom of soil movement.

With this in mind the objectives of our research were to: 1) Determine the impact of root pruning (RP) and of three annual cover crops (CC) (annual ryegrass, AR; buckwheat, BW; rosette-forming turnips, TP) planted directly under the vine on vine size, wine quality and production costs; 2) Determine the impact of RZM treatments on vine physiological processes and seasonal and spatial root dynamics; 3) Disseminate our results to local growers.

### **Project approach**

- Activities performed during the grant period

#### Cover crops and root pruning treatment implementation:

The experimental site was established within a 10-year-old Cabernet Franc (*V. vinifera* L.) commercial vineyard, grafted to 3309C, located in the east site of Cayuga Lake in the Finger Lakes region. The vines were spaced 10 x 5 ft and trained to bilateral cordon with vertical shoot positioning. Drip irrigation was installed to be used only under severe vine water stress conditions. Preceding soil management consisted of resident vegetation in the inter row and soil cultivation under the vines. The experimental design was a randomized complete block with 5 treatments (control, C; root pruning, RP; three annual cover crop species, CC) and 3 replications per treatment. Each replicate (plot) consist of 25 vines in 3 panels of 5 adjacent vines each surrounded by 2 buffer panels of 5 vines each. Around bloom (2010, 2011 and 2012), three annual CC, annual ryegrass (AR; *Lolium multiflorum*), buckwheat (BW;

*Fagopyrum esculentum*), and rosette forming turnips (TP; *Brassica rapa* var. *rapa*) were planted beneath the vines (Figure 1). In 2012 TP did not established well, producing almost no biomass. Thus, we decided to let the resident vegetation grow underneath the vines and the TP treatment was replaced by a resident vegetation (RV) treatment. Likely, soil and weather conditions were not favorable for TP seed germination and growth in 2012.

RP was implemented only in 2010 as we were concerned about the disturbance having too great an impact on the vines through reduced carbohydrate concentration for winter survival. RP was implemented shortly before budbreak to one side of randomly selected treatment plots. The roots were mechanically pruned to a depth of 60 cm, approximately 25 cm from the trunk (Figure 1). The C treatment consisted of a 1 m wide vegetation-free strip maintained by cultivation.

#### Data collected during the grant period:

During the 2010, 2011 and 2012 growing seasons shoot growth rate and its seasonal duration (shoot tip activity; Hatch et al., 2011) were monitored. In the winter (2011 and 2012) the vines were pruned, and the pruning weights and number of shoots per vine was recorded. Point quadrat analysis and light meter readings (EPQA; Meyers and Vanden Heuvel, 2008) were conducted in the fruit zone around fruit set and veraison yearly in order to evaluate canopy density and light environment in the fruiting zone.

Vine water status was monitored by periodically measuring midday stem water potential ( $\Psi_{\text{stem}}$ ) throughout the growing seasons. Leaf gas exchange (photosynthesis, transpiration and stomatal conductance) was also periodically monitored. Additionally, in 2011 and 2012 volumetric soil water content along the vine row (0–100 cm) was sampled bi-weekly during the growing season and monthly after leaf fall.

Every year vine nutrient status was assessed by plant tissue (petiole) nutrient analysis at fruit set and veraison.

The effect of RZM treatments on bud cold hardiness was assessed by differential thermal analysis (DTA). DTA analyses were conducted in the middle of March 2011, and monthly between December 2011 and March 2012.

Minirhizotron technology was used for monitoring the spatial and seasonal vine root physiology and dynamics in response to RP and specific CC root competition interactions. The first year (2010) was dedicated to the installation of the minirhizotrons which consist of 1.2 m long clear acrylic root observation tubes placed at 30° from vertical in the area underneath the vines and about 30 cm from the trunk. A specially designed laparoscopic camera was used to observe roots visible in the minirhizotron windows every two weeks during the 2011 and 2012 growing seasons and typically every month after leaf fall (2011). Captured images are currently being processed using specially designed software (ICAP; Bartz Technology) for root demographic information. Information collected from the images will include date of root birth and death, root diameter, number, and proximity to cover crop roots by soil depth.

Vines were harvested by hand just before commercial harvest on 10/20/2010, 10/18/2011 and 09/26/2012. Clusters were counted and weighed to determine yield per vine and average cluster weight. Basic juice analysis was performed on fresh fruit samples to determine: sugar content (measured as soluble solids, Brix scale), pH and titratable acidity (TA). Average fresh berry weight was determined by weighing a 200-berry harvest sample for each plot. Total anthocyanins concentration was quantified using a spectrophotometric method (abs@520nm).

Fruit from all the three replicates of each treatment was pooled together for wine production. Fruit was crushed and fermented on the skins, in 30 gal lots. The standardized winemaking protocol for red wine was followed for wine production.

For the 2010 vintage wine sensory analysis was performed. In November 2011, wines produced from the treatments were compared through a consumer preference ranking test by 30 sensory panelists (Joanes, 1985). In March 2012, wines produced from the same vintage (2010), were also screened for differences via a projective mapping test (Risvik et al. 1994, 1997; Nestrud and Lawless, 2008) by 19 sensory panelists.

➤ Results:

Weather conditions:

Total growing degree days (GDD, base 10°C) accumulated during the 2010, 2011 and 2012 growing seasons (bud-break to harvest) were 1550, 1625; and 1500. The 3 growing seasons were characterized by different rainfall amount and pattern. 2012 was drier than the previous two growing seasons; total rainfall recorded from bud-break to harvest was 350 mm compared to 526 and 450 mm recorded in 2010 and 2011, respectively. Moreover, rainfall recorded during June, July and August 2011 (160 mm) was much lower than that recorded in 2010 (302 mm).

Vine size and winter bud survival:

No significant differences in shoot growth rate, during the period from cover crop planting until shoot hedging (middle of July), were observed among C and RZM treatments in either year (data not shown). However, CC and RP treatments had a significant effect in reducing the duration of shoot growth (2010  $P = 0.027$ ; 2012  $P = 0.049$  (Figure 2). In 2011 and 2012 canopy architecture was significantly affected by RZM treatments (Table 1). Particularly, in both years the use of AR and RP significantly improved cluster and leaf light interception (CEFA: 2011, AR  $P = 0.039$ , RP  $P = 0.046$ ; 2012: AR  $P = 0.030$ , RP  $P = 0.042$ ; LEFA: 2011, AR  $P = 0.049$ , RP  $P = 0.048$ ; 2012: AR  $P = 0.039$ , RP  $P = 0.005$ ) as compared to the control. Thus, AR and RP resulted in a more light-porous fruit zone, with a greater fruit exposure compared with the C treatment. Moreover, in 2012 AR, BW and RP resulted in a less dense canopy, with significantly lower occlusion layer numbers (total number of leaf and cluster contacts for insertion) than the control (OLN: AR  $P = 0.018$ , BW  $P = 0.016$ , RP  $P = 0.024$ ).

A lower pruning weight trend was observed in the CC and RP treatments compared to C in both 2010 and 2011 (no data collected yet for 2012 growing season) (Figure 3). However, pruning weight and average cane weight were significantly depressed by the RP treatment in 2011 only. Finally, bud cold hardiness was not affected by RZM throughout the duration of the study (2010, 2011, Table 2) (no data collected yet for 2012 growing season).

Vine water status and leaf gas exchange:

Differences in rainfall patterns observed between the three growing seasons are clearly reflected in the seasonal vine water status trends (Figure 4). In 2010 the plants were never water stressed; midday  $\Psi_s$  was always above -0.8MPa; and midday  $\Psi_s$  of the vines assessed to the C and RZM treatments were quite similar until veraison (middle of August), after which time a few differences in  $\Psi_s$  were observed among treatments. Specifically, around veraison AR and BW vines had significantly lower  $\Psi_s$  values than the vines grown in the C plots. Again, in the middle of September,  $\Psi_s$  of AR and RP vines were significantly lower than that of the C vines. In 2011 and 2012 the vines reflected a greater water stress, reaching  $\Psi_s$  values of ca. -1.0 MPa to -1.3 MPa. Starting in August (2011 and 2012),  $\Psi_s$  was generally lower in treated vines (especially RP and AR) as compared to the C, although no significant differences

were observed on any specific sampling dates. When  $\Psi_s$  data from all the 2011 sampling times were analyzed together, AR and RP had a significant effect on reducing vine water status compared to the C (Figure 5). Moreover, when plotting the average  $\Psi_s$  of each treatment to the relative pruning weight values, a highly significant relationship was found for both years 2010 and 2011 (data not shown). Thus, reduced vine water status (lower  $\Psi_s$ ) resulted in a striking decrease of vigor. Those results suggest that, under our experimental conditions, a reduction in vine vigor was associated with decreased water availability to the vines associated with CC and RP treatments.

In the 2011 and 2012, average leaf carbon assimilation rate in the AR and RP plots was significantly lower than that of the C vines (data not reported). This finding is consistent with our vegetative growth data which shows a reduction in pruning weight (Figure 3) and shoot growth duration (Figure 2) in the AR and RP treatments relative to the control.

#### Vine nutrient status:

In 2011 and 2012, leaf petiole nitrogen levels at veraison were lower than optimal (Bates and Wolf, 2008). In general, RZM treatments did not significantly affect vine nitrogen uptake, with the exception of veraison 2011, when leaf petiole N content was significantly lower in RP than in C vines ( $P = 0.043$ ) (Table 2). Moreover, at veraison 2010 leaf petiole K was significantly lower in AR than in C vines. No significant differences in other macro and micro nutrients at leaf petiole level were found among treatments.

#### Yield components and crop load:

No significant differences in fruit yield, number of cluster per vine and cluster weight as well as in fruit composition parameters (soluble solids, pH, TA) were observed between RZM treatments and C in either year of the study (Table 4). The significant vine vigor reduction observed in RP vines in 2011 was accompanied by a decrease in yield relative to the C of 21%, although a biologically important result although we did not find statistical significance. Our findings are in agreement with previous research in RZM conducted in warmer climates (North Carolina) which show a reduction in vigor in treated vines not without evident improvement in fruit composition (Giese et al., 2011).

In 2010 vines of all treatments were not in balance; crop load values were below the optimal crop load range (5 to 10), going from 2.2 in the C to 3.9 in the TP treatment. On the other hand, in 2011, vines of all treatments were in balance and all crop load values were within 5-10 range (data not shown).

#### Wine sensory analysis:

Sensory analysis of 2010 wines via projective mapping and preference testing indicated there were no pronounced impacts of the treatments on wine perception.

For the 2011 vintage, pre-sensory testing performed by an expert panel indicated that there were not differences in wine perception among treatments.

#### ➤ Conclusions

Under our experimental conditions, RP was the most effective in reducing vine size. The vigor reduction effect was more pronounced in 2011 than in 2010 (pruning data not available for 2012 yet). This could be due to the compounded effect of vines being subjected to the treatments for a second year and can also be due to the different weather conditions observed during the two growing seasons. Moreover, RP reduced the duration of shoot growth after veraison and had a positive impact on canopy architecture.

Among the three cover crops evaluated, AR was the most effective in limiting the vegetative growth duration and improving canopy architecture. The period of optimal cover crop competition was mostly around and after veraison. Likely, the dense and extensive root system of the AR treatment and its ability to grow well in heavy soils (<http://www.hort.cornell.edu/bjorkman/lab/covercrops/annual-ryegrass.php>) made this cover crop a good competitor with vine roots. BW established well and grew quickly every year; however, its shallow root system (Valenzuela and Smith, 2002 and visual observation) made this cover crop susceptible to drought (in 2011 and 2012 BW yellowed under drought conditions, visual observation) and a poor competitor with vine roots. However, this fast growing cover crop could be used for reduced-chemical or nonchemical weed suppression and to improve soil health (Valenzuela and Smith, 2002). We noticed a high variation in TP establishment and growth within plots and years. Specifically, TP failed to produce viable biomass in one plot characterized by higher clay content (26% vs 18%) as well as under low soil moisture conditions (average volumetric soil water content at 0-0.4m depth in June 2012 = 23.8%).

Reduction in vine water status ( $\Psi_{\text{stem}}$ ) appeared to be the main cause of the reduction of vine vigor and duration of shoot growth observed in RP and CC vines.

While RZM practices, specifically RP and AR, could be used as a potential tool for reducing vine vigor, no impact of treatments in vine yield components, fruit composition and wine perception (2010 and 2011 vintage) was observed.

➤ Contributions and role of project partners in the project

Dr. Taryn Bauerle and Dr. Justine Vanden Heuvel supervised a post-doctoral scientist (Dr. Michela Centinari) during the implementation of CC and RP treatments and data collection throughout the grant period. Moreover, Dr. Bauerle and Dr. Vanden Heuvel provided all the field and laboratory equipment necessary to achieve the performance goals. For the 2010 vintage, sensory analysis of wines produced from each treatment was conducted by Dr. Anna Katharine Mansfield.

Knowledge gained from the first and partially second year of the study were disseminated to growers by the project leader Dr. Vanden Heuvel at a Finger Lakes grape growers meeting (Wagner vineyards, August 2011, about 40 growers in attendance). Moreover, meaningful results obtained during the first and second year of the study were presented at the American Society for Enology and Viticulture (ASEV) Eastern Section Annual Conference on July 18 2012.

## Goals and Outcomes Achieved

### Assess the impact of RZM treatments on vine size

The effect of treatments on vine vegetative growth was assessed by measuring primary and lateral shoot length every two weeks until shoot growth cessation. Moreover, to evaluate the treatments effect on the duration of shoot growth, the proportion of actively growing shoot tips was monitored at veraison 2010, 2011 and 2012 (Figure 2).

The effect of treatments on canopy architecture and light environment was assessed twice per year around fruit set and veraison (Table 1). Moreover, in the winter shoot number and pruning weight data were collected (Figure 3). Crop load was calculated as yield divided by pruning weight.

Although RZM may offer a potential method to control excessive vine vigor it could increase the chance of winter damage to the vine due to lower carbohydrates concentrations for winter survival. Differential thermal analysis (DTA) was conducted in the middle of March 2011, and monthly between December 2011 and March 2012 to assess the effect of RZM treatments on bud cold hardness (Table 2). DTA analyses will be performed monthly between December 2012 and March 2013.

#### Assess the impact of RZM treatments on yield parameters and wine quality

Vines were harvested by hand on October, 20 2010, October, 18 2011, and September, 26 2012 immediately before commercial harvest. Clusters were counted, and weighed to determine yield per vine and average cluster weight. Basic juice analysis was performed in fresh fruit sample to determine: sugar content (measured as soluble solids, Brix scale), pH and titratable acidity (TA). Average fresh berry weight was determined by weighing a 200-berry harvest sample for each plot (Table 4).

Small lot wine making was conducted at the Vinification and Brewing Laboratory, Cornell University, Geneva NY. Fruit was crushed and fermented on the skins, in 30 gal lots, with yeast strain GRE (*Lallemand*). Jacketed, stainless steel vessels (*Vance Metal Fabricators*) with temperature control and monitoring were used. After seven days fermentation on the skins, wines were pressed and inoculated with malolactic bacteria strain Alpha (*Lallemand*). Following completion of MLF, all wines were cold stabilized. In the spring (2011 and 2012) wines were bottled manually.

For the 2010 vintage, wines produced from the 5 treatments were evaluated and compared through a consumer preference ranking test by 30 sensory panelists. Moreover, wines from 2010 were screened for differences via a projective mapping test by 19 sensory panelists. Sensory panelists were selected from a list of volunteers with experience in red wine evaluation maintained by Cornell Enology Extension Laboratory. Sensory analysis of 2010 wines indicated that there were no pronounced impacts of the treatments on wine perception.

For the 2011 vintage, pre-sensory testing performed by an expert panel indicated that there were not differences in wine perception among treatments.

#### Assess the impact of RZM treatments on vine water, nutrient status, physiological processes and seasonal and spatial root dynamics

Plant water status ( $\Psi_{\text{stem}}$ ) (Figure 4) and leaf gas exchange (net photosynthesis, stomatal conductance and transpiration) were periodically monitored during the 2010, 2011 and 2012 growing seasons. Moreover, in 2011 and 2012 volumetric soil water content (0–100 cm depth) was measured bi-weekly during the growing seasons and monthly after leaf fall (data not reported).

Plant nutrient status was measured by plant tissue (petiole) analysis every year at fruit set and veraison. Concentrations of most essential macro and micro-nutrients elements were measured at the Cornell Nutrient Analysis Laboratory (Table 3).

Minirhizotron technology was used for monitoring the spatial and seasonal vine root dynamics in response to RP and specific CC root competition interactions. Root images were taken every two weeks during 2011 and 2012 growing seasons and monthly after leaf fall (2011). Captured images are currently being processed using specially designed software (ICAP; Bartz Technology) for root demographic information.

### Disseminate our results to local growers

Knowledge gained from the first and partially second year of the study were disseminated to growers by the project leader Dr. J. Vanden Heuvel at a Finger Lakes grape growers meeting (Wagner vineyards, August 2011, about 40 growers in attendance). Moreover, meaningful results obtained during the first and second year of the study were presented at the American Society for Enology and Viticulture (ASEV) Eastern Section Annual Conference on July 18 2012. Finally, in 2013, results obtained from the all three year study (2010-2012) will be presented to approximately 250 grape growers at the Finger Lakes grape growers' conference. At this meeting project leaders will survey growers to assess the impact of our recommendations on growers RZM adoption. In addition, in the spring of 2013 we are organizing a " Under-vine cover crops workshop" to inform growers of our results with Cabernet Franc and Riesling and to expose and interest growers in experimenting with under-vine cover crops on their farms.

### Assess impact of RZM treatments on production costs

Based on our experience, we estimated that root pruning would cost around \$30 per acre per year. Establishing a cover crop directly underneath the vine would cost between \$ 25- 70 per acre per year. The variation in cost depends on the cover crop seed price (AR = \$25; TP = \$ 55; BW = \$70) (White 2011). Moreover, by December 2013, reduction in production costs will be quantified by growers who adopted at least one RZM practice.

### **Beneficiaries**

The primary target group for this project is the approximately 250 NY wine grape growers and their vineyard managers who farm around 8,500 acres of wine grapes (*Vitis vinifera* L. and *Vitis* sp.) within NY. The outcomes of our project will have a direct impact on the economic and environmental sustainability of local vineyards and wineries. Current vineyard practices for remediating overly-vigorous vines are costly with respect to labor and provide only short-term cluster exposure. Using RZM practices will result in considerable herbicides and canopy management costs savings for wine grape growers. Our results show that RZM practices offer a potential method for vine vigor control (Figure 2; Figure 3, Table 1) without affecting dormant bud col hardiness (Table 2). Moreover, this research will help growers implement best management practices, by increasing the biodiversity of species within the vineyard thus promoting soil health in addition to reducing the use of herbicides. Finally, our work will give growers new insights on the whole plant (both below and above the ground) response to the RZM (Figure 4; Table 3; Table 4; and root analysis data) so that they can better utilize these practices to reduce vine vigor and canopy management labor.

### **Lessons Learned**

Our results showed that the use of RP can decrease vegetative vigor and improve canopy light environment. Data from captured root images will give insights on the root re-growth following RP. This information is critical for growers in order to determine how often they need to root prune to have a significant reduction in vine vigor. However, what cannot be predicted accurately is the amount of root biomass removed with the pruning. Vine roots biomass and distribution may vary among sites and vines, as well as the amount of roots severed.

Among the three cover crops evaluated, AR was the most effective in limiting the duration of vegetative growth and improving canopy architecture. The period of cover crop competition was mostly around and after veraison. It may be possible that the use of permanent cover crops would have resulted in a stronger reduction in shoot growth, especially in the early part of the season from bud-break through hedging (middle of July). However, the need to “hill up” the graft union for protection of cold-tender grapevines necessitated the use of annual cover crops. We noticed a high variation in TP establishment and growth within plots and years. Specifically, TP never produced a good stand in one plot characterized by higher clay content (26% vs 18%) as well as under low soil moisture conditions. On the other hand, BW always established well and grew quickly; however, its shallow root system made this cover crop a poor competitor with vine roots.

With regard to the cover crop planting technique, seed bed preparation could be done with a weed badger. In a small scale vineyard (1 acre or less) hand seeding with a belly grinder seeder would work well. In a larger setting the best way to seed the cover crops would be using an electric seeder side mounted on a tractor (Mike Colizzi, personal communication).

Although the use of RZM treatments, specifically RP and AR, resulted in a reduction of vine size and improvement of canopy light environment, no impact on fruit composition or wine quality (2010; 2011 vintage) was observed.

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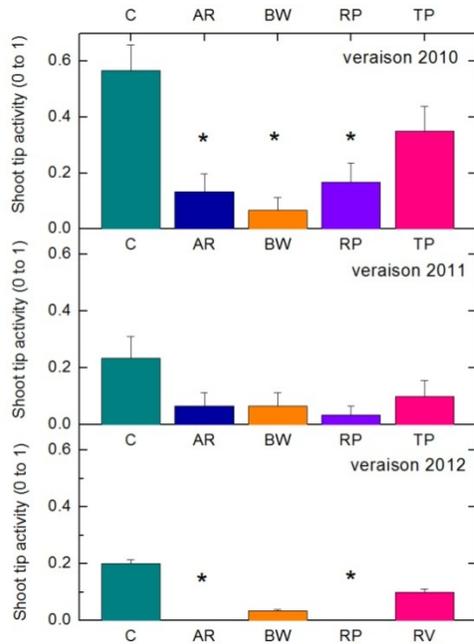
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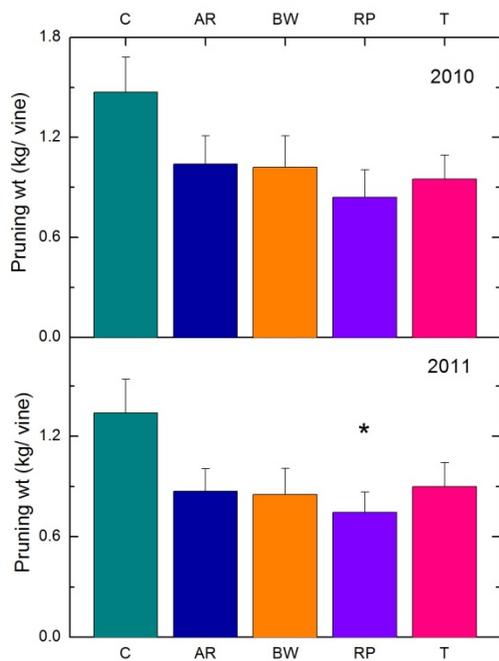
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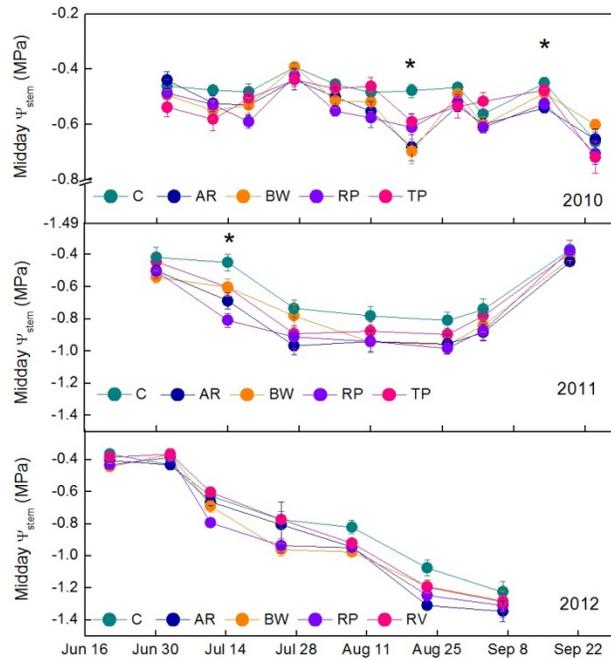
**Figure 1:** Root zone management (RZM) treatments.



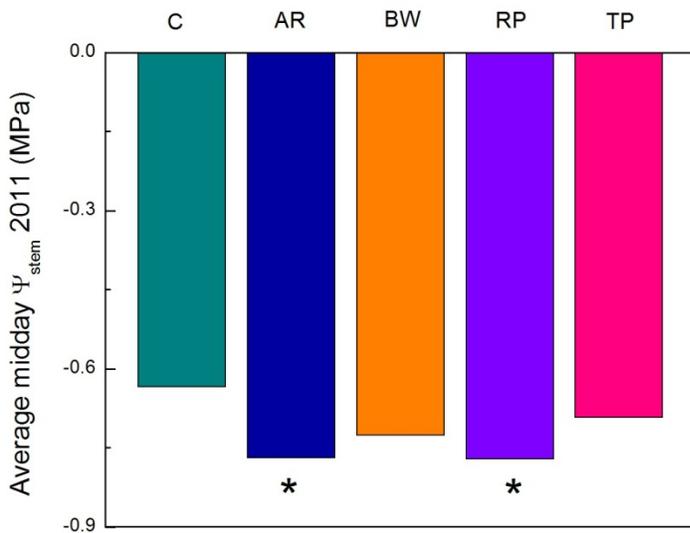
**Figure 2.** Shoot tip activity monitored at veraison 2010; 2011 and 2012 in control (C), annual ryegrass (AR), buckwheat (BW), root pruning (RP) and turnip (TP)/resident vegetation (RV) plots. Values are means ( $n=30$ )  $\pm$  1SE. Asterisk indicates significant differences with respect to the C based on Dunnett's test at  $P \leq 0.05$ .



**Figure 3.** Cane pruning weights (kg/vine), 2010 and 2011, in control (C), annual ryegrass (AR), buckwheat (BW), root pruning (RP) and turnip (TP) plots. Values are means ( $n=15$ )  $\pm$  1SE. Asterisk indicates significant differences with respect to the C based on Dunnett's test at  $P \leq 0.05$ .



**Figure 4.** Midday stem water potential ( $\Psi_{stem}$ ) trend measured in 2010, 2011 and 2012 in the control (C), annual ryegrass (AR), buckwheat (BW), root pruning (RP) and turnip (TP)/ resident vegetation (RV) treatments. Values are means ( $n=12$ )  $\pm$  1SE. Asterisk indicates significant differences with respect to the C based on Dunnett's test at  $P < 0.05$ .



**Figure 5.** Average midday stem water potential ( $\Psi_{stem}$ ) calculated for the 2011 growing season for the control (C), annual ryegrass (AR), buckwheat (BW), root pruning (RP) and turnip (TP) treatments. Asterisk indicates significant differences with respect to the C based on Dunnett's test at  $P < 0.05$ .

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**Table 1.** Selected enhanced point quadrat data collected around veraison 2011 and 2012 in control (C), annual ryegrass (AR), buckwheat (BW), root pruning (RP) and turnip (TP) /resident vegetation (RV) plots.

	OLN		CEL		LEL		CEFA		LEFA	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
C	4.42	4.31	1.30	1.17	0.66	0.58	0.10	0.09	0.29	0.28
AR	3.56	3.32*	0.85	0.79	0.47	0.44	0.28*	0.23*	0.38*	0.35*
BW	3.90	3.30*	0.99	0.85	0.55	0.40	0.25	0.20	0.37	0.36*
RP	3.54	3.38*	0.94	0.89	0.50	0.36*	0.27*	0.22*	0.38*	0.38*
TP/RV	4.28	3.52	1.11	0.93	0.69	0.42	0.21	0.14	0.33	0.36*
p-value	0.529	0.02	0.456	0.456	0.456	0.08	0.062	0.050	0.062	0.011

Within a column the asterisk indicates significant differences with respect to the C based on Dunnett's test at  $P < 0.05$ .

**Metrics explanation:** OLN: number of shade-producing contacts (leaves and clusters) per insertion; CEL: number of shading layers between clusters and nearest canopy boundary; LEL: number of shading layers between leaves and nearest canopy boundary; CEFA: percentage, expressed as a decimal, of above-canopy PPFD that reaches clusters; LEFA: percentage, expressed as a decimal, of above-canopy PPFD that reaches leaves.

**Table 2.** Low temperature exotherms (LTE in °C) of buds of control (C), annual ryegrass (AR), buckwheat (BW), root pruning (RP) and turnip (TP) vines sampled 4 times during the winter 2011-2012.

	13 Dec 2011	26 Jan 2012	21 Febr 2012	9 March 2012
	LTE <sub>50</sub>	LTE <sub>50</sub>	LTE <sub>50</sub>	LTE <sub>50</sub>
C	-21.86	-22.16	-21.82	-20.24
AR	-22.01	-22.12	-22.75	-20.51
BW	-21.86	-21.90	-21.57	-20.01
RP	-21.76	-21.31	-21.86	-20.60
TP	-21.85	-21.78	-22.08	-20.54
p-value	0.582	0.606	0.138	0.444

No significant differences among treatments were found at  $P = 0.05$  level (Dunnett's test).

**Table 3.** Petiole macronutrient concentrations at veraison 2010, 2011 and 2012 in control (C), annual ryegrass (AR), buckwheat (BW), root pruning (RP) and turnip (TP)/resident vegetation (RV) vines.

	Nitrogen (%)			Phosphorous (%)			Potassium (%)			Magnesium (%)		
	2010	2011	2012	2010	2011	2012	2010	2011	2012	2010	2011	2012
C	1.12	0.65	0.60	0.47	0.43	0.29	3.51	2.70	3.27	0.37	0.72	0.85
AR	0.89	0.60	0.57	0.40	0.47	0.38	2.24*	2.47	2.21	0.45	0.75	0.84
BW	0.92	0.64	0.43	0.45	0.41	0.36	2.58	2.41	2.44	0.57	0.71	0.83
RP	0.89	0.58*	0.53	0.48	0.55	0.34	2.54	2.41	1.98	0.56	0.81	0.88
TP/RV	1.18	0.68	0.47	0.42	0.40	0.31	3.34	2.29	3.04	0.34	0.62	0.74
p-value	0.13	0.019	0.491	0.276	0.570	0.115	0.071	0.140	0.155	0.311	0.428	0.658

Within a column the asterisk indicates significant differences with respect to the C based on Dunnett's test at  $P \leq 0.05$

**Table 4.** Harvest parameters and berry chemistry measured at harvest 2010, 2011, and 2012 in control (C), annual ryegrass (AR), buckwheat (BW), root pruning (RP) and turnip (TP)/ resident vegetation (RV) plots.

Treatment	Yield/ Vine (kg)	Clusters /vine	Cluster weight (g)	Berry weight (g)	Berry /cluster	°Brix	pH	TA (g/l)
<b>10/20/10</b>								
C	2.18	38.1	56.4	1.17	48	24.5	3.44	8.57
AR	2.22	40.5	55.0	1.15	48	25.1	3.46	8.55
BW	2.05	37.3	53.0	1.13	47	25.1	3.47	8.25
RP	2.07	37.4	57.1	1.17	50	25.0	3.47	8.83
TP	2.20	37.6	57.5	1.13	56	25.1	3.47	9.67
p-value	0.935	0.752	0.652	0.919	0.949	0.252	0.910	0.600
<b>10/18/11</b>								
C	4.75	66.7	71.1	1.24	57	22.2	3.46	6.91
AR	4.46	52.2	79.0	1.26	63	23.2	3.48	6.98
BW	4.19	61.6	67.5	1.20	56	22.9	3.48	6.68
RP	3.74	52.2	71.1	1.29	55	23.0	3.53	6.70
TP	4.08	52.9	76.3	1.27	60	23.3	3.51	6.31
p-value	0.473	0.146	0.385	0.278	0.444	0.330	0.327	0.345
<b>9/26/12</b>								

C	4.47	56	80.82	1.17	64	23.8	3.39	7.4
AR	3.63	49	73.70	1.20	67	24.3	3.42	7.18
BW	3.93	52	74.94	1.19	62	24.6	3.45	6.75
RP	3.78	50	74.27	1.19	63	23.8	3.42	6.96
TP	3.97	52	76.09	1.17	65	23.9	3.43	7.19
p-value	0.237	0.476	0.553	0.920	0.539	0.607	0.666	0.807

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No significant differences among treatments were found at  $P = 0.05$  level (Dunnett's test).

Variety	Total phenolic content (mg GAE/100 g)		Total carotenoid content ( $\mu\text{g BCE}/100\text{ g}$ )*, ( $\mu\text{g BC}/100\text{ g}$ )**		Hydrophilic antioxidant capacity ( $\mu\text{mol TE}/100\text{ g}$ )	Lipophilic antioxidant capacity ( $\mu\text{mol TE}/100\text{ g}$ )	Total Antioxidant Capacity ( $\mu\text{mol TE}/100\text{ g}$ )	
	2009	2010	2009*	2010**	2009	2009	2009*	2010**
PEACH	$p<0.0001$	$p=0.0044$	$p=0.0012$	$p=0.0108$	$p<0.0001$	$p=0.0544$	$p<0.0001$	$p=0.0035$
Baby Gold 5	$39.98 \pm 4.43^b$	NA	$696.01 \pm 132.94^{abc}$	$794.62 \pm 260.32^a$	<b>Table 3.</b> <b>Nutritional</b> <b>characteristics</b> <b>of selected</b> <b>New York</b> <b>peaches and</b> <b>apricots</b> $735.76 \pm 47.97^{bc}$	$24.71 \pm 3.62^a$	$760.47 \pm 44.48^{bc}$	NA
Bounty	$49.81 \pm 10.93^b$	$70.84 \pm 21.05^{ab}$	$1105.51 \pm 318.85^{ab}$	$652.31 \pm 235.07^{ab}$		$727.45 \pm 134.24^{bc}$	$32.93 \pm 11.85^a$	$760.38 \pm 124.69^{bc}$
Clings	$32.42 \pm 4.53^b$	NA	$562.59 \pm 98.73^c$	NA	$727.94 \pm 114.20^{bc}$	$15.28 \pm 13.97^a$	$743.22 \pm 122.16^{bc}$	NA
Glo Haven	$55.85 \pm 12.23^{ab}$	NA	$588.85 \pm 41.73^{bc}$	NA	$693.36 \pm 164.86^{bc}$	$24.86 \pm 6.80^a$	$718.22 \pm 170.92^{bc}$	NA
Harrow Beauty	$37.80 \pm 5.53^b$	$48.06 \pm 1.57^b$	$801.87 \pm 188.96^{abc}$	$665.76 \pm 104.80^{ab}$	$582.73 \pm 45.88^c$	$10.72 \pm 4.42^a$	$593.45 \pm 42.76^c$	$1943.63 \pm 99.13^{abc}$
John Boy	$30.58 \pm 3.09^b$	$44.99 \pm 7.24^b$	$839.78 \pm 92.12^{abc}$	$298.98 \pm 95.91^b$	$540.83 \pm 165.06^c$	$22.36 \pm 10.08^a$	$563.19 \pm 173.09^c$	$1534.33 \pm 305.87^{bc}$
John Boy II	$31.24 \pm 4.39^b$	$40.49 \pm 2.12^b$	$1152.93 \pm 369.35^a$	$281.96 \pm 136.80^b$	$438.84 \pm 32.83^c$	$17.44 \pm 3.31^a$	$456.28 \pm 36.13^c$	$2313.63 \pm 319.50^{abc}$
PF 22007	$59.31 \pm 24.30^{ab}$	$96.35 \pm 31.37^a$	$634.80 \pm 108.50^{abc}$	$376.90 \pm 22.60^{ab}$	$1047.79 \pm 159.35^b$	$18.02 \pm 8.95^a$	$1065.81 \pm 160.63^b$	$3019.69 \pm 870.74^a$
PF 23	$86.60 \pm 21.03^a$	$60.90 \pm 3.14^{ab}$	$660.86 \pm 50.14^{abc}$	$574.15 \pm 222.84^{ab}$	$1432.38 \pm 90.25^a$	$39.63 \pm 18.55^a$	$1472.01 \pm 95.99^a$	$1926.46 \pm 223.68^{abc}$
PF Lucky 13	$27.24 \pm 4.75^b$	$39.81 \pm 6.70^b$	$771.18 \pm 268.59^{abc}$	$490.15 \pm 238.24^{ab}$	$530.41 \pm 109.24^c$	$12.04 \pm 4.60^a$	$542.45 \pm 111.13^c$	$1177.86 \pm 198.98^c$
Red Haven	$41.03 \pm 9.75^b$	$54.03 \pm 12.17^{ab}$	$579.61 \pm 31.69^{bc}$	$323.56 \pm 30.92^{ab}$	$624.20 \pm 169.92^c$	$20.11 \pm 13.90^a$	$644.31 \pm 176.82^c$	$1754.98 \pm 223.16^{bc}$
Red Haven JB	$42.61 \pm 7.13^b$	NA	$462.46 \pm 4.84^c$	NA	$719.17 \pm 113.61^{bc}$	$29.40 \pm 7.64^a$	$748.57 \pm 113.68^{bc}$	NA
Vivid	$52.85 \pm 13.36^{ab}$	$61.59 \pm 17.00^{ab}$	$549.60 \pm 138.51^{bc}$	$419.16 \pm 81.53^{ab}$	$611.08 \pm 167.92^c$	$21.52 \pm 5.33^a$	$632.60 \pm 172.45^c$	$1809.00 \pm 370.23^{abc}$
<b>Mean</b>	<b>45.18 <math>\pm</math> 16.09</b>	<b>57.45 <math>\pm</math> 17.94</b>	<b>714.03 <math>\pm</math> 220.20</b>	<b>487.79 <math>\pm</math> 219.71</b>	<b>724.00 <math>\pm</math> 258.65</b>	<b>22.23 <math>\pm</math> 8.23</b>	<b>746.23 <math>\pm</math> 263.92</b>	<b>1992.83 <math>\pm</math> 541.22</b>
APRICOT	$p<0.0001$	$p<0.0001$	$p=0.0300$	$p=0.0953$	$p<0.0001$	$p=0.0009$	$p<0.0001$	$p<0.0001$
Harcot	$70.33 \pm 21.37^{bc}$	NA	$941.63 \pm 78.09^{ab}$	NA	$1420.97 \pm 104.05^{cd}$	$38.90 \pm 11.41^{abc}$	$1459.86 \pm 113.42^{cd}$	NA
Hargrand	$337.15 \pm 50.80^a$	$342.71 \pm 37.64^a$	$810.13 \pm 31.18^{ab}$	$5457.49 \pm 3022.09^a$	$3652.74 \pm 353.23^a$	$59.56 \pm 3.41^a$	$3712.3 \pm 356.62^a$	$7085.23 \pm 556.45^a$

Harlayne	45.35 ± 6.01 <sup>c</sup>	119.96 ± 16.30 <sup>b</sup>	764.97 ± 75.40 <sup>ab</sup>	4355.13 ± 2296.30 <sup>ab</sup>	851.78 ± 163.07 <sup>d</sup>	21.77 ± 8.85 <sup>c</sup>	873.55 ± 171.92 <sup>d</sup>	3484.37 ± 474.50 <sup>b</sup>
Harogem	125.98 ± 33.36 <sup>b</sup>	94.97 ± 19.3 <sup>b</sup>	881.36 ± 173.61 <sup>ab</sup>	5315.94 ± 1716.00 <sup>a</sup>	2194.86 ± 221.05 <sup>b</sup>	46.87 ± 6.60 <sup>ab</sup>	2241.72 ± 217.17 <sup>b</sup>	2844.04 ± 459.33 <sup>b</sup>
Mascot	83.17 ± 19.85 <sup>bc</sup>	NA	1068.06 ± 268.66 <sup>a</sup>	NA	1303.81 ± 62.43 <sup>cd</sup>	36.34 ± 6.28 <sup>bc</sup>	1340.15 ± 64.23 <sup>cd</sup>	NA
Tomcot	126.46 ± 14.11 <sup>b</sup>	111.85 ± 12.08 <sup>b</sup>	1031.51 ± 28.55 <sup>ab</sup>	983.18 ± 329.42 <sup>b</sup>	1772.35 ± 350.96 <sup>bc</sup>	40.0663 ± 11.19 <sup>abc</sup>	1812.42 ± 362.11 <sup>bc</sup>	2975.71 ± 123.37 <sup>b</sup>
Vivagold	85.65 ± 10.17 <sup>bc</sup>	NA	704.88 ± 24.67 <sup>b</sup>	NA	1166.01 ± 201.66 <sup>cd</sup>	25.69 ± 3.97 <sup>bc</sup>	1191.7 ± 205.63 <sup>cd</sup>	NA
<b>Mean</b>	<b>124.87 ± 98.01</b>	<b>167.37 ± 103.44</b>	<b>886.08 ± 135.80</b>	<b>4027.94 ± 2596.48</b>	<b>1766.07 ± 937.39</b>	<b>38.46 ± 12.68</b>	<b>1804.53 ± 949.34</b>	<b>4097.34 ± 1777.59</b>

**Table 4. Nutritional content of canned peaches and apricots**

Parameter	Total phenolic content (mg GAE/100 g)		Total Antioxidant Capacity ( $\mu\text{mol TE}/100\text{ g}$ )		$\beta$ -carotene concentration ( $\mu\text{g}/100\text{ g}$ )	
	With skin	Without skin	With skin	Without skin	With skin	Without skin
<b>PEACH</b>						
John Boy II	36.50 $\pm$ 1.18	34.37 $\pm$ 1.97	1868.75 $\pm$ 169.82	1851.09 $\pm$ 132.22	1035.37 $\pm$ 279.72	1046.54 $\pm$ 151.59
PF 23	41.25 $\pm$ 10.98	38.30 $\pm$ 2.98	1898.74 $\pm$ 208.35	1822.78 $\pm$ 60.55	946.91 $\pm$ 253.44	841.51 $\pm$ 47.99
Red Haven	38.31 $\pm$ 3.43	32.46 $\pm$ 3.65	1883.82 $\pm$ 233.61	1916.45 $\pm$ 132.63	1126.81 $\pm$ 137.18	856.48 $\pm$ .46
<b>Mean</b>	<b>38.63 <math>\pm</math> 6.40</b>	<b>35.04 <math>\pm</math> 3.68</b>	<b>1883.77 <math>\pm</math> 186.420</b>	<b>1863.44 <math>\pm</math> 110.65</b>	<b>1036.36 <math>\pm</math> 223.33</b>	<b>914.84 <math>\pm</math> 138.18</b>
<b>APRICOT</b>						
Hargrand	228.29 $\pm$ 44.10	193.58 $\pm$ 14.53	6106.02 $\pm$ 1906.60	4032.73 $\pm$ 75.82	14367.75 $\pm$ 3072.33	19517.23 $\pm$ 2301.86
Harlayne	135.00 $\pm$ 34.99	148.61 $\pm$ 23.91	3114.69 $\pm$ 553.07	3392.14 $\pm$ 83.32	16879.85 $\pm$ 1010.70	12834.60 $\pm$ 403.68
Harogem	122.61 $\pm$ 12.31	124 $\pm$ 9.96	3583.80 $\pm$ 253.77	3234.47 $\pm$ 210.88	1174.69 $\pm$ 3290.94	8620.64 $\pm$ 1696.71
<b>Mean</b>	<b>161.97 <math>\pm</math> 57.73</b>	<b>155.67 <math>\pm</math> 33.58</b>	<b>4268.17 <math>\pm</math> 1724.75</b>	<b>3553.11 <math>\pm</math> 381.55</b>	<b>14344.10 <math>\pm</math> 3244.54</b>	<b>13657.49 <math>\pm</math> 4922.63</b>

**Table 5. Nutritional content of dried peaches and apricots**

Parameter	Total phenolic content (mg GAE/100 g)		Total Antioxidant Capacity ( $\mu\text{mol TE}/100\text{ g}$ )		$\beta$ -carotene concentration ( $\mu\text{g}/100\text{ g}$ )	
	Sucrose + Pasteurization	Sucrose + Sulfur dioxide	Sucrose + Pasteurization	Sucrose + Sulfur dioxide	Sucrose + Pasteurization	Sucrose + Sulfur dioxide
<b>PEACH</b>						
John Boy II	72.33 $\pm$ 0.96	145.22 $\pm$ 36.39	3871.09 $\pm$ 811.80	8689.33 $\pm$ 1225.43	1338.24 $\pm$ 111.05	3343.05 $\pm$ 2239.69
PF 23	92.51 $\pm$ 2.27	158.09 $\pm$ 28.50	4966.89 $\pm$ 735.34	7801.25 $\pm$ 673.63	931.43 $\pm$ 271.16	1766.56 $\pm$ 220.23
Red Haven	108.53 $\pm$ 13.65	226.02 $\pm$ 38.09	4691.54 $\pm$ 1650.15	9828.27 $\pm$ 474.15	705.26 $\pm$ 90.43	1397.87 $\pm$ 114.16
<b>Mean</b>	<b>91.12 <math>\pm</math> 18.14</b>	<b>176.44 <math>\pm</math> 43.42</b>	<b>4509.84 <math>\pm</math> 570.05</b>	<b>8772.95 <math>\pm</math> 1016.09</b>	<b>991.64 <math>\pm</math> 317.99</b>	<b>2169.161 <math>\pm</math> 1367.31</b>
<b>APRICOT</b>						
Hargrand	391.75 $\pm$ 15.55	429.29 $\pm$ 255.12	14100.64 $\pm$ 579.77	15645.10 $\pm$ 6017.19	17708.45 $\pm$ 890.84	26519.63 $\pm$ 13982.32
Harlayne	484.26 $\pm$ 88.88	338.66 $\pm$ 46.28	13901.40 $\pm$ 1753.06	11325.61 $\pm$ 1237.51	19096.64 $\pm$ 650.40	11532.85 $\pm$ 400.87
Harogem	252.30 $\pm$ 1.10	291.06 $\pm$ 65.62	9417.26 $\pm$ 1036.95	9453.48 $\pm$ 733.51	12303.55 $\pm$ 44.89	17045.57 $\pm$ 4720.04
<b>Mean</b>	<b>376.11 <math>\pm</math> 116.77</b>	<b>353.00 <math>\pm</math> 70.22</b>	<b>12473.10 <math>\pm</math> 2648.31</b>	<b>12141.40 <math>\pm</math> 3175.40</b>	<b>16369.55 <math>\pm</math> 3247.86</b>	<b>18366.02 <math>\pm</math> 9463.39</b>

**Table 6. Nutritional content of peach and apricot jam**

Parameter	Total phenolic content (mg GAE/100 g)		Total Antioxidant Capacity ( $\mu\text{mol TE}/100\text{ g}$ )		$\beta$ -carotene concentration ( $\mu\text{g}/100\text{ g}$ )	
	Standard	Reduced	Standard	Reduced	Standard	Reduced
<b>PEACH</b>						
John Boy II	31.80 $\pm$ 2.00	33.75 $\pm$ 0.67	2007.01 $\pm$ 115.61	2106.14 $\pm$ 148.90	322.62 $\pm$ 94.10	371.54 $\pm$ 62.66
PF 23	30.26 $\pm$ 3.91	37.07 $\pm$ 1.02	1820.85 $\pm$ 169.81	2167.73 $\pm$ 121.63	139.95 $\pm$ 37.31	157.34 $\pm$ 94.72
Red Haven*	36.73 $\pm$ 2.45	NA	2334.36 $\pm$ 47.52	NA	107.31 $\pm$ 25.17	NA
<b>Mean</b>	<b>31.03 <math>\pm</math> 1.09</b>	<b>35.41 <math>\pm</math> 2.35</b>	<b>1913.93 <math>\pm</math> 131.64</b>	<b>2136.94 <math>\pm</math> 43.55</b>	<b>231.28 <math>\pm</math> 118.00</b>	<b>264.44 <math>\pm</math> 136.51</b>
<b>APRICOT</b>						
Hargrand*	138.00 $\pm$ 22.30	NA	5987.91 $\pm$ 702.68	NA	5123.92 $\pm$ 1065.56	NA
Harlayne	78.53 $\pm$ 14.85	84.27 $\pm$ 10.26	2966.95 $\pm$ 627.71	3186.62 $\pm$ 318.11	693.88 $\pm$ 465.38	1040.86 $\pm$ 730.99
Harogem	51.43 $\pm$ 5.45	78.27 $\pm$ 5.81	2360.21 $\pm$ 348.50	3039.92 $\pm$ 470.97	424.47 $\pm$ 288.86	2838.76 $\pm$ 1369.47
<b>Mean</b>	<b>64.98 <math>\pm</math> 19.16</b>	<b>81.27 <math>\pm</math> 4.24</b>	<b>2663.58 <math>\pm</math> 429.03</b>	<b>3113.27 <math>\pm</math> 103.73</b>	<b>559.17 <math>\pm</math> 386.42</b>	<b>1939.81 <math>\pm</math> 1398.69</b>

\*Not included in mean.

**Table 7. Nutritional content of peach and apricot nectar**

Product	Nectar					
	Total phenolic content (mg GAE/100 g)		Total Antioxidant Capacity ( $\mu\text{mol TE}/100\text{ g}$ )		$\beta$ -carotene concentration ( $\mu\text{g}/100\text{ g}$ )	
Treatment	Standard	Reduced	Standard	Reduced	Standard	Reduced
<b>PEACH</b>						
John Boy II	28.74 $\pm$ 1.16	27.72 $\pm$ 2.05	1342.18 $\pm$ 59.53	1137.23 $\pm$ 153.75	510.45 $\pm$ 66.25	551.60 $\pm$ 39.47
PF 23	35.02 $\pm$ 2.41	31.49 $\pm$ 3.15	1617.28 $\pm$ 134.81	1839.03 $\pm$ 328.86	480.91 $\pm$ 163.55	492.85 $\pm$ 87.11
Red Haven	36.28 $\pm$ 4.84	36.70 $\pm$ 4.20	2290.87 $\pm$ 211.47	2048.25 $\pm$ 133.54	528.95 $\pm$ 92.59	538.56 $\pm$ 115.21
<b>Mean</b>	<b>33.35 <math>\pm</math> 4.04</b>	<b>31.97 <math>\pm</math> 4.51</b>	<b>1750.11 <math>\pm</math> 488.10</b>	<b>1674.83 <math>\pm</math> 477.18</b>	<b>506.77 <math>\pm</math> 106.10</b>	<b>527.67 <math>\pm</math> 82.50</b>
<b>APRICOT</b>						
Hargrand	202.88 $\pm$ 5.95	217.85 $\pm$ 18.31	7966.92 $\pm$ 483.80	7389.31 $\pm$ 481.57	11721.20 $\pm$ 2101.98	10437.60 $\pm$ 1524.47

Harlayne	109.10 ± 4.33	118.59 ± 8.06	3626.04 ± 435.98	4131.40 ± 280.25	6596.30 ± 872.37	6726.87 ± 1122.84
Harogem	87.96 ± 4.18	85.75 ± 4.51	3479.74 ± 175.73	3182.51 ± 593.54	5171.22 ± 947.15	4268.84 ± 1464.56
<b>Mean</b>	<b>133.31 ± 61.17</b>	<b>140.73 ± 68.77</b>	<b>5024.23 ± 2549.49</b>	<b>4901.08 ± 2206.49</b>	<b>7829.56 ± 3207.36</b>	<b>7144.44 ± 2928.59</b>

## **Project Title: New York Farm and Food Online Directory**

### **Project Summary**

The interest in buying local New York specialty crop products has increased dramatically in recent years. Retailers, wholesalers, distributors, restaurants, schools, institutions and the public are seeking a wide range of farm products in varying quantities and geographic locations. This interest presents a significant opportunity; at the same time however, connecting consumers and interested buyers with producers on a timely basis can be very time consuming for producer while also presenting logistical challenges.

The purpose of this project was to take advantage of this shift and interest as well as newer technologies to develop an efficient, interactive, on-line directory of farms, farm products and related information. This directory would be utilized by a growing number of consumers and commercial buyers as well as specialty crop producers and other food and agricultural product marketers. The goals of creating a new electronic directory were to:

- a) Allow buyers ranging from consumers to commercial food and agricultural product buyers to easily search for and identify sources of New York food and agricultural products.
- b) Enable buyers to link directly to listed farms and other food and agricultural product suppliers.
- c) Enable farmers and others suppliers to quickly and easily establish initial on-line listings and provide the opportunity to make timely updates which will assure accuracy and usefulness. In some cases this might be the only online presence a New York Specialty Crop producer might have.
- d) Increase Department efficiency in compiling and editing information received from various sources.
- e) Accommodate farmers and others without Internet access to submit information on paper forms as well as allow the Department to print and mail search results to users who lack Internet access.
- f) Enable the Department to track use of the directory to help evaluate its impact on farmers, processors and consumers.

### **Project Approach**

Due to the scope of this project and limited Department staffing resources with relevant and necessary IT expertise available for this project, the Department contracted with a Minority and Women-Owned Business Enterprise (MWBE), pre- approved IT vendor selected through a competitive bid process. In order to ensure that the on-line directory conformed with State security and system requirements as well as to meet program objectives, a small team of Department IT, administrative and

program staff were involved with development and oversight of an implementation plan. With this team in place, a scope and budget was created, tools were identified, and a custom system was developed in accordance to the implementation plan, which included specified deliverables. Below is a summary of the activities performed:

**Project Initiation:**

1. Obtain Signed Agreement
2. Finalize Resources
3. Conduct Program Kickoff Meeting
4. Gain Understanding of Requirements
5. Create Detailed Project Plan
6. Determine Onboard Logistics
7. Review the environment including development, tools, deployment process, report information, and data delivery within NYS program
8. Define Project Communication protocols

**Deliverable:** Signed Agreement, An accepted, written, detailed Project Plan and Timeline, Environment Requirements, Documented and Agreed Upon Protocols

At the start of the project Tailwinds was provided with the following information:

- a. a sample list of user scenarios.
- b. a sample list of Actors and their attributes.
- c. data dictionaries or structure and field information for the above mentioned sources.
- d. a sampling of records and/or data following Tailwind's signature of the Department's Confidentiality and Non-Disclosure Agreement.
- e. a list of favorably comparable web sites
- f. a catalog of proprietary graphics

## **Business/Technical Design (NYSDAM Deliverables 1, 2, 3 and 4):**

1. Understand and document current processes and procedures.
2. Define and document User Interface Requirements including but not limited to:
  - a. Data Load and Management tools
  - b. Web Search requirements including searches on product, geography, special attributes, or any combination of these or other present data.
  - c. Web Interfaces including but not limited to
    - i. Food and Farm Online Directory (FFOD) main site pages
    - ii. web search pages
    - iii. web results pages including but not limited to
      1. geography
      2. result lists
      3. maps and directions (links or pages)
      4. calendar and special event pages
    - iv. member data submission pages
    - v. data review and approval pages
    - vi. List of Values maintenance pages including but not limited to
      1. Products
      2. Memberships
      3. Categories
      4. Classifications
      5. Demographics
      6. Descriptions
    - vii. Maintenance of private and public member data
    - viii. Data cleansing/consolidation tools and recommendations
    - ix. Standard reports
    - x. Ad-hoc query tools
    - xi. Contact management tools
  - d. The ability to provide a map and directions to scenarios of a single entity as well as multiple entities from a selected set of entities.
  - e. A mechanism for providing single or recurring time sensitive/ limited time information such as product availability or special events tied to an entity or location with automatic aging and removal.
  - f. Back-Office needs
  - g. Member / Participant Data Update needs
  - h. Data Update Approval Process
  - i. Protocol for data loading, cleansing and on-going maintenance
  - j. Defined search paths
  - k. Web Mapping components
  - l. Contact management tools and reporting.

3. Define and document Technical Architecture including but not limited to:
  - a. Technical requirements definition
  - b. Database design documents
  - c. Web mapping
  - d. Recommended tools
4. Design and document Reporting Architecture including but not limited to:
  - a. Ad-hoc (on-demand) query/reporting architecture and tools
  - b. Fixed reporting architecture and tools
5. Define Reporting Requirements including but not limited to:
  - a. Ad-hoc (on-demand) query/reporting requirements
  - b. Fixed reporting requirements with or without parameters
6. Conduct business requirement reviews
7. Deploy technical requirements (hardware & software)

***Deliverable:*** An accepted, documented set of requirements including but not limited to current processes, user interface requirements, technical architecture, reporting architecture and requirements, and deployment of agreed upon architecture and tools.

#### **Application Development (NYSDAM Deliverables 5 and 6)**

1. Develop web functionality
  - a. Develop/program web functionality as defined in requirements analysis noted above.
  - b. Develop web functionality with a table-driven approach to management of all underlying data and pick lists in an ad-hoc manner while automatically maintaining those changes in the search criteria.
2. Develop Database
  - a. Develop secured database including both front (public) and back (private/Department use) end applications as appropriate to above defined requirements.
3. Conduct Unit Testing

**Deliverable:** Accepted fully functional, table-driven, tested, documented and secured web site with specifications for movement or call of information to and from a single source database as defined in requirements above. Accepted reports catalog and ad hoc editing mechanism for altering or creating customized reports as required. Fully functional web mapping components.

#### **Integration/ User Acceptance Testing (UAT) (NYSDAM Deliverable 7)**

1. Develop Test Plan
2. Develop Test Scripts
3. Integration Test Runs.
4. UAT Test Runs
  - a. Address and repair any non-functioning or unacceptable outcomes or search results.
  - b. Ensure data migration was successful.
  - c. Confirm business process and flow is acceptable.

**Deliverable:** Provide accepted revised fully functional, coordinated, tested, corrected, documented and secured web site. Elements which comprise this deliverable will include but are not limited to:

1. Testing protocols
  - a. Test plans
  - b. Test environment
  - c. Iterative Testing and Resolution
    - i. Basic Functionality
    - ii. Data Assessment
    - iii. Process testing
    - iv. Final acceptance testing
2. Code and all Tools for the fully functional and accepted web site and all associated tools as defined above

#### **Go Live/Training (NYSDAM Deliverables 8, 9 and 10)**

1. Conduct Deployment Readiness Activities
2. Conduct Knowledge transfer activities
  - a. Provide system documentation for both single source database and web site including all programming code, data structures and web pages as well as a complete list of project hardware, software and licensing requirements.

3. Train End users
  - a. System Admin training (for IT)
  - b. Business Admin training (for Ag Protection)
4. Go Live Production Startup
  - a. Fully functional and accepted Production web site and all associated tools as defined above, accessible to participants and general public
  - b. Registration in relevant search engines
  - c. Fully loaded production data

**Deliverable:** Fully functional Production, Development and UAT web sites with documentation for configuration and maintenance and all production data. System documentation and user guides for all roles. At the discretion of the Department, Tailwind will provide instructor-led user / administration training for department staff.

SCBGP funds were used solely to enhance the competitiveness of specialty crops. Department funding provided the balance of funding for the non-specialty crop producers including in this project.

### **Goals and Outcomes Achieved**

#### **Goal 1** - Identify and highlight at least 800 specialty crop producers

The Department conducted outreach to industry members and consumers. The site was evaluated for both style and content by a number of stakeholders including lifestyle and food bloggers, local food promoters, industry group representatives, regional promotion and tourism representatives, growers, processors, restaurateurs and retailers. These included the NY Specialty Crop Block Grant Advisory Committee, NY Farm Bureau staff and members, NY Vegetable Growers Association, NY Apple Association, wool producers, NYS Horticultural Society, berry growers, NY Small Scale Food Processors Association as well as others.

A palm card was created for the farmers to establish initial business information listings or to update their listings as well as a means to direct them to the Department for assistance in updating their listings.

For those farmers that who do not use email or otherwise have an online presence, the Department created and/or updated their establishment data to ensure those farmers were included. Although an e-mail address is required for an account which is tied to a login and password system, Department staff have the ability to override that component.

**Outcome achieved:** 5,200 New York specialty crop producers are included in the database for the on-line directory.

**Goal 2:** 1,500-2,500 web hits/month (during growing season)

The New York Farm and Food Online Directory was showcased at a new kiosk at the Great New York State Fair (August 23-September 3, 2012, in Syracuse, NY). This was a limited release to test the site and obtain feedback from consumers and producers in attendance at the Fair (approximately 1 million attendees).

**Outcome achieved:** Google analytics indicated that there were 1,459 page views; approximately 500 discrete users and 137 distinct searches (farm look-up). Feedback received was incorporated in as much as feasible and specs allowed. Pending guidance and approval from the Governor's Office on how the new site will link with other Statewide initiatives, plans are for the site to go live by spring 2013.

### **Beneficiaries**

Beneficiaries of this project include the 5,200 New York specialty crop producers that are included in the database that stand to benefit from increased exposure and sales. In addition, consumers throughout New York will be able to easily search for and identify sources of New York food and agricultural products.

### **Lessons Learned**

Although a fairly comprehensive checklist of deliverables and expectations was created at the onset of this project, we learned that deliverable specifics should have been defined with more detail and pre-established checkpoints. Because of the many inter-related technical issues and continual need for clarifications throughout this project, particularly in the design/build stage, the project would have benefitted by having an experienced agency IT project manager assigned to this project. This would likely have resulted in better communication with the subcontractor and clearer expectations for all parties involved. Furthermore, again because of the inherent technical complexities, clear and throughout documentation at every decision point or change in direction is essential for a project of this nature.

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## Additional Information



# ARE YOU A NEW YORK FARMER OR FOOD PRODUCER?

The interest in buying local New York food and agricultural products has increased dramatically in recent years. While more consumers are seeking local products, effectively connecting with consumers and various buyers to develop solid sales and long-term business relationships can be very time consuming and present logistical challenges.

In response to this situation, the New York State Department of Agriculture & Markets, through the Pride of New York, is developing a new, interactive online directory that will offer consumers a one-stop shop for local food and ag products and give farmers and food producers the ability to provide tailored information about their farm and/or products. Whether you're looking to share timely, detailed information about agri-tourism activities available to the public on your farm, provide specific product information, or simply offer contact information for potential buyers, this new website can help.

*If you are interested in being included on this new website or want more information, please contact Kathryn Bamberger at the Department (518) 457-4383 or [kathryn.bamberger@agriculture.ny.gov](mailto:kathryn.bamberger@agriculture.ny.gov)*



