Long Island Vegetable Pathology Program
2014 Annual Research Report

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Evaluation of Cornell Late Blight Decision Support System for timing fungicide applications for foliar diseases in tomato
Investigators: Margaret T. McGrath and Karen LaMarsh
Location: Long Island Horticultural Research and Extension Center

The goal of this experiment was to evaluate the Cornell Decision Support System (DSS) for naturally-occurring late blight on organically-grown tomato using an organic copper fungicide applied to a susceptible variety (Mountain Fresh Plus) and a moderately resistant variety with the Ph2 gene for resistance to late blight (Legend).

The experiment was conducted in a field with Haven loam soil that has been dedicated to organic research since 2001. A combination of Pro-Grow, Cheep Cheep, and Cotton seed blend fertilizers was spread at 700 lb/A (105 lb/A total N) over rows to be planted, then incorporated on 28 Apr. Drip irrigation tape was laid as the rows were covered with black plastic mulch. A living mulch of annual ryegrass was planted between rows by broadcasting seed with a hand-operated spreader, then lightly raking to incorporate on 6 May. The ryegrass plus weeds that grew were mowed routinely. Some weeds were removed by hand. Tomato seed were sown in an organic seeding mix in the greenhouse on 6 May. Seedlings were transplanted by hand on 9 into holes pre-made by a waterwheel transplanter that also applied starter fertilizer, Neptune's Harvest Benefits of Fish (2-4-1 N-P-K). Additional drench applications of this fertilizer to the base of plants were made on 8, 15, and 29 Aug, and 5 and 12 Sep.

A completely randomized block design with four replications was used. Plots consisted of 10 plants in a single row with 24-in. plant spacing and 68-in. row spacing. Plots for each of the four replications were in two adjacent rows. Plants were staked and trellised using a Florida weave trellising system with 4-ft stakes according to standard commercial practices. Water was provided as needed through drip irrigation tape. Insect pests were managed by applying Entrust (8 oz/A) on 17 Jul, 25 Jul, 4 Aug, and 2 Sep. Treatment applications to foliage were made using a CO_2-pressurized backpack sprayer with a boom that has a single twin-jet nozzle (TJ60-11004VS), calibrated to deliver 50 gal/A when operated at 54 psi and 2.4 mph. Each side of the planted row was treated with the boom held sideways to obtain thorough coverage of foliage and to mimic the coverage obtained with a drop nozzle on a tractor sprayer. A preventive 7-day application schedule was the standard program. A total of 14 applications were made from 22 Jun through 24 Sep. Timing of applications made following the DSS (http://blight.eas.cornell.edu/blight/) were adjusted as needed to avoid weekend days. Leaves were examined for symptoms of any foliar disease twelve times from 16 Jul to 29 Sep. Late blight and other diseases observed were assessed by estimating the percentage of leaves in each plot with symptoms (incidence) and the severity of symptoms on these affected leaves. Canopy severity was calculated by multiplying these values. Area Under Disease Progress Curve (AUDPC) was calculated for late blight severity from 26 Aug through 29 Sep for all entries.

Late blight was first observed on 20 Jun on LI, NY, in 2014. Very few symptoms were found that day in a commercial potato crop in Suffolk County located about 5 miles from the research field for this experiment. Source of inoculum for this crop could not be determined. Symptoms were found in three additional production fields before being found in this experiment on 15 Aug. US-23 was the only genotype of *Phytophthora infestans* found in the region, including at LIHREC. Late blight remained at a very low level in this experiment including in the untreated late blight-susceptible variety (Mountain Fresh Plus). This may have been partly due to plants not continuing to grow well through the season as a result of insufficient fertility compounded by competition from ryegrass living mulch. Compared to the weekly schedule, the DSS recommended two more applications (16 total) to the susceptible variety and four fewer (10 total) to the moderately resistant variety. The DSS spray intervals ranged from 3 to 8 days for Mountain Fresh Plus and 6 to 15 days for Legend. Following the DSS application schedule resulted in significantly lower late blight severity on Mountain Fresh Plus and powdery mildew on both varieties compared to the untreated controls. Septoria leaf spot was numerically lower. There were no significant differences between the DSS and weekly application schedules. Thus implementing the DSS for late blight on a moderately resistant variety did not compromise control of other diseases although four fewer applications were made. For Mountain Fresh Plus, disease severity values for plants receiving the DSS fungicide schedule were numerically lower than for those treated with fungicides following a standard weekly application interval; however, two more applications were made.

In conclusion, the DSS has proven to be a useful tool for timing applications of organic fungicides (copper) for late blight to susceptible and moderately resistant varieties that did not compromise control of other foliar diseases.

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Evaluation of pyriofenone for powdery mildew in tomato
Investigators: Margaret T. McGrath and Karen LaMarsh
Location: Long Island Horticultural Research and Extension Center

Controlled release fertilizer (N-P-K, 15-5-15) was used at 675 lb/A (101 lb N/A). Drip irrigation tape was laid as the rows were covered with black plastic mulch. Tomato seeds were sown on 6 May in the greenhouse. Seedlings were transplanted on 9 Jun by hand into holes opened in the plastic mulch by a waterwheel transplanter that also placed in the holes a starter fertilizer, Black Label Zn (6-20-0 N-P-K). Plants were staked and trellised following standard procedure for fresh-market tomato production. Weeds between mulch strips were managed early in the season by applying post-transplant Devrinol DF (2 lb/A) plus Metribuzin (1.33 lb/A), and then by mowing and hand removal especially in the transplant hole. Actigard (0.75 oz/A) was applied on 19 Jul and 4 Aug to manage bacterial speck. Late blight was managed by applying Ranman (2.75 fl oz/A) on 20 Aug, 2 Sep, and 10 Sep. Insects were managed by applying Assail 70 WP (1.7 oz/A) on 17 Jul, Lannate (1 pt/A) on 4 Aug and 18 Aug, and Hero (10.3 fl oz/A) on 26 Aug and 2 Sep. Plots consisted of 10 plants in a single row with 24-in. plant spacing and 68-in. row spacing. There was 8-ft spacing between plots in a row. Plots for each of the four replications were in single adjacent rows. There was a spreader row planted between the second and third replication. Leaves with powdery mildew were put on plants in the spreader row on 18 Jul. Other diseases that occurred started from naturally-occurring inoculum.

A completely randomized block design with four replications was used. Foliar applications were made using a CO_2-pressurized backpack sprayer with a boom that has a single twin-jet nozzle (TJ60-11004VS), calibrated to deliver 50 gal/A when operated at 54 psi and 2.4 mph. Each side of the planted row was treated with the boom held sideways to obtain thorough coverage of foliage and to mimic the coverage obtained with a drop nozzle on a tractor sprayer. A 7-day application schedule was used. Applications were made on 7, 15, 20, and 27 Aug, and 5 Sep. Leaves were examined routinely for disease symptoms beginning on 14 Jul. Disease was assessed by estimating number of leaves with symptoms (incidence) and estimating severity of symptoms on affected leaves. Canopy severity was calculated by multiplying these values. AUDPC was calculated from 12 Aug through 16 Sep. Defoliation was assessed on 29 Aug, and 4, 9, and 16 Sep as percent of leaves that had died.

Powdery mildew was first observed on 25 Jul in three plots. On 6 Aug symptoms were found in all plots. Average incidence of affected leaves was 6% and average canopy severity was 0.31%.

Treatments were started the next day. All treatments with IKF-309, which contains the active ingredient pyriofenone (FRAC Code U8), were highly effective for powdery mildew. Treatments were 2 rates and 2 intervals (7 and 14 day for the higher rate). Efficacy was evident following two applications at the 19 Aug assessment; there were no significant differences among any treatments on 12 Aug. Symptoms were only found in untreated plots on 9 Sep following the 5 applications for the 7-day interval treatments. Excellent control was evident on 16 Sep, which was 11 days after the last application. Incidence of affected leaves for untreated plants then was 34% and average canopy severity was 18%, while these values were less than 1% for the three treatments. The 14-day spray interval was as effective as the 7-day interval. Late blight and bacterial speck both occurred at uniform, very low severity that likely did not interfere with evaluation of IKF-309 for powdery mildew.

In conclusion, this new fungicide will be recommended for managing powdery mildew in tomato when it is registered for this use.

Evaluation of late blight resistant tomato varieties conducted with organic practices
Investigators: Margaret T. McGrath and Karen LaMarsh
Location: Long Island Horticultural Research and Extension Center

Tomato is an important crop that is routinely affected by diseases. It is important for both organic and conventional diversified vegetable growers, which are common in the northeastern US. Fresh local tomatoes are one of the most popular items during summer, therefore they are grown by many organic and conventional growers. There are several foliar disease affecting tomatoes, including Septoria leaf spot, early blight, bacterial speck and spot, late blight, powdery mildew and leaf mold. Foliar diseases are a common occurrence wherever tomatoes are grown. All plantings are affected, even those grown under protection (greenhouses and high tunnels) and in small home gardens. Resistant varieties would be a valuable tool for managing these diseases, particularly late blight because it occurs sporadically and can be difficult to control with fungicide applications started after onset. Organic growers on LI have identified tomato as a high priority for research. The goals of this experiment, which is part of a multi-year project, were to evaluate new tomato varieties and experimental hybrids with resistance to late blight in terms of 1) susceptibility to naturally-occurring foliar diseases and 2) yield and fruit quality.

The experiment was conducted in a field with Haven loam soil that has been dedicated to organic research since 2001. A combination of Pro-Grow, Cheep Cheep, and Cotton seed blend fertilizers was spread at 700 lb/A (105 lb/A total N) over rows to be planted, then incorporated on 28 Apr. Drip irrigation tape was laid as the rows were covered with black plastic mulch. A living mulch of annual ryegrass was planted between rows by broadcasting seed with a hand-operated spreader, then lightly raking to incorporate on 6 May. The ryegrass plus weeds that grew were mowed routinely. Some weeds were removed by hand. Tomato seed were sown in an organic seeding mix in the greenhouse on 23 May. Seedlings were transplanted by hand on 30 Jun into holes pre-made by a waterwheel transplanter that also applied starter fertilizer, Neptune's Harvest Benefits of Fish (2-4-1 N-P-K). Additional drench applications of this fertilizer to the base of plants were made on 8, 15, and 29 Aug, and 5 and 12 Sep.

A completely randomized block design with four replications was used. Plots consisted of 10 plants in a single row with 24-in. plant spacing and 68-in. row spacing. Plots for each of the four replications were in single adjacent rows. A yellow cherry-type tomato plant (cv. SunGold) separated plots within rows. This variety was also planted in a spreader row between the second and third replication. Plants were staked and trellised using a Florida weave trellising system with 4-ft stakes according to standard commercial practices. Water was provided as needed through the drip tape. Thrips, tomato fruit worms, and other insect pests were managed by applying Entrust (8 oz/A) on 17 and 25 Jul, 4 Aug, and 2 Sep. Leaves were examined for symptoms of any foliar disease 16 times from 16 Jul to 8 Oct. Late blight and other diseases observed were assessed by estimating the percentage of leaves in each plot with symptoms (incidence) and the severity of symptoms on these affected leaves. Canopy severity was calculated by multiplying these values. Area Under Disease Progress Curve (AUDPC) was calculated for late blight severity from 17 Sep through 8 Oct. All diseases resulted from naturally-occurring inoculum. Ripe fruit were harvested on 26 Aug, 8, 15, 23, and 30 Sep and 8 Oct. Green fruit were also harvested on 8 Oct. Fruit quality attributes assessed included taste rated on a 1-5 scale with 5 being excellent.

Late blight was first observed on 20 Jun on LI, NY. Very few symptoms were found that day in a commercial potato crop in Suffolk County located about 5 miles from the research field for this experiment. Source of inoculum for this crop could not be determined. Symptoms were found in three additional production fields before being found in this experiment on 15 Aug. US-23 was the only genotype of *P. infestans* found in the region, including at LIHREC. Late blight became moderately severe in this experiment on the late blight-susceptible variety (Mountain Fresh Plus), reaching 52% leaves with symptoms and 46% canopy severity on 22 Sep. Subsequently many leaves died. Defoliation was 94% on 8 Oct. All varieties evaluated were significantly and substantially less severely affected by late blight than Mountain Fresh Plus, including Pruden's Purple and Wapsipinicon Peach, which were not bred to be resistant. Observations by others of less severe late blight on these relative to other varieties prompted their inclusion in this experiment. No symptoms of late blight were observed on cv. Mountain Merit (red slicer type fruit) or Mountain Magic (campari type), which are both heterozygous for *Ph2* and *Ph3* major genes for resistance. A few symptoms were found on Plum Regal, which is homozygous for *Ph3*. Powdery mildew and Septoria leaf spot were both most severe on Wapsipinicon Peach and least severe on Mountain Magic. JTO 1175, an experimental variety from Johnny's Selected Seeds, exhibited the least defoliation on 29 Sep, but this was only significantly different from Pruden's Purple and Wapsipinicon Peach. Late blight symptoms were also not found in the non-replicated plantings (single plots) of four varieties developed by Tom Wagner: Clackamas Blueberry, Fahrenheit Blues, Blue Pitts, and Stripe of Yore. Seed of these were provided by a local grower-breeder who felt they might have resistance from her observations.

Significant differences in yield were detected among varieties examined. Quantity of fruit produced was primarily determined by fruit type, with the greatest number produced by Mountain Magic, the variety with the smallest fruit (campari aka cocktail type fruit). Mountain Fresh Plus and Mountain Merit produce red slicer type fruit. JTO 1175 produces red plum type fruit.

In conclusion, varieties bred to be resistant to late blight that have the *Ph2* and *Ph3* major genes for resistance exhibit excellent suppression, and there are varieties not bred to be resistance that exhibit good suppression.

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Investigating occurrence and assisting growers manage late blight in organically-produced tomato and potato
Investigators: Amanda Gardner and Margaret T. McGrath
Location: North Fork, Long Island

Late blight is a very destructive disease of tomatoes and potatoes that has been routinely occurring on Long Island since 2009. Control of this disease is particularly challenging for organic growers because fungicides approved for organic production are not as effective as the synthetic fungicides that growers producing conventionally can use. Their efficacy is due to their ability to move into leaves and their targeted activity for the type of pathogen that causes late blight. Also, organic growers typically use an IPM approach (starting pesticide applications after disease/pest detection); however they increasingly understand that sometimes preventive treatment is needed for effective control. Late blight can be very difficult to suppress without preventive applications of a protectant fungicide, which organic growers increasingly understand.

The goal of this project was twofold. First was to help organic growers manage late blight by regularly monitoring their fields and alerting them when late blight was found. Additionally the regular monitoring throughout the season offers valuable insight into the effectiveness of different management strategies. This project is a continuation of the late blight monitoring project started in 2012. During the 2014 season, four organic farms were scouted on a weekly basis from the beginning of June until the end of September. All four farms were located on the North Fork of Long Island, three of the four have been involved with the project since 2012, the other has been involved since 2013. During the 2014 season the first case of late blight was found on June 20 in a potato field in Riverhead that was not part of this project.

Late blight management was very successful this year at the four farms, due in part to a combination of the growers' fungicide applications, the use of resistant varieties and the cooperation of the weather. This was the first year that all four growers planted resistant tomato varieties. In previous years two of the growers had not chosen them because they were concerned they may not perform as well as the varieties they were growing, but this year they decided to give them a try partly because of previous losses. The sunny, dry summer was generally unfavorable for late blight. It seemed that the pathogen took advantage of the few days the weather conditions were favorable for spread from farm to farm. Once late blight got to a farm it was slow to develop.

Farm 2 was the first to get late blight. It was found on July 25, just a little over 4 weeks after late blight was first found on Long Island. Farm 2 is near where late blight was first found. This grower had tomatoes growing in three separate areas. As the season progressed late blight spread to the other two areas. Interestingly late blight was only seen in the original spot on July 25. By the end of the season late blight was only a problem in the area that had the youngest and healthiest plants. The older, senescing plants either no longer had or never had gotten late blight. The grower applied copper fungicide routinely, maintaining good coverage through the season on the area of the field that had his youngest and healthiest plants.

Late blight reached Farm 4 on August 14. In past years this grower had a lot of trouble managing late blight. In the 2013 season he lost his entire 2nd tomato planting because he had to wait two weeks for a replacement part on his sprayer. The variety growing in this planting was Mountain Fresh Plus, which is susceptible to late blight. During the 2014 season he sprayed consistently throughout the season making sure to get very good spray coverage and chose to plant mostly resistant varieties in his later planting. Together these practices worked to create a very successful management program. Late blight was originally found in two spots of the field on older tomato plants on the varieties SunGold and Green Zebra. As the season progressed late blight spread to the plants of a susceptible variety in the last planting. In the SunGold tomatoes late blight did not spread far from the original spot. Towards the end of the season the infected plants of this variety only had stem lesions. Late blight may have been present in the field but it was definitely not thriving. The grower also had a few rows of potatoes but by the time late blight arrived the plants had already begun to senesce and thus it was not a problem.

Farm 1 was the next to get late blight. It was found there on August 20 in both the potatoes and tomatoes. This grower had intentionally planted potatoes late in hopes of escaping the worst of the Colorado potato beetle damage. This strategy worked quite well: the potatoes grew very well until mid August when leafhoppers were evident. Within a span of two weeks the field changed drastically. The leafhoppers killed off the foliage before late blight could become a problem. In the tomato crop, late blight was only seen at first in one area of the field. As the weeks went by it slowly spread to all the susceptible varieties growing in the field. By the end of September there were a few moderately severe patches in the field but control generally was good. The resistant varieties performed very well and remained late blight free.

Late blight was officially confirmed to be present at Farm 3 on August 28 but it is suspected to have been present a little earlier than that. One of the workers had suspected late blight on the tomatoes a few days earlier and removed all the plant material that was displaying symptoms of possible infection. There was quite a bit of late blight present on August 28, much more than is normally seen on a first sighting, suggesting that it had likely been there earlier and/or reflecting the fact conditions had been very favorable for late blight. This grower prefers to use neem oil over copper-based fungicides and has been satisfied with the foliar disease control achieved. In 2014 he grew all of the commercial late blight resistant varieties among the large diversity of tomato varieties he routinely grows. As the season progressed, late blight did not spread too much from where it was originally found in the field. The grower also had some potatoes but late blight came after they were already done for the season so there were no losses.

Overall the growers did very well managing late blight. Over the past three years this scouting program has been in place there is evidence that the growers have been improving their management programs. They have been learning from past experiences and are willing to try new approaches. Integrated management strategies that utilize both fungicides and resistant varieties are the most successful approach for managing late blight. However the resistant varieties are not always the varieties that customers are seeking. By growing both customer favorites and resistant varieties, growers can have something to fall back on in case fungicide treatments fail to protect the more susceptible customer favorites. The most successful fungicide spray programs are those with applications started promptly (preventive or at very first symptoms) and made on a consistent schedule.

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Efficacy of fungicides for managing powdery mildew in pumpkin
Investigators: Margaret T. McGrath and Karen LaMarsh
Location: Long Island Horticultural Research and Extension Center

The primary objective of this study was to evaluate the efficacy of several fungicides with mobility that enables them to move to the lower surface of leaves where powdery mildew develops best. They have single-site mode of action which puts them at risk for resistance development. Both new and currently registered products were tested. In previous years strains of the pathogen were detected with resistance to FRAC code 1, 7, and 11 fungicides and moderate resistance to FRAC code 3 fungicides.

The field was plowed on 11 Apr and tilled on 6 May. Seeds were planted at approximately 24-in. plant spacing within rows with a vacuum seeder on 23 Jun. The seeder applied fertilizer in two bands about 2 in. away from the seed. Controlled release fertilizer (N-P-K, 15-5-15) was used at 675 lb/A (101 lb/A N). The herbicides Strategy (3 pt/A), Curbit EC (1 pt/A), and Sandea (0.5 oz/A) were applied over the entire plot area on 20 Jun, which was followed by irrigation to activate. During the season, weeds were controlled by cultivating and hand weeding as needed. Cucumber beetles were managed by applying the insecticide Admire Pro (2.8 fl oz/1000 ft) in a narrow band over the planted rows immediately after the herbicide application on 25 Jun and applying Assail (4 oz/A) to foliage on 20 and 30 Jul. The following fungicides were applied for Phytophthora blight: Regalia (2 qt/A) on 12 Jul, 20 Jul, 25 Jul, 5 Aug, and 11 Aug; K-Phite (1 qt/A) on 12 Jul, 20 Jul, 11 Aug, 18 Aug, 25 Aug, 3 Sep, and 10 Sep; ProPhyt (2 pt/A) on 5 Aug; Presidio (4 fl oz/A) on 12 Jul; Ranman (2.75 fl oz/A) on 20 Jul, 5 Aug, 18 Aug, and 3 Sep; Revus (8 fl oz/A) on 25 Jul and 25 Aug; and Forum (6 fl oz/A) on 11 Aug and 10 Sep. A few young plants developed crown rot and were removed. Plots were three 15-ft rows spaced 68 in. apart. The 20-ft area between plots was also planted to pumpkin.

A randomized complete block design with four replications was used. Treatments were applied four or six times on a 7-day IPM schedule beginning on 30 Jul using a tractor-mounted boom sprayer equipped with twinjet (TJ60-11004VS) nozzles spaced 17 in. apart that delivered 68 gal/A at 65 psi and 2.3 mph. Plots were inspected for powdery mildew symptoms on upper and lower leaf surfaces weekly beginning on 23 Jul. Initially the examined leaves were selected from the oldest third of the foliage based on leaf physiological appearance and position in the canopy. Additional powdery mildew assessments were made on 29 Jul; 6, 12, 20 and 27 Aug; and 4 and 19 Sep. Mid-aged and young leaves were also assessed beginning on 6 Aug. At least nine leaves were examined in each plot on each assessment date. Powdery mildew colonies were counted; severity was assessed by visual estimation of percent leaf area affected when colonies could not be counted accurately because they had coalesced and/or were too numerous. Colony counts were converted to severity values using the conversion factor of 30 colonies/leaf = 1% severity. Average severity for the entire canopy was calculated from the individual leaf assessments. Area Under Disease Progress Curve (AUDPC) values were calculated from 20 Aug through 19 Sep. Defoliation was assessed on 19 Sep and 9 Oct. Fruit quality was evaluated in terms of handle (peduncle) condition for mature fruit without rot on 26 Sep and 9 Oct. Handles were considered good if they were green, solid, and not rotting.

Powdery mildew was first observed in this experiment on 23 Jul in 26 of the 52 plots; 8.8% of the older leaves examined had symptoms. Incidence had not increased by the next assessment date, which was 1 day before treatments were started. The action threshold for the IPM fungicide program is 1 out of 50 leaves with symptoms. Most treatments were individual products evaluated alone. This is neither a labeled nor recommended use pattern for growers. Such evaluations, however, identify appropriate rates for new products and monitor efficacy of registered fungicides at risk for resistance development in order to develop management recommendations for growers. Three fungicides registered for powdery mildew on pumpkin in 2014 were evaluated alone and in a combination program. Pristine (FRAC Code 7 and 11) applied at its highest label rate was moderately effective based on powdery mildew severity on lower leaf surfaces (54% control based on AUDPC values). In previous years at this location, pathogen isolates resistant to both components of this fungicide have been detected, and the fungicide has exhibited variable performance in previous evaluations. Pristine was ineffective at the last assessment date in 2014 based on powdery mildew severity on lower leaf surfaces, which suggests resistant strains were selected for during the experiment. It was the least effective treatment tested based on defoliation on 19 Sep. Procure (FRAC 3) applied at its highest label rate was as effective as Quintec (FRAC 13) except for the last assessment on lower leaf surfaces. Procure has exhibited variable control in previous experiments. Quintec was highly effective (96% control based on AUDPC values for severity on lower leaf surfaces). Similar control

(95%) was achieved by alternating among these three products with Quintec applied at its lowest labeled rate. Vivando (FRAC U8), a new fungicide expected to be federally registered for this use before the 2015 season, was as effective as Quintec at both rates tested (95 and 98% control). Another FRAC U8 fungicide, IKF-309 (pyriofenone), was not as effective as Quintec based on severity on lower leaf surfaces (55 and 66% control). Effective control (92%) was obtained by applying these fungicides in alternation. The other three treatments tested were applied four times. They were still exhibiting effective control on 19 Sep, 25 days after the last application. Several treatments exhibited as much defoliation as the untreated control on 9 Oct (72–99%); treatments with less defoliation were the grower standard of Quintec applied in alternation with Procure and Pristine (46%), IKF-309 alternated with Quintec (48%), and Vivando (22% and 30%). All treatments provided sufficient management of powdery mildew to avoid death of leaves and vines that leads to shriveled, rotting handles on pumpkin fruit. On 26 Sep, 75% of good fruit had good handles for untreated plants versus 98-100% for fungicide-treated plants. Almost all fruit were good; few rotted. A high percentage of fruit still had good handles on 9 Oct for most treatments (92-99%). The percentage had dropped to 83% for plants treated with Pristine and 90% for those treated with Procure; however these treatments did not differ significantly from the others. There were no significant differences in fruit quality among any fungicide treatments on either assessment date; all had higher percentage of fruit with good handles than the control (51%). No phytotoxicity was observed.

In conclusion, Quintec is the most effective currently-registered targeted fungicide for powdery mildew. It is recommended used in alternation with Vivando (once registered) and Torino (evaluated in 2013). Procure and Pristine (limit use) are recommended in addition.

Observations on powdery mildew management in cucurbits
Investigators: Margaret T. McGrath and Karen LaMarsh
Location: Long Island Horticultural Research and Extension Center

The experiment on "Evaluation of Biopesticides for Managing Phytophthora Blight in Squash" (see report below) provided an opportunity to evaluate an integrated management program for powdery mildew. A variety resistant to powdery mildew was selected (Royal Ace PM). Fungicides with targeted activity for powdery mildew were applied on a weekly schedule: Procure 8 fl oz/A on 1 Aug, Quintec 6 fl oz/A on 8 and 29 Aug, and Torino 8 fl oz/A on 22 Aug. This program was very success. Very few symptoms of powdery mildew were found on 2 Sep. Average severity was less than 1% on both leaf surfaces (0.18% on the upper surface and 0.31% on the lower).

Fungicide sensitivity of cucurbit powdery mildew pathogen isolates on LI in 2013
Investigators: Margaret T. McGrath and Karen LaMarsh
Location: Long Island Horticultural Research and Extension Center

Fungicide resistance can be a major constraint to effectively managing powdery mildew in cucurbit crops. Fungicides that are most effective for managing powdery mildew (because they are mobile and thus can redistribute from where deposited on upper leaf surfaces to the lower surface where powdery mildew develops best) are also more prone to the pathogen developing resistance (because they typically have single site mode of action). The pathogen, *Podosphaera xanthii,* has a long history of developing resistance, being the first pathogen to have been documented to have done so in the USA. Resistance to benomyl (FRAC Code 1), the first at-risk fungicide registered for this use, was detected in 1967. The next chemical class registered for cucurbit powdery mildew was the DMI (demethylation inhibitor) fungicides (FRAC Code 3). Bayleton, the first fungicide in this group labeled for cucurbit powdery mildew, was registered for this use in the USA in April 1984. Just two years later there were the first reported control failures documented through university fungicide efficacy experiments. QoI (quinone outside inhibitor) fungicides (FRAC Code 11) were the next chemical class developed for this disease. Quadris was registered in the USA in spring 1999. Control failures were reported from several states throughout the USA in 2002, and resistance was detected. Pristine, the first SDHI (FRAC Code 7) fungicide, was registered in August 2003. Quintec, the first FRAC Code 13 fungicide, was registered in 2007.

The objective of this study was to determine fungicide sensitivity of pathogen isolates (i.e. individuals) by testing them in the laboratory on treated leaf disks. Isolates of *Podosphaera xanthii*, the fungus that causes powdery mildew in cucurbits, were obtained 13-26 Sep 2013 from one research field, six commercial plantings of pumpkin, and a garden. This was near the end of the growing season when fungicide programs for powdery mildew were generally complete. Isolates were maintained on leaf tissue on agar media in Petri dishes (culture plates) until tested. Fifty-five isolates were tested.

For the leaf disk bioassay, pumpkin seedlings at the cotyledon leaf stage (about seven-days-old) were sprayed with various fungicide doses in a laboratory fume hood, the treated plants were left there to dry overnight, then disks were cut from the cotyledons and placed on water agar in sectioned Petri plates. Each plate has four sections thus there were three treatments per plate plus a nontreated control. Each plate was used to test one isolate. Six disks with the same treatment were placed in each section. Disks were inoculated by transferring spores from culture plates to each disk center. Then plates were incubated at room temperature under constant light. Amount of pathogen growth on the disks was assessed after 10 days of incubation when the control treatment usually had good growth of the pathogen, with white sporulating pathogen growth covering an average of about 50% of leaf disk area. The percent leaf disk area with symptoms of powdery mildew was recorded for each disk and averaged for each treatment. An isolate was considered to be insensitive (resistant) to a particular fungicide concentration if it was able to grow and produce spores on at least half of the disks. Due to limitations in the number of isolates and fungicide doses that can be done in each bioassay, the procedure was conducted multiple times over many weeks to obtain information on sensitivity to several fungicides.

The bioassay revealed that all isolates tested were resistant to FRAC code 1 and 11 fungicides. This supports the decision to continue not recommending these fungicides.

Of the 26 isolates from the research field, which was the one where fungicides were evaluated (see previous report), 23% were resistant to boscalid (FRAC 7 ingredient in Pristine); 73% were able to grow on leaf disks treated with 40 ppm myclobutanil (FRAC 3); 27% were able to grow on leaf disks treated with 80 ppm myclobutanil; and 81% on disks treated with 40 ppm quinoxyfen (active ingredient in Quintec)(FRAC 13). All four isolates from pumpkin treated with Pristine alone were resistant to boscalid (tolerated 500 ppm). This adds to previous observations that using at-risk fungicides alone during a growing season can select for resistant strains. In this case product efficacy was not impacted. Boscalid resistance was detected in one of three isolates from pumpkin treated once with Pristine applied in alternation with Quintec and Procure. An isolate tolerating 80 ppm quinoxyfen was obtained from a Quintec plot.

Of the 27 isolates from the six commercial plantings of pumpkin, 37% were resistant to boscalid (FRAC 7 ingredient in Pristine); 44% were able to grow on leaf disks treated with 40 ppm myclobutanil (FRAC 3); 3% were able to grow on leaf disks treated with 80 ppm myclobutanil; and 56% on disks treated with 40 ppm quinoxyfen (active ingredient in Quintec). Both boscalid-resistant and sensitive isolates were found in most plantings; however only resistant ones were found in one planting and only sensitive ones in another, which might reflect how much Pristine was applied.

In conclusion, documented occurrence in the cucurbit powdery mildew pathogen of resistance to some targeted fungicides (FRAC 1, 7, and 11) and variation in sensitivity to others (FRAC 3 and 13) reveals the necessity of using a resistance management program with this pathogen and is important for selecting fungicides to use. FRAC 3 and 13 fungicides (Procure and Quintec) are recommended used in alternation with Torino. Use of FRAC 7 fungicides (Pristine) should be limited. FRAC 1 and 11 fungicides should not be used.

Evaluation of biopesticides for managing Phytophthora blight in pepper
Investigators: Margaret T. McGrath and Karen LaMarsh
Location: Long Island Horticultural Research and Extension Center

The objective of this study was to evaluate the efficacy of EPA-classified biopesticides (which contain microbes or naturally-occurring substances as the active ingredient) used in combination treatment schedules with applications to soil and foliage. Products tested are labeled for Phytophthora blight in pepper and all are approved for organic production. Some treatments included foliar applications of a copper fungicide approved for organic production. Two treatments included oomycete-targeted fungicides for conventional production. These treatments were compared to a non-treated control, a conventional 'standard' treatment with these oomycete-targeted fungicides applied to foliage, and an organic 'standard' treatment with copper fungicide applied to foliage. The experiment was conducted in a field with Haven loam soil where Phytophthora blight has developed most years since 1994. Phytophthora blight was severe and occurred throughout the field in 2011 when conditions were very favorable for the pathogen. In addition to this experiment, there was an adjacent, parallel experiment on acorn winter squash with the same foliar treatments (see next report).

Pepper seeds were sown on 23 May in the greenhouse. A few days before transplanting, herbicide Devrinol DF-XT at 4 lb/A was applied to the entire experiment area. Controlled release fertilizer (N-P-K, 19-9-12 with 60% ESN slow release nitrogen) at 675 lb/A was spread over the rows to be planted. Herbicide and fertilizer were incorporated by cultivation. Seedlings were transplanted on 1 Jul by hand into holes opened in the bare-ground by a waterwheel transplanter that also placed in the holes a starter fertilizer, 20-20-20 Nutri-Leaf. Plants were irrigated using drip tape laid on the soil surface running down the length of the row next to the plant main stem. Cutworms were managed by applying Mustang Maxx (4 fl oz/A) on18 Jun. During the season, weeds in the plots were controlled by hand weeding while weeds between rows were mowed.

A completely randomized block design with four replications was used. Plots consisted of 12 plants in a single row with 15-in. plant spacing and 68-in. row spacing. There was 3-ft spacing between plots in a row.

Some biopesticides were applied to plants before and/or after transplanting for some treatments. Pre-transplant treatments were drenches to seedling trays done on 30 Jun. Additional soil applications were made along the rows directed at the base of the plants on 2, 10, 17, and 23 Jul. Applications were made using a CO_2-pressurized backpack sprayer with a boom equipped with a single Twin-jet nozzle (TJ60-11003) delivering 57 gal/A at 54 psi. Drip irrigation was run after each soil application to incorporate. Foliar applications also were made with a backpack sprayer using Twin-jet nozzle(s) delivering 50 gal/A operated at 54 psi and 2.4 mph. A boom with a single TJ60-8006vs nozzle was used when pepper plants were small. A boom with a nozzle delivering spray over the top of the plant plus two drop nozzles (all TJ60-8006vs) was used when pepper plants were larger. Plants and their fruit were examined every one to two weeks for disease symptoms. Due to very limited disease development through early Aug, a piece of infected zucchini fruit was placed in the center of each plot on 11 Aug before predicted rain.

Conditions were not favorable for Phytophthora blight during most of the growing season due to limited rainfall, with less than 2.5 inches of rain per month falling in Jul, Aug and Sep. Rainfall was at least 1 inch on only two days in Jul and Aug: 1 inch on 15 July and 1.8 inches on 13 Aug. Symptoms were first observed on 29 Jul. Disease development was slow initially. Symptoms were found in only ten plots on 12 Aug. Many plants died due to blight following inoculation on 11 Aug and an intense rainstorm on 13 Aug. Control was achieved with two of the three treatments that included an alternation of the conventional fungicides, Revus and Presidio. No dead plants were observed in these treatments on 19 Aug. While effective, 35 and 42% of plants were dead at the last assessment (9 Sep) versus 88% of untreated control plants. Control obtained with these foliar fungicides was not improved by adding soil drench or foliar applications of biopesticides. Similar results were obtained in the parallel experiment with acorn squash. Phytophthora blight was effectively controlled in pumpkin (2.3% fruit affected on 9 Oct) by applying the same and additional oomycete fungicides weekly in a nearby research field.

In conclusion, the fungicide programs evaluated that consisted of only biopesticides were ineffective. Control achieved by applying conventional fungicides with targeted activity for this type of pathogen was not improved by including biopesticides in the program. High disease pressure in this experiment may have affected results; Phytophthora blight is difficult to manage. Additionally it may be necessary to apply biopesticides active on the pathogen over a larger area by making broadcast applications rather than targeting the root-zone as done in this experiment.

Acknowledgments: Project funded by IR-4 Biopesticides and Organic Support Program.

Evaluation of biopesticides for managing Phytophthora blight in squash
Investigators: Margaret T. McGrath and Karen LaMarsh
Location: Long Island Horticultural Research and Extension Center

The objectives of this experiment and the treatments were almost identical to those of an adjacent experiment with pepper. See the introduction in the previous report for more information. The same treatments were applied to pepper and squash in the two experiments at the same time with the exception that pepper received transplant treatments.

Squash seeds were sown 4 Jun in the greenhouse. A few days before transplanting, herbicides Curbit EC (1 pt/A) and Sandea (0.5 oz/A) were applied to the experiment area. Controlled release fertilizer (N-P-K, 19-9-12 with 60% ESN slow release nitrogen) at 675 lb/A was spread over the rows to be planted. Seedlings were transplanted on 1 Jul by hand into holes opened in the bare-ground by a waterwheel transplanter that also placed in the holes a starter fertilizer, 20-20-20 Nutri-Leaf. Plants were irrigated using drip tape laid on the soil surface running down the length of the row next to the plant main stem. During the season, weeds in the plots were controlled by hand weeding while weeds between rows were mowed. Cucumber beetles were managed by applying the insecticide Admire Pro (2.8 fl oz/1000 ft) in a narrow band over the planted rows immediately after the herbicide application on 30 Jun. Powdery mildew was managed by selecting a resistant variety and routinely applying fungicides with targeted activity for this disease, alternating among Quintec, Torino and Procure. Insects were managed by applying Mustang Maxx (4 fl oz/A) on18 Jun and Assail 30SG (4 oz /A) on 30 Jul.

A completely randomized block design with four replications was used. Plots consisted of 8 plants in a single row at 68-in row spacing. There was 4-ft spacing between plots in a row.

Some biopesticides were applied to plants before and/or after transplanting following treatment protocol. Pre-transplant treatments were drenches to seedling trays done on 30 Jun. Additional soil applications were made along the rows directed at the base of the plants on 2, 10, 17, and 23 Jul. They were applied using a CO_2-pressurized backpack sprayer with a boom equipped with a single Twin-jet nozzle (TJ60-11003) delivering 57 gal/A at 54 psi. Drip irrigation was run after each soil application to incorporate. Foliar applications also were made with a backpack sprayer using Twin-jet nozzle(s) delivering 50 gal/A operated at 54 psi and 2.4 mph. A boom with a single TJ60-8006vs nozzle was used when squash plants were small. A boom with a nozzle delivering spray over the top of the plant plus two drop nozzles (all TJ60-8006vs) was used when squash plants were larger. Plants and their fruit were examined every one to two weeks for disease symptoms. Proportion of plant canopy affected by blight was estimated. Percent of fruit affected was estimated until the last assessment when all fruit were examined. Due to very limited disease development through early Aug, a piece of infected zucchini fruit was placed in the center of each plot before predicted rain on 11 and 19 Aug.

Conditions were not favorable for Phytophthora blight during most of the growing season due to limited rainfall, with less than 2.5 inches falling in Jul, Aug and Sep. Rainfall exceeded 1inch on two days in Jul and Aug: 1 inch on 15 July and 1.8 inches on 13 Aug. Symptoms were first observed on 29 Jul. Disease development was slow initially. Symptoms were found in only four plots on 12 Aug. Many plants died due to blight following inoculation on 11 Aug and an intense rainstorm on 13 Aug. None of the treatments were effective based on proportion of foliar tissue affected or percentage of fruit affected. Least amount of symptoms numerically were in plots treated with Serenade Soil post-transplant followed by weekly foliar applications of Revus alternated with Presidio. The next best treatment numerically was the same without Serenade Soil. Similar results were obtained in a parallel experiment with pepper. The inoculation procedure combined with an intense rain event may have created disease pressure sufficiently high to overwhelm chemical control. Phytophthora blight was effectively controlled in pumpkin (2.3% fruit affected on 9 Oct) by applying the same plus additional oomycete fungicides weekly in a nearby research field.

See conclusions with previous report.

Acknowledgments: Project funded by IR-4 Biopesticides and Organic Support Program.

Identification of pathotypes of the cucurbit downy mildew pathogen occurring on LI
Investigators: Margaret T. McGrath and Karen LaMarsh
Location: Long Island Horticultural Research and Extension Center

Cucumber, acorn and butternut squashes, cantaloupe, watermelon and giant pumpkin (*Cucurbita maxima*) were grown in a sentinel plot at LIHREC to determine when the different pathotypes of the cucurbit downy mildew pathogen were successfully dispersed to Long Island. The pathotypes differ in ability to infect the different cucurbit crop types. This pathogen is not capable of surviving in the absence of living host plant tissue; however, it produces spores capable of long-distance movement by wind. Successful dispersal to Long Island occurs when there is a source of spores (affected cucurbit crops in another region) and conditions are favorable for dispersal (wind currents moving from affected crops to LI at night or during overcast days when spores will be protected from solar radiation), and also for deposition of spores and then for infection (rain is ideal as it moves spores out of the wind currents down to plants and infection occurs when leaves are wet or humidity is high). This can occur any time during the growing season. With knowledge of when downy mildew is occurring on Long Island and which cucurbit crop types are at risk, growers can target their applications of fungicides with specific activity for downy mildew (oomycete) pathogens. This activity is also being done every growing season as part of the national forecasting program for cucurbit downy mildew. There are similar sentinel plots at universities throughout the eastern USA each year.

To ensure leaf tissue for infection was present throughout the growing season, seedlings were transplanted into plots at two times, on 12 June and 10 July. Insecticides and fungicides with targeted activity for powdery mildew were applied. See report below entitled 'Evaluation of Downy Mildew Resistance in Experimental Hybrids of Cucumber' for information on cultural practices. Leaves were examined routinely for symptoms.

Symptoms of downy mildew were not found until 2 Sep, which was substantially later than most previous years. This reflects reduced occurrence in much of the eastern USA in 2014. Previous first occurrences at LIHREC were 1 Aug 2010, 17 Jul 2011, and 22 Jul 2013. Downy mildew was only observed in the second planting of cucumber in 2014. This cucurbit type is susceptible to all pathotypes of the pathogen. Pathotypes able to infect other cucurbits probably were not present on LI in 2014; however, ability to detect downy mildew was at least partly compromised by the fact plants were senescing and powdery mildew had become severe on many leaves by early September. In sharp contrast, in 2013 symptoms also were observed on cantaloupe, butternut squash, giant pumpkin (*Cucurbita maxima*), watermelon, and acorn squash.

Validation of the CDM ipmPIPE Forecasting System: Relating aerial transport of pathogen spores to outbreaks of cucurbit downy mildew
Investigators: Katie N. Neufeld (North Carolina State University), Anthony Keinath (Clemson University) and Peter S. Ojiambo (North Carolina State University), with assistance from Margaret T McGrath (LIHREC)
Location: Multiple Locations including Long Island Horticultural Research and Extension Center

The cucurbit downy mildew (CDM) pathogen is an obligate parasite that cannot survive without live host tissue. Due to host sensitivity to frost, it is widely thought that the pathogen is introduced in northern states through spores that are dispersed by wind currents from sub-tropical regions in southern Florida. Current disease outbreaks and forecasts of the pathogen's movement are predicted by the CDM ipmPIPE forecasting website (cdm.ipmpipe.org). The CDM ipmPIPE was established in 2008 to provide growers with management oriented information, such as disease forecasts that are based upon the current epidemic status and forecasted weather conditions, to help them make decisions on management of CDM. Forecasts are available as interactive maps that depict the risk of infection in specific locations.

In order to ensure that disease outbreaks and dispersal of spores in real-time are being correctly predicted, validation of the forecasting system through collection of rainwater samples from multiple locations is being addressed through various approaches using data collected from 2013 to 2015. Rainwater has been collected from eight different states: New York at LIHREC, Alabama, Georgia, Louisiana, North Carolina, Ohio, Pennsylvania and South Carolina after each rain and sent to North Carolina State University for processing. Rainwater collection buckets are usually deployed near actively scouted cucurbit fields. Presence of CDM spores within rainwater will eventually be correlated to the first onset of symptoms within the field.

In 2013 and 2014, a total of 71 rainwater samples were collected each year from 8 states (NY, AL, GA, LA NC, OH, PA, SC) with the exception of Louisiana, which was only collected in 2014. LIHREC's rainwater collection bucket was located near the sentinel plots (see previous report). Samples were collected from June until first symptoms were found at LIHREC. In 2013, 14 samples were collected from 6 June to 22 July. In 2014, 10 samples were collected from 10 June to 2 Sep. Molecular primers have been developed to quantify cucurbit downy mildew spores from rainwater samples. These samples collected over 2013 and 2014 are currently being analyzed for spore counts. Quantified spores in rainwater will eventually be related to the timing of disease onset in the sentinel plots as a final step in the validation process.

Population biology of *Pseudoperonospora cubensis*, the causal agent of cucurbit downy mildew
Investigators: Anna Thomas, Ignazio Carbone and Peter S. Ojiambo (North Carolina State University), with assistance from Margaret T McGrath (LIHREC)
Location: Multiple Locations including Long Island Horticultural Research and Extension Center

It has been widely proposed that the source of inoculum for cucurbit downy mildew infections in the northern states is the overwintering sources in sub-tropical locations in southern Florida. Thus, every year, the pathogen is introduced in northern states during periods of strong southerly winds. However, there is no direct biological evidence to support the hypothesis of the pathogen overwintering in southern Florida. Thus, the main objective of this study is to test the hypothesis by examining genetic differentiation and diversity among isolates collected in eastern US. Another objective of the project is to examine the genetic basis of host specialization that the population of *P. cubensis* exhibits.

Isolates from different cucurbit host types including cucumber, cantaloupe, butternut squash, acorn squash and pumpkin were collected from throughout the eastern US including from LIHREC, NY in 2012 and 2013. A total of 9 isolates were collected from LIHREC. DNA has been extracted from 5 isolates that were originally collected from diverse host types (Single lesion isolates) in Long Island. Comparison of a reduced genome using double digest RAD-seq technique may help us trace back the source of inoculum to southern Florida or elsewhere.

Comparative analysis of the whole genomes of 9 isolates collected from different host types and locations have revealed the presence of two host specific evolutionary lineages. Lineage I was found to be associated with cucumber, cantaloupe and pumpkin and lineage II was found to be associated with acorn squash, butternut squash and watermelon. A detailed study using more isolates (90) is underway to infer the distribution of different lineages across the US and their association with particular host types.

The result of this study may help us identify the source of inoculum for infection in the southeast, northeast and the Great Lake regions. The differentiation of population into lineages may help us predict the outbreak on certain host types as compared to some others.

Evaluation of downy mildew resistance in experimental hybrids of cucumber
Investigators: Margaret T. McGrath and Karen LaMarsh
Location: Long Island Horticultural Research and Extension Center

A field experiment was conducted at LIHREC. Controlled release fertilizer (N-P-K, 15-5-15) was used at 675 lb/A (101 lb/A N). Drip irrigation tape was laid as the rows were covered with black plastic mulch on 3 Jun. A waterwheel transplanter was used to make planting holes in the beds and apply starter fertilizer (20-20-20 Nutri-Leaf) plus insecticide on 24 Jun. Seeds were sown on 3 Jun in the greenhouse. Seedlings were transplanted by hand into the holes in the beds on 25 Jun. During the season, water was provided as needed via drip irrigation lines. Weeds were controlled between mulched rows by applying a tank mix of Strategy (3 pt/A), Sandea (0.5 oz/A), Scythe (1% 1.3 fl oz/gal spray mix), and Roundup WeatherMAX (22 oz/A) on 4 Jun, and by hand weeding. Cucumber beetles were managed with Admire Pro (7.5 fl oz/A) applied with the transplanter on 24 Jun. These plus thrips were managed by applying Assail (5.3 oz/A) on 21 and 30 Jul; and Lannate (1 pt/A) on 12 Aug. The following fungicides were applied for Phytophthora blight, powdery mildew, and anthracnose: Regalia (2 qt/A) on 12, 21 and 29 Jul, 5 and 12 Aug; K-Phite (1 qt/A) on 12 and 21 Jul; ProPhyt (3 pt/A) on 29 Jul and 12, 19 and 25 Aug; Presidio (4 fl oz/A) on 12 and 21 Jul and 5 Aug; Torino (3.4 fl oz/A) on 21 Jul, and 5 and

25 Aug; Procure 480SC (8 fl oz/A) on 29 Jul, and 12 and 19 Aug; Topsin (0.5 pt/A) on 25 Aug; Quadris (1.5 fl oz/A) on 25 Aug. Fungicides selected have limited activity for downy mildew and were applied before downy mildew occurred. Plots were single 18-ft rows with 10 plants at 18-in. spacing. Rows were 8.5 ft apart. The plots were 9 ft apart within the row initially until plants began to vine. Vines were moved as needed to maintain plot separation.

A randomized complete block design with four replications was used. Downy mildew severity was assessed on 8, 11, 16, and 29 Sep by estimating incidence of symptomatic leaves in each plot and rating severity on nine representative affected leaves. Incidence and average severity for symptomatic leaves were used to estimate canopy severity. Area Under Disease Progress Curve (AUDPC) values were calculated from 8 Sep through 29 Sep. Defoliation was assessed as percentage of leaves that had died in each plot. Fruit of at least marketable size were harvested from the plants on 28 Jul, and 4, 11, 18, and 25 Aug.

Natural inoculum was depended on for this experiment. Downy mildew appeared in the area much later than in recent years, reflecting reduced occurrence in much of the eastern USA in 2014. Symptoms were first found in the ipmPIPE sentinel plots at LIHREC on 2 Sep 2014 versus 1 Aug 2010, 17 Jul 2011, and 22 Jul 2013. Symptoms were first found in this experiment on 8 Sep in one plot of Straight Eight. Symptoms were not found through the last assessment on 29 Sep on the three PIs evaluated, DMR-NY264, and Marketmore 97. Marketmore 97 and Ivory Queen, which developed few symptoms in this experiment, have also exhibited good resistance in other evaluations. DMR-NY264 is based on a cross between these two made by Cornell University plant breeders Michael Mazourek and William Holdsworth. They had found the PIs to be a good source of resistance, thus they were included in this experiment to further document this. The two commercially available cucumbers marketed as having resistance to current strains of the downy mildew pathogen, SV4719CS and SV3462CS, had numerically but not significantly less severe symptoms than the two susceptible varieties included for comparison, Straight Eight and Speedway. Similar results were obtained in a previous evaluations conducted at LIHREC. Marketmore 76 and Stonewall were included in this experiment because growers in eastern NY had observed these to be affected less by downy mildew than other varieties they were growing. This experiment has confirmed this. Defoliation, which was due to anthracnose and natural senescence as well as downy mildew, was numerically lowest for DMR-NY264. Plants were old and past the harvest period when downy mildew developed; therefore yield data obtained reflects yielding ability of the varieties in the absence of downy mildew. DMR-NY264 was the only entry that did not have marketable fruit on the first and second harvest dates (28 Jul and 4 Aug). Total yield for DMR-NY264 was significantly less than the other entries reflecting the fact its harvest period was not extended to compensate for the fact it began producing fruit later than the others.

In conclusion from this experiment, first commercial varieties bred to be resistant to current strains of downy mildew pathogen exhibit moderate resistance (SV4719CS and SV3462CS). A new variety developed at Cornell (DMR-NY264) and some varieties bred to be resistant to old pathogen strains (Marketmore 97, Stonewall, and Ivory Queen) provide more effective suppression.

Nine organic growers on LI were provided seed of DMR-NY264 to grow on their farms. They reported it was less affected by downy mildew than other varieties they grew. One grower commented it out survived the other varieties. Most growers observed that DMR-NY264 was later to begin producing fruit then others. Fruit quality was acceptable for some, two commented that shape and size of the cucumbers was more erratic than other varieties with some fruit shorter and fatter than typical.

Acknowledgments: Project funded by the Friends of Long Island Horticulture Grant Program.

Assessment of downy mildew resistance in experimental basil hybrids
Investigators: Margaret T. McGrath and Karen LaMarsh
Location: Long Island Horticultural Research and Extension Center

The goal of this experiment was to evaluate basil bred to be resistant to downy mildew by breeders at Rutgers University. Plants were exposed to naturally-occurring inoculum of the downy mildew pathogen under field conditions.

Fertilizer (N-P-K, 10-10-10) at 1000 lb/A (100 lb/A of nitrogen) was broadcast over the bed area and incorporated on 18 Jun. Beds were formed, drip irrigation tape was laid, and beds were covered with black plastic mulch on 18 Jun. Weeds between mulch strips were managed with Devrinol DF-XT (2 lb/A) applied before transplanting and then by mowing. A waterwheel transplanter was used to make planting holes in the beds and apply starter fertilizer on 10 Jul. To provide a source of natural inoculum within the experimental area, basil (variety DiGenova) was transplanted into a spreader row on 30 Jun before transplanting the plots. These plants were not inoculated; by being present before the experiment plants they had an increased opportunity to be exposed to pathogen spores. Basil plants for the experiment were rooted cuttings. They were transplanted on 28 Jul. A late planting date was used to increase the likelihood of downy mildew developing during the experiment. The primary source of initial inoculum in this area is considered to be long-distance wind-dispersed spores from affected plants.

A randomized complete block design with three replications was used. Each plot had 7 plants in 4.5-ft rows with 9-in. plant spacing. The plots were 5 ft apart in the row. Downy mildew was assessed in each plot six times between 20 Aug through 17 Sep. The percentage of leaves per plant with symptoms (sporulation of the pathogen visible on the underside) was estimated for all 7 plants in each plot. Area Under Disease Progress Curve (AUDPC) values were calculated from 25 Aug through 17 Sep. Defoliation was assessed as percentage of leaves that had died and dropped off plants in each plot. At the last disease assessment on 26 Sep, plants were removed from plots and held upside down while in the field to be able to thoroughly examine the underside of leaves. Percentage of leaves with symptoms (incidence) was estimated. Severity of symptoms was estimated as percent leaf surface with sporulation for five affected leaves. Canopy severity was calculated by multiplying these values.

Symptoms of downy mildew were first observed on 11 Aug in the spreader row and on 20 Aug in one of the 72 plots. On 2 Sep symptoms were found in 21 plots. No symptoms were found in 29 plots on any assessment date, which included all three plots for six of the 24 entries evaluated. In contrast, symptoms were found on all plants of one entry plus the control entry, and an average of 36 and 37% of the leaves on these plants were affected.

In conclusion, this experiment has documented that highly effective resistance has been identified through breeding work conducted at Rutgers University.

Acknowledgments: Project funded by USDA Specialty Crops Research Initiative Program.

Downy mildew susceptibility of basil varieties and experimental resistant hybrids
Investigators: Margaret T. McGrath and Karen LaMarsh
Location: Long Island Horticultural Research and Extension Center

The goal of this experiment was to determine if resistance was exhibited by two varieties that appeared less susceptible in an observational planting in 2013 and eight new, experimental varieties developed by Enza Zaden USA, Inc. Basil was grown under field conditions. Fertilizer (N-P-K, 10-10-10) at 1000 lb/A (100 lb/A of nitrogen) was broadcast over the bed area and incorporated on 18 Jun. Beds were formed, drip irrigation tape was laid, and beds were covered with black plastic mulch on 18 Jun. Weeds between mulch strips were managed with Devrinol DF-XT (2 lb/A) applied before transplanting and then by mowing. A waterwheel transplanter was used to make planting holes in the beds and apply starter fertilizer on 10 Jul. To provide a source of natural inoculum within the experimental area, basil (variety DiGenova) was transplanted into a spreader row on 30 Jun before transplanting the plots. These plants were not inoculated; by being present before the experiment plants they had an increased opportunity to be exposed to pathogen spores. Basil for the experiment was seeded on 10 Jun in trays in a greenhouse, placed outdoors to harden for a few days, then transplanted on 14 Jul. A late planting date was used to increase the likelihood of downy mildew developing during the experiment. The primary source of initial inoculum in this area is considered to be long-distance wind-dispersed spores from affected plants.

A randomized complete block design with four replications was used. Each plot had 13 plants in 10-ft rows with 9-in. plant spacing. The plots were 5 ft apart in the row. Downy mildew was assessed in each plot every week beginning on 11 Aug. Percentage of leaves per plant with symptoms (sporulation of the pathogen visible on the underside of leaves) was estimated for 10 plants in each plot. Area Under Disease Progress Curve (AUDPC) values were calculated from 20 Aug through 18 Sep. At the last disease assessment on 2 Oct, plants were removed from plots and held upside down while in the field to be able to thoroughly examine the underside of leaves. Percentage of leaves with symptoms (incidence) was estimated. Severity of symptoms was estimated as percent leaf surface with sporulation for five affected leaves. Canopy severity was calculated by multiplying these values.

Symptoms of downy mildew were first observed on 11 Aug in 18 of the 44 plots. Disease development started in plots at the north end of the field, and slowly progressed southward. Symptoms were not found in all plots until 2 Sep. None of the ten varieties evaluated had significantly less downy mildew than DiGenova, the standard susceptible variety included for comparison, based on assessments of incidence of affected plants, incidence of leaves with symptoms, or severity at the final assessment. Eleonora and BA108 had numerically less downy mildew than the others at all assessments. While not significantly different, these had 54% and 47% less affected leaves than DiGenova throughout the assessment period based on AUDPC values. Greater suppression of downy mildew likely would be achieved by growing Eleonora and BA108 alone rather than next to more susceptible varieties. Performance of some entries may have been compromised by location at the north end of the field where downy mildew started to develop. Among the 12 plots in this area were 3 plots of BA105, 2 plots of BA106, and 2 plots of Napoletano.

In conclusion, first generation resistant varieties being developed commercially exhibited little to no resistance to downy mildew when tested under high disease pressure in the absence of other control practices (e.g. fungicides).

Acknowledgments: Project funded by USDA Specialty Crops Research Initiative Program.

Evaluation of organic and conventional fungicide programs for downy mildew in sweet basil

Investigators: Margaret T. McGrath and Karen LaMarsh
Location: Long Island Horticultural Research and Extension Center

Fertilizer (N-P-K, 10-10-10) at 1000 lb/A (100 lb/A of nitrogen) was broadcast over the bed area and incorporated on 18 Jun. Beds were formed, drip irrigation tape was laid, and beds were covered with black plastic mulch on 18 Jun. Weeds between mulch strips were managed early in the season with Devrinol DF-XT (2 lb/A) applied before transplanting and then by mowing. A waterwheel transplanter was used to make planting holes in the beds and apply starter fertilizer on 10 Jul. Basil for the experiment was seeded on 10 Jun in trays in a greenhouse, placed outdoors to harden for a few days, then transplanted on 14 Jul. A late planting date was used to increase the likelihood of downy mildew developing during the experiment. The primary source of initial inoculum in this area is considered to be long-distance wind-dispersed spores from affected plants. Additionally, to provide a source of natural inoculum within the experimental area, a row of non-fungicide-treated basil plants (cultivar DiGenova) that extended the length of this experiment was transplanted on 30 Jun. These plants were not inoculated; by being present before the experiment plants they had an increased opportunity to be exposed to pathogen spores.

A randomized complete block design with four replications was used. Each plot had 13 plants in 10-ft rows with 9-in. plant spacing. The plots were 4 ft apart in the row. Drenches in the transplant holes were applied immediately after transplanting. An additional soil application was made along the rows directed at the base of the plants on 14 Jul using a CO_2-pressurized backpack sprayer with a boom equipped with a single Twin-jet nozzle (TJ60-11003) delivering 57 gal/A at 54 psi. Drip irrigation was run after each soil application to incorporate. Foliar applications also were made with a backpack sprayer using Twin-jet nozzle(s) delivering 50 gal/A operated at 54 psi and 2.4 mph. A boom with a single (TJ60-4004EVS) nozzle was used when basil plants were small. A boom with a nozzle delivering spray over the top of the plant plus two drop nozzles (all TJ60-8006vs) was used when basil plants were larger. Downy mildew was assessed in each plot every week beginning on 18 Aug. Percentage of leaves per plant with symptoms (sporulation of the pathogen visible on the underside of leaves) was estimated for 10 plants in each plot. Area Under Disease Progress Curve (AUDPC) values were calculated from 2 Sep through 2 Oct. At the last disease assessment on 3 Oct, plants were removed from plots and held upside down while in the field to be able to thoroughly examine the underside of leaves. Percentage of leaves with symptoms (incidence) was estimated. Severity of symptoms was estimated as percent leaf surface with sporulation for five affected leaves.

The fungicide programs applied to both varieties were:

1. Organic fungicide program (sprayed twice/week)
   Regalia 3 qt/A (soil drench after transplant and 10 days later).
   Foliar applications: Actinovate AG 6 oz/A alternated with Trilogy 1% v/v. (16 sprays total)
2. Current conventional fungicide program with registered fungicides (7-day spray schedule)
   Ridomil Gold SL (1 qt/A soil drench after transplanting)
   Foliar applications: Quadris (15.5 fl oz/A), then Ranman (3 fl oz/A) plus K-Phite (1 qt/A) alternated with Revus (8 fl oz/A) plus K-Phite. (8 sprays total)
3. Future conventional fungicide program (includes product not yet registered that has exhibited excellent efficacy in previous experiments)(7-day spray schedule)
   Quadris, then Zorvec (2.4 fl oz/A) alternated with Ranman and Revus. (8 sprays total)

Downy mildew developed naturally. Symptoms were first observed on 25 Aug in 3 of the 32 plots. They were found in 20 plots on 2 Sep. Foliar fungicide applications were started 1 week after transplanting and 4 weeks before symptoms were seen. Non-fungicide-treated Eleonora had numerically, but not significantly, fewer leaves affected by downy mildew than the non-treated susceptible variety, Italian Large Leaf, at all assessments. There also were no differences between the two varieties for any of the fungicide programs. However, severity of downy mildew was significantly lower for non-treated Eleonora than non-treated Italian Large Leaf when quantified, which was the last assessment date. Thus the resistance to downy mildew bred into Eleonora was not detectable compared to Italian Large Leaf when based on incidence but was evident when severity was considered. Incidence was the main variable assessed because any amount of diseased tissue can render unmarketable a leaf of an herb.

The organic fungicide program was not effective for managing downy mildew on either variety, despite starting well before disease onset and the frequency of applications (twice weekly). This may be due to the products tested being ineffective or due to insufficient fungicide being delivered to the underside of leaves where infection occurs. The organic fungicides applied to foliage have contact activity whereas many conventional fungicides (including those tested) are mobile and can move to the underside of leaves. Reduction in severity obtained with this program on Italian Large Leaf (about 50%) in the absence of impact on incidence was not a commercially-acceptable level of control.

Both conventional fungicide programs were very effective for managing downy mildew on both varieties. There were no significant differences among these 4 treatments. Based on AUDPC values, these programs provided 90-98% control on Italian Large Leaf and 96% control on Eleonora. At last assessment, which was 8 days after last application, symptoms were observed on 6.5 and 7.8% of leaves of these varieties, respectively, on plants receiving the current conventional fungicide program compared to 86% and 76% of leaves on non-treated plants.

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Organic copper fungicides compared for efficacy, crop safety and visible residue
Investigators: Margaret T. McGrath and Karen LaMarsh
Location: Long Island Horticultural Research and Extension Center

There are several different copper fungicides approved for use in organically-produced crops. Copper fungicides are important tools for managing diseases that cannot be effectively managed with cultural practices alone in organically-produced crops. They have broad-spectrum activity, acting on bacteria as well as fungi. Following many years of use, there is a lot more information on efficacy of copper fungicides than the newer biological products. Manufacturers of some biologicals recommend that they be used in a management program with copper fungicides (often in alternation or at low label rate). Copper fungicides are also commonly applied to conventionally-produced crops because of their broad-spectrum activity. Thus copper fungicides will continue to be important for managing diseases.

Copper fungicides differ in active ingredient, use rate, re-entry interval, and amount of copper. Copper is an inorganic compound thus it does not breakdown like organic compounds and consequently copper can accumulate in soil when used intensively. Plants take up some copper from soil because it is a micronutrient. Similarly, humans need some copper in their diets. Metallic copper equivalent (MCE) is a commonly used measure of copper quantity in fungicides.

Two experiments were conducted at LIHREC to evaluate three copper fungicides registered recently (Badge, Cueva, and Nordox) applied to two vegetable crops (lettuce and tomato) and compared to a standard copper (Basic Copper 53). The goals of the experiments were to determine whether there were differences among these products in ease of mixing, amount of visible residue on plants, crop safety, and efficacy. They differ in active ingredient, labeled rate, MCE, and REI. All four are OMRI-listed.

Procedures used to establish and maintain the plots were as follows. Controlled release fertilizer was spread with 2-row fertilizer spreader over rows to be covered with plastic. A 15-5-15 blend was used at 675 lb/A product (100 lb/A N) for both crops. Beds were formed with drip irrigation tape and covered with black plastic mulch. Herbicide was applied between the plastic. A waterwheel transplanter was used to make planting holes and apply starter fertilizer. Lettuce seeds were sown on 17 April in the greenhouse. Seedlings were transplanted by hand into the planting holes on 9 June. The plots consisted of 16 plants in a double row with 9-in. plant spacing and 68-in. row spacing. Tomato seeds were sown on 6 May in the greenhouse. Seedlings were transplanted by hand into the planting holes on 9 June. The plots consisted of single row of 8 plants of each variety on each bed with 24-in. plant spacing and 68-in. spacing between beds.

The four copper fungicides were applied three times on a weekly interval to plots of tomato and lettuce (4 varieties) in two adjacent replicated experiments. Applications were made using a CO_2-pressurized backpack sprayer with a boom that has a single twin-jet nozzle calibrated to deliver 50 gal/A when operated at 54 psi and 2.4 mph. A TJ60-4004evs nozzle was used on lettuce and a TJ60-11004vs nozzle on tomato. The boom was held over the top of the lettuce plants to deliver spray down on the plants similar to a standard boom sprayer. To obtain thorough coverage of foliage and fruit of tomato, the boom was held sideways, perpendicular to the ground, thereby mimicking a drop nozzle on a tractor sprayer. Applications were made to lettuce on 17, 23 and 30 June and to tomato on 19 and 26 Sep and 3 Oct. The two crops were examined for residue and injury from the treatments. Percent leaf or fruit tissue affected was rated. Tomato plants were also examined for foliar diseases. Severity was rated for diseases that occurred.

Another experiment was conducted to compare the four copper fungicides, plus three other products (Champ, NuCop, and Cuprofix Ultra) in terms of ability to suppress powdery mildew in zucchini. This experiment had to be terminated early in powdery mildew development before sufficient data could be collected to assess control when a storm with strong wind damaged a high percentage of plants.

Clear plastic bottles were used to prepare the fungicide solutions for application, which facilitated observations on mixing ability. The bottles were filled with the quantity of water needed, next the product was added, then the container was shaken before spraying. Cueva was observed to mix most readily into water, none of the product settled to the bottom of the container. In contrast, vigorous shaking was required with Basic Copper 53 to get product that settled into solution. After spraying, there was no residue of Cueva visible on the inside of the bottle. More time was needed for clean up with Basic Copper 53 and Nordox 75WG because both left residue on the inside of the bottle.

All copper fungicides in the tomato crop suppressed powdery mildew similarly based on the assessment on 7 Oct. Cueva and Basic Copper 53 were most effective based on AUDPC. Powdery mildew was widespread throughout the experiment before applications were started, thus the level of control achieved likely is not indicative of potential control with these fungicides. Copper fungicide residue was more visible on fruit of plants treated with Basic Copper 53 than all other products tested. There were no significant differences among other products. Amount of residue was numerically lowest for Nordox 75WG. There were no significant differences among all treatments in severity of other diseases or defoliation.

Copper fungicide residue was more visible on leaves of lettuce of all varieties treated with Basic Copper 53 than all other products tested. Cueva left the least visible residue. Amount was significantly less than all other fungicides based on the AUDPC value (which is a summation of residue over all assessments) for Great Lake and Romaine. In sharp contrast with tomato fruit, amount of residue was numerically greatest for Nordox 75WG. There were no significant differences among treatments in amount of damage following 3 applications. Severity of damage was very low with all.

In conclusion, Cueva was the best copper fungicide based on efficacy for powdery mildew in tomato, ease of mixing and amount of visible residue.

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