



Long Island Vegetable Pathology Program 2008 Annual Research Report

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SENSITIVITY TO FUNGICIDES OF THE CUCURBIT POWDERY MILDEW FUNGUS ON LONG ISLAND IN 2008

Investigators: M. McGrath and G. Fox

Location: Long Island Horticultural Research and Extension Center

Application of fungicides continues to be the principal practice for managing powdery mildew in cucurbit crops, but successful control is challenged by development of resistance to key fungicides. While there are varieties with genetic resistant to this disease, an integrated program is recommended to reduce selection pressure for pathogen strains able to overcome the genetic resistance in the plant as well as fungicide resistance. The pathogen develops best on the lower surface (underside) of leaves, thus a successful management program necessitates controlling the pathogen on the lower as well as the upper surface. It is difficult to directly deliver fungicide to the lower surface, therefore, an important component of fungicide programs has been fungicides able to move to the lower leaf surface. Unfortunately these mobile fungicides are prone to resistance development because they have single site mode of action.

The goals of this study were to 1) determine fungicide sensitivity of the cucurbit powdery mildew fungal population on LI at the start of disease development and 2) monitor sensitivity during the growing season. This was accomplished by conducting seedling bioassays with fungicide-treated seedlings in squash and pumpkin plantings. This information was used to guide fungicide recommendations. For the assay, pumpkin seedlings were treated with fungicide (Topsin M, Flint, Rally, Procure, Quintec, Endura), then placed with non-treated seedlings for about 4 hours in production and research fields where powdery mildew was developing. The seedlings were kept in a greenhouse until symptoms of powdery mildew were visible, which took about 10 days. Then severity (percent tissue with symptoms) was visually estimated for each leaf. Frequency of resistant pathogen strains in a field was estimated by calculating the ratio of severity on fungicide-treated plants relative to non-treated plants for each group, then determining the field average. Only one representative fungicide in each group is needed because of cross resistance (e.g. an isolate resistant to Flint is also resistant to other QoI fungicides). Only one concentration of Flint was used because QoI resistance is qualitative. Several concentrations of the other fungicides were used because resistance is known or suspected to be quantitative. Endura (which is not registered for use on cucurbits) was used rather than Pristine (which is registered) because Endura has only one of the active ingredients in Pristine, boscalid. The other active ingredient in Pristine is a QoI fungicide. Additionally isolates (individuals) of the powdery mildew pathogen were collected from research and commercial plantings and then tested in the laboratory.

Resistance to Topsin M and to Flint were detected in all squash plantings where the bioassay was conducted on 17 Jul. Therefore for managing powdery mildew in 2008 fungicides were not recommended in these chemical classes, which are the MBC (FRAC Code 1) and QoI (Code 11) fungicides, respectively. Proportion of the pathogen population estimated to have resistance varied among the plantings from 18-100% for Topsin M and 21-100% for Flint. Strains of the pathogen were detected with low sensitivity to Code 3 and 7 fungicides, tolerating 120 ppm of myclobutanil (active ingredient in Rally) and 175 ppm boscalid (a.i. in Endura), respectively.

All of the isolates collected from commercial pumpkin crops in Sep were resistant to QoI fungicides. 7% tolerated 80 ppm myclobutanil and 7% tolerated 125 ppm boscalid.

SENSITIVITY TO NEW AND CURRENTLY-REGISTERED FUNGICIDES OF THE CUCURBIT POWDERY MILDEW FUNGUS

Investigators: M. McGrath, M. Miazzi and G. Fox

Location: Long Island Horticultural Research and Extension Center

A study was started in 2007 to determine sensitivity of the cucurbit powdery mildew pathogen to several fungicides. Most of the pathogen isolates (individuals) used in this study were collected in 2007 from field-grown cucurbit plants on LI. There were also a few isolates from GA and from LI GH-grown verbena, an ornamental plant that is infected by the same pathogen as cucurbits. The study began with 73 isolates. It was not possible to completely test all these isolates due to the difficulty in maintaining isolates of the pathogen and the time required to do all of the testing required to determine sensitivity. Sensitivity for an isolate was measured as the highest concentration that it tolerated in a leaf disk assay conducted in the laboratory. This assay entailed spraying each fungicide at one of various concentrations onto pumpkin seedlings at the cotyledon stage; 1 day later leaf disks were cut from the cotyledons, placed on agar in Petri dishes, then spores were placed on the center of each disk; and about 10 days later growth of the isolate on each disk was quantified. The isolate was considered tolerant of a fungicide concentration if it grew and produced spores on at least half of the disks with that treatment. Growth of isolates at the highest concentration tolerated of each fungicide usually was reduced, often greatly, compared to growth on non-treated disks. For boscalid, a FRAC Code 7 fungicide that is one of the active ingredients in Pristine, the highest concentration tolerated by the isolates tested ranged from <25 to 125 ppm (concentrations below 25 were not tested). The range was 1 to 15 ppm for quinoxyfen (Code 13), which is in Quintec. The range for myclobutanil (Code 3), which is in Rally, was <20 to 120 ppm, which is similar to boscalid. Two newer Code 3 fungicides were also tested to assess whether these are inherently more active against the cucurbit powdery mildew fungus. This happened with the last generation of Code 3 fungicides: when control failures due to fungicide resistance were occurring with Bayleton in the early 1990s, the pathogen was more sensitive to myclobutanil than to triadimefon (a.i. in Bayleton) in leaf disk assays, and the then new fungicide Rally (aka Nova) was highly effective in field evaluations. Unfortunately the pathogen was not found to be more sensitive to the new Code 3 fungicides: the highest concentration tolerated was 20 to 80 ppm metconazole (a.i. in Quash) and 40 to 150 ppm difeconazole (Inspire). The range was <5 to 25 ppm for another new fungicide (LEM17). It was very low for two experimental compounds: <0.01 to 1 and <0.001 to 0.5 ppm. Only one of these is still being developed as a powdery mildew fungicide.

EVALUATION OF FUNGICIDES FOR MANAGING POWDERY MILDEW ON PUMPKIN AND TREATMENT IMPACT ON PATHOGEN SENSITIVITY TO FUNGICIDES

Investigators: M. McGrath and G. Fox

Location: Long Island Horticultural Research and Extension Center

The primary objective of this study was to evaluate the efficacy of several individual fungicides and fungicide alternations for the control of cucurbit powdery mildew. Both new and currently registered products were tested. Impact on product efficacy of the pathogen becoming less sensitive, and eventually resistant, to fungicides is a major issue with control of this common disease. Yearly testing is needed because of frequent changes in the pathogen's sensitivity to fungicides. Therefore three products at risk of resistance affecting efficacy (Procure, Pristine, and Quintec) were tested alone because individual product testing is the best way to assess resistance impact. This is not a labeled use pattern because of resistance. Procure and Pristine have been registered for use on pumpkin and other cucurbit crops for a few years. Quintec was registered only for use on melon in 2008. Its label is anticipated to be expanded to include pumpkin in late 2009.

Pumpkin variety Sorcerer was direct-seeded on 20 Jun. Controlled release fertilizer was used. Powdery mildew was first observed on 22 Jul on 0.7% of leaves examined. Treatments were started on 30 Jul when powdery mildew infection had reached the IPM threshold in most plots,

with subsequent applications made weekly on 5, 13, 19, and 27 Aug, 5 Sep, and 11 Sep with a tractor-mounted boom sprayer equipped with D5-25 hollow cone nozzles spaced 17 inches apart that delivered 96 gal/A at 100 psi. Upper and lower leaf surfaces were inspected for powdery mildew symptoms weekly beginning on 22 Jul. Last assessment was 2 Sep. Pathogen isolates (e.g. individuals) were collected from select plots and tested in a laboratory assay to determine their sensitivity to fungicides.

All treatments suppressed powdery mildew on both leaf surfaces. Applications were started when incidence of symptomatic leaves was at a very low level (6% of the older leaves examined). Differences in efficacy were mostly evident on lower leaf surfaces. As in previous experiments, degree of control of powdery mildew was inversely related to defoliation and directly related to fruit quality in terms of handle condition.

Quintec applied weekly at 4 fl oz/A, the lowest label rate, was the most effective treatment, providing 100% and 99% control on upper and lower leaf surfaces, respectively, based on AUDPC values (a summation measure of disease severity over all assessment dates). Similar control was achieved with labeled use patterns consisting of Quintec alternated with Procure or Rally, following a simple or 2-spray block alternation. The Quintec treatment with Rally also included sulfur each week, and thus had both components of a recommended fungicide resistance management program (alternation of at-risk fungicides tank-mixed with a protectant fungicide). This treatment started with sulfur alone thus there was one less spray of a mobile fungicide.

Both Procure at 8 fl oz/A and Pristine at 18.5 oz/A, the highest label rates for both, provided excellent control (93% and 94% on lower surfaces, respectively) which was not significantly different from that achieved with Quintec. In contrast, powdery mildew was not controlled well on the lower surfaces of leaves in many commercial pumpkin crops on LI where at least one of these fungicides was used in the fungicide program. This may reflect differences in application timing or spray coverage, which are especially important for these fungicides because the pathogen is developing resistance.

Four new fungicides were evaluated. Quadris Top was the least effective of all treatments tested in 2008 providing 89% and 67% control of powdery mildew on upper and lower leaf surfaces, respectively. Lower efficacy was detected from the first disease ratings analyzed, which were taken on 18 Aug after 3 applications. Efficacy likely reflects the fact the pathogen has developed qualitative resistance to the chemical group (FRAC Code 11) for one active ingredient in Quadris Top (azoxystrobin) and the pathogen is developing quantitative resistance to the chemical group (Code 3) for the other active ingredient (difenoconazole). Difenoconazole was expected to be more effective than the active ingredients (myclobutanil and triflumizole) in currently registered fungicides in this group (Rally and Procure); however, recent laboratory assays revealed that pathogen isolates are equally sensitive or less sensitive to difenoconazole than to myclobutanil and triflumizole. Resistance developing to this fungicide chemical group could be a reason that Inspire Super, another new fungicide containing difenoconazole evaluated at LIHREC in 2008, was numerically not as effective at the lowest rate tested compared to the highest (14 and 20 fl oz/A). The other 2 new fungicides tested are at an earlier stage in development.

Fungicide sensitivity testing of powdery mildew pathogen isolates collected from this research field revealed a decrease in pathogen sensitivity during the experiment likely in response to use of fungicides that are at risk for resistance developing (e.g. Rally, Procure, Pristine). Isolates were collected on 18 Aug from nontreated plants in part of the field not used for experiments and on 16 Sep from several plots. 60% of the isolates collected on 18 Aug and 92% of those collected on 16 Sep were resistant to Code 11 fungicides. With this high frequency of resistant strains, the Code 11 (QoI) component of Quadris Top and Pristine likely contributed little if anything to control. None of the 18 Aug isolates or 16 Sep isolates from nontreated plots tolerated 80 ppm myclobutanil (active ingredient in Rally) or 125 ppm boscalid (an active ingredient in Pristine). In contrast, 80% of the 16 Sep isolates from plots treated with Pristine alone tolerated 125 ppm boscalid, and 50% of the 16 Sep isolates from plots treated with Procure alone tolerated 80 ppm myclobutanil (both Code 3 fungicides). Thus fungicide use during a growing season appears to be selecting for less sensitive isolates. Dose in the spray tank for these treatments applied at 96 gpa was 156 ppm myclobutanil, 274 ppm triflumizole, and 364 ppm

boscalid. These concentrations are all higher than what the pathogen tolerated in the laboratory assays.

EVALUATION OF A BIOPESTICIDE AND THE FUNGICIDE RALLY FOR MANAGING POWDERY MILDEW ON PUMPKIN

Investigators: M. McGrath, S. Menasha and G. Fox

Location: Long Island Horticultural Research and Extension Center

The objective of this study was to evaluate MOI-106, a biopesticide with extract of the giant knotweed (*Reynoutria sachalinensis*) as the active ingredient, and Rally, a DMI (FRAC Code 3) fungicide. The powdery mildew pathogen has been developing quantitative resistance to the Code 3 class of fungicides. The goal was to assess whether the pathogen had become sufficiently insensitive to this fungicide class that efficacy of Rally was affected.

Pumpkin variety Sorcerer was direct-seeded on 20 Jun. Powdery mildew was first observed on 22 Jul on 0.7% of leaves examined. Treatments were started on 30 Jul when powdery mildew infection had reached the IPM threshold in most plots, with subsequent applications made weekly on 5, 13, 19, and 27 Aug, 5 Sep, and 11 Sep with a tractor-mounted boom sprayer equipped with D5-25 hollow cone nozzles spaced 17 inches apart that delivered 96 gal/A at 100 psi. Upper and lower leaf surfaces were inspected for powdery mildew symptoms weekly beginning on 22 Jul. Last assessment was 2 Sep. Pathogen isolates (e.g. individuals) were collected from select plots and tested in a laboratory assay to determine their sensitivity to fungicides.

Powdery mildew was at a low level at the first assessment on 1 Aug, which was 2 days after treatments were started. Symptoms were found in 6 of 12 plots on 23 of the 600 older leaves examined. On 26 Aug the biopesticide MOI-106 was providing 62% control on upper leaf surfaces and 11% control on lower leaf surfaces. Degree of control was 51% on upper leaf surfaces based on AUDPC values. Limited control on lower leaf surfaces is not surprising considering MOI-106 does not have systemic activity. Rally provided a very high level of control: 98 and 89% control on upper and lower leaf surfaces, respectively, based on AUDPC values. Therefore the level of insensitivity to Code 3 fungicides in this pathogen population did not affect control. None of the 5 isolates collected on 18 Aug from nontreated plots tolerated 80 ppm in the leaf disk assay. Based on the bioassay conducted on 13 Aug, 20% of the pathogen population tolerated this concentration. Dose in the spray tank was 156 ppm.

IDENTIFICATION OF RACES OF THE CUCURBIT POWDERY MILDEW PATHOGEN OCCURRING ON LONG ISLAND

Investigators: M. McGrath and G. Fox

Location: Long Island Horticultural Research and Extension Center

Races of the powdery mildew pathogen affecting cucurbit crops are defined based on their ability to infect melon varieties and experimentals with different genes for resistance. These melons are considered to be differentials. It is important to know what races are occurring in order to know what resistance genes are needed to effectively suppress powdery mildew in melons.

Eleven melon differentials plus two watermelon differentials were grown in 2008. Seedlings were transplanted into beds covered by black plastic mulch with drip irrigation in mid Jun. Plots were three adjacent rows each with three plants spaced 24-in. apart. There was a plant of a susceptible summer squash variety between each plot in each row to separate plots and provide a source of inoculum. No fungicides were applied with activity for powdery mildew. Fungicides were applied preventively for downy mildew and Phytophthora blight. Powdery mildew severity was evaluated on both leaf surfaces from 18 Jul through 27 Aug.

The two varieties with no genes for resistance to powdery mildew (Iran H and Hale's Best Jumbo) and a variety with resistance just to Race 0 (Vedrantais) all had symptoms on 18 Jul,

which was the first day that symptoms were seen in this experiment, and powdery mildew became severe. Based on this observation, Race 0 was either not present or at a very low frequency. Two entries had resistance only to Race 1. Powdery mildew was first observed on 23 Jul and became moderately severe for one (PMR-45) whereas symptoms were not found until 7 Aug and remained at a low level in the other (PI 414723). Two entries had resistance to Races 1 and 2 (PMR-5 and PI 313970). Powdery mildew was first observed on 18 Jul in both and became low to moderately severe. Based on these observations, both Races 1 and 2 of the powdery mildew pathogen were present. Powdery mildew was found on 13 Aug in 1 of the 2 plots of the entry with resistance to Races 1, 2 and 3 (MR-1). Very few symptoms were found in this 1 plot through the last assessment date. This suggests a new pathogen race may have been present at a very low frequency in 2008. A new race (S) has been reported in GA. Few symptoms of powdery mildew were observed on the watermelon differential susceptible to some races while none were observed on the watermelon differential that is resistant.

EVALUATION OF POWDERY MILDEW RESISTANT MELON VARIETIES

Investigators: M. McGrath, S. Menasha and G. Fox

Location: Long Island Horticultural Research and Extension Center

The objective of this study was to evaluate some of the varieties of muskmelon that were released recently with resistance to powdery mildew. They were compared to Athena, a resistant variety that is grown commonly, and to Superstar, a standard variety lacking genetic resistance.

Seedlings were transplanted into beds covered by black plastic mulch with drip irrigation on 11 Jun. Plots were three adjacent rows each with three plants spaced 24-in. apart. There was a plant of a susceptible summer squash variety between each plot in each row to separate plots and provide a source of inoculum. No fungicides were applied with activity for powdery mildew. Fungicides were applied preventively for downy mildew and Phytophthora blight. Powdery mildew severity was evaluated on both leaf surfaces from 22 Jul through 15 Aug just before the first harvest. More assessments were not made because of the impact on the canopy of harvesting. As fruit reached maturity from 15 Aug to 3 Sep, they were harvested, weighed, measured, and fruit characteristics evaluated and rated on a scale of 1 to 9 with 1 = poor and 9 = best.

Powdery mildew was first observed on 15 Jul at a very low level in Superstar, the susceptible variety (3 affected leaves out of 200 older leaves examined). Severity increased greatly on this variety. All of the varieties tested suppressed powdery mildew on upper leaf surfaces relative to Superstar. Eclipse, the only variety tested with resistance to just race 1, did not suppress powdery mildew on upper leaf surfaces as well as most of the other varieties that all have resistance to both races 1 and 2. Eclipse was no longer suppressing powdery mildew on lower leaf surfaces at the last assessment on 15 Aug. These results indicate that both race 1 and 2 of the pathogen were present, which was confirmed by an adjacent planting of cucurbit differentials. Sarah's Choice did not exhibit the level of suppression expected considering the resistance genes it was bred to contain. Suppression of powdery mildew on lower leaf surfaces based on AUDPC values (a summation measure of disease severity over all assessment dates) was 75% for Sarah's Choice, and 98-100% for the other varieties, which were Pixie, Halona, Wrangler, Athena, Strike, and Hannah's Choice.

Wrangler had the greatest yield. Superstar had the lowest Brix value and lowest taste rating likely due entirely to powdery mildew not being controlled. Strike had the highest taste rating and one of the highest Brix values.

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EVALUATION OF POWDERY MILDEW RESISTANT PUMPKIN VARIETIES

Investigators: M. McGrath, S. Menasha and G. Fox

Location: Long Island Horticultural Research and Extension Center

Resistance to powdery mildew in pumpkin and squash is conferred by one main major gene and several modifier genes. Past evaluations have revealed variation in degree of powdery mildew suppression among varieties that was due mostly to number of copies of the major gene, with mildew being less severe on those varieties having resistance from both parents compared to those with one copy. There was also additional variation likely due to modifier genes. Pumpkin varieties with a putative new major gene started to be released in 2008. The 2008 evaluation consisted of 13 varieties of Halloween-type pumpkin with one gene for resistance (PMR) or two resistance genes (PMRR), including two varieties with the new gene, and two susceptible varieties for comparison.

Seeds were direct-seeded on 10 Jun into beds covered by black plastic mulch with drip irrigation. Two seeds were placed and later thinned to one plant. Fertilizer (N-P-K 10-10-10) at 500 lb/A was broadcast and incorporated on 5 May. Additional fertilizer (N-P-K 46-0-0) at 30 lb/A was injected through the drip irrigation system on 9 and 17 Jul. Weeds were controlled between the rows of black plastic mulch by seeding white clover for a living mulch on 13 May after rototilling to prepare a seed bed and manage weeds that had already germinated. During the season, weeds were managed by mowing and hand weeding. No fungicides were applied specifically for powdery mildew. Fungicides were applied preventively for downy mildew and Phytophthora blight (Forum, Ranman, and Curzate). Plots were three adjacent rows each with three plants spaced 24 in. apart. Rows were spaced 68 in. apart. A summer squash plant was seeded between each plot in each row to separate plots and provide a source of inoculum. Upper and lower leaf surfaces were assessed for powdery mildew from 16 Jul to 26 Aug. Pumpkin fruit were harvested, weighed, and measured in Sep.

Symptoms of powdery mildew were first seen on 16 Jul at a very low level in plots of susceptible varieties. Plants did not grow well apparently as a result of inadequate water and fertilizer due to problems with the drip irrigation. Varieties with PMRR did not perform consistently better than those with PMR. Degree of disease suppression with resistant pumpkins was not as high as with resistant melon varieties, as in previous experiments. Relative to Sorcerer, suppression ranged from 2-49% on upper leaf surfaces and 10-57% on lower surfaces based on the 26 Aug assessment values. Suppression was greater at the 15 Aug assessment: excluding Midas Touch, it was 28-90% and 59-92% on upper and lower leaf surfaces, respectively. Midas Touch exhibited the least resistance: powdery mildew was significantly less severe on this variety than on the susceptible variety Sorcerer only for the 8 Aug lower leaf surface assessment. Gold Speck, a mini-fruited variety with no known genes for resistance, was substantially less severely affected by powdery mildew than Sorcerer. Mildew was not significantly less severe on Gold Dust, a similar variety with PMR. Gold Dust had the lowest severity on 26 Aug. This confirms previous observations that mini-fruited varieties are naturally less susceptible to powdery mildew. Wee-B-Little, another mini-fruited variety without resistance, performed well in previous evaluations. Camero, a variety thought to have a new gene for resistance, did not differ significantly from Gold Dust. An experimental with this gene, HSR 4710, did not perform as well, providing 12% and 33% suppression on 26 Aug compared to 34% and 46% for Camero. The varieties tested listed in order of powdery mildew severity on 26 Aug were: Gold Dust (PMR), Gold Speck (PMS), Camero (PMR), Gladiator (PMRR), Warlock (PMRR), OS 8615 (PMRR), Gargoyle (PMRR), Treasure (PMR), HSR 4710 (PMR), Magic Wand (PMRR), Superior (PMRR), Magic Lantern (PMR), OS 6866 (PMRR), Midas Touch (PMR), and Sorcerer (PMS).

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POWDERY MILDEW RESISTANT ZUCCHINI AND YELLOW SUMMER SQUASH VARIETY EVALUATION

Investigators: M. McGrath, S. Menasha and G. Fox

Location: Long Island Horticultural Research and Extension Center

The goal of this experiment was to determine whether squash varieties with homozygous resistance (e.g. two copies of the main powdery mildew resistance gene; PMRR) are better protected against powdery mildew than varieties with heterozygous resistance (PMR). This was the case in variety evaluations conducted in 2007 but not in 2006. Most commercial resistant squash varieties have PMR. Ability of the varieties evaluated in 2008 to resist powdery mildew as well as their yielding ability was determined relative to Spineless Beauty and Gentry, standard varieties lacking powdery mildew resistance.

Seedlings were transplanted into beds covered by black plastic mulch with drip irrigation on 12 Jun. Plots were three adjacent rows each with five plants spaced 24-in. apart. Weeds were controlled between the rows of black plastic mulch by seeding white clover for a living mulch on 13 May after rototilling to prepare a seed bed and manage weeds that had already germinated. There was a plant of a susceptible summer squash variety between each plot in each row to separate plots and provide a source of inoculum. No fungicides were applied with activity for powdery mildew. Fungicides were applied preventively for downy mildew and Phytophthora blight. Powdery mildew severity was evaluated on both leaf surfaces 5 times from 15 Jul through 15 Aug. Severity was also assessed on petioles and stems. Fruit were harvested, weighed, measured, and fruit characteristics evaluated and rated on a scale of 1 to 9 with 1 = poor and 9 = best.

Symptoms of powdery mildew were found on the powdery-mildew-susceptible varieties on 7 Jul at a low level (on 19 of 400 older leaves examined). Symptoms were found in all but one plot on 15 Jul. Among the zucchini varieties, powdery mildew on lower leaf surfaces was suppressed best by Zucchini #8517, a PMRR experimental variety developed by Outstanding Seeds. Degree of suppression based on AUDPC values (a seasonal disease severity summation) was 75% and 81% on upper and lower leaf surfaces, respectively. Performance varied among the PMR varieties reflecting differences in modifying genes. A zucchini variety considered to have a medium level of resistance to powdery mildew, Envy, provided only 33% and 31% suppression on upper and lower leaf surfaces, respectively, which was the lowest degree of suppression relative to Spineless Beauty, the susceptible check variety. Payroll, which has more resistance, provided 46% and 43% suppression on the two leaf surfaces, respectively. Amatista, a grey zucchini type with a higher level of resistance, suppressed powdery mildew by 64% and 50%, respectively. Zucchini #8517 and Amatista were both significantly better than Envy for most assessments. The yellow squash susceptible variety, Gentry, did not become as severely affected by powdery mildew as Spineless Beauty. The two resistant squash varieties evaluated, Success PM and Sunglo, are PMRR. They suppressed powdery mildew equally well: 68% suppression on upper leaf surfaces and 70% and 85% suppression on lower leaf surfaces. Better control of powdery mildew was obtained with resistant summer squash varieties in 2008 than in 2007.

Zucchini #8517 out-yielded the other zucchini varieties. Success PM did not yield as well as the susceptible variety, as in previous years; however, in 2008 it was not because Success PM, an OP variety, began producing fruit later than the other varieties. There were marketable fruit in all plots at the first harvest. Fruit quality was very good for all varieties. Lowest overall appearance rating was 7.5 for Success PM.

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POWDERY MILDEW RESISTANT ACORN SQUASH VARIETY EVALUATION

Investigators: M. McGrath, S. Menasha and G. Fox

Location: Long Island Horticultural Research and Extension Center

The goals of this experiment were 1) to determine whether winter squash varieties with homozygous resistance (e.g. two copies of the powdery mildew resistance gene; PMRR) are better protected against powdery mildew than varieties with heterozygous resistance (PMR) and 2) to determine whether striped acorn-types with PMRR are not as effective at suppressing powdery mildew as solid green acorn-types with PMRR. These were the results obtained in a similar experiment conducted in 2007. Ability of these varieties to resist powdery mildew as well as their yielding ability were determined relative to Table Ace, a commonly-grown variety lacking powdery mildew resistance.

Seedlings were transplanted into beds covered by black plastic mulch with drip irrigation on 16 Jun. Plots were three adjacent rows each with three plants spaced 24-in. apart. Weeds were controlled between the rows of black plastic mulch by seeding white clover for a living mulch on 13 May after rototilling to prepare a seed bed and manage weeds that had already germinated. There was a plant of a susceptible summer squash variety between each plot in each row to separate plots and provide a source of inoculum. No fungicides were applied with activity for powdery mildew. Fungicides were applied preventively for downy mildew and Phytophthora blight. Powdery mildew severity was evaluated on both leaf surfaces 5 times from 16 Jul through 26 Aug. Fruit were harvested, weighed, measured, and fruit characteristics evaluated and rated on a scale of 1 to 5 with 1= poor and 5 = best.

Symptoms of powdery mildew were first seen on 15 Jul on Table Ace, the susceptible variety. All varieties and almost all plots had symptoms on 23 Aug. The table contains the 4 solid green PMRR varieties, followed by the 2 green PMR varieties, the 2 striped PMRR varieties, and last the susceptible standard check. Varieties within these groups are organized by AUDPC value for lower leaf surface. Solid green acorn-type varieties with PMRR were not significantly less severely affected by powdery mildew than varieties with PMR. There was one exception to this conclusion: AUDPC for severity on upper leaf surfaces for Tay Belle PM (PMR) was significantly greater than for Sweet Reba (PMRR). The level of powdery mildew suppression achieved based on AUDPC values was 70-86% and 91-95% for upper and lower leaf surfaces, respectively, for the PMRR varieties and 60-82% and 83-89% for the PMR varieties. In 2007, when powdery mildew was more severe, lower leaf surface AUDPC value for Autumn Delight was significantly lower than for Table Star. In 2008, powdery mildew severity was numerically higher for the 2 striped acorn-type varieties with PMRR than the solid green acorn-types with PMRR; this was a significant difference only for severity on lower leaf surfaces on 15 Aug. Level of suppression for Celebration and Sugar Dumpling was 71% and 76% for lower leaf surfaces. Celebration did not suppress powdery mildew on upper leaf surfaces based on AUDPC values. Neither AUDPC value for Celebration in 2007 was significantly lower than Table Ace.

Celebration, Sweet Reba, and Royal Ace PM produced the greatest number and weight of marketable fruit per plant. These values were significantly greater than those for Tay Belle PM, which were the lowest and also Table Ace, which had the next lowest yield values. Yielding ability of Table Ace may have been affected by powdery mildew. Autumn Delight, Tay Belle PM and Table Ace produced the largest fruit by weight, while average fruit weight was lowest for Honey Bear, which was as expected because this variety was bred to produce a personal-sized fruit. Fruit of all varieties were rated 4 or 5 for color, appearance, and overall marketability.

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EVALUATION OF POWDERY MILDEW RESISTANT BUTTERNUT SQUASH VARIETIES

Investigators: M. McGrath, S. Menasha and G. Fox

Location: Long Island Horticultural Research and Extension Center

The goal of this study was to determine whether hybrids with homozygous resistance, e.g. two copies of the powdery mildew resistance gene (PMRR), provide better suppression of powdery mildew than varieties with heterozygous resistance (PMR). In order to have good comparisons, PMR and PMRR experimental hybrids were obtained from 2 plant breeders. A susceptible hybrid was also obtained from one of these breeders. Three additional PMRR hybrids were obtained from another source.

Seedlings were transplanted into beds covered by black plastic mulch with drip irrigation on 12 Jun. Plots were three adjacent rows each with three plants spaced 24-in. apart. There was a plant of a susceptible summer squash variety between each plot in each row to separate plots and provide a source of inoculum. No fungicides were applied with activity for powdery mildew. Fungicides were applied preventively for downy mildew and *Phytophthora* blight. Powdery mildew severity was evaluated on both leaf surfaces 5 times from 15 Jul through 15 Aug. Fruit were harvested, weighed, measured, and fruit characteristics evaluated and rated on a scale of 1 to 5 with 1= poor and 5 = best.

Powdery mildew symptoms were first seen on 25 Jul, 43 days after transplanting. At the last assessment on 15 Aug, powdery mildew was at a low severity on the susceptible hybrid (average of 4% and 9% of upper and lower leaf surfaces covered with symptoms). Powdery mildew was significantly more severe on the susceptible hybrid compared to the resistant hybrids at most assessments. There were no significant differences in powdery mildew severity among the PMR and PMRR hybrids in the two sets of experimental hybrids. Among the three additional PMRR hybrids, the one with the greatest severity values, WSXP1036, had significantly more powdery mildew on lower leaf surfaces based on AUDPC values (a seasonal disease severity summation) than 3 of the 4 other PMRR hybrids and also 1 of the 2 PMR hybrids. Based on these results, butternut hybrids with one gene for resistance provide adequate suppression, equivalent to that obtained by hybrids with two genes, and PMRR hybrids can vary in the degree of suppression possibly reflecting modifier genes. The hybrids provided 38% to 78% suppression of powdery mildew on upper leaf surfaces and 46% to 92% suppression on lower leaf surfaces. Greater suppression of powdery mildew on lower leaf surfaces is highly desirable because this disease develops best on this surface where control with fungicides can be compromised by resistance to mobile products.

Project funded by the Friends of Long Island Horticulture Grant Program

HARD-RIND PUMPKIN VARIETY EVALUATION FOR PHYTOPHTHORA FRUIT ROT

Investigators: M. T. McGrath and G. M. Fox

Location: Long Island Horticultural Research and Extension Center

The first pumpkins developed that form hard, gourd-like rinds (shells) when mature were shown to be less susceptible to *Phytophthora* fruit rot than pumpkins with conventional rinds in experiments conducted at LIHREC in 1997-8. One of these pumpkins, Lil' Ironsides, is now available commercially. The experiment conducted in 2008 was a continuation of research started in 2006 to examine new and experimental varieties with the hard rind trait, all developed by Harris Moran.

All 9 pumpkin varieties and experimental varieties were seeded in the greenhouse and transplanted into bare ground plots on 2 Jul. Each plot consisted of ten plants in two rows with two summer squash plants between plots. No fungicides with activity for *Phytophthora* were applied. Powdery mildew was controlled with fungicides.

Phytophthora blight started to develop in the low end of the research field following rain events in Jul. There were 0.53, 1.75, and 1.02 in. of rain on 23, 24, and 27 Jul. Symptoms of Phytophthora blight were seen on 31 Jul. Many plants in replications 4 and 5 died before fruit set. Rain events in Aug and Sep provided favorable conditions for further development of Phytophthora blight. Data from replications 1-3 were analyzed. A high percentage of fruit of the varieties with conventional soft rinds, Magic Lantern, Field Trip, and Mystic Plus, developed symptoms. As in previous experiments, more fruit of variety Magic Lantern, which produces large fruit, were affected than of Mystic Plus, which produces medium-sized fruit (not significant in 2008). Field Trip, which also produces medium-sized fruit, was included in the 2008 experiment to investigate whether the difference in susceptibility between Magic Lantern and Mystic Plus was related to fruit size. This does not appear to be the case. The rind of Mystic Plus appears harder than that of Magic Lantern and Field Trip. Apprentice had a relatively low number of fruit with symptoms of Phytophthora fruit rot and high number of healthy-appearing fruit. This variety also performed well in 2006 and 2007. Fruit of HMX 5681 also exhibited reduced susceptibility to Phytophthora fruit rot. Iron Man had the next lowest percent affected fruit, differing significantly from Magic Lantern and Field Trip. Lil' Ironsides and Gargoyle had fewer affected fruit than the conventional-rind varieties, but these numbers were not significantly different for most comparisons. Warlock did not perform as well as it had in 2007. Warlock has a different source of the hard-rind trait compared to other entries in this experiment. In Warlock, the hard-rind trait is associated with a softer, more carvable, hard shell.

Project funded by New York State Ag & Markets

EVALUATION OF PHYTOPHTHORA-RESISTANT BELL PEPPER VARIETIES WITH AND WITHOUT A FUNGICIDE PROGRAM

Investigators: M. McGrath and G. Fox

Location: Long Island Horticultural Research and Extension Center

The experiment was conducted in a field where Phytophthora blight has been observed since 1991. Six resistant varieties and two susceptible varieties were seeded in the greenhouse on 6 May and transplanted into bare ground plots on 13 Jun. Each plot consisted of 16 plants spaced 15-in apart in two 10-ft rows spaced 34-in apart. There were two sets of replicated plots. One set received a fungicide program for Phytophthora blight. This was done to improve control especially of the aerial phase of Phytophthora blight. Resistance is to the crown rot phase. A soil application of ProPhyt (5 pt/A) and Ridomil (1 pt/A) was made in a band on both sides of each row of transplants on 20 Jun using a backpack CO₂-pressurized sprayer. Foliage was treated with Forum (6 fl oz/A) + Kocide 3000 (0.75 lb/A) applied on 1 Jul, 14 Jul, and 29 Aug; ProPhyt (6 pt/A) + Kocide 3000 (0.75 lb/A) applied on 28 Jul; Fosphite (6 pt/A) + Kocide 3000 (1 lb/A) applied on 22 Aug; and Presidio (4 fl oz/A) + Kocide 3000 (0.75-1 lb/A) applied on 13 Aug and 11 Sep. These applications were made using a tractor-mounted boom sprayer equipped with D5-25 hollow cone nozzles spaced 17 in. apart that delivered 96 gal/A at 100 psi.

Rain events in 2008 provided very favorable conditions for development of Phytophthora blight. Symptoms of crown rot were observed on 26 Jun, 13 days after transplanting. An experimental variety, RPP 20809, had the lowest incidence or proportion of plants with symptoms. Incidence was 2% and 31% on 22 Sep and 20 Oct, respectively, for non-fungicide-treated plants, and 2% and 11% for fungicide-treated plants. These values were significantly lower than those for most other resistant varieties. While for Crusader, a susceptible variety, these values were substantially higher: 100%, 100%, 47%, and 95%, respectively. These values were 16%, 61%, 5%, and 23% for Paladin, 56%, 98%, 14%, and 27% for Aristotle, 31%, 94%, 9%, and 45% for Revolution, 31%, 100%, 11%, and 45% for Declaration, and 72%, 100%, 17%, and 65% for Alliance. These results demonstrate the importance of an integrated management program with fungicides and resistant varieties for managing Phytophthora blight.

Project funded by New York State Ag & Markets

OBSERVATIONAL STUDY OF A BIOFUMIGANT MUSTARD COVER CROP FOR MANAGING PHYTOPHTHORA BLIGHT IN CUCURBITS

Investigators: M. McGrath and G. Fox

Location: Long Island Horticultural Research and Extension Center

To obtain preliminary information on the potential of biofumigation for suppressing Phytophthora blight, Caliente 199 mustard blend (Siegers Seed Company) was grown during spring 2008 in a non-replicated planting in a field where Phytophthora blight occurred on squash in 2007. It was followed by a planting of zucchini. The field was prepared by plowing, tilling, and incorporating 10-10-10 fertilizer at 1000 lb/A. Fertilizer was applied to ensure ample biomass production. Mustard was drilled at 10 lb/A on 6 May using a Sukup no-till seeder because it could handle the small seed size which our standard grain drill couldn't do as it doesn't have a small-seed attachment. By 12 Jun the plants had started to flower. Seed development was monitored to ensure the plants would be incorporated before seed matured, which reportedly takes 6 wks. Seed were still immature on 7 Jul when the mustard plants were flail chopped and immediately incorporated by rototilling, then the soil surface was sealed by rolling with a cultipacker followed by irrigation (about 0.5 inch water). This was done early in the morning and quickly to minimize loss of biofumigant through volatilization. Mustard plants had grown another 4 ft after the start of flowering to reach a final height of about 5 ft 6 in. Caliente 199 was selected because it has a high concentration of glucosinolates, which breakdown as the plant decomposes into allyl-isothiocyanate, which is similar to methyl isothiocyanate, the active ingredient in the chemical fumigant Metam Sodium. Zucchini was direct seeded on 23 Jul into the strip where the mustard was incorporated and an adjacent strip that had been fallow during the spring. Crop plants and weeds that grew where the mustard was incorporated were stunted relative to the fallow strip, indicating that planting was done too soon after mustard incorporation. On 15 Aug symptoms of Phytophthora blight were observed on almost all plants in the non-fumigated strip whereas only end plants were affected in the biofumigated strip. Zucchini plants were not stunted in a second seeding done 4 weeks after biofumigation. Additional research on biofumigation for managing Phytophthora blight is warranted in particular to look at an earlier seeding date for mustard, which reportedly can be planted as soon as the soil can be prepared in the spring, and to examine planting time for a subsequent crop of pumpkin.

Project funded by New York State Ag & Markets

INVESTIGATION OF THE PHYTOPHTHORA PATHOGEN CAUSING POD ROT IN SNAP BEAN

Investigator: M. McGrath

Location: Long Island Horticultural Research and Extension Center

On 10 Sep 2008 for the first time on Long Island snap bean pods were observed with a rot that was confirmed to be caused by *Phytophthora capsici*, the pathogen that causes blight in pepper and cucurbits. Following this observation, experiments were conducted to determine whether the pathogen infecting beans was a unique strain, which would explain why symptoms had not been reported on beans previously on LI. The first report of this disease on snap beans was in 2003 in MI, where it has been causing losses ever since. Healthy-appearing bean pods were used for the experiments. They were put in chambers where humidity would remain high to provide favorable conditions for infection. Spores were taken from affected yellow squash and put on some bean pods. On to pods in other chambers were placed plugs of media with isolates of the pathogen obtained from tomato and also from the beans to serve as a check and to also confirm this pathogen strain's ability to cause pod rot. Additional pods received plain media without the pathogen to confirm the pods used in the experiment would remain healthy in moist chambers during the experiment. All groups of pods inoculated with *Phytophthora capsici* from the various sources (squash, tomato, and bean) developed rot. Based on these results, occurrence of *Phytophthora capsici* causing pod rot in snap bean, a new host, was not the result of a new pathogen strain being introduced to LI that was uniquely able to infect bean, but rather was the

result of a unique situation of beans being grown in an infested field and subjected to ideal conditions for disease development. The affected snap bean planting was in a low section of a commercial production field where blight had developed on pepper in 2007. Two consecutive days of significant rain (0.86 and 2.19 inches were recorded at LIHREC on 6 and 7 Sep) shortly before harvest provided ideal conditions for splash dispersal of the pathogen in the soil to the pods and for infection.

INVESTIGATION OF POPULATIONS OF PHYTOPHTHORA CAPSICI OCCURRING ON LONG ISLAND FARMS

Investigators: M. McGrath, W. Fry, and K. Lamour

Location: Long Island Horticultural Research and Extension Center

A study is underway to gain knowledge about strains of *Phytophthora capsici* that are on LI. This information will be used to guide management programs. To accomplish this, isolates (individuals) of the pathogen have been obtained from infected plant tissue (mostly pumpkin) collected from several farms on LI over a few years. These isolates are being examined in two other laboratories that have the equipment and experience with procedures to examine traits and perform genetic analysis. Results from the analyses that have been conducted so far on isolates collected in 2008 include detecting resistance to the fungicide mefenoxam (Ridomil). Occurrence of resistance generally corresponded with fungicide use, with resistant strains only present on farms where Ridomil had been used. At the two farms where resistance was detected, although Ridomil had not been used for several years, most of the isolates tested were resistant: 64% and 83%. These findings are further documentation of the pathogen's ability to develop fungicide resistance, which has been detected elsewhere, and to maintain this trait in the absence of selection pressure from fungicide use. Therefore it is critically important to manage fungicide resistance in this pathogen by using an integrated management program and alternating among fungicides. Resistance was not found at another farm where Ridomil had been used recently. Both mating types of the pathogen (which are the equivalent of male and female) were detected in most fields (3 of 5 populations examined so far). Interaction among opposite mating types results in formation of a structure (oospore) that enables the pathogen to survive for long periods without having a host plant to infect. One field where only 1 mating type was detected the grower couldn't remember when or if that field had been used to produce crops susceptible to Phytophthora blight. Occurrence of just one mating type suggests the pathogen may have been recently introduced to this field. Genetic analysis will provide more concrete evidence to support or refute the hypothesis that the pathogen was moved on equipment from another field on this farm. Genetic analysis is being conducted now on isolates from this field and from other fields on this and other farms.

MONITORING CUCURBIT DOWNY MILDEW ON LONG ISLAND

Investigators: M. McGrath and G. Fox

Location: Long Island Horticultural Research and Extension Center

A sentinel plot was maintained at LIHREC as part of the national downy mildew forecasting program being conducted in the eastern USA. This plot, along with two others in upstate NY, were among the 85 plots from Florida and Texas to Canada set up to monitor occurrence of downy mildew on the various cucurbit crops. This pathogen exists as different pathotypes that vary in their ability to infect the different cucurbit crop types. A set of differential varieties to distinguish pathotypes was planted at each sentinel plot.

Seedlings of the differential varieties at the 1- to 2-leaf stage were transplanted on 10 Jun and again on 18 Jul into beds covered by black plastic mulch with drip irrigation. Plants were examined routinely for symptoms. Fungicides were applied for powdery mildew; none had activity for downy mildew.

Symptoms were first observed on 27 Aug on cucumber in the sentinel plot and also in a commercial planting. It was not surprising that this cucurbit crop type was affected first because

cucumber is susceptible to all pathotypes. Rain occurred on 11 and 15 Aug when the forecasted risk for downy mildew on LI was moderate and low, respectively, at the forecast website. On 9 Sep symptoms were found on butternut squash and pumpkin. Cantaloupe were affected on 20 Sep.

Project funded by the USDA CSREES ipmPIPE Grant Program

SUSCEPTIBILITY TO DOWNY MILDEW OF SLICER AND PICKLING-TYPE CUCUMBER VARIETIES

Investigators: M. McGrath and G. Fox

Location: Long Island Horticultural Research and Extension Center

The main goal of this study was to evaluate select cucumber varieties that have exhibited relatively low susceptibility to downy mildew, compared to other varieties, in cucumber evaluations conducted at North Carolina State University since 2005. The evaluation was conducted as a component of an integrated management program for organically-produced cucumber by regularly applying an OMRI-listed botanical oil plus a copper fungicide. The oil used was Organocide, which has 5% sesame oil. An integrated approach was taken because cucumber varieties bred with resistance to pathogen strains present before 2004 are recognized as no longer providing sufficient suppression of downy mildew to achieve adequate control without also applying fungicides. Two adjacent experiments were conducted with the two cucumber variety types.

Cucumber was seeded on 11 Aug and transplanted on 22 Aug into bare-ground. A late planting date was used to increase the likelihood of downy mildew developing during the experiment. Organic fertilizers were used. Organocide at 1 oz/gal + Kocide 3000 at 1 lb/A were applied approximately weekly for 7 weeks beginning on 9 Sep, before symptoms were seen, using a tractor-mounted boom sprayer operated at 100 psi and 96 gal/A (D5-25 hollow cone nozzles spaced 17 in. apart). Downy mildew severity was assessed on 2 and 9 Oct by estimating incidence of symptomatic leaves and then rating average severity on the affected leaves. These measurements were used to estimate canopy severity.

Downy mildew symptoms were first seen on 22 Sep, which was 4 days after the third application, 8 days after the end of a 3-day rain period (1.03 inch on 12-14 Sep), and 10 days before the first rating date. Conditions for downy mildew development were favorable because of rain and long, heavy dew periods, in particular a 4-day rain period from 26-29 Sep during which 3.95 inches of rain fell. Temperatures were unusually cool during fall 2008, thus few fruit developed and the experiment was terminated due to poor plant growth.

Among the pickling-type varieties, Straight Eight was significantly more severely affected by downy mildew than the other varieties (Calypso, Feisty, Jackson Classic, Wainwright Classic, and Sassy). Straight Eight is an old variety with no genes for resistance to downy mildew. The other five varieties evaluated were bred to have resistance to the pathogen strains that dominated the pathogen population before 2004. This resistance is a common feature of modern varieties. It provided a very high degree of control, near immunity, to the old pathogen strains. No difference in downy mildew suppression was detected among the other varieties. Calypso and Feisty have generally exhibited better suppression than other varieties in several evaluations conducted at North Carolina State University since 2005. This experiment has documented that the old resistance still provides some suppression of downy mildew. Control was 84-94% based on canopy severity compared to Straight Eight. This high level of control likely is partly due to greater efficacy of fungicides when applied to resistant varieties.

No significant differences were detected among the slicer cultivars evaluated, all of which have resistance to the old pathogen strains. No significant differences were detected among the varieties in downy mildew incidence or severity. On 9 Oct the incidence of leaves with symptoms was 34-51% and the severity of downy mildew symptoms on these leaves was 5-15%. Dasher II, Poinsett 76, and Stonewall were less severely affected by downy mildew than Marketmore 76 in several evaluations conducted at North Carolina State University since 2005.

General Lee, a variety commonly grown on Long Island, was also tested. And there were two experimental varieties.

Project funded by the Friends of Long Island Horticulture Grant Program

EFFICACY OF FUNGICIDES FOR MANAGING DOWNY MILDEW IN ORGANICALLY-PRODUCED CUCUMBER

Investigators: M. McGrath and G. Fox

Location: Long Island Horticultural Research and Extension Center

The goal of this study was to evaluate fungicides approved for organic production using a cucumber variety (Dasher II) that has exhibited relatively low susceptibility to downy mildew compared to other varieties in cucumber evaluations conducted in NC since 2005. This integrated approach was taken because downy mildew is considered a difficult disease to manage organically.

Cucumber was seeded on 11 Aug and transplanted on 25 Aug into bare-ground. A late planting date was used to increase the likelihood of downy mildew developing during the experiment. Organic fertilizers were used. Fungicides were applied weekly for 5 weeks beginning on 9-10 Sep, before symptoms were seen, using a backpack CO₂-pressurized sprayer. The first application was reapplied on 10 Sep because an unexpected heavy rain shower occurred shortly after the treatments were applied on 9 Sep. The products tested included Nu-Cop 50DF at 2 lb/A. Copper is considered an organic standard for downy mildew. Sporatec AG is 18% rosemary oil, 10% clove oil, and 10% thyme oil. It was tested at 2 pt/A. Actinovate AG contains *Streptomyces lydicus*. It was applied at 12 oz/A with the adjuvant Biolink at 4 pt/100 gal. The fourth product tested, Taegro, is not labeled for this use yet and is the only product tested that is not yet OMRI-listed. Downy mildew severity was assessed on 2 and 9 Oct by estimating incidence of symptomatic leaves and then rating average severity on the affected leaves. These measurements were used to estimate canopy severity.

Downy mildew symptoms were first seen on 22 Sep, 12 days after the first application and 7 days after 3 days of rain. Favorable conditions for downy mildew development were provided by rain and long, heavy dew periods. Rain fell over 4 days starting with 3 inches on 27 Sep. All treatments provided some control based on incidence on 2 Oct. Degree of control was 21% to 46%. Sporatec was not effective based on severity on affected leaves. No significant differences were detected among treatments on 9 Oct, but values were highest for the non-treated control plants.

Project funded by the Friends of Long Island Horticulture Grant Program

EFFICACY OF BIOPESTICIDES FOR MANAGING FOLIAR DISEASES IN ORGANICALLY-PRODUCED TOMATO

Investigators: M. McGrath and G. Fox

Location: Long Island Horticultural Research and Extension Center

The objective of this study was to evaluate for foliar diseases in tomato fungicides that are approved for organic production and are defined as biopesticides by EPA. The products were Actinovate SP (0.0371% *Streptomyces lydicus*), Companion (0.03% *Bacillus subtilis* GB03), MOI-106 (5% extract of *Reynoutria sachalinensis*), Organocide (5% sesame oil), Sporatec AG (18% rosemary oil, 10% clove oil, and 10% thyme oil), and Taegro (*Bacillus subtilis* var. *amyloliquefaciens* strain FZB24 24.5%). Taegro is the only product tested that is not labeled for foliar diseases in tomato and not yet OMRI-listed. BioLink, an organic surfactant and penetrant, was applied with Actinovate and with Sporatec. Sporatec was also tested tank-mixed with Saf-T-Side, an OMRI-listed spray oil emulsion with 80% petroleum oil that is labeled for use as a fungicide, insecticide, and miticide. Treatments with biopesticides were compared to a nontreated control and also an organic standard consisting of copper fungicide applied weekly and a conventional fungicide

program. Kocide 3000 was selected for the copper fungicide because it was anticipated that in the future it would be listed again by OMRI.

Seedlings were no-till transplanted on 1 Jul into straw mulch from spring-planted triticale. Flail chopping did not kill the triticale as expected based on success with rye plus hairy vetch used for mulch in previous experiments, therefore the herbicide Roundup was applied on 26 Jun. The field was fertilized with Pro-Grow 5-3-4 organic fertilizer at 1000 lb/A (which provided 50 lb N/A) before seeding the triticale at 125 lb/A on 15 April. Fish emulsion (Neptune's Harvest Benefits of Fish 2-4-1) was put in the transplant hole before setting the seedlings. Pro-Grow organic fertilizer at 1000 lb/A was banded across the row at planting. Drip tape was laid next to each row. Additional straw mulch was spread around plants. Plants were staked and trellised following standard procedure for fresh-market tomato production. Most treatment applications were made using a CO₂-pressurized backpack sprayer with a boom that has a single twin-jet 110-degree nozzle that delivered 74 gpa at 50 psi. Each side of the planted row was treated with the boom held sideways to obtain thorough coverage of foliage. Applications were made weekly beginning on 21 Jul for the conventional fungicide program and on 20-21 Aug for most of the other treatments, which was before diseases were expected to begin developing based on crop physiology. The conventional program was started earlier following the guidelines for Actigard for bacterial speck management. It was not a true standard because Actigard was inadvertently continued in the alternation program through the marketable fruit production period, for which this product is not labeled. Disease incidence, severity and defoliation were assessed for the major diseases that developed. Incidence was assessed as the proportion of leaflets with symptoms. Severity was assessed for symptomatic leaflets only. Severity for the entire canopy was calculated by multiplying the average symptomatic leaflet severity value by incidence. Tomato fruit were not harvested due to the anticipated confounding effect on yield of variable damage among plots that occurred during unusual severe storms in 2008.

Conditions were not ideal for tomato production in 2008 with several severe rainstorms that included hail and strong winds as well as heavy rain. Diseases developed naturally in the research field. Symptoms were not seen until around the time that the first ripe fruit were seen, which was 9 Sep. The third or fourth application was made for each of the biopesticide treatments on 10 Sep. Dates of first observations were 10 Sep for powdery mildew, 15 Sep for Septoria leaf spot and 3 Oct for late blight. All treatments provided some suppression of powdery mildew. Septoria leaf spot became more severe, with incidence and severity being numerically higher than for powdery mildew on nontreated plants, and degree of control was not as high as that obtained for powdery mildew, even with the standard organic fungicide. Based on degree of control calculated from canopy severity at the 6 Oct assessment, Taegro was moderately effective for powdery mildew (56% control) but ineffective for Septoria leaf spot. Actinovate was moderately effective for powdery mildew (75% control) and for Septoria leaf spot (58%). Companion provided 98% control of powdery mildew and 68% control of Septoria leaf spot. MOI-106 also provided excellent suppression of powdery mildew (100%) and moderate control of Septoria leaf spot (61%). Level of control of Septoria leaf spot was significantly better when MOI-106 was applied in alternation with Kocide 3000 rather than used every week (94% control). Organocide also provided excellent suppression of powdery mildew (99%) and moderate control of Septoria leaf spot (54%). Level of control of Septoria leaf spot was significantly better (95%) when Organocide was applied at half the rate tank-mixed with Kocide 3000 at the lowest labeled rate. Sporatec AG applied with the surfactant BioLink controlled powdery mildew but not Septoria leaf spot. However, excellent control of both diseases (97% and 100%) was obtained when Sporatec was mixed with Saf-T-Side. Degree of control of both diseases obtained with MOI-106 alternated with Kocide, Organocide plus Kocide (at low rates), and Sporatec plus Saf-T-Side was not significantly different from the organic standard or the conventional fungicide program. Degree of disease control was related to the amount of subsequent defoliation. Taegro was the only product tested that did not provide sufficient control of foliar diseases to decrease defoliation compared to non-treated plants.

Cost per application for the treatments tested were \$9.70/A for Kocide 3000 used alone, \$36.52/A for the conventional fungicide program and ranged from \$17.67/A to \$71.25/A for the biopesticide treatments (excluding the high rate of Companion which was not more effective than the lower rate tested).

This experiment needs to be repeated to assess efficacy under more severe disease pressure.

Project funded by the USDA IR-4 Biopesticide Grant Program

OZONE CONCENTRATIONS IN RIVERHEAD IN 2008

Investigators: M. McGrath and G. Fox

Location: Long Island Horticultural Research and Extension Center

Ozone reached sufficiently high levels to cause acute, visible injury to leaves of sensitive crops in 2008 on Long Island. Ozone also causes sensitive plants to senesce prematurely. Concentration was ≥ 80 ppb for at least 57 hours on 20 days in 2008: 3 Jun (1 hours), 7 Jun (2), 8 Jun (1), 9 Jun (5), 10 Jun (6), 14 Jun (3), 28 Jun (2), 3 Jul (1), 4 Jul (1), 15 Jul (2), 16 Jul (4), 17 Jul (5), 18 Jul (6), 19 Jul (5), 21 Jul (4), 30 Jul (2), 31 Jul (3), 6 Aug (1), 18 Aug (1), and 4 Sep (2). Ozone was at least 50 ppb on 818 hours on 95 days and at least 60 ppb on 343 hours on 56 days. The highest concentrations in 2008 (120-1288 ppb) occurred on 18 and 19 Jul. The ozone monitor was not working for 10 days in 2008, in particular 23-30 July when ozone could have reached high levels. Typically high concentrations occurred between 1200 and 2200, as in previous years. Ozone was ≥ 80 ppb for 60, 124, 121, 184, 77, at least 67, 94, 40, at least 10, 95, 65, 47, and 57 hrs in 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, and 2008 respectively.

ASSESSMENT OF OZONE CONCENTRATIONS IN RIVERHEAD USING A CLOVER BIOINDICATOR SYSTEM

Investigators: M. McGrath and G. Fox

Location: Long Island Horticultural Research and Extension Center

An ozone-sensitive clone and an ozone-resistant clone of the commercial white clover line 'Regal' were used to estimate the concentrations of ambient ozone and its effects on plants. These clones were selected because they have similar growth rates in the absence of ozone stress. This system is being used in other locations throughout the world. Cuttings were planted in 1-liter pots on 18 Mar and then transplanted to 15-liter pots on 21 May. Clover was harvested every 4-5 weeks for a total of four harvests. Cutting was done at 7 cm above the soil surface. Both wet and dry weights of harvested forage (leaves, stems, and flowers) were measured.

The forage dry weight ratios (sensitive/resistant) were 1.08, 0.82, 0.72, and 0.78 for tissue harvested from clover on 26 Jun, 29 Jul, 28 Aug, and 8 Oct, respectively. Dry weights of the two clones differed significantly at the third harvest and were very close to significant ($P=0.051$) at the second harvest. Similar growth during the first period documents that the two grow similarly. Ozone exposure during these growth periods expressed as AOT40 (accumulated ozone dose over the threshold of 40 ppb between 7 am and 7 pm) was 3707, 6050, 5620, and 941 ppb.h, respectively. Ozone exposure was highest during the second growth period; however, ozone injury was most severe during the last period, especially in the sensitive clone. The highest ozone episode recorded in 2008 occurred on 18 Jul, 10 days before the second harvest; concentration was at least 60 ppm for 13 hours peaking at 168 ppb.

ASSESSMENT OF AMBIENT OZONE IMPACT ON PLANT PRODUCTIVITY USING A SNAP BEAN BIOINDICATOR SYSTEM

Investigators: M. McGrath and G. Fox

Location: Long Island Horticultural Research and Extension Center

Research on ozone-sensitive and ozone-resistant snap bean lines was continued in 2007 using field-grown plants. The lines, sensitive S156 and resistant (tolerant) R331, were developed at the USDA-ARS Air Quality Research Unit in Raleigh, NC, to be used to investigate the impact of ambient ozone (O₃) on plant productivity. These lines yield similarly under low ozone concentrations. There were 3 successive field plantings to be able to assess the impact of ambient

ozone occurring throughout the growing season. Seed were inoculated with Rhizobia then sown by hand with 2 seeds placed every 9 inches, then thinned to 30 plants per plot in a row with 4 replications. Drip tape was laid next to each row for irrigation. Bean pods were harvested when immature for fresh-market consumption from half the plants repeatedly as they developed. Bean pods were harvested when seed were mature from the rest of the plants. Plants were examined routinely for ozone injury. Injury and defoliation due mainly to ozone injury were rated. Ozone concentration data were obtained from a monitor maintained at LIHREC by the DEC Air Quality Division. The hourly values were used to calculate ozone exposure expressed as AOT40 (accumulated ozone dose over the threshold of 40 ppb between 7 am and 7 pm). AOT40 is a commonly used measure of ozone exposure.

The O₃-sensitive snap bean line S156 yielded less than the tolerant line R331 when grown under ambient O₃ conditions on Long Island in 2008. Reduction was greatest for the second planting when ozone concentrations were greatest. Total weight of bean pods harvested for fresh-market consumption from planting 1 (14 May) plants was 11% lower for S156 compared to R331 (pods were harvested from 2 July through 6 Aug). However, this difference was not significant. Total number of bean pods harvested per plant was the same for the two lines. There was a 62% and 38% reduction in total weight and number of pods, respectively, for planting 2 (12 June) plants (harvested from 31 July through 5 Sept). This was the greatest reduction in these yield variables recorded since 1999 when this project was started. Impact of ozone exposure on yield was lowest at the first harvest (31 July). Reduction was 25% and 18%, respectively, for planting 3 (14 July) plants (harvested from 3 Sept through 6 Oct).

From emergence until 77 days after planting, which was about a week before the last fresh-market pod harvest, plants in the three plantings were exposed to O₃ that was at least 40 ppb for more* than 839, 803, and 443 hours, respectively (*ozone monitor was not working 23 - 30 July; all 3 plantings were present during this period). During these growth periods, O₃ exposure expressed as AOT40 was 10,724 ppb.h, 9,718 ppb.h, and 4,139 ppb.h, respectively. These values greatly exceed the long-term critical level of ozone exposure for crops of 3000 ppb.h accumulated over three months. These AOT40 values for the 3 bean plantings are not closely related to the level of yield reduction in the sensitive bean line compared to the tolerant line. This documents the need for a more detailed examination of O₃ exposure, which is the goal of a national research team involved with this project. This data from LI contributes to the database of plant response to ambient O₃. An extensive set of data from multiple locations, environmental conditions, and O₃ concentrations is needed in order to model O₃ impact on plant productivity.

Very severe injury due to O₃ was observed in the second planting on 25 July, which was 6 days before the first harvest of fresh market pods. The week before there was an extended period with extremely high O₃ concentrations: O₃ exceeded 80 ppb on 6 of 7 days during 15 - 21 July with hourly average reaching 120 -128 ppb three times. This exposure caused acute injury that had much greater impact on yield than the chronic exposure described by the AOT40 value. On 3 Aug many of the severely injured leaves were dried up and some had dropped.

EVALUATION OF REDUCED TILLAGE PRODUCTION SYSTEM WITH CONVENTIONAL AND CONTROLLED RELEASE FERTILIZER FOR PUMPKIN

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Location: Long Island Horticultural Research and Extension Center

Fine-tuning the weed management program and testing a fertilizer program with controlled release fertilizer were the goals of research on reduced-till pumpkin production in 2008. Inadequate weed control has been the main challenge to successful reduced-till pumpkin production in previous experiments conducted at LIHREC (Long Island Horticultural Research & Extension Center). A modified herbicide program was used in 2008. Half of the reduced-till and half the conventional-till plots received controlled release fertilizer while the other plots received conventional, soluble fertilizer as in past experiments. This objective was identified as a priority to examine because of the escalating interest in this type of fertilizer to reduce the potential for contaminating ground-water with leached conventional fertilizer, an especially important issue

on Long Island, and to provide fertilizer as needed during the growing season without side-dressing.

The experiment was conducted in a research block that has been dedicated to reduced tillage research since 2004. This 1.7A field has 4 pairs of conventional and reduced tillage plots that run the 300-ft length of the field. In Oct 2007, the field was mowed to remove weeds and break-up remaining pumpkin fruit and corn stalks from that year's crops, conventional-till plots were disked twice, then the whole field was seeded to rye at 4.5 bu/A using a non-till seeder.

Conventional-till strip-plot preparation. On 1 May 2008 the conventional-till plots were subsoiled. Rye was flail chopped on 26 May, which is when rye was rolled in the adjacent reduced-till plots, and again on 10 June. Some of the rye straw was removed from the conventional-till plots by using a Robe Werk cultivator to drag straw to the field end. The plots were roto-tilled on 11 June to incorporate the remaining rye straw and to prepare the soil for seeding. Plots in replications 1 and 3 received conventional fertilizer: before seeding 10-10-10 fertilizer at 250 lb/A (25 lb/A N) was broadcast and incorporated by disking, then 500 lb/A 10-10-10 fertilizer was applied with the seeder. Plots in replications 2 and 4 received controlled release fertilizer: 750 lb/A 10-10-12 controlled release fertilizer was applied with the seeder.

Reduced-till strip-plot preparation. On 26 May, rye was rolled twice with a coulter packer in the reduced-till. Round-up WeatherMax (22 oz/A) was applied on 3 June. On 26 June a 2-row Unverferth zone builder was used to prepare and fertilize rows in the reduced-till plots. For each row this piece of equipment has a 20-inch coulter to open the row, shank to disrupt plow pans and create compression fissures between the shanks and 2 17-inch wavy coulters followed by a 15-inch wide rolling basket to prepare the soil for planting. Rows were at 68-in spacing. Soil was in larger clumps after 1 pass with the zone builder than in past years, perhaps due to the soil being moister than ideal for this process, but with field preparation already delayed by rain and rain forecast it was decided this was the best time to prepare the beds. The zone builder was run twice through the field to create a smoother seed bed. Liquid fertilizer was applied during the second pass to the conventional fertilizer plots. The Unverferth is set-up to inject liquid fertilizer at about 4-inch depth through a nozzle placed on the back of each shank. was used to inject 25.5 gpa of liquid 9-18-9 fertilizer (= 25 lb/A N). 500 lb/A 10-10-10 fertilizer was applied with the seeder. The controlled release fertilizer plots received 750 lb/A 10-10-12 applied with the seeder.

'Gargoyle' pumpkin variety was used for all plots. It was too windy to apply herbicide immediately after seeding on 2 July. On 3 July Strategy (3 pt/A), Sandea (0.5 oz/A), plus RoundUp WeatherMAX (32 oz/A) were applied across the entire plot. In the past Sandea was not applied before pumpkins had emerged and Strategy was applied at a lower rate (2 pt/treated A) in a 36-inch band over the planted row. It was not possible to irrigate the field immediately after treatment to activate the Strategy, but rain fell the next day (0.22 in.). The entire field was overhead irrigated when dry throughout the season. Pumpkins were harvested on 15 Oct from two rows in a 40-ft section of each plot. Marketable fruit were counted and weighed. Green and rotten fruit were counted.

Weed control was better in 2008, especially in the reduced tillage plots, than in previous years. Effectively controlling weeds in reduced-till pumpkins with Strategy is challenging because, as stated on the label, plant residue, existing weeds and cloddy soil conditions interfere with performance of this herbicide. Poor control in past years with Strategy was also likely due to there being no water, as irrigation or rain, shortly after the application was made. Any weeds that germinate before water activated Strategy would not be affected by this herbicide. In addition to using the highest label rate of Strategy in 2008, the spectrum of weed control achievable with Strategy was augmented by also applying Sandea and RoundUp.

Grubs were found feeding on the ground-side of a high percentage of fruit in both the conventional and reduced-till plots. There were both oriental beetle grubs and Asiatic garden beetle grubs. Adult beetles may have been attracted to the field because of the quantity of organic matter plus the permanent driveways between each replication. A few slugs were also seen.