Final Project Report to the NYS IPM Program, Agricultural IPM 2003 – 2004

Title:

Developing a Management Program for Powdery Mildew in Winter Squashes with Resistant Varieties

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Pest-resistant crops; allelopaths

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Abstract:

Powdery mildew is an important disease of winter squash and other cucurbit crops. It occurs throughout New York every year. Management is usually needed to avoid a reduction in yield. Application of fungicides has been the main practice. Several winter squash varieties with resistance to powdery mildew are now commercially available. The source of this gene for resistance is Cornell's Department of Plant Breeding. Growers need to know how well these resistant varieties perform compared to horticulturally-similar, fungicide-treated susceptible varieties, and whether there are benefits to an integrated program with reduced fungicide inputs (fungicides applied every 14 days compared to the standard 7-day interval). Two experiments were conducted to evaluate acorn and butternut squashes. Growing varieties with resistance to powdery mildew was shown to be an effective and economic means to manage powdery mildew. Powdery mildew was managed better with chemical control than with heterozygous-based genetic control (resistance from one parent): fungicide-treated susceptible Taybelle had less powdery mildew than non-treated resistant Taybelle PM. However, homozygous-based genetic control (resistance from both parents) was more effective than chemical control: non-treated resistant Autumn Delight and resistant Bugle had less powdery mildew than fungicide-treated susceptible Table Ace and susceptible Waltham, respectively.

Efficacy of chemical control, however, was likely compromised by the presence of pathogen strains that were resistance to the two main groups of systemic fungicides used. Resistance to QoI fungicides was very common when assessed on 31 Aug, one month after fungicide applications were started on the susceptible varieties, and most of the pathogen population also was moderately insensitive to DMI fungicides. Control of powdery mildew was improved significantly by applying fungicides to the resistant acorn squash varieties but not to the resistant butternut variety. Regardless of disease control benefit, an integrated program is recommended to reduce selection pressure for new races of the pathogen able to overcome the resistance in these varieties and for new strains of the pathogen that are able to tolerate the fungicides. A reduced-sprays fungicide program with a 14-day spray interval was as effective as the conventional program with a 7-day interval when applied to resistant varieties but not when applied to susceptible varieties. The greater cost of seed of Bugle, $48.50/lb versus $15.15/lb for Waltham, is offset by the additional fungicide applications needed to affectively control powdery mildew in Waltham. It will cost about $16 more to grow an acre of Waltham sprayed seven times than an acre of Bugle sprayed thrice. Although seed of Taybelle PM and Autumn Delight is priced slightly higher than seed of Taybelle and Table Ace, overall production costs are lower because of the cost difference between a 7- and 14-day fungicide program and because fungicide treatment is needed earlier in susceptible varieties. It will cost about $109 less to grow an acre of Autumn Delight sprayed thrice compared to Table Ace sprayed seven times and $131 less for Taybelle PM compared to Taybelle. The resistant varieties evaluated are commercially available, thus growers can implement an integrated program (fungicides applied on a reduced schedule) for managing powdery mildew now.

Background and justification:

Powdery mildew is one of the most important diseases of cucurbit crops. It occurs throughout New York every year. Management practices usually must be implemented to avoid a reduction in yield. Application of fungicides is presently the principal practice for managing powdery mildew in most cucurbit crops, except for cucumber and muskmelon, for which there are several commercially available varieties with resistance. The cucurbit powdery mildew fungus has demonstrated ability to develop resistance to fungicides (1), thus efficacy of fungicides can be compromised. A few varieties of summer squash and pumpkin with resistance have been available for a few years.

Several winter squash types with resistance to powdery mildew have very recently become commercially available. Three of these powdery mildew resistant (PMR) varieties were developed by Molly Jahn in Cornell's Department of Plant Breeding. Others are expected to be released soon. This resistance has been provided to private plant breeders who have also developed PMR varieties. One of these breeders is Bill Johnson at Seminis Vegetable Seeds who provided acorn squash for experiments conducted in 2002. There is a single gene source of resistance in squash and pumpkin that is codominant. Thus a higher level of resistance is obtained when both parents carry the resistance allele. There are also believed to be several modifier genes. Consequently, PMR varieties exhibit two levels of resistance, moderate and high, with some variation among varieties.

Evaluation of resistant varieties and implementing recommendations for these varieties are considered high priorities for research and implementation projects for cucurbits by the IPM Vegetable Working Group. Growers need to know how well these PMR varieties perform compared to horticulturally-similar varieties treated with fungicides, which is the current management program. Growers also need guidelines on the fungicide program to use with the PMR varieties.

Two experiments were conducted in 2002 to evaluate acorn and butternut squashes (2, 3). This work was funded by the NYS IPM Grant Program. Growing varieties with resistance to powdery mildew was shown to be an effective and economic means to manage powdery mildew. Control of powdery mildew obtained with the resistant varieties was not improved significantly by applying fungicides. Although also not significant, there was a trend toward improved yield with fungicide treatment (more fruit, greater fruit weight, and higher sucrose content). Regardless of disease control benefit, an integrated program is recommended to reduce selection pressure for new races of the pathogen able to overcome the resistance in these varieties and for new strains of the pathogen that are able to tolerate the fungicides. The powdery mildew fungus has an established track record of developing new races and strains. A reduced-sprays fungicide program with a 14-day spray interval was as effective as the conventional program with a 7-day interval when applied to a resistant variety but not when applied to a susceptible variety.

Growing varieties with resistance to powdery mildew is an effective and economic means to manage powdery mildew. Cost of seed for the resistant acorn squash varieties tested in 2002 is only slightly more than that of comparable susceptible varieties. Cost of 1M seed from Siegers is $15.31 for Taybelle and $17.45 for Taybelle PM, an increase of $2.14 (= 14%), and $15.30 for Table Ace and $20.15 for Autumn Delight, an increase of $4.85 (= 32%). Cost of the fungicides applied was $79.80/A for the two applications made to the resistant varieties and $196.29/A for the five applications to the susceptible varieties.

Interest in growing resistant varieties of cucurbit crops is expected to grow not only because of the economics and reduced need for fungicides, but also because control with fungicides is declining due to fungicide resistance. Resistance to the QoI type fungicides was detected in 2002 in New York and elsewhere in the United States. Resistance was associated with control failure because the type of resistance is qualitative (pathogen strains are either sensitive or fully resistant).

The goal of the 2003 project was to repeat experiments conducted in 2002 to confirm those results.

Objectives:

1. Evaluate PMR varieties of butternut and acorn type winter squash with moderate and high levels of resistance and determine if fungicide treatment is warranted.
2. Evaluate project results.

Procedures:

1. Two experiments were conducted with butternut and acorn type winter squash at the Long Island Horticultural Research and Extension Center. Varieties and fungicide treatments evaluated are listed in Tables 1 and 2. For the butternut squash experiment, Bugle, a homozygous PMR variety developed by the Cornell Plant Breeding program was compared to the standard susceptible variety, Waltham. Three dark green PMR acorn varieties were included in the second experiment, plus two susceptible varieties for comparison. Taybelle PM is heterozygous for PMR (1 parent with PMR) and is horticulturally similar to susceptible Taybelle. Autumn Delight is homozygous for PMR (both parents have PMR) and compares to susceptible Table Ace. Seed of these four varieties were obtained from Seminis Vegetable Seeds. A homozygous resistant experimental line from Seminis, 10605, was also evaluated.

Fertilizer (666 lb/A of 15-15-15) was broadcast and incorporated during spring.

Seeding of the butternut type winter squash varieties was done in the greenhouse on 29 May. Waltham was reseeded on 10 Jun due to poor germination. Seedlings were transplanted into black plastic mulch with drip irrigation on 24 Jun. Symptoms were first observed on the susceptible variety on 29 Jul and in most plots of the resistant variety on 14 Aug. Fungicide applications were started within two days of detection.

Transplants of the acorn type winter squash varieties were seeded in the greenhouse on 27 May and planted into bare ground on 27 Jun with starter fertilizer (15-30-15) at 24-in. plant spacing and 68-in. row spacing. Plots contained a total of 9 plants in three rows of 3 plants each. There was 10 ft between plots. Weeds were controlled by cultivation and hand weeding. Symptoms were first observed on the susceptible varieties on 31 Jul and on the resistant varieties on 14 Aug. Fungicide applications were started the day of detection.

To manage Phytophthora fruit and crown rot (*Phytophthora capsici*), Phostrol (2.5-5 pt/A) was applied on 26 Jul; 6, 13, 20, and 28 Aug; and 7 Sep.

Upper and lower surfaces of 15 to 50 leaves in each plot were examined approximately weekly for powdery mildew beginning in late July when fruit were starting to enlarge. Initially, 50 older leaves were examined in each plot. The examined leaves were selected from the oldest third of the foliage based on leaf appearance and position in the canopy. As disease progressed, the number of leaves examined was adjusted based on the incidence of affected leaves in a plot, and mid-aged and young leaves were also examined. Powdery mildew colonies were counted; severity was assessed when colonies could not be counted accurately because they had coalesced and/or were too numerous. Average severity for the entire canopy was calculated from the individual leaf assessments.

All treatments were initiated after the IPM threshold of one leaf of 50 old leaves examined with powdery mildew symptoms was reached in most plots of each variety. This threshold was shown previously to be as effective as using a preventive schedule (3). Symptoms were first observed on susceptible varieties on 29 or 31 Jul and in most plots of the resistant varieties on 14 Aug; thus fungicides were applied to resistant varieties starting 2 weeks after susceptible varieties. Fungicide applications were started within two days of detection. Applications were made weekly in both experiments (31 Jul; 7, 14, 20, and 26 Aug; and 6 and 17 Sep) with a tractor-mounted boom sprayer equipped with D5-25 hollow cone nozzles spaced 17 in. apart that delivered 110 gpa at 100 psi. The last two applications were delayed by rainy weather. The fungicide program was Flint (2 oz/A) plus Bravo (2.7 lb/A) applied in alternation with Procure (6 oz/A) plus Microthiol Disperss (sulfur)(4 lb/A) then Microthiol Disperss applied alone the last week. Defoliation, which was mostly due to powdery mildew, was assessed several times from late August through September.

A fungicide sensitivity seedling bioassay was conducted in the butternut winter squash field as part of another IPM project, 'Providing Growers Local Information on QoI Fungicide Resistance to Guide Fungicide Selection for Cucurbit Powdery Mildew'. Summer squash seedlings were dipped in solutions of Flint and/or Nova, then after they had dried they were placed out in the research field with nontreated seedlings for one day. Flint is a QoI fungicide. Nova is a DMI fungicide similar to Procure. They were kept in a greenhouse until symptoms developed, which took at least 7 days. This bioassay was conducted 31 Aug. Another bioassay was conducted on 27 Jul in a nearby experiment where powdery mildew started to develop earlier than in the winter squash experiments.

Representative samples of 10 ripe fruit were harvested from each plot in the acorn type winter squash experiment and weighed on 1 and 14 Oct, remaining fruit were counted. Representative samples of 6 ripe fruit were harvested from each plot in the butternut type winter squash and weighed on 29 Sep and 8 Oct, remaining fruit were counted. Percentage of sucrose was determined using a hand-held refractometer for two fruit per plot.

Differential melon genotypes were grown near the powdery mildew experiments to determine which races of the pathogen were present. Topmark is susceptible to all races. PMR-45 is resistant to race 1 and PMR-6 is resistant to races 1 and 2. Seedlings were transplanted into black plastic mulch on 11 Aug.

2. Project results were evaluated by statistically analyzing the data from the replicated experiments. Cost of controlling powdery mildew with the various variety/fungicide treatments was calculated. A presentation was made at the 2003 NYS Vegetable Conference on the 2002 results. An update will be given at the 2004 Conference. A news article will be distributed and results will be posted with photographs at the vegetablemdonline web site. A Twilight meeting was held in early September so that growers could see the level of disease control at the end of the season and examine the fruit.

Results and discussion:

Powdery Mildew Races

Powdery mildew was first observed on the differential melon genotypes on 29 Aug. Symptoms developed on both Topmark and PMR-45, but not on PMR-6; therefore, both race 1 and race 2, but not race 3, occurred in 2003. Similar results were obtained in previous years.

Butternut Squash

On the susceptible variety Waltham, powdery mildew was controlled more effectively with a standard fungicide program (7-day spray interval) than with a reduced fungicide program (14-day interval)(Table 1). Both fungicide programs were equally effective at reducing defoliation. Severity was similar on Waltham that received 7 fungicide applications as on the non-fungicide-treated powdery mildew resistant (PMR) variety Bugle. Defoliation, however, was significantly lower for Bugle on 4 and 15 Sep indicating that genetic control might have been more effective than chemical control. Powdery mildew causes leaves to senesce prematurely.

Efficacy of chemical control was likely compromised by fungicide resistance. The fungicide sensitivity bioassay revealed that resistance to QoI fungicides was very common (estimated frequency of 100%) and most of the pathogen population (54%) also was moderately insensitive to DMI fungicides on 31 Aug. This was a large change from the results of the previous bioassay conducted in a nearby experiment on 27 Jul. No powdery mildew developed on the Flint-treated seedlings, indicating that resistance to QoI fungicides was 0% or below detection. Proportion of the population moderately insensitive to DMI fungicides was estimated to be 16%. Control of powdery mildew on Bugle was not improved significantly by applying fungicides. A reduced fungicide program, however, could function to delay selection of a new pathogenic race able to overcome this resistance.

Applying fungicides to control powdery mildew did not affect yield significantly for either variety. Fungicide treatment did not affect size, quantity, or sucrose content of fruit produced. Bugle produced significantly smaller fruit than Waltham (1.8 vs 2.9 lb) but more fruit/plant (7.7 vs 5.6); consequently, total fruit weight did not vary significantly between them (13.7 versus

16.2 lb mature fruit/plant). The greater cost of seed of Bugle, $48.50/lb versus $15.15/lb for Waltham, is offset by the additional fungicide applications needed to affectively control powdery mildew in Waltham. It will cost about $16 more to grow an acre of Waltham sprayed seven times than an acre of Bugle sprayed thrice.

ACORN SQUASH

Fungicides suppressed powdery mildew through 26 Aug, then control declined, especially on the lower surface of the susceptible varieties, most likely due to the development of fungicide resistance. On 9 Sep, the level of control obtained with weekly applications was 92% and 97% on the upper leaf surface for Taybelle and Table Ace, respectively, but only 43% and 48% on the lower surface of these leaves. This was a decline from control on the lower leaf surface of 87% and 79% on 26 Aug. Systemic fungicides provide most of the control on lower surfaces because protectant fungicides function where the spray is deposited, which is mostly upper surfaces. Good control on upper leaf surfaces indicates application timing was good. Resistance to the 2 types of systemic fungicides used for powdery mildew control was common on Long Island by the end of August, as revealed by the bioassay conducted in the butternut squash experiment and elsewhere on Long Island.

Powdery mildew was managed better with chemical control (fungicide-treated Taybelle) than with heterozygous-based genetic control (non-treated Taybelle PM) on upper surfaces of leaves (94% and 51% control based on AUDPC values), similar control was obtained on lower leaf surfaces (67% and 66% control). Numerically there was less defoliation with chemical control, but differences were not significant.

Powdery mildew was managed better with homozygous-based genetic control (non-treated Autumn Delight) than with chemical control (fungicide-treated Table Ace) based on severity on lower leaf surfaces (93% and 58% control); chemical control was better based on defoliation. Based on severity on 9 Sep, control of powdery mildew on upper leaf surfaces of PMR varieties was improved significantly by applying fungicides. Reduced fungicide program (14-day spray interval) was as effective as a standard program (7-day interval) when applied to resistant Taybelle PM. Reduced fungicide program applied to susceptible Table Ace was not as effective as a standard program based on severity on lower leaf surfaces on 9 Sep.

Controlling powdery mildew with resistant varieties and/or fungicides did not affect yield as much as in a parallel experiment conducted in 2002. Non-treated plants tended to produce fewer fruit and smaller fruit than fungicide-treated plants, but these differences were not significant. Fruit of 10605, Table Ace, and Autumn Delight tended to be smaller Taybelle (1.5 lb/fruit versus 1.7). Sucrose content of fruit, a measure of fruit quality, did not vary significantly among treatments or varieties. In conclusion, growing varieties with resistance to powdery mildew is an effective and economic means to manage powdery mildew. Although neither control of powdery mildew nor yield were improved significantly by applying fungicides to Taybelle PM, Autumn Delight, or 10605, there was a trend toward improvement. An integrated program with two applications on a 14-day schedule would reduce selection pressure for new races of the pathogen able to overcome host resistance or become less sensitive to fungicides. Although seed of Taybelle PM and Autumn Delight is priced slightly higher than seed of Taybelle and Table Ace, overall production costs are lower because of the cost difference between a 7- and 14-day fungicide program. It will cost about $109 less to grow an acre of Autumn Delight sprayed thrice compared to Table Ace sprayed seven times and $131 less for Taybelle PM compared to Taybelle.

The resistant varieties evaluated are commercially available, thus growers can implement an integrated program (fungicides applied on a reduced schedule) for managing powdery mildew now.

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