

Powdery Mildew Fungicide Insensitivity Evaluations on Pumpkin Leaves

Final report to Ohio Vegetable and Small Fruit Research and Development Program

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Introduction

Powdery mildew (*Podosphaera xanthii*) is a key pathogen on cucurbit crops not only in Ohio, but throughout the county. The spores of this pathogen do not overwinter in Ohio, but blow in on frontal weather systems predominantly from the southern region of the U.S. Over the past several years, this pathogen has exhibited quantitative resistance (control in response to increased rate) and qualitative resistance (loss of control independent of rate) based on the fungicide class used to control this disease. Over the past few years, anecdotal evidence from Ohio growers particularly in the northeast suggested specific compounds seemed to have lost their efficacy against powdery mildew. The basis for this project is to determine empirically which commonly used fungicides effectively control powdery mildew on susceptible and powdery mildew resistant pumpkin leaves, and which, if any have lost their effectiveness. Two types of experiments, one with fungicides rates below label rates to identify sensitive isolates and one using high labeled rates were conducted in parallel at two locations, Columbus and Wooster. Having a geographic spread of trials sites will allow the researchers to better ascertain and characterize the scope of the resistance issue.

Methods

Experiment 1: Below label rate powdery mildew sensitivity trial

Ten commonly used cucurbit fungicides (Nova, Pristine, Flint, Quadris, Cabrio, Pristine, Endura, Quintec, Topsin M, and Sulfur) were applied at below label rates to susceptible (Howden) and powdery mildew tolerant (Magician) pumpkin leaves to assess powdery mildew (PM) development (Table 1). Both Quintec and Endura are not labeled in Ohio for powdery mildew control on cucurbits

In a greenhouse at Columbus and Wooster, seeds of each hybrid were planted in 4" square pots filled with Metromix 360 on 21 July. There were four single plant replications of each treatment except for the three sites monitored in Columbus using Magician seedlings, which only had 3 replicates. When the seedlings at either location reached the second fully expanded leaf stage, fungicide treatments were applied with three sprays to the top surface of both the first and second leaf from a mister bottle, which had been calibrated at approximately 54 GPA. One day after the leaves were treated with fungicides in the greenhouse, they were transported via cargo van to pre-determined field locations. For the seedlings based at Columbus, they were transported to two sites in Greenford and one site in South Charleston on 7 August. For the seedlings based in Wooster, they were transported via cargo van to a nearby field in Wooster on 7 August. At each location, the seedlings were placed in pumpkin or zucchini fields to be exposed to powdery mildew spores at that location for 4-6 hours.

The field sites were either untreated for powdery mildew or had only one application to maximize spore exposure and limit selective pressure. After field exposure, the seedlings were returned to their respective greenhouse and monitored for PM colony development. In Columbus and Wooster, the first and second leaves were evaluated for PM colonies on 15, 18, and 22 August, which corresponds with 8, 11, and 15 days after field exposure. The last data reading was not taken on 22 August at Wooster.

Another trial based at Wooster was seeded 10 August, treated with fungicides in the greenhouse on 27 August, transported to Willard for field exposure to PM spores on 28 August, and evaluated in the greenhouse for PM colonies on 5, 8, and 12 September, which corresponds to 8, 11, and 15 days after field exposure.

Methods

Experiment 2: High label rate powdery mildew sensitivity trial

The second experiment was conducted at Columbus and Wooster using the same treatment protocol as first experiment, except the concentrations were increased to high label rates (Table 7). Each trial used 4 single plant replicates for each treatment. Both Howden and Magician hybrids were seeded in Wooster for the Willard site but in Columbus only Howden was grown for use at the South Charleston site. At Wooster, the study was seeded in the greenhouse on 8 August, treated with fungicides on 27 August, transported to Willard for exposure to PM spores on 28 August, then evaluated in the greenhouse for PM colonies on 5, 8, and 12 September, which corresponds to 8, 11, and 15 days after field exposure. At Columbus, the study was seeded in the greenhouse on 22 August, treated with fungicides on 4 September, transported to South Charleston for exposure to PM spores on 5 September, then evaluated in the greenhouse for PM colonies on 12, 15, and 19 September, which corresponds to 7, 10, and 14 days after field exposure.

Results

Experiment 1: Below label rate powdery mildew sensitivity trial

The Howden seedlings at the Greenford fairground site had significantly less disease on leaves treated with Quintec, Procure at both rates, Nova, Pristine, Endura and Quadris than the water treated check (Table 1). All treatments had statistically equivalent disease pressure on the leaves compared to the check when Magician seedlings were evaluated, although Microthiol Disperss and Cabrio had significantly more disease than the check (Table 1).

The Howden seedlings at the Greenford southern site had significantly less disease on leaves treated with Quintec, Nova, both rates of Procure, Pristine, and Endura compared to the water treated check (Table 2). The Magician seedlings at the Greenford southern site had significantly less disease on leaves treated with Quintec, Nova, and both rates of Procure compared to the water treated check (Table 2).

Both the Howden and Magician seedlings at the Western Agriculture Research Station (WARS) site had significantly less disease on leaves treated with Quintec, Nova, both rates of Procure, Pristine, and Endura compared with the water treated check (Table 3).

The Howden seedlings at the Wooster site had significantly less disease on leaves treated with Quintec, both rates of Procure, Nova, Pristine, and Endura compared with the water treated check (Table 4). At the same location using Magician seedlings, only Quintec had less disease pressure on the leaves compared to the water treated check, although Topsin M had significantly more disease than the check (Table 4).

The Howden seedlings at the Willard site had significantly less disease on leaves treated with Quintec and Pristine compared to the water treated check (Table 5). The Magician seedlings exposed to PM spores at the Willard site are represented as percent leaf colonies using the mean of leaves one and two at 8, 11, and 15 days after field exposure (Table 6). At the 15 day reading, Quintec, Endura, Pristine, Microthiol Disperss, and Topsin M averaged slightly lower disease pressure on their leaves compared to the untreated check.

In the trials based out of Columbus (sites Greenford fairgrounds, Greenford southern, and WARS) Quintec, Nova, Procure, Pristine, and Endura all performed significantly better at reducing pm colonies on Howden leaves at all three sites compared to the water treated check. In addition, at the Greenford fairground site only, Quadris also performed better than the check. In those same trials looking at Magician seedlings, only Quintec, Nova, and both rates of Procure performed better than the check at the Greenford southern and WARS location.

In trials based out of Wooster (sites Wooster and Willard) only Quintec and Pristine had consistently lower disease pressure on Howden leaves compared to the water only treated check. For Magician seedlings at both these locations, only Quintec performed significantly better than the water treated check. When comparing treatments by hybrid type, 69% of the time there is a decrease in the amount of disease recorded when comparing Howden (pm susceptible) to Magician (pm tolerant).

Table 1. Area under the disease progress curve (AUDPC) of powdery mildew colony development using the mean of first and second leaves of Howden and Magician pumpkin seedlings exposed to spores at the Greenford fairground site. Observations made in a Columbus greenhouse from 6 August to 22 August.

Treatment	AUDPC			
	Howden ^a		Magician ^a	
Quintec 10 ppm	1.4	D	1.2	D
Procure 480SC 120 ppm	2.1	D	3.6	D
Nova 40W 120 ppm	3.4	D	2.2	D
Procure 480SC 80 ppm	4.9	D	3.8	D
Pristine 50 ppm	16.7	DC	9.0	DC
Endura 50 ppm	27.1	CB	11.1	DCB
Quadris 50 ppm	28.4	CB	14.6	CBA
Microthiol Disperss 50 ppm	35.9	BA	23.0	A
Topsin M 50 ppm	39.1	BA	8.1	DC
Flint 50 ppm	42.3	BA	19.4	BA
Cabrio 50 ppm	44.4	BA	21.3	A
Water only check	52.7	A	10.6	DCB

^a Column numbers followed by the same letter are not significantly different at P=0.05 determined by Fisher's protected LSD.

Table 2. Area under the disease progress curve (AUDPC) of powdery mildew colony development using the mean of first and second leaves of Howden and Magician pumpkin seedlings exposed to spores at the Greenford southern site. Observations made in a Columbus greenhouse from 6 August to 22 August.

Treatment	AUDPC			
	Howden ^a		Magician ^a	
Quintec 10 ppm	20.6	C	31.9	D
Nova 40W 120 ppm	27.2	C	16.9	D
Procure 480SC 120 ppm	81.7	C	44.5	D
Procure 480SC 80 ppm	125.6	C	115.3	DC
Pristine 50 ppm	301.0	B	343.9	BA
Endura 50 ppm	312.3	B	294.2	CB
Microthiol Disperss 50 ppm	458.1	BA	505.8	A
Flint 50 ppm	514.2	A	504.0	A
Cabrio 50 ppm	518.3	A	408.6	BA
Water only check	521.7	A	459.8	BA
Quadris 50 ppm	531.7	A	384.9	BA
Topsin M 50 ppm	556.1	A	518.8	A

^a Column numbers followed by the same letter are not significantly different at P=0.05 determined by Fisher's protected LSD.

Table 3. Area under the disease progress curve (AUDPC) of powdery mildew colony development using the mean of first and second leaves of Howden and Magician pumpkin seedlings exposed to spores at the Western Agricultural Research Station site. Observations made in a Columbus greenhouse from 6 August to 22 August.

Treatment	AUDPC			
	Howden ^a		Magician ^a	
Quintec 10 ppm	28.4	F	54.5	F
Nova 40W 120 ppm	114.7	F	58.4	F
Procure 480SC 120 ppm	139.2	F	96.2	F
Procure 480SC 80 ppm	296.9	E	265.1	E
Pristine 50 ppm	508.8	D	301.5	ED
Endura 50 ppm	639.2	DC	444.6	DC
Flint 50 ppm	735.5	CB	647.2	BA
Topsin M 50 ppm	738.7	CB	524.7	CBA
Cabrio 50 ppm	789.0	B	688.0	A
Water only check	801.0	BA	649.5	BA
Quadris 50 ppm	823.9	BA	675.1	A
Microthiol Disperss 50 ppm	911.2	A	505.5	CB

^a Column numbers followed by the same letter are not significantly different at P=0.05 determined by Fisher's protected LSD.

Table 4. Area under the disease progress curve (AUDPC) of powdery mildew colony development using the mean of first and second leaves of Howden and Magician pumpkin seedlings exposed to spores at the Wooster site. Observations made in a Wooster greenhouse from 6 August to 18 August. Data was transformed from spots to % powdery mildew colonies.

Treatment	AUDPC			
	Howden ^a		Magician ^a	
Quintec 10 ppm	0	C	0	E
Procure 480SC 120 ppm	1.99	C	4.14	ED
Nova 40W 120 ppm	4.27	C	9.31	EDC
Pristine 50 ppm	4.41	C	11.84	EDC
Procure 480SC 80 ppm	7.25	C	6.98	ED
Endura 50 ppm	7.84	CB	16.97	EDCB
Topsin M 50 ppm	19.72	BA	105.69	A
Cabrio 50 ppm	26.63	A	25.68	EDCB
Flint 50 ppm	26.97	A	36.97	CB
Water only check	27.27	A	31.98	DCB
Quadris 50 ppm	28.61	A	40.20	B
Microthiol Disperss 50 ppm	29.70	A	22.65	EDCB

^a Column numbers followed by the same letter are not significantly different at P=0.05 determined by Fisher's protected LSD.

Table 5. Area under the disease progress curve (AUDPC) of powdery mildew colony development using the mean of first and second leaves of Howden pumpkin seedlings exposed to spores at the Willard site. Observations made in a Wooster greenhouse from 27 August to 12 September.

Treatment	AUDPC			
	Howden ^a			
Quintec 10 ppm	645.69	C		
Pristine 50 ppm	906.63	B		
Endura 50 ppm	953.94	BA		
Cabrio 50 ppm	998.63	BA		
Nova 40W 120 ppm	999.81	BA		
Procure 480SC 120 ppm	999.92	BA		
Microthiol Disperss 50 ppm	1019.13	BA		
Topsin M 50 ppm	1039.69	A		
Water only check	1048.63	A		
Flint 50 ppm	1049.06	A		
Quadris 50 ppm	1053.44	A		
Procure 480SC 80 ppm	1056.44	A		

^a Column numbers followed by the same letter are not significantly different at P=0.05 determined by Fisher's protected LSD.

Table 6. Percent powdery mildew colony development using the mean of first and second leaves of Magician pumpkin seedlings exposed to spores at the Willard site. Observations made in a Wooster greenhouse from 5 Sept. to 12 September; 8, 11, and 15 days after field exposure. No statistics were performed on these data.

Treatment	Mean % PM on Magician		
	5 Sept.	8 Sept.	12 Sept.
Quintec 10 ppm	33.8	44.0	62.8
Endura 50 ppm	63.1	78.8	83.8
Pristine 50 ppm	50.6	60.0	84.4
Microthiol Disperss 50 ppm	74.8	85.1	90.8
Topsin M 50 ppm	81.3	89.4	91.8
Water only check	77.9	91.6	92.3
Procure 480SC 120 ppm	73.5	86.3	92.9
Nova 40W 120 ppm	65.1	80.6	94.1
Cabrio 50 ppm	73.1	87.0	94.4
Quadris 50 ppm	81.3	93.9	95.4
Procure 480SC 80 ppm	80.6	92.3	97.3
Flint 50 ppm	87.4	96.6	98.8

Results

Experiment 2: High label rate powdery mildew sensitivity trial

Powdery mildew infection rates varied tremendously by location between Willard and South Charleston based on the Area Under the Disease Progress Curve (AUDPC) generated (Table 7). At the Willard location the most effective treatments were Quintec and Procure, with Nova being no different than Procure on the variety Howden. At the same site on the variety Magician, Quintec, Procure, and Nova controlled powdery mildew better than the other treatments. Although very effective, Quintec is not labeled on cucurbits in Ohio. Both Nova and Procure are DMI fungicides suspected anecdotally to have lost their ability to control powdery mildew, but this claim is not substantiated based on results from this experiment and trial location. The second tier of efficacious fungicides at Willard include Microthiol Disperss, Endura, and Pristine on both Howden and Magician. Since Pristine is a combination of pyraclostrobin (FRAC 11) and boscalid (FRAC 7), it appears the boscalid component is responsible for most of the control seen against powdery mildew. Microthiol Disperss (FRAC M) performed well against powdery mildew, but since it is only a contact material, coverage is important to prevent infection. The QoI fungicides (FRAC 11) Cabrio, Flint, and Quadris performed no better than the untreated check suggesting insensitivity or resistance to these compounds at this site has been reached. In terms of genetic resistance, Magician had generally lower infection rates than Howden at this location, suggesting little net benefit to using PMT varieties for additional protection against powdery mildew.

Table 7. Powdery mildew Area Under the Disease Progress Curve's (AUDPC) for at two locations using ten fungicides to treat two pumpkin hybrids from 22 Aug to 19 Sept. for South Charleston and 10 Aug. to 12 Sept. for the Willard location.

Treatment and rate/A ^z	Willard ^u		South Charleston ^s			
	Magician ^v	Howden ^w	Howden ^w			
	AUDPC ^y					
Quintec 2.08 SC fl oz	3.9	C	12.4	E	0.4	C
Procure 480SC 8 fl oz	30.9	C	63.9	DE	0	C
Nova 40W 5 oz	49.9	C ^x	117	D ^x	0.2	C ^x
Endura 70W 7 oz	211.3	B	287.1	C	7.1	BC
Microthiol Disperss 7.5 lbs	242.6	B	272.3	C	0.1	C
Pristine 38WG 18.5 oz	302	B	314.8	C	7.7	BC
Cabrio EG 16 oz	672.1	A	729.6	A	38.5	A
Flint 50W 2 oz	677.8	A	727	A	39.4	A
Non-treated (control)	727.1	A	726.8	A	22.6	Ab
Quadris 22 F 15.5 fl oz	754.9	A	585.9	B	16.5	BC
Topsin M WSB 8 oz	775.6	A	663.8	AB	37.7	A
P-value	<0.0001		<0.0001		<0.0001	

^z Rate of formulated product.

^y Powdery mildew AUDPC based on mean of leaf 1 and 2 upper surface only.

^x Column numbers followed by the same letter are not significantly different at P=0.05 determined by Fisher's protected LSD.

^w Obtained from Rupp Seeds Inc.

^v Obtained from Harris Moran Seed Company.

^u Ohio Agriculture Research and Development Center Research Station, Willard, OH.

^s Ohio Agriculture Research and Development Center Research Station, South Charleston, OH.

Conclusions

Below label rate powdery mildew sensitivity trial

The purpose of this trial was to identify compounds that had a likelihood of insensitivity toward powdery mildew. Most of the rates used in this trial were well below even low label field rates in an effort to demonstrate if powdery mildew could easily overcome the fungicide, i.e., if it had a high likelihood of developing insensitivity in the near future. This was demonstrated with most of the fungicides used in the trial, regardless if the location appeared to have high PM (Greenford southern, Willard, WARS) or low PM pressure (Greenford fairgrounds, Wooster).

Even at these reduced rates where you would expect lower efficacy against this pathogen, it appears that the strobiluron type fungicides, along with Topsin M and Microthiol Disperss, are not performing as well as the DMI type fungicides, Nova and Procure, in preventing PM colonies. One exception to this rule would be Pristine, which has a non-strobiluron component that is most likely responsible for the higher level of control demonstrated.

High label rate powdery mildew sensitivity trial

Unlike the first trial, rates used in this experiment were at the high field labeled rate providing a significant challenge to PM spore and colony development. The South Charleston trial showed drastically lower powdery mildew infection curves compared to the Willard site. At the South Charleston site the development of insensitive or resistance to QoI fungicides seems apparent based on the lack of efficacy of Cabrio, Flint, Quadris, and Pristine, though Pristine has the best control of the group. One possible reason for the comparatively low rates of powdery mildew infection on the seedlings at the South Charleston location may be due to the light rain falling on the day the seedlings were brought to the field for exposure to spores. Although the seedlings were shielded from the rain and set in the path of spores blown from the field, this may account for the overall lower levels of infection seen compared to the Willard site. At the Willard site, in addition to the fungicides already mentioned, Pristine also performed significantly better than the water only treated check. Because Pristine is a combination product, it is the boscalid (non-strobiluron) component that is responsible for the control seen. Microthiol, Quintec, Nova, and Procure had significantly better powdery mildew control compared to the untreated check at both locations and over both hybrids.

An important message in this trial is the use of materials at full rates, not low label rates, to maximize control of this pathogen. Early PM escapes will promote larger secondary infections that may be more difficult to control given increased canopy and microclimates.

Based on data from these two sites in Northeast and Southwest regions of the state, these experiments help build the case that QoI (strobiluron) insensitive or field resistant strains of powdery

mildew exist in Ohio. In step with this knowledge means that strobiluron type fungicides should not be used to control PM on cucurbits, but can be used to protect against other fungal pathogens.