

Ohio Vegetable & Small Fruit Research & Development Program

Final Report

2017

Project Title: Evaluation of Pumpkin Cultivars for Resistance to Powdery Mildew and Determination of Efficacy of Fungicides in Multiple Locations

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Why was the project funded? One of the suggestions for research submitted to OVSRDP from a southern Ohio farmer was evaluation of pumpkin cultivars for resistance to powdery mildew. Powdery mildew is an important, recurring problem throughout Ohio, and cultivar resistance is a preferred means of managing the disease. Many cultivars labeled powdery mildew-resistant are only partially resistant, and fungicides are needed to protect the foliage and stems. There are differences among locations in efficacy of fungicides against powdery mildew, and differences in the degree of resistance by location have also been observed. Conducting large-scale evaluations at multiple locations, however, is prohibitively expensive. We proposed to screen young plants of at least 30 pumpkin cultivars for resistance to powdery mildew using inoculum from southern, central and northern Ohio. We used the same cultivars that Brad Bergefurd tested in a separate field trial at South Centers, and rate this field trial for powdery mildew at least three times. A similar bioassay for fungicide efficacy was conducted using inoculum from these three locations. We have conducted this bioassay numerous times, including in 2016 (not OVSRDP funded; see <http://go.osu.edu/BnNQ> for report).

Project outline (cultivar resistance). The experiment was conducted in a greenhouse located at The Ohio State University - Ohio Agricultural Research and Development Center (OARDC) in Wooster, OH. Pumpkin seeds were sown on 2, 18 and 31 Aug and 12 Sep into 4 in. pots filled with Baccto Professional Grower Potting Mix. The experiment was set up in a randomized complete block design with four replications. Each replication consisted of three individual potted plants. Plants were hand watered daily, and fertilized (N-P-K 20-20-20; 0.53 oz/gal water) once per week from germination through the end of the experiment. Plants were inoculated when the second true leaf was fully expanded. Pumpkin leaves exhibiting >80% powdery mildew severity were used for inoculation. Fifteen leaves were shaken on top of the seedlings per replication; leaves remained in the room for approximately 8 hours. Leaves with powdery mildew inoculum were collected from three cucurbit fields: OARDC North Central Agricultural Research Station in Fremont, OH, OARDC Western Agricultural

Research Station in South Charleston, OH, and the OSU South Centers in Piketon, OH. Inoculum was collected at two time points: early and late during the season. Inoculum from each location was used in separate greenhouse rooms. Any new growth after the third true leaf was removed. Severity of powdery mildew was evaluated per plant by rating the upper surface of the three true leaves at 3, 7, 10, and 14 days after inoculation (DAI). Area Under the Disease Progress Curve (AUDPC) values were calculated using disease severity assessments at 3, 7, 10, and 14 days after inoculation according to the formula: $\sum [(x_i+x_{i-1})/2](t_i-t_{i-1})$ where x_i is the rating at each evaluation time and (t_i-t_{i-1}) is the number of days between evaluations. An extra rating was performed 21 DAI. Disease severity per leaf was assessed using a rating scale illustrating powdery mildew at 0.5, 1, 2, 4, 8, 16, 32, 64, and 80 percent foliage affected. Experiments were performed twice for each location, except OSU South Centers. Analysis of variance was performed on the angular transformed ($\arcsine [\sqrt{(\text{severity}/100)}]$) powdery mildew percent severity data using the GLIMMIX procedure, and transformed means were separated by Fisher's least significant difference test with SAS software. Powdery mildew severity data were analyzed independently for each location and for each experiment. Transformed means were back-transformed by squaring the sine of the means. Average maximum and minimum temperature for each experiment before inoculation was: Fremont early season inoculation: 92.0 F and 80.0 F, Fremont late season inoculation: 86.4 F and 72.3 F, South Charleston early season inoculation: 94.6 F and 75.3 F, South Charleston late season inoculation: 92.1 F and 71.8 F, and Piketon early season inoculation: 86.8 F and 76.9 F. Average maximum and minimum temperature for each experiment after inoculation was: Fremont early season inoculation: 86.3 F and 78.8 F, Fremont late season inoculation: 84.1 F and 66.0 F, South Charleston early season inoculation: 87.1 F and 69.1 F, South Charleston late season inoculation: 84.9 F and 68.8 F, and Piketon early season inoculation: 86.0 F and 74.8 F.

What was discovered (cultivar resistance)? None of the cultivars tested were consistently highly resistant to powdery mildew with inoculum from all locations at two times during the year. Each cultivar exhibited >80% powdery mildew severity in at least one of the experiments, with the exception of Bella Trix, EX#5, JPN62005R, Renegade, and RPX6880, which had <80% powdery mildew severity in all experiments (Table 1).

Take home message (cultivar resistance). It is possible that powdery mildew disease pressure was too severe for seedlings and field results may be more informative.

Table 1. Powdery mildew severity (percent) in 30 pumpkin cultivars 14 days after inoculation (DAI). Pathogen inocula from three different locations in Ohio were used. The experiment was performed once using early season inoculum and once with late season inoculum, except for Piketon.

Cultivar	Company	Powdery Mildew severity - 14 DAI ^{z y x}				
		Early season inoculum			Late season inoculum	
		Fremont ^w	South Charleston ^u	Piketon ^v	Fremont ^w	South Charleston ^u
Cronus	Harris Moran	47.0 e-g	70.9 a-c	89.2 ab	76.9 a-g	82.4 a-c
Kratos	Harris Moran	69.0 a-c	68.5 a-f	86.2 a-e	76.7 a-g	81.3 a-c
Rhea	Harris Moran	51.1 c-g	70.1 a-d	86.8 a-d	79.5 a-d	81.7 a-c
Zeus	Harris Moran	64.9 a-f	63.4 c-f	85.1 b-f	84.0 a	84.0 a-c
Bellatrix	Enza Zaden	58.1 a-g	71.2 a-c	79.6 e-i	74.0 c-h	79.9 a-e
EX#3	Enza Zaden	70.1 a-g	66.9 a-f	89.2 ab	76.9 a-f	78.2 b-f
EX#5	Enza Zaden	61.2 a-f	61.3 ef	75.8 i	68.4 f-h	77.0 c-f
1512	Abbott & Cobb	73.5 ab	61.3 ef	86.8 a-d	82.9 a	81.3 a-c
1543	Abbott & Cobb	73.5 ab	73.4 ab	82.1 c-i	83.1 a	77.0 c-f
ACX7606	Abbott & Cobb	75.2 ab	71.7 a-c	86.8 a-d	81.7 a-c	78.6 b-f
JPN62005R	Johnny's	52.3 c-g	61.8 d-f	78.1 f-i	69.3 f-h	78.4 b-f
JPN62009	Johnny's	49.2 d-g	66.7 a-f	80.4 d-i	73.0 d-h	83.4 a-c
JPN-14-4090	Johnny's	61.3 a-f	63.8 c-f	83.8 b-h	69.7 e-h	72.3 ef
Renegade	Johnny's	65.8 a-f	63.4 c-f	76.8 hi	67.1 h	73.0 d-f
BayhorseGold	Rupp	62.3 a-f	63.8 c-f	85.2 b-f	72.3 d-h	80.9 a-d
EagleCityGold	Rupp	68.9 a-d	73.4 ab	83.5 b-h	82.4 ab	83.8 a-c
PX6229	Rupp	70.3 a-c	74.2 a	88.4 a-c	74.6 b-h	84.9 ab
RPX6208	Rupp	45.9 fg	61.3 ef	83.4 b-h	66.0 h	80.1 a-e
RPX6880	Rupp	57.9 b-g	59.3 f	77.6 g-i	68.2 gh	71.4 f
RPX6883	Rupp	51.1 c-g	61.3 ef	82.7 c-i	69.7 e-h	70.9 f
RPX6927	Rupp	62.3 a-f	72.6 ab	87.0 a-d	78.9 a-d	84.2 a-c
SkidooGold	Rupp	65.2 a-f	61.1 ef	84.3 b-h	82.4 ab	80.7 a-d
SolidGold	Rupp	76.7 a	73.4 ab	89.3 ab	79.3 a-d	83.9 a-c
CrackerJack	Sakata	52.5 c-g	64.2 c-f	86.8 a-d	74.0 c-h	82.4 a-c
Diablo	Sakata	66.9 a-e	74.2 a	87.9 a-c	81.5 a-c	81.3 a-c
Hulk	Sakata	68.2 a-d	65.1 b-f	88.2 a-c	74.7 b-h	80.2 a-e
JackSprat	Sakata	65.2 a-f	65.9 a-f	88.4 a-c	78.8 a-d	86.8 a
SPU6016	Sakata	75.6 ab	70.1 a-d	91.3 a	78.1 a-e	84.0 a-c
Blaze	SeedWay	39.8 g	63.3 c-f	86.8 a-d	80.5 a-d	81.3 a-c
Jason	SeedWay	67.8 a-d	73.7 a	85.1 b-f	78.1 a-e	84.4 a-c
P-value		0.0109	0.0002	0.0001	<0.0001	0.0023
Average		62.3	67.0	84.8	76.1	80.3
Maximum		76.7	74.2	91.3	84.0	86.8
Minimum		39.8	59.3	75.8	66.0	70.9

^zDisease ratings based on a scale of 0-100% foliage affected using a rating scale of 0.5, 1, 2, 4, 8, 16, 32, 64, and 80% foliage affected.

^yValues are the back-transformed means.

^xMeans followed by the same lower case letter within a column are not significantly different at P<0.05. Means were separated using Fisher's least significant difference test on angular transformed data.

^wOhio Agricultural Research and Development Center North Central Agricultural Research Station, Fremont, OH.

^vOSU South Centers, Piketon, OH.

^uOhio Agricultural Research and Development Center Western Agricultural Research Station, South Charleston, OH.

Project outline (fungicide efficacy). The experiment was conducted in a greenhouse located at The Ohio State University - Ohio Agricultural Research and Development Center (OARDC) in Wooster, OH. Pumpkin 'Solid Gold F1' FarMore-treated seeds were sown on 2, 18 and 31 Aug and 12 and 20 Sep into 4 in. pots filled with Baccto Professional Grower Potting Mix. The experiment was set up in a randomized complete block design with four replications. Each replication consisted of three individual potted plants. Plants were hand watered daily, and fertilized (N-P-K 20-20-20; 0.53 oz/gal water) once per week from germination through the end of the experiment. When the second true leaf was fully expanded, treatments were applied to the top surface of both the first and second true leaves by using a hand held sprayer at a rate of 54 gal/A. Non-treated control plants were sprayed with water. Each leaf received approximately 0.08 fl oz. of spray. Pumpkin leaves with >80% powdery mildew severity were used for inoculation. Eight leaves were shaken on top of the seedlings per replication; leaves remained in the room for approximately 8 hours. Leaves with inoculum were collected from three cucurbit fields: OARDC North Central Agricultural Research Station in Fremont, OH, OARDC Western Agricultural Research Station in South Charleston, OH, and the OSU South Centers in Piketon, OH. Inoculum from each location was used in separate greenhouse rooms. Treatments were sprayed one day before inoculation. Any new growth after the third true leaf was removed. Phytotoxicity and the severity of powdery mildew were evaluated on the upper surface of the first two true leaves at 3, 7, 10, and 14 days after inoculation. Disease severity per leaf was assessed using a rating scale illustrating powdery mildew at 0.5, 1, 2, 4, 8, 16, 32, 64, and 80 percent foliage affected. Area Under the Disease Progress Curve (AUDPC) values were calculated using disease severity assessments at 3, 7, 10, and 14 days after inoculation according to the formula: $\sum ((x_i+x_{i-1})/2)(t_i-t_{i-1})$ where x_i is the rating at each evaluation time and (t_i-t_{i-1}) is the number of days between evaluations. Experiments were performed twice for each location. Analysis of variance was performed on the angular transformed ($\arcsine \sqrt{(\text{severity}/100)}$) powdery mildew percent severity data using the GLIMMIX procedure, and transformed means were separated by Fisher's least significant difference test with SAS software. Powdery mildew severity data were analyzed independently for each location and for each experiment. Transformed means were back-transformed by squaring the sine of the means. Average maximum and minimum temperature for each experiment before inoculation was: Fremont early season inoculation: 93.7 F and 76.4 F, Fremont late season inoculation: 86.4 F and 72.3 F, South Charleston early season inoculation: 87.7 F and 76.7 F, South Charleston late season inoculation: 92.1 F and 71.8 F, Piketon early season inoculation: 85.4 F and 72.6 F, and Piketon late season inoculation: 86.9 F and 72.9 F. Average maximum and minimum temperature for each experiment after inoculation was: Fremont early season inoculation: 88.8 F and 70.7 F, Fremont late season inoculation: 84.1 F and 66.0 F, South Charleston early season inoculation: 86.3 F and 76.8 F, South Charleston late season inoculation: 84.9 F and 68.8 F, Piketon early season inoculation: 85.0 F and 72.7 F, and Piketon late season inoculation: 82.4 F and 73.7 F.

What was discovered (fungicide efficacy)? Powdery mildew severity was medium to high ($\geq 60\%$ severity) in all experiments 14 days after inoculation (Tables 2 and 3), except the experiment using late season inoculum from Piketon (untreated control: 32.2% powdery mildew severity). No phytotoxicity was observed with any of the treatments, except Quintec 2.08SC on the experiments using late season inoculum.

Powdery mildew severity was high in the non-treated controls of the early season inoculum experiments. Based on disease severity 14 days after inoculation, all fungicide treatments except Bravo Weather Stik with inoculum from all locations, MBI 10612 at a rate of 24 fl oz/A with inoculum from Fremont or South Charleston, and Pristine WG with inoculum from Fremont or Piketon performed

significantly better than the non-treated control. Plants treated with Procure 480SC, Quintec 2.08SC or Rally 40WSP showed <11% powdery mildew severity with inoculum from all locations. Plants treated with Aprovia Top EC or Inspire Super EW showed <10% powdery mildew severity with inoculum from Piketon and South Charleston, while those treated with Fontelis 1.67SC, Merivon Xemium 2.09SC, or Torino 0.85SC showed <10% powdery mildew severity only with inoculum from South Charleston. Based on the experiment-long disease severity values (AUDPC), all of the treatments performed better than the non-treated control when inoculum from South Charleston was used. When inoculum from the other two locations was used, all treatments performed better than the non-treated control based on AUDPC, except Bravo Weather Stik and MBI 10612 at a rate of 24 fl oz/A with inoculum from Fremont, and Bravo Weather Stik and Pristine WG with inoculum from Piketon (Table 1).

Powdery mildew severity was high on the non-treated controls in the experiments using late season inoculum 10 days after inoculation, except for Piketon (untreated control: 13.6% powdery mildew severity). Plants treated with Procure 480SC, Quintec 2.08SC, Rally 40WSP, Aprovia Top EC or Inspire Super EW showed <14% disease severity with inoculum from Fremont and South Charleston (Figure 1). Those treated with Fontelis 1.67SC, Merivon Xemium 2.09SC, and Torino 0.85SC had <10% powdery mildew severity only with inoculum from South Charleston (Figure 1), as observed in the early season inoculum experiments. Severity 14 days after inoculation was <15% on plants treated with Procure 480SC, Quintec 2.08SC, Rally 40WSP, Aprovia Top EC or Inspire Super EW and inoculated with inoculum from all locations, except Quintec 2.08SC with Fremont inoculum. Quintec 2.08SC showed some level of phytotoxicity. Plants treated with Fontelis 1.67SC, Merivon Xemium 2.09SC, and Torino 0.85SC exhibited <15% powdery mildew severity with inoculum from South Charleston. Plants inoculated with powdery mildew inoculum from Piketon and treated with Inspire Super EW and Torino 0.85SC also showed <15% powdery mildew severity 14 days after inoculation. AUDPC values for all treatments were lower than the non-treated control, with the exception of Bravo Weather Stick at all locations, and Fontelis 1.67SC, Merivon Xemium 2.09SC, and Pristine WG with inoculum from Piketon (Table 3).

Take-home message (fungicide efficacy). Results of the trials across locations are summarized in Figures 2 (early season inoculum) and 3 (late season inoculum). With the exception of Quintec, fungicide efficacy against powdery mildew did not vary for early- and late-season inoculum. Quintec was very effective in five of six trials, and its relatively poorer performance with late season inoculum from Fremont could be an anomaly. At this time Quintec remains a recommended product, along with Procure and Rally, both of which have similar modes of action (MOA) (see Figures 2,3 for FRAC codes). Aprovia Top and Inspire Super demonstrated slightly less efficacy in two locations than in the remaining four, but still may be considered effective against powdery mildew. It is very important that fungicide programs be managed to include products with different modes of action to reduce the risk of resistance developing in powdery mildew pathogen populations.

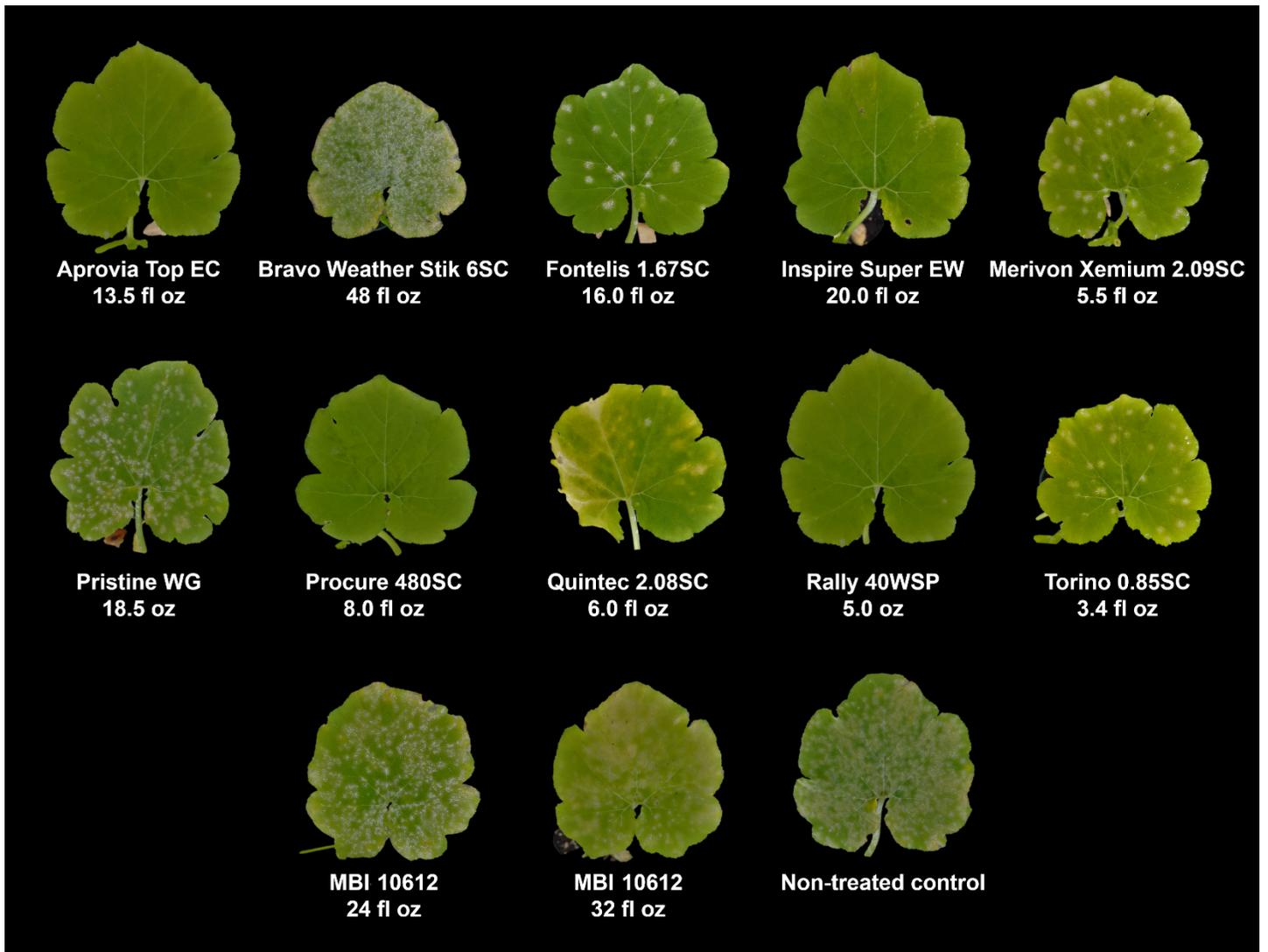


Figure 1. Powdery mildew on second true leaves of pumpkin 'Solid Gold F1' 10 days after inoculation (DAI). Results with late-season inoculum from South Charleston, OH.

Table 1. Powdery mildew (PM) severity (percent) on pumpkin ‘Solid Gold F1’ leaves 7, 10, and 14 days after inoculation (DAI) of treatments, percentage control, and Area Under the Disease Progress Curve (AUDPC). Results of experiments using early season inoculum.

Location	Treatment and rate/A	% PM ^{z,y,x}		% PM ^{z,y,x} (% control ^s)		% PM ^{z,y,x} (% control ^s)		AUDPC ^f
		7 DAI	10 DAI	10 DAI	14 DAI	14 DAI		
Fremont ^w	Aprovia Top EC 13.5 fl oz	4.7 fgh	n.e. ^t		15.1 ef	(83.5)	81.6 ef	
	Bravo Weather Stik 6SC 48 fl oz	78.6 a	n.e.		97.7 a	(0.0)	771.4 a	
	Fontelis 1.67SC 16.0 fl oz	10.1 ef	n.e.		36.6 d	(60.0)	185.9 de	
	Inspire Super EW 20.0 fl oz	19.1 de	n.e.		38.7 d	(57.7)	242.8 d	
	Merivon Xemium 2.09SC 5.5 fl oz	12.8 ef	n.e.		40.7 d	(55.5)	216.5 d	
	Pristine WG 18.5 oz	37.2 c	n.e.		81.3 bc	(11.3)	475.1 c	
	Procure 480SC 8.0 fl oz	1.3 gh	n.e.		5.7 f	(93.8)	30.2 f	
	Quintec 2.08SC 6.0 fl oz	0.8 h	n.e.		7.1 f	(92.2)	32.4 f	
	Rally 40WSP 5.0 oz	7.1 fg	n.e.		10.6 ef	(88.4)	79.2 ef	
	Torino 0.85SC 3.4 fl oz	6.8 fg	n.e.		23.0 de	(74.9)	120.2 def	
	MBI 10612 24 fl oz	38.9 c	n.e.		90.6 abc	(1.1)	530.0 bc	
	MBI 10612 32 fl oz	27.1 cd	n.e.		75.5 c	(17.6)	414.9 c	
	Non-treated control	56.1 b	n.e.		91.6 ab		620.5 b	
P-value	<0.0001			<0.0001		<0.0001		
South Charleston ^v	Aprovia Top EC 13.5 fl oz	0.1 e	n.e.		1.7 fg	(97.2)	8.7 e	
	Bravo Weather Stik 6SC 48 fl oz	7.6 ab	n.e.		44.6 ab	(25.6)	201.2 b	
	Fontelis 1.67SC 16.0 fl oz	0.3 de	n.e.		7.5 defg	(87.6)	45.0 de	
	Inspire Super EW 20.0 fl oz	0.2 e	n.e.		8.7 def	(85.5)	37.3 de	
	Merivon Xemium 2.09SC 5.5 fl oz	0.0 e	n.e.		2.3 fg	(96.2)	11.1 e	
	Pristine WG 18.5 oz	0.4 de	n.e.		14.5 cde	(75.8)	56.5 de	
	Procure 480SC 8.0 fl oz	0.0 e	n.e.		0.8 g	(98.7)	4.2 e	
	Quintec 2.08SC 6.0 fl oz	0.0 e	n.e.		1.6 fg	(97.3)	6.0 e	
	Rally 40WSP 5.0 oz	0.2 e	n.e.		6.1 efg	(89.8)	25.5 e	
	Torino 0.85SC 3.4 fl oz	0.1 e	n.e.		1.4 fg	(97.6)	8.4 e	
	MBI 10612 24 fl oz	4.3 bc	n.e.		30.2 bc	(49.6)	134.5 c	
	MBI 10612 32 fl oz	2.2 cd	n.e.		18.8 cd	(68.7)	89.7 cd	
	Non-treated control	10.7 ab	n.e.		60.0 ab		267.3 a	
P-value	<0.0001			<0.0001		<0.0001		
Piketon ^u	Aprovia Top EC 13.5 fl oz	0.2 ef	1.5 de	(96.0)	5.3 de	(92.3)	20.4 de	
	Bravo Weather Stik 6SC 48 fl oz	23.9 a	42.5 a	(0.0)	63.8 a	(6.6)	362.0 a	
	Fontelis 1.67SC 16.0 fl oz	2.5 cde	7.9 cd	(79.7)	17.3 cd	(74.6)	73.9 cde	
	Inspire Super EW 20.0 fl oz	1.1 def	2.5 de	(93.6)	7.2 de	(89.5)	35.6 de	
	Merivon Xemium 2.09SC 5.5 fl oz	8.0 bc	19.0 bc	(51.0)	36.7 bc	(46.3)	179.2 bc	
	Pristine WG 18.5 oz	16.2 ab	27.2 ab	(30.1)	49.1 ab	(28.1)	260.5 ab	
	Procure 480SC 8.0 fl oz	0.0 f	0.1 e	(99.9)	0.3 e	(99.6)	1.6 e	
	Quintec 2.08SC 6.0 fl oz	0.2 ef	0.7 e	(98.1)	3.2 e	(95.2)	16.2 de	
	Rally 40WSP 5.0 oz	0.2 ef	0.7 e	(98.1)	2.3 e	(96.6)	8.6 de	
	Torino 0.85SC 3.4 fl oz	7.3 c	18.5 bc	(52.5)	37.2 bc	(45.5)	168.2 bc	
	MBI 10612 24 fl oz	7.0 c	18.0 bc	(53.6)	38.4 b	(43.7)	169.4 bc	
	MBI 10612 32 fl oz	4.5 cd	12.1 c	(68.9)	27.2 bc	(60.1)	116.3 cd	
	Non-treated control	18.9 a	38.9 a		68.2 a		341.0 a	
P-value	<0.0001	<0.0001		<0.0001		<0.0001		

^zDisease ratings after application based on a scale of 0-100% foliage affected using a rating scale of 0.5, 1, 2, 4, 8, 16, 32, 64, and 80 % foliage affected.

^yValues are the back-transformed means of leaf 1 and 2, upper surface only.

^xMeans followed by the same lower case letter within a column are not significantly different at P<0.05. Means were separated using Fisher’s least significant difference test on angular transformed data.

^wOhio North Central Agricultural Research and Development Center Snyder Farm, Fremont, OH.

^yOhio Agricultural Research and Development Center Western Agricultural Research Station, South Charleston, OH.

^zOSU South Centers, Piketon, OH.

^tn.e. = not evaluated.

^sPercentage control values were calculated for each plot according to the formula: $[(SC - ST)/SC]*100$ where SC is the average severity on the non-treated control and ST is the average severity on the treatment.

^rArea under the disease progress curve values were calculated according to the formula: $\Sigma [(x_i+x_{i-1})/2](t_i-t_{i-1})$ where x_i is the rating at each evaluation time and (t_i-t_{i-1}) is the number of days between evaluations.

FRAC	Product and rate/A	2017 – early season inoculum			
		Very good in 3 of 3 locations	Very good in 2 of 3 locations	Very good in 1 of 3 locations	Fair or poor
3	Procure 480SC 8.0 fl oz	X			
13	Quintec 2.08SC 6.0 fl oz	X			
3	Rally 40WSP 5.0 oz	X			
3,7	Aprovia Top EC 13.5 fl oz		X		
3,9	Inspire Super EW 20.0 fl oz		X		
7	Fontelis 1.67SC 16.0 fl oz			X	
7,11	Merivon Xemium 2.09SC 5.5 fl oz			X	
U6	Torino 0.85SC 3.4 fl oz			X	
7,11	Pristine WG 18.5 oz				X
M5	Bravo Weather Stik 6SC 48 fl oz				X
	MBI-10612 24 fl oz				X
	MBI-10612 32 fl oz				X

Figure 2. Summary of fungicide efficacy across locations against powdery mildew in a bioassay – early season inoculum.

Table 2. Powdery mildew (PM) severity (percent) on pumpkin ‘Solid Gold F1’ leaves 7, 10, and 14 days after inoculation (DAI) of treatments, percentage control, and Area Under the Disease Progress Curve (AUDPC). Results of experiments using late season inoculum.

Location	Treatment and rate/A	% PM ^{z,y,x}		% PM ^{z,y,x} (% control ^l)		% PM ^{z,y,x} (% control ^l)		AUDPC ^s
		7 DAI	10 DAI	10 DAI	14 DAI	14 DAI	14 DAI	
Fremont ^w	Aprovia Top EC 13.5 fl oz	4.5 ef	9.9 e	(84.6)	13.6 g	(83.2)	77.8 ef	
	Bravo Weather Stik 6SC 48 fl oz	47.3 a	63.4 a	(1.6)	83.5 a	(0.0)	552.2 a	
	Fontelis 1.67SC 16.0 fl oz	17.1 cd	36.0 cd	(44.0)	51.8 de	(36.0)	292.1 cd	
	Inspire Super EW 20.0 fl oz	2.9 ef	8.7 ef	(86.5)	14.4 g	(82.3)	70.4 ef	
	Merivon Xemium 2.09SC 5.5 fl oz	24.9 bc	44.2 bc	(31.3)	63.5 cd	(21.6)	369.5 bc	
	Pristine WG 18.5 oz	25.1 bc	46.0 bc	(28.6)	66.1 cd	(18.3)	381.2 bc	
	Procure 480SC 8.0 fl oz	0.0 g	0.3 g	(99.6)	1.0 h	(98.8)	4.3 f	
	Quintec 2.08SC 6.0 fl oz	6.5 e	13.1 e	(79.6)	33.8 f	(58.3)	138.3 e	
	Rally 40WSP 5.0 oz	1.7 f	3.5 f	(94.6)	4.3 h	(94.7)	27.4 f	
	Torino 0.85SC 3.4 fl oz	28.2 bc	53.1 ab	(17.4)	70.7 bc	(12.6)	426.5 b	
	MBI-10612 24 fl oz	25.5 b	44.8 bc	(30.3)	60.1 cd	(25.8)	366.5 bc	
	MBI-10612 32 fl oz	15.7 d	31.1 d	(51.6)	44.5 ef	(45.1)	260.2 d	
	Non-treated control	44.7 a	64.4 a		81.0 ab		542.5 a	
		P-value	<0.0001	<0.0001		<0.0001		<0.0001
South Charleston ^v	Aprovia Top EC 13.5 fl oz	0.0 f	0.4 gh	(99.4)	0.6 f	(99.3)	3.9 e	
	Bravo Weather Stik 6SC 48 fl oz	50.4 a	77.6 a	(0.0)	89.9 a	(0.0)	627.0 a	
	Fontelis 1.67SC 16.0 fl oz	2.6 de	7.1 e	(89.3)	11.9 d	(86.1)	59.4 e	
	Inspire Super EW 20.0 fl oz	0.1 f	1.1 fgh	(98.4)	1.7 ef	(98.1)	11.3 e	
	Merivon Xemium 2.09SC 5.5 fl oz	3.0 de	7.4 e	(88.9)	12.1 d	(85.8)	66.7 e	
	Pristine WG 18.5 oz	6.6 cd	21.4 d	(67.9)	33.5 c	(60.8)	169.9 d	
	Procure 480SC 8.0 fl oz	0.0 f	0.0 h	(100.0)	0.0 f	(100.0)	0.0 e	
	Quintec 2.08SC 6.0 fl oz	0.0 f	1.8 fg	(97.2)	1.4 f	(98.4)	10.1 e	
	Rally 40WSP 5.0 oz	0.0 f	0.0 h	(100.0)	0.4 f	(99.5)	1.0 e	
	Torino 0.85SC 3.4 fl oz	1.1 ef	4.6 ef	(93.2)	7.3 de	(91.4)	37.2 e	
	MBI-10612 24 fl oz	11.7 c	34.7 c	(47.9)	57.5 b	(32.8)	277.3 c	
	MBI-10612 32 fl oz	11.3 c	29.2 cd	(56.1)	44.4 bc	(48.1)	234.0 cd	
	Non-treated control	30.8 b	66.6 b		85.5 a		511.1 b	
		P-value	<0.0001	<0.0001		<0.0001		<0.0001
Piketon ^u	Aprovia Top EC 13.5 fl oz	0.0 e	0.3 fg	(97.7)	0.4 g	(98.7)	2.3 f	
	Bravo Weather Stik 6SC 48 fl oz	18.9 a	34.9 a	(0.0)	60.3 a	(0.0)	311.5 a	
	Fontelis 1.67SC 16.0 fl oz	5.1 bc	9.9 bc	(26.6)	21.6 bcd	(33.1)	99.3 bcd	
	Inspire Super EW 20.0 fl oz	0.0 e	0.1 fg	(99.1)	1.1 g	(96.7)	5.6 ef	
	Merivon Xemium 2.09SC 5.5 fl oz	4.8 bc	11.1 bc	(17.8)	18.1 bcde	(43.9)	102.8 bcd	
	Pristine WG 18.5 oz	5.1 bc	11.8 bc	(12.9)	28.5 bc	(11.7)	130.1 bc	
	Procure 480SC 8.0 fl oz	0.0 e	0.0 g	(99.9)	0.0 g	(100.0)	0.2 f	
	Quintec 2.08SC 6.0 fl oz	0.1 e	1.9 ef	(86.0)	2.2 fg	(93.2)	11.8 ef	
	Rally 40WSP 5.0 oz	0.0 e	0.0 g	(100.0)	0.0 g	(100.0)	0.0 f	
	Torino 0.85SC 3.4 fl oz	1.5 d	3.5 de	(74.4)	8.5 ef	(73.6)	35.6 ef	
	MBI-10612 24 fl oz	3.3 cd	6.5 cd	(51.9)	15.6 cde	(51.4)	68.1 cde	
	MBI-10612 32 fl oz	1.4 d	4.1 de	(70.1)	11.0 de	(65.8)	42.2 def	
	Non-treated control	7.2 b	13.6 b		32.2 b		143.7 b	
		P-value	<0.0001	<0.0001		<0.0001		<0.0001

^zDisease ratings after application based on a scale of 0-100% foliage affected using a rating scale that illustrates powdery mildew at 0.5, 1, 2, 4, 8, 16, 32, 64, and 80 percent foliage affected.

^yValues are the back-transformed means of leaf 1 and 2, upper surface only.

^xMeans followed by the same lower case letter within a column are not significantly different at P<0.05. Means were separated using Fisher’s least significant difference test on angular transformed data.

^wOhio North Central Agricultural Research and Development Center Snyder Farm, Fremont, OH.

^vOhio Agricultural Research and Development Center Western Agricultural Research Station, South Charleston, OH.

^uOSU South Centers, Piketon, OH.

^lPercentage control values were calculated for each plot according to the formula: [(SC – ST)/SC]*100 where SC is the average severity on the non-treated control and ST is the average severity on the treatment.

^sArea under the disease progress curve values were calculated according to the formula: $\sum ((x_i+x_{i-1})/2)(t_i-t_{i-1})$ where x_i is the rating at each evaluation time and (t_i-t_{i-1}) is the number of days between evaluations.

FRAC	Product and rate/A	2017 – late season inoculum			
		Very good in 3 of 3 locations	Very good in 2 of 3 locations	Very good in 1 of 3 locations	Fair or poor
3	Procure 480SC 8.0 fl oz	X			
3	Rally 40WSP 5.0 oz	X			
13	Quintec 2.08SC 6.0 fl oz		X		
3,7	Aprovia Top EC 13.5 fl oz		X		
3,9	Inspire Super EW 20.0 fl oz		X		
7	Fontelis 1.67SC 16.0 fl oz			X	
7,11	Merivon Xemium 2.09SC 5.5 fl oz			X	
U6	Torino 0.85SC 3.4 fl oz			X	
7,11	Pristine WG 18.5 oz				X
M5	Bravo Weather Stik 6SC 48 fl oz				X
	MBI-10612 24 fl oz				X
	MBI-10612 32 fl oz				X

Figure 3. Summary of fungicide efficacy across locations against powdery mildew in a bioassay – late season inoculum.