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Project title – Fungicide-resistance and strategies for maintenance of fungicide efficacy for control of powdery mildew of melons in California

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Objectives

1) To develop a fungicide-resistance testing protocol so that growers can have their isolates tested cost-effectively.
2) To continue to assess fungicide resistance to *Podosphaera xanthii* in California with addition of Quintec (FRAC Resistance Group 13).
3) To continue to assess strategies for fungicide-resistance management for powdery mildew on melons.

Summary of Research Results:

Podosphaera xanthii (synonyms, *P. fusca*, *Sphaerotheca fuliginea*) is the major causal agent of powdery mildew on melons in California. In 2012, we tested the efficacy of ten recently collected isolates *Podosphaera xanthii* to a range of concentrations of nine fungicides. All 10 isolates were highly sensitive to Quintec (FRAC resistance group 13). Nine of the isolates were highly sensitive to Rally (a DMI, FRAC group 3) and only one was moderately sensitive. The other seven fungicides were not efficacious with all isolates. With Procure (another member of FRAC group 3), two of the isolates were highly sensitive, five were moderately sensitive, and three were moderately resistant. With Topsin (FRAC group 1), nine isolates were highly resistant and one isolate was moderately resistant, i.e., Topsin would not be a good use of grower funds for disease control. Pristine is formulated with two fungicides, a “SDHI” in FRAC group 7 and a QoI in FRAC group 1); two isolates were highly sensitive, six isolates were moderately sensitive and one isolate was moderately resistant. There is widespread resistance and/or comprised efficacy amongst *P. xanthii* isolates to the QoI fungicide group (FRAC group 1). With Quadris (FRAC group 1), six of the isolates were highly resistant, three were moderately resistant, and one was moderately sensitive. Similarly, with Flint (FRAC group 1), six of the isolates also were highly resistant, three of the isolates were moderately resistant, and one isolate was moderately sensitive. With Cabrio (FRAC group 1), five of the isolates were highly resistant, three were moderately resistant, but two were highly sensitive. Sovran (FRAC group 1) had greater efficacy than the other QoIs. With Sovran (FRAC group 1), only one isolate was highly resistant, three isolates were moderately resistant, one was moderately sensitive, and five isolates were highly sensitive. In comparison to results in 2011, resistance is widespread but not uniform across FRAC group 1, and resistance may be developing to Pristine and to Procure.

Results

Isolates were collected with the assistance of our cooperators. Conidia of all isolates were first examined microscopically for fibrosin bodies, and were all consistent with being *P. xanthii* (synonyms, *P. fusca, Sphaerotheca fuliginea*). We have not observed *Erysiphe cichoracearum* (=*Golovinomyces cichoracearum)*, which occasionally causes powdery mildew on melons.

Isolates were single colony purified in two cycles on surface-sterilized zucchini leaves to both obtain single isolates and to multiply conidia. All isolates have been stored on silica gel at -70 °C, essentially as described by Pérez-Garcia et al. (2006); recovery has been checked periodically and survival is good. Bioassays were conducted essentially as described by López-Ruiz et al. (2010) except that the density of spore suspensions is carefully controlled. Each isolate was screened on surface-sterilized, 10 to 12 day old cotyledonary zucchini leaves. For each of two replicates in each of either one or two independent trials, there were five leaf discs, each 0.4 inches across. To apply the fungicide, a 5.5 cm diameter Whatman 1 filter paper was soaked with 3 ml of four treatments: water for the untreated; the indicated fungicide with the lowest and the highest recommended dose; and 1/10 of the lowest recommended dose, as an indication of residual activity. The leaf discs were then placed upside down on the treatment for 24 hours at 68 °F. Then leaf discs were transferred to sterilized filter paper and placed on a sucrose (0.02M)-mannitol (0.1M)-0.8% agar medium with tetracycline.(Bardin et al. 2007). After 8 days at approximately 68 °F, leaf discs were scored as follows: 0, no mildew seen; 1, visible mildew, but on less than 5% of the leaf surface; 2, sporulation but only on 1/20 to ¼ of the leaf surface; 3, sporulation on more than ¼ but less than ½ of the leaf surface; 4, sporulation on more than ½, but less than ¾ of the leaf surface; and 5. at least ¾ of the leaf disc sporulating (Ishii et al. 2001). Pictures of each of the scores are shown in our 2011 report.

A summary of our results in comparison to last year's results are shown in Table 1. More detailed summary results from 2012 are shown in Table 2. Last year, all isolates were resistant to Topsin (FRAC Resistance Group 1); this year 90% of the isolates were resistant. As last year, all isolates were sensitive to Rally (FRAC resistance group 3), but in contrast to last year, 30% of isolates were resistant to Procure, another FRAC resistance group 3 fungicide. Critically, as with last year, most of the isolates were resistant to the strobilurins (QoI inhibitors, FRAC group 11). Consequently, this year we expanded tests of the strobilurins.and found both evidence of some cross resistance within the group, most strongly with Quadris and Flint, as well as some differences within the strobilurins, with efficacy in just some isolates, particularly in Sovran and Cabrio. Although 60% of the isolates were at least somewhat sensitive to the QoI Sovran, 80% or more of the isolates were resistant to the Quadris, Flint and Cabrio. Table 3 has data from the Pesticide Use Reports as estimates of grower use of fungicides. While we did not confirm that application dates during the period were most likely used for powdery mildew control, the data suggest that there are applications of Quadris (and/or Quadris Top) and Cabrio in which the grower is unlikely to get the full value of the cost of a patented fungicide.

One of our objectives was to develop a fungicide-resistance testing protocol so that growers can have their isolates tested cost-effectively. Assuming application and material costs at $40/acre, application of a 150 acre melon field costs the grower $6,000 plus costs of any additional sprays that are needed due to less than full control, plus any loses from the impact of powdery mildew on quality or harvestable quantity. We currently can test a grower's isolate for fungicide sensitivity for $450; the relatively high cost is primarily because "culturing" powdery mildew is labor-intensive. Ultimately, we might be able to reduce costs further by either simplifying the protocol or by using a DNA-based polymerase chain reaction (PCR) test that could detect specific mutations that confer fungicide resistance. However, a PCR strategy would require additional research.

Surprisingly, the Fresno isolate from 2012 developed chasmothecia, the sexual structures, on zucchini leaves in the laboratory. This might provide a mechanism for generating fungicide resistance in this fungus.

For best fungicide efficacy, we recommend that growers either have their isolates tested for fungicide-sensitivity or they avoid use of FRAC resistance group 11 fungicides. Fresno county Farm Advisor Tom Turini has performed trials on powdery mildew control on melons with fungicides that are mostly unregistered but that may be registered in the near future. Most fungicides provided a level of control, with few statistically significant differences among treatments. We note that many of the new materials are blends (Luna Sensation, with a FRAC groups 11 and 7; Priaxor, with a FRAC groups 11 and 7; and Inspire Super, with FRAC groups 3 and 40). Because our California *P. xanthii* isolates have widespread and often cross-resistance to other FRAC group 11 fungicides, it is unclear that new materials containing a FRAC group 11 compound will warrant the premium price. In addition, we have evidence for the emergence of resistance in a FRAC group 7 compound, which should be monitored carefully.

Table 1. Summary of results on resistance to fungicides of *Podosphaera xanthii* from melons in California in 2011 and 2012.

Mode of action	FRAC group	Fungicide	2011, n=12	2012, n=10
			Resistant isolates, %[a]	
QoI	11	Quadris[b]	83	90
QoI	11	Flint[c]	83	90
QoI	11	Cabrio	Not tested	80
QoI	11	Sovran	Not tested	40
SDHI & QoI	7 & 11	Pristine[d]	0	10
B-tubulin	1	Topsin	100	90
DMI	3	Procure	0	30
DMI	3	Rally	0	0
(Signal transduction)	13	Quintec	Not tested	0

[a] Leaf discs were scored on a scale of 0 to 5. For each isolate, there were four discs per replicate, two replicates per trial, two trials in 2011, and either one or two trials. The average of untreated discs was 3.6 or higher. Discs with an average of 2 or higher were considered fungicide-resistant, although there was some control

[b] Azoxystrobin is the sole ingredient in Quadris, and one of the two fungicides in Quadris Top.

[c] Trifloxystrobin, the active ingredient in Flint, is also one of the two fungicides in Luna Sensation, which is registered in watermelon, and may be registered in melons soon.

[d] Pristine includes the active ingredient in Cabrio, in addition to the SDHI boscalid.

Table 2. Predicted efficacy of fungicides on California isolates collected in 2012 that cause powdery mildew of melon.

Host, Source, (Isolate name)	Fungicide	Fungicide concentration, recommended dose	Score 0 (protected) to 5 (max disease)	Standard error of 4 replicates[a]	Isolate sensitivity to fungicide
Melon, Fresno Co. (M-FS-1)	Untreated	Untreated	**4.4**	0.4	-
	Flint	Highest	**3.1**	0.5	Moderately resistant
		Lowest	**2.5**	0.1	
		1/10 the lowest	**3.7**	0.1	
	Quadris	Highest	**3.6**	0.4	Resistant
		Lowest	**3.5**	0.1	
		1/10 the lowest	**3.8**	0.2	
	Sovran	Highest	**0.3**	0.3	Moderately sensitive
		Lowest	**2.2**	0.7	
		1/10 the lowest	**2**	0.2	
	Cabrio	Highest	**3.1**	0.1	Moderately resistant
		Lowest	**2.8**	0	
		1/10 the lowest	**3.9**	0.3	
	Procure	Highest	**0**	0	Sensitive
		Lowest	**0.1**	0.1	
		1/10 the lowest	**3.4**	0.2	
	Rally	Highest	**0**	0	Sensitive
		Lowest	**0**	0	
		1/10 the lowest	**3.3**	0.3	
	Topsin	Highest	**3.7**	0.1	Highly resistant
		Lowest	**3.7**	0.1	
		1/10 the lowest	**4.1**	0.1	
	Pristine	Highest	**0**	0	Sensitive
		Lowest	**1.1**	0.3	
		1/10 the lowest	**2.8**	0.2	
	Quintec	Highest	**0**	0	Highly sensitive
		Lowest	**0**	0	
		1/10 the lowest	**0**	0	
Watermelon, San Joaquin Co. (WM-SJ-1)	**Untreated**	**Untreated**	**4.1**	0.1	**-**
	Flint	Highest	**3.5**	0.1	Resistant
		Lowest	**3.7**	0.3	
		1/10 the lowest	**3.4**	0.2	
	Quadris	Highest	**2.6**	0.6	Moderately resistant
		Lowest	**2.7**	0.3	

CONTINUED Host, Source, (Isolate name)	Fungicide	Fungicide concentration, recommended dose	Score 0 (protected) to 5 (max disease)	Standard error of 4 replicates[a]	Isolate sensitivity to fungicide
	Quadris	1/10 the lowest	**3.2**	0.4	
	Sovran	Highest	**2.4**	0.4	Moderately resistant
		Lowest	**2.4**	0.4	
		1/10 the lowest	**2.9**	0.3	
	Cabrio	Highest	**0**	0	Highly sensitive
		Lowest	**0**	0	
		1/10 the lowest	**2.3**	0.1	
	Procure	Highest	**0.4**	0.2	Sensitive
		Lowest	**1**	0.4	
		1/10 the lowest	**2.9**	0.1	
	Rally	Highest	**0**	0	Sensitive
		Lowest	**1.3**	1.3	
		1/10 the lowest	**2.3**	0.5	
	Topsin	Highest	**2.9**	0.1	Moderately resistant
		Lowest	**3.2**	0.2	
		1/10 the lowest	**3.2**	0.2	
	Pristine	Highest	**0**	0	Highly sensitive
		Lowest	**0**	0	
		1/10 the lowest	**2.2**	0.4	
	Quintec	Highest	**0**	0	Highly sensitive
		Lowest	**0**	0	
		1/10 the lowest	**0**	0	
Watermelon San Joaquin Co. (WM-SJ-2)	**Untreated**	**Untreated**	**4.8**	0.2	-
	Flint	Highest	**3.4**	0.4	Highly resistant
		Lowest	**4**	0.2	
		1/10 the lowest	**4.3**	0.1	
	Quadris	Highest	**3.8**	0.2	Highly resistant
		Lowest	**4.1**	0.3	
		1/10 the lowest	**4.7**	0.1	
	Sovran	Highest	**0**	0	Highly sensitive
		Lowest	**0**	0	
		1/10 the lowest	**3.3**	0.1	
	Cabrio	Highest	**3.6**	0.2	Highly resistant
		Lowest	**4.3**	0.3	

CONTINUED Host, Source, (Isolate name)	Fungicide	Fungicide concentration, recommended dose	Score 0 (protected) to 5 (max disease)	Standard error of 4 replicates[a]	Isolate sensitivity to fungicide
	Cabrio	1/10 the lowest	**4.7**	0.3	
	Procure	Highest	**0.7**	0.3	Sensitive
		Lowest	**1.7**	0.1	
		1/10 the lowest	**4.6**	0.2	
	Rally	Highest	**0**	0	Highly sensitive
		Lowest	**0**	0	
		1/10 the lowest	**3.4**	0	
	Topsin	Highest	**4.2**	0	Highly resistant
		Lowest	**4.5**	0.1	
		1/10 the lowest	**4.9**	0.1	
	Pristine	Highest	**0.4**	0.2	Sensitive
		Lowest	**0.9**	0.3	
		1/10 the lowest	**3.3**	0.1	
	Quintec	Highest	**0**	0	Highly sensitive
		Lowest	**0**	0	
		1/10 the lowest	**0**	0	
Watermelon, San Joaquin Co. (WM-SJ-3)	**Untreated**	**Untreated**	**4.9**	0.1	-
	Flint	Highest	**3.7**	0.1	Highly resistant
		Lowest	**4.6**	0	
		1/10 the lowest	**4.6**	0	
	Quadris	Highest	**2.8**	0.4	
		Lowest	**3.8**	0.2	Resistant
		1/10 the lowest	**4.7**	0.1	
	Sovran	Highest	**0**	0	Highly sensitive
		Lowest	**0**	0	
		1/10 the lowest	**2.3**	0.5	
	Cabrio	Highest	**3.9**	0.1	Highly resistant
		Lowest	**3.7**	0.1	
		1/10 the lowest	**4.6**	0.2	
	Procure	Highest	**0**	0	
		Lowest	**1.4**	0	Sensitive
		1/10 the lowest	**3.5**	0.1	
	Rally	Highest	**0**	0	Highly sensitive
		Lowest	**0**	0	
		1/10 the lowest	**3.7**	0.3	
	Topsin	Highest	**3.4**	0.2	
		Lowest	**3.2**	0.2	Resistant

CONTINUED Host, Source, (Isolate name)	Fungicide	Fungicide concentration, recommended dose	Score 0 (protected) to 5 (max disease)	Standard error of 4 replicates[a]	Isolate sensitivity to fungicide
	Topsin	1/10 the lowest	**4.4**	0.2	
	Pristine	Highest	**0.1**	0.1	
		Lowest	**1.3**	0.3	Sensitive
		1/10 the lowest	**2.9**	0.1	
	Quintec	Highest	**0**	0	Highly sensitive
		Lowest	**0**	0	
		1/10 the lowest	**0**	0	
Cantaloupe, Yolo Co. C-YO-UCD-1	**Untreated**	**Untreated**	**4.1**	0.4	-
	Flint	Highest	**2.6**	0.2	Moderately resistant
		Lowest	**2.9**	0.1	
		1/10 the lowest	**2.8**	0.2	
	Quadris	Highest	**2.6**	0	Moderately resistant
		Lowest	**2.2**	0.2	
		1/10 the lowest	**2.7**	0.1	
	Sovran	Highest	**3.7**	0.1	Highy resistant
		Lowest	**3.7**	0.3	
		1/10 the lowest	**3.8**	0.2	
	Cabrio	Highest	**0**	0	Highly sensitive
		Lowest	**0**	0	
		1/10 the lowest	**0**	0	
	Procure	Highest	**0.7**	0.5	Moderately sensitive
		Lowest	**1.5**	0.1	
		1/10 the lowest	**3**	0	
	Rally	Highest	**0**	0	Sensitive
		Lowest	**0.1**	0.1	
		1/10 the lowest	**2.2**	0	
	Topsin	Highest	**3.3**	0.1	Highly resistant
		Lowest	**3.6**	0.4	
		1/10 the lowest	**3.6**	0	
	Pristine	Highest	**0**	0	Highly sensitive
		Lowest	**0**	0	
		1/10 the lowest	**0.2**	0.2	
	Quintec	Highest	**0**	0	Highly sensitive
		Lowest	**0**	0	
		1/10 the lowest	**0**	0	

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Host, Source, (Isolate name)	Fungicide	Fungicide concentration, recommended dose	Score 0 (protected) to 5 (max disease)	Standard error of 4 replicates[a]	Isolate sensitivity to fungicide
Honeydew, Yolo Co. (HM-YO-SW)	**Untreated**	**Untreated**	**4.7**	0.1	-
	Flint	Highest	**1.1**	0.3	Moderately sensitive
		Lowest	**1.1**	0.1	
		1/10 the lowest	**2.5**	0.3	
	Quadris	Highest	**2.4**	0	Moderately resistant
		Lowest	**2.4**	0.2	
		1/10 the lowest	**3.3**	0.1	
	Sovran	Highest	**0**	0	Highly sensitive
		Lowest	**0**	0	
		1/10 the lowest	**0**	0	
	Cabrio	Highest	**2.4**	0.2	Moderately resistant
		Lowest	**2.7**	0.1	
		1/10 the lowest	**2.5**	0.3	
	Procure	Highest	**1.8**	0.4	Moderately resistant
		Lowest	**2.2**	0.4	
		1/10 the lowest	**3.1**	0.1	
	Rally	Highest	**0**	0	Highly sensitive
		Lowest	**0**	0	
		1/10 the lowest	**3**	0.2	
	Topsin	Highest	**3.2**	0.4	Highly resistant
		Lowest	**3.5**	0.1	
		1/10 the lowest	**3.6**	0.2	
	Pristine	Highest	**1.1**	0.5	Moderately sensitive
		Lowest	**0.9**	0.5	
		1/10 the lowest	**2.9**	0.3	
	Quintec	Highest	**0**	0	Highly sensitive
		Lowest	**0**	0	
		1/10 the lowest	**0.3**	0.3	
Honeydew, Yolo Co. (HM-YO-Ridge)	**Untreated**	**Untreated**	**3.6**	0	-
	Flint	Highest	**1.9**	0.9	Resistant
		Lowest	**2.9**	0.1	
		1/10 the lowest	**3.1**	0.1	
	Quadris	Highest	**1.7**	0.3	Moderately sensitive
		Lowest	**1.6**	0	
		1/10 the lowest	**2.5**	0,1	
	Sovran	Highest	**0**	0	Highly sensitive
		Lowest	**0**	0	

CONTINUED Host, Source, (Isolate name)	Fungicide	Fungicide concentration, recommended dose	Score 0 (protected) to 5 (max disease)	Standard error of 4 replicates[a]	Isolate sensitivity to fungicide
	Sovran	1/10 the lowest	**0**	0	
	Cabrio	Highest	**0**	0	Somewhat resistant
		Lowest	**2.7**	0.1	
		1/10 the lowest	**3.1**	0.1	
	Procure	Highest	**2.9**	0.1	Moderately resistant
		Lowest	**2.7**	0.1	
		1/10 the lowest	**2.8**	0	
	Rally	Highest	**0**	0	Highly sensitive
		Lowest	**0**	0	
		1/10 the lowest	**2.1**	0.1	
	Topsin	Highest	**2.2**	0	Moderately resistant
		Lowest	**2.9**	0.5	
		1/10 the lowest	**3.3**	0.1	
	Pristine	Highest	**0.2**	0.2	Somewhat resistant
		Lowest	**2.6**	0.2	
		1/10 the lowest	**3**	0.2	
	Quintec	Highest	**0**	0	Highly sensitive
		Lowest	**0**	0	
		1/10 the lowest	**0**	0	
Honeydew, Yolo Co. (HM-YO-112)	**Untreated**	**Untreated**	**4.7**	0.1	-
	Flint	Highest	**4.2**	0.4	Highly resistant
		Lowest	**4.5**	0.1	
		1/10 the lowest	**4.5**	0.1	
	Quadris	Highest	**3.8**	0.2	Highly resistant
		Lowest	**4.4**	0	
		1/10 the lowest	**4.7**	0.1	
	Sovran	Highest	**0.4**	0.4	Sensitive
		Lowest	**1.4**	0	
		1/10 the lowest	**3.1**	0.3	
	Cabrio	Highest	**3.2**	0.2	Resistant
		Lowest	**3.4**	0	
		1/10 the lowest	**4.1**	0.3	
	Procure	Highest	**0**	0	Sensitive
		Lowest	**0.5**	0.1	
		1/10 the lowest	**3.7**	0.1	
	Rally	Highest	**0**	0	Highly sensitive
		Lowest	**0**	0	
		1/10 the lowest	**3.5**	0.3	

CONTINUED Host, Source, (Isolate name)	Fungicide	Fungicide concentration, recommended dose	Score 0 (protected) to 5 (max disease)	Standard error of 4 replicates[a]	Isolate sensitivity to fungicide
	Topsin	Highest	**4.5**	0.1	Highly
		Lowest	**4.1**	0.1	resistant
		1/10 the lowest	**4.7**	0.1	
	Pristine	Highest	**0**	0	Sensitive
		Lowest	**1.1**	0.3	
		1/10 the lowest	**3.9**	0.1	
	Quintec	Highest	**0**	0	Highly
		Lowest	**0**	0	Sensitive
		1/10 the lowest	**0**	0	
Canary melon,	**Untreated**	**Untreated**	**5**	0	-
Yolo Co.	Flint	Highest	**3.3**	0.3	Highly
(JCM-YO-112)		Lowest	**3.3**	0.1	resistant
		1/10 the lowest	**4**	0.4	
	Quadris	Highest	**3.7**	0.1	Highly
		Lowest	**3.7**	0.3	resistant
		1/10 the lowest	**4.5**	0.1	
	Sovran	Highest	**0**	0	Sensitive
		Lowest	**2**	0.2	
		1/10 the lowest	**3.1**	0.1	
	Cabrio	Highest	**3.5**	0.1	Highly
		Lowest	**3**	0.2	resistant
		1/10 the lowest	**3.3**	0.1	
	Procure	Highest	**0**	0	Highly
		Lowest	**0**	0	Sensitive
		1/10 the lowest	**3.5**	0.3	
	Rally	Highest	**0**	0	Highly
		Lowest	**0**	0	Sensitive
		1/10 the lowest	**2.9**	0.1	
	Topsin	Highest	**3.1**	0.1	Highly
		Lowest	**3.7**	0.1	resistant
		1/10 the lowest	**3.7**	0.3	
	Pristine	Highest	**0**	0	Highly
v		Lowest	**0**	0	sensitive
		1/10 the lowest	**3**	0.2	
	Quintec	Highest	**0**	0	Highly
		Lowest	**0**	0	sensitive
		1/10 the lowest	**0**	0	

CONTINUED Host, Source, (Isolate name)	Fungicide	Fungicide concentration, recommended dose	Score 0 (protected) to 5 (max disease)	Standard error of 4 replicates[a]	Isolate sensitivity to fungicide
Honeydew, Yolo Co., (HM-YO-NC)	**Untreated**	**Untreated**	**5**	0	-
	Flint	Highest	**3.7**	0.5	Highly resistant
		Lowest	**3.8**	0.2	
		1/10 the lowest	**4.5**	0.1	
	Quadris	Highest	**3.9**	0.3	Highly resistant
		Lowest	**4.2**	0.2	
		1/10 the lowest	**4.7**	0.3	
	Sovran	Highest	**0**	0	Highly sensitive
		Lowest	**0**	0	
		1/10 the lowest	**2.4**	0.2	
	Cabrio	Highest	**3.9**	0.1	Highly resistant
		Lowest	**3.8**	0	
		1/10 the lowest	**4.2**	0.2	
	Procure	Highest	**0.6**	0	Moderately sensitive
		Lowest	**2.1**	0.3	
		1/10 the lowest	**3.6**	0.2	
	Rally	Highest	**0**	0	Highly sensitive
		Lowest	**0**	0	
		1/10 the lowest	**3.5**	0.1	
	Topsin	Highest	**3.8**	0.2	Highly resistant
		Lowest	**4.1**	0.1	
		1/10 the lowest	**4.3**	0.3	
	Pristine	Highest	**0**	0	Sensitive
		Lowest	**0.7**	0.1	
		1/10 the lowest	**3.1**	0.1	
	Quintec	Highest	**0**	0	Highly sensitive
		Lowest	**0**	0	
		1/10 the lowest	**0**	0	

[a]The scores are the means of two replicates each with five determinations per replicate.

Discussion

Podosphaera xanthii (synonyms, *P. fusca, Sphaerotheca fuliginea*) is the major causal agent of powdery mildew on melons in California. The fungus has a relatively wide host range; in addition to infecting many plants in the cucurbit family, *P. xanthii* infects multiple species in the Solanaceae. Fungicides are critical for sustained disease control of *P. xanthii* on melons. However, our data show widespread resistance to QoIs (strobilurins, FRAC resistance Group 11) and Topsin (FRAC group I); we note that QoIs might still have some, albeit diminished, efficacy against the QoI-resistant isolates. That is, genetic changes to fungicide resistance can confer either quantitative or qualitative differences (McGrath 2001). In addition, this year, we have indications of developing resistance in FRAC resistance groups 3 and 7.

Table 3. Department of Pesticide Regulations' 2010 Pesticide Use Reports (PUR) for fungicides on melons that were probably used for powdery mildew control[a].

Fungicide active ingredient	Fungicides	Was fungicide resistance detected in 2012? [b]	DPR PUR 2010 data for melons	
			Lbs. applied	Acres treated[c]
Azoxystrobin	**Quadris, one component of Quadris Top**	**Yes**	**254**	**2,253**
Boscalid	Endura, one component of Pristine	Possible (only tested Pristine)	5	26
Chlorothalonil	Bravo, Chloronil, (others)	Not tested, but unlikely	1,457	1,032
Kresoxim-methyl	Sovran	Some	86	621
Myclobutanil	Rally	No	524	4,606
Pyraclostrobin	**Cabrio**	**Many**	**323**	**2,100**
Quinoxyfen	Quintec	No	69	916
Sulfur	(Many)	Not tested, but highly unlikely	24,325	2,856
Thiophanate-methyl	Topsin	Yes	11	,,,,,31
Trifloxystrobin	Flint	Yes	39	,,,530
Triflumizole	*Procure*	*Some*	*423*	*2,122*

[a]Fungicides that were applied onto melons in 2010 onto more than 2,000 acres and in which fungicide-resistance seems common based on our data are bolded. Fungicides that were applied in 2010 onto more than 2,000 acres and in which fungicide-resistance was not common but detected are in italics.
[b] Based on our data, summarized in Table 1.
[c] An acre that is treated twice is counted as two treated acres.

California is not unique in having fungicide-resistant *P. xanthii*. *P. xanthii* previously has been reported both in the U.S. and internationally multiple times (Ortuno *et al.* 2006 & 2008a; FRAC 2007; Heaney *et al.* 2000; Ishii *et al.* 2001; López-Ruiz et al. 2010; McGrath 2008; McGrath & Shishkoff 2003a&b; Miazzi & McGrath 2008; Naegler *et al.* 1977; Schepers 1983, 1984 & 1985; Schroeder & Providenti 1971). Clearly sustained fungicide efficacy will require careful management of fungicide use. Currently, the main UCCE recommendation for controlling or at least delaying fungicide resistance is to alternate fungicides with different modes of action. That is, if fungicides in either groups 1, 3, 7, 11, or 13 are used, they should be followed by a fungicide in a different group. However, there are several potential complications. One, whether or not alternation actually delays the development of field-level fungicide resistance depends upon there being a "fitness cost" of fungicide resistance (van den Bosch F & Gilligan 2008); sometimes there is, but often there is not. For example, in powdery mildew on wheat, the researchers could not detect any fitness cost of strobilurin resistance (Chin et al. 2001). (Here's an explanation of fitness costs…After fungicide resistance appears in a population, when the fungicide is present, those cells with the resistance will be selected for and will reproduce to a greater extent than the susceptible population. For alternation to suppress the development of field-level resistance, in the absence of the fungicide, the fungicide-sensitive population must reproduce to a greater extent than the fungicide-resistant population. If the fungicide-sensitive population does out-reproduce the fungicide-resistant population in the absence of the fungicide, there is a “fitness cost” to fungicide resistance, and the extent that fungicide-resistance isolates declines depends upon the cost. If there isn’t a fitness cost, the resistant population will remain at the proportion that it was the last time that the fungicide of interest was applied). Interestingly, two Monterey Co. isolates from Jim McCreight that we examined in 2011 apparently were not exposed for four or more years to any of the fungicides to which they were resistant; this suggests that there might not be a fitness cost of their fungicide resistance. It is unknown whether there is a fitness cost for any of the fungicide resistances in any California melon isolates. Secondly, the recommendation for alternation of fungicides with different modes of action is based on the fact that resistance to fungicides in each group can be caused by a spontaneous mutation in a single site, e.g., resistance in group 11 is caused by a mutation in the “**q**uinone **o**utside *i*nhibitor” (QoI). However, just as there are multi-drug resistant bacterial pathogens of humans, there are plant pathogenic fungi that can have spontaneous mutations in various “transporters” (typically ABC and MFS) that confer multi-fungicide resistance (e.g., deWard et al. 2006, Kretschmer et al. 2009). Basically, the transporters are “pumps” in the membranes that expel fungicides and other toxins from the fungus. Typically, in fungi with multi-fungicide resistance, the mutations are in the regulatory portion of the genes (the promoters), and the mutant transporters are “constitutively” active, i.e., they expel fungicides (and other toxins) all the time. The best strategy for avoiding development of multi-drug resistance is unclear. Regardless, alternation of fungicides in different groups does not reduce risk from this kind of resistance, because this resistance spans multiple (although not all) groups (Kretschmer et al. 2009). Thirdly, the fungicides Pristine and Quadris Top contain two fungicides, each from a different group. Growers should be aware that fungicide manufacturers are increasingly introducing mixes with two fungicides, and some of them will likely be available for powdery mildew control in the near future, e.g., Merivon, Priaxor, Luna Sensation, Revus Top, and Inspire Super. Although the fungicide manufacturers have argued that mixes will decrease the likelihood of fungicide resistance (FRAC, 2010), this is debatable point, and it is at least unclear to what extent the mixes are a sales strategy in which the lack of efficacy of a product is obscured by a efficacious product. Regardless, if one is following the alternation strategy, Pristine for example should not be followed by any fungicide in either groups 7 or 11. To summarize, the current UCCE recommendations to alternate fungicides in different groups addresses one kind of risk of fungicide resistance but not necessarily all kinds of fungicide resistance in California melons.

We have identified a high incidence of fungicide-resistance in the two FRAC risk groups (11 and 1), and what appears to be emerging resistance in FRAC groups 7 and 3. As indicated above, the UCCE and FRAC recommendations are based on a resistance mechanism that would affect, in the case of the QoIs (FRAC Resistance Group 11) the binding of the strobilurin fungicide to a molecule in the fungus called cytochrome b (Fernandez-Ortuno et al. 2008a). If so, it is likely that isolates that are resistant to Quadris and Flint would also be resistant to all QoIs, e.g., Cabrio, Sovran and pyraclostrobin, the strobilurin in Pristine; indeed we have some isolates that are resistant to all four fungicides in FRAC Resistance Group 11. Importantly, if indeed there is a fitness cost to resistance to QoI’s, then fungicide-resistant populations would decrease when the fungicides are not being used, and the fungicides could be rationally cycled out and back into use. However, as also indicated above, there also may be a mutation in an efflux transporter, which may explain why some of our isolates are resistant to four different FRAC Resistance Groups. To conclude, we recommend that melon growers contact us to see if we can assay their powdery mildew for fungicide resistance (lepstein@ucdavis.edu). Without assays, we recommend that growers alternate between the following: sulfur if conditions are acceptable; Pristine; Procure (if label restrictions permit); and Quintec. We note that Quintec is only effective if applied preventatively or at very early stages of disease development. Although Rally has done well in our trials, it has not done as well in California field trials.

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