

## Fungicide Resistance Management Guidelines for Cucurbit Downy and Powdery Mildew Control in the Mid-Atlantic and Northeast Regions of the United States in 2018

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In the mid-Atlantic and Northeast regions of the United States, approximately 17,500 farms produce vegetable crops annually with a value of more than \$1.2 billion (NASS 2012). Over 60,000 acres of cucurbit crops were grown in both regions in 2012 (NASS 2012). In recent years, several new fungicide chemistries and modes-of-action (MOAs) labeled for use in vegetable production have been registered in the United States. Many of these fungicides have MOAs that target pathogen development at a single site. Fungicides with a single-site MOA are often considered at high risk for the development of fungal resistance and possess a much greater risk for resistance development than fungicides with multiple MOAs (i.e., protectant fungicides such as chlorothalonil). In the mid-Atlantic region in recent years, fungicide resistance has developed in important cucurbit pathogens, such as *Podospaera* (sect. *Sphaerotheca*) *xanthii* (Castagne) U. Braun & Shishkoff causing powdery mildew (McGrath 2001; McGrath and Wyenandt 2017; Wyenandt et al. 2008) and *Didymella bryoniae* (Auersw.) Rehm causing gummy stem blight in watermelon (Everts 1999).

Since 2007, a fungicide resistance management guide has been available to vegetable growers in the mid-Atlantic region to help manage resistance development (Wyenandt et al. 2009b). Now in its 12th edition, over 25,000 hard copies of these guidelines have been distributed to cucurbit growers in the mid-Atlantic and Northeast regions (Wyenandt, *personal communication*). The guide is now available online for free through a number of university websites in the region. In 2009, the first fungicide resistance management table for the control of cucurbit downy and powdery mildew was developed (Wyenandt et al. 2009a). Since that time, there have been significant changes in the efficacy of some recommended fungicides and availability of new active ingredients for the control of both pathogens. The updated fungicide resistance management table consists of currently recommended fungicides listed for the control of cucurbit downy mildew and powdery mildew from commercial recommendations guides developed for the mid-Atlantic region (Pennsylvania, New Jersey, Delaware, Maryland, Virginia, and West

Virginia), New York, and the Northeast region (Maine, New Hampshire, Vermont, Connecticut, Massachusetts, and Rhode Island). The table lists labeled fungicides, their active ingredient(s), Fungicide Resistance Action Committee (FRAC) and risk management codes, and resistance management guidelines (Table 1). In the updated table are 41 labeled fungicides that include 23 different FRAC codes with their corresponding codes for risk of resistance development (L = low risk, M = medium risk, and H = high risk) established by FRAC (Table 1) (FRAC 2018). Importantly, the fungicides, active ingredients, and FRAC numbers are color-coordinated to help distinguish between fungicides belonging to the same FRAC code (i.e., similar MOAs). A superscript R next to the FRAC code indicates that resistance to that particular chemistry has been detected in the region. To denote if resistance management is required, a Y for yes or an N for no is listed (Table 1). Currently, 36 of 41 fungicides listed (88%) require the use of resistance management strategies to help reduce the chances for resistance development. To date, resistance has been detected in 6 of the 23 FRAC codes (1, 3, 4, 7, 11, and U6) (~22%) listed for either cucurbit powdery mildew or downy mildew control in both regions, and poor control has been noted in some recently (e.g., FRAC codes 33, 40, and 43) (Table 1). The current anticipated efficacy of each fungicide is denoted by the use of a plus system in which one (+) designates little or poor fungicide efficacy, two (++) equates poor to good efficacy, three (+++) designates good efficacy, four (++++) designates very good efficacy, and five (+++++) equals excellent efficacy. If control failure has been detected to a fungicide, the designated (+) signs are colored red, emphasizing that a particular fungicide/pathogen combination may be at risk for resistance development (Table 1).

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TABLE 1

2018 fungicide resistance management table for control of cucurbit downy mildew and powdery mildew in the mid-Atlantic and Northeast regions of the United States

Fungicide	Active ingredient(s)	FRAC code*	Risk rating**	Management required***	Efficacy ratings		General fungicide resistance management guidelines****
					Powdery mildew	Downy mildew	
Kocide 3000 or OLF	Fixed copper(s)	M1	L	N	+		FRAC code M fungicides are low-risk, protectant fungicides. Use alone, or tank mix with high-risk fungicides to improve control.
Microthiol or OLF	Sulfur	M2	L	N	++		
Manzate or OLF	EBDC	M3	L	N		++	
Bravo or OLF	Chlorothalonil	M5	L	N	++	++	
Topsin M	Thiophanate methyl	1	H <sup>R</sup>	Y	+		Select fungicides with at least ++ rating. Rotate among fungicides with different FRAC codes. Tank mix high-risk fungicides with FRAC code M product if the product is not formulated with a FRAC code M fungicide.
Proline	Prothioconazole	3	M <sup>R</sup>	Y	++++		
Procure	Triflumizole	3	M <sup>R</sup>	Y	+++		
Rally	Myclobutanil	3	M <sup>R</sup>	Y	++		
Folicur	Tebuconazole	3	M <sup>R</sup>	Y	++		
Rhyme	Flutriafol	3	M <sup>R</sup>	Y	++		
Inspire Super	Difconazole + cyprodinil	3 + 9	M <sup>R</sup> + M <sup>R</sup>	Y	+		
TopGuard EQ	Flutriafol + azoxystrobin	3 + 11	M <sup>R</sup> + H <sup>R</sup>	Y	++++		
Ridomil Gold Copper	Mefenoxam + copper	4 + M1	H <sup>R</sup> + L	Y		+	
Ridomil Gold Bravo	Mefenoxam + chlorothalonil	4 + M5	H <sup>R</sup> + L	Y		+	
Fontelis	Penthiopyrad	7	H <sup>R</sup>	Y	+		When resistance is qualitative (FRAC code 1 and 11 fungicides), resistant pathogen isolates are completely insensitive and cannot be controlled with the fungicide or another in the group due to cross resistance.
Luna Experience	Fluopyram + tebuconazole	7 + 3	M-H + M <sup>R</sup>	Y	+++		
Aprovia Top	Benzovindiflupyr + difenoconazole	7 + 3	M-H + M <sup>R</sup>	Y	+++		
Luna Sensation	Fluopyram + trifloxystrobin	7 + 11	M-H + H <sup>R</sup>	Y	++		
Pristine	Boscalid + pyraclostrobin	7 + 11	M-H <sup>R</sup> + H <sup>R</sup>	Y	+	+	
Quadris or OLF	Azoxystrobin	11	H <sup>R</sup>	Y	+	+	With quantitative resistance (FRAC Code 3 and 7 fungicides), pathogen isolates exhibit range in fungicide sensitivity, and efficacy depends on level of insensitivity and inherent activity of the active ingredient. Control may be obtained with most active chemistry, high label rates, and tight spray intervals.
Cabrio	Pyraclostrobin	11	H <sup>R</sup>	Y	+	+	
Flint	Trifloxystrobin	11	H <sup>R</sup>	Y	+		
Reason	Fenamidone	11	H <sup>R</sup>	Y		+	
Tanos	Famoxadone + cymoxanil	11 + 27	H + L-M	Y		+	
Quintec <sup>a</sup>	Quinoxifen	13	M <sup>R</sup>	Y	+++++		
Ranman	Cyazofamid	21	M - H	Y		+++	
Gavel	Zoxamide + mancozeb	22 + M3	L-M + L	Y		++	
Zing!	Zoxamide + chlorothalonil	22 + M5	L-M + L	Y		++	
Curzate	Cymoxanil	27	L - M	Y		++	
Ariston	Cymoxanil + chlorothalonil	27 + M5	L-M + L	Y		++	
Previcur Flex <sup>b</sup>	Propamocarb HCL	28	L - M	Y		+ /+++	<sup>a</sup> While resistance to Quintec has been confirmed, impact on control has not yet been documented, likely reflecting low numbers of resistant strains present. Use sparingly.
Omega	Fluazinam	29	L	N		+++	
Alliete	Aluminum tris	33	L <sup>R</sup>	Y		+	
Phosphonates	Phosphorous acid salts	33	L <sup>R</sup>	Y		+	
Forum <sup>b</sup>	Dimethomorph	40	L - M <sup>R</sup>	Y		+	
Revus <sup>b</sup>	Mandipropamid	40	L - M <sup>R</sup>	Y		+ /+++	<sup>b</sup> Revus is poor on cucumber. Presidio, Previcur Flex, and Forum have exhibited poor control in some recent fungicide evaluations.
Presidio <sup>b</sup>	Fluopicolide	43	H	Y		+ /++++	
Zapro	Ametoctradin + dimethomorph	45 + 40	M-H + L-M <sup>R</sup>	Y		+ /+++	
Orondis Ultra	Oxathiapiprolin + mandipropamid	49	H + L-M <sup>R</sup>	Y		++++	
Torino	Cyflufenamid	U6	M <sup>R</sup>	Y	+ /++++		
Vivando	Metrafenone	U8	M	Y	+++++		

Efficacy ratings: + = poor (not recommended), ++ = poor to good, +++ = good, ++++ = very good, +++++ = excellent; red font indicates control failures detected in the mid-Atlantic and Northeast regions.

\* FRAC code: M = multisite mode of action (MOA); numbered groups = fungicides with similar MOA; fungicides with the same number or color belong to the same FRAC code.

\*\* Risk ratings: L = low risk, M = moderate risk, and H = high risk for fungicide resistance to develop; <sup>R</sup> = resistance known to develop according to Fungicide Resistance Action Committee (FRAC 2018).

\*\*\* Risk management required according to fungicide label.

\*\*\*\* See fungicide label for specific crops, rates, and instructions on use.

Trade or brand names disclaimer: The trade or brand names given herein are supplied with the understanding that no discrimination is intended and no endorsement by the Cooperative Extension is implied. Furthermore, in some instances the same compound may be sold under different names, which may vary as to label clearances.

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