

# Integrated Management of Common Hop Diseases in Wisconsin



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of  
**WISCONSIN**  
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**Extension**  
Learning for life

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**Hop Production Seminar**  
**March 2, 2013 – 10:30-11:00AM**  
**Moose Jaw Inn, Wisconsin Dells, WI**

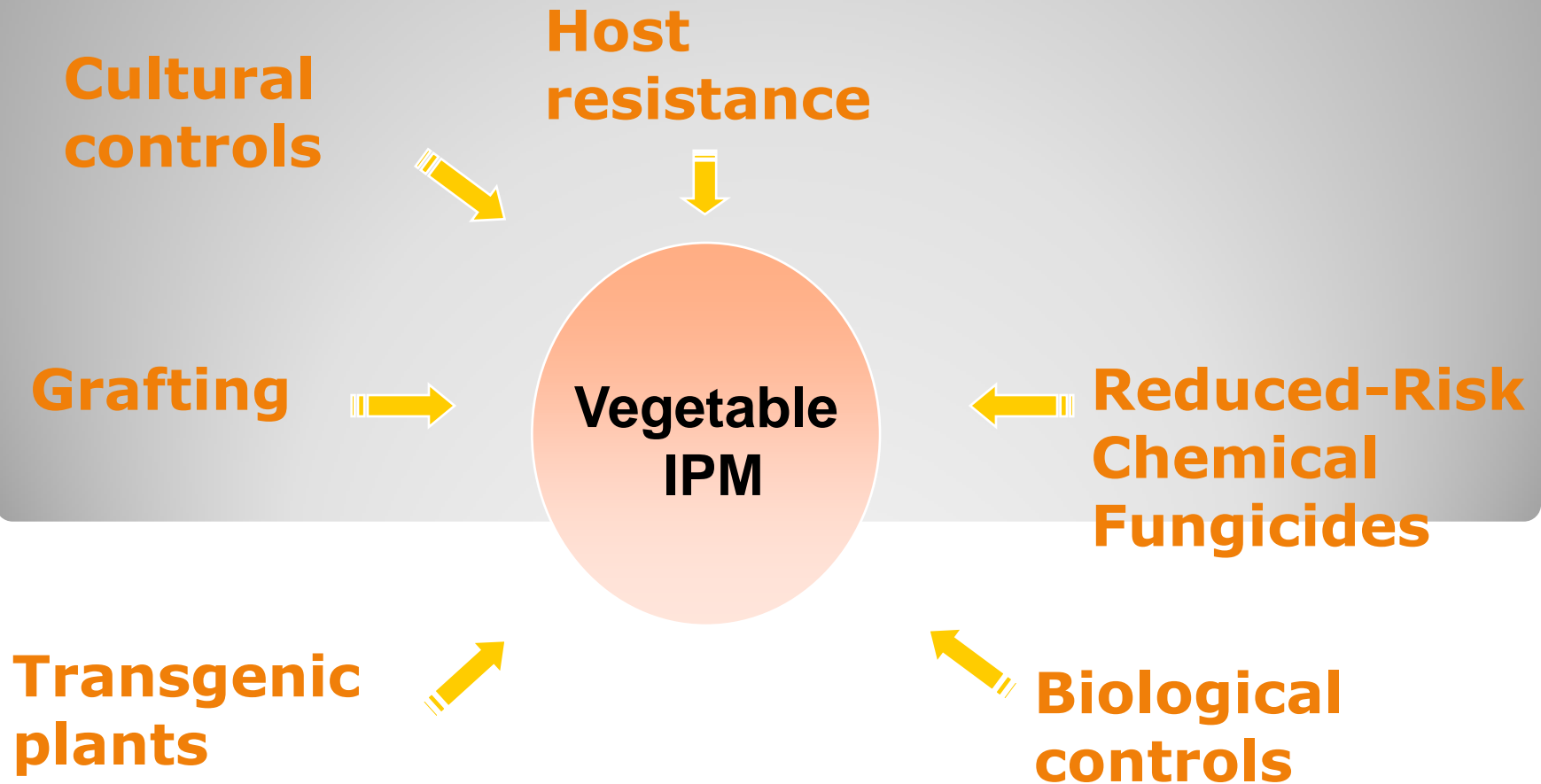
# Components of an Integrated Pest Management Program

- Monitoring and Sampling (inspect)
- Pest Identification (what pest)
- Decision-making (what action(s))
- Intervention (take action (s))
- Follow-up (re-inspect)
- Record-keeping (write it down, history)
- Education (learn)

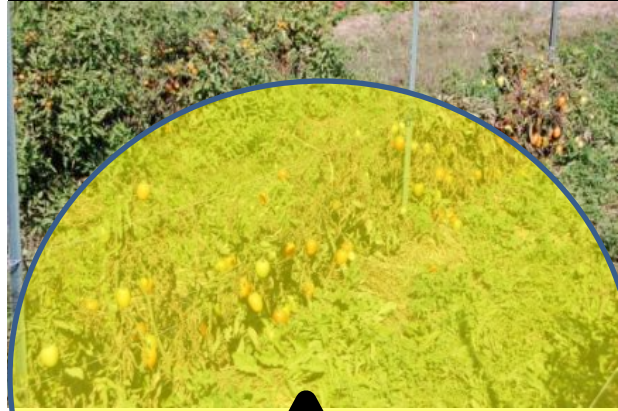


# Wisconsin Vegetable Pest Management

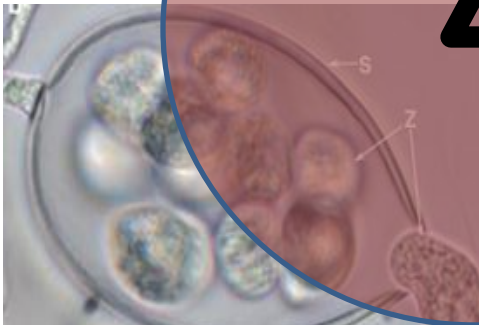
## Options for Disease Management



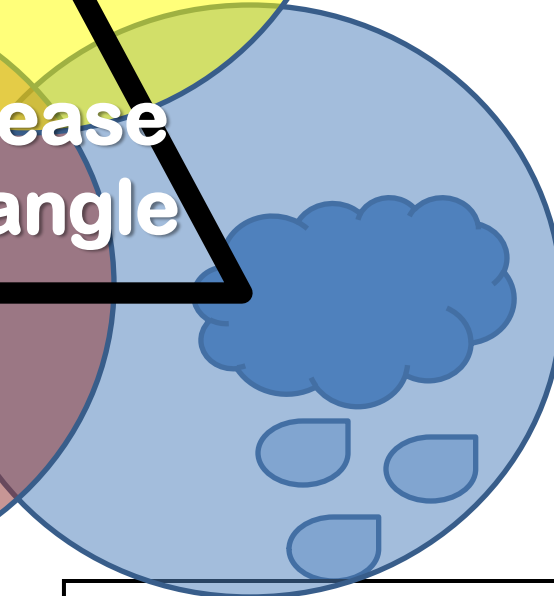
**Susceptible Host**



**Disease  
Triangle**



**Virulent Pathogen**



**Favorable Environment**

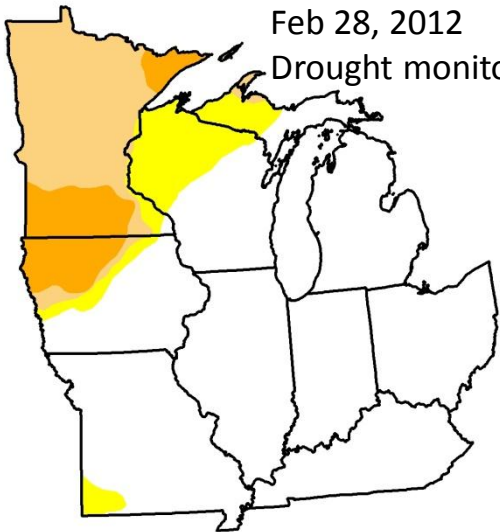
# 2012 Heat and Drought

**Conditions promoted excellent foliar disease control**

**However, plant stress can make root disease symptoms more severe**

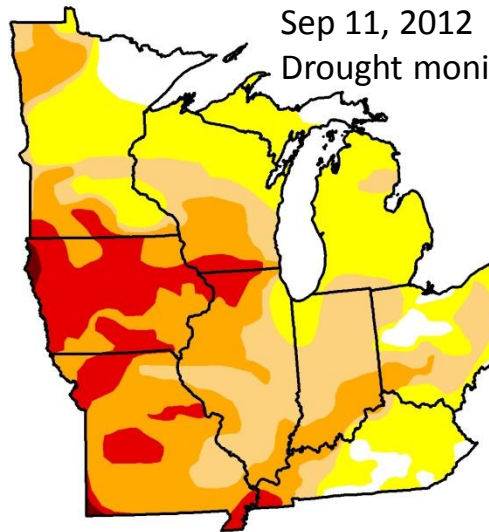
Feb 28, 2012

Drought monitor



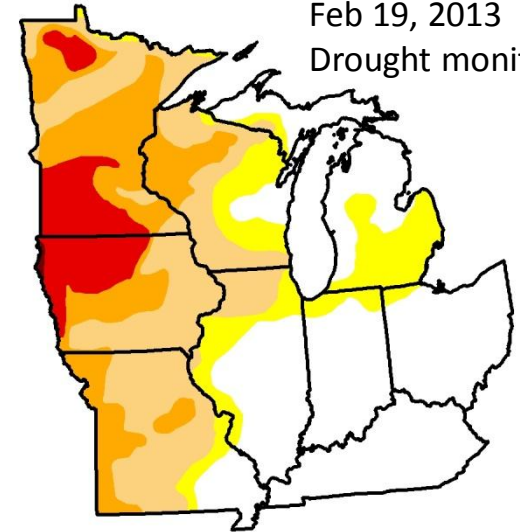
Sep 11, 2012

Drought monitor



Feb 19, 2013

Drought monitor



## Drought Severity



D0 - Abnormally Dry



D1 Drought - Moderate



D2 Drought - Severe



D3 Drought - Extreme



D4 Drought - Exceptional



# NOAA

NATIONAL OCEANIC AND  
ATMOSPHERIC ADMINISTRATION  
UNITED STATES DEPARTMENT OF COMMERCE

# **Powdery Mildew**

## ***Podosphaera macularis***



PM disease develops at 64 to 70°F and reduced when >75°F. Infection can be greatly reduced by short intervals (> 2 h) of temperatures >86°F. Higher temperatures reduce the susceptibility of leaves to infection.

# **Powdery Mildew *Management***

Disease incidence was low in yards with low incidence of flag shoots or that were pruned thoroughly in spring, and suggested that disease management practices prior to pruning likely were not needed if the pruning was done such that no green plant tissue was left (Washington study, Turechek 2001)

Potential savings with early pruning practice are estimated at \$60-\$120/acre, depending on the method of pruning and irrigation. Pruning must be done very well if fungicide applications are to be delayed until after spring pruning, which can be difficult to achieve in practice because of logistical constraints (Ghent et al., 2008)

Cone infection is greater in poorly pruned yards (Gent, *unpublished*).

Management of powdery mildew in cones is dependent on the success and thoroughness of early season control measures.

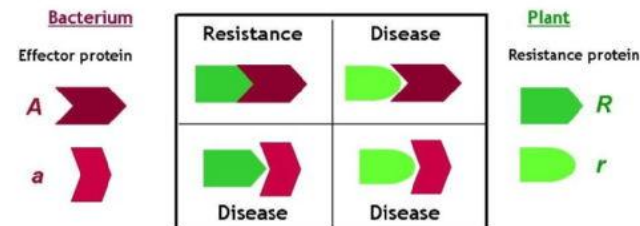
# Varietal resistance to powdery mildew in hops

- A hop variety can carry a gene or genes for resistance to powdery mildew (PM)
- There are 7 resistance genes to PM in hops
  - Rb
  - R1
  - R2
  - R3
  - R4
  - R5
  - R6

- Gene-for-gene relationship between hops PM races and host resistance

The Gene-for-Gene Model of Plant Immunity

Bacterium \ Plant	Resistance gene	
	<i>R</i>	<i>r</i>
Effector gene	<i>A</i>	Resistance
	<i>a</i>	Disease



# Varietal resistance to powdery mildew in hops

- Varieties **resistant** to Pac NW PM:
  - 'Nugget' (R6)
  - 'Cascade' (R5)
  - 'Mt. Hood'
- Varieties moderately **resistant** to Pac NW PM:
  - 'Fuggle'
  - 'Perle'
  - 'Tettnang'
  - 'Hallertau'
- Varieties **susceptible** to Pac NW PM include
  - 'Horizon'
  - 'Columbus'
  - 'Tomahawk'
  - 'Zeus'
  - 'Cluster'
  - 'Chinook'
  - 'Willamette'
  - 'Liberty'
  - 'Chelan'
  - 'Eroica'
  - 'Symphony'
  - 'Galena'
  - Any variety with Rb PM resistance gene

# Fungicides for hop powdery mildew control, WI Feb 28, 2013

## Powdery mildew (*Podosphaera macularis* and *humili*)

trifloxystrobin 11	1.0 oz with every 15-30 gal spray volume Flint	14	Apply preventatively for best results. Apply on a 10 to 14 day interval. Follow resistance management guidelines.
pyraclostrobin and boscalid 11, 7	14.0 oz/100 gal spray volume Pristine	14	Use preventatively and apply at 14-21 day intervals as needed. Follow resistance management guidelines.
myclobutanil 3	2.0-10.0 oz Rally	14	Emergence to training label rate is 2-4 oz/training to wire is 4-6 oz/wire to 14-day prior to harvest is 6-10 oz. Follow resistance management guidelines. (Old product name was Nova)
tebuconazole 3	4.0-8.0 fl oz Monsoon, ONSET 3.6L, Orius 3.6F, Tebustar 3.6L, Tebuzol 3.6F, Toledo 3.6F	14	Apply at 10 to 14 day intervals. Follow resistance management guidelines.
triflumizole 3	12.0 fl oz Procure 480SC	7	Use prior to or at disease onset for best results and reapply on a 14 day schedule.
quinoxifen 13	4.0-8.2 fl oz Quintec	21	Follow resistance management guidelines, including 'do not apply more than 4X per season.' Minimum spray interval is 7 days.

# Fungicides for hop powdery mildew control, WI Feb 28, 2013

## Powdery mildew (*Podosphaera macularis* and *humili*)

potassium bicarbonate	2.5-5.0 lb/100 gal spray volume Armicarb 100	0	Do not exceed mix rate of 5.0 lb/100 gal of water. Do not store unused portion of spray for more than 12 hours prior to use.
sodium bicarbonate	4.0 oz/10 gal water spray volume Milstop	0	Begin application when weather favors disease and apply at 1 to 2 week intervals. Tighten intervals when disease pressure heightens.
copper octanoate	0.5-2.0 gal Cueva in 100 gal water	14	Apply soon after training vines.
potassium bicarbonate	2.5-5.0 lb Kaligreen	1	Apply when weather conditions favor disease and repeat on a 7-10 day basis.
mono and dipotassium salts of phosphorous acid	1-3 qt/100 gal water Phosphite  1.0-3.0 qt in 20 gal of water Rampart	0	Apply at 2 to 3 week intervals. Do not apply at an interval less than 3 days.
Extract of <i>Reynoutria sachalinensis</i>	1.0-4.0 qt Regalia	0	Use preventatively and apply at 7 day intervals as needed. Emergence to wire-touch 1.0-2.0 qt recommended/wire-touch through harvest 2.0-4.0 qt. OMRI approved

# Fungicides for hop powdery mildew control, WI Feb 28, 2013

## Powdery mildew (*Podosphaera macularis* and *humili*)

<i>Bacillus subtilis</i> QST 713 strain	4.0-6.0 qt/100 gal spray volume of Serenade ASO	0	Use when conditions favor disease and apply at 7 day intervals as needed. OMRI approved.
<i>Bacillus subtilis</i> QST 713 strain	2.0-3.0 lb/100 gal spray volume of Serenade MAX	0	Use when conditions favor disease and apply at 7 day intervals as needed. OMRI approved.
<i>Bacillus pumilis</i> QST 2808	2.0-4.0 qt/100 gal spray volume of Sonata	0	Use when conditions favor disease and apply at 7-14 day intervals as needed. OMRI approved.
neem oil	0.5%-1.0% in 25-100 gal water spray volume of Trilogy	0	Use when conditions favor disease and apply at a 7-14 day interval as needed. OMRI approved. Also a miticide/insecticide.

# What the FRAC?

## Fungicide Resistance Mitigation

<http://www.frac.info/index.htm>

MOA	TARGET SITE AND CODE	GROUP NAME	CHEMICAL GROUP	COMMON NAME	COMMENTS	FRAC CODE
C. respiration	<b>C1:</b> complex I NADH Oxido-reductase	pyrimidinamines	pyrimidinamines	diflumetorim	Resistance not known.	<b>39</b>
	<b>C2:</b> complex II: succinate-dehydrogenase	SDHI (Succinate dehydrogenase inhibitors)	phenyl-benzamides	benodanil flutolanil mepronil	Resistance known for several fungal species in field populations and lab mutants. Target site mutations in sdh gene, e.g. H/Y (or H/L) at 257, 267, 272 or P225L, dependent on fungal species. Resistance management required.  <b>Medium to high risk.</b>  <b>See FRAC SDHI Guidelines for resistance management.</b>	<b>7</b>
			pyridinyl-ethyl-benzamides	fluopyram		
			furan- carboxamides	fenfuram		
			oxathiin- carboxamides	carboxin oxycarboxin		
			thiazole- carboxamides	thifluzamide		
			pyrazole- carboxamides	benzovindiflupyr bixafen fluxapyroxad furametpyr isopyrazam penflufen penthioapyrad sedaxane		
				boscalid		
	<b>C3:</b> complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site ( <i>cyt b gene</i> )	QoI-fungicides (Quinone outside Inhibitors)	methoxy-acrylates	azoxystrobin coumoxystrobin enoxastrobin flufenoxystrobin picoxystrobin pyraoxystrobin	Resistance known in various fungal species. Target site mutations in cyt b gene (G143A, F129L) and additional mechanisms.  Cross resistance shown between all members of the QoI group.  <b>High risk.</b>  <b>See FRAC QoI Guidelines for resistance management.</b>	<b>11</b>
				pyraclostrobin pyrametostrobin triclopypiricarb		
				kresoxim-methyl trifloxystrobin		
				dimoxystrobin fenaminostrobin metominostrobin orysastrobin		
				famoxadone fluoxastrobin		
			oximino-acetamides	fenamidone		
			oxazolidine-diones			
			dihydro-dioxazines			
			imidazolinones			
	<b>C4:</b> complex III: cytochrome bc1(ubiquinone reductase) at Qi site	QiI - fungicides (Quinone inside Inhibitors)	cyano- imidazole	cyazofamid	Resistance risk unknown but assumed to be medium to high (mutations at target site known in model organisms). Resistance management required.	<b>21</b>
			sulfamoyl-triazole	amisulbrom		
	<b>C5:</b> uncouplers of		dinitrophenyl crotonates	binapacryl meptyldinocap dinocap	Resistance not known. Also acaricidal activity.	<b>29</b>
			2,6-dinitro-		Low risk. However, resistance	

# Powdery Mildew Fungicides

## Standard protectants

Group M1

- Coppers (Nu-Cop, Kocide, Cueva, etc.)

## Reduced risk fungicides

SDHIs  
Group 7

- boscalid (7) + pyraclostrobin (11) (Pristine)

- trifloxystrobin (Flint)
- boscalid (7) + pyraclostrobin (11) (Pristine)

QoI inhibitors  
Group 11

# Powdery Mildew Fungicides (continued)

## Reduced risk fungicides

- tebuconazole (Folicur, Tebustar, etc.)
- myclobutanil (Rally)
- triflumizole (Procure)

Group 3  
triazoles

- quinoxyfen (Quintec)

Group 13  
quinoline

# Downy Mildew

## *Pseudoperonospora humili*



Cultivated hop, *Humulus lupulus* is only host  
Closely related annual or Japanese hop, *H. japonicus*,  
seems to be resistant

Fungus-like pathogen overwinters as bud infections or  
as a systemically infected crown

In spring, infected shoots, called primary spikes,  
emerge from the crown and are stunted, pale-green to yellow,  
upright, and brittle with downward cupped leaves



# **Downy Mildew**

## ***Pseudoperonospora humili***



Systemic infection – systemic symptoms of shortened internodes (bunchy new growth), pale green leaves, small leaves

Disease favored by cool, wet conditions

# Downy Mildew *Management*

Removal of primary basal spikes

Heavily prune and strip leaves in lower 3 ft of bine

Limits downy mildew from moving up the bine and infecting cones

Pruning and thinning also helps reduce moisture in lower canopy which further aids in limiting disease



# Varietal resistance to downy mildew in hops

- 'Centennial' and 'Nugget' are susceptible to downy mildew
- Most (~75%) of hop varieties grown in U.S. are susceptible to DM
- Remaining ~25% have some crown tolerance to DM ('Bullion', 'Brewer's Gold', 'Cascade')
- European hop varieties with DM resistance are 'extract' high alpha types (bitters are extracted for flavoring – not directly used from plant product)
- 'Resistant' varieties still require ~3 fungicide applications to control DM

# Fungicides for hop downy mildew control, WI Feb 28, 2013

## Downy mildew (*Pseudoperonospora humili*)

fosetyl aluminum 33	2.5 lb Aliette  5.0 lb/100 gal spray volume Linebacker	24	Do not tank-mix with coppers. Initiate application when weather conditions favor disease (warm and humid). Avoid mixing with foliar fertilizers or surfactants.
cymoxanil 27	3.2 oz Curzate DF	7	Apply with a protectant fungicide such as copper hydroxide.
dimethomorph 40	6.0 fl oz Forum	7	Do not make more than 3 applications per season. Addition of an adjuvant to spray mix is recommended.
famoxadone and cymoxanil  11,27	8 oz Tanos	7	Use with a tank-mix partner. Apply preventatively and on a 6-8 day spray schedule. Follow resistance management guidelines.
mandipropamid  40	8.0 fl oz Revus	7	A non-ionic surfactant is recommended with use of this product. Follow resistance management guidelines.
cyazofamid 21	2.1-2.75 fl oz Ranman	3	Apply prior to or at first sign of disease. Follow resistance management guidelines.
pyraclostrobin and boscalid  11, 7	14.0 oz/100 gal spray volume Pristine	14	Use preventatively and apply at 14-21 day intervals as needed. Follow resistance management guidelines.
mefenoxam  4	0.5 pt Ridomil Gold SL	45	Label allows drench and foliar applications. Follow resistance management guidelines.

# Fungicides for hop downy mildew control, WI Feb 28, 2013

## Downy mildew (*Pseudoperonospora humili*)

Extract of <i>Reynoutria sachalinensis</i>	1.0-4.0 qt Regalia	0	Use preventatively and apply at 7 day intervals as needed. Emergence to wire-touch 1.0-2.0 qt recommended/wire-touch through harvest 2.0-4.0 qt. OMRI approved.
potassium bicarbonate	2.5-5.0 lb/100 gal spray volume Armcarb 100	0	Do not exceed mix rate of 5.0 lb/100 gal of water. Do not store unused portion of spray for more than 12 hours prior to use.
copper oxychloride and copper hydroxide	1.8 pts Badge SC  0.75 lb Badge X2	14	Treat after pruning but before training.
copper oxychloride and basic copper sulfate	C-O-C-S WDG 4.0-6.0 lb	14	Apply soon after training vines.
copper hydroxide	1.33 lb Champ Dry Prill 1.33 lb Champ Formula II Flowable 1.06 lb Champ WG 0.75-1.5 lb Kocide 3000 1.5 lb Kocide 2000	14	Apply after pruning but before training. Apply again as needed on a 10 day basis after training.

# Fungicides for hop downy mildew control, WI Feb 28, 2013

## Downy mildew (*Pseudoperonospora humili*)

mono and dipotassium salts of phosphorous acid	1-3 qt/100 gal water Fosphite  1.0-2.0 qt/acre in a spray volume of 25 gal water Fungi-phite  2.0-4.0 pt Helena Prophyt  2.5 pt Phostrol	0	Apply at 2 to 3 week intervals. Do not apply at an interval less than 3 days.      Apply when conditions favor disease when shoots are 6-12 in high, after training at 5-6 ft tall, about 3 weeks after 2nd application, and during bloom.
mono potassium phosphate and mono potassium phosphite	2.0-4.0 qt Phorcephite  1.0-3.0 qt in 20 gal of water Rampart	0	Apply when conditions favor disease when shoots are 6-12 in high, after training at 5-6 ft tall, about 3 weeks after 2 <sup>nd</sup> application, and during bloom.
<i>Bacillus pumilis</i> QST 2808	2.0-4.0 qt/100 gal spray volume of Sonata	0	Use when conditions favor disease and apply at 7-14 day intervals as needed. OMRI approved.

# Thank you!

## Information Resources

UW Vegetable Extension Team Website

<http://vegetables.wisc.edu/vegetable-team>

University of Wisconsin Vegetable Disease  
Website (newsletter access)

<http://www.plantpath.wisc.edu/wivegdis/>



[http://www.cals.uidaho.edu/pses/Research/r\\_ent\\_hoppest\\_powderymildew.htm](http://www.cals.uidaho.edu/pses/Research/r_ent_hoppest_powderymildew.htm)

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