Managing Disease in Wisconsin Hops
Fungicide & Project Updates



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Plant Pathology

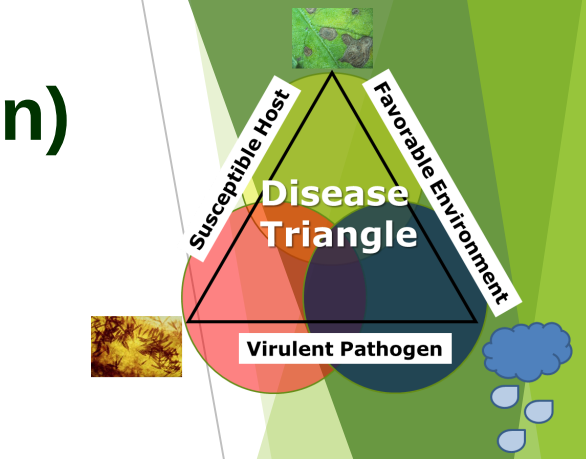
University of Wisconsin-Madison

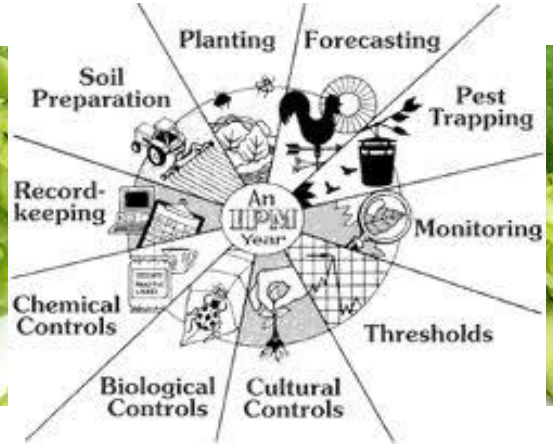
Hop Production Seminar
March 1, 2014 - 10:30-11:15AM
The Great Dane Brewery, Wausau, WI

Photo courtesy (left-right): NC State Coop. Ext.; Oregon Dept. of Ag.; David Gent

Components of an Integrated Pest Management Program

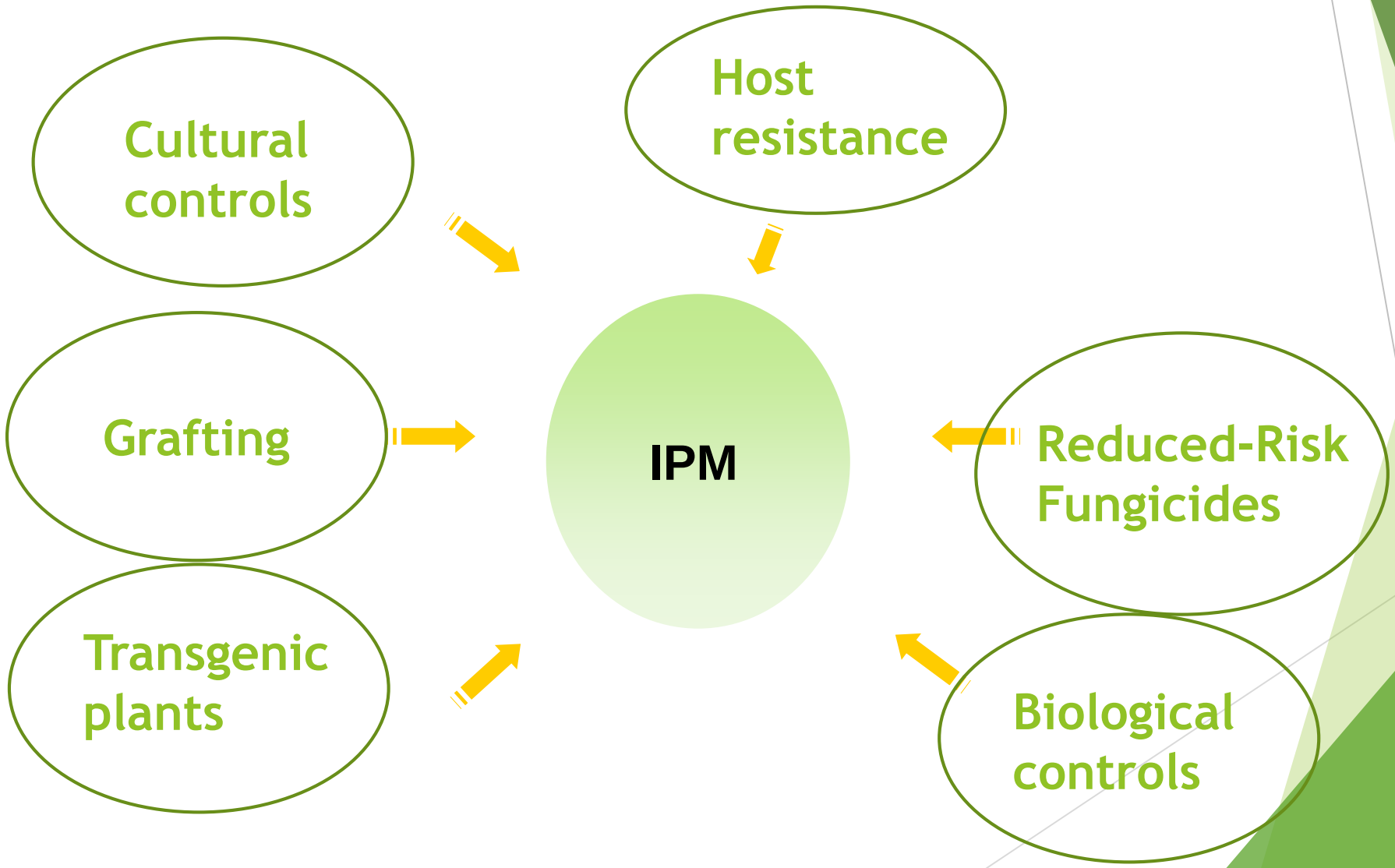
- Monitoring and Sampling (inspect)
- Pathogen Identification (what pathogen)
- Decision-making (what action(s))
- Intervention (take action (s))
- Follow-up (re-inspect)
- Record-keeping (write it down, history)
- Education (learn)





Integrated Disease Management

Options for Disease Management – not all available in hops



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.

No known detections of powdery mildew on hops in WI in 2013 or recent years.

Photo courtesy: David Gent

Powdery Mildew Management

Low disease incidence in yards with few flag shoots or that were pruned thoroughly in spring. 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 (Gent et al., 2008)

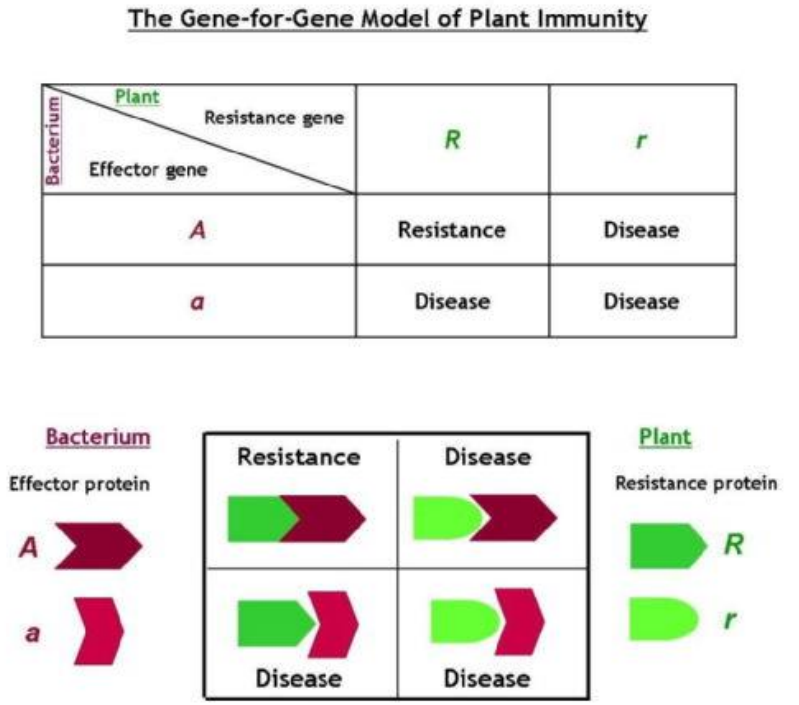
Cone infection is greater in poorly pruned yards (Gent, *unpublished*).

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



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, 2014

Powdery mildew (*Podosphaera macularis* and *humili*)			
trifloxystrobin 11	1.0 oz with every 15-30 gal spray volume Flint	14 DAYS PHI	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.
quinoxyfen 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, 2014

Powdery mildew (*Podosphaera macularis* and *humili*)			
potassium bicarbonate	2.5-5.0 lb/100 gal spray volume Armicarb 100	0 DAYS PHI	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 *Reynoutria sachalinensis*	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, 2014

Powdery mildew (*Podosphaera macularis* and *humili*)			
Bacillus subtilis QST 713 strain	4.0-6.0 qt/100 gal spray volume of Serenade ASO	0 DAYS PHI	Use when conditions favor disease and apply at 7 day intervals as needed. OMRI approved.
Bacillus subtilis 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.
Bacillus pumilis 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.

FRAC Fungicide Resistance Action Committee

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	**C1:** complex I NADH Oxido-reductase	pyrimidinamines	pyrimidinamines	diflumetorim	Resistance not known.	39
	C2: complex **II**: succinate-dehydro-genase	SDHI (**S**uccinate **de**h**y**drogenase **i**nhibitors)	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. **Medium to high risk.** **See FRAC SDHI Guidelines for resistance management.**	7
			pyridinyl-ethyl-benzamides	fluopyram		
			furan- carboxamides	fenfuram		
			oxathiin-carboxamides	carboxin oxycarboxin		
			thiazole-carboxamides	thifluzamide		
			pyrazole-carboxamides	benzovindiflupyr bixafen fluxapyroxad furametpyr isopyrazam penflufen penthiopyrad sedaxane		
			pyridine-carboxamides	boscalid		
	C3: complex **III**: cytochrome bc1 (ubiquinol oxidase) at Qo site *(cyt b gene)*	**QoI**-fungicides (**Q**uinone **o**utside **I**nhibitors)	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. **High risk.** **See FRAC QoI Guidelines for resistance management.**	11
			methoxy-carbamates	pyraclostrobin pyrametostrobin triclopyricarb		
			oximino acetates	kresoxim-methyl trifloxystrobin		
			oximino-acetamides	dimoxystrobin fenaminostrobin metominostrobin orysastrobin		
			oxazolidine-diones	famoxadone		
			dihydro-dioxazines	fluoxastrobin		
			Imidazolinones	fenamidone		
			benzyl-carbamates	pyribencarb		
	C4: complex **III**: cytochrome bc1(ubiquinone reductase) at Qi site	**QiI** - fungicides (**Q**uinone **i**nside **I**nhibitors)	cyano- imidazole	cyazofamid	Resistance risk unknown but assumed to be medium to high (mutations at target site known in model organisms). Resistance management required.	21
			sulfamoyl-triazole	amisulbrom		
	C5: uncouplers of		dinitrophenyl crotonates	binapacryl meptyldinocap dinocap	Resistance not known. Also acaricidal activity.	29
			2,6-dinitro-		Low risk. However, resistance	

Powdery Mildew Fungicides

Standard protectants

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

Group M1

Reduced risk fungicides

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

SDHIs
Group 7

- 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*, is resistant

Fungus-like pathogen overwinters as bud infections or 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

Few detections of downy mildew in WI in 2013 and recent years.

Photo courtesy: North Carolina State Univ. Cooperative Extension

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 – Prediction models aid in proactive management

Photo courtesy: North Carolina State Univ. Cooperative Extension

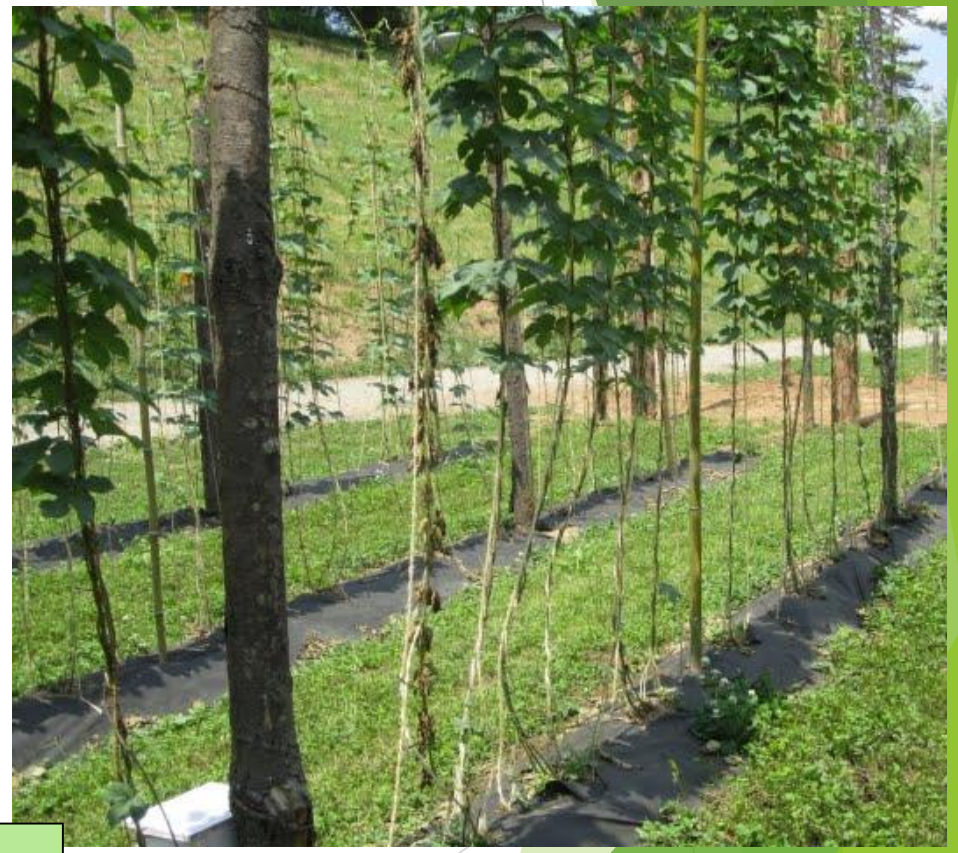
Downy Mildew
Management – Initial phase

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



Degree-day model to predict emergence of basal spikes

Accumulation of 111 degree-days, base 6˚C

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

Downy Mildew
Management – Initial phase

Downy mildew is likely systemic in most hop yards, meaning that the pathogen is inside the rhizomes and can ‘awaken’ when spikes emerge in the spring.

As such, fungicides are important for early season control of this pathogen so as to limit the amount of initial inoculum that can become available to the developing crop.

The start of a preventative fungicide program for downy mildew should begin at spike emergence. This timing is based on temperature or growing degree days, aligning with growing degree days (GDD) of 111.3. Notes below provide further explanation and directions for determining this number for your location.

Downy Mildew
Management – Initial phase

The time to initiate a fungicide program for preventative downy mildew control in hops is at predicted spike emergence (emergence of basal shoots in spring, growing degree day 111.3 air temperature) (Gent).

This is calculated using growing degree days starting from February 1 (base 6.5 degrees C). To get to this emergence date, there is a GDD calculator (link below) that can be used with your specific zip code. Base 6.5C can be defaulted to 40F. With this tool, you select current day's date for 'end'. For example, on April 26, 2013, in Madison, we had GDD 100.5.

http://www.weather.com/outdoors/agriculture/growing-degree-days/53706:4

Downy Mildew
Management

Spike emergence tool enables you to identify the earliest phase of emergence and as such aids in timing of preventative downy mildew control.

When to **follow up** with fungicide sprays will vary on the weather. There is a disease risk index utilized by some Pacific northwestern hop growers that has not yet been validated for WI.

The premise is that the **more rainfall and relative humidity** present under moderate temperatures (46-86F) the **greater the disease pressure.**

Under high pressure times, fungicides should be applied on a 5-7 day spray program.

When rainfall is reduced, relative humidity is low and we experience either temps cooler than 46 or higher than 86F, disease pressure is low and fungicides should be applied on a 10-14 day program.

Downy Mildew
Fungicide Program

A good fungicide for use in a 14-day calendar program is fosetyl aluminum or Aliette/Linebacker. Phostrol also provides similar extended control as it upregulates resistance in the plant.

Use of an 'Aliette' type product alternated with a tank mix of copper hydroxide plus cymoxanil (Curzate) creates a sound program.

Western states also alternate with copper hydroxide (ie: Kocide) and trifloxystrobin (Flint) in control of powdery mildew.

If you raise other crops and have familiarity with common base protectant fungicides, remember that **you cannot use captan, chlorothalonil, or mancozeb on hops.** These fungicides do not have EPA Section 2 or any other special labeling to permit their use on this crop. The only base protectant, broad spectrum fungicide for hops is copper (or copper containing formulations such as Kocide).

Proposed fungicide program for Downy mildew control of hops in WI

Time of application	Fungicide selection Active ingredient (trade name examples)	Comments
Spray 1: Spike emergence (or GDD 111.3, 40C base, Feb 1 start) *For southern WI 2013, this was around May 1*	Fosetyl aluminum (Aliette, Linebacker) Salts of phosphorous acids (Phostrol)	The Aliette program is used in the Pacific northwest with good results. Fosetyl aluminum products cannot be tank mixed with coppers. Phostrol has similar activity as Aliette. Be careful with spray volume and rate – as concentrated Phostrol can potentially be phytotoxic.
Spray 2: 2 weeks after Spray 1 *Roughly May 15*	Cymoxanil (Curzate) Copper hydroxide (Kocide) Dimethomorph (Forum) Cyazofamid (Ranman) Pyraclostrobin + Boscalid (Pristine) Famoxadone + Cymoxanil (Tanos) Mandipropamid (Revus) Mefenoxam (Ridomil Gold SL)	The Curzate + Kocide tank-mix program is used in the Pacific northwest with good results. Curzate and Kocide are good downy mildew fungicides across multiple vegetable crops. Pre-mixes that have good downy mildew and powdery mildew control are: Pristine and Tanos. Price point and availability of products in this list may influence selection. All listed have performed well on downy mildews of various crops.
Spray 3: 2 weeks after Spray 2 *Roughly May 30*	Fosetyl aluminum (Aliette, Linebacker) Salts of phosphorous acids (Phostrol)	The Aliette program is used in the Pacific northwest with good results. Fosetyl aluminum products cannot be tank mixed with coppers. Phostrol has similar activity as Aliette. Be careful with spray volume and rate – as concentrated Phostrol can potentially be phytotoxic.
Spray 4: 2 weeks after Spray 3 *Roughly June 15*	Cymoxanil (Curzate) Copper hydroxide (Kocide) Dimethomorph (Forum) Cyazofamid (Ranman) Pyraclostrobin + Boscalid (Pristine) Famoxadone + Cymoxanil (Tanos) Mandipropamid (Revus) Mefenoxam (Ridomil Gold SL)	The Curzate + Kocide tank-mix program is used in the Pacific northwest with good results. Curzate and Kocide are good downy mildew fungicides across multiple vegetable crops. Pre-mixes that have good downy mildew and powdery mildew control are: Pristine and Tanos. Price point and availability of products in this list may influence selection. All listed have performed well on downy mildews of various crops.
Spray 5: 2 weeks after Spray 4 *Roughly June 30*	Fosetyl aluminum (Aliette, Linebacker) Salts of phosphorous acids (Phostrol)	The Aliette program is used in the Pacific northwest with good results. Fosetyl aluminum products cannot be tank mixed with coppers. Phostrol has similar activity as Aliette. Be careful with spray volume and rate – as concentrated Phostrol can potentially be phytotoxic.
Spray 6: 2 weeks after Spray 5 *Roughly July 15*	*For Powdery and Downy mildew control:* Pyraclostrobin + Boscalid (Pristine) Famoxadone + Cymoxanil (Tanos) *For Powdery mildew control:*	Powdery mildew (PM), if present, may be problematic at this time of the year. We often see PM on cucurbits and other crops at this time (earlier in hot years). Pristine and Tanos are good pre-mix selections for both PM and Downy mildew. Products with individual disease activity can be tank-mixed.

Fungicides for hop downy mildew control, WI Feb 28, 2014

Downy mildew (*Pseudoperonospora humili*)			
fosetyl aluminum 33	2.5 lb Aliette 5.0 lb/100 gal spray volume Linebacker	24 Days PHI	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.
metalaxyl 4	1.O qt MetaStar 2E	45	Label allows drench and foliar applications. Follow resistance management guidelines.

Fungicides for hop downy mildew control, WI Feb 28, 2014

Downy mildew (*Pseudoperonospora humili*)			
ametoctradin + dimethomorph (45+40)	11-14.0 fl oz Zampro	7 DAYS PHI	Use a spreader or penetrating adjuvant. Do not use more than 3X per acre/production season for resistance management. Do not make more than 2 sequential applications before alternating to a different mode of action (different FRAC group).
Extract of *Reynoutria sachalinensis*	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 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.
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 2.0 lb Kentan DF 1.33-2.67 pt NuCop 3L	14	Apply after pruning but before training. Apply again as needed on a 10 day basis after training.

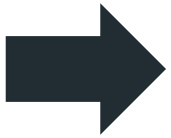
Fungicides for hop downy mildew control, WI Feb 28, 2014

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 DAYS PHI	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 2nd application, and during bloom.
Bacillus pumilis 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.

Clean Rhizome Project

Tissue culture and greenhouse production of pathogen-free hop rhizomes

http://healthyplants.wsu.edu



http://www.plantlabs.com

Dr. Ruth Genger, Plant Pathology, UW-Madison

Outline

- Why is a clean rhizome system needed?
- How do hop pathogens spread?
- How do hop pathogens affect productivity?
- Plans for clean rhizome research to support the Wisconsin hop industry

Why is a clean rhizome system needed?

- Hop diseases can be carried in rhizomes
- Hop viruses and viroids
  - Hop Latent Virus
  - Hop Mosaic Virus
  - American Hop Latent Virus
  - Apple Mosaic Virus
  - Hop Stunt Viroid
  - Hop Latent Viroid
- Fungal and oomycete diseases:
  - Hop Downy Mildew
  - Verticillium wilt

http://www.grapesandgrainsnyc.com

How do hop viruses and viroids spread?

- Hop Latent Virus
- Hop Mosaic Virus
- American Hop Latent Virus

- Apple Mosaic Virus

- Hop Stunt Viroid
- Hop Latent Viroid

- Hop Downy Mildew
- Verticillium wilt

Photo: David Gent, USDA ARS

Photo: thankheavenforbeer.com

Photo: David Gent, USDA ARS

Hop viruses and viroids

- Many perennial crops have virus and viroid diseases
- Rate of spread in hops is often much higher than in other perennials such as tree fruit
- Why is spread so rapid compared to other perennials?
  - Rapid annual growth – more than 15 feet of main stem growth in 3-4 months
  - Slashing basal growth
  - Close spacing
  - Aphid infestations
  - **Hop latent viroid was detected in WI in 2013**

Apple mosaic virus

Hop latent viroid

How do hop downy mildew and Verticillium wilt spread?

- Downy mildew
  - infected rhizomes
  - airborne spores
- Verticillium wilt
  - infected rhizomes
  - in soil and plant debris

plantmanagementnetwork.org

hopmintstress.wsu.edu

Photos: David Gent, USDA ARS

How are hops affected?

- Viruses and viroids
  - Yield losses can be severe
  - Reduced acid levels
  - Shift in ratio of α:ß-acids
  - Stunting, chlorosis, slower growth
- Downy mildew and Verticillium wilt
  - Plant mortality
  - Reduced cone quality

Hop stunt viroid

David Gent, USDA ARS

Downy mildew effects on cones

B. Engelehard

Start clean – stay clean!

- Plant disease-free rhizomes and plugs
- Sanitation for pruners and other tools
- Prevent movement of soil/infected plants onto your property
- Plant disease resistant cultivars

Planting stock production & certification programs

- Self-sustaining programs that serve grower needs
- Responsive to grower priorities
- Foster research and education
- Training opportunities

Wisconsin ‘clean rhizome’ research

- Establish a pathogen-free tissue culture collection of hop varieties, and produce pathogen-free planting material for on-farm variety evaluations.
- Trial hop rhizome production methods to optimize productivity and economic sustainability.
- Coordinate participatory variety trials in Wisconsin hop yards, and evaluate disease incidence in existing plantings

- **Work funded by the WI Specialty Crop Block Grant Program for 2013-2014**

Sources of tissue culture plants

National Clonal Germplasm Repository

- Corvallis, OR
- 185 cultivars and selections
- Some have viral or viroid infections
- Only uninfected plants will be distributed

Clean Plant Center of the Northwest

- http://healthyplants.wsu.edu/
- Limited distribution

Hop yards and native/feral hops

- Bine cuttings or rhizomes can be put into culture
- Challenging to eliminate pathogen infections

Varieties requested

- Survey circulated in fall 2013 to prioritize requests
- Not all requested varieties available
- Request for 23 varieties submitted in September

Brewer's Gold	Hallertauer Gold	Nugget
Cascade	Hallertauer Magnum	Perle
Chinook	Hallertauer mf tetraploid	Saazer 36
Crystal	Hallertauer mittelfruher	Saazer 38
Fuggle H	Hallertauer Tradition	Santiam
Fuggle Tetraploid	Liberty	Spalter Select
Galena	Mt. Hood	Tettnanger
	Northern Brewer	Willamette

- Multiple strains for some varieties – Fuggle, Hallertauer, Saazer

Varieties just received!

- Cascade
- Fuggle Tetraploid
- Hallertauer Gold
- Hallertauer Tradition
- Hallertauer mitterfruher
- Santiam

Next steps:

- Maintain these (and others as they arrive) in tissue culture
- Transfer to greenhouse for plug and rhizome production

Plant tissue culture to greenhouse plug and rhizome production

Compare productivity of standard and “NFT” methods

Standard

- transfer tissue culture plants to potting mix (nuclear stock)
- take softwood cuttings and root in misting chamber (propagation stock)

- Nutrient film technique
  - Nuclear stock will be maintained in an NFT system
  - since NFT systems allow access to parts of the plant normally covered by soil, it may be possible to take both softwood cuttings and rhizome cuttings from these plants

Future production possibilities

http://healthyplants.wsu.edu

http://www.plantlabs.com

Growers
- Multiplication
- Hop Production

Growers
- Multiplication (hoophouse/greenhouse)
- Hop Production

Growers
- Multiplication
- Hop Production

Potential for Wisconsin to become a leader in supplying pathogen-free hop rhizomes

North Central Regional SARE Grant
High Quality Beverage Raw Materials for the Craft Brewing Industry

Overall hops research objective

- Develop a season-long IPM program for enhanced productivity of Wisconsin hops
- PhD Student Michelle Marks
- Post-doctoral Research Associate

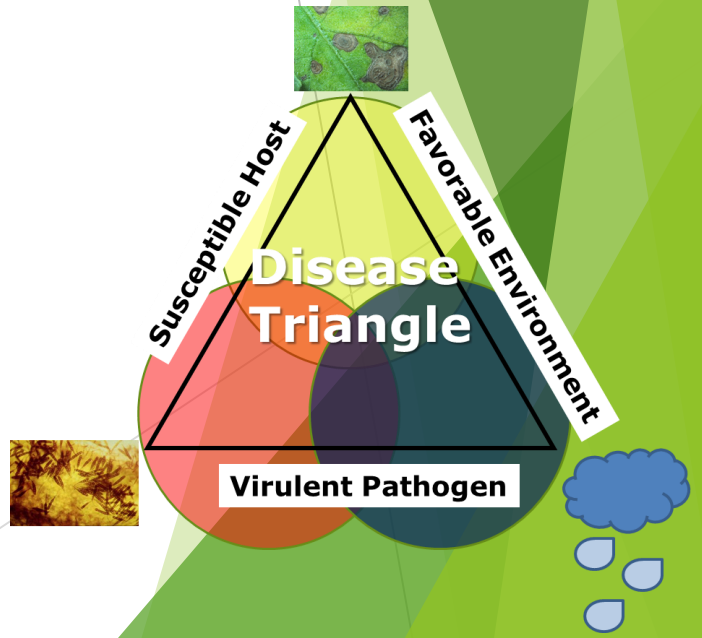
  Dr. Kenneth Frost

Specific Project Components Addressed by UW-Plant Pathology

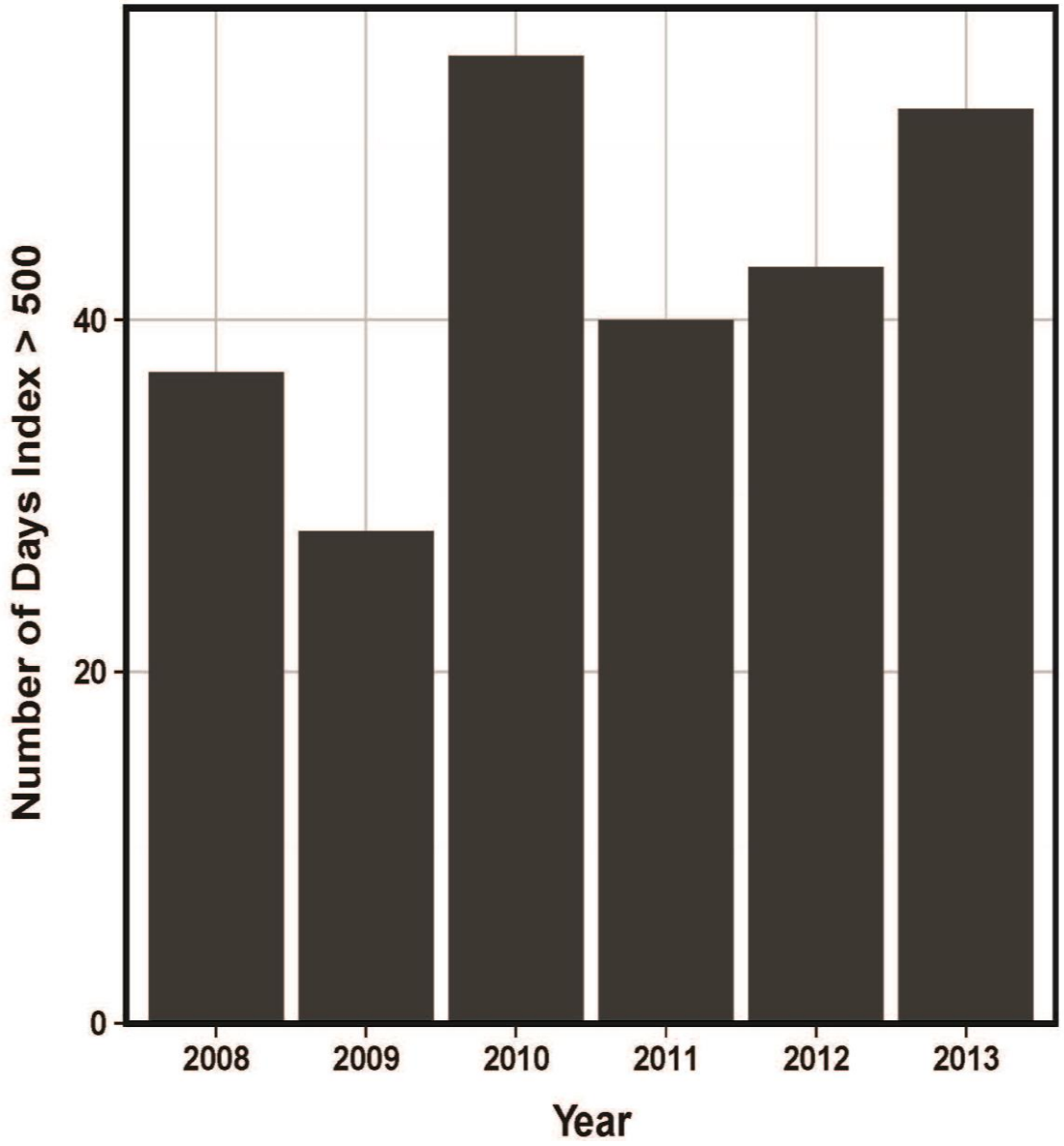
1. Hop Yard Surveys
   - Survey bine health and pathogen pests in commercial hop yards over space and time
     - Also, insect and weed pests
2. Fungicide Program Development
   - Using disease forecasting and pathogen detection to optimize product applications for WI
3. Development of Best Practices Handbook
   - Aggregate results of proposed and current research, as well as specialist recommendations
4. Optimize Bine Training Dates
   - Based on growing degree days

Disease Forecasting Updates

- Completed models from Oregon/Washington work
- **Degree-day model to predict emergence of basal spikes**
  - Accumulation of 111 degree-days, base 6°C
    - As of 2/27 we are at 0 growing degree-days
- **Risk index predicts infection events**
  - Primary parameters are rain, relative humidity, and temperature
  - Accumulation of 500 (risk index) indicates time of likely infection
- **Validation for Wisconsin is needed and will be conducted in 2013-15**



Annual Variation in DM Risk



DM risk index calculates an index that correlates with infection

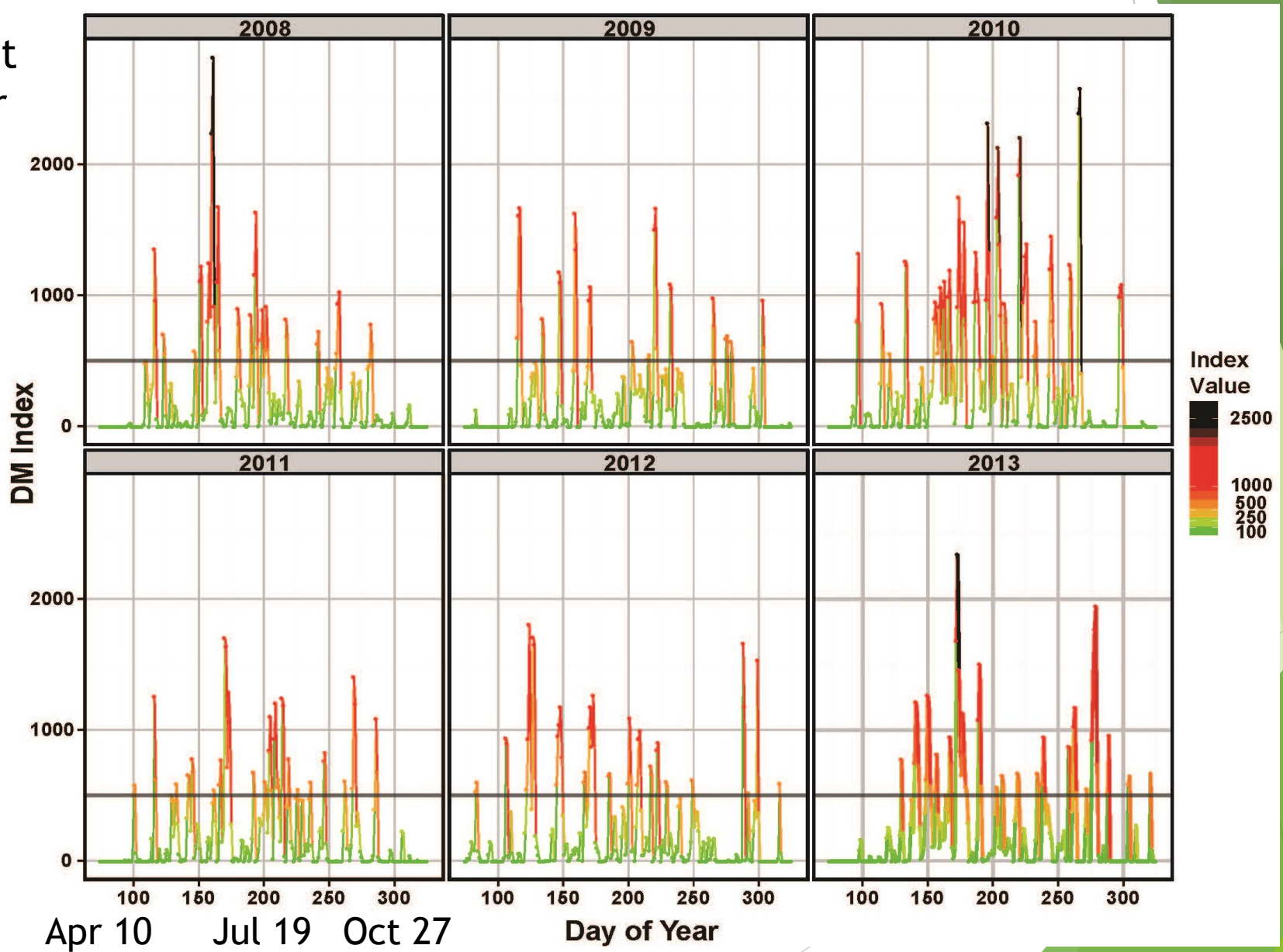
Index is based on rain, relative humidity, and temperature

For Oregon – An empirical threshold of 500 “risk” units was considered to indicate a severe infection event

Days with weather conducive for infection may group together (i.e. days above 500 is not a suitable measure for # sprays needed to achieve control)

Seasonal Variation DM Risk Index

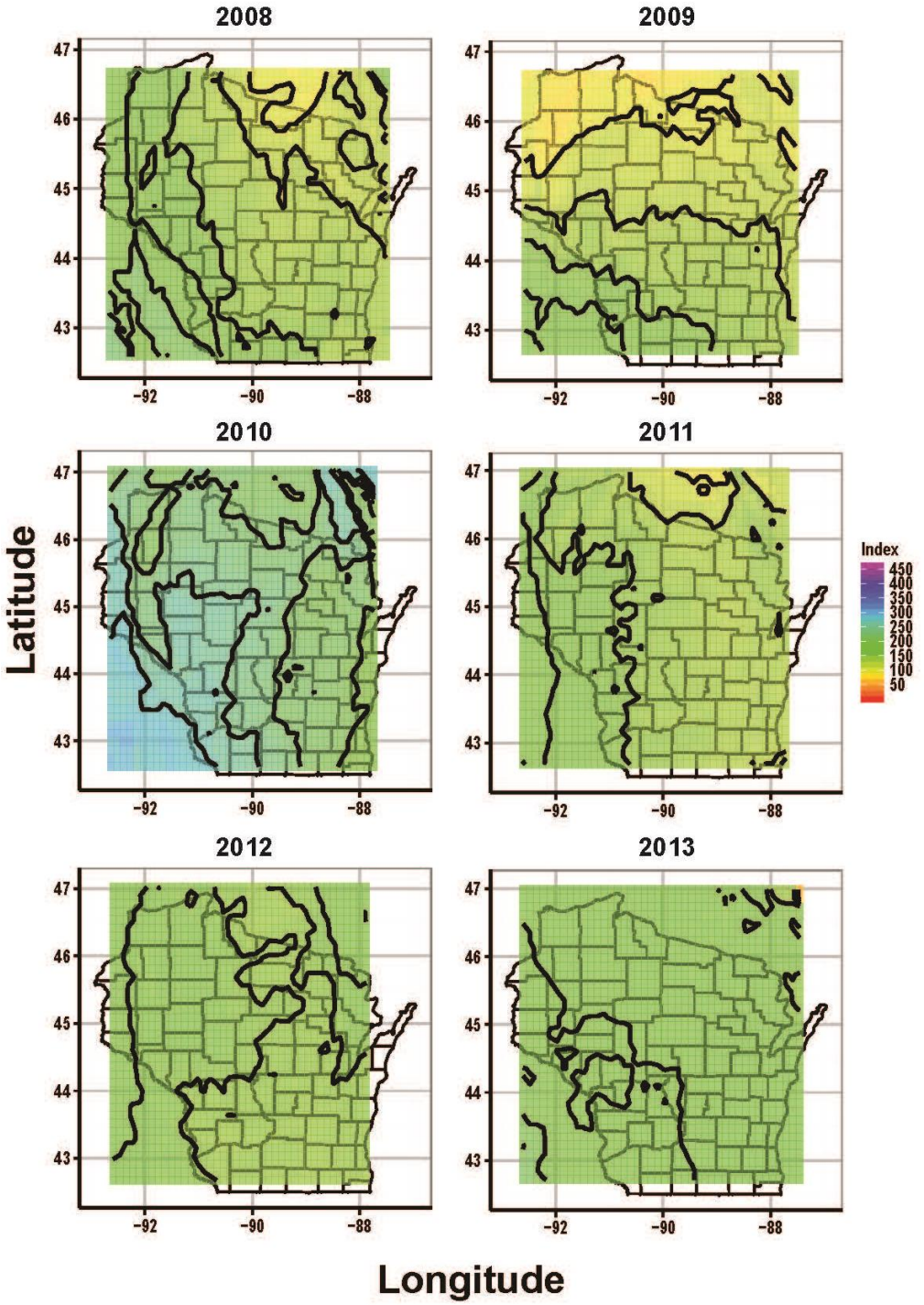
Not possible to predict likely time of weather favorable for hop downy mildew based on calendar alone



Variation of DM risk also occurs in space

Risk averaged for the whole year

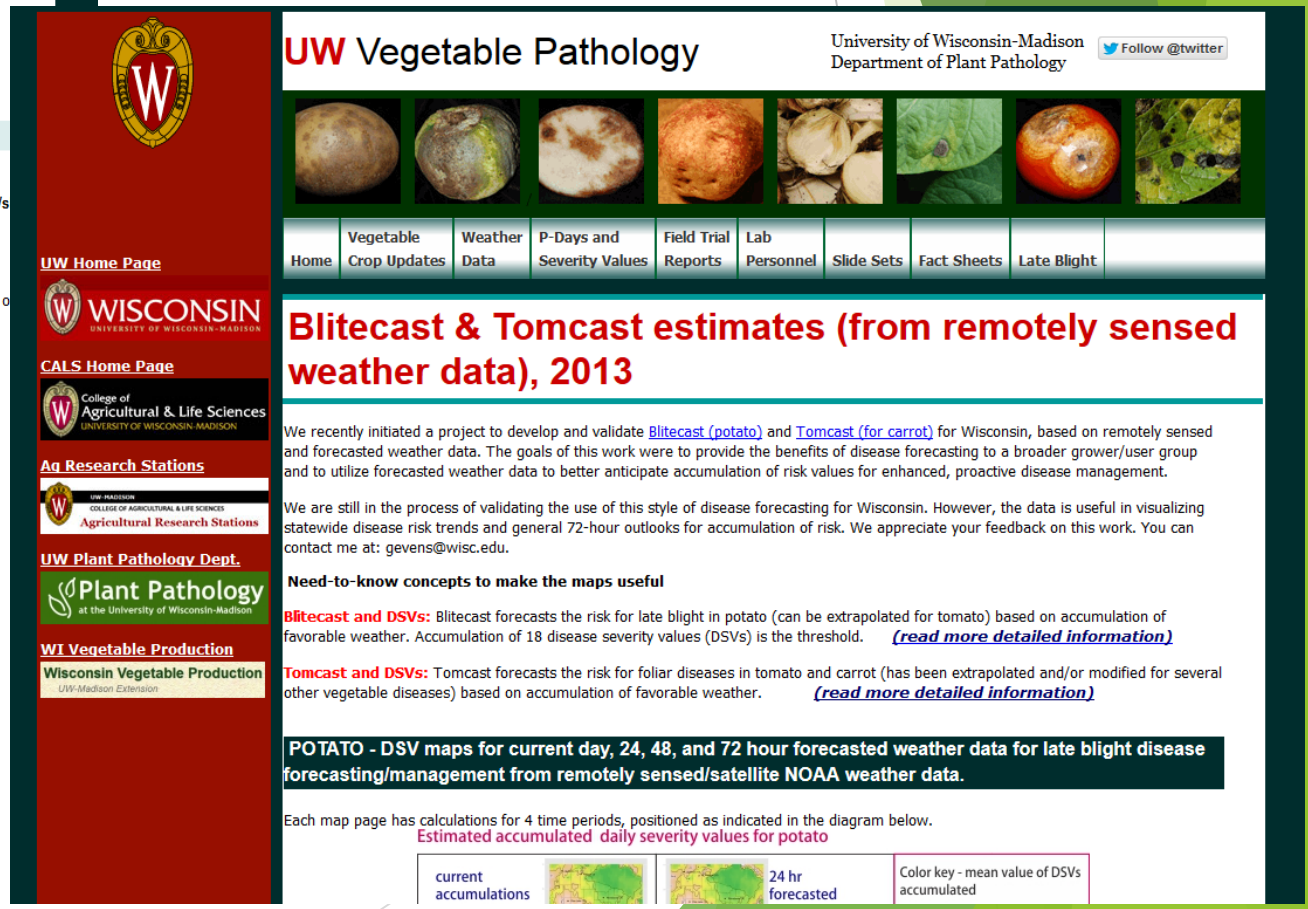
2010 was a year with higher risk for DM infection according to the model



Information Resources

Web-based disease forecasting
Information available in 2014
- useful tool to aid in disease control decision making
- requires validation for WI

UWEX Veg Crop Updates Newsletter
- weekly updates with disease forecasting information



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

Plant Pathology
at the University of Wisconsin - Madison

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