Wisconsin Hop Production & Downy Mildew Research: A 2014 Update

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Hop Basics

- Scientific name for common hop: *Humulus lupulus* – "little wolf"
- Native to Europe, Western Asia, and North America
- Dioecious flowering plant
- Perennial; dies back to rhizome in the fall, new shoots emerge in spring
- Cones (flowers) used as flavoring agent and preservative in beer


April 30 – Pepin County


April 30 – Pepin County


April 30 – Pepin County


April 16 – Dodge County

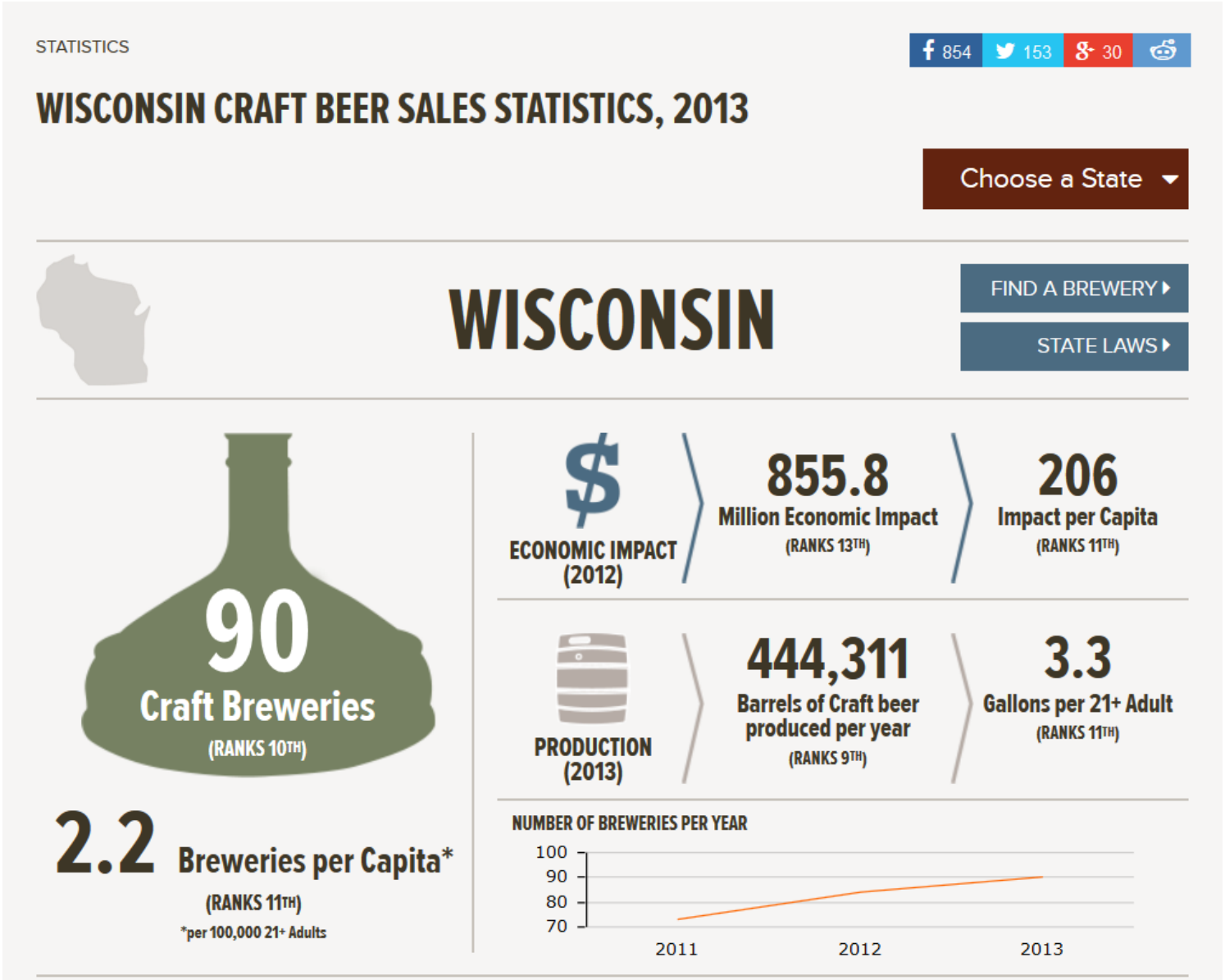

July 16 – Pepin County

July 17 – Dodge County

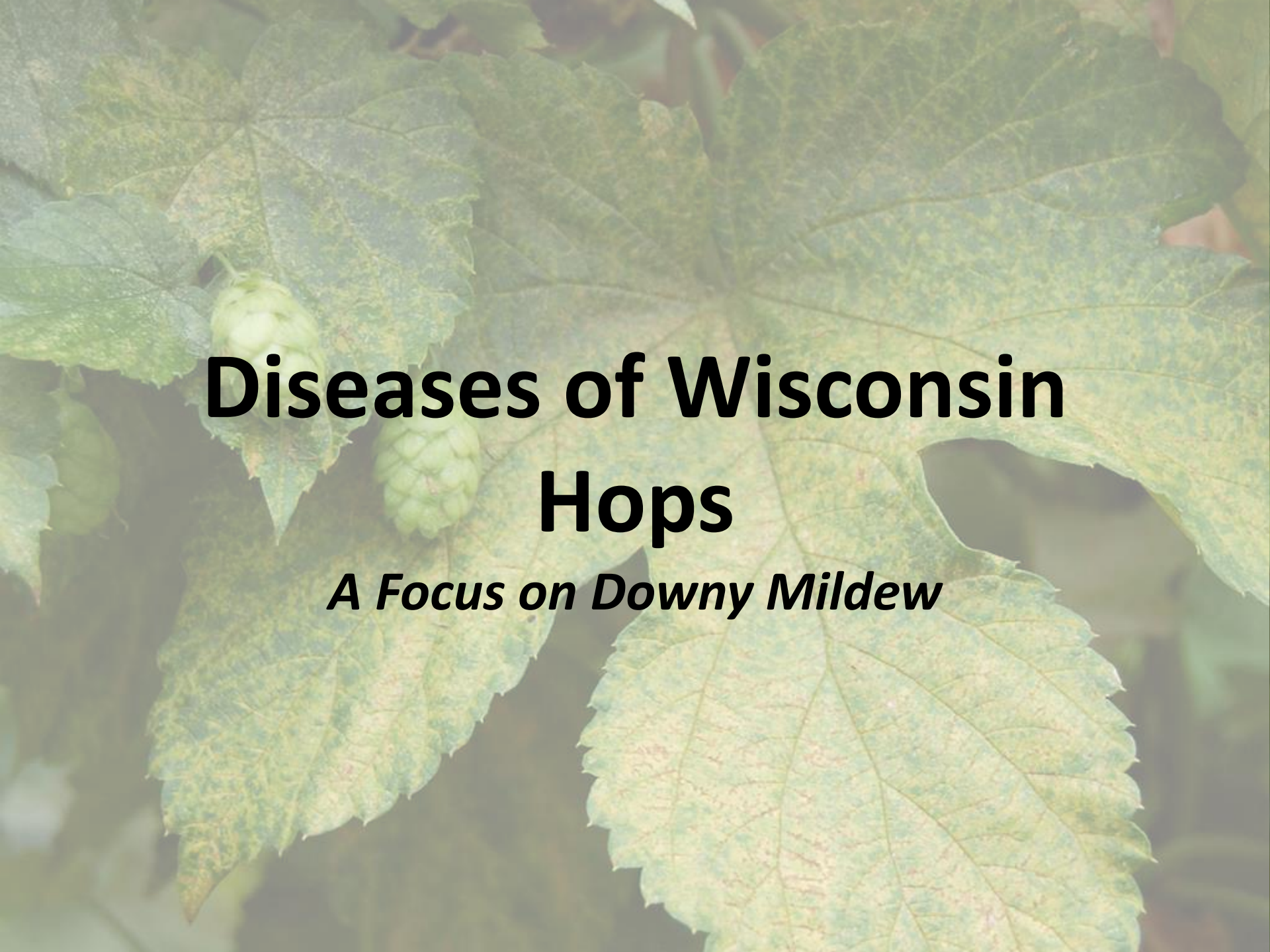
Current Wisconsin Hop Production

- Roughly 120 acres currently in production (summer 2014 estimate from Hop Growers of America)
- Expansion to ~500 acres in next two years estimated!

Local Demand



http://www.brewersassociation.org/statistics/by-state/?state=WI



Diseases of Wisconsin Hops

A Focus on Downy Mildew

General Hop Disease Timeline

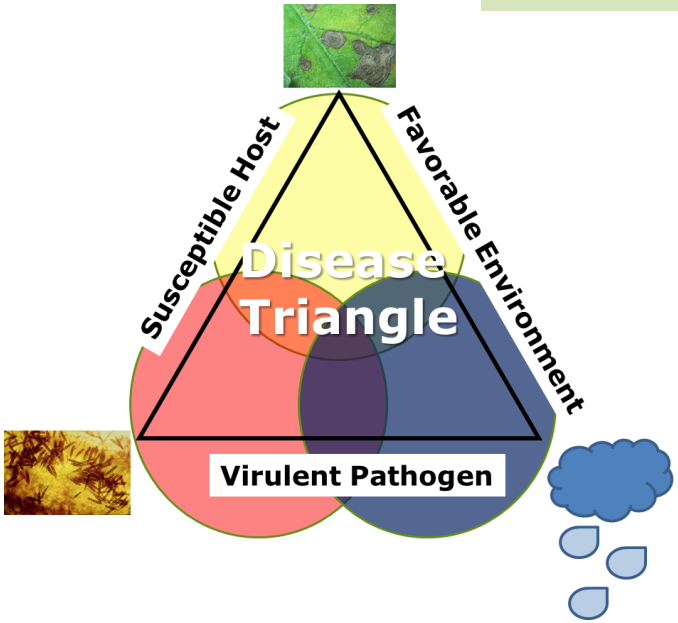
April-May	June	July	August	September	October

Poor emergence, Rhizoctonia, Fusarium Rhizome decay

Fusarium, Viruses (apple mosaic, hop latent, Carlavirus group)

Downy mildew, Powdery mildew

Botrytis



Hop Downy Mildew

- Caused by the oomycete obligate pathogen *Pseudoperonospora humuli*
- Survives systemically as mycelia in hop perennial rootstock
- May be introduced via rhizomes in new hop yards
- Capable of infecting shoots, leaves, and cones
- Oospore survival outside of host tissues is not well understood
- Host range: Hop, some evidence of limited infectivity on cucumber & wild cucurbit relatives (*Bryonia dioica* and *Sicyos angulatus)*

Runge, F., and Thines, M. 2012. Reevaluation of host specificity of the closely related species *Pseudoperonospora humuli* and *P. cubensis*. Plant Dis. 96:55-61.

Life Cycle

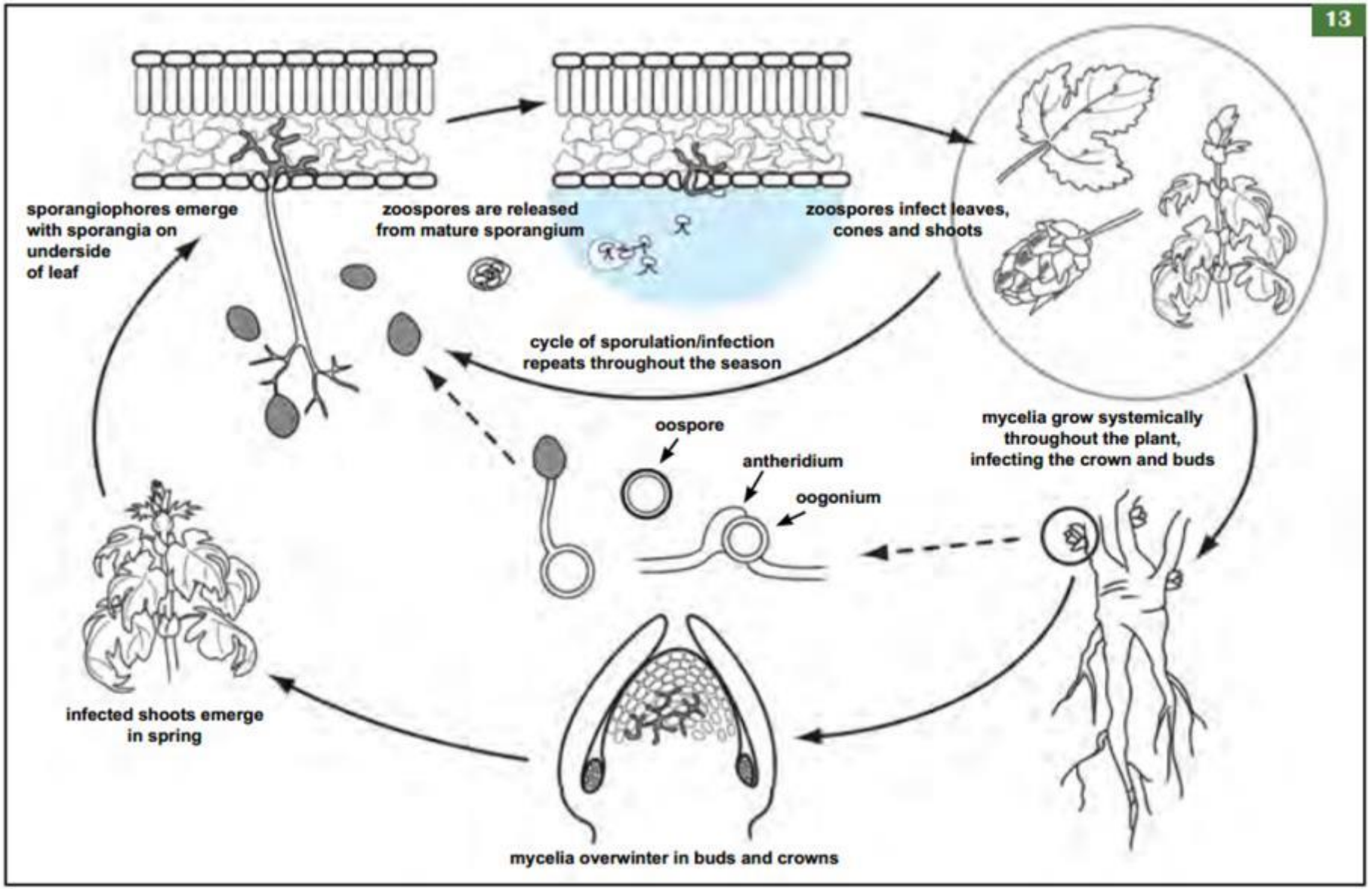
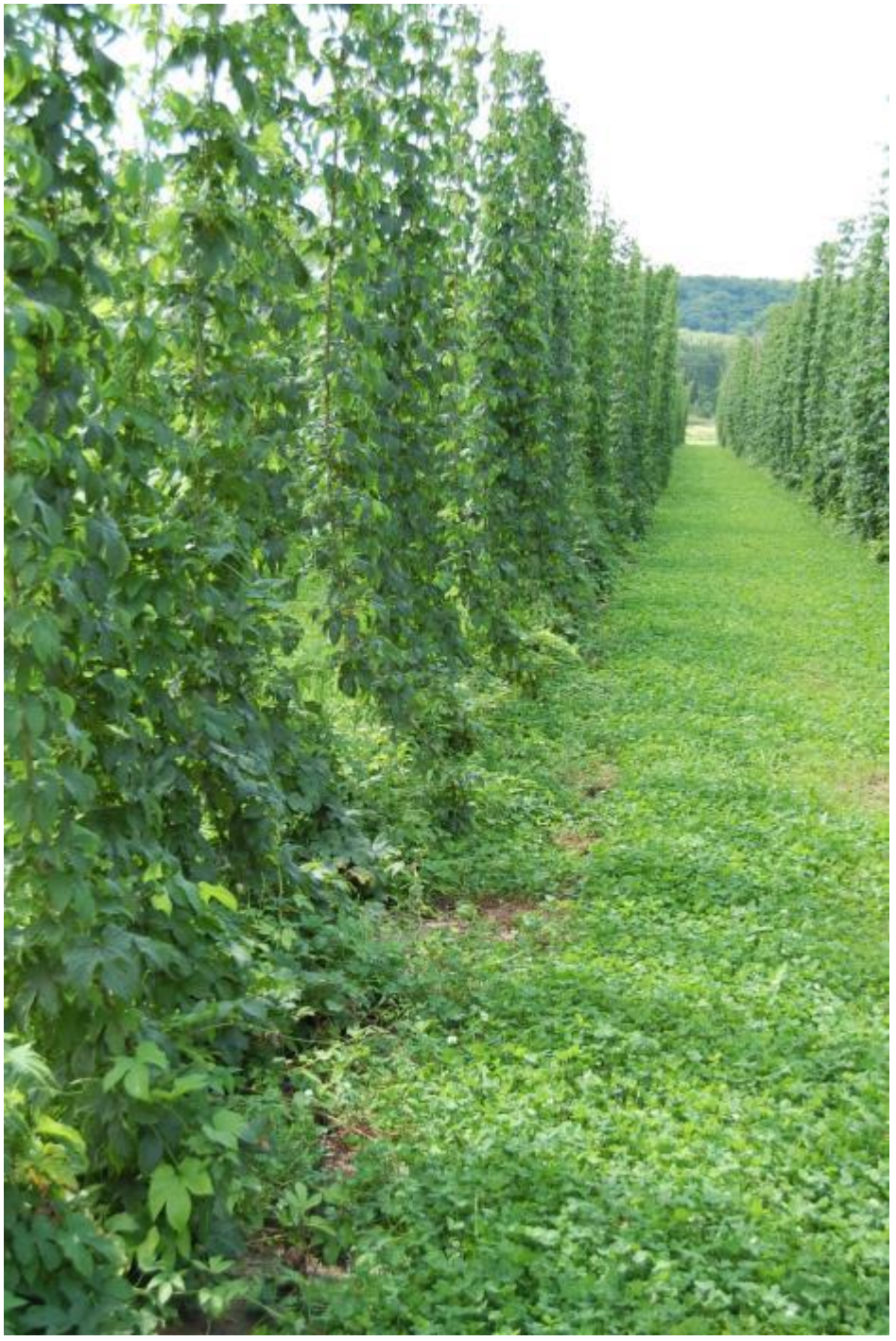


Photo credit: V. Brewster, Compendium of Hop Diseases and Pests

Hop Downy Mildew: Symptoms

Management

- Resistant varieties
  - Cascade, Fuggle, Perle, Willamette
  - But…grow what brewers want?
- Clean planting material
- Environmental/cultural management
  - Removing first shoots of season, cutting back basal growth, maintaining airflow
- Fungicide applications (more on this later)
  - Fosetyl aluminum (Aliette, Linebacker), cymoxanil (Curzate), copper hydroxide (Kocide), mono and dipotassium salts of phosphorus acid (Phostrol)



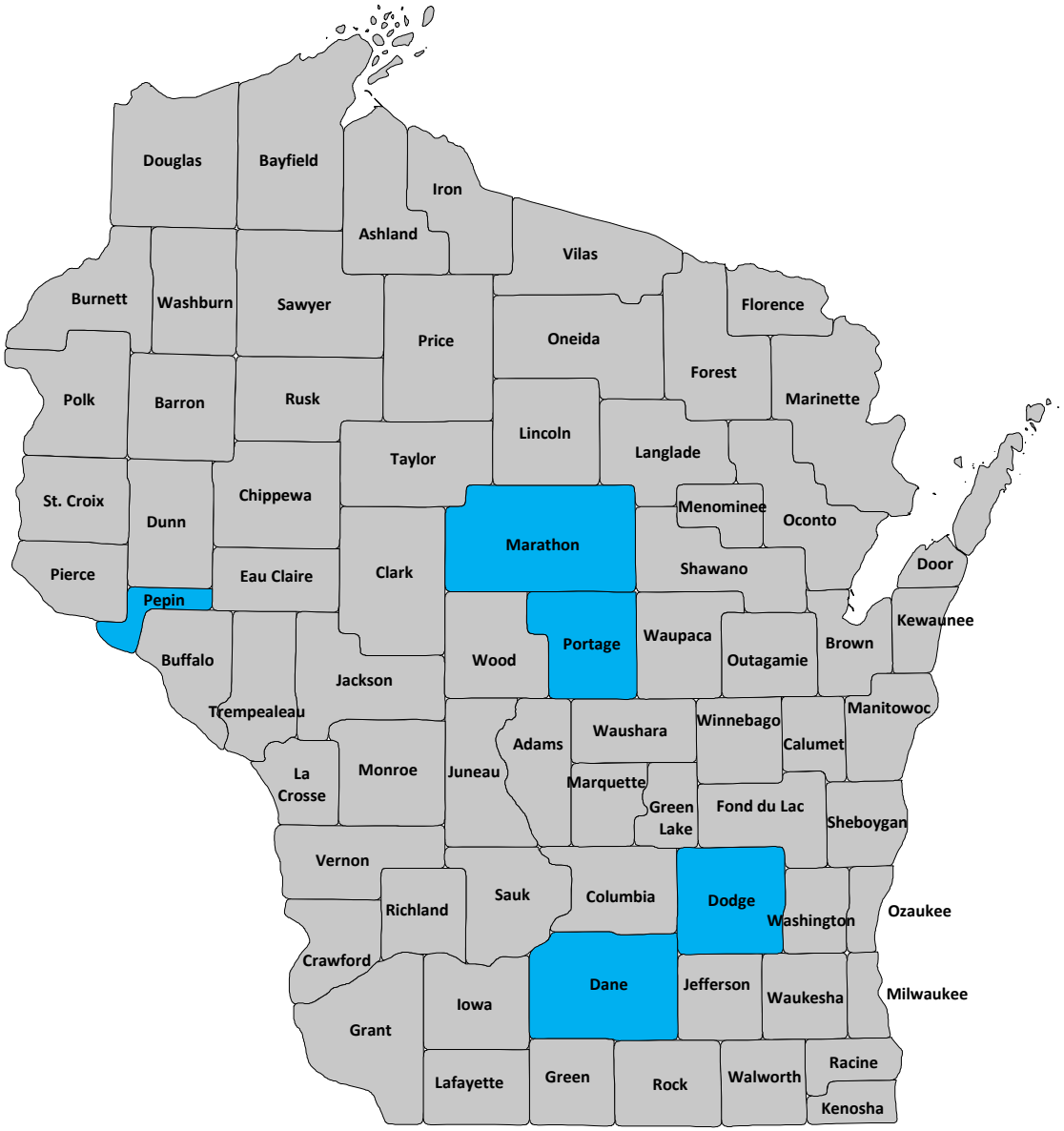
Current Research Objectives

- Investigate the survival of overwintering *Pseudoperonospora humuli* in hop rootstock, and develop a risk model based on cold duration and cooling degree-days
  - Correlate winter temperature conditions to spring emergence/severity
- Investigate the role of *Pseudoperonospora humuli* oospores in hop production
  - Are they here? In plant tissue/soil/roots?
- Optimize fungicide application programs for Wisconsin hops
  - Investigate post-harvest applications

Summer 2014
(continuing to summer 2015)

- A thorough assessment of hop diseases (timing and disease identification not previously known)
- Goals: identify diseases that are currently present in state and how they are currently managed; learn how disease incidence and progression varies

Grower Collaborator Locations



What was out there in 2014?

County	May	June	July	August
Dodge	Downy mildew	Downy mildew, leafhoppers	Apple mosaic virus, Carlavirus, spider mites, downy mildew	Downy mildew
Dane	Downy mildew	Downy mildew	Downy mildew, Japanese beetles	Downy mildew
Pepin			Carlavirus, Leafhoppers	
Portage	Downy mildew	Downy mildew	Leafhoppers, Japanese beetles, downy mildew	Downy mildew
Marathon		Leafhoppers	Downy mildew, Carlavirus (Hop latent virus)	Downy mildew

Powdery Mildew
(*Podosphaera macularis)*
Incidence & Management

- To date, powdery mildew has *not* been confirmed here in WI
- A few anecdotal reports have been made here in state
- Varietal resistance can limit disease
- Multiple fungicides are registered in WI (see handout)
- Contact us or the Plant Disease Diagnostic Clinic if you think PM is present in your yard!

Powdery mildew: symptoms

PM disease develops at 64 to 70°F and is 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.

Photo courtesy: David Gent

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

Viruses in WI Hop Production

- Apple mosaic virus, hop latent virus (Carlavirus group), and hop latent viroid have been confirmed on hop in WI
- Others include hop mosaic virus & American hop latent virus (both in Carlavirus group), Arabis mosaic virus, and hop stunt viroid
- Possible negative effects variable and dependent on variety, environment, and type of virus

Fungicides Registered on Hop in Wisconsin & Sample Fungicide Programs

Downy Mildew

Management – Initial phase

Downy mildew is systemic and the pathogen inside rhizomes 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.

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. Copper “drench applications” are most common.

When to **follow up** with fungicide sprays will vary on the weather. 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).

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).

Downy Mildew

Proposed Fungicide Program

Alternate between "Spray 1" and "Spray 2" programs every 7-14 days depending upon weather and disease pressure

Time of application	Fungicide selection Active ingredient (trade name example)	Comments
Spike emergence or spray #1	Fosetyl aluminum (Aliette, Linebacker) Salts of phosphorous acids (Phostrol)	Can be mixed with copper.
Spray #2	Cymoxanil (Curzate) Copper hydroxide (Kocide) Dimethomorph (Forum) Cyazofamid (Ranman) Pyraclostrobin+boscalid (Pristine) Famoxadone+cymoxanil (Tanos) Mandipropamid (Revus) Mefenoxam (Ridomil Gold SL) Ametoctradin + dimethomorph (Zing)	Curzate and Kocide are good downy mildew fungicides. Premixes which also control powdery mildew are Pristine, Tanos.

Fungicides for hop downy mildew control, WI Mar 3, 2015
One new registration in the past year - Zampro

Downy mildew (*Pseudoperonospora humili*)			
ametoctradin 45 + dimethomorph 40	11.0-14.0 fl oz Zampro	7 days PHI	Do not apply >40 fl oz/acre/season. Make no more than 3 applications/season. Do not make >2 sequential applications before alternating to a different mode of action.
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 11 + and cymoxanil 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 11 + boscalid 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 Mar 3, 2015
One new registration in the past year - Zampro

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.

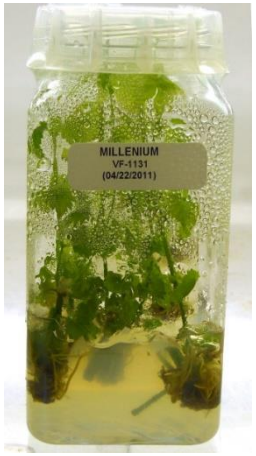
Fungicides for hop downy mildew control, WI Mar 3, 2015
One new registration in the past year - Zampro

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 and plants

http://healthyplants.wsu.edu



http://www.plantlabs.com

Dr. Ruth Genger, Researcher
Department of Plant Pathology, UW-Madison

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

Photos: David Gent; USDA Agricultural Research Service; Bugwood.org

Hop virus and viroid effects

- Yield losses can be severe
- Reduced acid levels
- Shift in ratio of α:β-acids
- Stunting, chlorosis, slower growth

Found in WI hop yards:

  - Hop latent viroid (2013)
  - Apple mosaic virus, Hop latent virus (2014)

- Found in hop propagative material (2014):
  - Carlavirus
  - Apple mosaic virus

Apple mosaic virus

Hop latent viroid

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, 2014-2015**

Sources of pathogen-free plants

National Clonal Germplasm Repository

- Corvallis, OR
- 185 cultivars and selections (not all are pathogen-free)

National Clean Plant Network

- http://healthyplants.wsu.edu/
- Twice-yearly sales
- Newer cultivars

Hop yards and native/feral hops

- Bine cuttings or rhizomes can be put into culture
- Anti-viral compounds and temperature therapy can be used to eliminate virus infections


National Clonal Germplasm Repository


National Clean Plant Network

Hop variety collection – pathogen free

Variety	Source	Tissue culture	Greenhouse
Cascade	NCGR	y	Y
Fuggle Tetraploid	NCGR	y	y
Galena	NCGR	y	y
Hallertauer Gold	NCGR	y	
Hallertauer Tradition	NCGR	y	
Hallertauer mitterfruher	NCGR	y	
Mt. Hood	NCGR	y	y
Nugget	NCGR	y	y
Saazer 36	NCGR	y	
Saazer 38	NCGR	y	y
Santiam	NCGR	y	
Willamette	NCGR	y	y
Yakima Gold (just received)	NCPN		y

Tissue culture collection

- Optimized tissue culture conditions for collection maintenance
- Plants adapt rapidly when transferred to greenhouse
- Planning trials of growth media for more efficient micropropagation

38 days after subculture

Transferred to greenhouse

12 days after greenhouse transfer

Greenhouse propagation trials

- Trialed standard method from NCPN website (healthyplants.wsu.edu)
- Two minute dip of cutting in 1000 ppm indole butyric acid and boric acid
  - Excessive root production, little shoot growth
  - Trialed lower concentrations
  - 100 ppm level seems optimum for root and shoot growth
  - Continuing trials suggest 10 ppm may improve success rate

A well-balanced cutting with shoot and root growth (left), compared to cuttings with excessive rooting.

Future propagation trials

- Propagating plants for Cascade, Galena and Willamette under mist and humidity dome conditions
- Plant in hop yards in Spring 2015 and follow their progress
- We can provide plants to growers in small numbers as part of preliminary field trialing (no charge)

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

Resources

- Plant Disease Diagnostic Clinic
- UW Vegetable Pathology
  - Virus testing
- UW Vegetable Pathology Web Page
  - http://www.plantpath.wisc.edu/wivegdis/
- UW Vegetable Pathology Facebook Page
  - https://www.facebook.com/UniversityOfWisconsinPotatoVegetablePathology




New UWEX Hop Disease Fact Sheets

A4053-01

Hop Downy Mildew

Identification and Management

Michelle Marks and Amanda Gevens

Hop cones maturing in a Wisconsin hop yard

Multiple stunted downy mildew spikes showing pale yellow-green leaves in the variety 'Santiam' in early June

A4053-02

Hop Powdery Mildew

Identification and Management

Michelle Marks and Amanda Gevens

Maturing hop cones in a hop yard in northern Wisconsin

Flag shoot showing severe infection with powdery mildew.

Foliar signs of powdery mildew on hop in Wash State.

Photos (left and above): David Gent, USDA Agricultural Research Service, Bugwood.org

A4053-03

Hop Viruses

Identification and Management

Michelle Marks and Amanda Gevens

Maturing hop cones in a Wisconsin hop yard

Hop leaves above show mild apple mosaic virus symptoms and leaves on the right show more severe symptoms.

Photo: David Gent, USDA Agricultural Research Service, Bugwood.org

Thank you! Questions?

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