Cucurbit Downy Mildew and *Phytophthora capsici* Management

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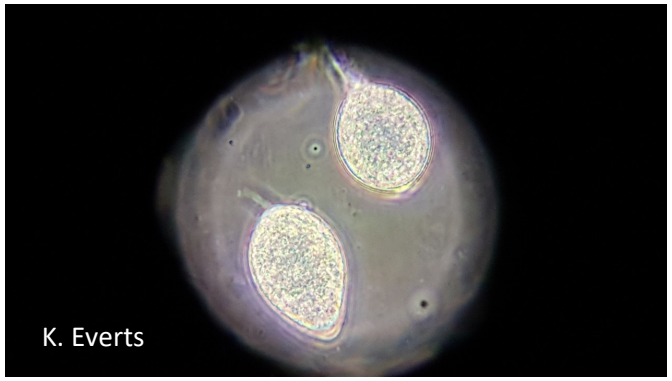
UNIVERSITY OF DELAWARE

Phytophthora Rot



- Caused by *Phytophthora capsici*
- Ideal conditions: wet soil, 77-86°F air temperature, and high humidity
- Infection to sporulation as fast as 2-3 days
- Sexual and asexual reproduction
- Overwinters as oospores
- Aerial dispersal of sporangia plays a minor role in epidemics
  - Infected soil/plants on equipment
  - Infested water used for irrigation
  - Soilborne oospores
- High reproductive potential

P. capsici Disease Cycle

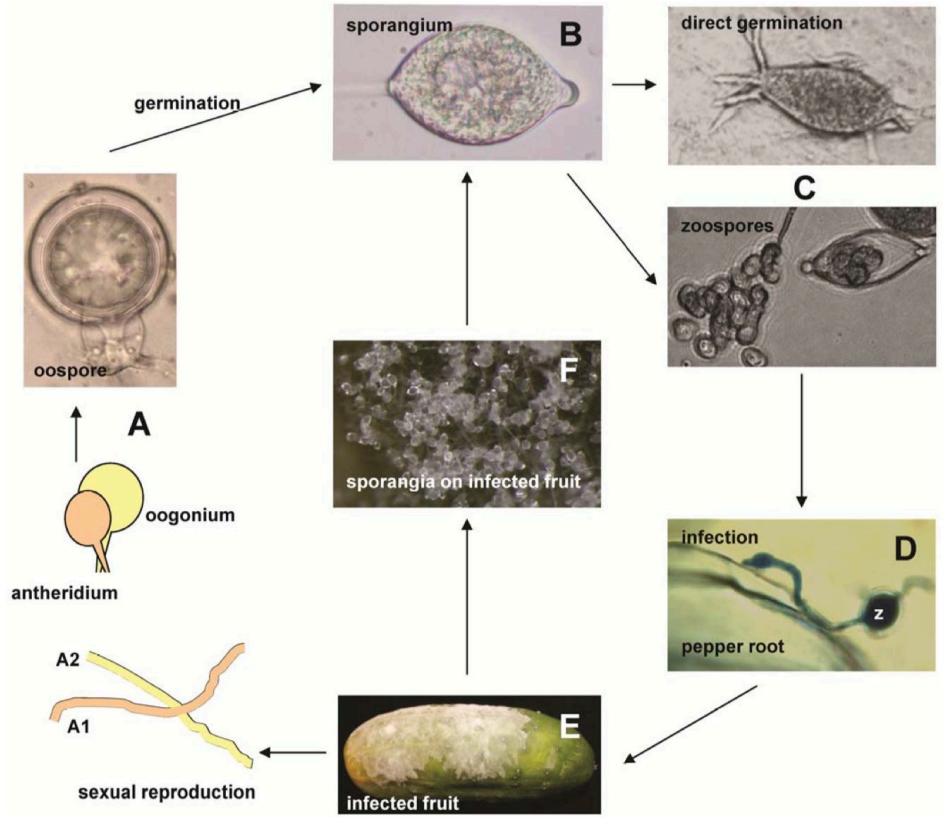


Fig. 3. Disease cycle of *Phytophthora capsici* on cucumber. When both mating types are present in the same field, oospores are produced **(A),** which allow *P. capsici* to overwinter and survive for years in the soil even in the absence of a susceptible host. Dormant oospores germinate to produce lemon-shaped sporangia **(B)** during wet conditions. Each sporangium **(B)** may germinate directly or via the formation of 20 to 40 bi-flagellate swimming zoospores **(C)** to infect the host **(D).** Sporangia are dispersed via irrigation water or wind-blown rain from one plant to another. Zoospores may swim in soil water toward plant roots, encyst, and germinate to penetrate the host **(D).** As the pathogen colonizes the host **(E),** copious amounts of sporangia **(F)** form on the host, which are able to infect new plants or new parts of the same plant causing multiple cycles of infection during a single growing season.

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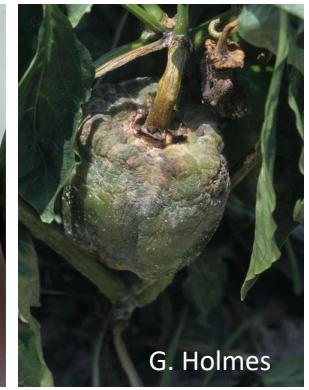
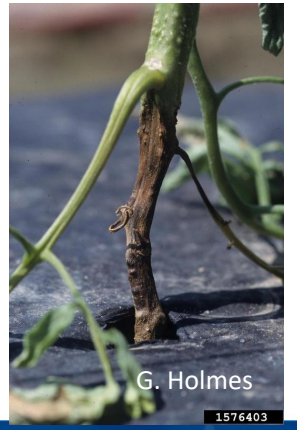
Granke et al. 2012

P. capsici Host Range

- Oospores can survive for years in soil, even without a host
- Virulence can vary on hosts
- Cucurbits
  - Cucumber
  - Melon
  - Squash
  - Pumpkin
- Nightshades
  - Peppers
  - Tomatoes
  - Eggplant
- Legumes
  - Snap bean
  - Lima bean
- Weeds
  - Nightshade
  - Velvet leaf





Lima Bean Pod Blight

- Only infects maturing lima bean pods
- Infects those low in the canopy and contacting the ground first
- Pods develop a whitish granular appearance
- Warm temperatures, rainfall, and high humidity provide optimal disease conditions
- Begin scouting when pin pods start to form

Lima Bean Pod Blight (*Phytophthora capsici*)

P. capsici has a very broad host range and can survive in the soil for several years. Avoid heavy irrigation and irrigating at night, especially after pod set. Avoid planting on poorly drained or compacted soils and in fields with rotations of cucurbits and peppers that are also hosts.

Code	Product Name	Product Rate	Active Ingredient(s) (*=Restricted Use)	PHI (d)	REI (h)	Bee TR
When weather conditions are favorable for disease development, apply and rotate between the following fungicides with different modes of action:						
4 + M01	Ridomil Gold Copper 65WP	2.0 lb/A	mefenoxam + copper	3	48	N
7	Endura 70W	8.0 to 11.0 oz/A	boscalid	7	12	--
21	Ranman 400SC	2.75 fl oz/A	cyazofamid	0	12	L
29	Omega 500F[1,2]	8.0 fl oz/A	fluazinam	14/30	12	N
40	Forum 4.17SC	6.0 fl. oz/A	dimethomorph	0	12	N
P07	Phosphite	4.0 to 6.0 pt/A	phosphite	0	4	N

[1]Applied for downy mildew management may also control *P. capsici*. [2]Not labeled for aerial applications.

Phytophthora Blight in Cucumber

- Damping-off can occur in seedlings
- Fruit are susceptible at all stages and more susceptible than plants
- Infection starts where fruit contacts the ground or on upper areas of fruit, due to rain-splashed sporangia
- Dark water-soaked lesions appear first
  - Lesions are soft and easily punctured
- White mycelial growth then occurs
  - “Powdered sugar” appearance
- Post-harvest infection is significant
  - 48-hour symptom delay can occur after infection

Phytophthora Crown and Fruit Rot - continued

Code	Product Name	Product Rate	Active Ingredient(s) (*=Restricted Use)	PHI (d)	REI (h)	Bee TR
Apply one of the following fungicides. Rotate fungicides with different FRAC codes and tank mix with a fixed copper (exception: do not tank mix Ranman 400SC with copper).						
49 + 40	Orondis Ultra	5.5 to 8.0 fl oz/A	oxathiapiprolin + mandipropamid	0	4	--
40	Revus 2.08F	8.0 fl oz/A	mandipropamid	0	4	--
40 + 45	Zampro 525SC	14.0 fl oz/A	dimethomorph + acetoctradin	0	12	--
43	Presidio 4SC[1]	3.0 to 4.0 fl oz/A	fluopicolide	2	12	L
M3 + 22	Gavel 75DF	1.5 to 2.0 lb/A	mancozeb + zoxamide	5	48	--
11 + 27	Tanos 50DF	8.0 to 10.0 oz/A	famoxadone + cymoxanil	3	12	--
21	Ranman 400SC	2.75 fl oz/A (plus a non-ionic or organosilicon surfactant; see label for additional precautions)	cyazofamid	0	12	L
40	Forum 4.17SC	6.0 fl oz/A	dimethomorph	0	12	N

[1]Presidio may also be applied through the drip irrigation (see supplemental label). Soil drench followed by drip application has given good results in some trials on crown rot caused by *Phytophthora capsici*.

Damping-Off caused by *Pythium*, *Phytophthora*, and *Rhizoctonia*

Code	Product Name	Product Rate	Active Ingredient(s) (*=Restricted Use)	PHI (d)	REI (h)	Bee TR
Apply one of the following at-planting (see label for application methods and restrictions):						
Phytophthora and Pythium root rot						
4	Ridomil Gold 4SL	0.5 to 1.0 pt/A	mefenoxam	5	48	N
4	Ultra Flourish 2E	2.0 to 4.0 pt/A	mefenoxam	5	48	N
4	MetaStar 2E AG	4.0 to 8.0 pt/A	metalaxyl	AP	48	N
Phytophthora, Pythium, and Rhizoctonia root rot						
4 + 11	Uniform 3.66SE	0.34 fl oz/1000 ft row. Avoid direct seed .contact, which may cause delayed emergence.	mefenoxam + azoxystrobin	AP	0	N

Preferred *Phytophthora* Fungicides for CUCUMBER			
Product	**A.I.**	**FRAC***	**Comment**
Elumin	ethaboxam	22	Rotate between applications. Apply as a soil or foliar spray or via drip.
Orondis Gold 200	oxathiapiprolin	49	Apply at-plant in-furrow or via drip (after plant emergence if direct-seeded).
Orondis Ultra	oxathiapiprolin/ mandipropamid	49/40	Rotate to a fungicide with a different FRAC after 2 sequential applications. Use either soil or foliar applications of oxathiapiprolin products, but not both for disease control.
Presidio 4SC	fluopicolide	43	Use in a tank mix. Apply via drip or as a foliar spray.
Revus 2.08SC	mandipropamid	40	Include surfactant.
**Apron XL	mefenoxam	4	Seed treatment. Wait 6 weeks after transplant to apply mefenoxam products.
**Ridomil Gold	mefenoxam	4	Apply as a preplant-incorporated, at-plant soil spray or via drip.
***Phytophthora* 'B' Team for CUCUMBER**			
Forum 4.18SC	dimethomorph	40	Use in a fungicide tank mix.
Gavel 75DF	mancozeb/ zoxamide	M03/22	Relatively long PHI.
Ranman 400SC	cyazofamid	21	See label about surfactant.
Zampro 4.4SC	ametoctradin/ dimethomorph	45/40	Apply via drip or as a foliar spray.

*The FRAC code is an alphanumeric code assigned by the Fungicide Resistance Action Committee and is based on the mode of action of the active ingredient.

**While mefenoxam is not labeled for *Phytophthora*, it is labeled for control of *Pythium*. Fungicide resistance has been detected in *Phytophthora* where mefenoxam has been used frequently.

Michigan State University

Chemical Control

- Chemical- cannot be relied upon as sole tool
  - Seed treatment
  - Pre-plant
  - At planting
  - Sprays every 5-7 days when conditions are favorable for disease development
- Mefenoxam resistance has been reported in Delaware but can occur at the field level
- Fungicide overlap with cucurbit downy mildew
  - Both pathogens are oomycetes
  - Effective options that target both diseases

Fungicide Resistance

- High selection pressure on the pathogen population following fungicide applications
  - Singe site modes of action apply the most pressure
- High reproduction directly increases the chance of mutations arising
- Clonal reproduction, allows for a selective advantage of mutants and a fast population shift
- Must balance the use targeted fungicides with broad spectrum fungicides

P. capsici Cultural Control Measures

- Crop rotation minimum of 3 years between hosts
- Effective weed control
- Select well-drained fields
- Promote drainage
- Careful irrigation practices
  - Reduce leaf wetness time
- Limit irrigation from aboveground water sources
- Rogue infected plants

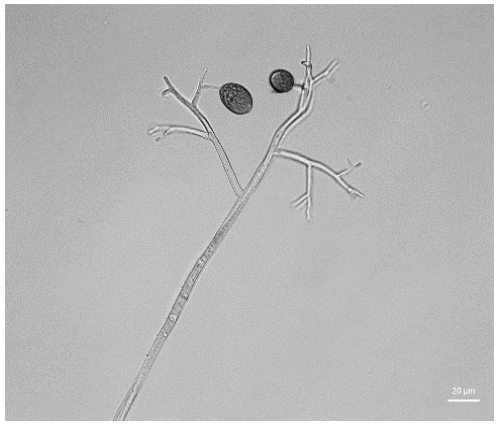
Sanitation

- Wet soil increases likelihood of spread
- Clean equipment before moving from an infected field to a clean field
- Prevent infestation of non-problematic fields
- Work in infected fields last
- Make sure used equipment is clean


Canola Council of Canada

Cucurbit Downy Mildew

- Oomycete pathogen
- Wide host range
- Caused by *Pseudoperonospora cubensis*
- Sporangia are windblown to new areas, does not overwinter in our region
- High reproductive potential, fast disease cycle



Cucurbit Downy Mildew

- Foliar disease symptoms include:
  - Water-soaked lesions
  - Angular chlorotic then necrotic lesions delineated by the leaf veins in cucumber
  - Can vary in other cucurbits with angular lesions surrounded by yellow halos in cantaloupe
- Can cause devastating yield losses depending largely on timing of disease onset
  - 2004- National cucumber yield loss of 40%

CDM Symptoms

Control Measures for CDM

- Prior to 2004, host-plant resistance was the major control measure for downy mildew on cucumber
- Post-2004, well timed preventative fungicide sprays are the backbone of CDM management programs
- Rotation and tank-mixing of efficacious chemicals is important to combat fungicide resistance in this rapidly evolving pathogen

Delmarva CDM First Reports

	2000	2015	2016	2017	2018	2019	2020	2021
Cucumber	"Mid-August"	July 8	June 29	June 23	June 15	June 27	July 6	June 17

- In all recent years, CDM was found in a commercial field before the sentinel plots
- cdm.ipmpipe.org
  - Forecasting and epidemic mapping website

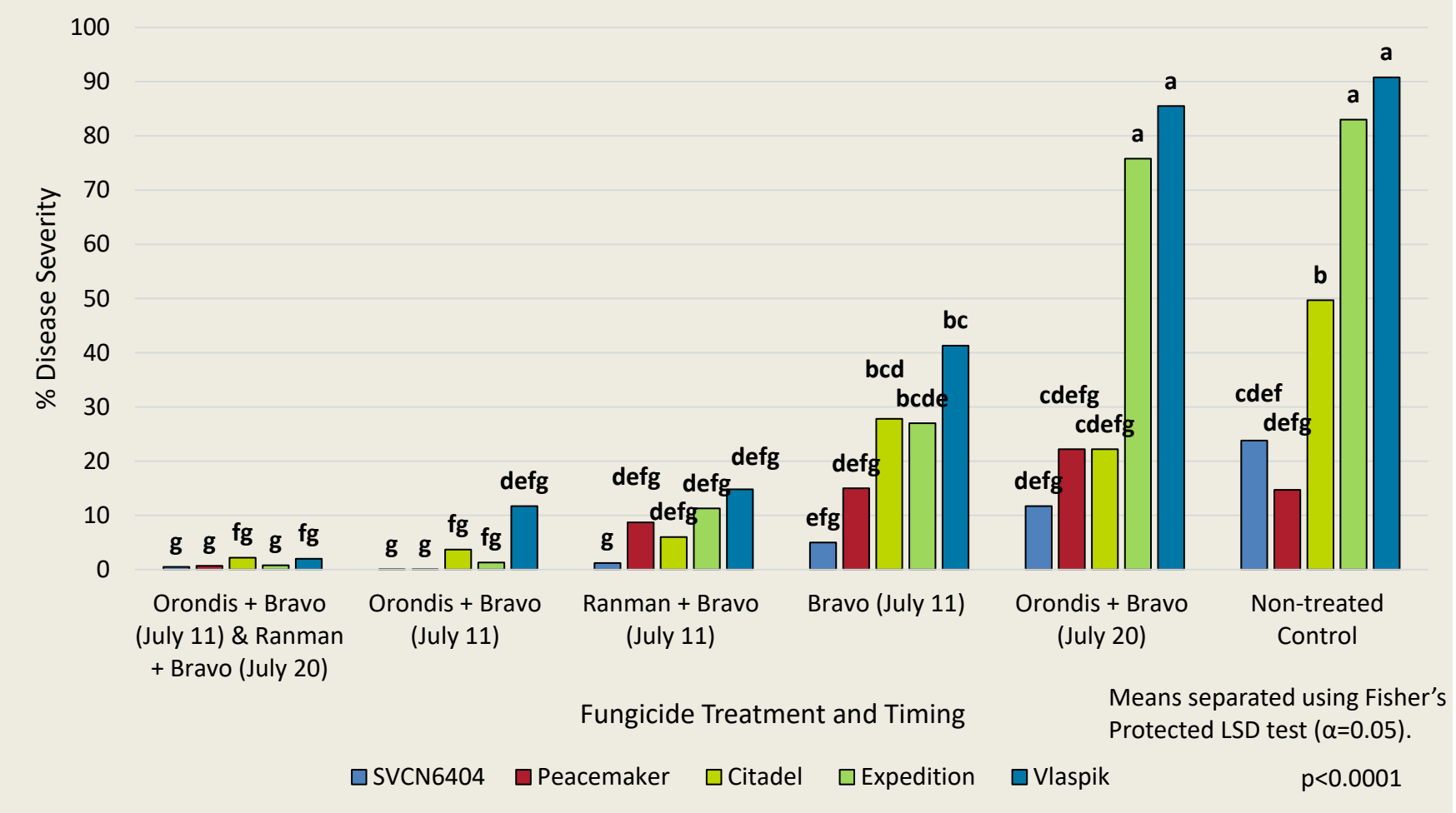
Fungicide and Variety Trial

Treatment No.	Fungicide	Rate/A	Application Dates		Active Ingredient
			Trial 1	Trial 2	
1	Orondis Opti 3.37 SC +	1.75 pt	July 11	Aug 17	Oxathiapiprolin
	Bravo Weather Stik 6SC	1 pt			Chlorothalonil
	Ranman 400SC	2.75 fl oz	July 20	Aug 28	Cyazofamid
	Bravo Weather Stik 6SC	2 pt			Chlorothalonil
2	Orondis Opti 3.37 SC +	1.75 pt	July 11	Aug 17	Oxathiapiprolin
	Bravo Weather Stik 6SC	1 pt			Chlorothalonil
3	Ranman 400SC	2.75 fl oz	July 11	Aug 17	Cyazofamid
	Bravo Weather Stik 6SC	2 pt			Chlorothalonil
4	Bravo Weather Stik 6SC	2 pt	July 11	Aug 17	Chlorothalonil
5	Orondis Opti 3.37 SC +	1.75 pt	July 20	Aug 28	Oxathiapiprolin
	Bravo Weather Stik 6SC	1 pt			Chlorothalonil
6	Non-Treated Control	N/A	N/A	N/A	N/A

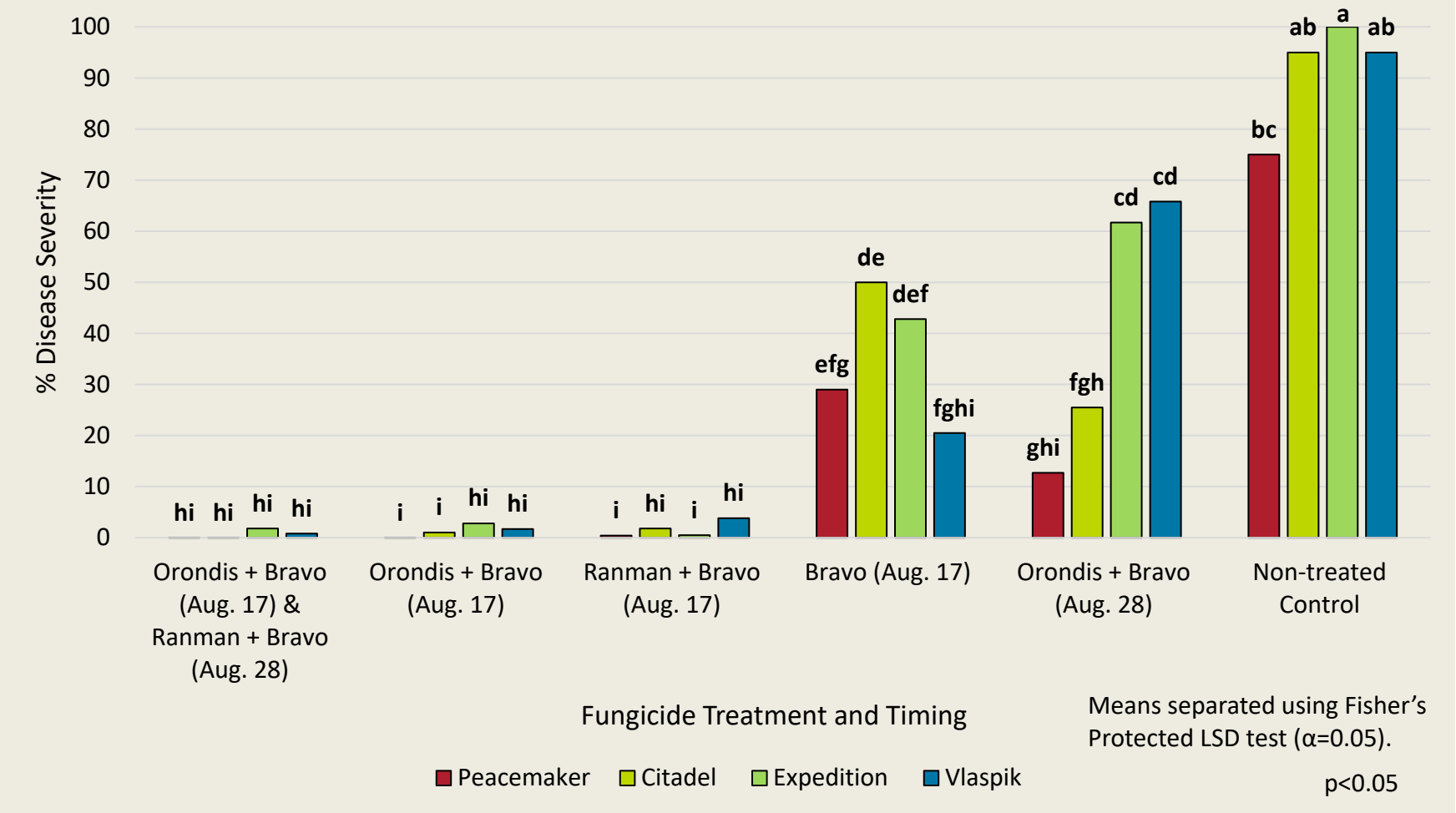
Varietal Selection

- ‘Expedition’ and ‘Vlaspik’
  - Standard varieties
  - Susceptible to CDM
- ‘Citadel’
  - Moderately resistant to CDM
- ‘Peacemaker’ and ‘SVCN6404’
  - Improved moderately resistant to CDM
  - ‘SVCN6404’ included in Trial 1 only

Fungicide and Variety Trial 1



Fungicide and Variety Trial 2



Fungicide and Variety Trial Conclusions

- Importance of preventative sprays
  - All early sprays performed much better than later sprays
- Late sprays with Orondis and Bravo provided some protection to plants compared to the untreated control
  - Late sprays are asking for fungicide resistance development due to large populations
- Resistant varieties had lower disease ratings in earlier trial
  - Possibly due to less CDM pressure, different pathogen populations between the two trials

- Citadel, Peacemaker, SVCN6404 all performed poorly in high severity trial in Ohio 2020 (95% + CDM severity)

Fungicide Bioassay Design

- Modified from: Keinath, A.P. 2016. in multiple states (DE, MD, PA, NY)
- Two to three leaf seedlings
  - ‘Silver Slicer’ cucumber
- Treated with full and half labeled rates
- 24 hours later placed in cucurbit downy mildew infected field for 48 hours
- Rated disease severity 10 days later

Fungicide Bioassay Treatments

Active Ingredient	Trade Name	FRAC Code	Full Rate (per hectare)
Chlorothalonil 82.5%	Bravo Ultrex 82.5WDG	M5	1.57 kg
Cymoxanil 60%	Curzate 50DF	27	0.35 kg
Ethaboxam 42.5%	Elumin 4SC	22	0.58 L
Dimethomorph 43.5%	Forum 4.17SC	40	0.44 L
Fluazinam 40%	Omega 500F	29	1.75 L
Oxathiapiprolin 10.2 - 18.7%	Orondis Formulations[a]	49	0.15-0.67 L
Propamocarb 66.5%	Previcur Flex 6SL	28	1.40 L
Fluopicolide 39.5%	Presidio 4SC	43	0.29 L
Azoxystrobin 22.9%	Quadris 2.08F	11	1.13 L
Cyazofamid 34.5%	Ranman 400SC	21	0.20 L
Mandipropamid 23.3%	Revus 2.08SC	40	0.58 L
Ametoctradin 26.9% + dimethomorph 20.2%	Zampro 525SC	45 + 40	1.02 L
Zoxamide 6.8% + chlorothalonil 40%	Zing! 4.9SC	22 + M5	2.63 L
Zoxamide	Zoxamide (Technical Grade)	22	400 ppm

[a]Orondis Gold 200SC (18.7% oxathiapiprolin) in New York, Orondis Opti A 0.83OD (10.2% oxathiapiprolin) in Pennsylvania, and Plenaris 200FS (18.7% oxathiapiprolin) in Maryland.

Fungicide Bioassay Results

- I = ineffective
  - RDS >35%
- E = effective
  - RDS <35% but significantly higher than treatment with the lowest RDS
- H = highly effective
  - RDS similar to best treatment
- * = lowest RDS in the bioassay.
- ND = no data

Fungicide Bioassay Results

	2016		2017				2018	2019	
Fungicide	**DE**	**NY**	**MD**	**NY**	**PA[a]**	**PA[b]**	**NY**	**MD**	**NY**
Quadris 2.08F	E	I	I	I	I	E	I	I	I
Revus 2.08SC	E	I	I	I	ND	ND	I	I	I
Presidio 4SC	*	E	H	I	E	H	I	I	I
Forum 4.17SC	ND	I	I	E	E	I	E	H	E
Curzate 50DF	H	H	H	I	H	E	H	I	H
Zoxamide	ND	ND	ND	ND	ND	ND	*	ND	I
Zampro 525SC	E	I	E	E	H	*	H	E	ND
Previcur Flex 6SL	*	E	ND	E	E	E	H	*	H
Omega 500F	ND	ND	ND	ND	ND	ND	ND	*	E
Ranman 400SC	*	E	H	E	H	H	H	*	E
Bravo Ultrex 82.5WDG	ND	*	H	*	H	H	H	*	E
Zing! 4.9SC	*	E	H	H	*	*	ND	*	ND
Elumin 4SC	ND	ND	ND	ND	ND	ND	ND	*	ND
Orondis Formulations[c]	ND	ND	*	ND	*	*	H	*	*

[a]Blair County, Pennsylvania
[b]Berks County, Pennsylvania
[c]Orondis Gold 200SC (18.7% oxathiapiprolin) in New York, Orondis Opti A 0.83OD (10.2% oxathiapiprolin) in Pennsylvania, and Plenaris 200FS (18.7% oxathiapiprolin) in Maryland.

Fungicide Bioassay Conclusions

- Orondis, Zing!, Bravo, and Ranman are the most efficacious fungicides for cucurbit downy mildew
- FRAC Groups 49, 22, M5, 21
- Quadris, Revus, Presidio, Forum, and Curzate were all ineffective in multiple bioassays
- Elumin, Omega, and Previcur Flex were effective in every trial

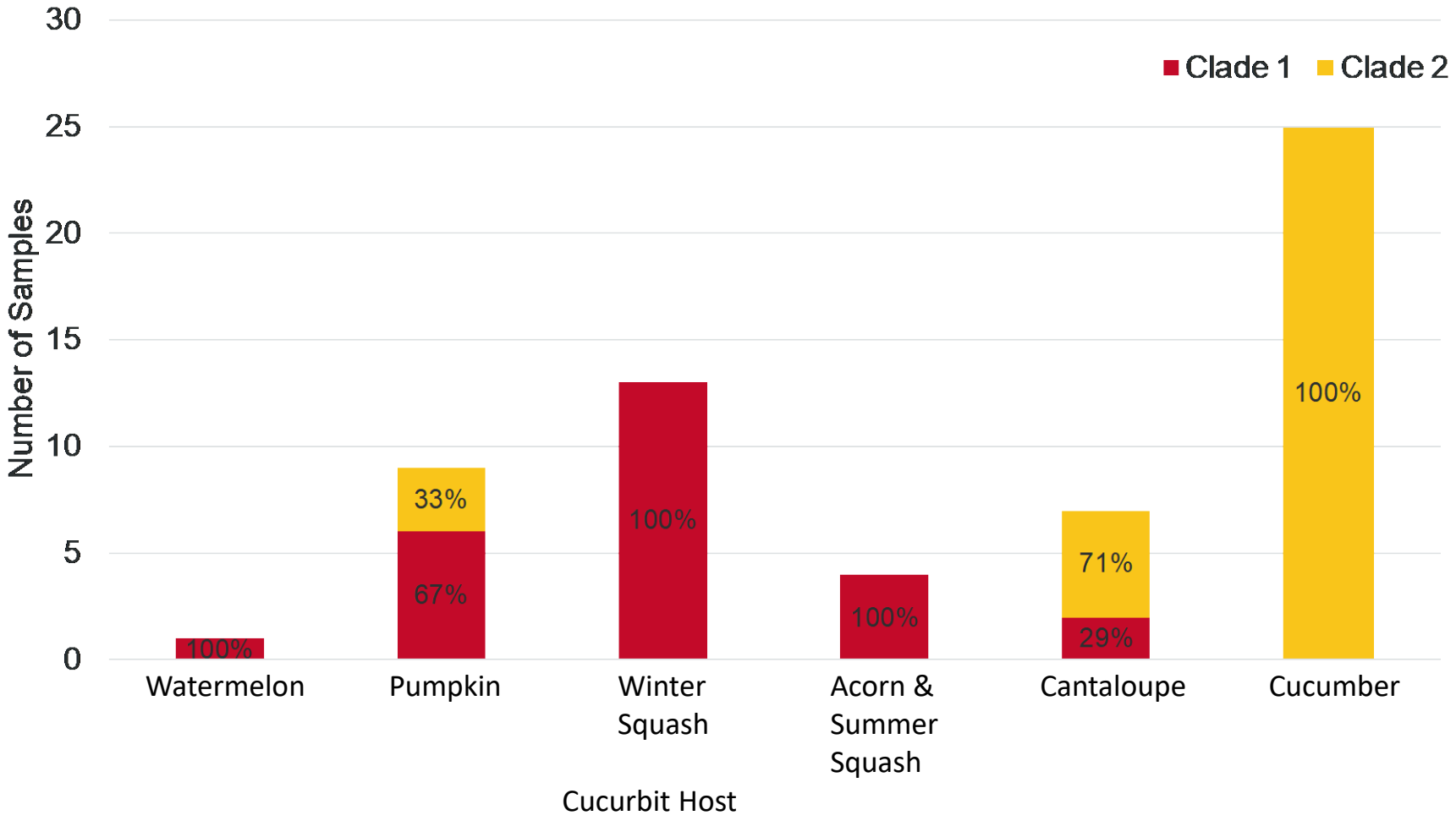
Fungicide Bioassay Discussion

- Location
  - *P. cubensis* populations are exposed to fungicides throughout CDM's spread northward and this could result in insensitivities to the fungicides used in the South
  - Main regional cucurbit host could play a role in the population present
- Timing
  - *P. cubensis* populations are constantly shifting throughout the growing season
- Cucurbit crop
  - Recommendations could be made for most efficacious chemicals to be applied to cucumber and the moderately effective chemicals (Zampro, Curzate, etc.) to be applied to squash and watermelon

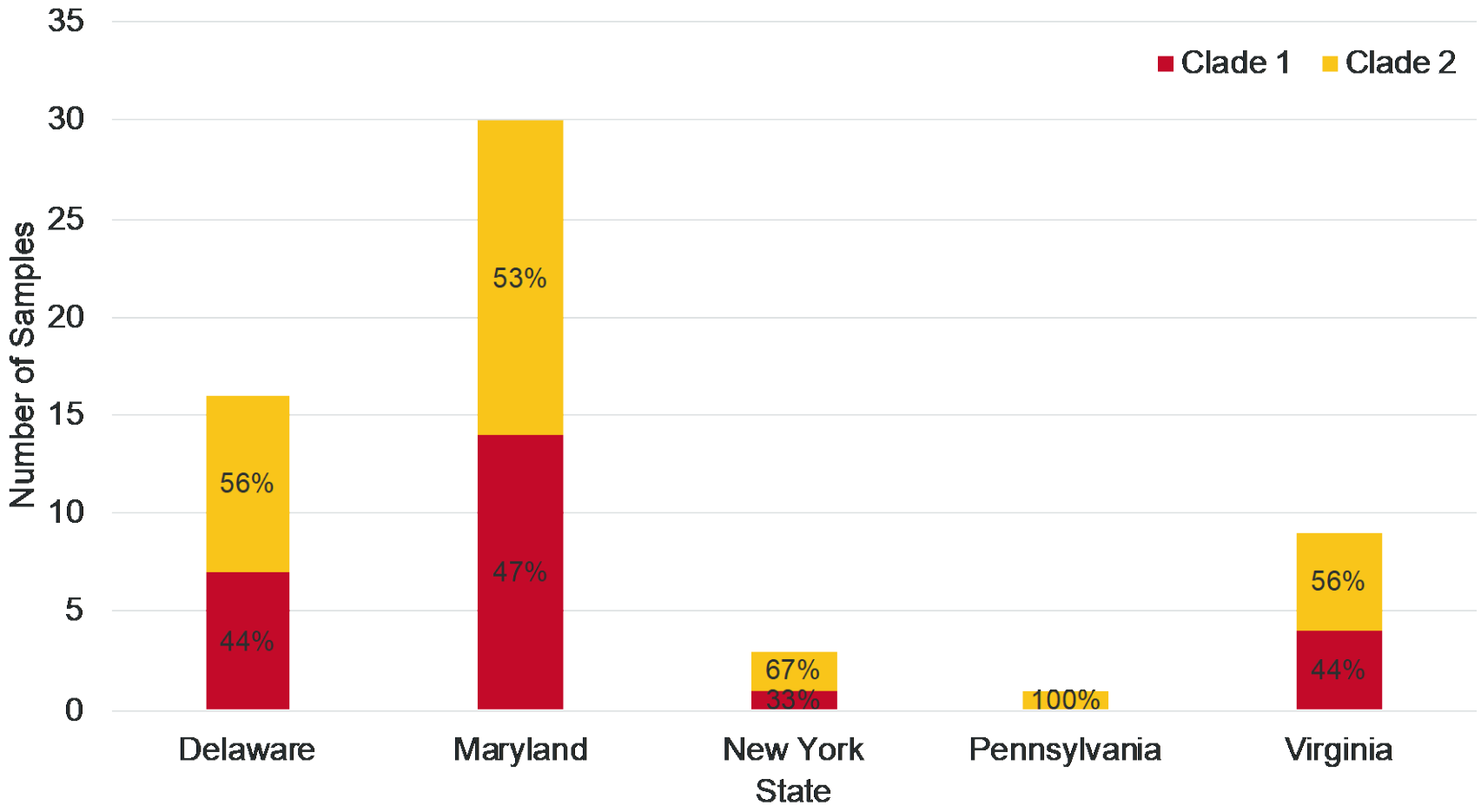
P. cubensis Clade-Host Relationship

- CDM Re-emerged in 2004 with a severe epidemic on cucumbers
  - Overcame long standing host resistance
  - 1984 Europe epidemic
- Difference in virulence, fungicide sensitivity, timing of infection, etc. led to research
- Appears to be two clades
- Clade 1
  - Appears later in the season
  - Associated with winter squash, watermelon, and summer squash
- Clade 2
  - Appears earlier in the season, virulent
  - Associated with cucumbers

Clade Results by Cucurbit Host



Clade Results by State



Clade Host Discussion

- Supports recent research from North Carolina with similar clade-host associations
- Provides information on population dynamics of *P. cubensis* in the Mid-Atlantic
- Can be used for more accurate disease forecasting and fungicide recommendations
    - Crop specific disease forecasting
    - Use most efficacious fungicides on the more aggressive clade 2
        - Fungicide efficacy tests based on clade
    - Helps explains the occurrence of *P. cubensis* on cucumber every year but not watermelon/squash

Takeaways

- First report of CDM is trending earlier
  - Scout and stay up to date with forecasting websites & Weekly Crop Update
- Preventative fungicide sprays are key
- Rotate FRAC Groups and use broad spectrum fungicides in tank mix
- Host-resistance can play a role in your CDM management strategy
  - Multiple commercial varieties available
- Orondis, Ranman, Zing!, and Bravo are the most effective fungicides currently available to control CDM

Oomycete Disease Control in Cucumbers

- With certain fungicides that are efficacious on both *P. capsici* and *P. cubensis* it's possible to make sprays more valuable
  - Orondis- expensive but works well for both
    - Orondis soil applications cannot be followed by Orondis foliar applications
  - Presidio
  - Zampro
  - Elumin
  - Revus
  - Ranman
- Use cultural controls when possible
  - Field selection and irrigation management for *P. capsici*
  - Resistant varieties for *P. cubensis*

Questions?

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