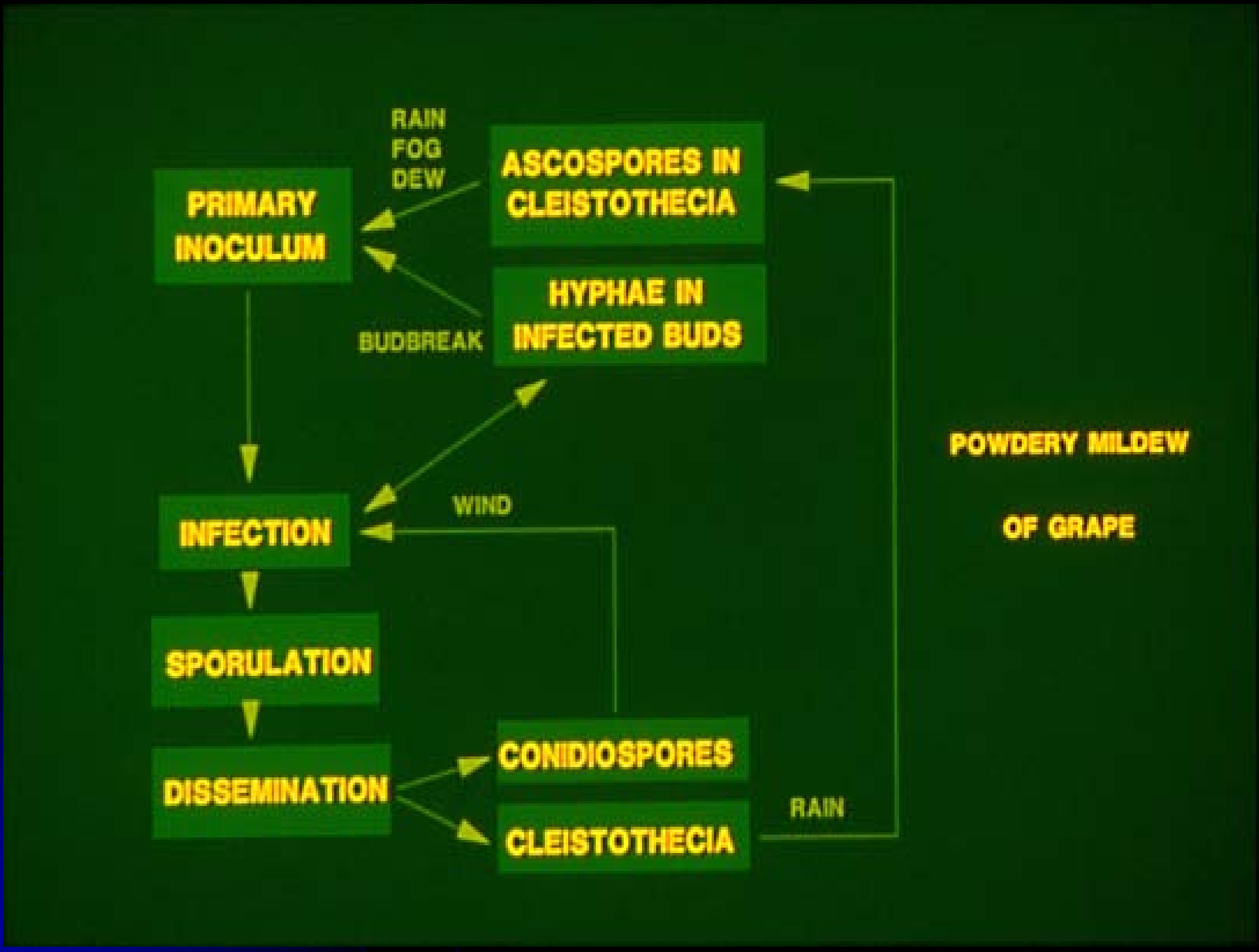
Grapevine Powdery Mildew: Biology, Epidemiology, and Management in California

Dr. Doug Gubler
Dept of Plant Pathology
University of California, Davis


RAIN
FOG
DEW
ASCOSPORES IN CLEISTOTHECIA
PRIMARY INOCULUM
HYPHAE IN INFECTED BUDS
BUDBREAK
POWDERY MILDEW
OF GRAPE
WIND
INFECTION
SPORULATION
DISSEMINATION
CONIDIOSPORES
CLEISTOTHECIA
RAIN

Chasmothecia

- Form in late summer and fall.
- Wash from leaves with fall and winter rains onto cordons, canes, and spurs.
- Monitor for disease 7-10 days after ascospore release—lower surface of basal leaves.
- Control
  - Postharvest application of JMS Stylet Oil at 1.5-2.0%
  - Dormant application of Lime sulfur at 10-15 gal/A
  - Budbreak application of Kumulus,Thiolux, Microthiol Special 5#/A
  - Budbreak application of JMS Stylet Oil at 0.5-1.0%

GRAPE POWDERY MILDEW:

BUD PERENNATION

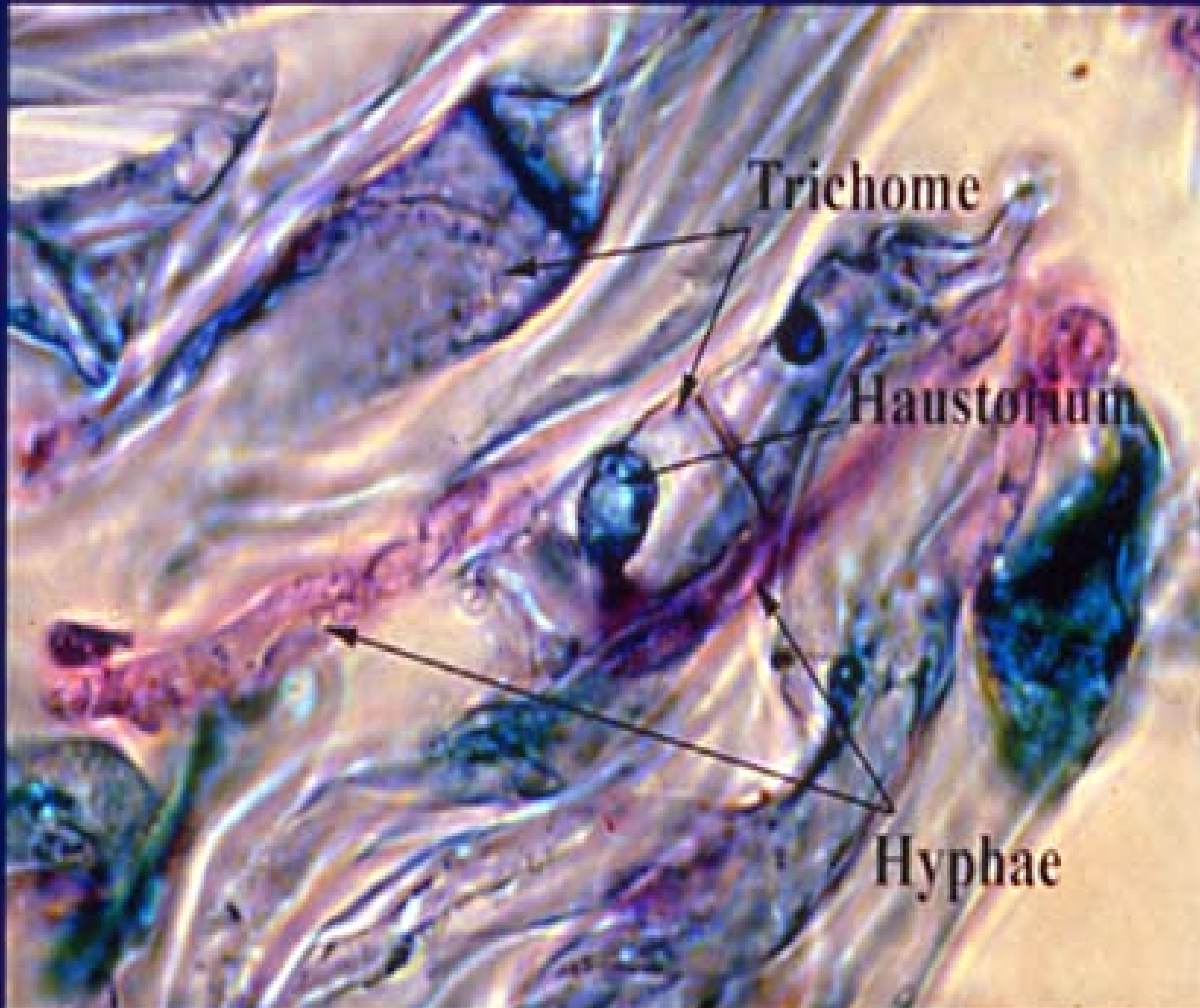


Figure 5a. Longitudinal sections of developing dormant bud showing the vacuous trichome cells with hyphae and haustorium of *U. necator*.

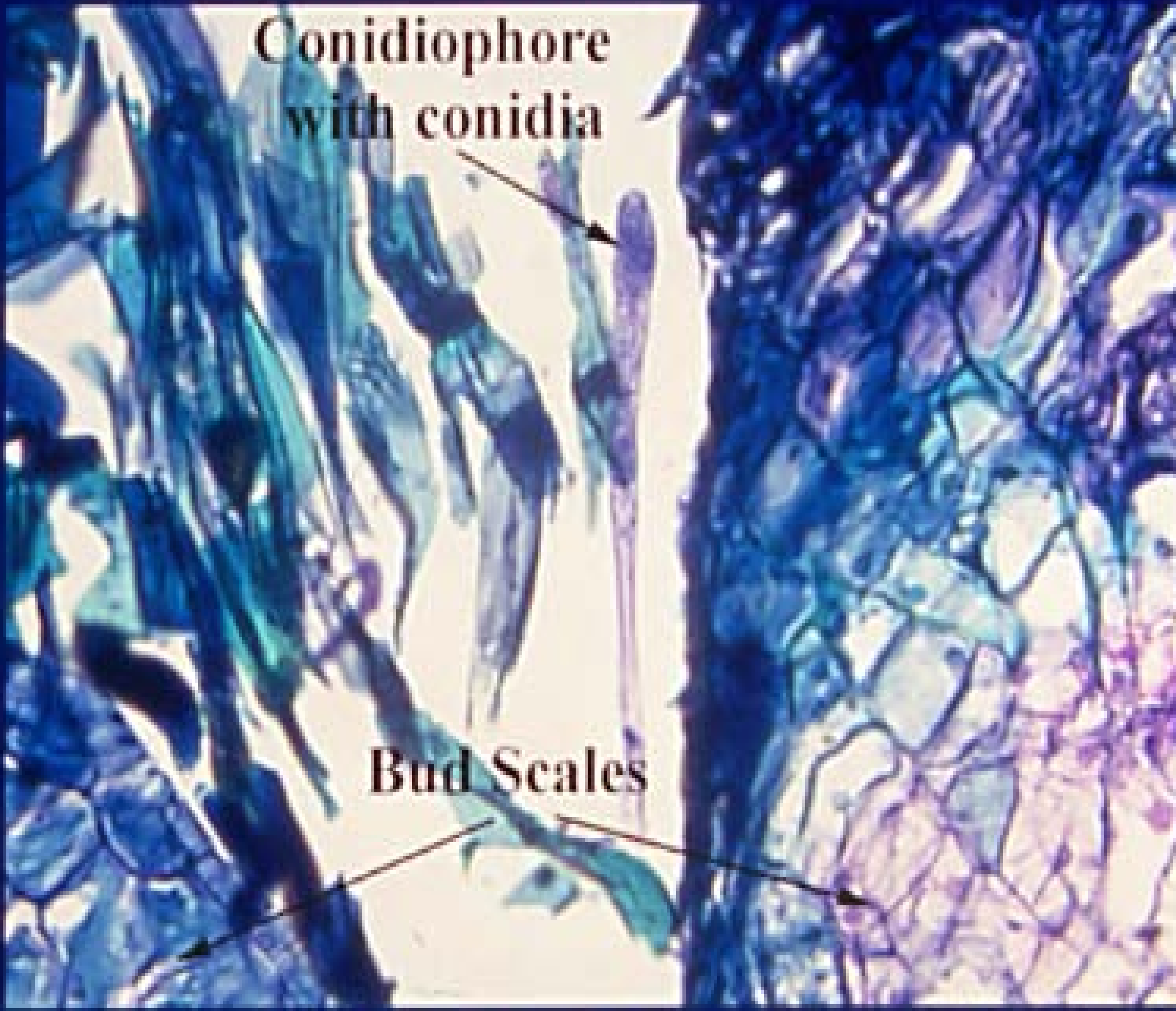


Figure 9. Longitudinal section of the developing dormant bud collected two months after shoot growth showing a conidiophore with one spore. This suggests that sporulation is occuring inside the bud. Bud collected six weeks after shoot growth.

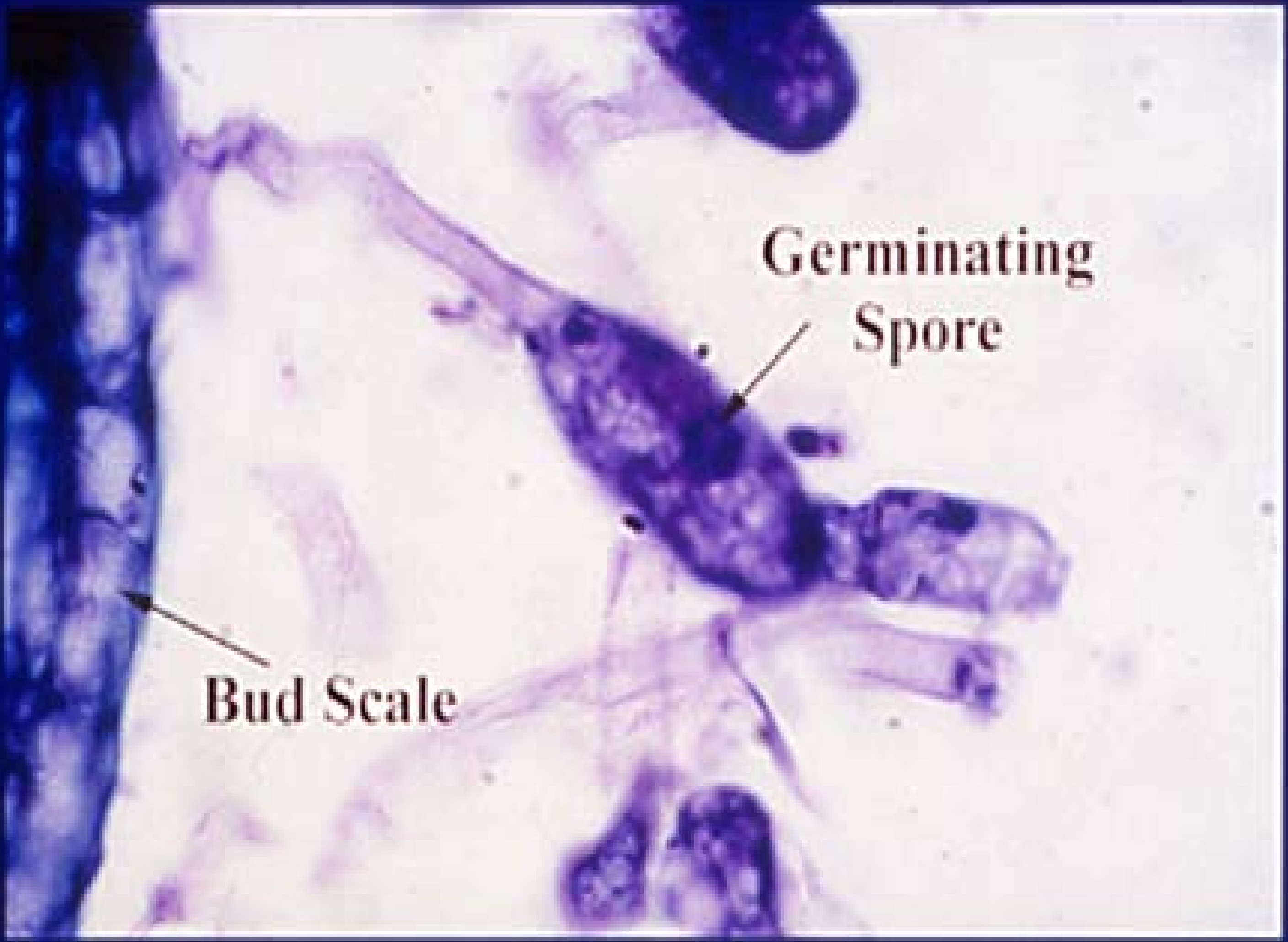
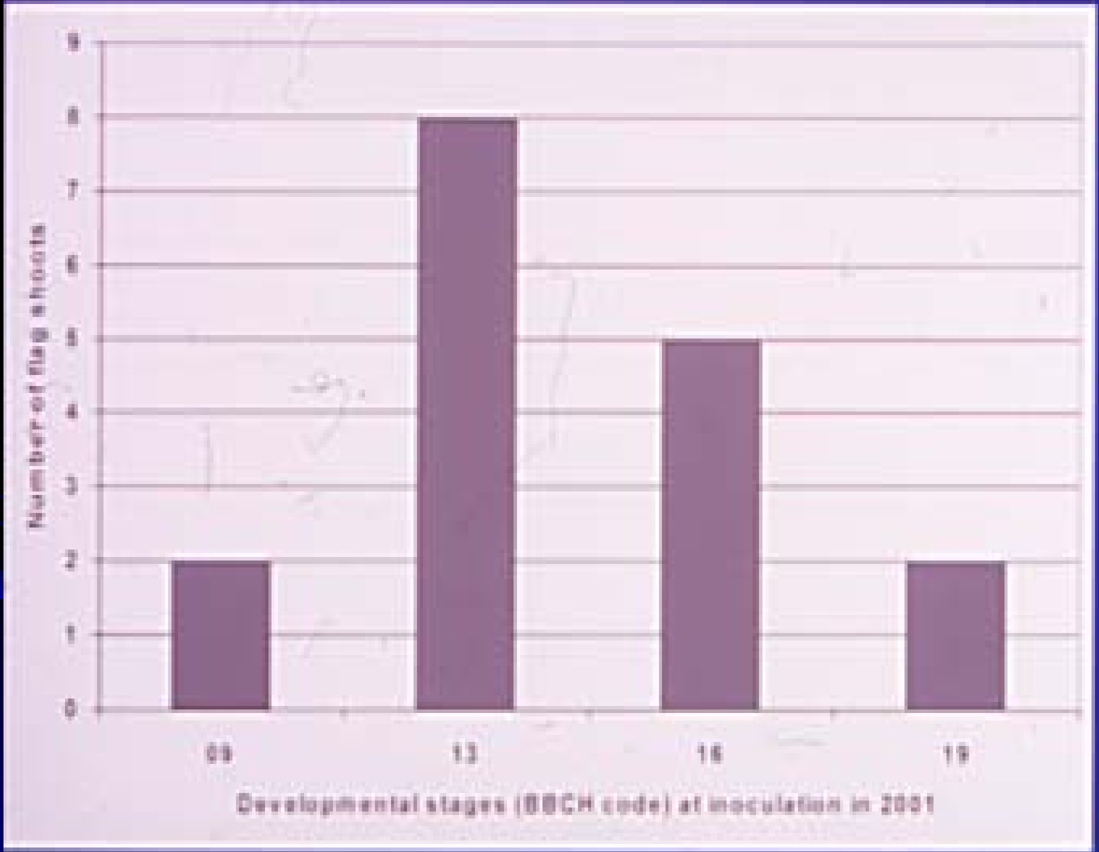


Figure 8. Longitudinal section of a developing dormant bud collected two months after shoot showing one spore of *U. necator* germinating inside the bud. Bud collected six weeks after shoot growth.

Flag shoot incidence: Distribution

Flag shoots/overwintered mycelium on *V. vinifera* cv. Carignane (Spring 2002):



30 vines per stage were surveyed (120 in total)

- av. flag shoot rate/vine: 0.14
- av. flag shoot rate/bud: 0.014

Powdery Mildew
-Uncinula (Erysiphe) necator

- Disease epidemiology/ Pathogen biology
  - Direct sunlight
    - Reduces viability of spore germination and infection
    - Leaf removal reduces disease by about 50%
  - High temperatures
    - Reduces spore production
    - Reduces spore germination rate
    - Reduces infection rate
    - Affects reproduction rate
    - High Temps mask resistance to DMI fungicides

Figure 4. E. Necator colony size as a function of temperature, duration, and age of colony. Three-day-old colonies were incubated at the temperatures and durations shown. Perpendicular colony diameters were measured every 2 days and averaged.

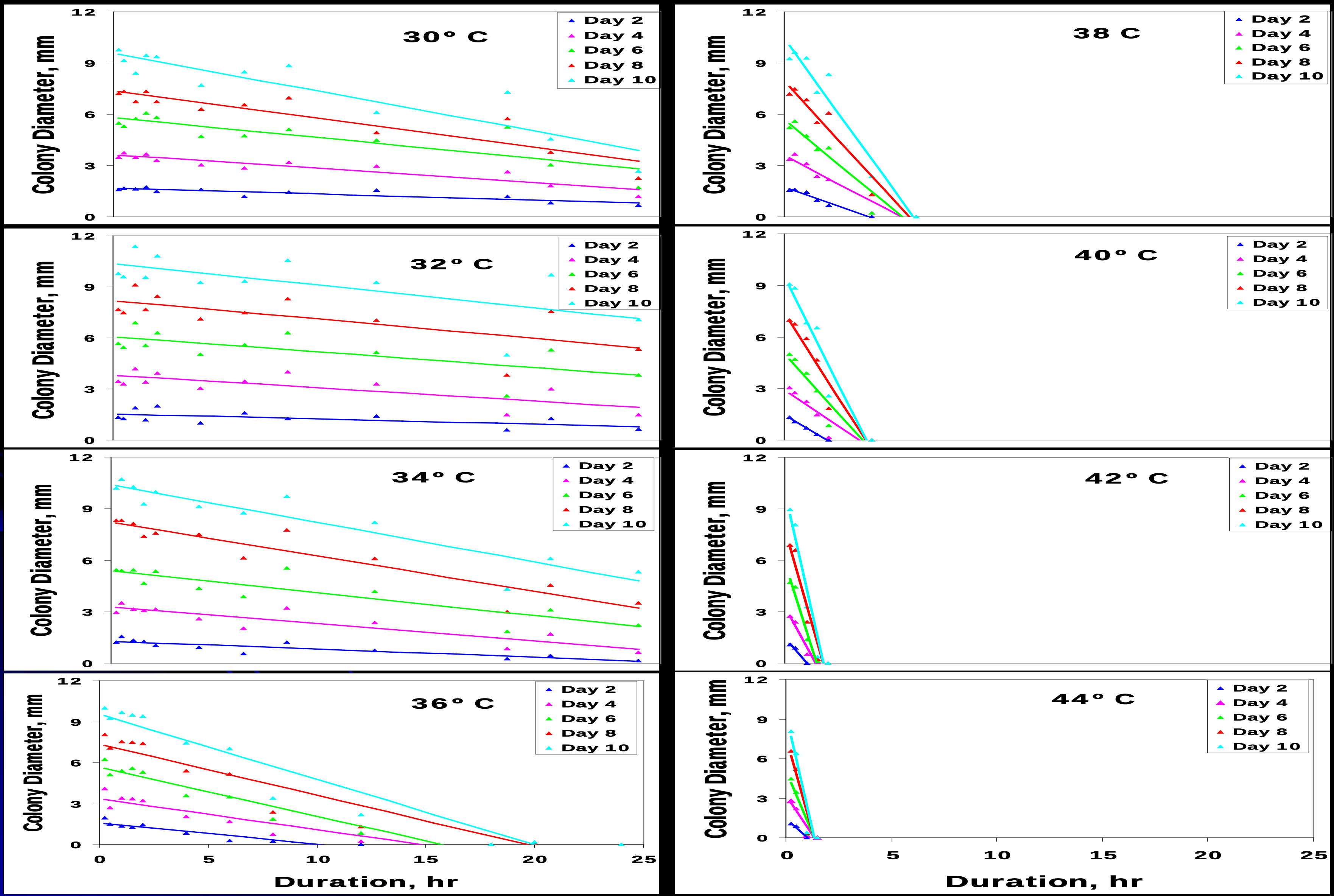


Figure 7. The effects of temperature and duration on first appearance of *E. necator* colonies. Days on "x" axis and hrs on "y" axis.

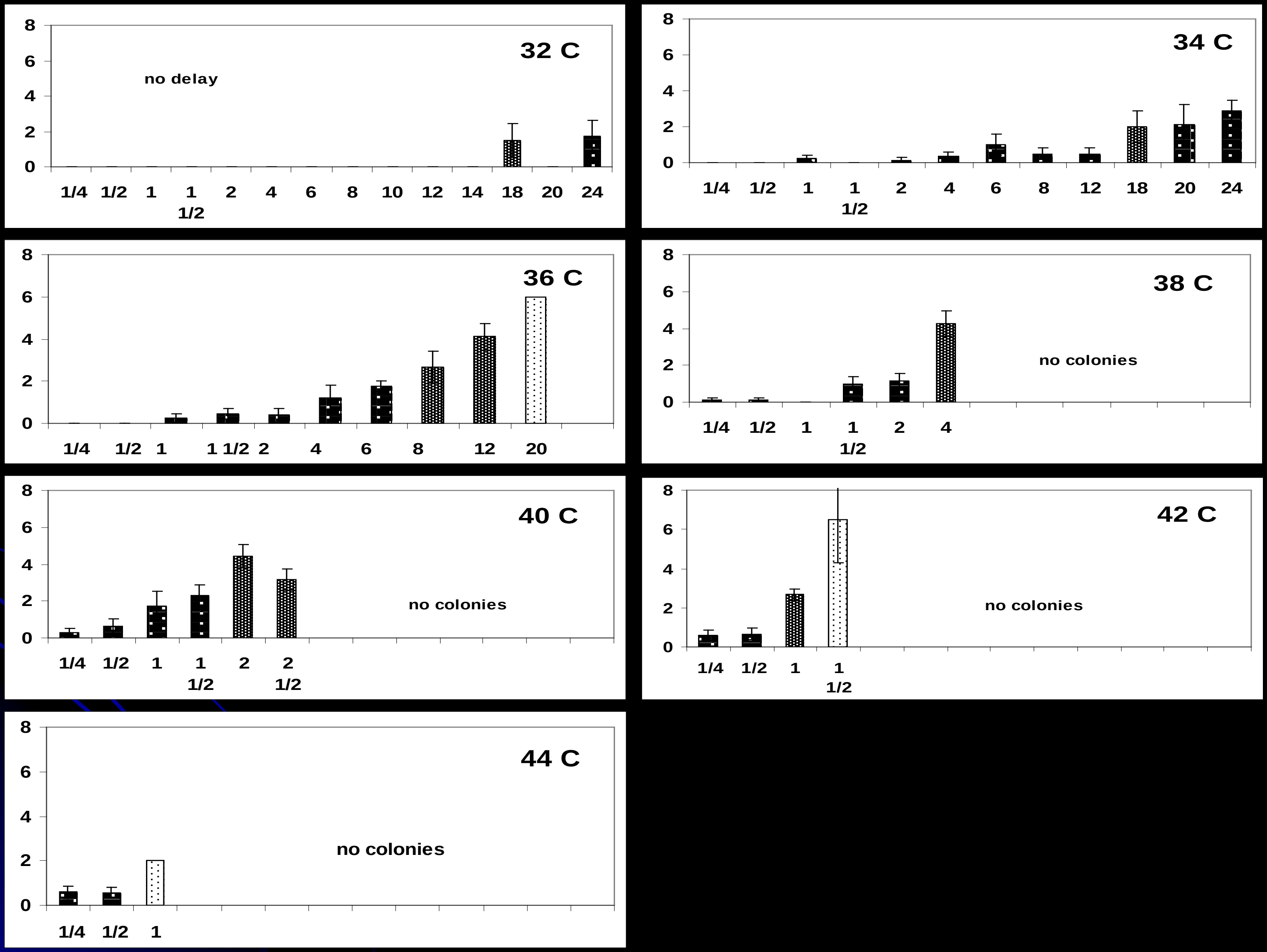
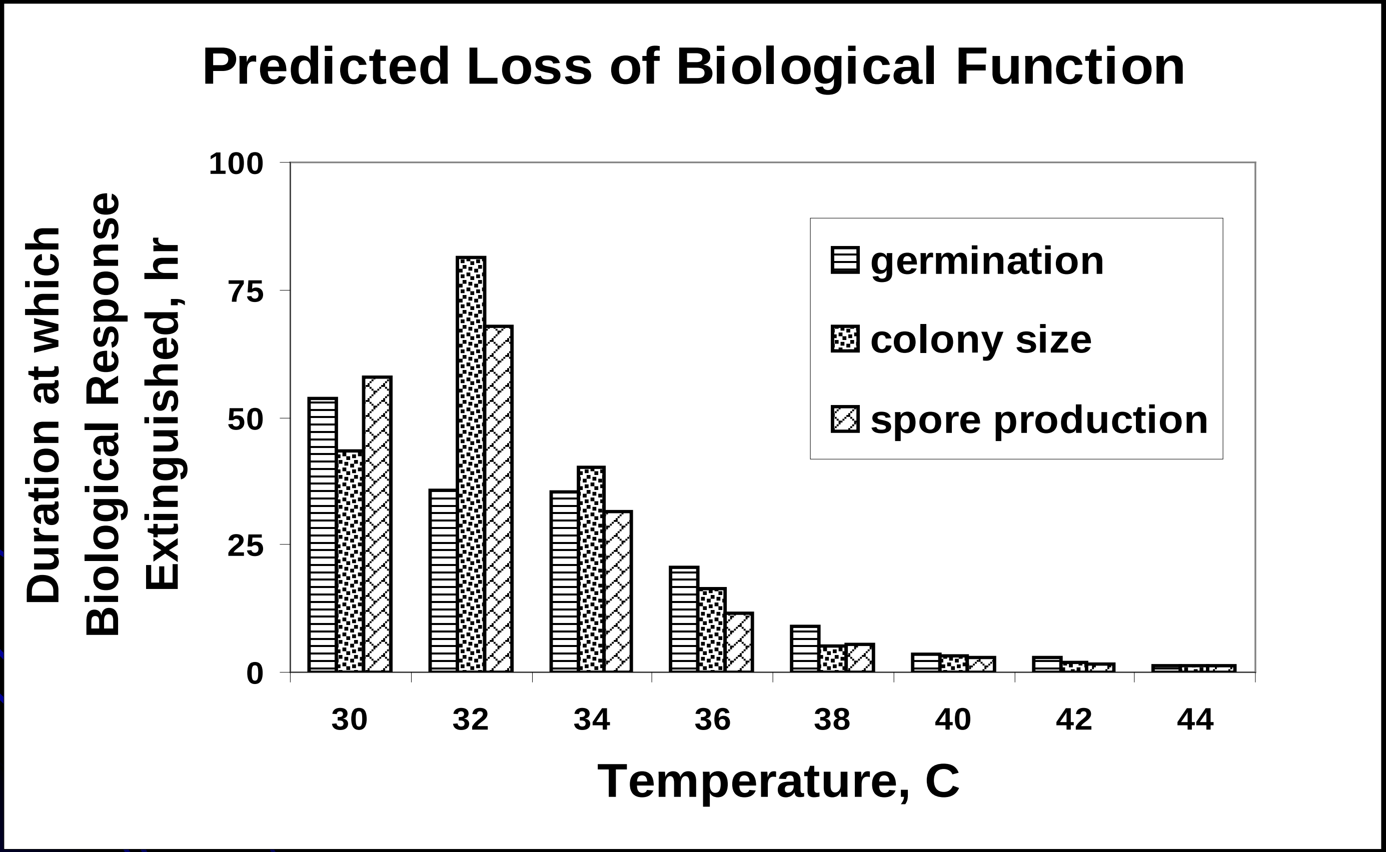


Figure 10. Predicted loss of biological response as a function of temperature and duration of treatment for spore germination, colony size on day 10 and spore production. The predicted duration (h) at which the biological response is zero (x-intercept) was obtained from linear regression analysis of primary data in SAS.



Powdery Mildew

- Effects of Moisture
  - Optimum RH is 65%
  - No effect of higher RH
  - RH of 65% overcome by temperature i.e. temperature more important.
  - Free water has negative effect on sporulation, infection, and lesion expansion.
  - Free water has positive effect on ascospore germination

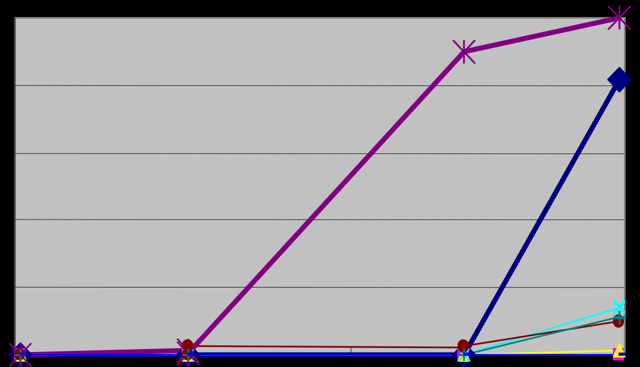
What is important??

- Know whether you have disease.
- Know how much disease you have.
- What is the weather forecast?
- What length of spray interval are you using for any particular product?
- Is this a particularly susceptible variety?
- Were leaves pulled at cluster set?

Why was a powdery mildew model developed?

- Numerous control failures
- Disease development is explosive
- Rapid development of fungicide resistance
- Only available control options are protectant fungicides

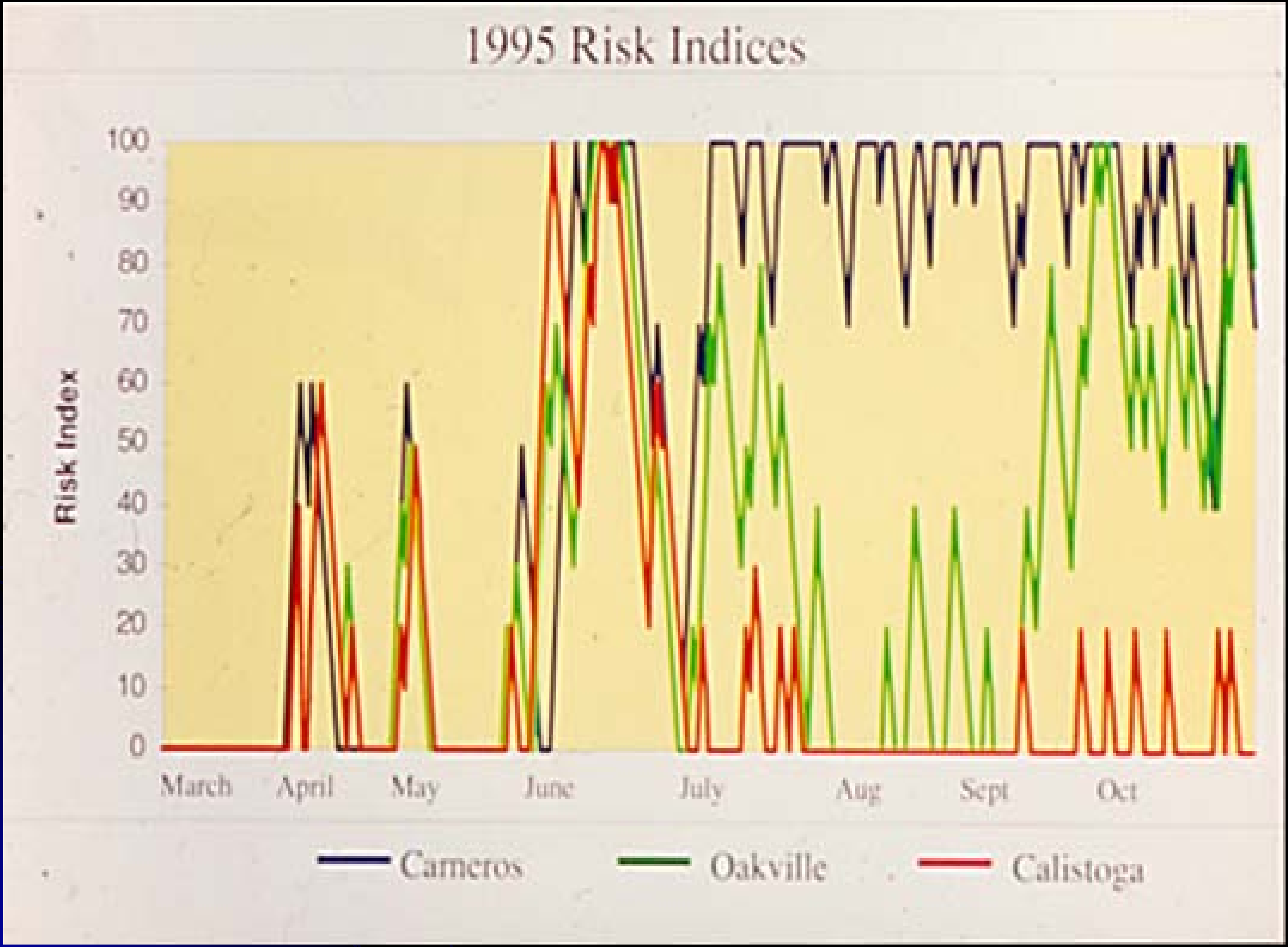
Epidemics are Explosive



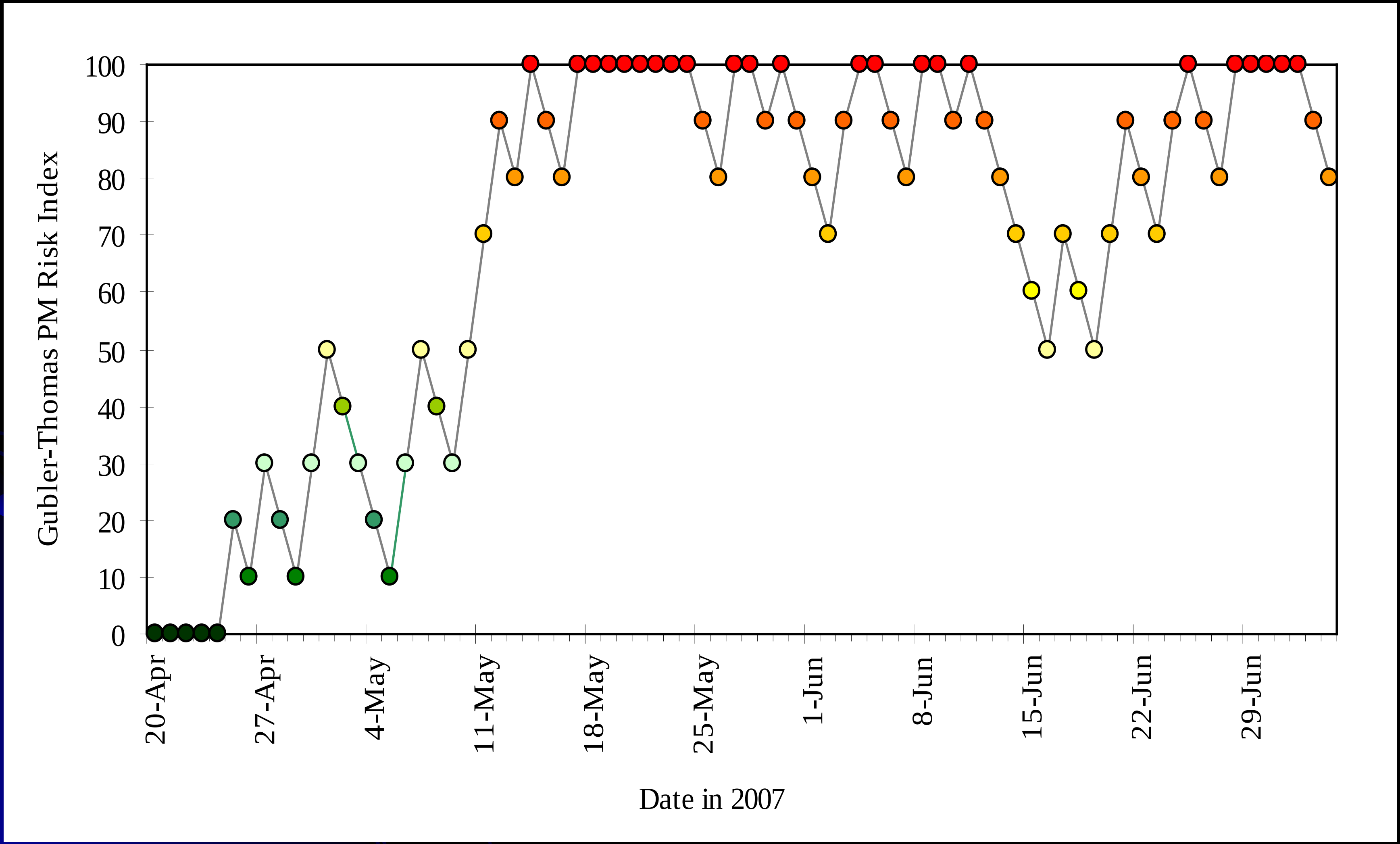
$3.53x10^5$spores/cm^2
30-40 generations per season

Gubler-Thomas Powdery Mildew Risk Index (UCRI)

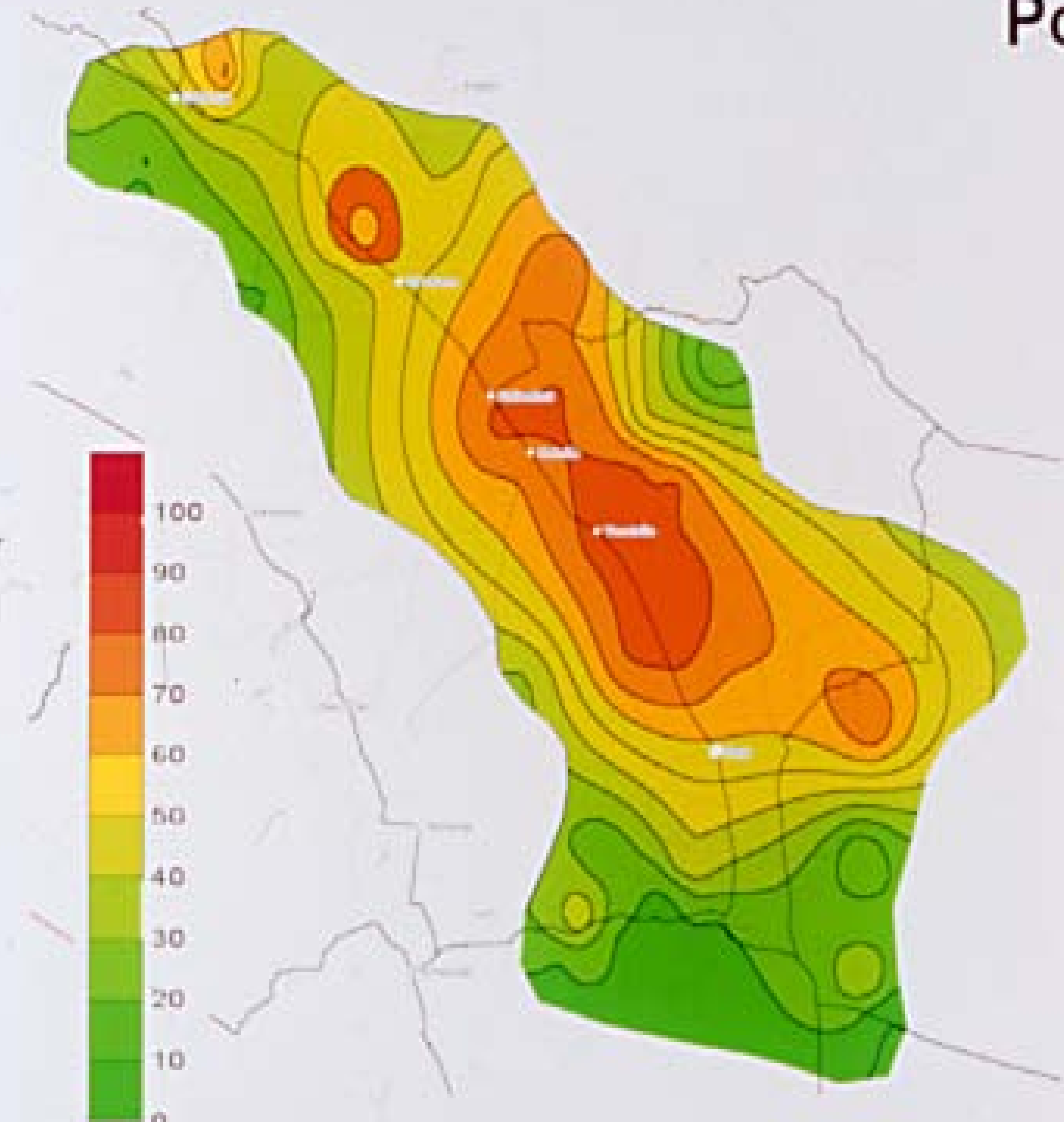
- Based on Canopy Temperatures
- Start - Post bud break
- Model- 20-30 C is optimum temp for pathogen reproduction
  - 3 consecutive days with 6 or more continuous hours in 20-30 C kicks off epidemic
- Add 20 per day when:
  - 6 continuous hours of 20-30 C
- Subtract 10 per day when:
  - Less than 6 hours
  - 95 F or greater
- Index never less than zero or more than 100


1995 Risk Indices
Risk Index
100
90
80
70
60
50
40
30
20
10
0
March
April
May
June
July
Aug
Sept
Oct
Carneros
Oakville
Calistoga

Gubler-Thomas Risk Index, Courtland CA. 2007



Powdery Mildew Pressure 06/16/98



Terra Spāse

What does Mildew Index mean???

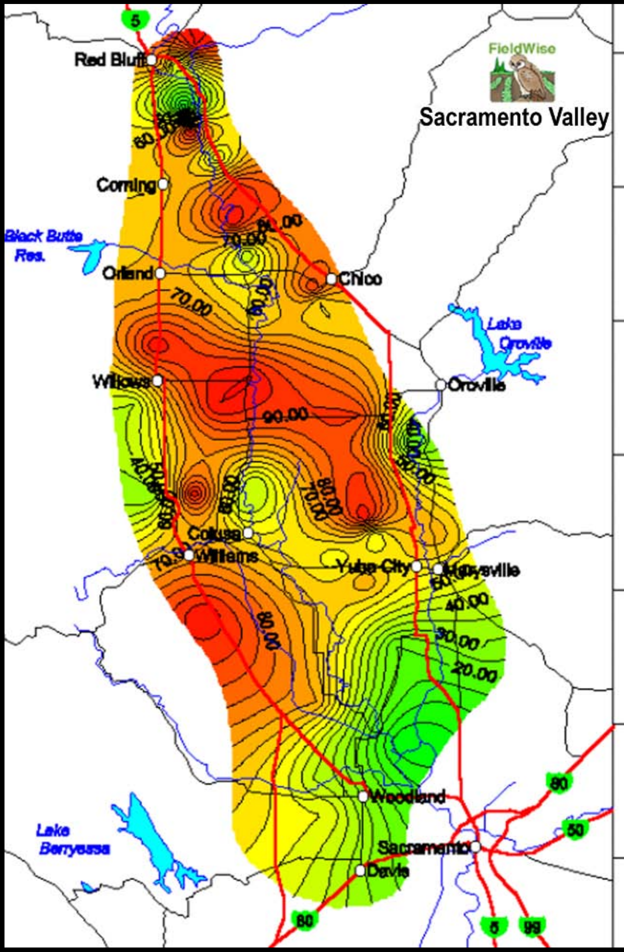
- Index = 0 to 30
  - Spray interval lengthened
  - Stop applications
  - No reproduction
- Index = 40 to 50
  - Spray interval normal
  - Reproduction 15 days
- Index = 60-100
  - Spray interval shortened
  - Reproduction 5 days

Powdery Mildew

- Model Use
  - Stretch spray intervals under low to intermediate disease pressure.
  - Shorten spray intervals under high disease pressure
    - Organic products should be used on 5-7 day interval under high disease pressure with the exception of JMS Stylet Oil which can be used on 14 day interval under high pressure.
    - Sulfur dust use stretched to 30 day intervals using the model in California and Germany.

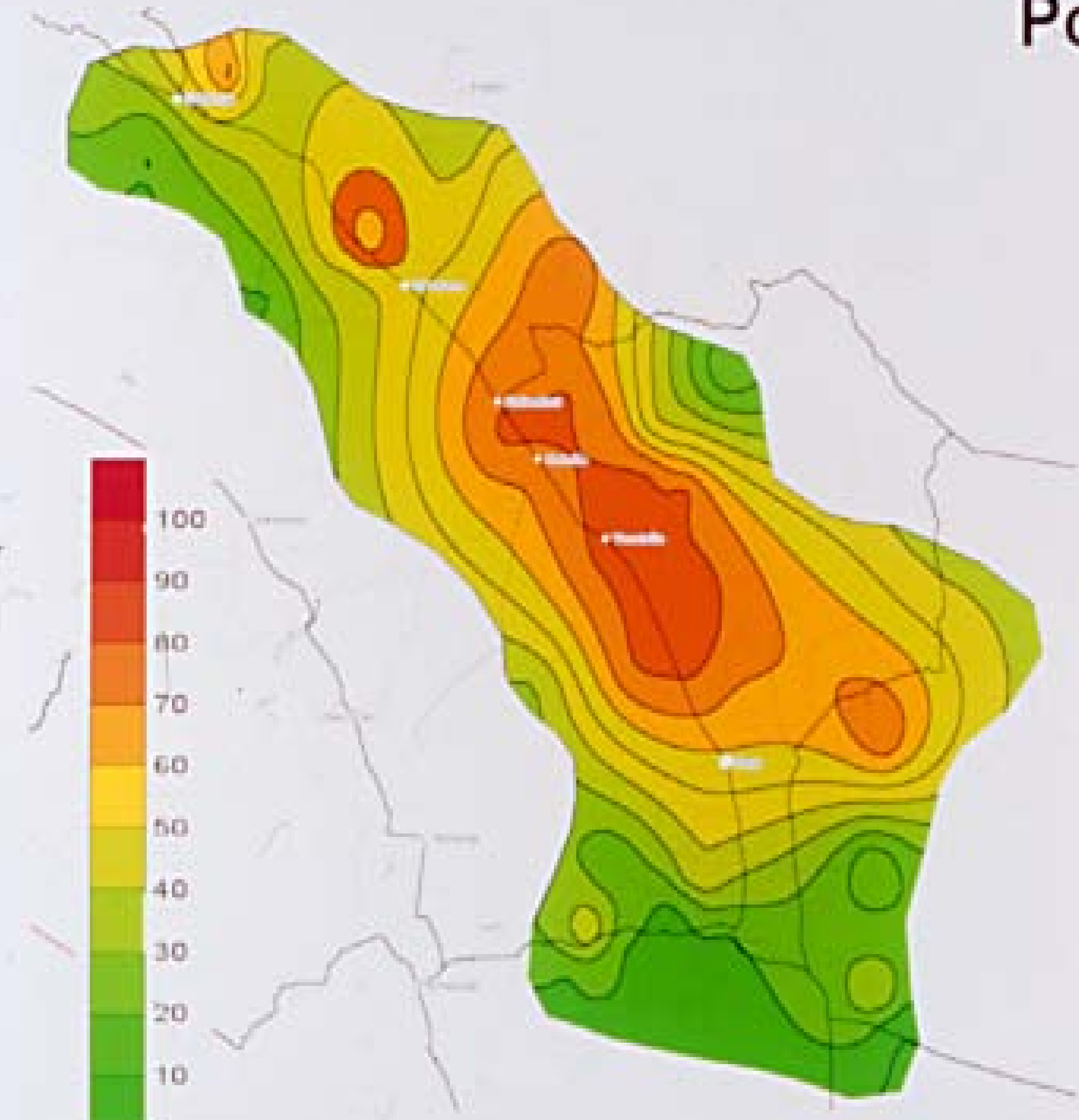
Gubler/Thomas Model for Grape Powdery Mildew

- Developed 1990-1995
  - Funded by the Ag-chemical Industry
- Pilot Implementation and Public Release 1995
  - A partnership funded by UC state-wide IPM, Adcon Telemetry, growers
- Full Implementation 1997
  - Privatization
    - Terra Spase
    - Western Farm Service
    - Ag Unlimited
    - Western Weather
    - Metos
  - Ongoing university networks
    - Pest Cast (UCIPM)



Powdery Mildew Pressure 06/16/98

Terra Spase



Gubler/Thomas Model for Grape Powdery Mildew

- One of the most widely used disease models
  - Used on 300,000+ acres of Grapes in California
  - Validated and used in 11 countries and being validated in 5 others.
  - Usage spans all major grape growing regions in the world.
  - Used for Cherry and Hop powdery mildew in Pacific North West
- Reduction in pesticide usage 20-40% in most years and in some cases 80%.
  - Raisin Grape growers are projected to save over 1,000,000 lbs of sulfur / year through reduction in early season applications

Gubler/Thomas Model for Grape Powdery Mildew

- Improves Sustainability
  - Crop quality and yield was equal to or better than the standard control program in every case (200 evaluations) despite reduced pesticide applications.
- $700,000 research investment over 5 yrs
  - largely funded by agrichemical industry
- 33:1 research investment return
  - 260,000 acres x 3 sprays saved=780,000A x $30 / spray
  - $23,400,000 from 780,000 acre sprays saved per year
- 23:1 return on maintenance requirements
  - $1,000,000 per year for equipment and labor
  - largely supported by agrichemical industry

Gubler/Thomas Model

- Adapted or modified for other powdery mildews
  - Cherry (Grove et al, 2000)
  - Hops (Mahaffee et al, 2003)
  - Nectarine (Grove)
  - Apple (Grove)
  - Peach (Grove, Adaskaveg)
  - Strawberry (Gubler)
  - Melon (Gubler)

Cultural Control

- Reduce RH
- Increase air flow
- Increase sunlight penetration
- All can be done with use of leaf removal.
  - Leaf removal at cluster set will reduce powdery mildew by over 50% in the absence of fungicides
  - Will allow 200X increase in spray coverage

Fungicides

- SBI's
  - Rally
  - Viticure
  - Elite
  - Vintage
  - Bayleton
- Strobilurin's
  - Sovran
  - Flint
  - Abound
- Quinoline's
  - Quintec
- Combination's
  - Pristine
  - Adament
  - Inspire Super

Powdery Mildew
Soft/Biological Fungicides

- Sulfur
- Dust
  - Micronized df- Kumulus
  - JMS Stylet Oil
- Purespray Green Oil
- Serenade *(Bacillus subtillus*)- Biocontrol
- Sonata (*Bacillus pumilus)- Biocontrol*
- *Elexa (chitosan) SAR*
- Messenger (Harpin Protein) SAR
- Trilogy (Neem Oil)
- Copper materials-Champ 50wp(Nufarm)
- Milstop
- Milsana
- Kaligreen
- Physpe
- Vigor Cal, Vigor K
- Prevam
- Valero

BENZIMIDAZOLE

- Benlate*benomyl DuPont systemic (local) Topsin-M thiophanate-methylCerexagri
  systemic (local)***label withdrawn**
- **Mode of action:** FRAC1 Group 1; single-site inhibitors that interfere with nuclear division.
- **Resistance risk:** high; levels of resistant populations do not decline in absence of fungicide use
- **Growth effects:** inhibits mycelial growth
- **Sporulation:** inhibits

DEMETHYLATION (ERGOSTEROL OR STEROL BIOSYNTHESIS) INHIBITORS ("DMI" OR "SBI")

- Bayleton triadimefonTriazole systemic (local)Elite tebuconazoleTriazole Bayer CropScience systemic (local)
- Mettle tetraconazole Triazole Sipcam Agro USA systemic (local)
- Indar fenbuconazole Triazole Dow Agrosciences systemic (local)
- Orbit propiconazoleTriazole Syngentasystemic (local)
- Bumper*propiconazole Triazole Makhteshim-Agan systemic (local)
- Procure triflumizole Imidazole Chemtura systemic (local)
- Rally (Laredo) myclobutanil Triazole Dow Agrosciences systemic (local)
- Rubigan fenarimol Pyrimidine Gowan systemic (local)
- Inspire difenconazoleTriazole Syngenta systemic (local)* Registration pending

- Mode of action: FRAC1 Group 3; single-site inhibitors; inhibit demethylation and other processes in sterol biosynthesis; locally systemic; have little effect on spore germination, but interfere with other early developmental processes; all inhibit mycelial growth and may stop lesions from sporulating; Resistance risk: high
- Growth effects: inhibit mycelial growth
- Sporulation: suppresses

QUINOLINE

Quintec quinoxyfen

- **Company** Dow AgroSciences
- **Activity** contact
- **Mode of action**: FRAC Group 13; probably single-site inhibitor; disrupts early cell signaling events.
- **Resistance risk:** medium
- **Growth effects:** suppresses spore germination, early germ tube development and/or appressorium formation
- **Sporulation:** no effect

STROBILURIN

- Abound azoxystrobin Syngent acontact and systemic
- Cabrio pyraclostrobin BASFcontact and systemic
- Evito*fluoyxstrobin Arysta contact and systemic
- Flint trifloxystrobin Bayer CropScience contact and systemic
- Pristine pyraclostrobin + boscalid BASFcontact and systemic
- Sovran kresoxim methyl BASFcontact and systemic

- Mode of action: FRAC1 Group 11; single-site; blocks respiration by interfering with cytochrome b.
- Resistance risk: high
- Growth effects: inhibits spore germination and mycelial growth
- Sporulation: no effect

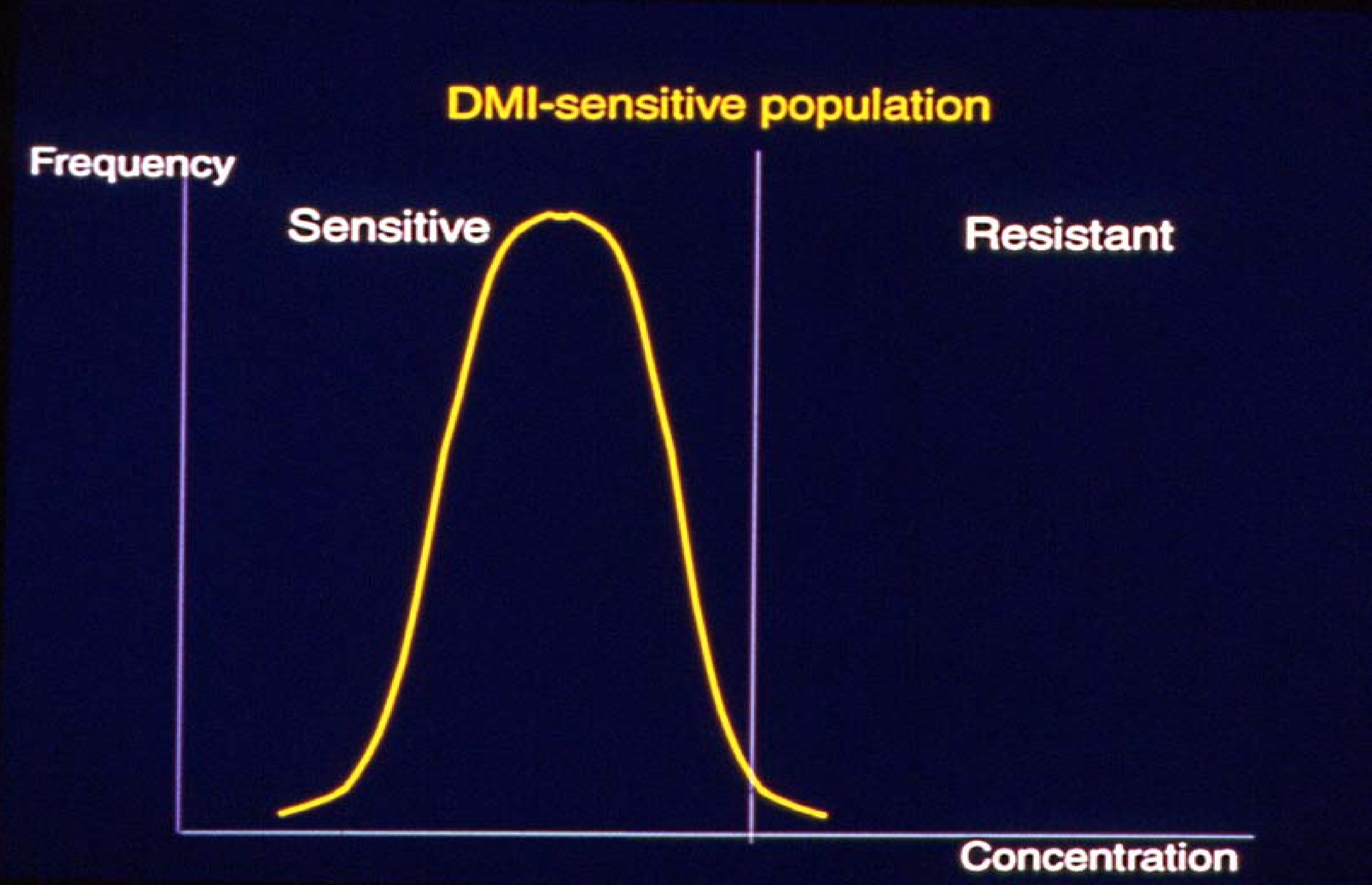
STROBILURIN + CARBOXYANILIDE

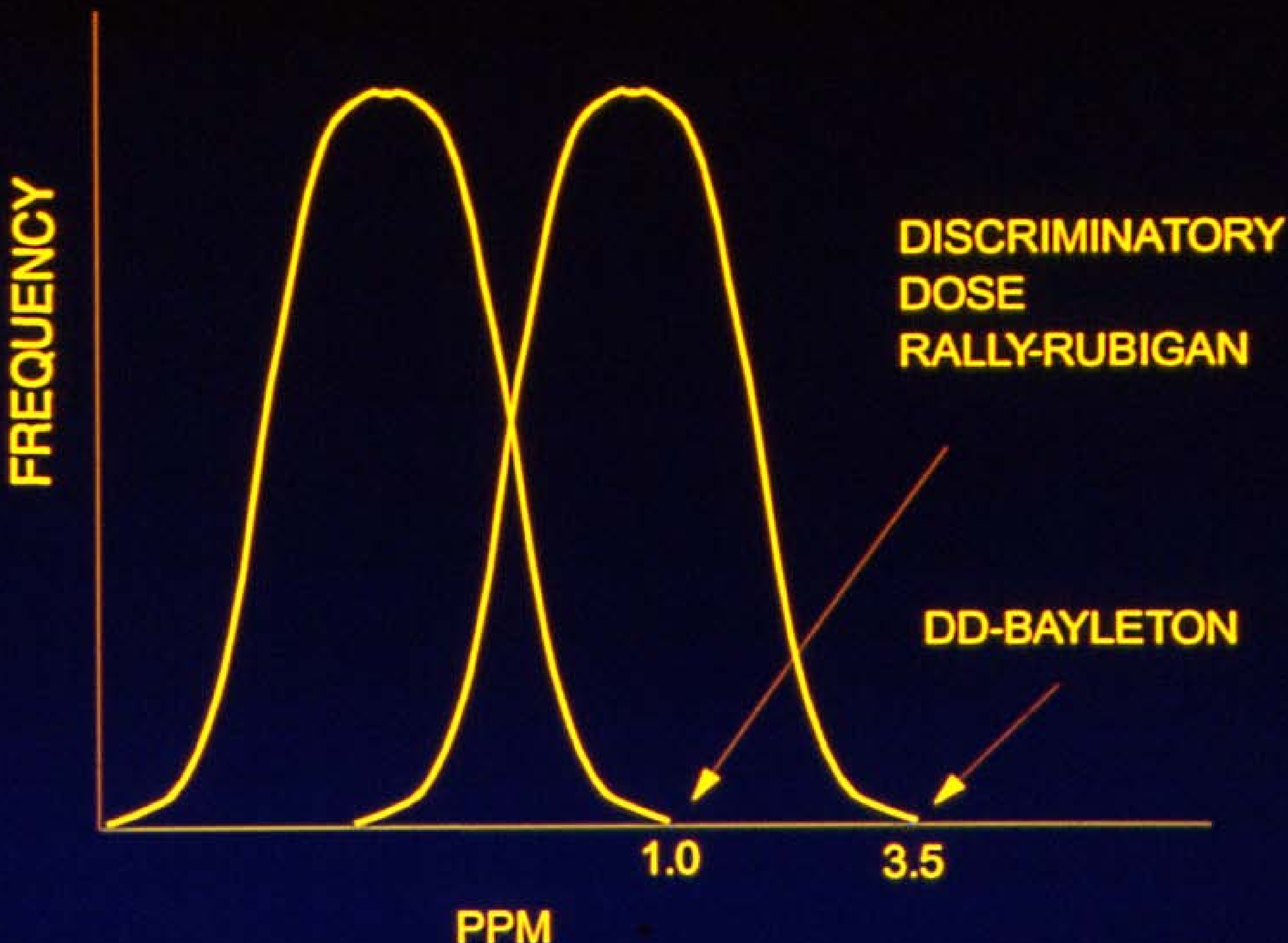
- Pristine **pyr**aclostrobin/boscalid
  BASF **Mode of action: Activity** contact and systemic
- FRAC1 Groups 11 and 7; see above for strobilurin; unknown for carboxyanilide.
- **Resistance risk:** low-med (combination of different chemistries)
- **Growth effects:** see above for strobilurin; unknown for carboxyanilide
- **Sporulation:** see above for strobilurin; unknown for carboxyanilide

Fungicides

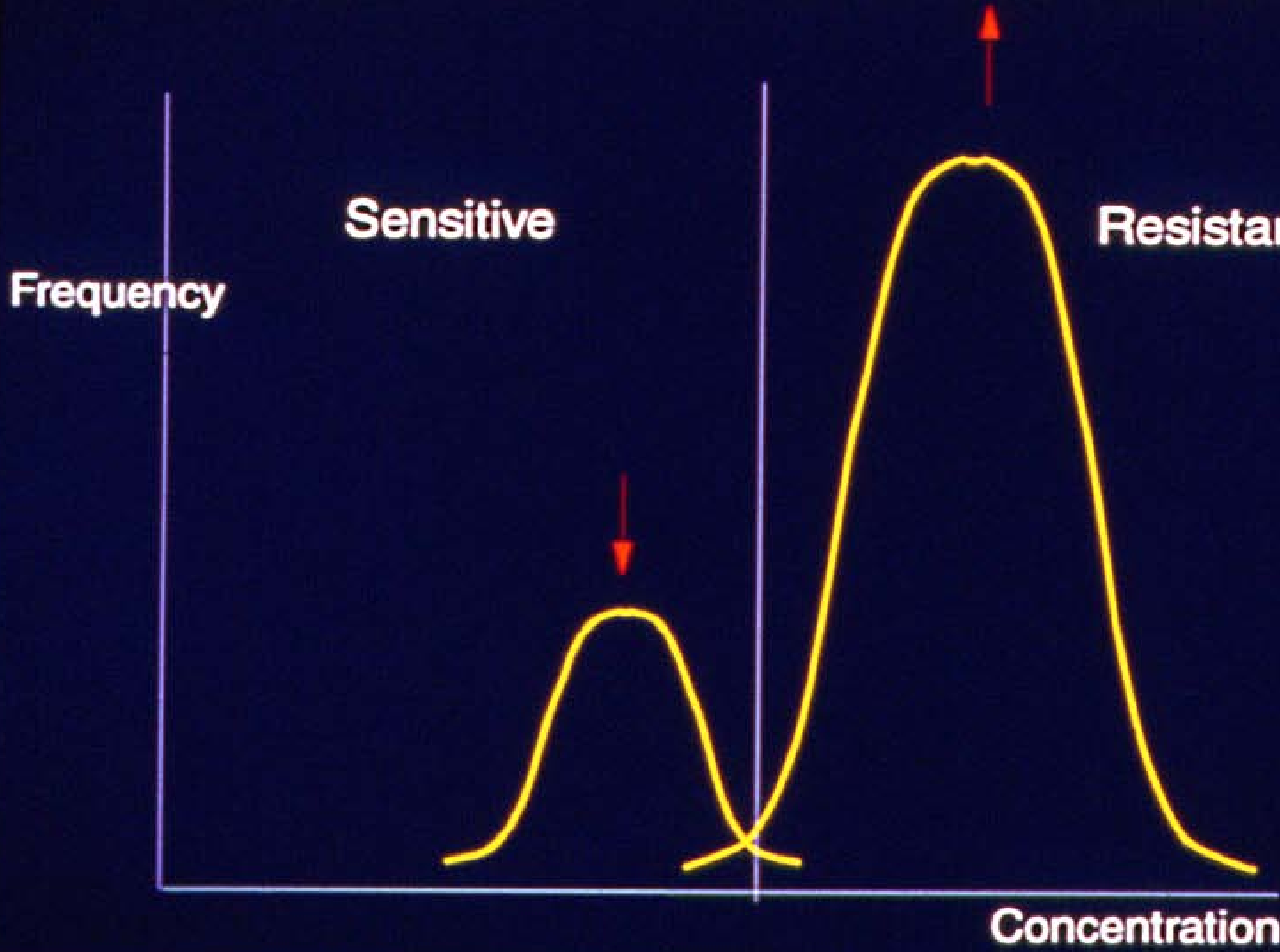
- **SUCCINATE DEHYDROGENASE INHIBITORS (SDHIs)**

- Endura boscalid BASF contact
- (DPX-LEM17)* penthiopyrad DuPont contact
- Luna Privilege (USF-2015)* fluopyram Bayer CropScience contact

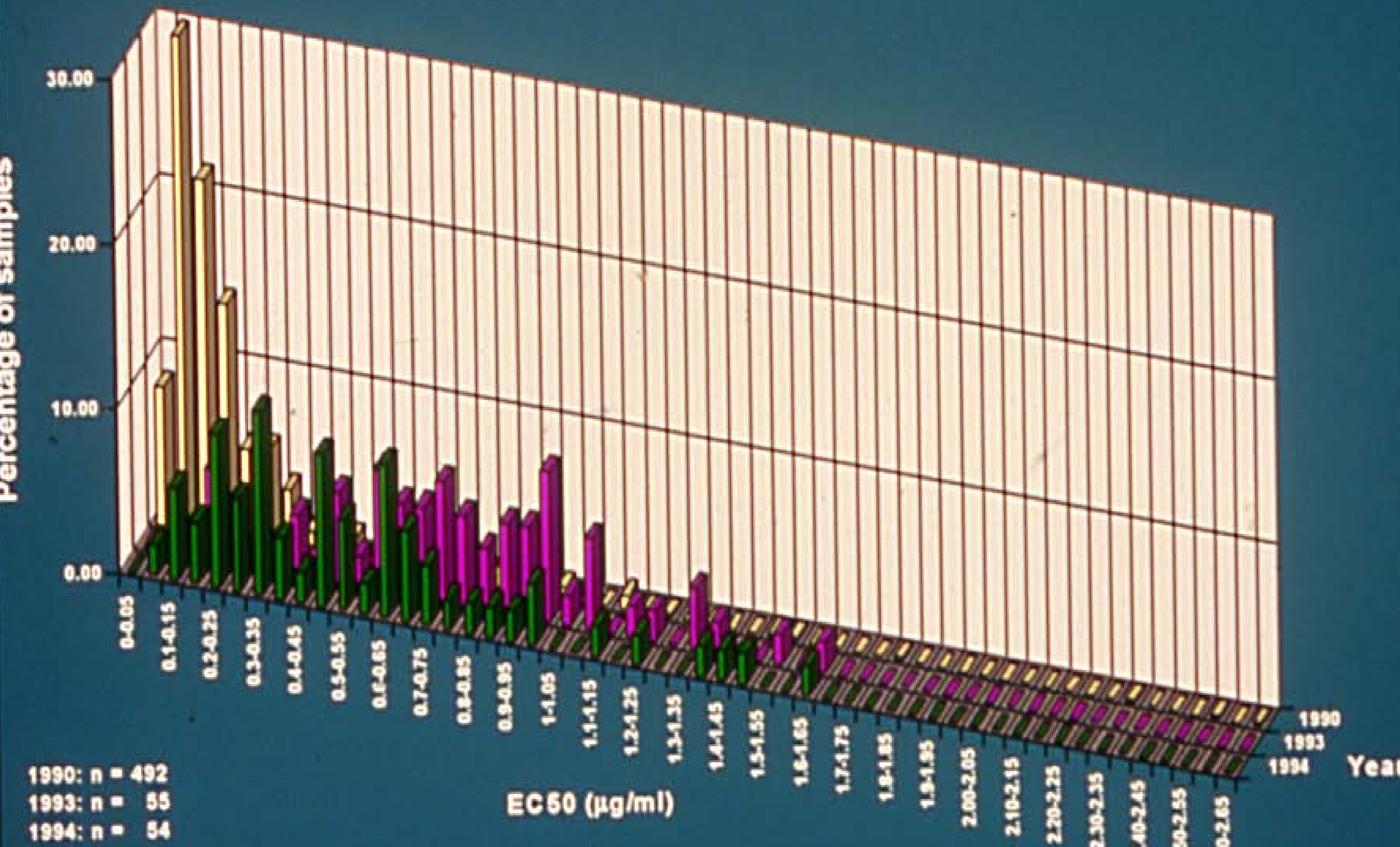

DMI-sensitive population
Frequency
Sensitive
Resistant
Concentration


FREQUENCY
DISCRIMINATORY
DOSE
RALLY-RUBIGAN
DD-BAYLETON
1.0
3.5
PPM

DMI-Resistance - Favorable environmental conditions



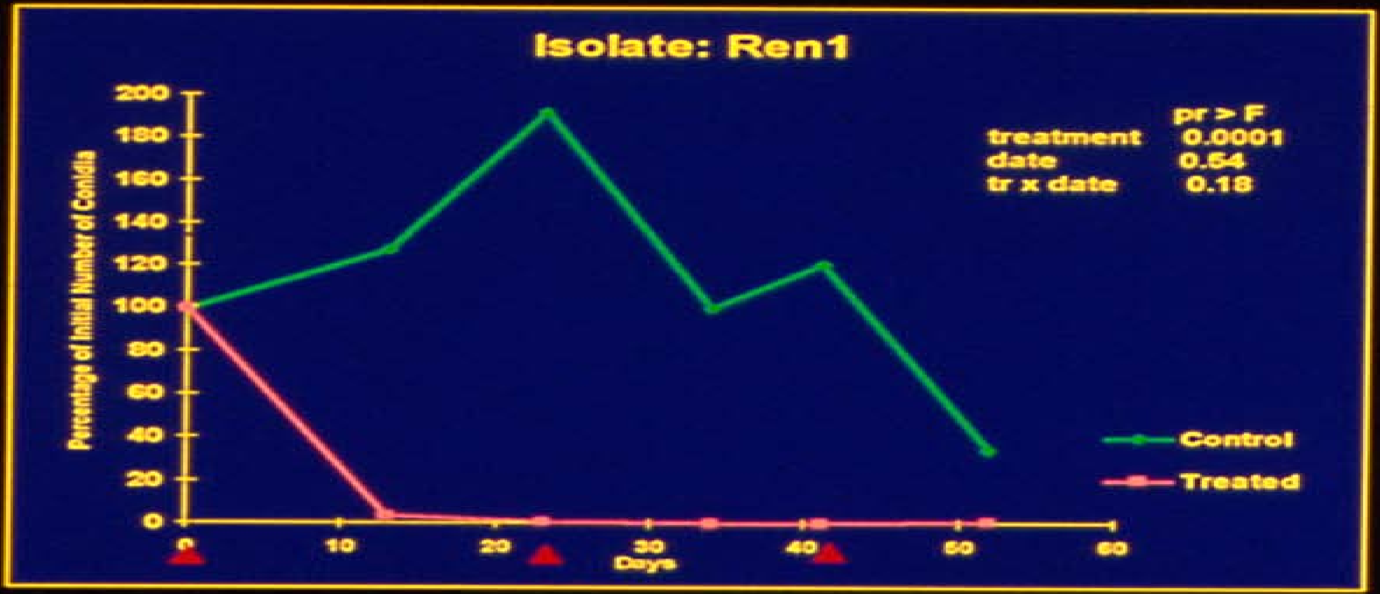
Resistance monitoring to fenarimol
Frequency Distributions 1990-1994

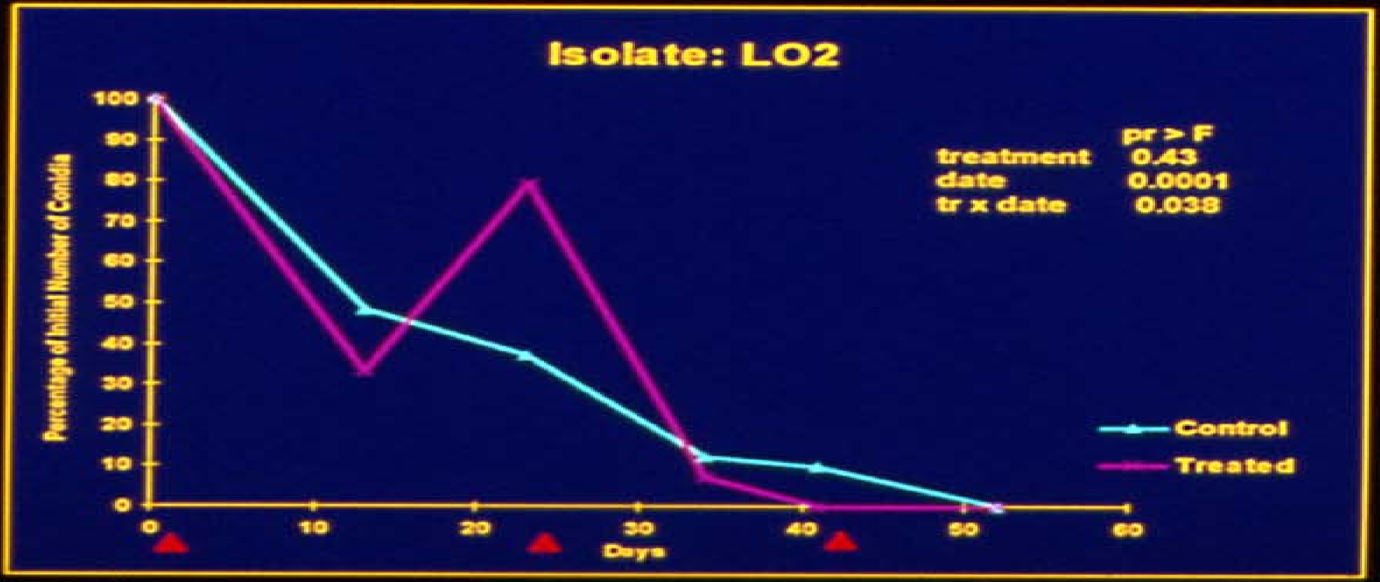


Do environmental conditions affect efficacy of fungicides in the presence of resistance?

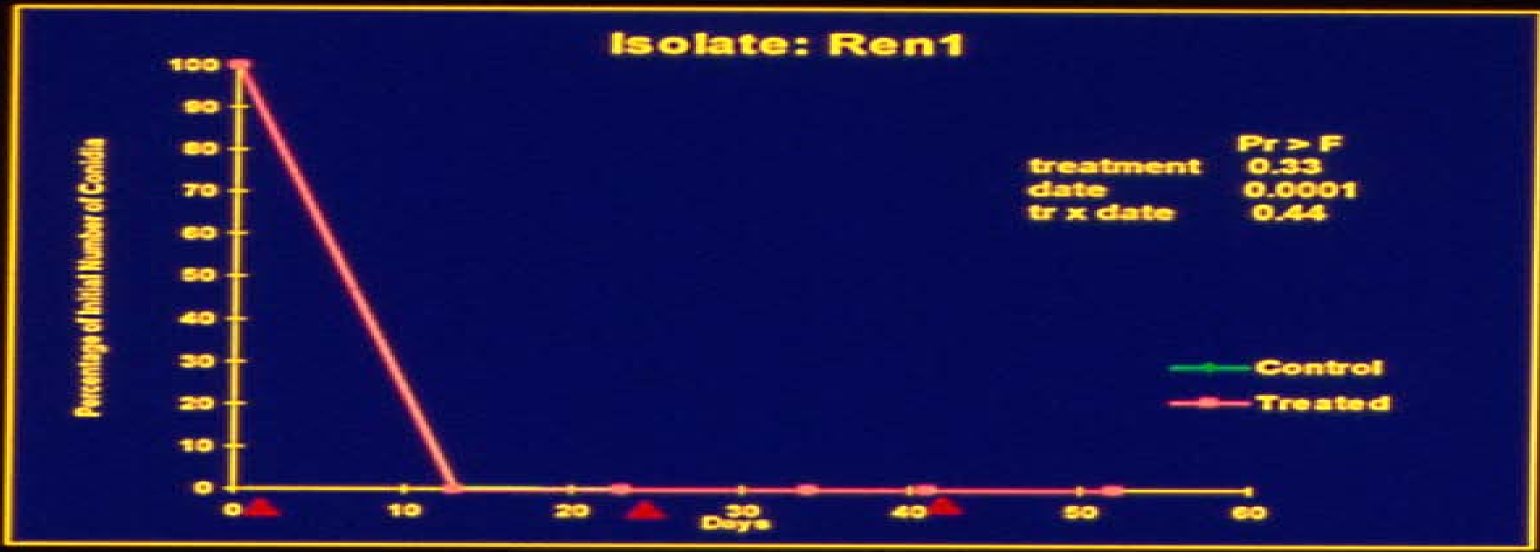
- Loss of control in 1986 partially due to fact that temperatures were conducive for rapid population buildup nearly all season.
- In 1987, temperatures were high and powdery mildew pressure was low---Bayleton worked.
- What are the effects of temperature on how well a fungicide might work in the presence of resistance?

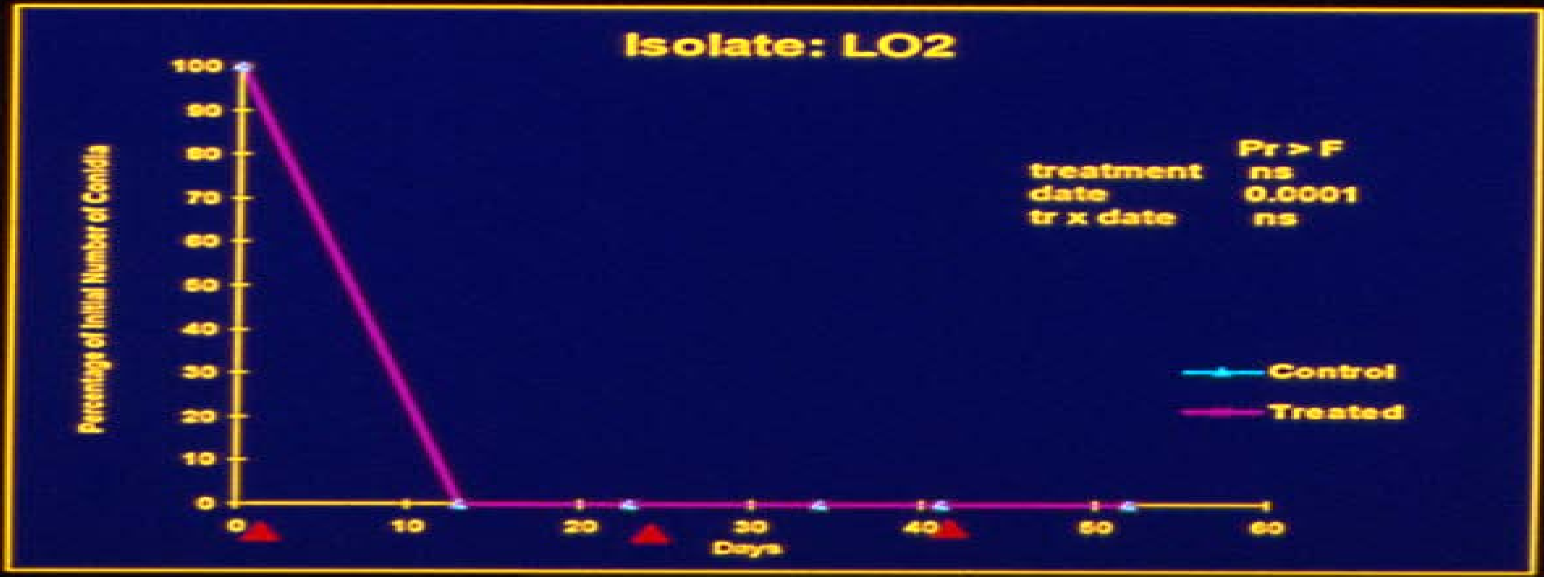
Temperature 25 C, 24 hrs per day





Temperature 32 C, 24 hrs per day





Weather Plays an Important Role in Fungicide Efficacy

- Moderate Temps = Increase population
  - Effect is increase in resistant members of population
  - Population becomes more resistant over time simply because sensitive members are being killed by fungicide
  - Degree of resistance also increases over time with continued use of at risk products

Using Biofungicides

- Need confidence in product
- Does disease pressure effect control.
  - Length of interval
  - Dose
- For each pathogen
  - Understand pathogen biology
  - Understand disease epidemiology
- What other products can be safely and effectively integrated into use pattern

Biofungicides

- Definitely a place for biofungicides in control strategies
- Generally do an ok job on own if conditions are right.
  - Products work better under low to medium disease pressure.
  - Need to know what disease pressure is.
    - Use of disease forecasting and risk assessment models.
    - For economic control need to be able to switch products rapidly.
- Better control if used in integrated program???