A step towards more sustainable vine health: the clean plant approach to grape virus disease management

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The ostensible problem: Grape virus diseases

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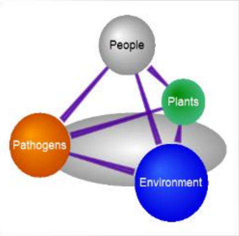
Three-cornered alfalfa treehopper (3-CAT)

Spissistilus festinus

The actual problem: Between block infection causes shared costs and responsibilities



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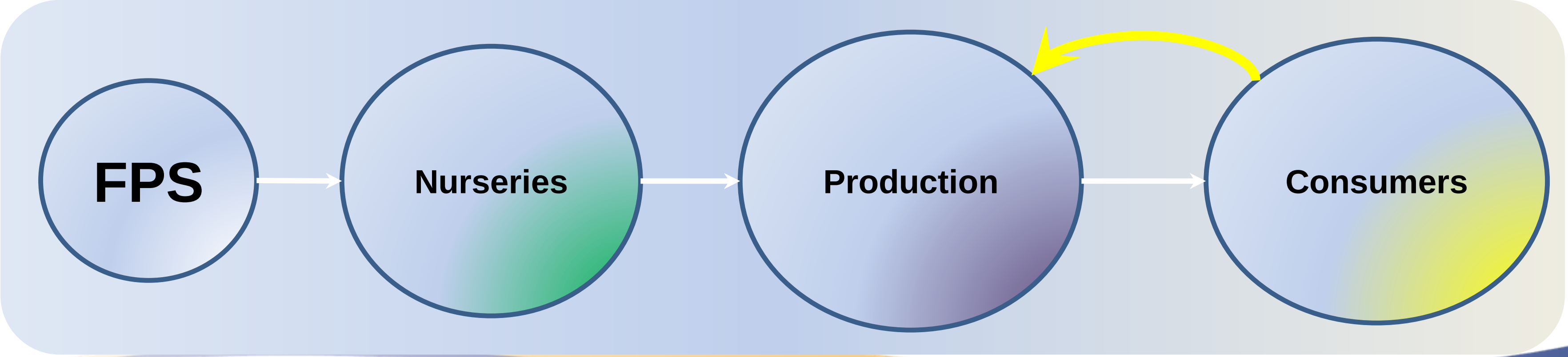

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the message: **"Get clean, stay clean"**

Starting clean with 'certified' planting stock

California Registration and Certification of Grapevines

3 CCR § 3024-3024.8

Last updated 2010

CDFA CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE

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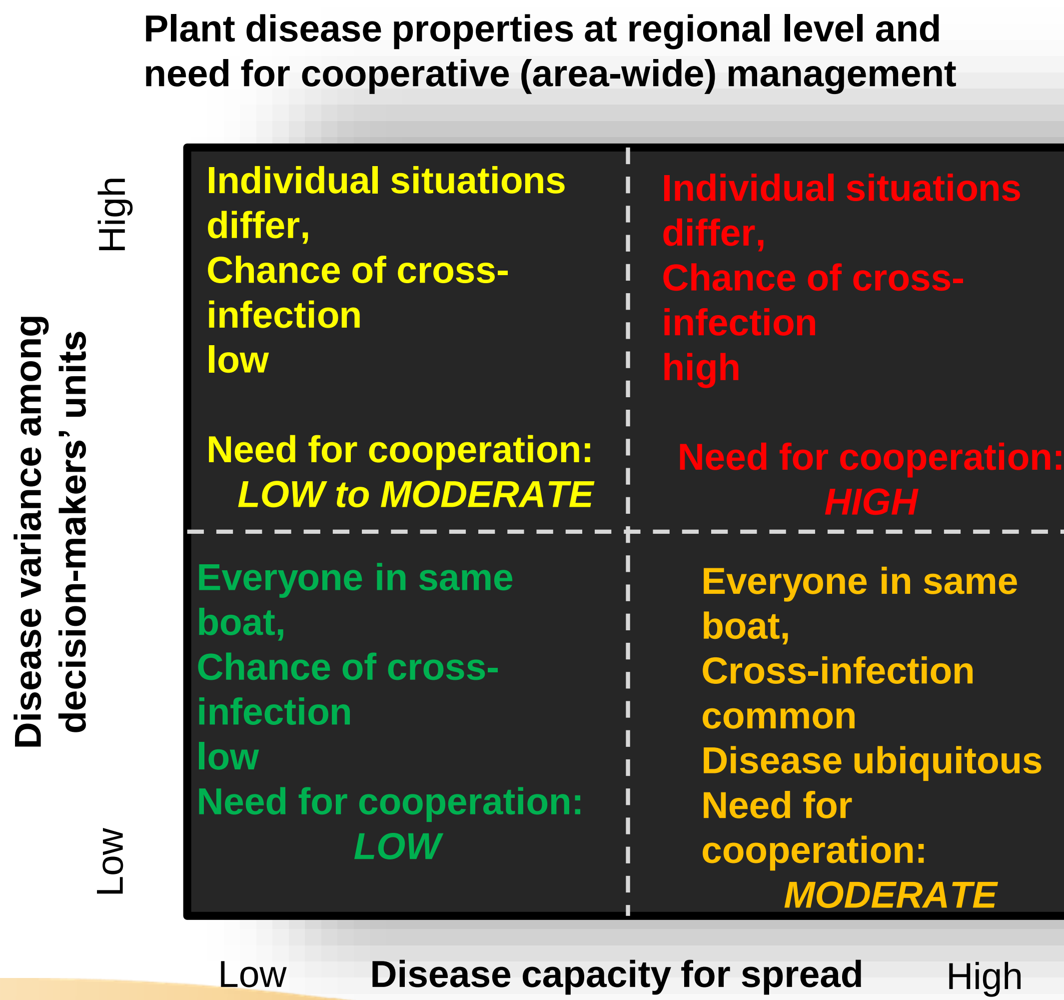
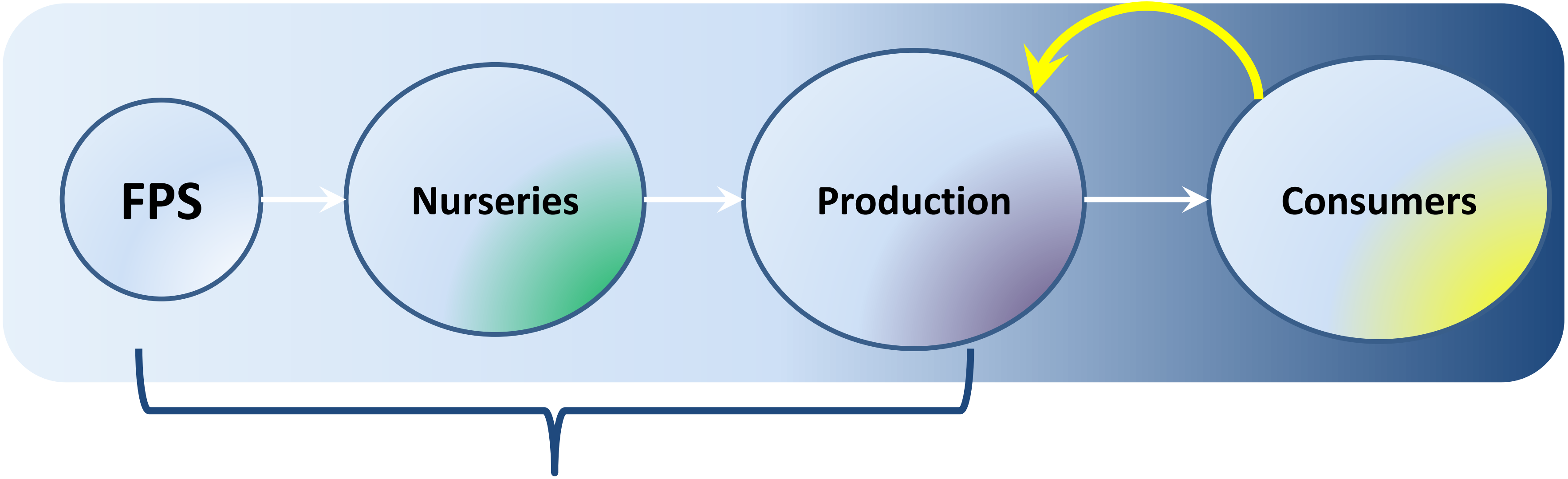
When does disease drive cooperation?

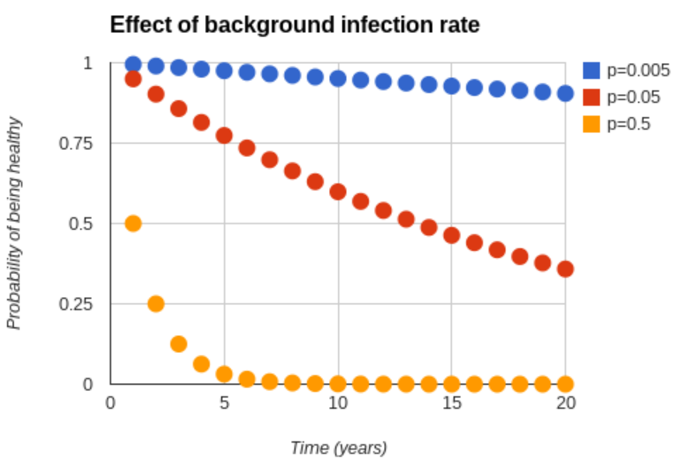




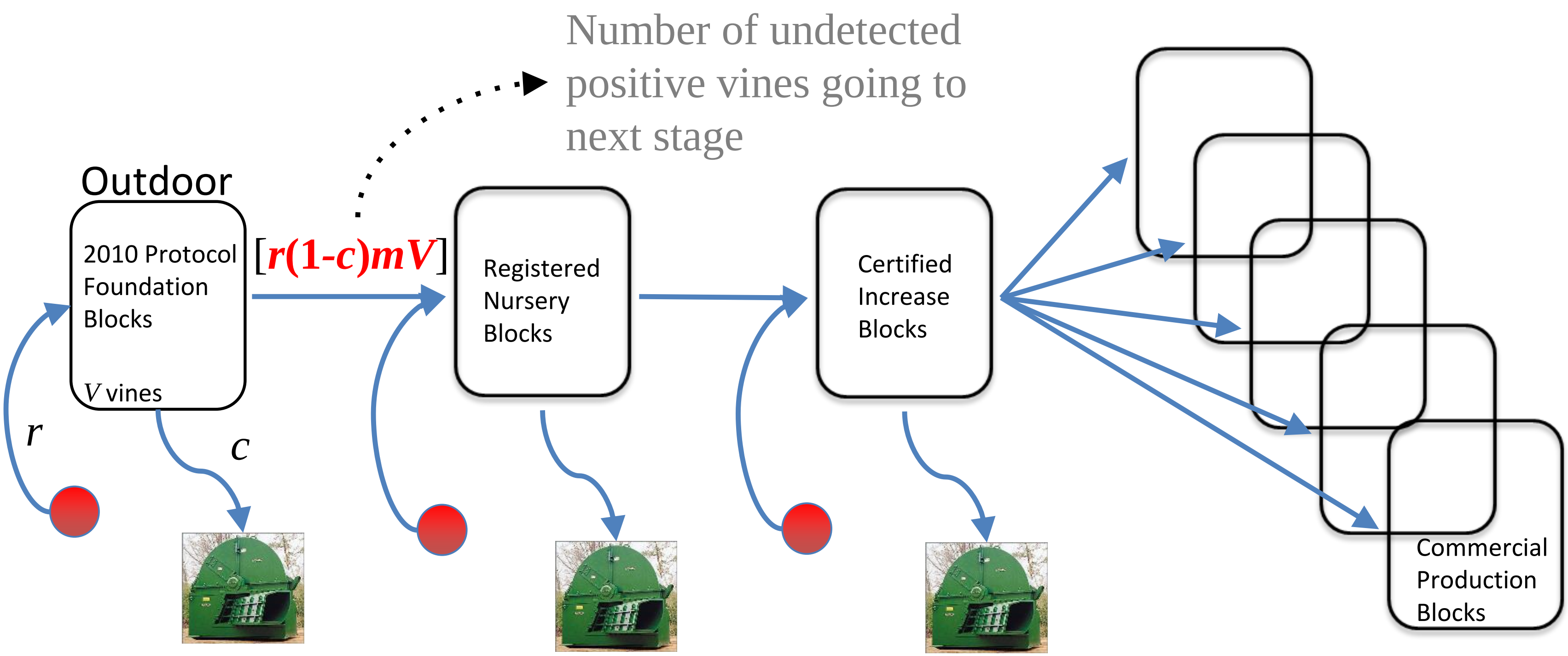
Sampling can be used to produce a supply chain with known performance for delivery of healthy vines

Assume background probability of vine being infected per year is p, so probability of staying healthy is $(1-p)$. Probability of being healthy after t years is $(1-p)^t$.

Let V_H = value of healthy vine
V_I = value of infected vine
Expected value of vine at time, t, = $\$[(1-p)^t V_H]+[1-(1-p)^t V_I]$



The certification discussion and the future: Education is the key



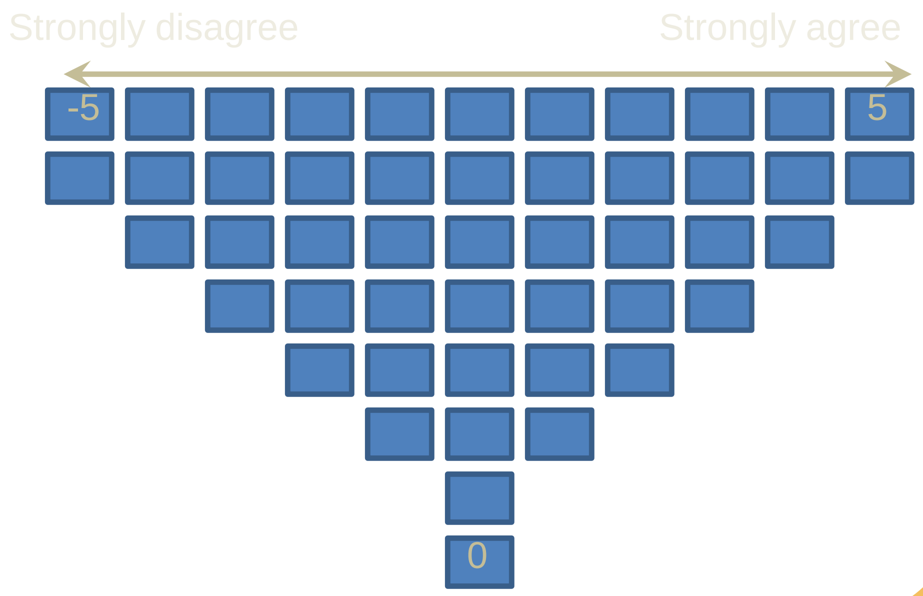
$c = d \times tpp$

d = probability of detection (sampling) = $f(n,N,p,\theta)$

tpp = diagnostic true positive proportion

Q-method study

- Q-method: Study of subjectivity
- Workshops to generate discourse (3)
- Extraction of a set of characteristic statements (47 from discourse)
- Ranking of statements by participants in Q-sort (37)
- Statistical analysis



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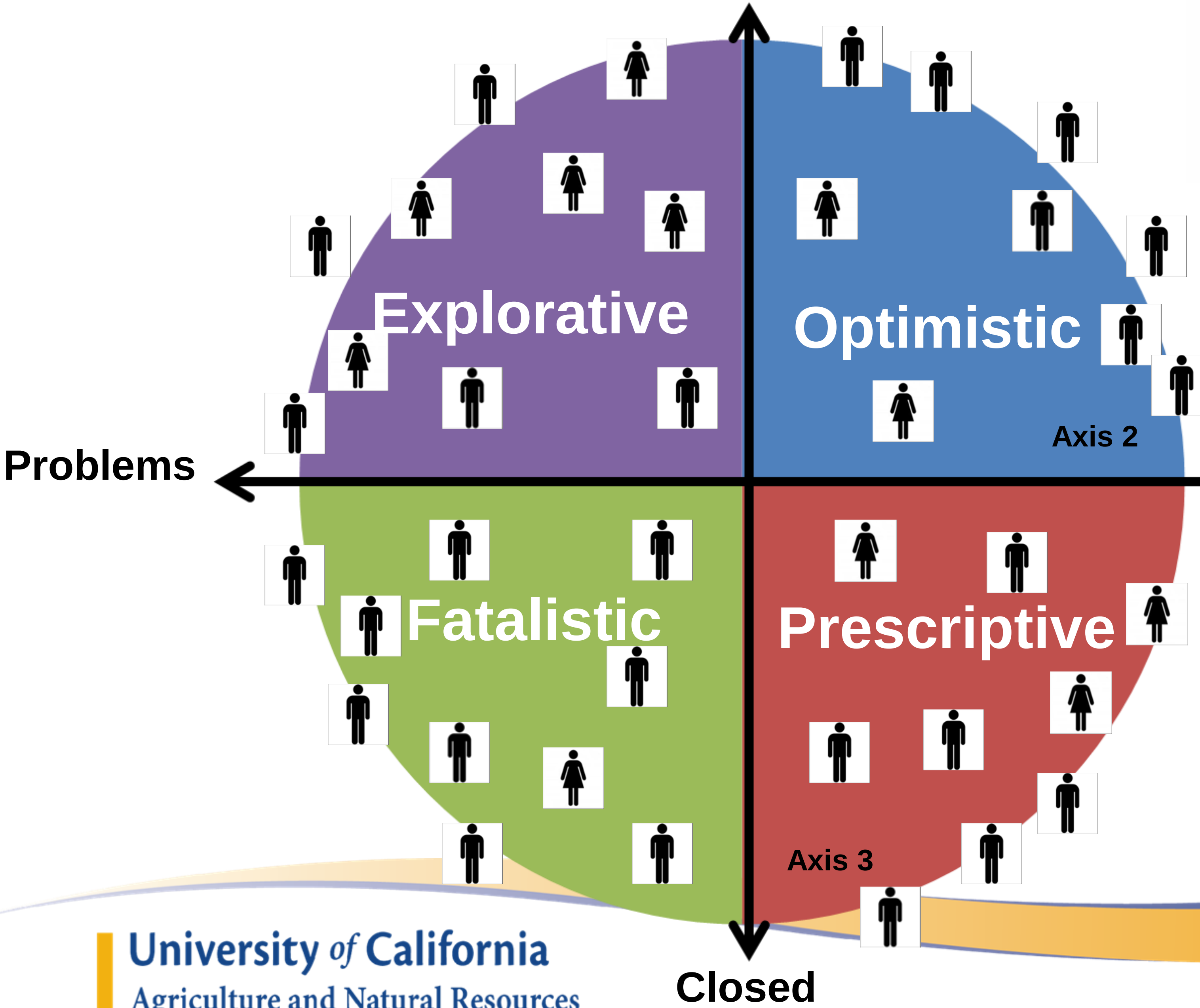
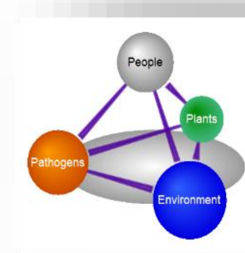
Slide 2





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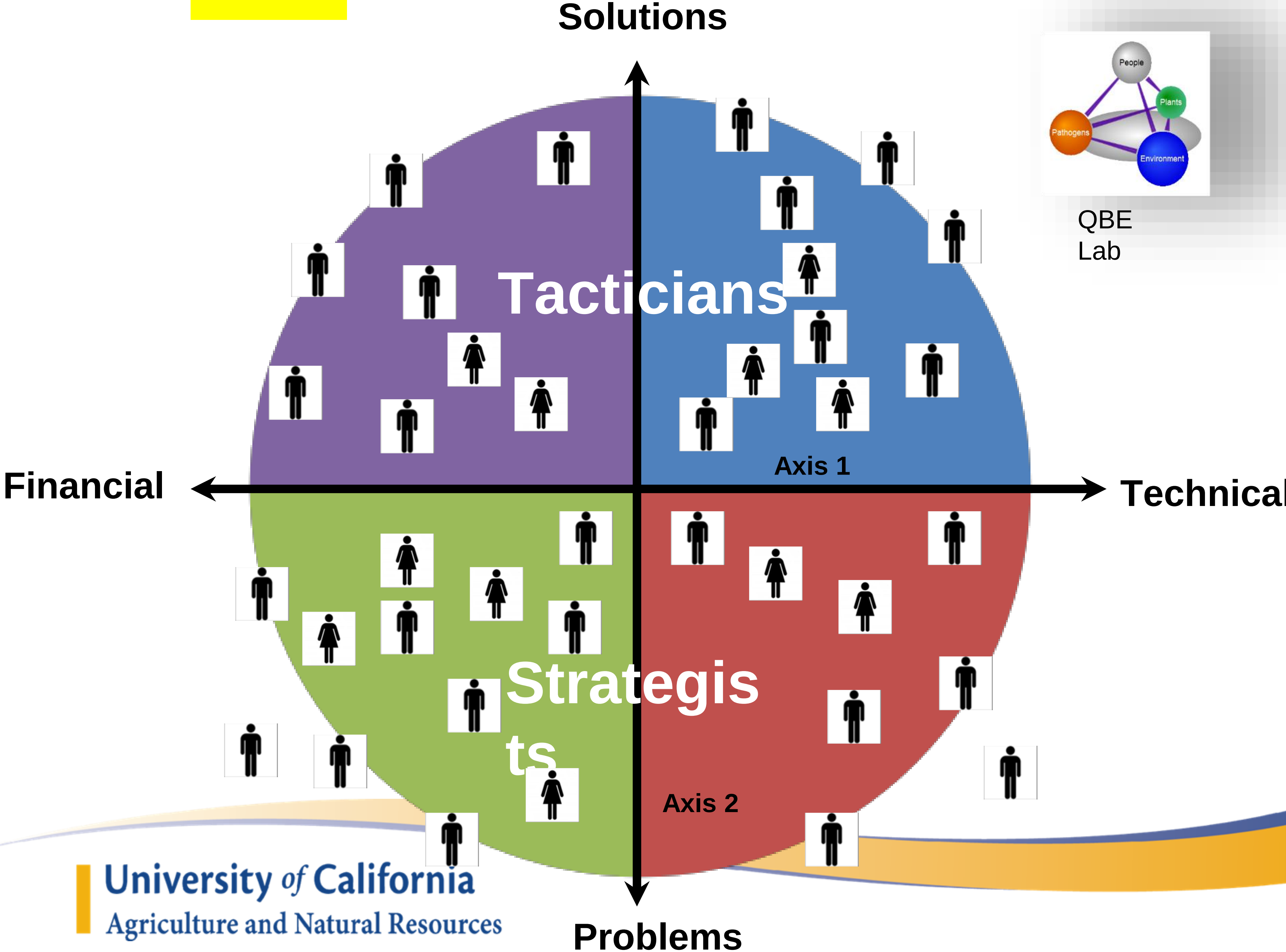
Slide 1



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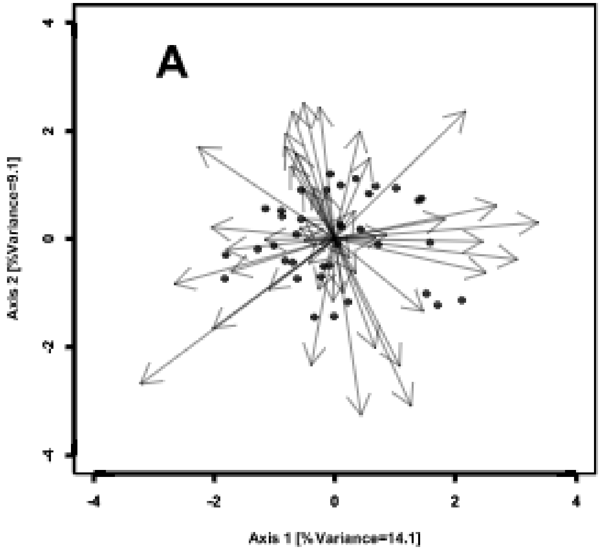
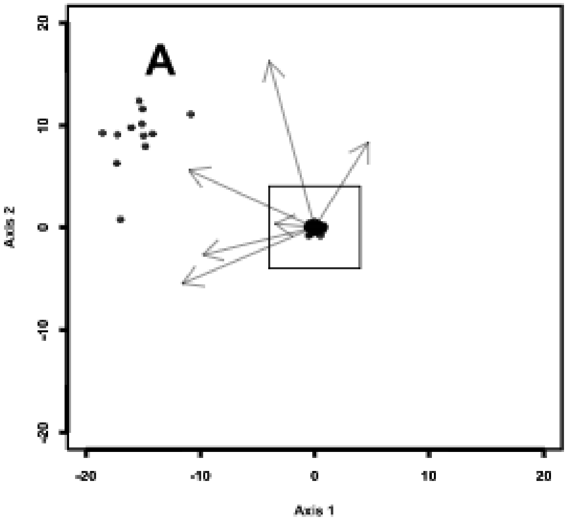
O wad some Power the giftie gie us
To see oursels as ithers see us!

Robert Burns, To a Louse (1786)

Diversity among growers/winemakers with respect to leafroll management and clean plant programs



But they're all close together when we include nursery stock producers in the same analysis



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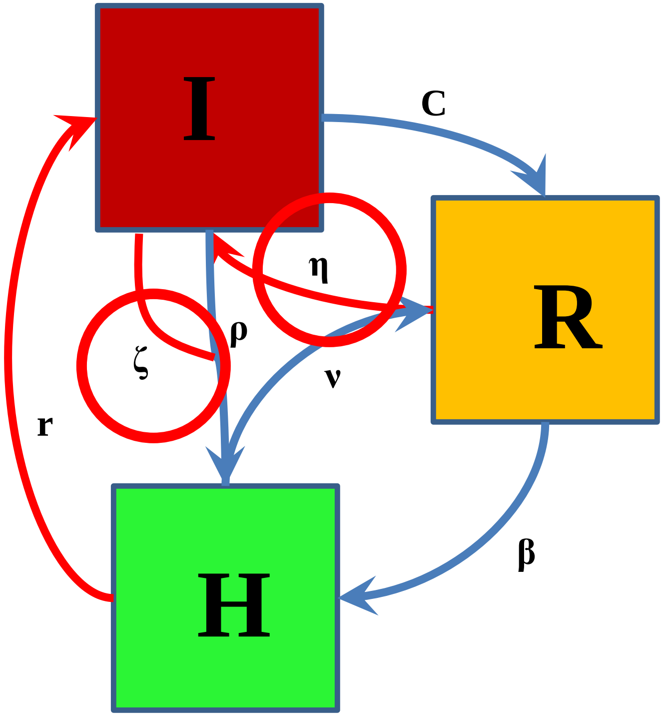
Inter-block meta-population model



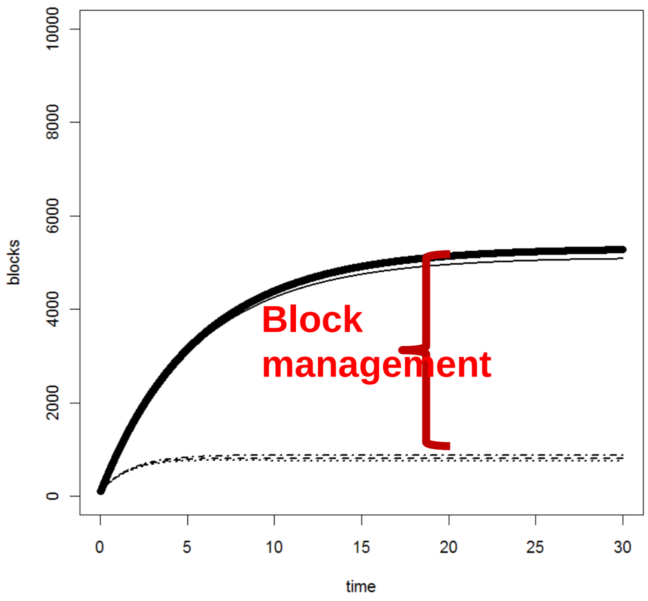
$$\frac{dI}{dt} = rH + \eta R - cI - (1 - \zeta)\rho I$$

$$\frac{dH}{dt} = \beta R + (1 - \zeta)\rho I - rH - \nu H$$

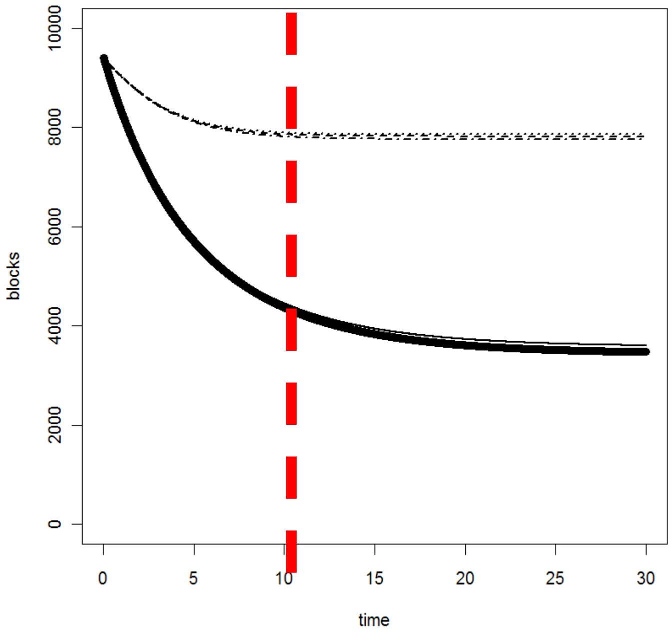
$$\frac{dR}{dt} = cI + \nu H - \beta R - \eta R$$

What drives the leafroll epidemic regionally?

Infected



Healthy



Yountville-Oakville neighborhood group

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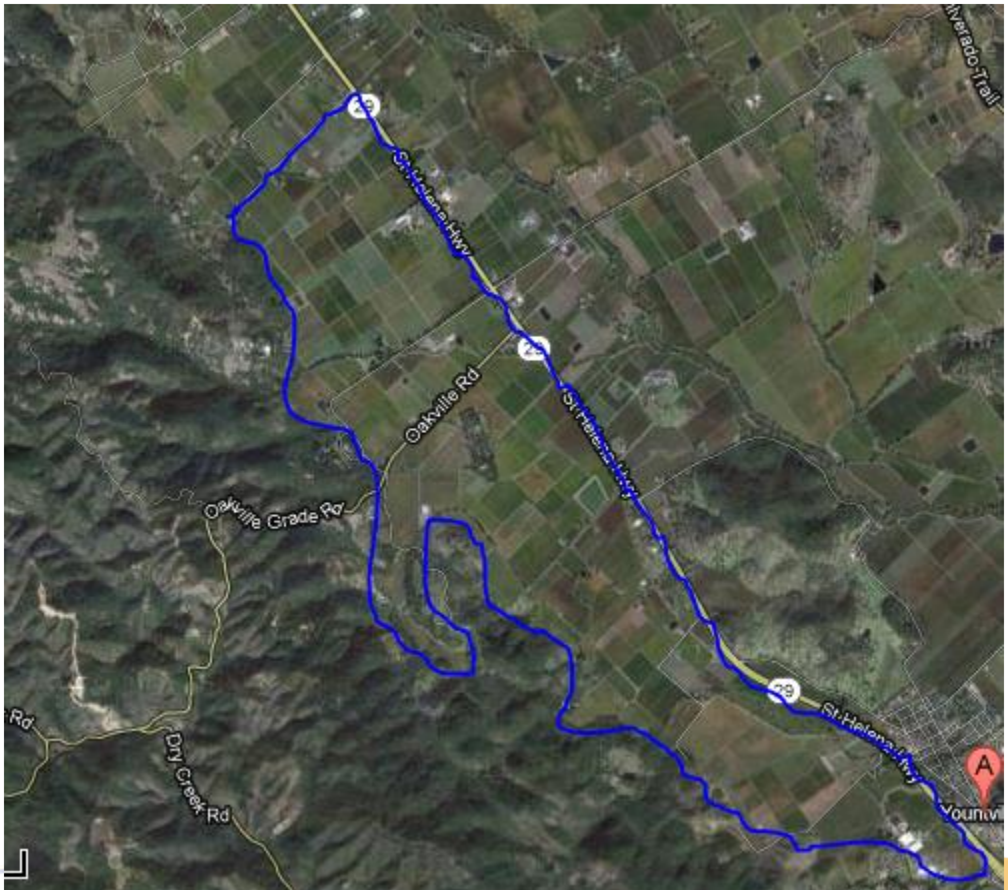

Mealybug counts
Discussion on control
Interest in virus testing and detection

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Sampling propagated vines

Sampling the source material will be more efficient

Illustrating the scale of the problem
Suppose N = 5 mother vines
n = 10 budsticks from each = 50 propagated vines

Suppose we want to take Simple Random Sample (SRS) of m = 5 sticks

There are $\binom{50}{5} = 2{,}118{,}760$

ways to draw the sample. n^N***=100,000 combinations have wood from all 5 mother vines so only 100,000/2,118,760 = 0.047 (5%) of SRS capture all 5 mother vines.***

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Sampling propagated vines cont'd.

Sampling the source material will be more efficient

More realistic (but still tiny-size) problem
Suppose N = 50 mother vines
n = 100 budsticks from each vine

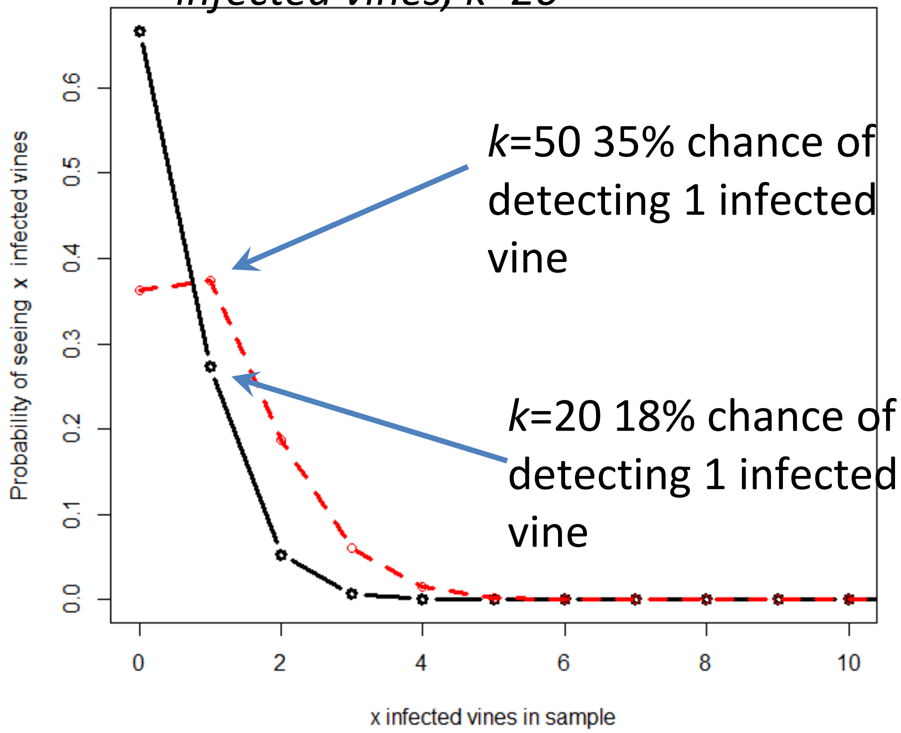
Suppose d = 1 infected mother vine = n*d = 100 infected daughter vines in n*N = 5000

We sample k = 20 vines off the truck using a SRS and send for testing. What is the probability we find x = 0,1, … k infected vines in the sample?

Hypergeometric distribution

$$\Pr(X = x) = \frac{\binom{n \cdot d}{x}\binom{n \cdot N - n \cdot d}{k - x}}{\binom{n \cdot N}{k}}$$

>65% chance of detecting no infected vines, k=20



k=50 35% chance of detecting 1 infected vine

k=20 18% chance of detecting 1 infected vine

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If you don't find it, is it really not there?

$$\Pr(X = 0) = (1 + n\theta)^{-N\frac{p}{\theta}}$$

Probability of not detecting disease if true vine incidence is p, group size is n and N groups of tests are made

$$p = -\theta \cdot log(P)/N \ \cdot \log(1 + n\theta)$$

Maximum true vine disease incidence that could result in zero positives, given group size n, N groups, with probability P.

$$N = -\theta \cdot log(P)/p \ \cdot \log(1 + n\theta)$$

Sample size required to generate zero positives, given group size n and true disease incidence p, with probability P. Larger samples will give one or more positives

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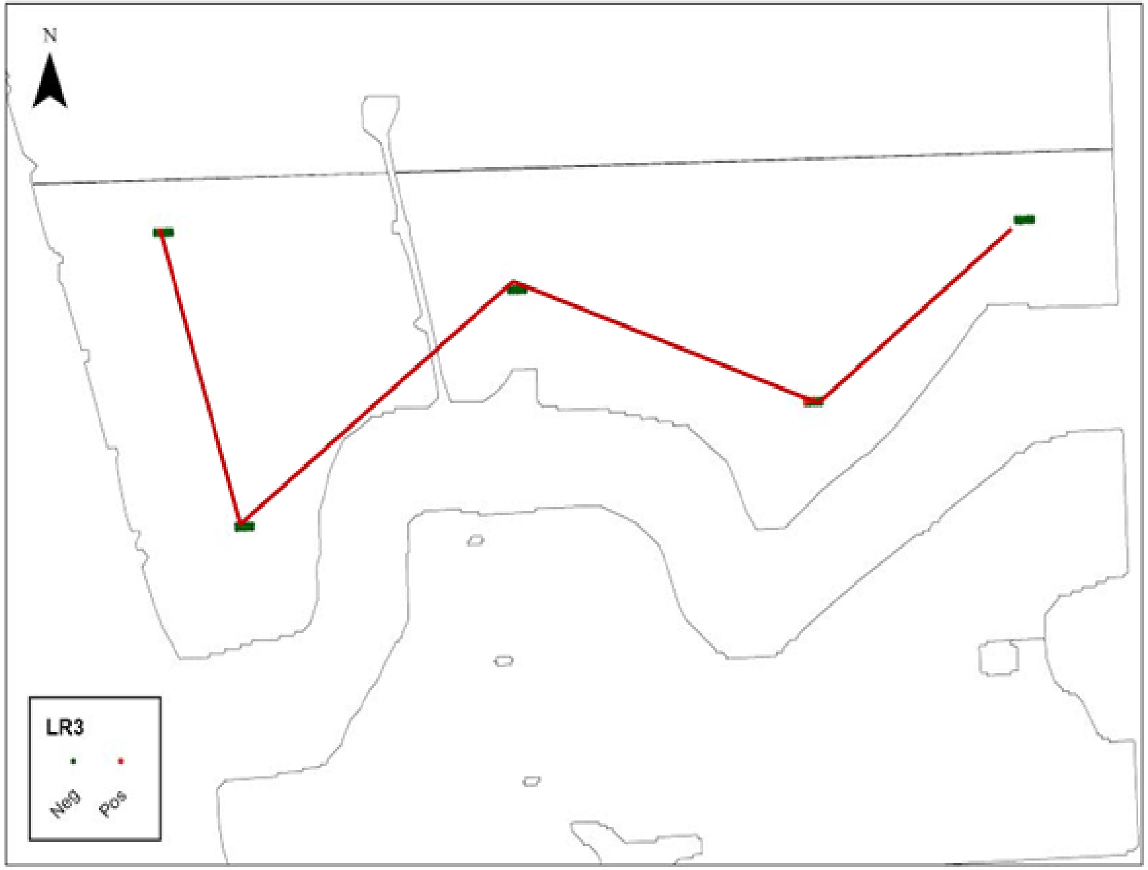
Case Study



Grower decided to test using this structure:

- 5 sets (quadrats)
- 10 samples (n=10) in each set

Row	XXXXX
Row	XXXXX

- Each vine individually tested
- "W" formation throughout field block
  - "X" works too

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Where are the positives?

GRBaV

15 positive of 50, approx. 30%

5 Quadrats of 10:

Quadrat	# Positive
1	3/10
2	2/10
3	0/10
4	0/10
5	10/10

GLRaV-3

5 positive of 50, approx. 10%

5 Quadrats of 10:

Quadrat	# Positive
1	1/10
2	0/10
3	0/10
4	0/10
5	4/10

GRBaV in the given samples

BINOMIAL

Fit Statistics	
-2 Log Likelihood	43.9
AIC (smaller is better)	45.9
AICC (smaller is better)	47.2
BIC (smaller is better)	45.5

BETA-BINOMIAL

Fit Statistics	
-2 Log Likelihood	19.4
AIC (smaller is better)	23.4
AICC (smaller is better)	29.4
BIC (smaller is better)	22.6

Label	Estimate	Standard Error	DF	t Value	Pr > |t|	Alpha	Lower	Upper
p	0.3	0.06481	5	4.63	0.0057	0.05	0.1334	0.4666

Label	Estimate	Standard Error	DF	t Value	Pr > |t|	Alpha	Lower	Upper
p	0.3519	0.1738	5	2.02	0.0988	0.05	-0.09483	0.7986
alpha	0.1928	0.1709	5	1.13	0.3105	0.05	-0.2465	0.6321
beta	0.3551	0.3511	5	1.01	0.3582	0.05	-0.5474	1.2576
rho (intraclass corr.)	0.646	0.2017	5	3.2	0.0239	0.05	0.1277	1.1644

PD/GWSS project on vine health A network of neighborhoods

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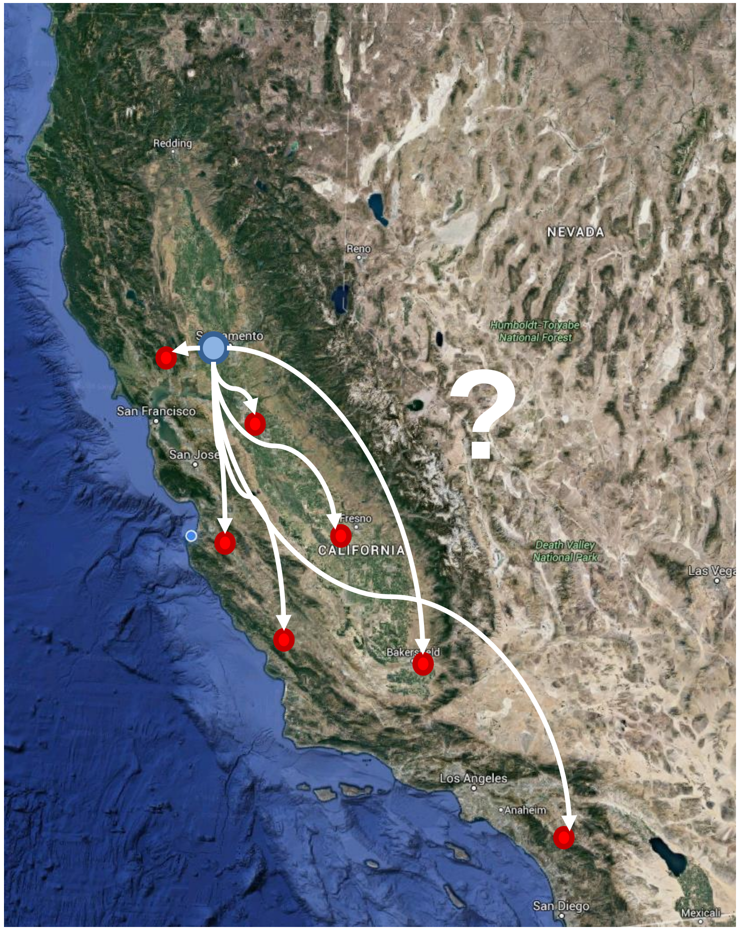

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Discussion time