Controling Primary Infection in Young Plantings

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Young groves

- The continued success of the citrus industry will depend on bringing young groves in to production
  - More boxes/ac = lower unit cost per lb solids
- Most (all?) people would agree that the longer you can keep the trees clean, the better off you will be (higher production)
- The question is how do we keep them clean?

Young groves

- Given the current inoculum load, we haven't been able to keep them clean……
  - Even with intensive management (2-4 sprays/month)

Trial	Year 1	Year 2	Year 3	Year 4 (partial)
CRDF 1	51%	70%	85%	
CRDF 2	22%	100%	86%	
CRDF 3	14%	29%	79%	
SGC	2% (4)	3% (6)	16% (32)	72% (100)

CRDF data provided by Dr. Catharine Hatcher (rootstock trials, based on PCR testing)
SGC data based on visual scouting

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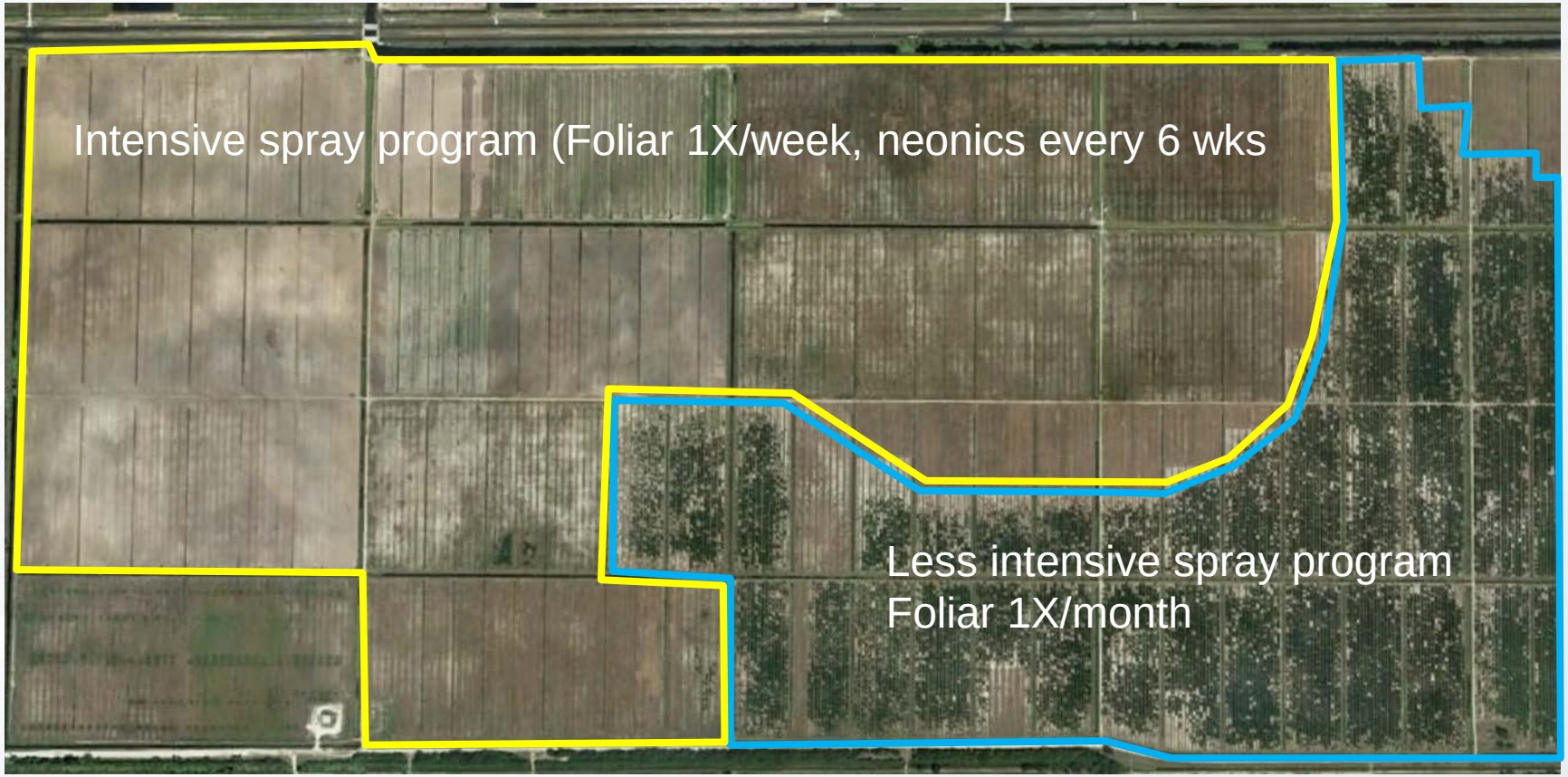
New Plantings



- All of the yellow area replanted, existing grove (blue) still there

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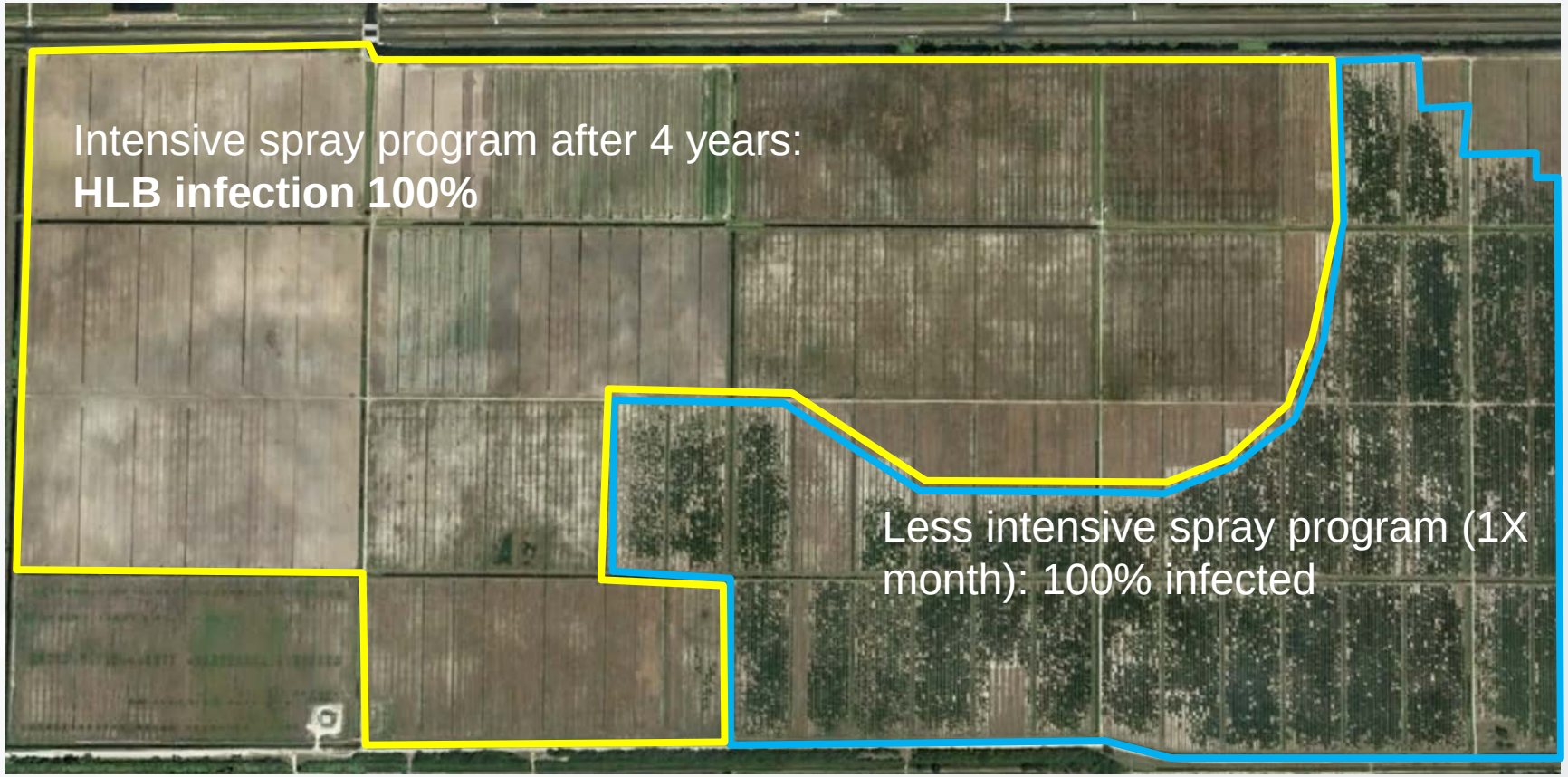
ACP lifecycle 14 days at 28C, and generation to generation time ~17-22 days



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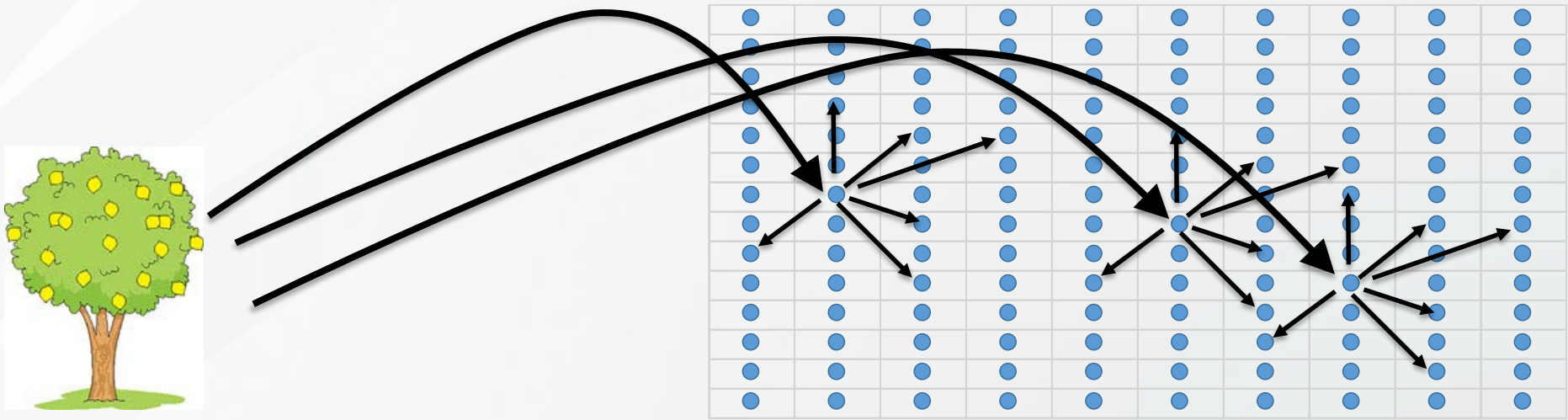
Types of spread

Primary spread
(coming from outside, long distance)

Secondary
(coming from inside, short distance)



Types of spread – how does that apply to our situation?

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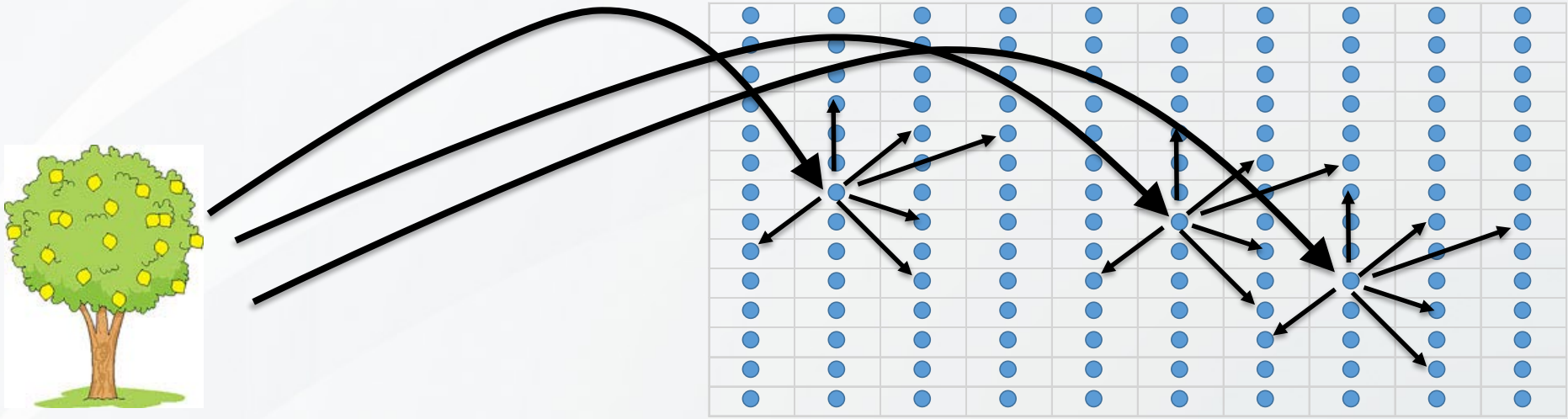


Mature block – 1X/Month

Will complete life cycle

- Eggs to nymphs: 3-4 days
- Nymphs to adults:10-14 days

Young block – 4X/Month

Will not complete life cycle, may get nymphs but should not get adults

ACP Data

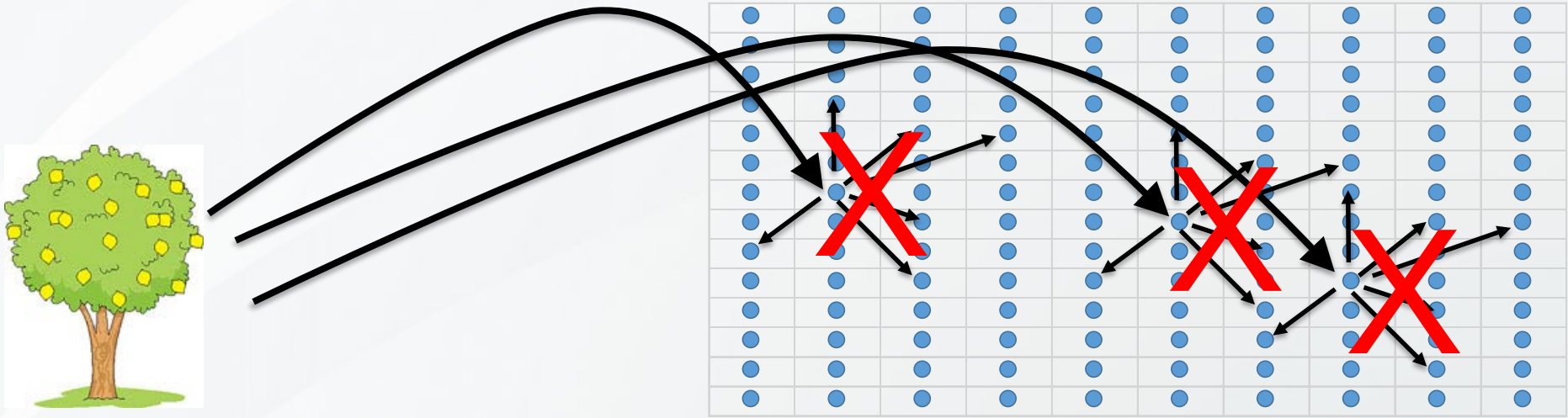
- So is this what is actually happening in the field?

Column Labels	2015			2016			2017		
Row Labels	Tap	Nymphs	Adults	Tap	Nymphs	Adults	Tap	Nymphs	Adults
Blocks with older trees	0.07	0.14	0.07	0.38	0.57	0.18	0.02	0.07	0.05
316-F,	0.22	0.36	0.25	1.34	1.24	0.59	-	-	-
317-A,	-	-	-						
317-A,D	-	-	-	-	0.53	0.17			
317-A,E	0.02	0.02	0.01	0.08	0.27	0.08	-	-	-
317-A,F	-	-	-	0.13	0.54	0.06	-	0.07	0.04
317-B,E	-	-	-	0.71	1.33	0.33			
317-B,F	-	0.13	-	0.04	0.34	0.04			
318-A,B	0.02	0.05	0.00	0.03	0.21	0.04	0.03	-	-
318-A,C	0.01	0.02	-	0.10	0.29	0.08	-	-	-
318-B,C	-	-	-						
319-A,B				-	0.50	0.11	-	-	-
319-A,C	0.00	0.01	0.02	0.12	0.26	0.08	0.05	0.06	0.03
319-A,D	-	-	-	0.35	0.47	0.18			
320-A,B							-	-	-
320-A,C	0.24	0.35	0.17	0.26	0.50	0.10	0.11	0.64	0.47
320-A,D	-	-	-	0.20	0.35	0.09			
320-B,D							-	-	0.17
321-A,C	0.03	0.18	0.04	0.32	0.67	0.13	-	-	0.13
321-A,D				-	0.92	0.17	-	0.17	-
321-B,C	-	-	-	0.42	1.08	0.17			
321-B,D	0.06	0.26	0.06	0.45	0.76	0.10	-	0.11	-
321-F,F	-	-	-						
Young trees	0.01	-	-	0.08	0.10	0.01	-	-	-
315-1,1				-	-	-			
315-1,2	-	-	-	0.13	0.13	0.03	-	-	-
315-3,	-	-	-	0.10	0.19	-	-	-	-
316-1,				-	-	-			
316-1,2	0.02	-	-	0.12	0.15	0.02	-	-	-
316-3,							-	-	-
316-3,4				0.01	-	-	-	-	-
317-1,2				-	-	-	-	-	-
317-2,				-	-	-			
318-1,							-	-	-
318-1,2				-	-	-	-	-	-
Grand Total	0.06	0.11	0.05	0.29	0.43	0.13	0.01	0.05	0.03

Types of spread – how does that apply to our situation?

Primary spread
(coming from outside, long distance)

Secondary
(coming from inside, short distance)



Mature block – 1X/Month

Young block – 4X/Month

No secondary spread due to reproduction, limited spread due to movement

- Eggs to nymphs: 3-4 days
- Nymphs to adults:10-14 days

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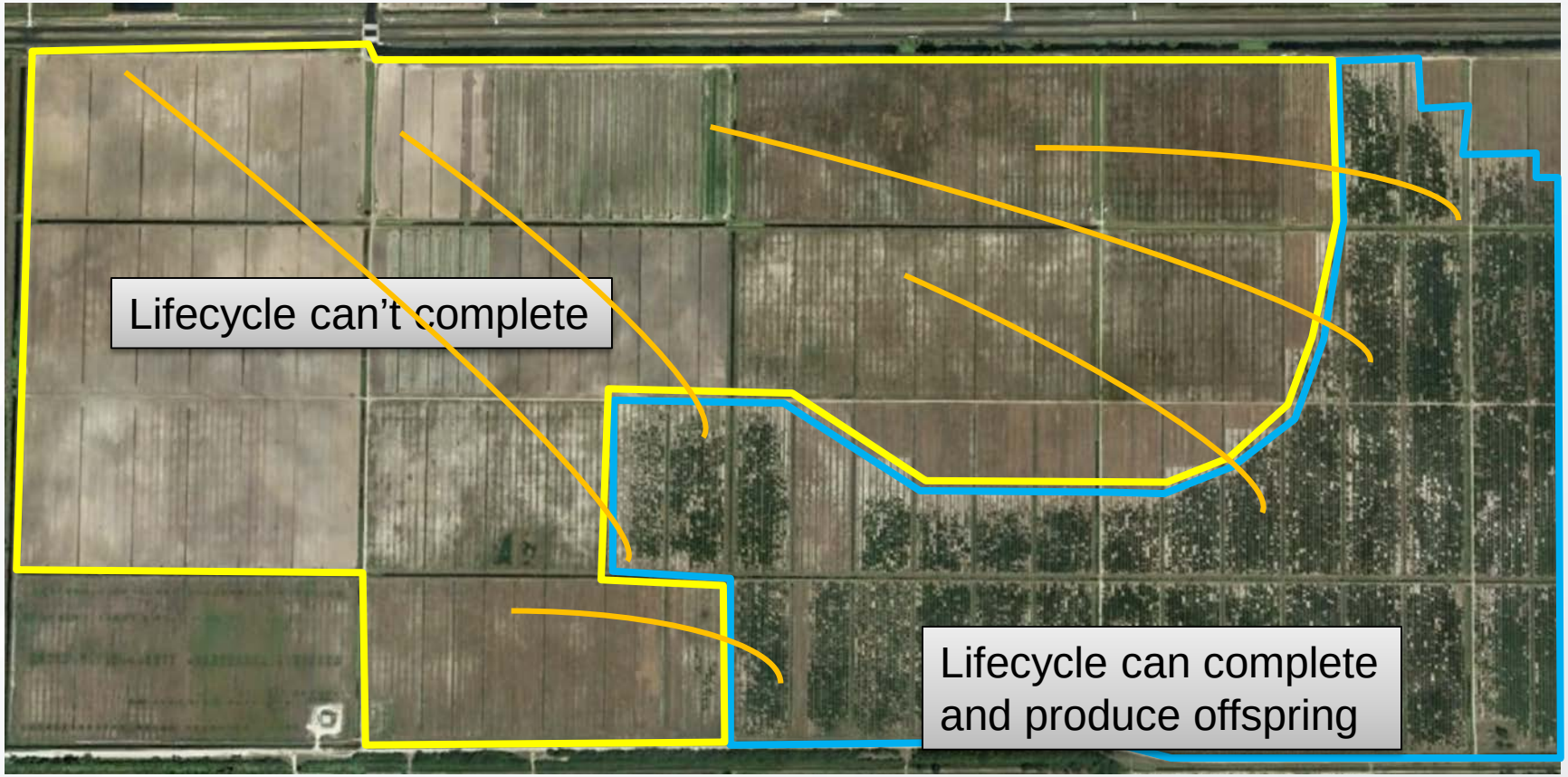
ACP lifecycle 14 days at 28C, and generation to generation time = 22 days



- Infection has to be coming from the outside
- No amount of spraying in the young trees would prevent ingress

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What is the best control strategy to protect the young trees

- Scenario 1:
  - Intensive control on young trees (life cycle -), less intensive control on surrounding trees (life cycle +)
- Scenario 2:
  - Moderate control on young trees (life cycle -/+), moderate control on surrounding trees (life cycle -/+)
- Scenario 3:
  - Less intensive control on young trees (life cycle +), intensive control on surrounding trees (life cycle -)

Modeling The Spread of HLB

Model Background

- Individual Based: Every tree, every flush on every tree, and every psyllid are represented in the model.
- Behavior and interactions between individuals are deduced as well as possible from the scientific literature.
- Spatially Explicit: We include the positions of objects so that can explore spatial aspects of HLB
  - Edge effects
  - Invasion pattern

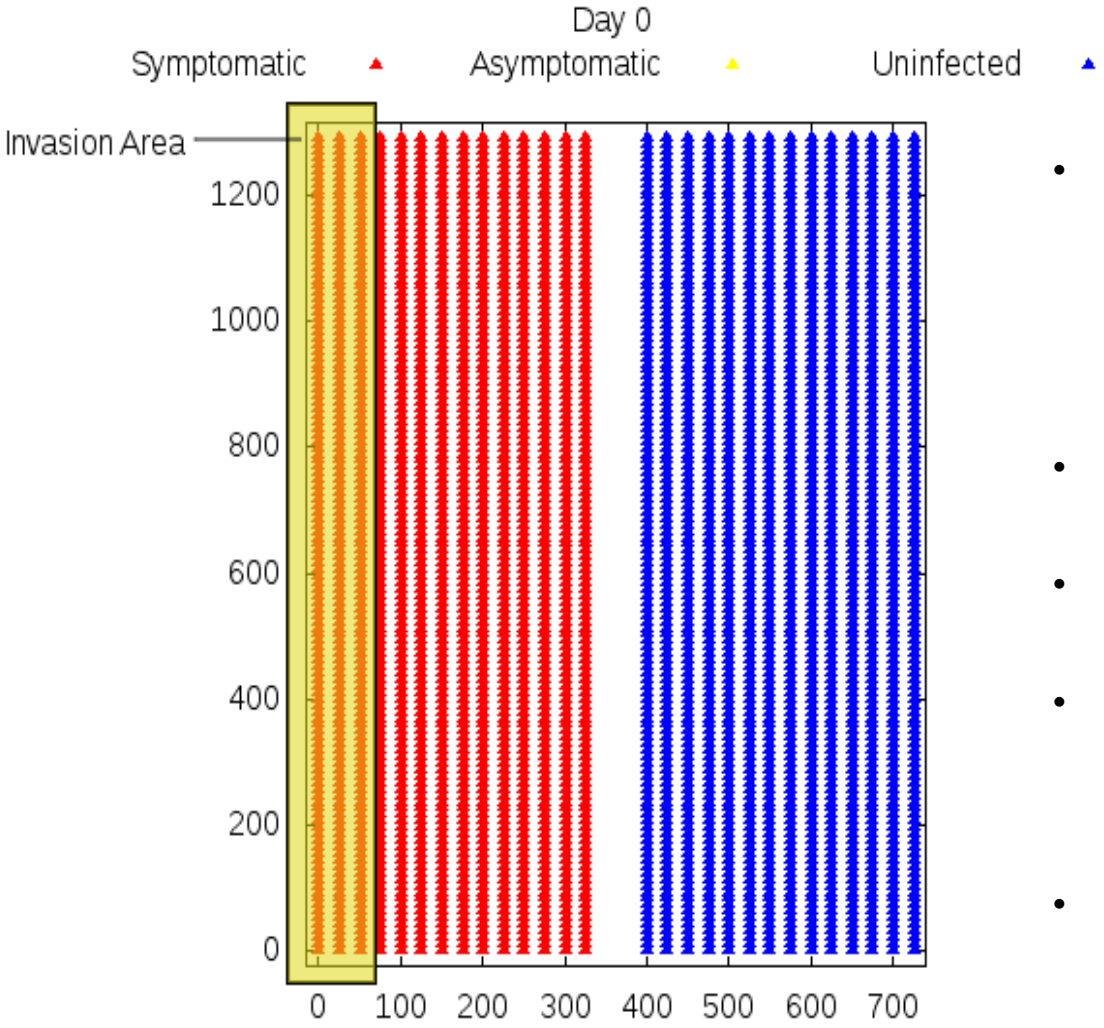
Model Daily Activities

- New flushes emerge and mature
- Eggs and psyllid nymphs develop on the flush
- Psyllids develop and die at some rate (may be influenced by insecticide)
- Psyllids move to a new tree and flush
- Psyllids infect and lay eggs on their host flush

Model Parameterization

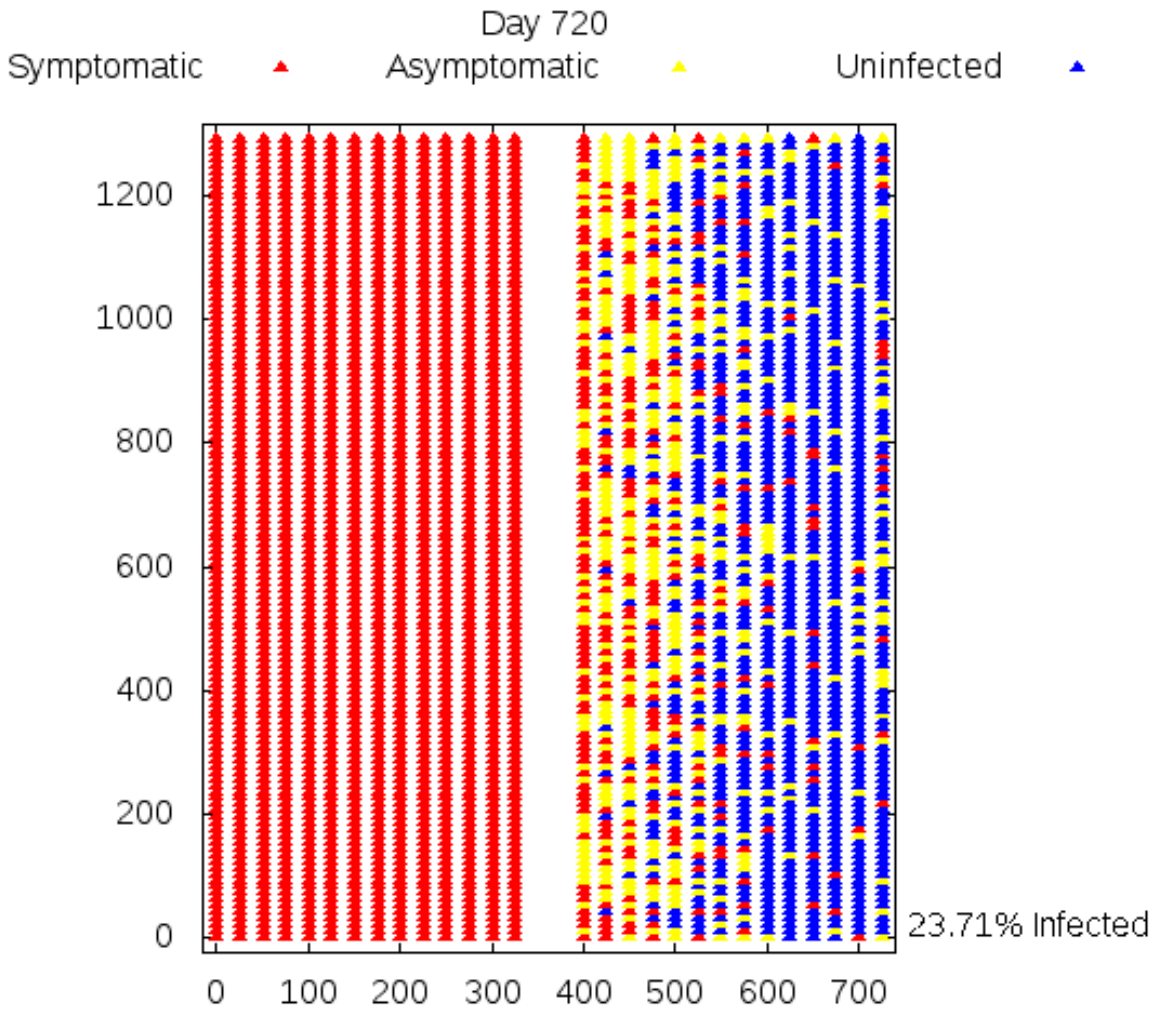
Parameter Name	Value
Psyllid Daily Survival Probability	0.9847
Eggs Per Female Per Day	10
Egg to Adult Survival Rate	0.07912
Egg to Adult Time	17d
Flush Maturation Time	30
Flush Max Occupancy	100 (nymph + eggs)
Nymph Infectible Age	10
Flush to Nymph Infection Probability	0.1078
ACP to Flush Infection Probability	0.063
Flush CLas Latent Period	10d
Transovarial Transmission Probability	0.04
Flush to Root Transport Probability	0.3
Root Latent Time	730d
Psyllid Jump Rate	10

Simulation Setup - Visual

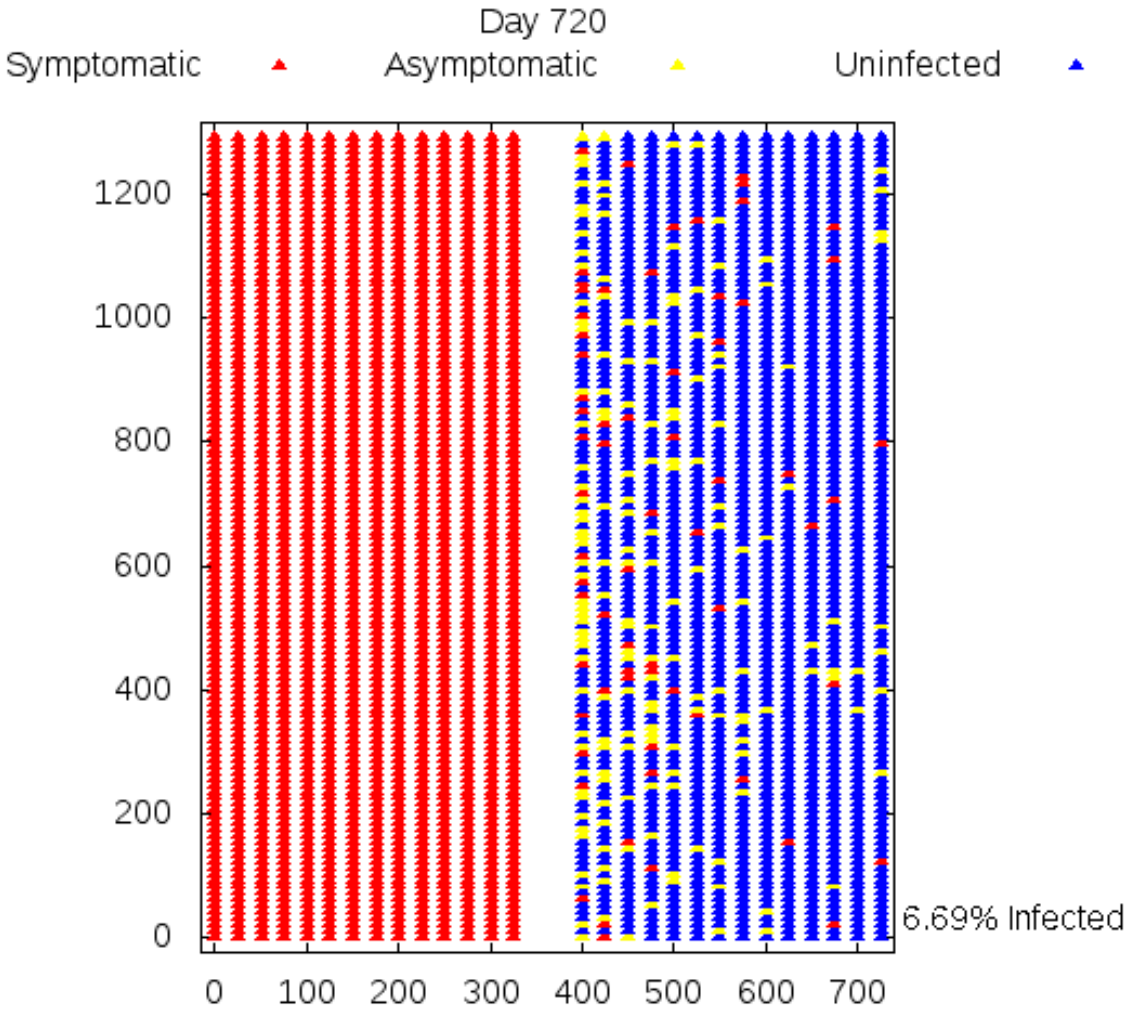


- Two blocks of trees
  - Block 1 (West): Older trees, 100% infected
  - Block 2 (East): New Planting, 0% infected
- Psyllid invasion occurs only in the yellow region
- We will primarily alter the relative spraying rates of the two blocks
- West N East M means that the west block was sprayed every N days while the east was sprayed every M days
- Spray is assumed 90% effective on adults and nymphs

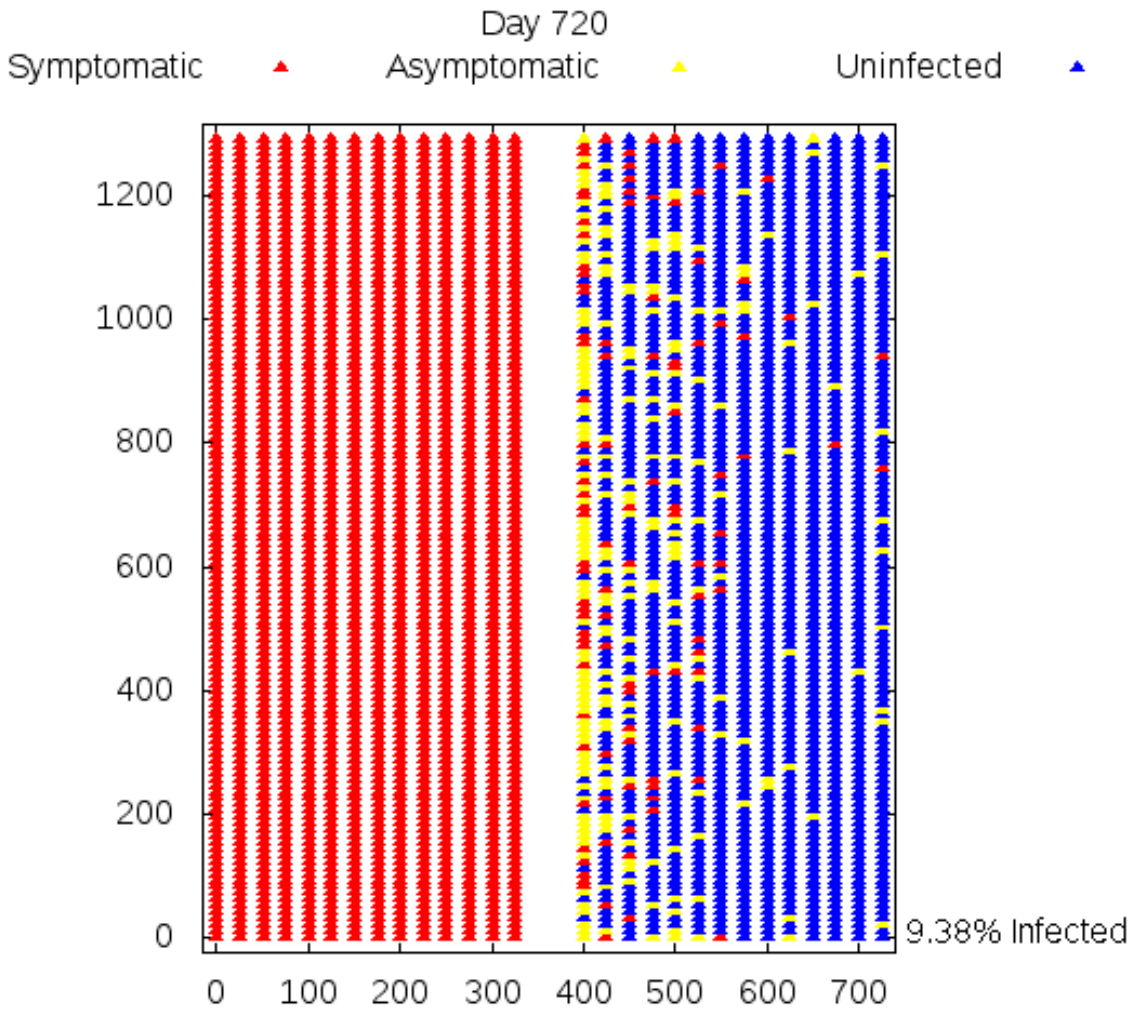
Results – East 10 West 30



Results – East 30 West 10



Results - East 15 West 15



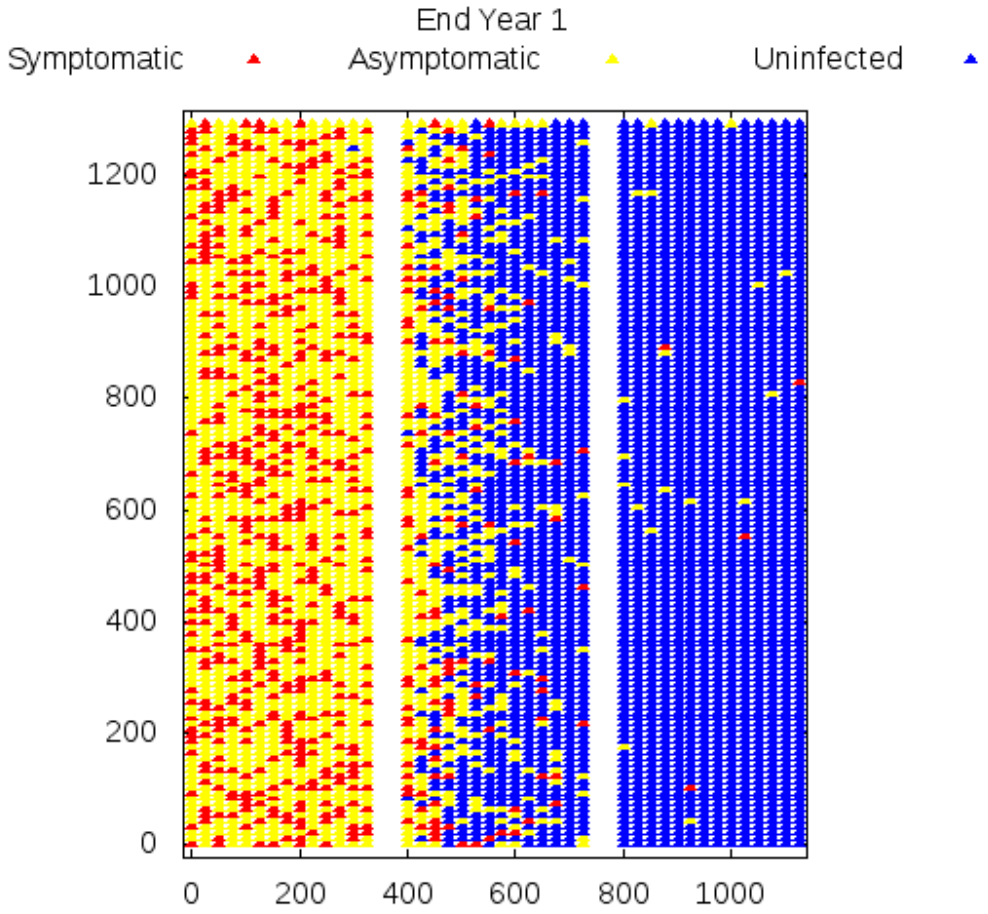
Conclusions

- Monthly sprays do not disrupt the psyllid lifecycle – eventually they overflow into the new planting
- Twice monthly is sufficient to disrupt the psyllid lifecycle and mostly protect the young planting
  - Some psyllids do randomly make a longer jump, but this is unavoidable
  - Ideally the young planting is sprayed twice monthly to prevent these from reproducing.

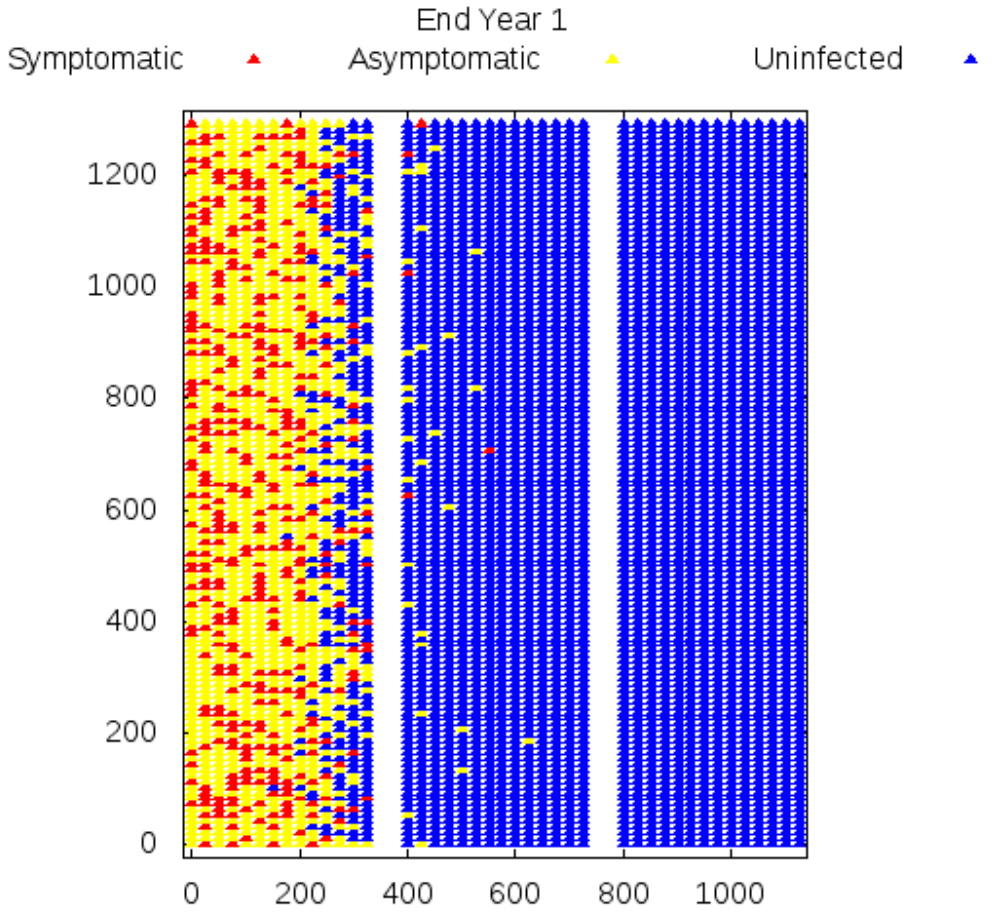
Three Block Simulations

- In order to more clearly see the effect of spray duration on dispersal, we will simulate with three blocks
- Now East N West M means the most eastern block is sprayed every N days while the **two** most western blocks are sprayed every M days

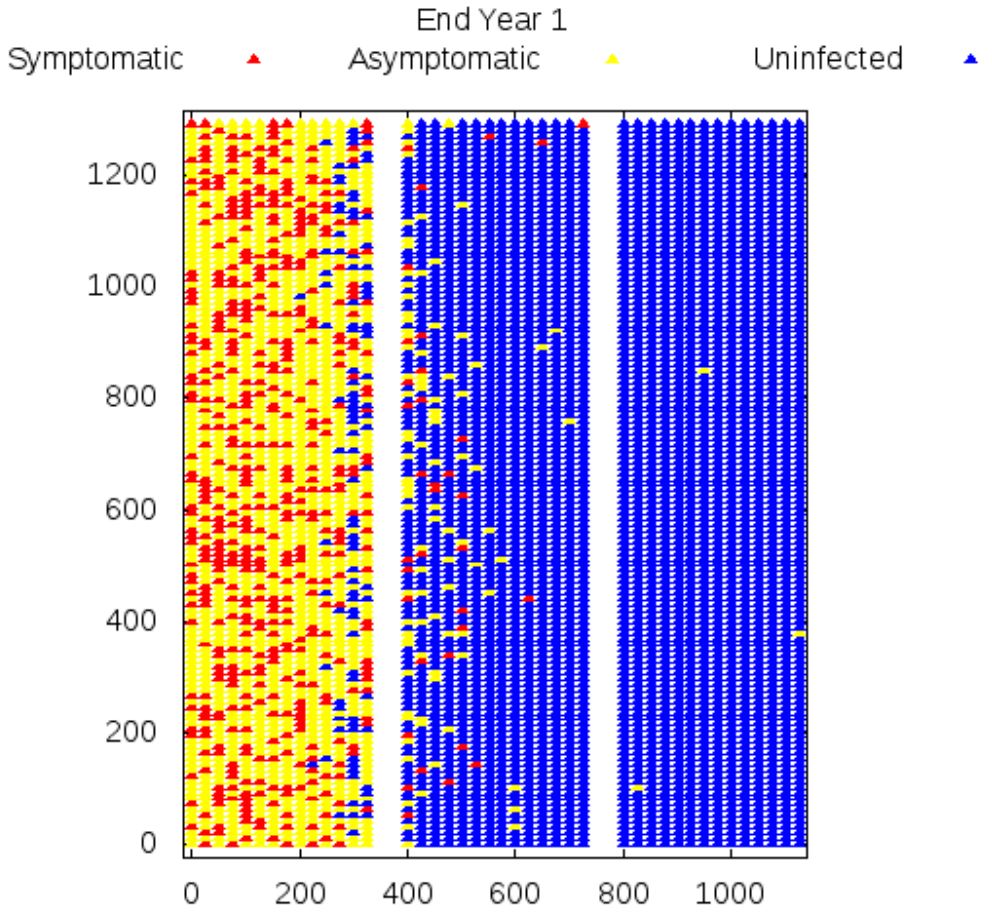
Three Block – East 10 West 30



Three Block – East 30 West 10



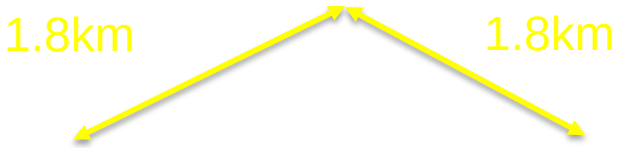
Three Block – East 15 West 15



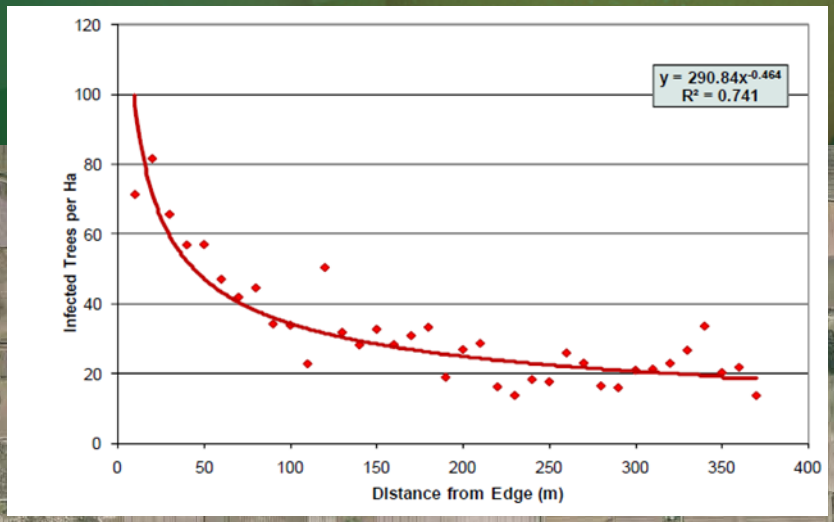
Are we doing it backwards……..

- What should we be doing?
  - Treat surrounding blocks (source of inoculum and ACP) more aggressively
    - 2X or more times a month
  - Treat young blocks less aggressively than now but enough to control ACP
    - 1-2X/month
  - Apply to new plantings and existing plantings
  - Model economics (yield vs. cost)

How far do you have to treat?



1.8 km swath



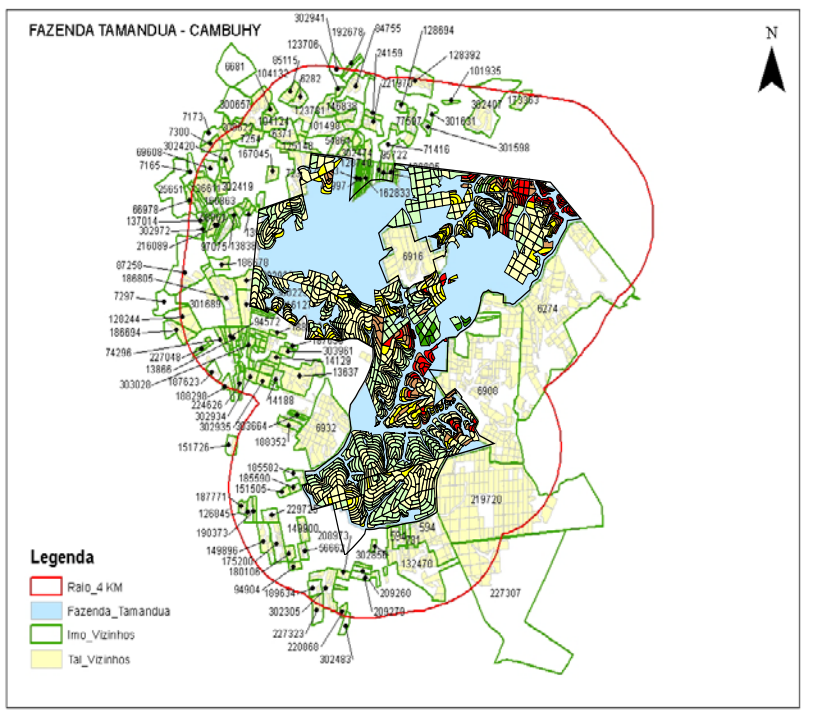
Benefit-cost of Regional Management

A study case:
Cambuhy farm HLB management outside the farm (in their neighbors)

Neighbor’s effect

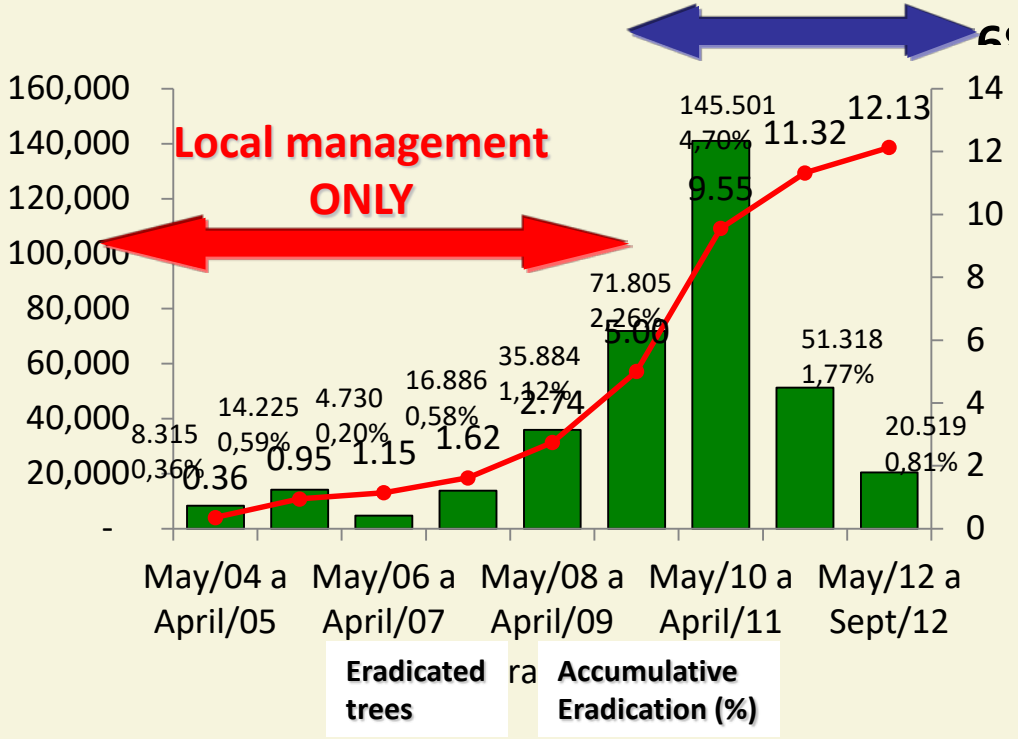
CAMBUHY

HLB Edge effect



HLB Eradication 2004/05 - 2012/13

Local + Regional management (with or in the neighbors)



External management (300 ha around farm)

- Weekly ACP monitoring
- Insecticide spray when ACP is found
- Aerial insecticide spray 4-5x/year
- Neighbor's citrus eradication

CAMBUHY

Tachibana (2012)

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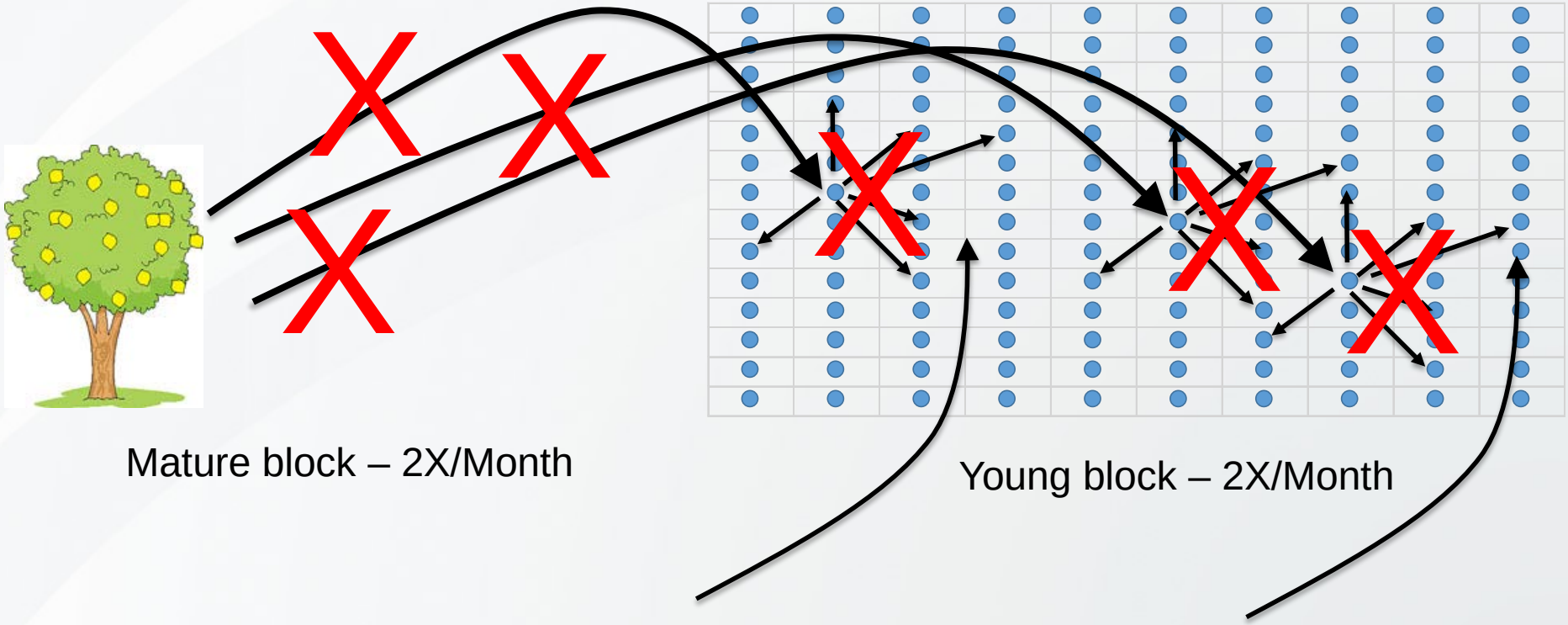
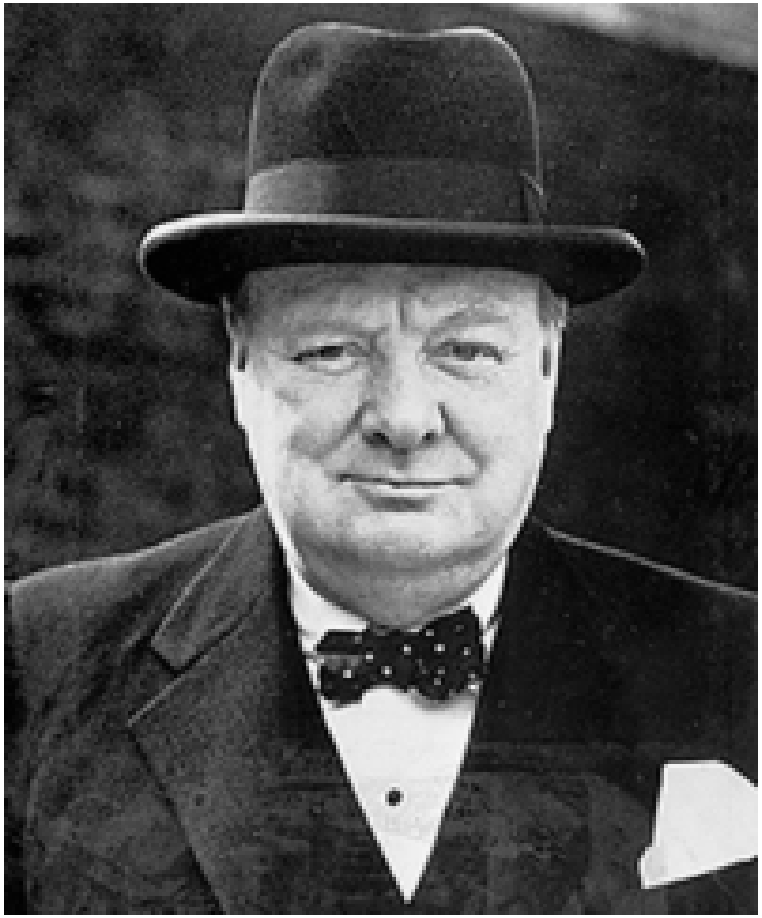


Mature block – 2X/Month

Young block – 2X/Month

Most spread will be from the outside (inverse distance law)



“ It is not enough that we do our best; sometimes we must do what is required”

Winston S. Churchill