Examination of host responses of different citrus varieties and relatives to HLB infection

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HLB host range

Greenhouse experiments

under
'select agent'
conditions

Main objectives in this study:

1) Examine different citrus genotypes or citrus relatives with the purpose of understanding at the whole plant level how different citrus varieties respond to Las, and whether there are resistant or tolerant varieties.

2) Understand whether there is a correlation between severity of disease and the level of bacterial concentration

3) Examine how Las is distributed in infected plant, and where through out the infected host the bacterium is present at the highest concentration

4) Determine how environmental conditions affect symptoms development

Citrus varieties and relatives that have been screened

- 1 Citrus macrophylla (Alemow)
- 2 Valencia Sweet orange
- 3 Ruby Red grapefruit
- 4 Nules clementine (mandarin)
- 5 Minneola tangelo
- 6 Eureka lemon
- 7 Volkamer lemon
- 8 Persian lime
- 9 Mexican lime
- 10 Citron
- 11 Carrizo citrange
- 12 Poncirus trifoliata
- 13 Citrus halimii
- 14 Citrus indica
- 15 Citrus micrantha
- 16 Citrus ambyllocarpa
- 17 Sour orange
- 18 Meiwa kumquat
- 19 Calamondin
- 20 Citrus hystrix
- 21 Swingle citrumelo
- 22 Sun Chu Sha (mandarin)
- 23 Palestine Sweet lime
- 24 Citrus latipes
- 25 Cleopatra mandarin
- 26 Madam vinous Sweet Orange
- 27 Duncan grapefruit
- 28 Ling Ping Yau pummelo
- 29 Hirado Buntan Pink pummelo
- 30 Siamese Sweet pummelo
- 31 Severinia buxifolia

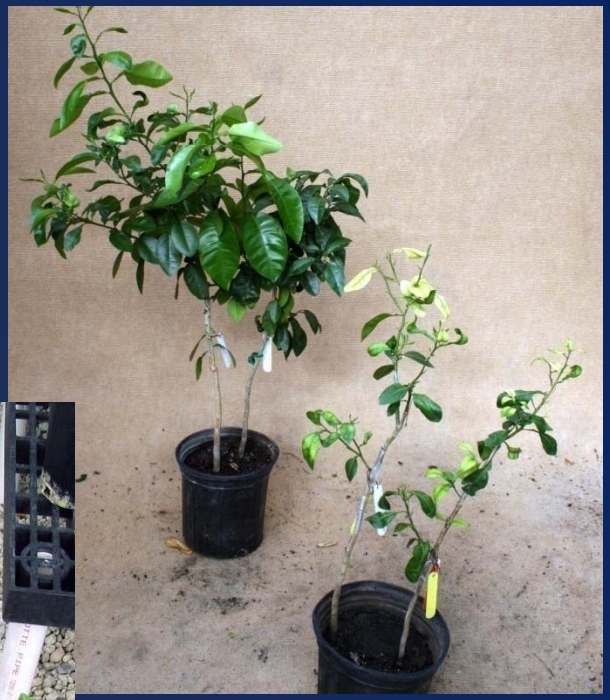
We have not found citrus varieties or relatives that are resistant to infection by Candidatus Liberibacter asiaticus.

However, there were major differences in host response between different varieties.

Different citrus varieties have different degrees of susceptibility to HLB

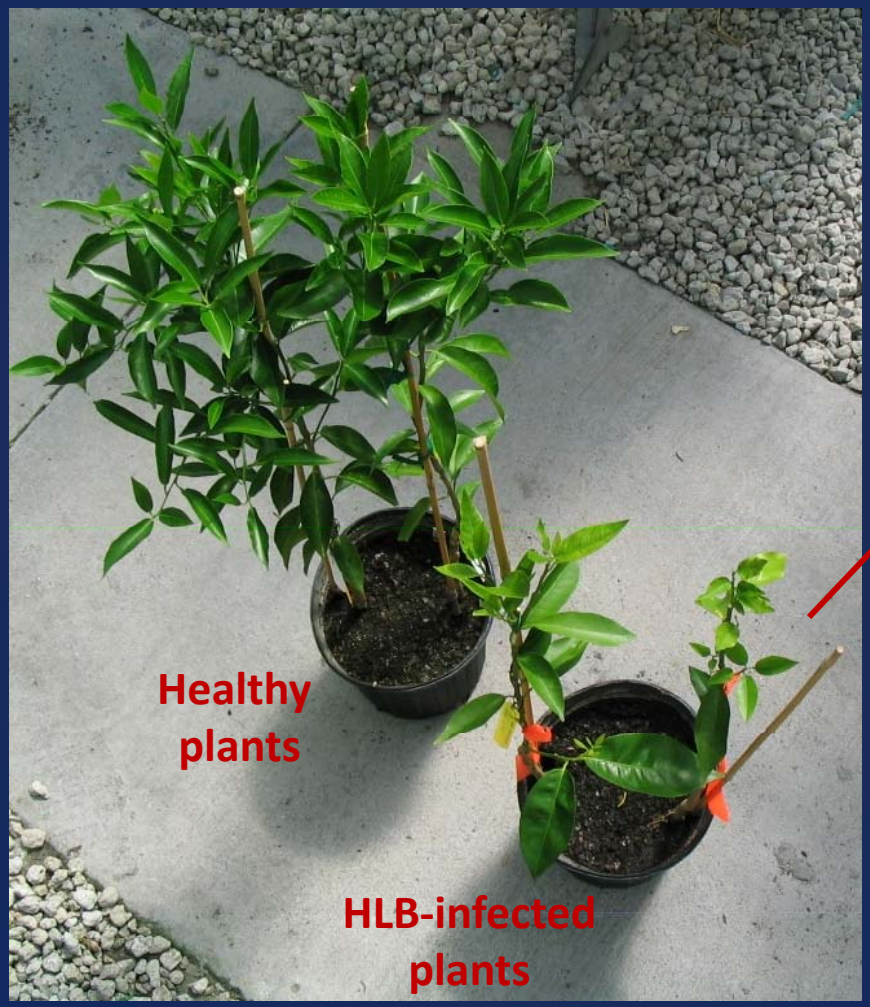
Eureka lemon

Cleopatra mandarin



Duncan grapefruit

Nules clementine: high sensitivity to HLB

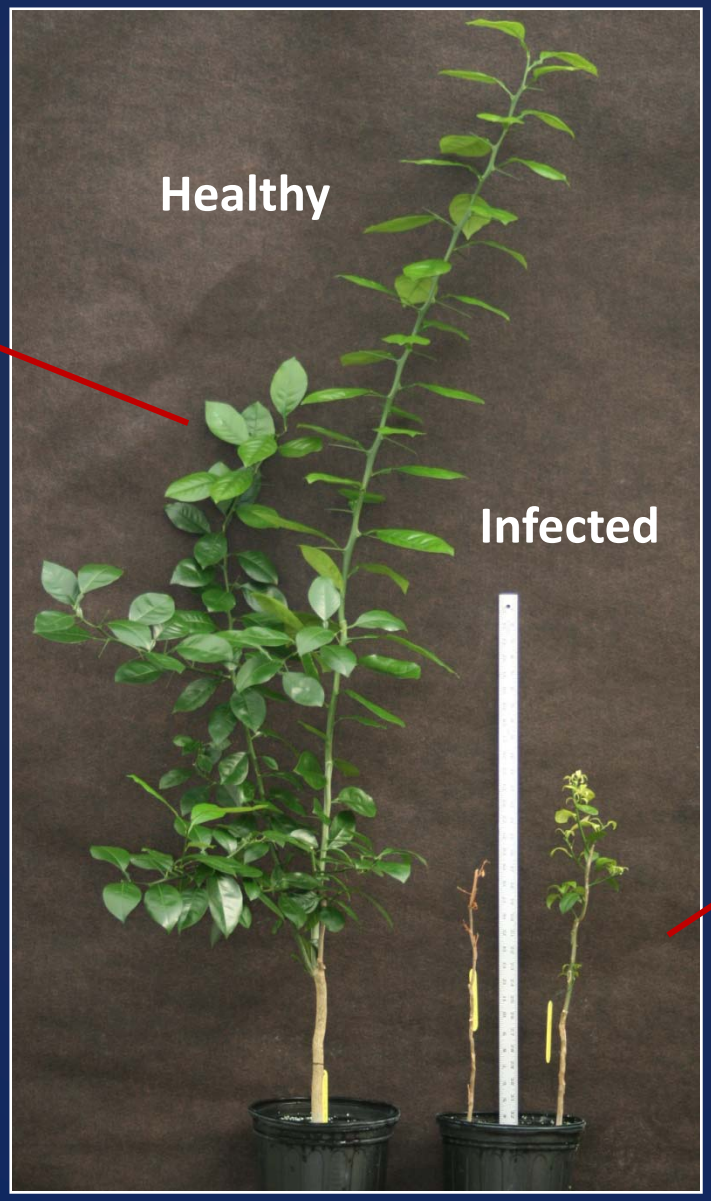


3 months upon inoculation

6 months upon inoculation

Effect of HLB on Madam Vinous sweet orange

(9 months after inoculation)



Symptoms produced by different citrus varieties under greenhouse conditions

Eureka lemon

Mexican lime

Duncan grapefruit

Hirado Buntan pink pummelo

Madam Vinous sweet orange

Response of different citrus genotypes to HLB under greenhouse conditions

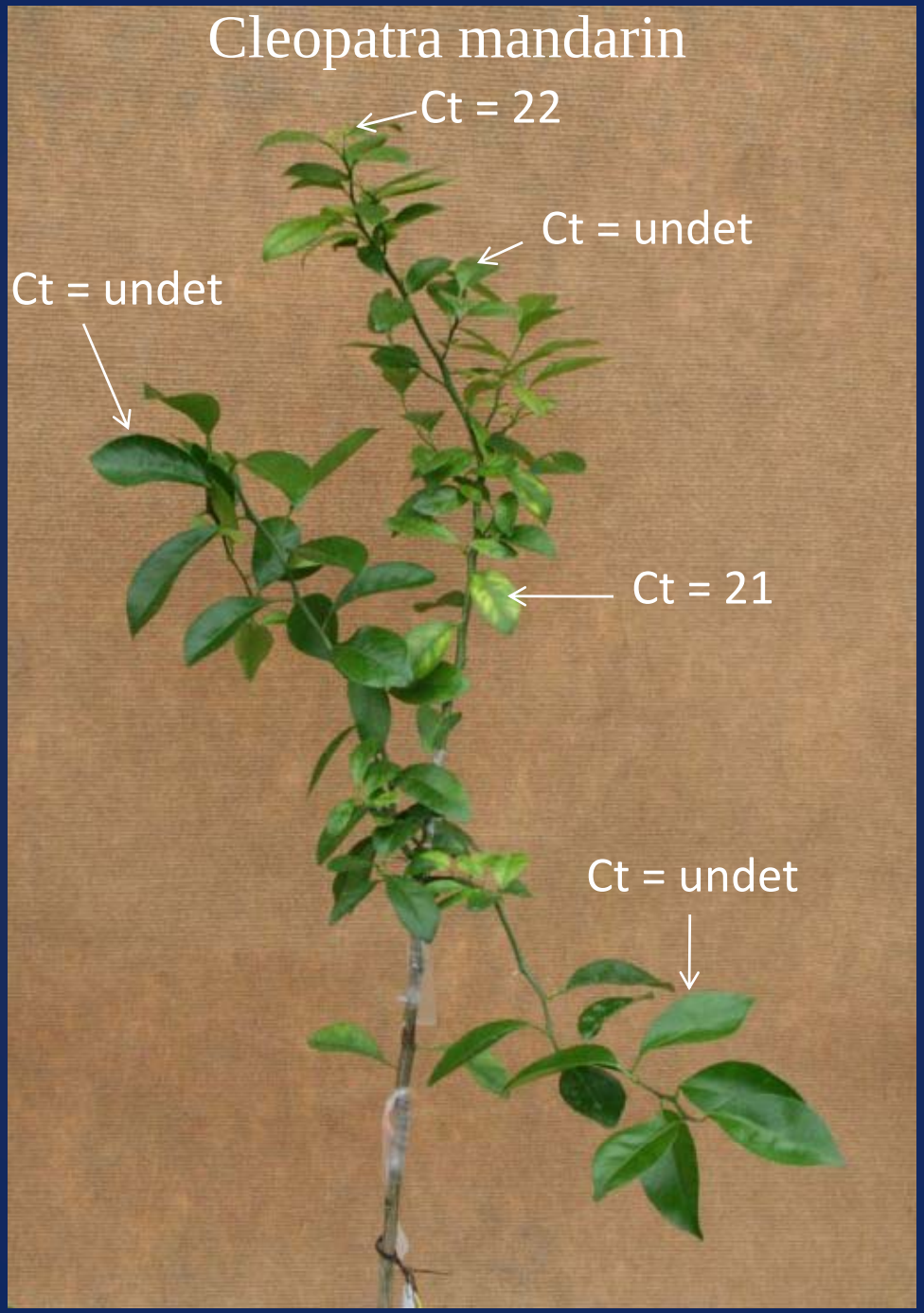
Citrus or relative	Las titer	Symptoms description
Poncirus trifoliata	+	Extreme tolerance some stunting
Carrizo citrange	+	Extreme tolerance little or no chlorosis
Eureka lemon	++	Extreme tolerance chlorosis only under high light
Persian lime	+++	Extreme tolerance no distinct symptoms

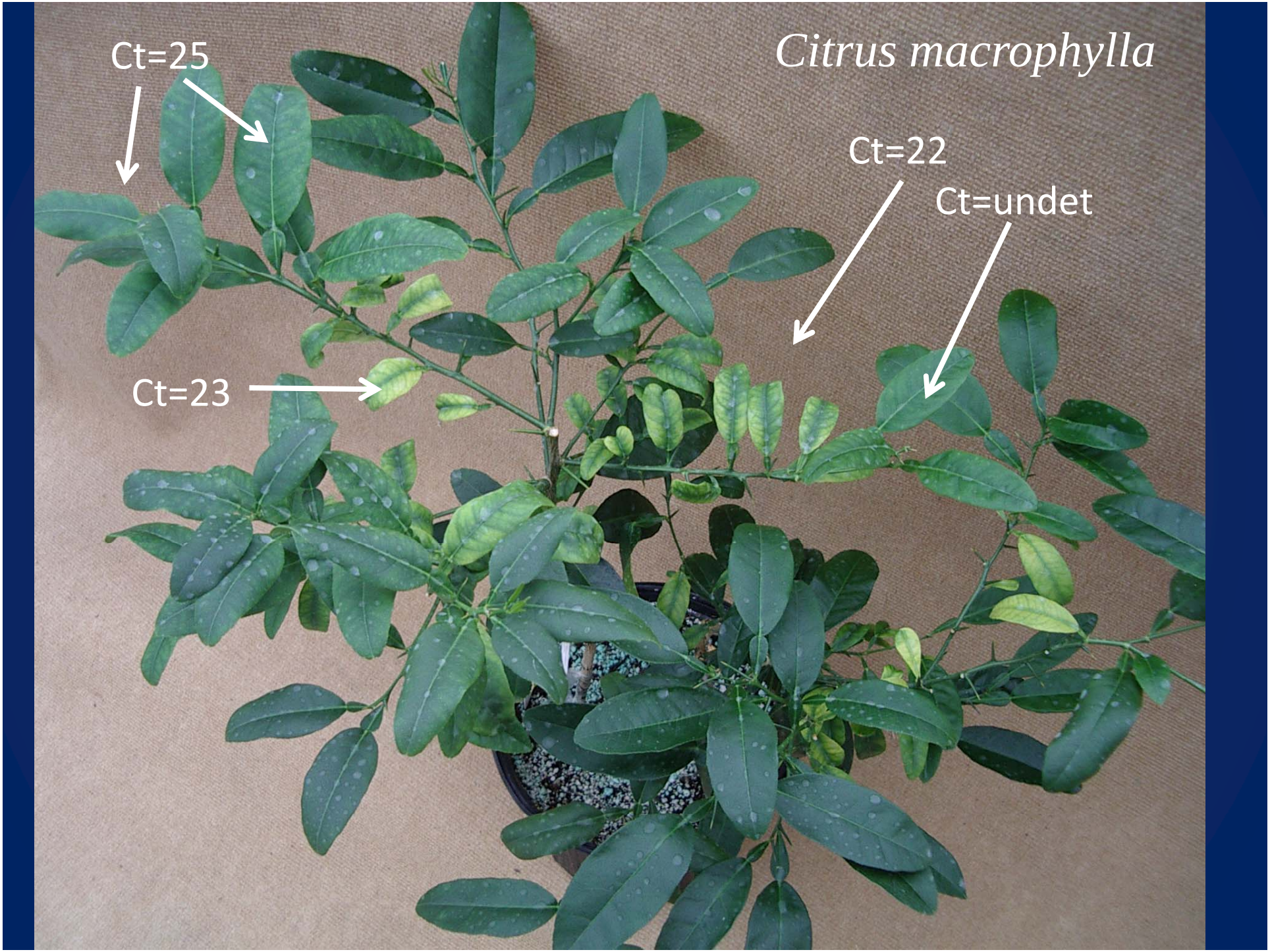
Sun Chu Cha	+++	**Tolerant:** scattered groups of chlorotic leaves
Sour orange	+++	**Tolerant**
Volkamer lemon	+++	**Tolerant**
C. macrophylla	+++	**Tolerant**
Swingle citrumelo	+++	**Tolerant**
Citron	++	**Tolerant**
Palestine sweet lime	+++	**Tolerant**
Mexican lime	+++	**Tolerant**
Calamondin	+++	**Tolerant**
C. micantra	+++	**Tolerant**

Siamese sweet pummelo	++	Intermediate: chlorotic leaves, some growth reduction
Ling Ping Yau pummelo	++	Intermediate
Hirado Buntan pink pummelo	++	Intermediate
C. ambyllocarpa	+++	Intermediate
Cleopatra mandarin	+++	Intermediate
C. indica	++	Intermediate
Meiwa kumquat	++	Intermediate

Valencia sweet orange	+++	Sensitive: chlorosis including tip, reduced growth
Madam Vinous sweet orange	+++	Sensitive - same
Duncan grapefruit	++	Sensitive - same
Ruby Red grapefruit	++	Sensitive - same
Citrus halimii	++	**Sensitive:** chlorosis, vein corking, death
Nules clementine	++	**Sensitive:** strong chlorosis, reduced growth, death
Minneola tangelo	++	**Sensitive:** strong chlorosis, reduced growth

Liberibacter often is unevenly distributed in infected trees

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Citrus macrophylla
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Disease Symptoms Are Correlated with Abnormal Sugar Distribution

Phloem blockage (phloem necrosis, callose deposits)

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Disruption of sugar movement pathway – lack of sugar export

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Starch granules accumulate and disrupt chloroplasts

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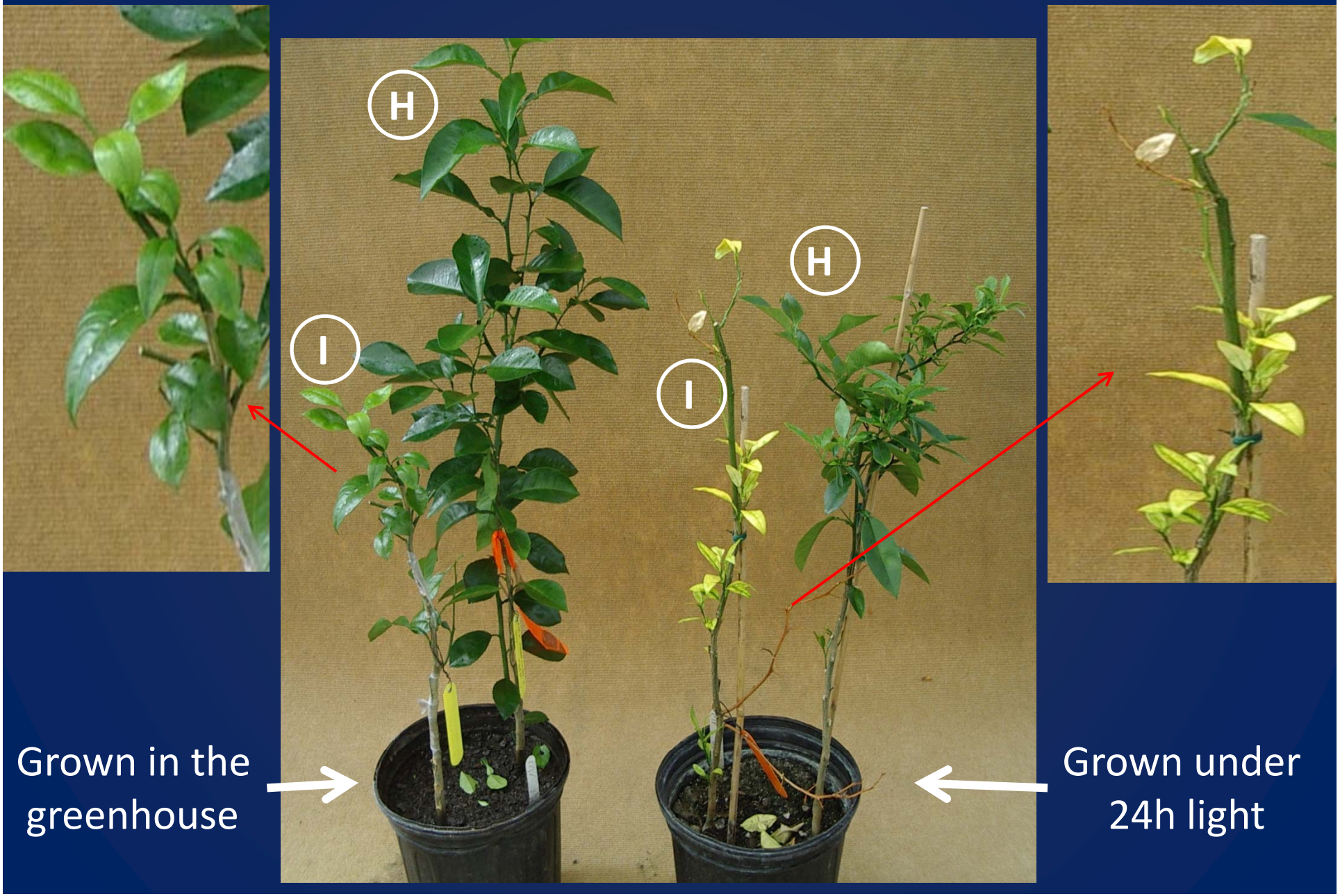
Chlorotic symptoms on leaves

Effect of light on HLB symptoms development



Severity of symptoms increases when plants are incubated under continuous light

Eureka lemon

Greenhouse conditions

24 hours light growth room

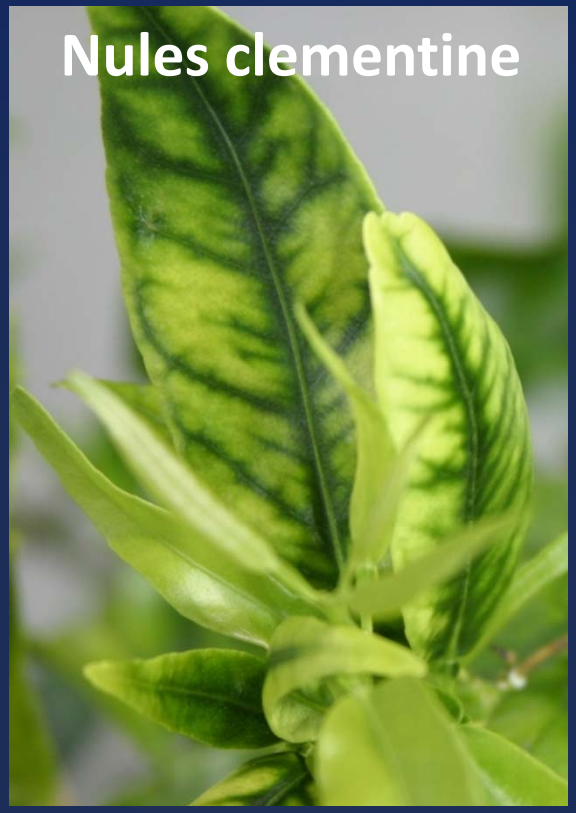
Symptoms in greenhouse

Symptoms under continuous light

Sour orange

Cleopatra mandarin

Typical light room symptoms



Non-inoculated sweet orange plants of 5 different cultivars

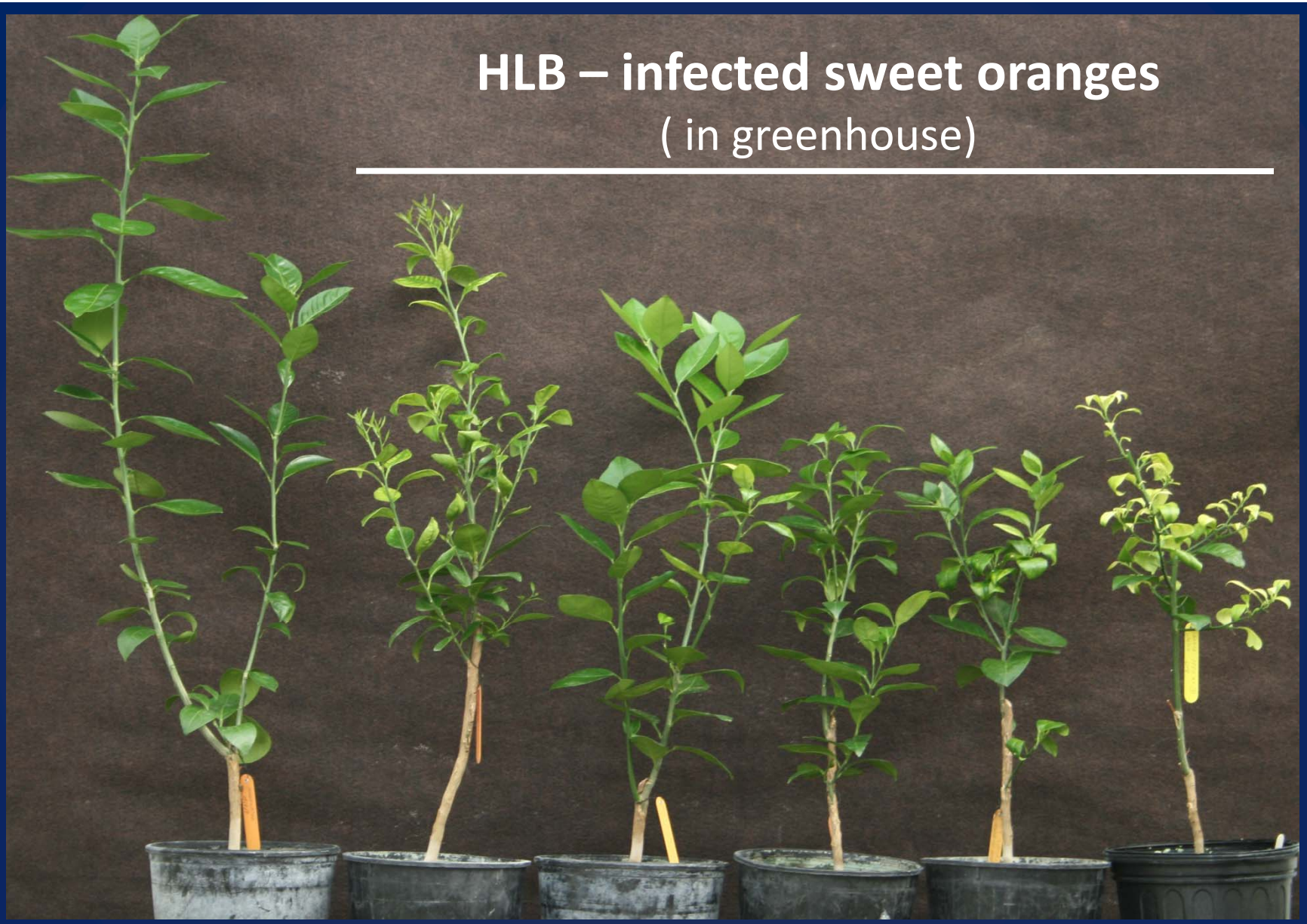
Hamlin Pineapple Madam Vinous

Rohde Red Valencia

Valencia 1-18-31

HLB – infected sweet oranges

(in greenhouse)



Healthy Hamlin

Hamlin

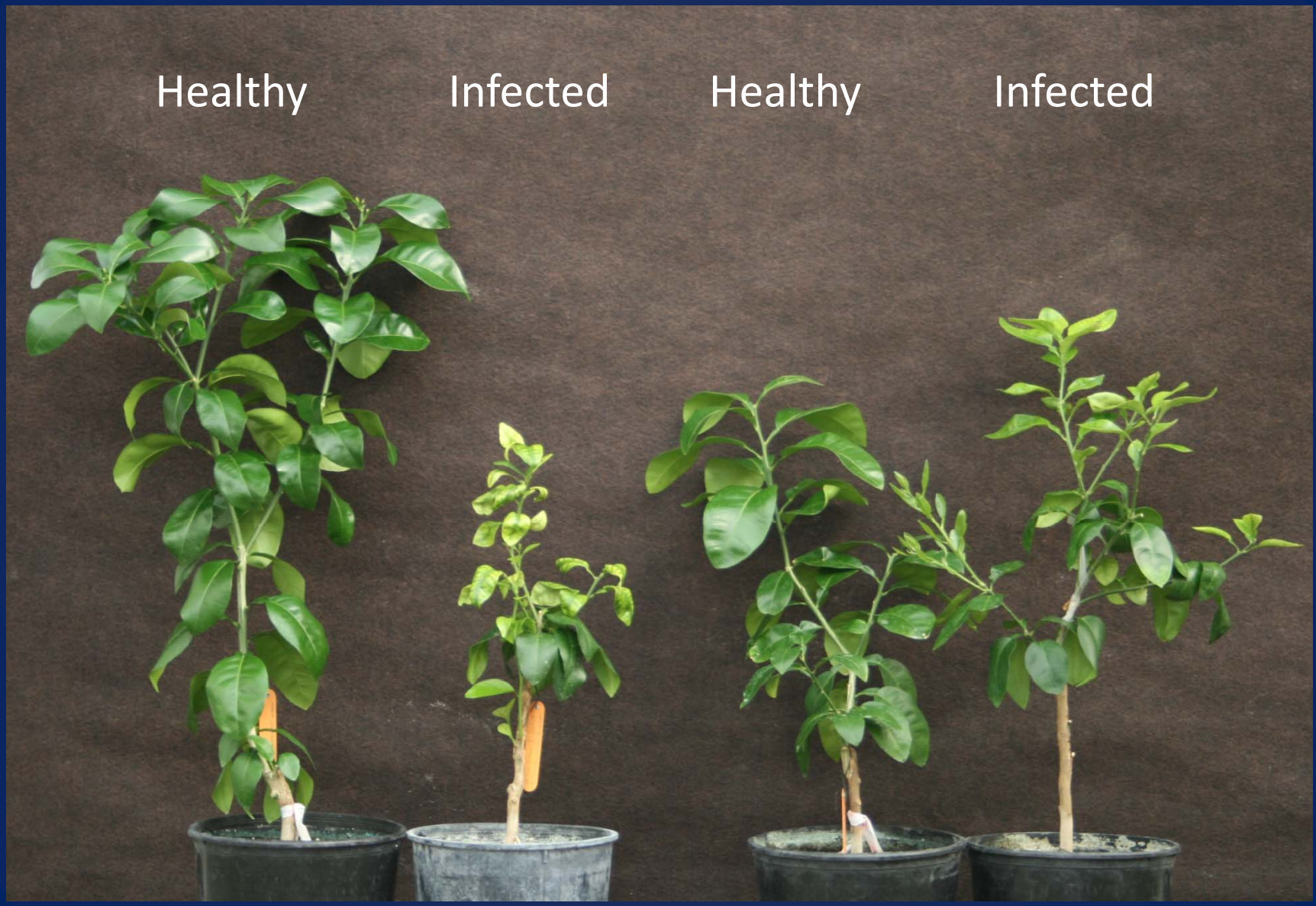
Rohde Red Valencia

Pineapple

Valencia 1-18-31

Madam Vinous

Effect of HLB on grapefruit (in greenhouse)



Healthy plants

HLB-infected plants

Marsh Grapefruit

Rio Red Grapefruit

Summary:

1. Susceptibility to Las:
   Although Las was able to multiply in all tested citrus genotypes, there was a range of responses in different varieties from extreme tolerance to high sensitivity to HLB infection.

2. Distribution of Las within a tree:
   In a particular plant higher titers are often associated with symptomatic areas.

3. Las titer and severity of disease:
   When different citrus genotypes are compared, there is no clear correlation between bacterial titer and severity of disease.

4. Light intensity and duration greatly affect symptoms development.

Important questions:

What makes some citrus hosts tolerant and others – sensitive to HLB infection?

Can plants be modified to become resistant or tolerant?