2nd International
Citrus Canker and Huanglongbing
Research Workshop

Huanglongbing
- Research Recommendations – HLB
- HLB Priority Research Recommendation Chart 2005
- HLB Priority Prioritized Research Recommendation List

Citrus Canker
- Research Recommendations – Citrus Canker
- Citrus Canker Priority Research Recommendation Chart 2005
- Citrus Canker Prioritized Research Recommendation List
Research Recommendations: Huanglongbing 2005

- Economics
- Alternate Hosts
- Detection of Disease/Vector
- Differentiation
- Resistance and Breeding
- Culturing HLB
- Pathogen/Vector Interactions
- Citrus Genetics
- Chemical Control
- Biological Control
- Cultural Control
- Pathogenesis
- Epidemiology
- Transgenics
- Genomics
- Vector Biology
- Fruit Yield/Quality
1 Economics

1.1 Economic Analysis

- Economic losses due to restricted movement
- Economic analysis of lost markets (domestic and international)
- Economic benefit of tree removal
- Economic analysis of control measures
- Phytosanitary systems for fruit movement from quarantine areas
- Rotational/cropping systems
- Ornamental industry
- Pest risk analyses
- Phytosanitary measures for nurseries
2nd International Citrus Canker and Huanglongbing Research Workshop
Orlando, FL
Research Recommendations: Huanglongbing 2005

2 Alternative Hosts
- 2.1 Identify alternative hosts of pathogen/vector and geographic distribution
- 2.2 Bacterial population level in alternative hosts
- 2.3 Risk assessment of alternative hosts
- 2.4 Vector biology ref. alternative hosts
3 Detection of Disease and Vector

- 3.1 Field vs Nursery Symptomology
- 3.2 Development Of New Serological Tools
- 3.3 EM, Light Microscopy, CF
- 3.4 Molecular Detection Methods
  - Dot blot probes (vectors)
  - PCR – 16S RNA; rpl-based PCR; Duplex: nested PCR; Multiplex Real-time PCR
  - Improve detection (sensitivity); understand host-pathogen interaction leading to better control, etc.
- 3.5 Sentinel Indicator Plant
- 3.6 Sample Criteria
- 3.7 Psyllid Population Density Sampling
- 3.8 Chemical or Volatile Detection
- 3.9 Storage of Samples Effects
- 3.10 Remote Sensing
4 Characterization Taxonomy of HLB

- 4.1 Differentiation of species and strains
- 4.2 Genetic diversity studies
- 4.3 Repositories for voucher specimens
5 Resistance and Breeding

- 5.1 Assessment of Citrus Relatives For Resistance/Susceptibility
- 5.2 Cold Hardiness for Citrus
- 5.3 Host Genotype Strain/Species Interactions
- 5.4 Vector Repellency/Lethal Genes
- 5.5 Field Testing of Cultivars
6 Culturing HLB
   6.1 Culturing HLB
7 Pathogen/Vector/Host Interactions

- 7.1 Population In Different Cultivars
- 7.2 Pathogen Vector Relationships
  - Transovarial Transmission
8 Chemical Control

- 8.1 Insecticides To Keep Psyllids Off Nursery And Grove Bearing And Non-bearing Trees
  - Scouts
  - Encourage Beneficials
- 8.2 Effect of Insecticides on Disease Spread
  - Duration of Protection
- 8.3 Urban Homeowner Control of Psyllids
- 8.4 Systemic Bactericide
- 8.5 Baseline Toxicity Studies
- 8.6 Natural Chemicals
- 8.7 Application Methods and Interaction With Beneficials
- 8.8 Chemicals to Control Flush
- 8.9 Effect of Toxicants On Vector Transmission
9 Biological Control

- 9.1 Determination of Presence of Hyperparasites
- 9.2 Foreign Exploration
- 9.3 Trap Plants (Mp Et Al)
- 9.4 Biological Control of Pathogen
- 9.5 BC of Vector in Residential Areas
- 9.6 Distribution of Parasitoids and Efficiency
10 Cultural Control

- 10.1 HLB-free budwood
- 10.2 Nursery design, management and location away
  - Budwood sources/nurseries under screen
- 10.3 Pruning and rogueing
- 10.4 Orchard design and management
  - Intercropping
- 10.5 Greenhouse production of citrus
- 10.6 Cultural control of alternate hosts
11 Epidemiology

- 11.1 Invasive Potential of Disease And Vector
- 11.2 Effect of Cultural Practices
  - Effect Of Effect of Vector Control on Disease Development
  - Rogueing
  - Effect of Trap Plants
- 11.3 Effect of Insect Population Dynamics on Disease Dynamics
- 11.4 Distance of Disease and Vector Spread
- 11.5 Aging Infection
- 11.6 Seed Transmission and Graft Transmission from Asymptomatic Plants
- 11.7 Proportion of Infected Insects in Population Relative to Disease Incidence
- 11.8 Survey of Incidence and Distribution in FL
- 11.9 Eradication Methods
12 Transgenics

- 12.1 Find and introduce resistance:
- 12.2 Resistance genes in related spp.
  - Anti-bacterial genes
  - Anti-bacterial peptides
  - Use of viral vectors
  - Anti-insect genes
- 12.3 Rapid screening method for resistance
- 12.4 Genetic modification of vector
- 12.5 Development of transformation methodologies for citrus and citrus relatives and ornamentals
13 Genomics

- 13.1 Citrus Responsive Genes for Early Detection
- 13.2 Sequencing of Bacterial Genomes
- 13.3 Sequencing of Citrus Genome
- 13.4 EST Microarray
- 13.5 Comparative and Functional Genomics
14 Vector Biology

- 14.1 Reproductive Biology And Behavior
- 14.2 Pheromones and Attractants
- 14.3 Dispersal Behavior of Vector
15 Fruit Yield and Quality

- 15.1 Relationship of Fruit Quality to Disease Incidence
- 15.2 Physical Means for Culling
- 15.3 Crop or Yield Loss Models
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Research Recommendations: Citrus Canker 2005

- Remote Sensing
- Spectral Analysis
- Economics
- Survival of Xac
- Detection of Disease
- Differentiation
- Resistance
- Citrus Breeding

- Citrus Genetics
- Citrus Resistance
- Chemical Control
- Biological Control
- Cultural Control
- Pathogenesis
- Epidemiology
- Transgenics
- Genomics

1 Chemical

- 1.1 Evaluation of ISR/SAR etc. related to ccA
- 1.2 Application Methods for Chemicals – Aircraft et al.
- 1.3 Investigation of Curative and Preventative Properties of Microbicides
- 1.4 Combinations of Chemical Controls with Copper – IPM
- 1.5 Asian Citrus Leaf Miner
  Evaluation of New and Existing Compounds: Vydate, E2Y, Copper GX
  Pheromones monitoring and mating disruption
- 1.6 Resistance of Xac to copper
- 1.7 Testing of sanitizing compounds to pre- post-harvest, packing house
- 1.8 Search for systemic bactericide
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Orlando, FL
Research Recommendations: Citrus Canker 2005

2 Cultural Control

- 2.1 Effect of Irrigation and Spray Practices on Disease Increase
- 2.2 Optimization of Windbreaks
- 2.3 Pruning (disease control, dwarfing)
- 2.4 Field Susceptibility of Cultivars - Flush management
- 2.5 Nutrition
- 2.6 Defoliation
- 2.7 Orchard Management Systems
- 2.8 Mechanical Harvesting Impact
- 2.9 Protected Production (relocation, greenhouses: nursery vs grove)
- 2.10 Alternative Land Uses during Fallow Period
- 2.11 Investigation of Practices – foreign sources
3 Biological Control

- 3.1 Xanthomonas Control with Bacteriophages to Decrease Inoculum
- 3.2 Use of Antagonistic or Site-competitive Microorganisms
- 3.3 Interaction of A and B Strains of Citrus Canker and Their Competition
- 3.4 Microbial Community Phyloplane and Endophytes
- 3.5 Citrus Leaf Miner
- 3.6 Cross-protection using Avirulent Canker Strains
- 3.7 Antagononistic Effects of HLB Controls
4 Remote Sensing and Information/Tracking (GIS+) Systems

- 4.1 Proof of Concept of Spectral Analysis to Citrus Canker
- 4.2 Application and Deployment
  - Low Level spectral Characteristics
  - Application to Finding Citrus Canker / Citrus Trees
  - Focus on Aircraft-based Hyperspectral Analysis
5 Detection Technology

- 5.1 Prove Canines can Differentiate Citrus Canker
- 5.2 Visual Detection – Sensitivity & Reliability
- 5.3 Electronic Noses - Pathways for Citrus Entry
- 5.4 Electronic Noses - Application to Citrus and Citrus Canker Detection
- 5.5 Quantitative PCR to Detect Non-culturable Citrus Canker
- 5.6 Detect Host Response prior to Lesion Development – microarrays et al.
- 5.7 High Throughput of PCR for Citrus Canker Detection
- 5.8 Improved Detection Sampling Designs
- 5.9 Nanotechnology
- 5.10 Field Deployable Rapid Detection Technology
- 5.11 Nursery Detection Technology
6 Citrus Resistance and Breeding

- 6.1 Knowledge of Pathogen-based Resistance
- 6.2 Genomic Comparisons - Resistance Responses
- 6.3 Citrus Resistance Triggers and Map-based Cloning
- 6.4 Generation of Resistant Germplasm
- 6.5 Performance of Resistant Cultivars from Worldwide Sources
- 6.6 Genetic Characterizations of Resistance in Citrus
- 6.7 Rutaceae Susceptibility to Citrus Canker
- 6.8 High Throughput/Improved Screening Systems
- 6.9 Determination Of Biological Elicitors of Plant Defenses
- 6.10 Lytic Peptides and Delivery Systems
- 6.11 Develop Markers For Selection In Breeding Programs Linked to Resistance
- 6.12 Differentially Expressed Genes - cca EST or cdna Library
- 6.13 Exploitation Of Resistance Gene Candidate Sequences Already Cloned from Citrus
- 6.14 Classical Breeding Techniques for Resistance
- 6.15 Dwarfing Rootstocks
- 6.16 Foreign Exploration for Other Sources
- 6.17 Expedited Field Trials for Performance
7 Differentiation / Characterization of Xac Strains

- **7.1 Standardization and Quality Assurance:**
  - Ring test and methods of certification; global web site

- **7.2 Establish International Collections / Repositories**
  - Permanent Florida, national (Beltsville), and international location
  - Funding and collection size

- **7.3 Improve Rapid Strain Differentiation Techniques**

- **7.4 Strain Characterization for Origin**
  - Differentiation for host/pathogen interactions
  - Creating marked strains
8 Pathogenesis

- 8.1 Nature of Mesophyll Resistance to ccA
- 8.2 Xanthomonas Genomics and Functional Analysis
  Identification of genes necessary for
  1) infection and
  2) induction of resistance expression due to infection
9 Survival

- 9.1 Survival of Bacterium in Packing Container
- 9.2 Probability of Transmission from Fruit and or Plant Materials Disinfested
- 9.3 Survival of Bacterium on Lesioned or Lesionless Plant Tissues
- 9.4 Use Dilution Strength, Biodegradable, Bactericide

  Develop all-purpose disinfectant
10 Economics

10.1 Economic Analysis

- Economic losses due to restricted movement
- Conclusive science to achieve a defensible position related to risk of fruit movement (risk assessment: Florida’s white paper, in part)
- Economic analysis of lost markets (domestic and international)
- Economic benefit of defoliation vs tree removal
- Economic analysis of control measures
- Phytosanitary systems for fruit movement from quarantine areas
11 Transgenics

- 11.1 Differentially Expressed Libraries to Identify Promoters
- 11.2 Transgenic Citrus with Resistance Genes from Citrus and other Plants and Organisms
- 11.3 Transformation System Development
- 11.4 High throughput Screening
- 11.5 Transgenic Rootstocks
- 11.6 Use of Viral Vectors
- 11.7 Interaction between Scion and Rootstock
- 11.8 Site-directed Mutagenesis
- 11.9 Novel Technologies
12 Genomics

- 12.1 Differentially Expressed Libraries in Response to Asian Citrus Leaf Miner feeding
- 12.2 Sequencing citrus genome
13 Epidemiology

- 13.1 International Field-scale Study (multinational):
  - Large vs small scale
  - Sampling Methods / Technology
  - Visual survey efficiency
  - Deployment of survey and sampling technologies (coordination)
  - Chemical of leafminer and Xac, windbreaks, weather forecast systems, defoliation, irrigation etc.

- 13.2 Meteorological Events and their Distance of Spread
  - Effects on development of disease
  - Evaluation in Different Cultural Settings
    - Local, international, greenhouse / laboratory

- 13.3 Latency Duration of Fallow
- 13.4 Isolation Distances for Nurseries
- 13.5 Alternative Distances and Timing
13. 6 Control studies within an Endemic / Epidemic
   - Eradication Campaign – Epidemic
   - Management – Endemic: surrogate organisms, environmental variations
   - Application and impact of windbreaks, defoliation techniques
   - Pre-eradication inoculum suppression techniques – defoliation, tarping

13.7 Insecticide / Microbicide / Surfactant Influences
   - Enhance disease expression on trap plants using surfactants
   - Cuticle studies for adjuvants and penetrants for systemic chemical delivery
   - Microbicide as prevention of inoculum transfer using local or systemic compounds

13.7 Damage Evaluation System
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**Probability of Success**

**Potential Impact**

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## Citrus Canker Prioritized Research Recommendation List

Scale is 1 (low) to 5 (high)

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