National Citrus Breeding Collaboration Meeting

February 27-28, 2018 | Denver, Colorado

FINAL REPORT

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CITRUS RESEARCH BOARD

USDA-HLB-MAC

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Executive Summary

On February 27-28, 2018, sixty-two citrus rootstock and scion breeders, university administrators, citrus industry representatives, federal government officials and citrus research funding agency representatives met in Denver, Colorado to discuss barriers and find solutions to achieve more effective coordination and collaboration among citrus breeder scientists working on huanglongbing (HLB) mitigation.

The first plenary session opened with presentations by citrus industry representatives on the current state of the citrus industry's battle with HLB and its devastating effects. Two presenters followed with a hopeful message about successful collaborative scientific efforts: Gennaro Fazio of USDA-ARS on the Apple Scion and Rootstock project and Jeff Gwyn on the International Wheat Yield Collaboration. The participants then identified four major areas of barriers based on the whole group's discussion of the pre-workshop survey: 1) Scientific Barriers, 2) Regulatory Barriers, 3) Intellectual Property and Tech Transfer Barriers and 4) Funder-related Barriers.

The participants then broke into four groups based on these major groupings of barriers to dive deeper into their contributing factors to the barriers and to develop potential solutions and actions needed to move these solutions forward after the meeting.

The groups reconvened in a final plenary session to report on the work of their respective groups and to identify the critical priority action plans toward achieving the desired goal moving the citrus industry significantly forward to finally conquer HLB. In the end, there was broad agreement among all the parties present that more cooperation among all the stakeholder groups was critical if the citrus industry is to be effective in finding a long-term, sustainable, effective solution to ensure the continued production of citrus, based on host resistance to, or tolerance of, CLas infection and HLB disease development.

If this goal is regarded as the long-term solution for the citrus industry to survive the devastating effects of HLB, then establishing some kind of central body or organization to set up and manage the infrastructure needed to support collaboration among citrus scientists/breeders must be strongly considered. This central coordinating organization is needed to address the major barriers identified by each breakout group, such as establishing the means for scientists to share data which in turn must be supported by legal agreements among the host institutions on intellectual property rights, publishing rights, etc. Additionally, a central coordinating body would be in the best position to seek funding and support to establish an effective field trial system for all breeder researchers.

This proposed coordinating body would be designed with input from all groups that have a stake in the outcome. It was clear during this meeting that the scientists involved in seeking sound scientific HLB solutions are willing to collaborate with each other and share data. They agreed such a collaboration to address the barriers identified during the meeting would most certainly speed up the time to finding that long lasting solution. They just need the coordinating structure to support such a collaboration. They alone do not have the big picture perspective or resources to create such an organization.

Three Priority Action Items where identified at the end of the two-day meeting:

1. Establish an organization similar to the International Wheat Yield Partnership and/or the NC-140-type program for conducting citrus germplasm evaluation greenhouse and field trials, coordinating data collection standards, and other service functions to achieve the greater coordination and collaboration among citrus researchers to expedite the development of HLB resistant/tolerant citrus
2. Hold a Summit meeting to address the issue of interstate movement of citrus plant materials for research purposes
3. Set up a multi-agency project through NIFA to establish a means to conduct better coordinated trials as a starting point.

Group Breakout Session Outcomes:

The Scientific Barriers Breakout Group explored the following barriers and developed solutions for each:

1. General researcher-related barriers such as scientists not having a complete picture of ongoing work by other labs or scientists
2. Data-related issues, such as the lack of uniformity in the data scientists collect and report.
3. Critical gaps in scientific research that need funding.
4. An integrated system for coordinated data collection and reporting is lacking.
5. Poor communication among funders, growers and scientists.
6. Need to expedite release of new commercially relevant citrus materials/varieties.
7. The need to address state regulations that slow the movement of citrus plant materials for research purposes delaying research and the need to provide assistance and guidance to scientists to meet regulatory requirements for developing and sharing genetically modified plant materials.

The Regulatory Breakout Group addressed the following barriers and developed solutions for each:

1. The current pipeline for the movement of HLB tolerant/resistant research materials between states causes long delays in research.
2. Each state has different regulatory requirements for movement which can be contradictory and confusing.

3. The risks associated with moving citrus propagative materials for research purposes are not clearly understood.
4. The citrus industry acting alone on regulatory issues may not be as effective as acting with other crop industries.
5. Scientists do not understand the regulatory requirements for genetically engineered citrus propagative materials.
6. It is important to maintain the momentum of this focus on regulatory issues.

<u>The Intellectual Property (IP) and Tech Transfer (TT) Breakout Group</u> identified and discussed the following barriers and developed solutions for:

1. The need to find ways for tech transfer offices to support, motivate and compensate researchers collaborating and co-creating intellectual property;
2. Scientists don't have a protected workspace where they can collaborate and share data;
3. There is no central structure to foster the coordination and support for the desired scientific collaboration.

<u>The Funder-related Breakout Group</u> discussed the merits of the International Wheat Yield Program to serve as a good model for citrus research groups to emulate to achieve the desired outcome of improved coordination and collaboration. The funders also discussed the need to improve the system for conducting field trials for which the Apple Scion Rootstock's NC-140 Program served as a good model for the citrus breeding program. There was a consensus that additional funding is needed to further explore industry-wide multi-disciplinary structures and mechanisms for addressing HLB, and that HLB MAC is the logical group from which to request additional funding to continue this work.

Background

Huanglongbing (HLB) is a severe and growing threat the U.S. citrus industry that has already proven devastating. Citrus growers in Florida have tried, unsuccessfully, for many years to battle the disease. HLB has migrated across the U.S. to citrus growing regions in Texas and residential trees in California.

A number of industry, academic, and government efforts in citrus-growing states are underway but have not kept pace with the spread of HLB. Though promising approaches to detect, manage, and combat the disease are on the horizon, no definitive solution is at hand. Based on experience successfully fighting diseases that have affected other specialty crops, such as the plum and the papaya, many scientific experts in the citrus industry believe a particularly promising path to success is development and release of resistant or tolerant rootstocks and/or scions. This could be accomplished through both traditional breeding methods, and through new breeding techniques like genetic modification and genetic engineering.

In order to greatly decrease the time required to develop, test, and release HLB resistant or tolerant rootstocks and/or scions, a significant improvement in coordination and cooperation must occur among the scientists working on this issue. Currently, research work on this topic is taking place at over ten different research institutions with funding from at least five different sources. The overlapping permutations based on the number of research institutions and funders unintentionally creates a level of redundancy and disorganization that is an inherent drag on the pace of innovative change.

When intellectual property (IP), technology transfer, scientific publication needs, inter- and intrastate regulatory requirements and other issues are added, the process begins to suffer due to interests at cross purposes. The current model based on institutional competition and highly restrictive IP paradigms limits the speed and flexibility needed to identify and rapidly implement solutions. In summary, the current pathway to develop HLB resistant or tolerant citrus varieties is cumbersome, lacks coordination, does not include or minimizes incentives for collaboration, and is generally not well structured for efficiency. The country's citrus industry needs those disparate institutions to identify the non-scientific, as well as scientific barriers to enhanced cooperation and begin to develop tools, structures and other methods by which those barriers can be overcome.

In order to serve the growers and consumers of citrus, industry and governmental funding sources must demand a much higher level of cooperation and accountability from the teams of breeders, geneticists, and others that receive funding, as well as the institutions to which they belong. A new structure, designed to solve the problems listed above, must be developed and deployed. To that end, relevant government agencies, commodity boards, public and private researchers must come together to address current and future efforts of incorporating HLB resistance into commercial citrus varieties, but more importantly to remove the barriers limiting research collaborations, intellectual property coordination, technology transfer, commercialization and other implementation issues.

In the fall of 2017, The Citrus Research Board (CRB) submitted a proposal to the huanglongbing Multi-Agency Coordinating Group (HLB MAC) to fund a two-day workshop to identify and develop solutions to overcome roadblocks to effective coordination among the Citrus Breeding Programs for HLB mitigation.

This workshop would bring together current university and federal government citrus rootstock breeders, citrus scion breeders and geneticists, relevant administrative representatives from the scientists' host institutions, relevant funding agency staff, and other industry in Denver, Colorado.

The expected outcomes from this two-day meeting included:

- Identification of the scientific, IP, tech transfer, commercialization and other barriers to collaboration and new variety development.
- Outline structures or tools to overcome said barriers going forward.
- Creation of a mutually agreed upon standard testing protocol to test candidates for CLas/HLB resistance.
- Initiate data sharing agreements/programs across citrus breeding programs to limit duplication of efforts.

The HLB MAC funded CRB's proposal and with additional support from the CRB and Sunkist, the meeting was held February 27-28, 2018 at the Embassy Suites by Hilton Denver International Airport in Denver, Colorado.

A consultant/facilitator, Jane Berkow, was hired in December 2017 and led the meeting planning group that included Jeffrey Steen (CRB), Melinda Klein (CRB), Carolina Evangelo (CRB), Ed Civerolo (CRB), Gary Schulz (CRB), John Konda (CRB) Paul Frankel (CRB), Harold Browning (Citrus Research and Development Foundation/CRDF), Catherine Hatcher (CRDF) and Tom Bewick (USDA National Institute of Food and Agriculture/NIFA).

This group identified the participants to be invited to the meeting, created a meeting design and agenda (see Appendix A) that would ensure the desired outcomes would be achieved. Additionally, the planning group identified the following pre-work assignments for participants that included:

1. A *U.S. Breeding Scoping Document* that outlined the issues the citrus industry is currently facing, the current state of citrus scientific research and the desired outcome of the two-day meeting. (See Appendix B)
2. An online article about Responsible Conduct of Research: Collaborative Science, produced by Columbia University.(http://ccnmtl.columbia.edu/projects/rcr/rcr_science/foundation/index.html) This article identified many of the typical barriers to collaborative research that must be addressed.

3. An online survey to gauge participants' thoughts about the barriers to a more coordinated and collaborative approach. Forty-two attendees participated in the survey; a 66% response rate. (See Appendix C for the survey results.)

Sixty-two participants attended the meeting in person and two to six people participated by phone at various times throughout the meeting. During the opening plenary session of the meeting, Mike Sparks (Florida Citrus Mutual), Jeff Steen (CRB) and members of an industry panel delineated the current state of the citrus industry to highlight the urgency of working on the critical issues that the industry is facing. Then Jeff Steen outlined the desired end state needed from the scientific community if the citrus industry is to survive the devastating effects of HLB. These opening remarks were followed by two presenters who have successfully run collaborative scientific programs with other agricultural products: Dr. Jeff Gwyn, Program Director, International Wheat Yield Partnership and Dr. Gennaro Fazio, Apple Rootstock Breeder and Geneticist Plant Genetic Resources Unit, USDA ARS. These two presenters provided a road map and ideas that were extremely relevant to the meeting participants in responding to the challenges that the citrus industry is currently facing. (See Appendix D for their PowerPoint slides.)

Once the foundational information was laid, the participants engaged in a large group discussion of the pre-workshop survey results to identify the major barriers to the citrus scientists working in a more collaborative and coordinated way. The result of this discussion was the identification of four major barriers:

1. **Scientific Barriers** regarding data standardization, collection and sharing in addition to other scientific and researcher-related issues.
2. **Regulatory Barriers** regarding the interstate movement of citrus plant material for research purposes and the need for help in complying with biotechnology regulations.
3. **Intellectual Property and Tech Transfer (IP/TT) Barriers** associated with scientists' host institutions, i.e., university or government entities.
4. **Funder-related Barriers** regarding their role in promoting better coordination and collaboration among scientists.

The identification of these four major barriers provided the basis for forming the breakout groups tasked to more fully understand the factors contributing to these barriers and to come up with recommended solutions. The breakout groups worked together for the rest of the afternoon of the first day and the morning of the second day of the meeting. The following chapters in this report provide a more in-depth summary of each breakout group's work.

Glossary

Agricultural Biotechnology: A range of tools, including traditional breeding techniques, that alter living organisms, or parts of organisms, to make or modify products; improve plants or animals; or develop microorganisms for specific agricultural uses. Modern biotechnology today includes the tools of genetic engineering.

Citrus Producing States: Collective term to generally refer to the states producing the largest amounts of commercial citrus; Florida, California, Texas and Arizona.

CLas: '*Candidatus* Liberibacter asiaticus' is the bacterial agent that infects citrus plants leading the expression of HLB symptoms.

CRB: Citrus Research Board is the grower-funded and grower-directed program established in 1968 under the California Marketing Act as the Citrus Research Program and the mechanism enabling the state's citrus producers to sponsor and support needed research. The program is administered by the Citrus Research Board, which is better known in the industry as simply "CRB."

CRDF: Citrus Research and Development Foundation is a non-profit corporation organized under Florida State laws as a Direct Service Organization of the University of Florida. The Mission of the Foundation is to "Advance disease and production research and product development activities to insure the survival and competitiveness of Florida's citrus growers through innovation".

Field trial: A test of a new technique or variety, including biotech-derived varieties, done outside the laboratory but with specific requirements on location, plot size, methodology, etc.

Funders or Funding Agencies: The terms used in this document to collectively refer to the organizations that fund citrus research. This group includes, CRB, CRDF, USDA NIFA and USDA HLB MAC.

Gene: The fundamental physical and functional unit of heredity. A gene is typically a specific segment of a chromosome and encodes a specific functional product (such as a protein or RNA molecule).

Gene mapping: Determining the relative physical locations of genes on a chromosome. Useful for plant and animal breeding.

Gene (DNA) sequencing: Determining the exact sequence of nucleotide bases in a strand of DNA to better understand the behavior of a gene.

Genetic engineering: Manipulation of an organism's genes by introducing, eliminating or rearranging specific genes using the methods of modern molecular biology, particularly those techniques referred to as recombinant DNA techniques.

Genome editing is a way of making specific changes to the DNA of a cell or organism. An enzyme cuts the DNA at a specific sequence, and when this is repaired by the cell a change or 'edit' is made to the sequence.

Genomics: The mapping, sequencing and assembly of genetic material in the DNA of a particular organism as well as the use of that information to better understand what genes do, how they are controlled, how they work together, and what their physical locations are on the chromosome.

Genotype: The genetic identity of an individual based on specific characteristics of its genome or genetic material (e.g., DNA). Genotype often is evident by outward characteristics but may also be reflected in subtler biochemical ways not visually evident.

HLB-resistant tree has the ability to suppress infection by the CLas bacteria, preventing HLB symptom development.

HLB-tolerant tree may be infected by CLas and exhibit some HLB symptoms. In some cases, fruit production may be of sufficient quality and quantity to provide adequate economic returns over the grove lifetime.

HLB MAC: Huanglongbing Multi-Agency Coordinating Group is chaired by the USDA's Animal and Plant Health Inspection Service (APHIS) and includes participation by the Agricultural Research Service (ARS), and National Institute of Food and Agriculture (NIFA), the Environmental Protection Agency (EPA), State departments of agriculture, and industry groups. These partners jointly collaborate on coordinating and prioritizing research efforts among Federal and industry groups to complement and fill research gaps, reduce unnecessary duplication, speed progress, and more quickly provide practical tools for citrus growers to use in the fight against HLB.

IP: Intellectual property is a category of property that includes intangible creations of the human intellect, and primarily encompasses copyrights, patents, and trademarks. It also includes other types of rights, such as trade secrets, publicity rights, moral rights, and rights against unfair competition.

IRC HLB: International Research Conference on HLB is sponsored and organized by U.S. Citrus Industry groups, USDA ARS and Universities and occurs biannually.

NCPN: The National Clean Plant Network provides high quality asexually propagated plant material free of targeted plant pathogens and pests to protect the environment and ensure the global competitiveness of specialty crop producers.

NIFA SCRI: The Specialty Crop Research Initiative (SCRI) Citrus Disease Research and Extension Program (CDRE) is authorized in the Agricultural Act of 2014 (H.R. 2642) to award grants to eligible entities to conduct research and extension activities, technical assistance and development activities to: (a) combat citrus diseases and pests, both domestic and invasive and including huanglongbing and the Asian citrus psyllid, which pose imminent harm to United States citrus production and threaten the future viability of the citrus industry; and (b) provide support for the dissemination and commercialization of relevant information, techniques, and technologies discovered pursuant to research and extension activities funded through SCRI/CDRE and other research and extension projects targeting problems caused by citrus production diseases and invasive pests.

Pest-resistant plants: Plants with the ability to withstand, deter or repel pests and thereby prevent them from damaging the plants. Plant pests may include insects, nematodes, fungi, viruses, bacteria, weeds, and other. In the context of HLB, the plant would suppress infection by the CLas bacteria preventing or reducing HLB symptom development.

Phenotype: The visible and/or measurable characteristics of an organism (how it appears outwardly).

Plant breeding: The use of cross-pollination, selection, and certain other techniques involving crossing plants to produce varieties with specific desired characteristics (traits) that can be passed on to future plant generations.

Rootstock: A rootstock is part of a plant, often an underground part, on which new above-ground growth can be produced. It can refer to a rhizome or underground stem.

Scion: A scion is a detached living portion of a plant (such as a bud or shoot) joined to a stock in grafting and usually supplying solely aerial parts to a graft.

SNP genotyping: is the measurement of genetic variations of single nucleotide polymorphisms (SNPs) between members of a species. It is a form of genotyping, which is the measurement of more general genetic variation. SNPs are one of the most common types of genetic variation.

SOPs: Standard Operating Procedures

Strains: breed, stock, or variety of an animal or plant developed by breeding.

Tech Transfer: Technology transfer is the process of transferring scientific findings from one organization to another for the purpose of further development and commercialization. The process typically includes: Identifying new technologies and protecting technologies through patents and copyrights.

Traditional breeding: Modification of plants and animals through selective breeding. Practices used in traditional plant breeding may include aspects of biotechnology such as tissue culture and mutational breeding.

USDA APHIS: United States Department of Agriculture-Animal Plant Health Inspection Service- The Animal and Plant Health Inspection Service is a multi-faceted agency with a broad mission area that includes protecting and promoting U.S. agricultural health, regulating genetically engineered organisms, administering the Animal Welfare Act and carrying out wildlife damage management activities.

USDA APHIS BRS: USDA APHIS Biotechnology Regulatory Services implements APHIS regulations for certain genetically engineered (GE) organisms that may pose a risk to plant health. APHIS coordinates these responsibilities along with the other designated federal agencies as part of the Federal Coordinated Framework for the Regulation of Biotechnology.

USDA APHIS PPQ: USDA APHIS Plant Protection and Quarantine (PPQ) program safeguards U.S. agriculture and natural resources against the entry, establishment, and spread of economically and environmentally significant plant pests, and facilitates the safe trade of plants and plant products.

USDA ARS: United States Department of Agriculture-Agriculture Research Service is the primary scientific in-house research agency. The agency's job is finding solutions to agricultural problems that affect Americans every day from field to table.

USDA NIFA: United States Department of Agriculture-National Institute of Food and Agriculture provides leadership and funding for programs that advance agriculture-related sciences. NIFA invests in and support initiatives that ensure the long-term viability of agriculture. NIFA applies an integrated approach to ensure that groundbreaking discoveries in agriculture-related sciences and technologies reach the people who can put them into practice.

Chapter One

Scientific Barriers

The breakout group researchers first explored the issues or barriers identified in the pre-workshop survey. The questions are encapsulated in boxes below.

Scientific Barrier I. General Researcher Related Issues

Initially, the researcher breakout group's discussion explored the issues or barriers identified in the pre-workshop survey. In particular, the group offered two possible reasons for research scientists not having a complete picture of what other labs or scientists are working on:

- The current researcher/lab culture does not sufficiently promote collaboration.
- Funders currently do not provide researchers with information regarding who is awarded research funds, research progress, etc. which would help scientists to have a more complete picture of what other labs or scientists are working on.

The Proposed Solutions to Scientific Barrier I:

1. Funding Agencies (USDA NIFA, HLB MAC, CRB, CRDF) could:
    - Make available for public consumption abstracts of all the funded projects.
    - Include reporting requirement as part of their Requests for Proposals (RFP)
    - A highlight report for public consumption; or perhaps
    - Two versions of a report: one for growers and another for other scientists including a summary of important data with standardized bullets with agreed metrics.
    - Include specific wording in RFPs mandating collaboration for applications to be successful.
2. HLB Research Scientists could interact more frequently, with the assistance of Funding Agencies by:
    - Establishing an HLB Online forum to provide an opportunity for more interaction among scientists;
    - Talking once a quarter by WebEx which could possibly be set up by one of the funding agencies;
    - Getting all U.S. HLB research scientists together every other year in a face-to-face meeting: The International Research Conference on HLB (IRC HLB) convenes in odd number years and US researchers only meet in even number years.

Scientific Barrier II. Data Related Issues

Discussion of the survey results that identified data-related barriers, the researcher breakout group characterized the issues in their group discussion as follows:

- Scientific researchers do share their results in professional and grower meetings, but do not routinely or formally share details of their data or even broad details of ongoing projects with one another.

- There is no uniformity in what data is collected or how it is reported. . Researchers agreed that standardization of data collection protocols and reporting, would be beneficial for easier understanding and comparison between labs for growers, funding agencies and reviewers.
- If Funding Agencies issue reporting requirements: some workshop participants argued that there should be a mechanism for sharing negative data, to avoid useless duplication of unsuccessful approaches. Perhaps the project-specific websites mandated for USDA NIFA Specialty Crop Research Initiative (SCRI) grants would allow reporting of such negative data.
- Researchers understand that some metrics will change over time and can place more weight on data from periods that are more commercially relevant.
- The issues regarding data ownership and use were highlighted in this section.
- Questions were raised about the use of raw or refined data? Each of these may be appropriate to share with different audiences.
- Is there a way to share data amongst the researchers without it becoming publicly accessible? Could some information be password protected allowing researchers to share with one another, while other data may be publicly accessible.

Proposed Solutions to Scientific Barrier II

There was a general consensus among the research scientists that they can agree on a minimal set of parameters for what data to collect and, on the methods, used to take measurements to be able to report data in a manner permitting easy and relevant comparisons. To that end, the scientists made the following two recommendations:

1. <u>Form a Researcher Group</u> to establish the metrics to be collected and reported by all researchers receiving grants from CRB and CRDF. The group will provide these data requirements to CRDF and CRB by March 15 to be included in the upcoming RFPs to be issued this spring. (Initial recommendations attached as Appendix F)

   The members of this group include:
   - Ute Albrecht (Lead PI), University of Florida
   - Ed Stover, USDA-ARS, Ft. Pierce, FL
   - Kim Bowman, USDA-ARS, FL
   - Mikeal Roose, University of California, Riverside
   - Eliezer Louzada, Texas A&M-Kingsville
   - Jude Grosser, University of Florida
   - Glenn Wright, University of Arizona
   - Yongping Duan, USDA-ARS, Ft. Pierce, FL

   Possibly include the following two scientists not present at the meeting:
   - Kris Godfrey, University of California-Davis
   - Fred Gmitter, University of Florida

This group will come to agreement on:

- Critical definitions such as, tolerance versus resistance;
- Standardized procedures for how to test plants for HLB tolerance/resistance, inoculation methods, consistent phenotyping etc.;
- Standardized data collection protocols for evaluating citrus from greenhouse and field trials (May be different metrics based on trial objectives).

2. Funding Agencies should:
    - Include reporting requirement for the metrics to be collected and reported by all researchers receiving grants from funding agencies;
    - Develop some rules of engagement with host institution IP and Tech Transfer staff to address such issues as authorship and sharing of data and circulate for input; Collaborators need to make clear who will be cited on papers and how data will be managed.
    - Establish an online, password protected portal for scientists to deposit these data.

Scientific Barrier III. Critical gaps in Scientific Research that needs funding

The breakout group saw the need to fund some specific scientific challenges and gaps in knowledge. The basic assumption here is that if these questions are answered, then the other research could speed up. These specific challenges or research gaps include:

1. Develop tools to overcome or reduce the long juvenility period in citrus. This may not require additional funding because investigators are making progress on this issue; these technologies should be shared with other researchers.
2. Efficient citrus genome editing methodology resulting in non-genetically modified plants is needed. Methods and tools (including vectors) should be widely shared.
3. A better understanding of CLas including:
    - A better understanding of CLas isolate characteristics;
    - Consolidation and creation of a baseline of the different isolates of CLas and biological differences such as strain by genotype interactions. This could be done at the USDA ARS Beltsville lab so that international isolates could be included;
    - CLas genetic characterization in all experiments to document isolates used in case there are meaningful biological differences;
    - A more efficient tool for identifying the different strains of CLas other than sequencing so it can be applied to a large number of trees, such as a SNP chip or a capture array.
4. More high-quality sequences of the important commercial citrus varieties need to be completed and uploaded into the existing Citrus Genome Database; this information is critical to genome editing.

Proposed Solutions to Scientific Barrier III

1. The specific gaps in scientific knowledge listed above should be met with additional or sustained funding by Funding Agencies. The research on biological characterization of CLas

isolates could be funded by USDA NIFA or HLB MAC as a complete package or components could be funded independently by grower funding groups.

2. To address the need for more high-quality sequences of the important commercial citrus varieties, a group of growers, processors and scientists needs to be formed to come to agreement on the cultivars to be included and then the project needs to be funded.

Scientific Barrier IV. A system for conducting trials and collecting and sharing data from trials is lacking

There are a number of issues identified relating to trials:

- There is a lack of rootstock and scion germplasm sharing across the country in different climate and growing conditions. The major impediment to this is the regulatory/phytosanitary restrictions;
- Scientists don't have a common source for plant material to be used in trials, like the apple scion program;
- There is a lack of capacity to run the number of field trials necessary. The time horizon on such trial efforts can be 7-8 years;
    - Not clear as to who carries the burden of collecting the data associated with the trials;
    - Scientists need funding to collect field trial data which requires many resources.
- Standardization of testing protocols is needed so results can be compared across trials;
- It would greatly facilitate research and meaningful comparisons of conventional and genetically modified advanced selections between programs if there were collective coordination. Perhaps an advanced selections project manager could be hired to manage and coordinate field trials, collect data and post in a central database accessible to all researchers and growers. Growers need this information to make decisions;
- The ability to facilitate or expedite a variety for industry/grower use.

Proposed Solutions to Scientific Barrier IV

1. Funders could establish a NC-140-like group to independently test trees (based on the Apple Rootstock Project Gennaro Fazio spoke about.
2. A common facility (both field and greenhouse) to test putatively tolerant/resistant varieties was thought by some to be useful but there was mixed support for this idea.
3. Funding agencies could think about providing sizable funding needed to support such a project as an independent field trial system.
4. Funders would need to set this up and involve the Scientist Committee identified above to develop the parameters and data for collection.

Scientific Barrier V. Poor Communication among Funders, Growers and Scientists

Need better communication between researchers and industry stakeholders regarding research progress, so that misconceptions are minimized. Funders may not fully understand research efforts and outcomes. For example, the appearance of duplication of efforts may be misunderstood and exaggerated in the minds of grower funding agencies. Researchers use different methodologies and several teams tackling the same key problems may result in quicker resolutions. The researcher group agreed, however, that there is a need for more communication across all groups on these duplicative efforts so everyone can benefit from the knowledge gained.

Proposed Solutions to Scientific Barrier V:

1. Funders could mandate to put researcher presentations and posters online to make it accessible to both growers and other researchers.
2. Funders could provide a mechanism to share the outcomes of research efforts with the entire scientific community to benefit both the researcher community and growers. This could also be viewed as confirmation of results.

Scientific Barrier VI. Need to expedite the release of new citrus materials

During the final plenary session, the whole group discussed the need to expedite release of new citrus materials. Definitive solutions were not fully developed although some ideas were considered. Below is a summary of that discussion:

- It was noted that researchers are releasing varieties earlier than in years past and doing things such as disease indexing and propagation in parallel to speed up the process.
- Nurseries and other industry partners must realize that early releases of potentially HLB resistant varieties with less data may mean a higher risk that significant effort/expense will be devoted to material which is later shown to be of minimal value.
- In the current business model, nurseries don’t propagate trees of new varieties without orders from the growers. Nurseries are being asked to take big risks in establishing and propagating unproven materials. We need to understand this and find a way to accommodate this:
  - Perhaps grant funds can frontload this cost to incentivize nurseries. Researchers should include grant funding to pay nurseries to grow/propagate materials for field trials;
  - It is often hard to get enough trees of newer varieties to establish critical field trials, and incentives for nurseries may help overcome this problem.
- A further step toward expedited release would be an improvement of horticultural methods to grow trees faster.

Scientific Barrier VII. Poorly harmonized state regulations prohibit the movement of citrus propagative materials for research purposes and the regulatory requirements for genetically modified plant materials is complex and difficult to follow.

See pages 20-21 in Chapter Two on Regulatory Barriers for the scientists' discussion of this issue and proposed solutions.

Chapter Two

Regulatory Barriers

Respondents to the pre-workshop survey identified the process to move citrus plant material interstate for research and evaluation purposes, not for commercial use, as a major impediment to a more efficient and effective citrus research program facilitating rapid release of promising plant material. During the Denver meeting, the science researchers stated numerous times that the regulations used for the movement of plant material for research (seed, pollen, bud wood, tissue cultured and micro propagated materials) between states are the same regulations that govern the movement of nursery stock for commercial use. As a result, there is a major barrier to their ability to make scientific progress to obtaining, assessing and using necessary germplasm for research purposes.

There are multiple agencies that potentially regulate the movement of nursery stock depending on whether it is genetically engineered or not. Movement of all nursery stock from areas quarantined for citrus pests is regulated by USDA APHIS -PPQ and each state department of agriculture. In addition to USDA APHIS PPQ and state regulations, genetically engineered citrus, including nursery stock, is also subject to regulation by USDA APHIS -BRS and the Environmental Protection Agency (EPA) which regulates outdoor field trials for plants with Plant Incorporated Protectants (PIP). The involvement of multiple agencies can also create confusion among researchers about the requirements for moving material between states. The different regulations of the citrus producing states also contributes to the confusion.

There is inadequate outreach to or education of scientists regarding regulatory processes (state or federal) on how to use these required regulations for moving citrus materials to other states. Funding for this type of initiative is lacking.

A comprehensive process or pathway for safely and rapidly moving both promising HLB genetically engineered and conventional tolerant/resistant scions and rootstocks and other plant materials among states, by researchers and industry for research investigation and field evaluation trials simply does not exist.

Testing rootstocks or scions broadly in citrus growing regions of different states is a lengthy process unless there is a mechanism for quick and safe movement of research material between states for confined field evaluation trials and other research purposes. The great example of collaboration in comparing apple rootstocks in different states is possible because all trees can be produced in a common nursery which is currently not possible for citrus researchers under the current circumstances.

Regulatory Barrier I. The current pipeline for the movement of HLB tolerant/resistant research materials between states is inadequate.

There is currently only one pathway for the movement of HLB tolerant/resistant research materials between states which was designed for the movement of commercial quantities of citrus plants and citrus nursery stock. This pathway is described in the "Interstate Movement of Citrus Nursery Stock from a Quarantined Area", found on the USDA APHIS website under "citrus-nursery-stock-protocol-interstate-movement." The perception of the citrus producing states' existing regulations governing the movement of citrus rootstock and scions is that they contain poorly understood policies which are not supported by helpful protocols and procedures. This is further complicated by a mosaic of state regulations with inconsistent requirements where compliance in one state is not considered adequate by another state.

Proposed Solutions to Regulatory Barrier I:

An alternative pipeline for small quantities of research materials needs to be developed that would: 1) facilitate faster movement of citrus for research and confined field trials; and 2) would allow states to protect their citrus industries from plant pest or pathogen threats. The breakout group developed a proposed pipeline that will be issued as a white paper or strawman so the importance of this issue does not to get lost in conversation with state regulators. Tom Delfino (of the California Citrus Nursery Board) will prepare a draft of this white paper.

Regulatory Barrier II: Each state has different regulatory requirements for movement which are confusing to work with.

Each state has different requirements for the movement of citrus materials. Previous efforts at harmonization of regulations has not been successful. Since National Clean Plant Network (NCPN) centers essentially move only small amounts of 'starter' plants under strict permitting and quarantine conditions, this procedure cannot cover the complete spectrum of industry and research needs on the fight against HLB. Years of solid research have been slowed down considerably because of the regulatory inconsistencies among states.

Proposed Solutions to Regulatory Barrier II:

1. Identify officials at the Federal and State levels that should be included as part of the dialogue to address these regulatory issues. This action was completed during the Denver meeting.
2. Initial Contacts with State Regulatory Officials and others need to be made. Ground work for each state for the HLB research material movement issue needs to be done in preparation for discussions with State Regulators so a complete picture of the issues can be

understood and presented in addition to the perceived benefits for more flexible regulations for research materials.

3. Convene a Summit Meeting to address the specific issue of movement of citrus nursery stock for research purposes. This proposed summit could include state and federal regulators, research and evaluation foundations, grower associations, researchers and citrus industry representatives. Funding agencies should submit a proposal to HLB-MAC by March 30 for such a Summit Meeting. Some of the possible outcomes of the summit could include: development of a risk-based consistent, efficient and streamlined rapid process for moving citrus plant materials among the states for confined HLB field evaluation trials; a proposed written protocol for states to adopt to move plant materials based on plant pest risk assessments; development of written SOP's for individual researchers to follow to successfully move plant materials across State and quarantine boundaries; and a strategy for citrus industry representatives to address current state regulations to foster appropriate changes as might be required by statute, regulation or policies.

Regulatory Barrier III. The risks associated with moving citrus propagative materials for research purposes are not clearly understood.

Existing State regulations do not easily accommodate the movement of citrus propagative material needed for research purposes. The risks of such movement are not clearly understood. In addition to approaching the States on this issue, USDA APHIS PPQ could possibly play a helpful role here.

USDA APHIS PPQ has permit provisions to move research materials. Modifications to what already exists could be made. The crux of the problem is really at the State level; at times are best resolved in consultation with Federal regulators. There are pathogens that are not regulated at the federal level that are regulated by the states.

Proposed Solutions to Regulatory Barrier III:

USDA APHIS PPQ should be asked to conduct a risk assessment on the movement of citrus propagative materials for research to evaluate the risk of that movement. The risk assessment could then be used to develop revised movement protocols for small volume research materials for different research projects with emphasis on confined field trials, similar to existing protocols for genetically modified plants. USDA APHIS PPQ's risk assessment would only cover the Federally regulated pathogens. This federal risk assessment could be shared with the states which may or may not influence the states' decision making with such a high-profile crop.

Regulatory Barrier IV. Citrus Industry acting alone on regulatory issues may not be as effective as acting with other crop industries.

There are other plant industries, including other members of the NCPN, who face similar issues with state regulations inhibiting the interstate movement of cleaned plant materials.

Proposed Solutions to Regulatory Barrier IV:

There is an opportunity to collaborate on regulatory issues with other crop industries.

NCPN participants with Farm Bill support are conducting a workshop in April 2018 in the Maryland/DC area to address 'Plant Movement: Next Steps'. The citrus industry/researcher community should identify and send emissaries to this workshop. Additionally, the states themselves, through the National Clean Plant Board and under a program called the Systems Approach to Nursery Certification (SANC) have been engaging in discussions designed to promote a harmonized, risk-based systems approach to greenhouse and nursery certification. Collaboration with this initiative may also help with better understanding of barriers and ways to overcome them.

Regulatory Barrier V: Scientists do not understand the regulatory requirements for genetically engineered (GE) citrus propagative materials.

Conducting initial field trials in compliance with the USDA APHIS Biotechnology & Regulatory Services (BRS) and the EPA can be complex and time-consuming. This is especially true for scientists who interact with BRS only occasionally-unlike major corporations that have dedicated staff for such interactions. It requires engagement early and often in the development and implementation of new research projects. It takes time to come up to speed on regulations and learn what is required for compliance at each stage of the process. Researchers do not adequately understand the regulatory requirements that will ultimately affect their plants (GE or conventional) as plants are developed and then advance for commercialization. Genetically engineered products can have difficulty gaining acceptance in international markets.

Proposed Solutions to Regulatory Barrier V:

Note: this issue was discussed in both the Scientific Barriers Breakout Group and the Regulatory Barriers Breakout Group. The proposed solutions from each group are reported here.

<u>Scientist Researcher Breakout Group proposed the following solutions</u>:

To streamline the regulatory process, it is highly desirable to have one or two coordinators (possibly in each state) to help researchers with regulations governing genetic engineering and working with APHIS BRS, EPA, and other regulators.

1. Jim Thomson, Genetics Research Scientist with USDA ARS and a meeting participant, is working on guidelines re: the regulatory requirements and will be happy to share the guidelines he develops.
2. Perhaps, there are staff at some private companies associated with citrus (e.g., PepsiCo) who have had experience with genetic engineering and could participate in developing a plan for coordinated genetically engineered citrus testing, etc.
3. Citrus researchers and funding agencies could work with regulators regarding implications of new technologies so there are no surprises or failed investments down the line.
4. The industry could educate the public about the genetically engineered option and why it might be the key to the HLB crisis: a key argument may be if HLB is not sustainably solved by new technologies, including genetic engineering, we may be faced with having no citrus at all.

<u>The Regulatory Breakout Group proposed the following solutions</u>:

1. Scientists could check out the APHIS BRS process described on the BRS website: "Am I regulated?" or questions on the regulatory oversight of USDA APHIS BRS.
2. Request assistance from CRB and CRDF to develop coordinated assistance for researchers to navigate the regulatory hurdles for genetically engineered citrus. This could be a Program Manager position.
3. Develop SOPs for citrus biotech field trials
   - Request CRB and CRDF assistance in developing SOP's
   - Engage BRS, EPA, state regulators to review SOP's
4. Provide training to scientists: engage online training specialists to develop course for researchers and make it a requirement for receiving funding from NIFA, HLB MAC, CRDF, or CRB. Such training should include the regulatory requirements of EPA, BRS, PPQ national requirements, and individual state modules could be developed for state regulatory requirements. Additionally, it would be good to have a process to regularly update any changes to policies/regulations.
5. Funders could develop language to include in RFPs requiring researchers to demonstrate completion of regulatory training modules.

Regulatory Barrier VI. Need to maintain the momentum of this focus on regulatory issues

To avoid a common pitfall of coming out of meetings like this with great ideas that don't go any further than the airport tarmac when landing at home and returning to the demands of our "day jobs" someone or some entity needs to maintain a focus on the regulatory issues.

Proposed Solutions to Regulatory Barrier VI:

This Core Coordinating Group on Regulatory issues will be led by Angela McMellen-Brannigan (HLB MAC) and shall remain together for a while to ensure proposed solutions are understood and moving forward. The group would like to expand its membership to include CRB, CRDF and additional researchers. There will be a conference call within 2 weeks to discuss progress on all action items of working group and as required thereafter.

Chapter Three

Intellectual Property and Tech Transfer (IP/TT) Barriers

This breakout group thought the perceived barrier identified in the pre-workshop survey that one cannot patent and publish was a fallacy. Different tech transfer offices and institutions have different rigors and requirements. Scientists want to publish. Part of the problem is there is a lack of training in IP and TT, CRADAs and related issues. A course like, "Patent 101: How-To for Breeders" would be helpful if were required for grantees.

There is a lack of standardization of patenting process in Public Land Grant Institutions. Proximity of the scientist to the Tech Transfer Office may not be ideal. Some Tech Transfer offices are regional and others are more local. Not sure if proximity affects the working relationship.

IP/TT Barrier I. Host Institutions Tech Transfer and IP policies need to support researchers working collaboratively.

Institutional IP and TT officials need to make informed decisions backed with data. Decision makers in IP or TT need to have "walked the field" to better understand what citrus producers are up against. These officials need to let scientists know that they CAN share data and collaborate with other scientists. There is a lack of clarity in the meanings of terms or concepts, such as "collaboration" and what that looks like in practical terms. There are different ways of measuring research outcomes, e.g., yield or tree size. There is a lack of data curation and monitoring and timing in sharing data among scientists.

Proposed Solutions to IP/TT Barrier I

1. This group needs to develop and send a clear message to the involved institutions describing how things would change at the funding level working through an HLB Consortium, if a new formal organization were created. Such a group would necessarily be a key part of negotiating the parameters of IP agreements and CRADA. Mike Pazanni and John Beuttenmuller offered to work on this effort and requested help from Mike Ward.
2. There is a need for tech transfer guidelines and requirements for the breeder audience.

IP/TT Barrier II. Scientists don't have a protected workspace where they can share data or collaborate.

The responsibility of data sharing infrastructure needs to be offloaded from the breeders who do not have the resources or the larger picture perspective to stand up the required infrastructure and to make it work effectively. Scientists do need to help identify the data to be shared and to standardize data elements to be included, etc.

Proposed Solutions to IP/TT Barrier II

Funders in partnership with host institutions' TT and IP officials could set up a virtual shared workspace. The Arabidopsis Biological Resource Center (ABRC) is good model for this idea.

Three kinds of data need to be negotiated:

1. Data you have now
2. Data you create after you join the Consortium
3. Data you collectively create with others

Other questions about the larger structure of the database need to be resolved, such as: will raw data or summary data to be included? just data or will materials (germplasm, pollen, etc.) also be available. Data submitted to the database could be time-stamped and associated with the contributing scientist.

For this to be successful:

- There needs to be a desire with the scientists to collaborate and share;
- It must be easy to use;
- Must be clear about specifically what will be shared (data, germplasm, pollen, etc.) and how it will be shared;
- Researcher's interests are respected (what is theirs is theirs)
- It demonstrates to the contributors, "what is in it for me" so the participating researchers share in the outcomes and benefits, which will incentivize the host institutions where the researchers work
- Agreements need to be established to protect intellectual input
- Data sharing agreements need to be in place to preserve patent rights so that by sharing we do not risk someone besides the researcher not being able to get exclusive rights on the researcher's work
  - Might need to change the language in grants and agreements to reflect this incentive to collaborate.

IP/TT Barrier III. There is no central structure to foster the coordination and support for the desired scientific collaboration.

It is clear from the discussions during this meeting that the goal to achieve the desired coordination and collaboration among citrus researchers to decrease the time it takes to develop, extensively and successfully field evaluate, and release CLas/HLB resistant or tolerant rootstocks cannot be reached by any one entity (i.e., scientists, regulators, funders or host institutions) represented at this meeting. If this goal is regarded as the long-term solution for the citrus industry to survive the devastating effects of HLB in this country, then options must be considered to improve collaboration between researchers, funders, host institutions potentially even the establishment of a central body or organization to set up and manage the infrastructure needed to support collaboration among citrus scientists/breeders.

This central coordinating organization is needed to address the major barriers identified by each breakout group, such as establishing the means for scientists to share data which in turn must be supported by legal agreements among the host institutions on intellectual property rights, publishing rights, etc. Additionally, a central coordinating body would be in the best position to seek funding and support to establish an effective field trial system for all breeder researchers.

The Proposed Overarching Solution to IP/TT Barrier III

Establish an American Citrus Growers Scientific Coordinating Body or Consortium to ensure a higher level of coordination and collaboration among all citrus research efforts in developing, testing and releasing CLas resistant or tolerant citrus rootstocks and/or scions in a timelier manner to meet the citrus industry's urgent needs. The scientific research required to address the problems that HLB has created for the citrus industry greatly exceed the resources of any one state affected by this devastating disease. Now is the time to pool resources and to seek additional funding from other sources to work smarter and more efficiently to develop the enduring solutions that all citrus producing states could use.

Collaboration starts at the top with the industry sponsored organizations, State agencies and research universities. This proposed coordinating body would be designed with input from all groups that have a stake in the outcome produced. It was clear during this meeting that the scientists involved in seeking sound scientific HLB solutions are willing to collaborate with each other and share data. They agreed such a collaboration to address the barriers identified during the meeting would most certainly speed up the time to finding that long lasting solution. They just need the "container" to support such a collaboration and sharing critical data. They alone do not have the big picture perspective or resources to create such an entity or cooperative working environment with structures and systems. Thus, the implementation of this solution falls to the industry funding agencies, the relevant government entities and universities to carry out.

Below is an outline of the work needed to launch such a coordinating body:

Develop a Statement of Work to address the following:

- Data – selection and standardization
- Data – collection and curation, replicated field trials, etc.
- Commercialization services
- Post commercialization services, e.g., horticulture support

Identify and Spell out the Business and Legal Terms involved:

- Organizational infrastructure needed
- Funding mechanisms
- Personal Property
- Liability
- Obligations for maintaining propriety information
- Obligation to protected Consortium information (CRADA info)
- Rights in Generated information – who owns what, pre, post,
- What are the required data, abstracts and reports
- Copyrights, authorship
- Reporting subject inventions
- Title to Inventions

Design Governance Structure which is Critical:

- Is there a board?
- Who is on it?
- Determine the metrics that will be used for such things as, selecting projects, determining efficacy, deciding what to continue to invest in, success of the process, etc.
- Messaging to the Grower industry
- Considerations of Academic freedom
- Strategic Plan

Develop Data Sharing Agreements

- Develop a clear message from this group to the institutions
- Describe how things would change (at the funding level) via working through a 'Consortium' or MOU.
- Put together the parameters of the agreements

The following people offered to work on this proposal:

- Mike Pazanni, Vice Chancellor for Research and Economic Development, UC, Riverside
- John Beuttenmuller, Executive Director, Florida Seed Producers
- Mike Ward, Partner, International Law Firm Morrison and Foerster
- Paul Zankowski, Senior Advisor for Plant Health Products, USDA Office of the Chief Scientist
- Mojdeh Bahar, Citrus Research Board to track down/share the governing documents (e.g., NC140, IWYP)
- John deGraça, Director of the Citrus Center at Texas AM: (Kingsville),
- Heather Hirsch, Corporate Relations, Texas A&M AgriLife Research (College Station)
- Paul Frankel, California Citrus Research Board

Chapter Four

Funder-Related Barriers

The funders first considered some of the feedback from researchers expressed in the pre-workshop survey.

Researchers commented within the survey that having different funding cycles was less troubling than having short-term funding. This explains why there was such low agreement to the survey question suggesting different funding cycles made it difficult to synchronize their projects for collaboration. This short-term funding is especially challenging with breeding projects which generally take 6 to 7 years to produce any results. So, having to go through the process of responding to annual RFPs feels like time only takes away from critical research activities. Their desire was for funding agencies to provide longer term funding for such breeding projects.

The funders considered the possibility of shifting to funding fewer but larger projects with multi-disciplinary technical expertise on the team to mirror the IWYF Program's approach to funding one project at $2 million over 3 years. No decision was made on this idea.

The research community expressed in the survey results that the funding agencies were not giving explicit enough instructions on expected outcomes. The funders thought that was an issue that would be easy to rectify.

The other funding issues researchers identified was the lack of monies provided to collect data from field or greenhouse trials. The funders discussed the idea of coming up with standard data collection requirements and standard design protocols. All the funders agreed that they are prepared to require standardized data collection as a condition for funding.

The International Wheat Yield Program (IWYP)

Further discussion in the Funders group centered around their interest in gathering more specific information about the International Wheat Yield Program (IWYP) which seems to offer a good model for what the citrus industry groups might do. In particular, they were interested in learning:

- More specifics about how the IWYP went about setting up their structure in the first place;
- The IWYP's use of "the box", i.e., the mechanism for program participants to share data;
- The IWYP's funding model and coordination of funding calendars by agencies and their extensive number of private sector partners;
- The IWYP's proprietary research database; how that was set up and operates.

Field Trials

The Funder group explored various approaches to conducting field trials:

- Florida would like third-party validation for HLB resistance or tolerance
- Texas wants to do validation for HLB resistance or tolerance and production adaptability
- California wants to conduct field evaluation trials for fresh fruit production adaptability
- Hatch Multi-state organization for citrus, similar to NC-140 for Apples; the application process for this will be initiated by USDA NIFA.

Commercialization

- There is grower anxiety of exclusivity of solution; they don't want to pick winners and losers.
- Funders find themselves asked repeatedly for support of Extension specialists. If there is no Extension person available, perhaps our institutions need to invest in this position.

There were three levels of cooperation the organizations comprising the funders group agreed to explore:

- Communicate — information sharing so that each organization is at least aware of what the others are doing and when they are doing it.
    - Action: everyone agreed to share their schedules of funding / calendars and processes for picking projects and criteria for awardees. This is a no- to low-cost way for group work to get started.
- Coordinate — informed intentional division of responsibilities, costs, and resources to accomplish mutual goals. Certain aspects and activities would take place inside different organizations in a complimentary fashion. This would require even more communication and combined effort to delegate topics and tasks, and to ensure desired outcomes, efficiency, and timeliness of results.
- Collaborate — organized sharing of resources, planning and executing that could occur through a joint "task force" or through a newly formed organization that would receive funding, own intellectual property rights, employ staff, and manage activities like fundraising, field trials, regulatory compliance, pre-commercialization, and industry partnerships.

There was general agreement amongst the group that the HLB MAC would be a logical place to apply for funding to continue fleshing out the details of an optimal partnership structure for the industry.

Chapter Five

Summary of Priority Action Items

(Listed in priority order)

1. **Establish an American Citrus Growers Scientific Coordinating Body or Consortium** to meet this pressing challenge of ensuring a higher level of coordination and collaboration among all citrus research efforts in developing, testing and releasing CLas resistant or tolerant citrus rootstocks and/or scions in a timelier manner to meet the citrus industry's urgent needs. This proposed coordinating body would be designed with input from all groups that have a stake in the outcome produced. It was clear during this meeting that the scientists involved in seeking sound scientific HLB solutions are willing to collaborate with each other and share data. They agreed such a collaboration to address the barriers identified during the meeting would most certainly speed up the time to finding that long lasting solution. They just need the "container" to support such a collaboration and sharing critical data. They alone do not have the big picture perspective and resources to create such a "container". Thus, the implementation of this solution falls to the Industry Funding Agencies, the relevant government entities and universities to carry out. An in-depth proposal for creating this coordinating body is needed before attempting such an ambitious effort. This proposal would include details regarding the organization structure, terms for participation, and other issues such as, governance, funding, legal, data sharing and intellectual property issues.

2. **Convene a Summit Meeting to address the specific issue of movement of citrus nursery stock for research purposes.** HLB MAC could possibly fund such a meeting. This proposed summit could include state and federal regulators, research foundations, grower associations, researchers and citrus industry representatives. Some of the possible outcomes of the summit could include: development of a consistent, efficient and streamlined rapid process for moving citrus plant materials among the states for HLB field trials; a proposed written protocol for states to adopt to move plant materials based on plant pest risk assessments, development of written SOPs for individual researchers to follow to successfully move plant materials across state and quarantine boundaries and a strategy for citrus industry representatives to address current state regulations to foster appropriate changes.

3. **Establish an NC-140 Type Program for conducting citrus rootstock trials.** The NC-140 is an independent evaluation group that independently tests apple rootstocks. It coordinates experiments on apple, cherry, peach, pear and plum rootstocks developed by other breeders. It replicates experiments that are planted in many different locations in the U.S., Canada and Mexico. Their committees meet yearly to report on findings. Each trial is led by a trial coordinator. Potential participants discuss objectives, entries, trial size, trial location and data

format.   The trial coordinator sources the plant material and coordinates the development of trees in a central location (nursery). The nursery develops plant material and sells them to each trial organization. Trials are planted according to established protocols. Progress reports on the trials are written by each state representative. This model would serve the citrus research community well to expedite research progress.

4. Set up a Hatch Multi-State Research and Extension Project through NIFA. Hatch MultiState Research and Extension projects are initiated by the Director of one State Experiment Station. In this case it would be Jackie Burns from University of Florida, who has agreed to move things forward. The way this project would work is that a small group of scientists convene to develop a series of objectives to achieve a desired outcome. The desired outcome in this case it would be the multi-state field evaluation of citrus germplasm potentially resistant/tolerant to HLB. One major objective would be to determine whether a specific genotype was HLB resistant/tolerant. That might only be done in States where HLB is present in production fields. Other objectives would be to look at growth rate, juvenility, yield potential and fruit quality. Those trials might go on in areas where HLB was not present in production fields. Once the project is approved, Experiment Station Directors from the appropriate states can designate faculty/scientists to work on the multistate project. The largest citrus producing states (CA, FL, and TX) are the primary focus of this project but AZ, LA, MS and AL could also be included because they too have commercial citrus groves. This process has been initiated by NIFA.

5. Get a copy of the International Wheat Yield Program's (IWYP) MOU that provided the basis that program's success. (Done)! The IWYP can serve as a good prototype for an American Citrus Growers Scientific Coordinating Body. This program coordinated a very successful research effort aimed at increasing wheat yield throughout the world. It worked in partnership with a number of private enterprises to achieve impressive results. A copy of the MOU used by the IWYP with their research and private partners has been obtained and can assist in the development of agreements for citrus researchers to share their data with one another.

Appendix A

Meeting Agenda

Citrus Breeding Programs Workshop
February 27-28, 2018
Denver, Colorado

Meeting Purpose: To create a framework/structure that will ensure a higher level of coordination and collaboration among citrus researchers and their respective institutions in developing, testing and releasing CLas resistant or tolerant Citrus rootstocks and/or scions in a timely manner to meet the citrus industry's needs.

Outcomes/Deliverables:

- Identification, description of, and agreement on the major scientific and non-scientific barriers to coordination, cooperation and collaboration among researchers and their respective institutions.
- Agreement on a strategy to address the major barriers to ensure productive coordination and collaboration among citrus researchers and their respective institutions including:
  - The creation of a unified approach or structure that will encourage increased coordination and collaboration among scientists conducting research to develop, test and release CLas resistant or tolerant citrus rootstocks and/or scions in a timely manner to the citrus industry;
  - Agreement on principles or guidance for research institutions for developing agreements to address non-scientific issues effectively, including intellectual property, authorship for sharing and publishing research data and results, standards for the disclosure of potential financial conflicts of interest, and material transfer among collaborators and for managing accountability.
- Mechanisms identified to facilitate communication, data sharing and collaboration among researchers.
- Potential funding solutions identified to incentivize and reward collaboration among researchers and host institutions. **Pre-Meeting Work**

- Attendees to provide a short (1/2-1page) bio focusing on areas of relevant research to citrus • Read the following article:
  - Responsible Conduct of Research: Collaborative Science: http://ccnmtl.columbia.edu/projects/rcr/rcr_science/foundation/index.html
- Read "Strawman" document outlining the current state of affairs and the desired outcome
- Based on the reading of the article, attendees provide input regarding perceived scientific and nonscientific barriers to achieve a more coordinated effort among citrus research efforts to develop, test and release CLas resistant or tolerant Citrus rootstocks and/or scions.

Monday, February 26

6:30 pm – Welcome Dinner

Tuesday, February 27 - Plenary Session

8:30 Welcome

Opening Remarks — Gary Schulz (CRB) & Angela McMellen-Brannigan (USDA HLB MAC)

Review Meeting Purpose, Agenda, and Ground Rules — Facilitator, Jane Berkow

8:45 Overview of Current State: Where we are today? — **Panel**

Tom Bewick (USDA NIFA)

* Mike Sparks, (Florida Citrus Mutual)

* Jeff Steen (CRB)

Tom Delfino (CA Nurserymen Society)

Harold Browning (CRDF)

Alec Hayes (Coca-Cola)

Pat Ouimet (PepsiCo-Tropicana)

* Presenting

9:30 What is the Desired End State — Jeff Steen (CRB)

- Where we need to be and why?
- What we hope to gain if there were better coordination and collaboration
- Open Discussion

10:00 BREAK

10:15 Examples of Coordinated Research Efforts — Panel

- International Wheat Yield Collaboration — Jim Gwyn, Program Director
- Apple scion & Rootstock — Gennaro Fazio, ARS, USDA

11:00 What is keeping citrus researchers from getting there? — Facilitator, Jane Berkow

Whole Group Discussion/Brain Storm

Discussion Question: What are the major scientific and non-scientific barriers to better coordination and collaboration among researchers and their respective institutions in conducting research in developing, testing and releasing CLas resistant or tolerant Citrus rootstocks and/or scions to meet the citrus industry's needs in a timely manner?

11:30 How do we proceed to achieve the desired state?

- Based on the group discussion, we will organize into logical groupings of issues (also see below)

- These groupings provide the basis of the breakout work groups to address the barriers for the remainder of the meeting

Tentative Breakout Groups
(This may change or be refined based on the group brainstorming discussion.)
- o **Research Scientists** to develop a unified research framework
- o **Host Institutions** to address the IP issues, authorship questions, etc.; mechanisms to facilitate communication and collaboration among the researchers
- o **Others** that emerge from group brainstorming discussion

12:00 LUNCH

Tuesday, February 27 - Breakout Group Sessions

1:00 Breakout Groups continue throughout the afternoon. Each group manages their own breaks.

Group Task: To develop strategies and plans to overcome barriers and to create mechanisms to enhance coordination and collaboration among citrus research scientists.

5:00 Break for the Day
Manager's Reception

7:00 Dinner

Wednesday, February 28 - Opening Plenary Session and Breakout Groups

8:30 Plenary Session: Breakout Groups quick check-in, entertain questions and clarify expectations re: Breakout Group deliverables

9:00 Breakout Groups continue developing strategies to overcome barriers and self-manage breaks

12:00 LUNCH

Wednesday, February 28 - Final Plenary Session

1:00 Breakout Group Report outs (High Level) **& Gain Consensus on Proposals**

3:30 Next steps:
- To finalize and ensure proposals and work continues beyond the 2-day workshop.
- How do we bring others not in attendance to support the outcomes from the meeting?
- Funders next steps

5:00 Wrap up and close

Appendix B

U.S. Citrus Breeding Scoping Document

Current State

Citrus breeding programs at the University of California, University of Florida and USDA-Agricultural Research Service (ARS) have enjoyed long, distinguished and successful histories. From the earliest days into current programs, the development of new citrus germplasm for both scion and rootstock has taken 15 to 20 years from the initial cross to release of new material. Application of current genetic and genomic techniques has trimmed the timeline somewhat, but it is not uncommon for new cultivars to take more than 10 years to develop. In a relatively stable environment, such as that which occurred prior to 2006, such a timeline was acceptable since the pipeline was always full of material that would eventually benefit growers and processors.

That situation changed completely with the discovery of huanglongbing (HLB) in Florida in 2005. In the 13 years since that discovery, Florida has lost approximately 60% of citrus yield and 40 % of citrus acreage. Thousands of citrus growers have stopped production. Juice processors, the backbone of the Florida citrus industry, are having difficulty finding enough fruit from Florida to legally produce products labeled as Florida orange juice. And the disease has spread to Texas and California, expanding the threat to citrus production in the U.S.

Industry groups, such as the Citrus Research Board (CRB) and the Citrus Research and Development Foundation (CRDF), and state and federal government agencies have responded by investing significant financial resources in the development of new germplasm that is resistant to, or at least tolerant of, HLB. USDA-National Institute of Food and Agriculture (NIFA) alone has invested almost $30 million since 2014 in projects designed to develop citrus genotypes that can be managed profitably in the presence of HLB and the investment of other funding sources is at least equivalent to that figure.

With such a massive investment comes the need for accountability. USDA Secretary Sonny Perdue has personally told NIFA program staff that USDA must be able to document the benefit of public investment in HLB research. CRB and CRDF are funding projects with money set aside by growers, who also demand that same level of accountability. To that end, managers of these funding sources have been communicating regularly.

The picture that has emerged is unsettling: there appears to be duplication of effort due to a lack of communication / coordination among the scientific community and there appears to be more than one funding source providing funds for the same objectives across multiple projects. The number of research institutions involved and the number of funding sources creates a level of redundancy and disorganization that is an inherent drag on the pace of innovative change. When intellectual property, technology transfer, scientific publication needs, trade secrets, intrastate regulatory requirements and other issues are added to the mix, the process begins to suffer due to the interests at cross purposes. In summary, the process is cumbersome, lacks coordination, and is generally not well structured for efficiency. Attempts to bring clarity to the situation have been met with either a refusal by the scientific community and their host institutions to accept these findings or vagueness of response. That situation is no longer acceptable.

Desired Outcome

A major focus of the USDA/CRB/CRDF collaboration is to create a structure that overcomes current inefficiencies and results in a more rapid release of HLB resistant/tolerant rootstocks and scions. The development of HLB-resistant/tolerant germplasm is not the only end-point. This material must also be characterized under various growing conditions to allow the nursery industry to predict grower demand based on potential acreage in various production regions. If a nurseryman has to wait for orders before producing grafted plants, there will be an 18-24 month lag period before those trees are available to the grower for planting. And that lag may be the death knell for a citrus business.

One possible manifestation of this new approach could be a new consortium among all the research institutions involved in citrus breeding and associated projects. Some goals of this effort could be:

- Implement mechanisms to standardize data collection and field trials:
- Negotiate data sharing agreements that will advance the breeding process;
- Sponsor scientists visiting other consortium labs to build on the knowledge scientists are discovering in their respective projects or to discover complimentary skills for partnering opportunities.
- Negotiate legal aspects of the technology transfer, patents, licensing, and publication issues that may arise.
- Work with commercial entities to enhance release and distribution efforts

USDA agencies that provide funding for genetic improvement for HLB management have agreed in principal with CRB and CRDF that cooperation and coordination will be requirements for future funding. Determining exactly how and what that cooperation and coordination will look like is the purpose of this effort. Full participation is imperative if we are going to meet the needs of the growers and ensure all viewpoints are taken into consideration prior to implementing change.

It is absolutely time that all parties involved in the development of new citrus germplasm work together to develop a new way of approaching the process that meets the needs of all involved. The urgent need of the growers MUST be paramount in this process development. The science community, their administrators and IP officers must work with funding agencies and grower groups to ensure that the HLB challenge is met before there is no longer a need for new citrus germplasm in the U.S.

This document was prepared for the National Citrus Breeding Collaboration Meeting to be held in Denver, Colorado on February27-28, 2018 by meeting coordinators.

Appendix C

Survey Results

Survey Questions	Agree	Somewhat Agree	Disagree
1. Research Scientists do not have a complete picture of what other labs or scientists are working on	19	20	3
2. Research Scientists informally network with other scientists but do not collect, measure, analyze and share data or the results of field trials, etc. in any standardized or formal way beyond publication	27	12	3
3. There are few, if any, formal mechanisms or technologies established to share our data or results of field trials, etc. with each other	26	14	3
4. Scientists are concerned that their data or results will be misinterpreted, misused or misappropriated	23	13	6
5. There is little incentive to share data or results of our research beyond publication	20	17	6
6. Sharing our data with each other can create issues such as: who "owns the data," who determines broader distribution of the data, who gets credit for results, who may use it for publication, etc.	22	15	5
7. Scientists are concerned they will not be able to publish their results in a timely manner or get full credit for the research	23	12	7
8. The host institution of our labs sometimes places restrictions on scientists on sharing research outcomes with other scientists to protect the institution's intellectual property rights	21	17	4
9. The host institution's technology transfer protocols that scientists must follow may be a barrier to collaboration with scientists from other institutions	19	16	7
10. Funders of citrus research have not set the expectation for scientists to collaborate or incentivize collaborative efforts	14	20	8
11. Citrus scientists sometimes work in isolation from one another so the opportunity to benefit from the perspectives of complimentary skillsets, other disciplines or other approaches is lessened.	10	26	6
12. Different research styles or approaches make it difficult for some scientists to work together collaboratively.	18	17	7
13. Citrus Researchers are on different funding cycles which make it difficult to synchronize our projects for collaboration.	11	15	17

Question 14 Other [potential roadblocks] (please specify):

- Planning, measuring success, collaborating on matters such as succession support, and clearly understanding and addressing the needs of industry are factors that are lacking.
- I think the most critical barrier to progress is the regulatory obstacles to transferring citrus propagation materials across state lines for trials.
- Collaboration with other commodity breeders and private companies involved in breeding fruit trees are important and must be considered to overcome HLB. Collaboration with researchers in citrus producing countries and learn from their experience and knowledge and exchange of materials.
- Central tools for labs to share like sequencing, marker/SNP discovery labs, chips, metabolic profiling tools etc are need to help create a pipeline of solutions.
- Realistic time frames for citrus research need to be addressed. Bioinformatic and metabolomic data generation is incredible and fast but proving those possible solutions in a living plant is a an order ofmagnitude different in timing. This should be at least acknowledged if not addressed.
- Quarantine issues Geography issues
- Incentives to try to overcome barriers to collaborative efforts might be helpful.
- The administrative burden associated with multiple HLB related projects is already high. We need to be careful to develop sharing protocols that do not further increase this.
- HLB is very different from other crop diseases with its causal agent unculturable. There are no standard protocols for greenhouse tests and field trials. We heard anecdotal HLB resistant or tolerance germplasm, but how many of the materials have been vigorously tested is unknown. Potential revenue streams for patented methods, materials etc, consciously or unconsciously distort the transparent sharing of information and may prevent data collection that would be ideal for rational industry decision-making. Institutional impediments to hiring are a major hindrance to progress in some programs
  The competition for funding or insecure of funding make it impossible for scientists who are not good on networking to share their findings and data before publication.

Question 15. Of all the items you checked above, list 3-5 issues that you think should be addressed during the upcoming meeting to move us forward toward achieving enhanced coordination and communication among Citrus Research Scientists?

- Nos. 3, 5, 7, 10.
- Incentives for collaboration among all citrus scientists in state citrus producing regions.
- item 4 and 6
- Developing a joint program plan among locations, budgeting together, and focusing first on the needs of industry are critical.
- A need for standardized protocols for high level germplasm evaluation, field trial set up at various stages. Collaboreative side by side comparison of germplasm. Data sharing with the industry. Reducing barriers for collaboration and data disclosure. Host institution legal teams could collaborate to ease red tape for researchers. Look at other crops where data sharing issues have been largely overcome for examples.

- Research Scientists informally network with other scientists but do not collect, measure, analyze and share data or the results of field trials, etc. in any standardized or formal way beyond publication The host institution of our labs sometimes places restrictions on scientists on sharing research outcomes with other scientists to protect the institution's intellectual property rights Funders of citrus research have not set the expectation for scientists to collaborate or incentivize collaborative efforts
- Emphasize urgency of achieving solution
- Development of a coordinated nursery evaluation network among breeders Rapid advancement of new HLB tolerant traits (genome editing, transgenic) for broader field testing Sharing of enabling tools - germplasm, rapid screening tools.
- common data collection protocols standardized data colled and analyzed collborstion across teams tobdrive a pipeline of innovations
- Asking host's institutions to remove barriers against transfer of knowledge, technology and commercialization. 2.Researchers must be open-minded and perceive HLB as a national agenda. 3. Share data by signing documents to protect IP and technology transfer. 4. Collaborate with international institutes involved in citrus breeding. 5. Visit to citrus producing countries and learn about their horticultural practices to tackle HLB.
- Resolve personal agendas, technology transfer and IP issues.
- ability to move research solutions to commercialization. - design of research projects and protocol to meet all regulatory requirements. - availability of data and results to comply with and meet regulatory requirements. - researcher awareness of need to protect IP to ensure commercialization of technology.
- The role of intellectual property and technology transfer in limiting research, and the issue listed in #2 above
- I think that the most important issue is that the funders need to require that researchers collaborate. Duplicate funding from different agencies needs to be stopped.
- alignment across geography and institution of defined criteria for evaluation of new varieties - in order to collect a common set of characteristics and allow comparison of results
- 1- Coordinated funding to reduce redundancy
  2- Data collection standardization and sharing
  3- Central repository for data being generated
- Standardization of data so comparisons can be made. 2. Proper data collection and statistics 3. Protection of IP so that industry may be interested, especial in the area of GE trees.
- Required collaboration and formation of a formal consortium
- 2, 3, 5, 8/9, 10
- Sharing Data. Who owns. Incentive.
- 1. Technology Transfer issues 2. - Lack of incentive 3. - Data missapropriation
- 1. For transgenics, we need at least two genes that work by different mechanisms to back each other up, as necessary to achieve long-term stable resistance worthy of grower investment. Labs that have proof that individual genes work should get together to build trees that stack these genes. 2. We need multi-state testing of tolerant/resistant commercial scion/rootstock combinations. Help with regulatory constraints and identification of field cooperators in the different citrus regions is needed.
- 10, 11, 12

- Incentive to share results and data. 2. Research styles make it difficulty to work together
- #s 1,3,6,8,10
- Items 1, 3, 5, and 6 should be further discussed.
- Provide long-term funding for field trials evaluating performance of new scions and rootstocks. Nearly all funding sources provide funding on 1-3 year, or with NIFA 5 year, cycles. For citrus field evaluation of cultivars, the field evaluation is just barely getting started at 4 years from planting, not to mention 1-2 years to propagate the material to be tested. As long as researchers need to keep scrambling to find funding to keep technicians employed with short term grants, it impedes putting together thoughtful long-term collaborative field projects.
- 1, 2, 3, 6, 7
- Technology transfer sharing information   Standardizing methods of evaluation
- 1, 2, 3, and 9

Question 16. What is your role?

Research Scientist	17 Respondents
Administrator/Tech Transfer	5 Respondents
Funder	7 Respondents
Other	13 Respondents

Appendix D

Meeting Participants

Listed by Breakout Group

Carolina Evangelo, Director of Communications, Citrus Research Board, Overall Meeting Coordinator

Scientific Barrier Breakout Group

1. Jane Berkow, M.S., Consultant, Facilitator
2. Ute Albrecht, Ph.D., Assistant Professor, Plant Pathology, University of Florida
3. Kim Bowman, Ph.D., Research Geneticist and Lead Scientist, USDA ARS Florida
4. Jose Chaparro, Ph.D., Associate Professor in Horticultural Sciences, University of Florida
5. Ed Civerolo, Ph.D., Technical Consultant, Citrus Research Board
6. Zhanao Deng, Ph.D., Professor, University of Florida's Gulf Coast Research and Education Center
7. Yongping Duan, Ph.D., Research Plant Pathologist, USDA ARS Ft Pierce, Florida
8. Gennaro Fazio, Ph.D., Apple Rootstock Breeder and Geneticist, USDA ARS and Cornell University
9. Fred Gmitter, Ph.D., Professor, University of Florida- Citrus Research and Education Center (Participated by phone)
10. Jude Grosser, Ph. D., Professor of Plant Cell Genetics, University of Florida-Citrus Research and Education Center
11. Gabe Gusmini, Ph.D., Director Agro Discovery-Crop Improvement and PepsiCo Research and Development
12. Catherine Hatcher, Ph.D., Program Manager, Citrus Research and Development Foundation
13. Vivian Irish, Ph.D., Daniel C. Eaton Professor of Plant Biology, Professor and Chair of the Department of Molecular, Cellular and Developmental Biology at Yale University
14. Tracy Kahn, Ph.D., Curator and Givaudan Citrus Variety Collection Endowed Chair for the University of California, Riverside Citrus Variety Collection
15. Melinda Klein, Ph.D., Chief Research Scientist, Citrus Research Board
16. John Konda, Secretary/Treasurer, Citrus Research Board
17. Eliezer Louzada, Ph.D., Professor of Breeding and Molecular Biology, Texas A&M University, Kingsville Citrus Center
18. Feng Luo, Ph.D., Associate Professor, School of Computing, Clemson University
19. Mojtaba Mohammadi, Ph.D., Associate Research Scientist, Citrus Research Board
20. Gloria Moore, Ph.D., Emeritus Professor of the Horticulture Sciences Department, University of Florida
21. Zhonglin Mou, Ph.D., Associate Professor, University of Florida
22. Chandrika Ramadugu, Ph.D., Associate Project Scientist in the Dept of Botany and Plant Sciences, University of California, Riverside.

23. Mikeal Roose, Ph.D., Professor, Department of Botany and Plant Sciences, University of California, Riverside
24. Ed Stover, Ph.D., Research Horticulturist, USDA ARS, Ft. Pierce, Florida
25. James Thomson, Ph.D., Genetics Research Scientist, USDA ARS, California
26. Glen Wright, Ph.D., Associate Professor and Associate Extension Specialist, tree fruits, University of Arizona, Yuma, Arizona
27. Qibin Yu, Ph.D., Biological Scientist, IFAS-CREC of University of Florida

Regulatory Breakout Group

1. Erich Rudyj, M.S., Coordinator of the National Clean Plant Network, USDA APHIS PPQ Facilitator
2. John daGraça, Ph.D., Director of the Citrus Center, Texas A&M University, Kingsville
3. Tom Delfino, Executive Director, California Citrus Nursery Society
4. Alec Hayes, Principal Scientist, Global R&D, the Coca-Cola Company
5. Margaret Jones, Ph.D., Senior Biotechnologist, USDA APHIS BRS
6. Rick Kress, Vice President, Citrus Research and Development Foundation
7. Angela McMellen-Brannigan, Ph.D., National Coordinator, Citrus Health Response Program (CHRP) and Chair HLB MAC, USDA APHIS PPQ
8. Georgios Vidalakis, PH.D., Professor and UC Extension Specialist in Plant Pathology; Director, Citrus Clonal Protection Program (CCPP); Department of Microbiology and Plant Pathology, University of California, Riverside.

Intellectual Property & Tech Transfer Breakout Group

1. Deborah Millis, Facilitator, USDA APHIS
2. John Beuttenmuller, Executive Director, Florida Foundation Seed Producers
3. Tim Eyrich, Vice President of Research and Commercialization, Southern Gardens Citrus
4. Paul Frankel, RD&I Business Consultant, Citrus Research Board
5. Heather Hirsch, Corporate Relations, Texas A&M AgriLife Research, College Station, Texas
6. Michelle Miller, Founder and CEO, High Desert Discovery District.
7. Shad Nelson, Ph.D., Dean of the Dick and Mary Lewis Kleberg College of Agriculture, Natural Resources and Human Sciences and Professor of Plant and Soil Sciences, Texas A&M University-Kingsville.
8. Michael Pazzani, Ph.D., Vice Chancellor for Research and Economic Development, University of California, Riverside
9. Alan Rasmussen, Ph.D., Vice President for Research and Graduate Studies and Interim Provost, Texas A&M University-Kingsville.
10. Tim Rinehart, Ph.D., National Program Leader for Specialty Crops-Crop Protection, USDA ARS
11. Jeffrey Steen, Chair of New Varieties Committee, Citrus Research Board

12. Kathryn Uhrich, Ph.D., Dean of the College of Natural and Agricultural Sciences and Professor of Chemistry, University of California, Riverside.
13. Michael Ward, Partner, International Law Firm Morrison & Foerster, California
14. Lisa Weaver, Senior Program Manager, Citrus Research and Development Foundation
15. Paul Zankowski, Ph.D., Senior Advisor for Plant Health and Production and Plant Products, USDA Office of the Chief Scientist (OCS)

Funders Breakout Group

1. Thomas Bewick, Ph.D., National Program Leader, Horticulture, USDA NIFA
2. Justin Brown, Vice Chair, Citrus Research Board
3. Harold Browning, Ph.D., Chief Operations Officer, Citrus Research and Development Foundation
4. Dan Dreyer, Chairman, Citrus Research Board
5. Jeff Gwyn, Ph.D., Director, International Wheat Yield Partnership
6. Goutam Gupta, Ph.D., Senior Research Scientist, New Mexico Consortium
7. Dale Murden, President and CEO, Texas Citrus Mutual
8. Pat Ouimet, Ph.D., Greening Officer and R&D Director, PepsiCo
9. Gary Schulz, President, Citrus Research Board
10. Don Seaver, Ph.D., National Science Manager, USDA APHIS PPQ
11. Michael Sparks, Executive Vice President and CEO, Florida Citrus Mutual
12. Larry Wilkinson, Board Member, Citrus Research Board

Appendix E

Meeting Power Point Presentations

Mike Sparks, Executive Vice President and CEO, Florida Citrus Mutual

Jeff Gwyn, Ph.D., Director, International Wheat Yield Partnership

Gennaro Fazio, Ph.D., Apple Rootstock Breeder and Geneticist, USDA ARS and Cornell University

The Florida Citrus Industry - The Era of Challenges

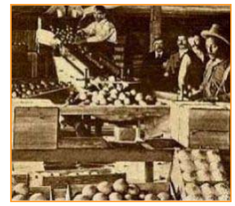
Citrus Breeding Programs Workshop – Denver, CO
February 27-28, 2018

Michael W. Sparks
Florida Citrus Mutual

1

Florida has been growing citrus for a long time

- Citrus introduced to Florida by Spanish explorers, probably Ponce de Leon
- First plantings in St. Augustine around 1513
- Commercial citrus production began to gather steam in 18th century
  - Soon after the Civil War, Florida's annual commercial citrus production totaled one million boxes
  - Climbed to more than five million boxes by 1893



2

Florida reached peak production in 2003-04, 289 million boxes (nearly 1.5 billion gallons of orange juice), but then…

- 2004 and 2005, four significant hurricanes – Charley, Frances, Jeanne and Wilma - hit Florida and Florida citrus. Florida total citrus production – oranges, tangerines and grapefruit – plummeted 44 percent to 161 million boxes during the 2006-07 season.

3

Huanglongbing (HLB) Discovered

- HLB and the Asian Citrus Psyllid are not native to the state.
- Found in 2005, now endemic to Florida
- No "silver bullet" to stop spread.
- Production declining to historic lows.
- The citrus industry once covered almost 900,000 acres in Florida, has decreased to less than 412,000 acres.

4

Florida Citrus by Boxes & Acres

Healthy Grove

Stressed Grove

Season	Boxes	Bearing Acres
2007-08	203,800,000	538,900
2009-10	159,350,000	517,100
2011-12	170,990,000	495,100
2013-14	124,030,000	476,300
2015-16	94,170,000	445,786
2016-17	78,130,000	412,662
2017-18 USDA Est.	50,500,000	412,662

Abandoned Groves

Hurricane Irma

5

Huanglongbing (HLB) Discovered

	2007-08 Season	2017-18 Season	Decrease	Percent Decrease
Annual On-tree Value (billion)	$1.5	$0.8	($0.7)	-47%
Annual Economic Impact (billion)	$10.0	$8.6	($1.4)	-14%
Jobs	76,336	45,422	(30,914)	-41%
Processing Plants	25	12	(13)	-52%
Fresh Fruit Packinghouses	45	22	(23)	-51%
Florida Citrus Growers	8,000	3,800	(4,200)	-53%

6

Things were looking up for the citrus industry this season

Have We Bottomed Out?

WINTER HAVEN - August 26, 2017– Citrus consultant Elizabeth Steger has some good news for a Florida citrus industry desperately seeking it. The consultant's widely watched preseason forecast shows Florida orange growers can expect a crop of 75.5 million boxes in the upcoming 2017-18 season. If Steger is correct, that would represent a 10 percent increase in the state's 2016-17 orange crop of 68.7 million boxes.

It would also mark the first time the state's orange crop increased after five seasons of declines.

Source: Lakeland Ledger

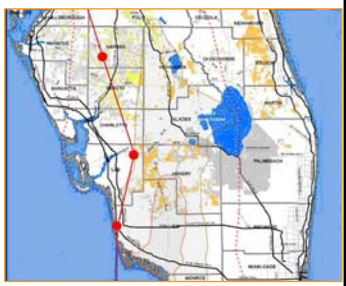
7

This was the season we were going to make the turn. Using tools such as nutritionals, bactericides, high density plantings and a few new tolerant rootstocks, 2017-2018 was expected to be a rebound year.

8

Then Irma Hit…

- On Sunday September 10, 2017 the Hurricane made landfall in the southern part of the peninsula near Marco Island and made her way up through the heart of the Florida citrus industry. It was a methodical march through Collier, Lee, Charlotte, Desoto, Highlands, Hardee, Hendry, Glades and Polk counties. Communities in these counties rely heavily on the economic impact of citrus.



9

Florida crop losses due to Hurricane Irma are catastrophic

Irma damage will continue in the future.

10

What's at stake if we buckle under the pressure and lose citrus? The industry is still a big economic driver despite challenges

- Bearing acreage 412,000
- Provides 45,000 jobs
- Annual Economic impact $8.6B (multiplier)

- Annual on-tree value, $800 M
- Leading US citrus juice producer
- Storage, transport, ports, fertilizer, communities

11

The HLB solution will be found in research

- More than 400 research projects have been completed or are currently underway across the globe.
- The Florida citrus industry has spent more than $117 million over the past eight years on research.
- Research results and new Best Management Practices were providing some optimism for the industry.

12

The Florida Citrus industry needs to re-plant trees to be sustainable

- Goal: 125 million box production – a 150 percent increase
- It is hard for growers to assume the risk of replanting while HLB is still killing trees and there is no "cure"
- It is more expensive to grow citrus in an HLB environment
- HLB research shows promise but needs to be field tested
- **The industry needs grower incentives to replant, and confidence in new rootstocks for the future!!!**

13

Grower Incentives to Replant

- Private Planting Incentive Programs
- Positive Research Results and continued research funding.
- Federal and State Cost-Share Program.
  - FSA Tree Assistance Program
  - Block Grants for Grove Renovation and Abandoned Grove
  - Grower Replanting Initiative Proposal (GRIP)

14

Additional Tools to Rebuild

- In February, Congress appropriated $2.36 billion for Agriculture disaster programs, $760 million relief/rebuild package to the Florida citrus industry. Growers will use these dollars to re-invest and cover losses.
- Emergency Citrus Disease Response Act – IRS tax incentive
- Citrus Crop Insurance Reform

15

New Rootstock Products are Essential

- Thank you all for your hard work on this complex puzzle. We have world class breeders and there are very promising results in the pipeline!
- Breeding for HLB resistance and/or tolerance is of primary importance.
- Dire need among growers to know which rootstocks and scions to choose for best performance
- New rootstocks and scions are being made available to the industry in Florida, but time has not allowed significant research data to help us understand how growers can count on them. We know there are a lot of variables; geography, soil, variety, production techniques, etc.

16

New Rootstock Products are Essential

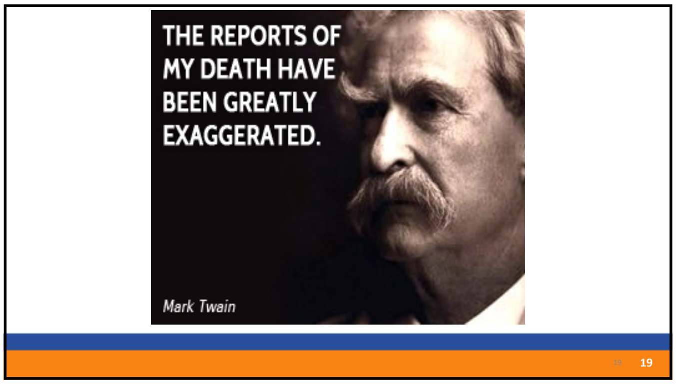
- Nursery producers must be better informed on currently available materials and how to recommend to growers the best rootstock/scion combinations. Communication between breeders and nurseries is a must.
- There is a limited availability of materials emerging from the new releases (seed for rootstocks) and budwood for scions. This is affecting nursery ability to deliver trees ready to plant in a timely and economical way. Seeking state and federal support to help alleviate logjam.
- **Speed is critical. Time is not on our side and we are in an emergency situation.**

17

We and Florida Citrus Can Do This!

- Resilience is a hallmark of the Florida citrus grower. Growers are proud to produce products that support the economy, taste good and are good for you. Our history tells us that the Florida citrus grower will step up and fight the "knock-out blows" delivered by Mother Nature. We can rebuild after freezes, hurricanes, pest and diseases.
- We have tools and incentives to rebuild.
- New Rootstock Products (ASAP) are a must if Florida citrus is going to be sustainable.
- Don't write our obituary just yet. FCM is "all in" on the future of Florida citrus.

18


THE REPORTS OF MY DEATH HAVE BEEN GREATLY EXAGGERATED.
Mark Twain
19


Thank You!
FLORIDA CITRUS MUTUAL
20

The International Wheat Yield Partnership

A Collaborative Model for Using Science to Address Important Problems

Jeff Gwyn, PhD

Program Director

1

The Target / Need - Impact of Wheat on Food, Nutrition and Health

Wheat is essential to global food and nutritional security

Wheat is the most widely grown of any crop globally (230m + ha) and accounts for:

- Over 21% food calories
- ~ 20% daily protein

The Problem – Urgent Need to Increase Wheat Yields to Feed 9+ Billion People by 2050

Will require a 60+ % increase in wheat production to meet food demands by 2050

3

www.iwyp.org

The International Wheat Yield Partnership

IWYP was conceived and operates as:

- An Associated Programme of the *Wheat Initiative* and the lead on delivering against Core Theme 1 of its Strategic Research Agenda
- Wheat Initiative endorsed by G20 Agriculture Ministries as a vehicle to address the "need" and the "problem"

IWYP is a partnership (formed as a consortium) between:

- Funding agencies in different countries
- Science teams in different countries
- Different research projects
- Private and public sector institutions

4

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IWYP Research and Funding Partners (13)

WHEAT INITIATIVE · USAID · CIMMYT · CGIAR · BBSRC · USDA National Institute of Food and Agriculture · USDA Agricultural Research Service · syngenta foundation for sustainable agriculture · INRA · Department of Biotechnology, Government of India · GRDC Grains Research & Development Corporation · Agriculture and Agri-Food Canada / Agriculture et Agroalimentaire Canada · SAGARPA

5

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IWYP Private Partners (9)

syngenta · mahyco · DuPont Pioneer · Limagrain · KWS · BAYER Science For A Better Life · SEED-CO The African Seed Company · RAGT · LongReach

6

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IWYP Goal

*Increase the **genetic** yield potential of wheat by 50% in 20 years*

Why ?

- Because this is urgently required and not enough progress is evident
- Because others are not focused here

How ?

- By deploying a new model for funding and conducting international research programs
- By combining the best ideas internationally
- By making scientific breakthroughs
- By being focused on delivery with a high degree of urgency

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“The electric light did not come from the continuous improvement of candles”

Oren Harari

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The IWYP Model was Purposely Designed

- Do things differently – use a new model that is effective, efficient and delivers
- Capitalize on wide research collaboration, among and within individual research projects – share back from the beginning
- An Initiative with own governance and independent management
- Be flexible (funding mechanisms, inclusiveness, adapting to changing conditions)
- Accept high risk / high reward science - seek breakthroughs
- Take advantage of new technical opportunities
- Align and partner with other funded projects
- Focus on outputs for farmers and consumers
- Take discoveries down the product development path to delivery
- Benefit from strong links with the private sector

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Impact of a Successful IWYP Model

- Until IWYP, there wasn’t a successful mechanism (of infrastructure, science and commercial partners) internationally that enables a system (for any crop) whereby strategic ouputs of collaborative research could be leveraged into new germplasm and products
- IWYP is different than other current systems, e.g., CGIAR – brings together all the important aspects and players, including private industry, in a formulated strategic plan for execution
- Exemplifies a science-based coordinated initiative that is international in scope with tailored fits to national needs
- Shows value / effectiveness of being (and staying) strategically focused with defined targets, targets delivery with sense of urgency
- Success driven by individual projects, as well as the integrated effort, delivering technology, tools and pre-products as planned
- Impact realized by discoveries and outputs continuously channeled into local, national or international wheat breeding programs, both public and private

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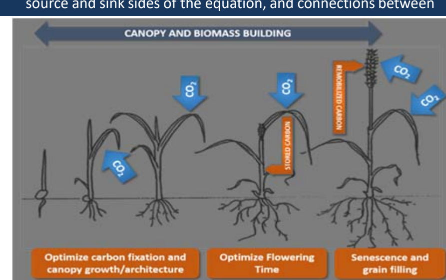
Important Considerations to Make the IWYP Model Work

- Partners must be committed, long term, to the overall goals and objectives (funders, researchers, industry)
- Defined and agreed “ways of working” – can document or formalize a number of ways
- A management structure conducive to coordination of the total activities and needs
- Consolidated and / or synchronized funding cycles for Calls
- Predetermined targets / research scope – avoid scope creep
- Terms and Conditions in Offer of Grant that defines the needs and expectations of the funding groups, e.g.,
  - Active participation in the holistic Program
  - Sharing of results and data from early stages
  - Non-exclusivity of inventions
  - Reporting and progress tracking

11 www.iwyp.org

IWYP Targets Specific Areas of Science to Seek Breakthroughs in Wheat Yield Potential

Primary Focus - **enhance photosynthesis** to drive yield increases - both source and sink sides of the equation, and connections between



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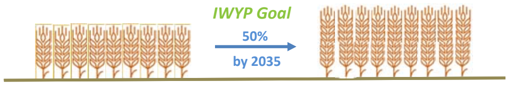
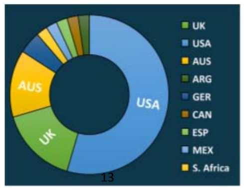
Current IWYP Research Portfolio



- IWYP Science Program is made up of **23 "hand-picked" overlapping and / or complementary research projects**, conducted by top international scientists, working collaboratively to create pre-products
  - 1st IWYP Call Projects (8)
  - NIFA-IWYP Call Projects (6+1 CAP)
  - IWYP Aligned Projects (8)
  - 2nd IWYP Call Projects soon (#TBD)

Number of Projects	23
Number of Countries	9
Number of Institutions	47



13

The IWYP Science **Portfolio** – December '17

Research Scope / Target Area of Current 23 Projects	# Projects Related
Increasing carbon capture before flowering	2
Increasing biomass	2
Optimizing harvest index	3
Enhancing photosynthetic pathways	3
Specific changes in plant architecture	2
Modifying phenology, e.g., flowering time, fit genotype to environment	1
Traits and markers for yield components	3
Increasing carbon flow into grains	2
Enabling technology development – photosynthetic efficiency, gene editing, HTP phenotyping	1 (PSE), 2 (GE), 1 HTPP
Hybrid wheat development	1
Root structure and growth	0
Faster / alternative breeding methods	0
Modeling to define the optimal traits / combinations per environment	0

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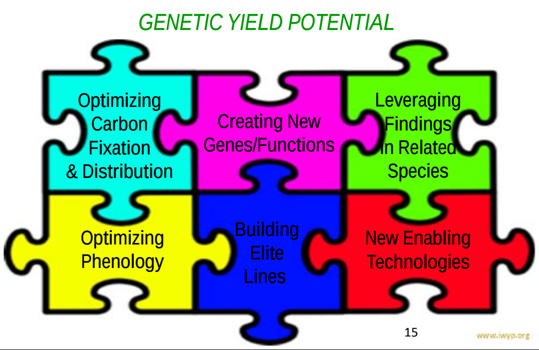
Integrating Results



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IWYP is a Long Term Continuous Program with Multiple Research Components

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	etc.
IWYP Aligned Projects	3	3	2	etc.								
IWYP 1st Call		8										
NIFA - IWYP Call			6 + 1									
IWYP 2nd Call				4 – 6?								
Aligned Calls					4 - 8							
IWYP 3rd Call						4 – 8?						
Etc.							etc.					
IWYP Hub												

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IWYP HUB – Validation and Development

HUB Platform approach for ***Translation***

- Brings all discoveries into a single central source to compare and combine to seek synergies and generate added value
  - ✓ Trait validation
  - ✓ Precision phenotyping
  - ✓ Field evaluation
  - ✓ Prebreeding
  - ✓ Trials and distribution (via IWIN, directly)
- Enables the IWYP to drive the discoveries/traits toward the market

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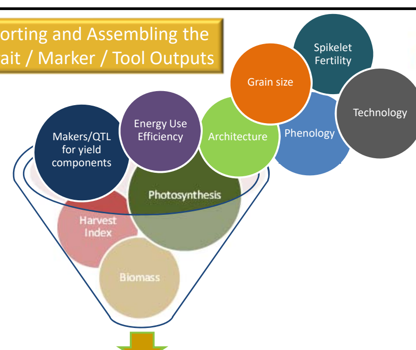
Sorting and Assembling the Trait / Marker / Tool Outputs



Traited Germplasm
Markers
Tools
Methods

IWYP Hub(s)

Delivery
Elite Lines
(via IWIN, others)

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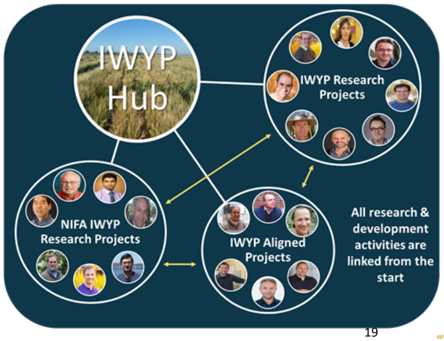
Linking Elements in the IWYP Science Program Portfolio – Generates Added Value



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Some Effective Linking Tools for Both Researchers and Stakeholders

- **Science and Impact Executive Board** – meetings, white papers, quarterly updates
- **Communication** – regular correspondence and updates, newsletters, group meetings / workshops
- Private **members space portal(s)** with webpage and shared drive accessible through the IWYP website
- **Central databases** housed at CIMMYT embargoed for IWYP use
- **Annual IWYP Program Conference** – science overviews and progress updates, brainstorming and feedback, field tours, interaction with private sector
- External *ad hoc* **Scientific Advisory Committee**

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Generating Added Value in IWYP

- Upstream during the discovery and research phase by linking projects at early stages of research and creating opportunities for new discoveries not originally envisaged by single projects
- Downstream in the IWYP Hub – by integrating and combining research outputs (traits, tools, germplasm) to generate performance impacts that are greater than the sum of the parts (trait stacking, synergies, additivity, etc.)

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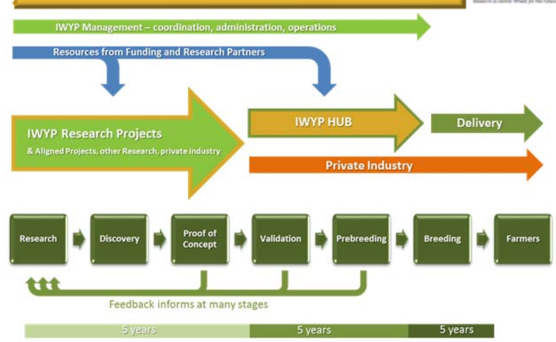
The IWYP Initiative – Driven by Strategic Plan
Collaboration + Integration + Development + Delivery



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How Is IWYP Doing So Far?

- The model is proving to be effective and efficient, highly visible
- Over half way to the initial funding goal of US$100 mio
- Research is delivering outputs as planned
- Large quantities of germplasm are being evaluated with high levels of sophistication for many traits, especially for photosynthetic enhancement
- First outputs are being be applied in prebreeding
- Getting close to understanding some of important underpinning genes
- New lines with traits are being delivered that are pushing yields higher
- Several important new molecular markers for breeding have been developed, many more in development
- New technologies have been developed and are being applied
- Private industry is also taking up certain discoveries at early stages

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Learn More About IWYP

- Go to the IWYP website www.iwyp.org
- *IWYP Strategic Plan 2017-2022* (Full and Summary versions) published on the IWYP website
- *IWYP Annual Reports 2015/16 and 2016/17* published on the IWYP website

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Thank You
iwypprogdirector@iwyp.org
www.iwyp.org
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CORNELL UNIVERSITY New York State Agricultural Experiment Station USDA ARS

Geneva Breeding Programs

Hidden Below Ground:
Collaborative Research and Tech Transfer – The Apple Rootstock Story

The Geneva Apple Rootstock Breeding Team

1

The Geneva® Apple Rootstock Breeding Program

USDA United States Department of Agriculture Agricultural Research Service — Apple Rootstock Breeding Program Plant Genetic Resources Unit, Geneva, NY

Research work on apple rootstocks features many collaborations and institutions

- Cornell University:
  - T. Robinson (Orchard Systems)
  - P. Francescatto, J. Lordan (Physiology)
  - Kenong Xu (Genomics)
  - L. Chang (Horticulture - Nutrition)
  - Awais Khan (Plant Pathology)
  - S. Brown (Scion Breeding)
- Michigan State University:
  - G. Lang
- Washington State University:
  - K. Evans, (Scion Breeding)
  - Stefano Musacchi
  - Lee Kalcsits
  - Cameron Peace
  - B. Beers
- USDA ARS:
  - Mike Grusak (Nutrition)
  - T. Chao (Apple Collection)
- USDA ARS AFRS Kearneysville:
  - J. Norelli (Fire Blight, Transgenics)
  - C. Dardick (Architecture)
  - Tom Tworkosky (Physiology)
  - Michael Glenn (Physiology)
- USDA ARS Wenatchee:
  - M. Mazzola (Plant Pathology)
  - Y. Zhu (Genomics)
- PENN State University:
  - T. McNellis
  - Rich Marini (Statistics Pomology)
  - J. Schupp (Horticulture)
- Georgia Tech Research Institute
  - G. McMurray and D. Sabo
- Over 40 scientists as NC-140 collaborators
- Washington Tree Fruit Research Commission International Collaborators

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Why am I here?

- To compare apples to oranges?
- Despite the obvious differences, the two industries are very similar:
  - Tree model: Rootstock and Scion
  - Multi-Year investment into permanent structures
  - Nursery industry intermediary (partner)
  - Fresh and processing outcome
  - Varied types of growers (small to very large, standard IPM to Organic, etc.)
  - Billion dollar stakes

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Fire Blight Limits Planting of New Varieties

Caused by Gram-negative bacteria Erwinia amylovora – clogs vascular systems, causes cankers and tree deaths.

High susceptibility of new varieties such as Cosmic Crisp, SnapDragon, Pink Lady and Jazz make it difficult to plant new orchards on susceptible rootstocks.

Rootstock Fire Blight causes tremendous losses ($100M 2000 Michigan, $20-30M WA, $10M 2016 Hudson Valley…)

With a fire blight-resistant rootstock, when the tree is infected the tree survives and the infected branches can be quickly re-grown.

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Experiences to share:

A. Work with independent evaluations groups
B. Let industry organizations work with you
C. Seek Nursery and Industry Partner Collaboration
D. Enable GOOD Tech Transfer
E. Choose Growers\Industry over “Fancy Science”
F. Accept the fact that our creations are not perfect – but better than not having nothing at all
G. The work of a public breeder should be about serving growers and industry first – Institutions (Land Grant, etc.) ought to know that and enable breeders

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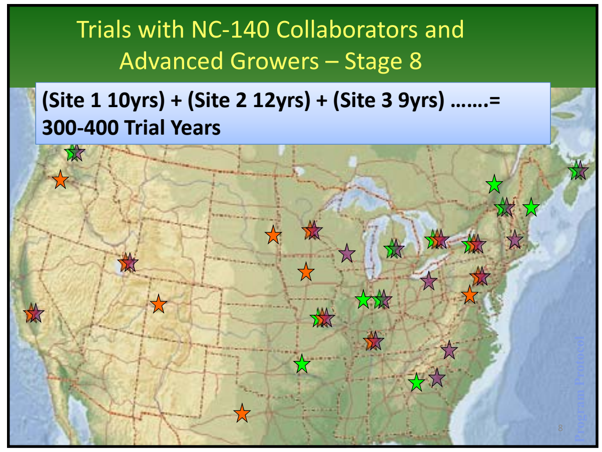
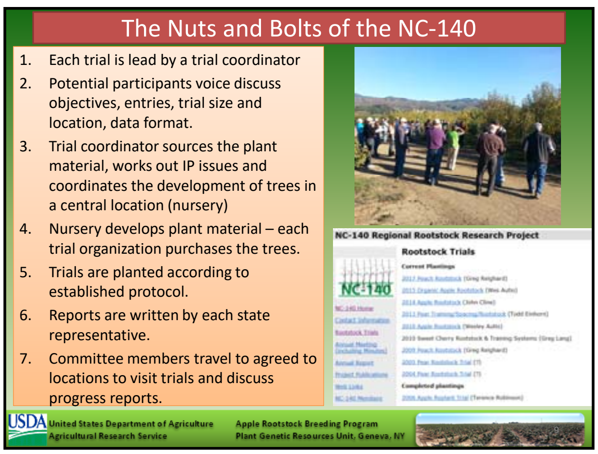
Work with Independent Evaluation Groups
• Award winning NC-140 role in independent testing of apple rootstocks.
– Coordinates experiments on apple, cherry, peach, pear, plum rootstocks.
– Replicated experiments are planted in many different locations in the U.S., Canada and Mexico.
– Committees meet yearly to report on findings.
"Improving economic and environmental sustainability in tree fruit production through changes in rootstock use."
USDA United States Department of Agriculture Agricultural Research Service
Apple Rootstock Breeding Program Plant Genetic Resources Unit, Geneva, NY


Trials with NC-140 Collaborators and Advanced Growers – Stage 8
(Site 1 10yrs) + (Site 2 12yrs) + (Site 3 9yrs) …….=
300-400 Trial Years


The Nuts and Bolts of the NC-140
1. Each trial is lead by a trial coordinator
2. Potential participants voice discuss objectives, entries, trial size and location, data format.
3. Trial coordinator sources the plant material, works out IP issues and coordinates the development of trees in a central location (nursery)
4. Nursery develops plant material – each trial organization purchases the trees.
5. Trials are planted according to established protocol.
6. Reports are written by each state representative.
7. Committee members travel to agreed to locations to visit trials and discuss progress reports.
NC-140 Regional Rootstock Research Project
Rootstock Trials
USDA United States Department of Agriculture Agricultural Research Service
Apple Rootstock Breeding Program Plant Genetic Resources Unit, Geneva, NY


Let Industry Organizations Work with you
• Washington Tree Fruit Research Commission
• International Fruit Tree Association
• New York Apple Research and Development Board.
• And more……
• Conduct independent field trials.
• Support research.
• Know and serve stakeholders.
• May be able to do things that some other public institutions can't
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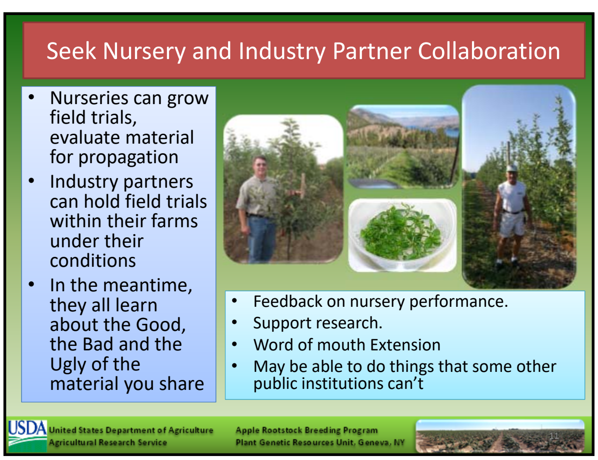
Apple Rootstock Breeding Program Plant Genetic Resources Unit, Geneva, NY


Seek Nursery and Industry Partner Collaboration
• Nurseries can grow field trials, evaluate material for propagation
• Industry partners can hold field trials within their farms under their conditions
• In the meantime, they all learn about the Good, the Bad and the Ugly of the material you share
• Feedback on nursery performance.
• Support research.
• Word of mouth Extension
• May be able to do things that some other public institutions can't
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2007 UT Rootstock performance turned into Fire Blight Trial
USDA United States Department of Agriculture Agricultural Research Service
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Willow Drive Nursery – Family Operated
G.41 budded liners
USDA United States Department of Agriculture
Agricultural Research Service
Apple Rootstock Breeding Program
Plant Genetic Resources Unit, Geneva, NY


Willamette Nursery
Added 14 new greenhouses to accommodate new cutting production of Geneva Rootstocks
USDA United States Department of Agriculture
Agricultural Research Service
Apple Rootstock Breeding Program
Plant Genetic Resources Unit, Geneva, NY


Sierra Gold Nursery
USDA United States Department of Agriculture
Agricultural Research Service
Apple Rootstock Breeding Program
Plant Genetic Resources Unit, Geneva, NY


North American Plants – Subsidiar
Agromillora
USDA United States Department of Agriculture
Agricultural Research Service
Apple Rootstock Breeding Program
Plant Genetic Resources Unit, Geneva, NY


Enable GOOD Tech Transfer
Apple Rootstock Breeding Program (USDA ARS and Cornell Partnership) was Awardee of the Federal Labs Consortium 2015 Excellence in Technology Transfer – competing against other federal labs (NASA, U.S. Army, Naval Research Laboratory, etc.)
G.41
Really?!?!? Apple Rootstocks?
• Feedback on nursery performance.
• Support research.
• Word of mouth Extension
• May be able to do things that some other public institutions can't
USDA United States Department of Agriculture
Agricultural Research Service
Apple Rootstock Breeding Program
Plant Genetic Resources Unit, Geneva, NY


Enable GOOD Tech Transfer
• Most Tech Transfer handled by one partner (Cornell University)
• From 2005 to 2014 handled more than 70 testing agreements
• Many Material Transfer Agreements and contracts!
• More than 40 demonstration sites to ensure market education with field visits and field days
• More than 100 presentations to grower and industry organizations
• More than 50 scientific publications on aspects of the plant material
• Five or more new U.S. Nurseries in business
Jess Lyga
Technology Licensing Officer | Cornell CTL
Exclusivity may not be the best answer
USDA United States Department of Agriculture
Agricultural Research Service
Apple Rootstock Breeding Program
Plant Genetic Resources Unit, Geneva, NY


Enable GOOD Tech Transfer
• Licensed US Nurseries:
– Treco (Oregon)
– Willow Drive Nursery (Washington)
– Willamette Nursery (Oregon)
– Copenhaven (Oregon)
– Cummins (New York)
– Kit Johnston (Oregon)
– Todd Cameron (Washington)
– KCK Farms (Oregon)
– Van Well Nursery (Oregon)
– Helios Nursery (Washington)
– Phytelligence (Washington)
– Gold Crown Nursery (Washington)
– Waffler (New York)
Copenhaven Nursery
North American Plants – Subsidiary of Agromillora
Exclusivity may not be the best way forward
USDA United States Department of Agriculture Agricultural Research Service
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Phytelligence
USDA United States Department of Agriculture Agricultural Research Service
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Kit Johnston Nursery
• Field of Geneva Apple Rootstock G.41 planted in 2011, 2012 – first crop in 2012
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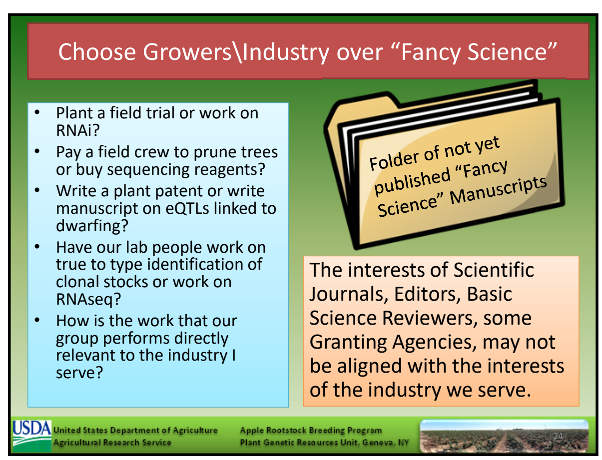
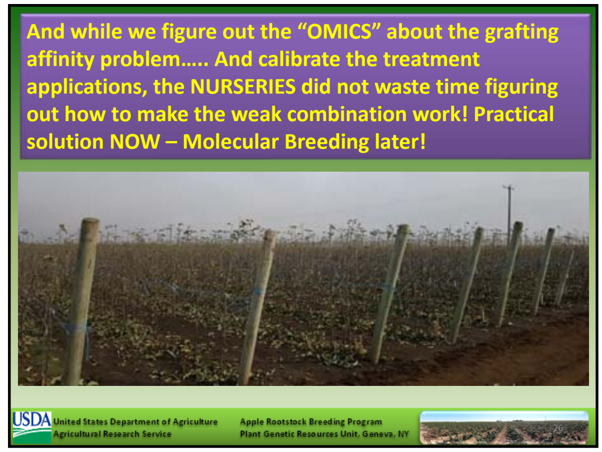
Apple Rootstock Breeding Program Plant Genetic Resources Unit, Geneva, NY

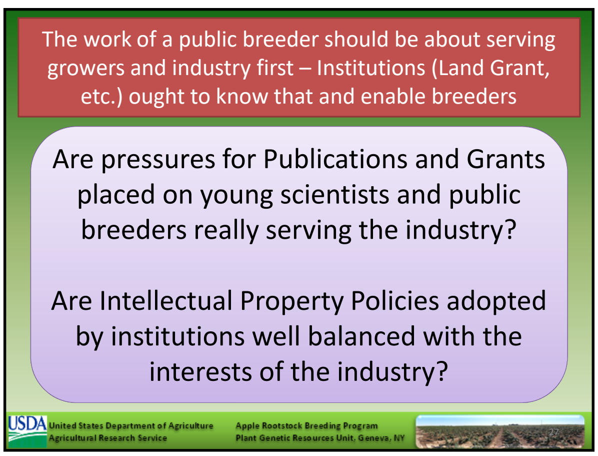

Helios Nursery
USDA United States Department of Agriculture Agricultural Research Service
Apple Rootstock Breeding Program Plant Genetic Resources Unit, Geneva, NY


Copenhaven Nursery
G.41 Stool bed
USDA United States Department of Agriculture Agricultural Research Service
Apple Rootstock Breeding Program Plant Genetic Resources Unit, Geneva, NY


Choose Growers\Industry over “Fancy Science”
• Plant a field trial or work on RNAi?
• Pay a field crew to prune trees or buy sequencing reagents?
• Write a plant patent or write manuscript on eQTLs linked to dwarfing?
• Have our lab people work on true to type identification of clonal stocks or work on RNAseq?
• How is the work that our group performs directly relevant to the industry I serve?
Folder of not yet published “Fancy Science” Manuscripts
The interests of Scientific Journals, Editors, Basic Science Reviewers, some Granting Agencies, may not be aligned with the interests of the industry we serve.
USDA United States Department of Agriculture Agricultural Research Service
Apple Rootstock Breeding Program Plant Genetic Resources Unit, Geneva, NY


Accept the fact that our creations are not perfect – but better than not having nothing at all
G.41
• M.9 vigor
• Very high yield efficient
• Highly productive
• Very precocious
• Resistant to replant disease
• Very cold hardy
• Does well in warmer climates (Mexico)
• Highly Resistant to Fire Blight and Crown Rot and Wooly Apple Aphid
• Requires tissue culture mother plants for stoolbed
G.41 Fuji CIV 2008
USDA United States Department of Agriculture Agricultural Research Service
Apple Rootstock Breeding Program Plant Genetic Resources Unit, Geneva, NY


And while we figure out the "OMICS" about the grafting affinity problem….. And calibrate the treatment applications, the NURSERIES did not waste time figuring out how to make the weak combination work! Practical solution NOW – Molecular Breeding later!
USDA United States Department of Agriculture Agricultural Research Service
Apple Rootstock Breeding Program Plant Genetic Resources Unit, Geneva, NY


The work of a public breeder should be about serving growers and industry first – Institutions (Land Grant, etc.) ought to know that and enable breeders
Are pressures for Publications and Grants placed on young scientists and public breeders really serving the industry?
Are Intellectual Property Policies adopted by institutions well balanced with the interests of the industry?
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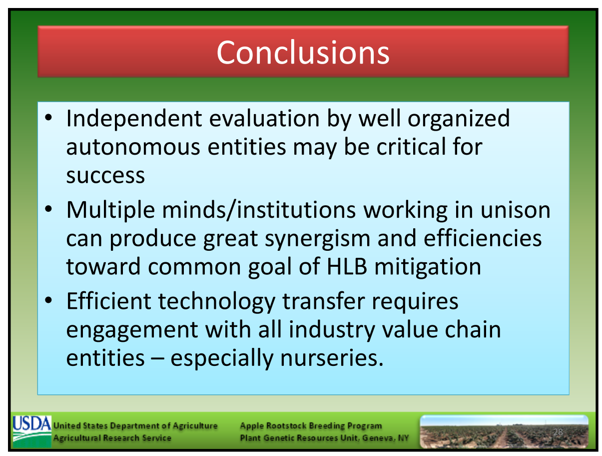
Conclusions
• Independent evaluation by well organized autonomous entities may be critical for success
• Multiple minds/institutions working in unison can produce great synergism and efficiencies toward common goal of HLB mitigation
• Efficient technology transfer requires engagement with all industry value chain entities – especially nurseries.
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Thank You!
USDA United States Department of Agriculture Agricultural Research Service
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rootstocks
breeding
rootstock
apple
orchard
dwarfing
disease
program
resistance
genotypes
evaluation
Geneva
traits
populations
tree
trees
new
replant
markers
selection
fire
germplasm
nursery
resistant
efficiency
project
stool
years
blight
genetic
root
test
trait
commercial
analysis
several

Appendix F

Draft guidelines for data/metrics collection for citrus HLB greenhouse and early-stage field trials

The following guidelines are suggested for use in HLB-related research, when possible. The guidelines are not intended to be absolute and final as new and improved procedures are likely to emerge in the months and years to follow. As available resources, goals, and approaches to research vary among different research groups, it is expected that some of the suggested guidelines will have to be modified for particular research projects. This is not a "consensus" document and it is not agreed that it should be used to restrict the range of different approaches to research that are funded or published. The guidelines are also not intended to restrict researchers from conducting additional analyses, but it is recommended to follow suggested practices as best as possible.

The team members involved in the discussion and assembly of the guidelines were as follows (in alphabetical order): The team members involved in the discussion and assembly of the guidelines were as follows (in alphabetical order): Ute Albrecht (SWFREC, UF/IFAS, Immokalee, FL), Kim Bowman (USDA ARS, Ft. Pierce, FL); Yongping Duan (USDA ARS, Ft. Pierce, FL); Fred Gmitter (CREC, UF/IFAS, Lake Alfred, FL); Jude Grosser (CREC, UF/IFAS, Lake Alfred, FL); Madhura Kunta (TAMUK, Kingsville, TX); Eliezer Louzada (TAMUK, Kingsville, TX); Mikeal Roose (UCR, Riverside, CA); Ed Stover (USDA ARS, Ft. Pierce, FL) and Glenn Wright (YAC, Yuma, AZ).

Greenhouse experiments

Experimental design:

- Experiments must use control (non-inoculated) plants of the same variety and age as the inoculated or infected plants.
- Experiments must maintain controls and infected plants under the same conditions. Plants should be randomized.
- It is suggested to use at least 10-12 plants per treatment and variety to conduct disease/health evaluations. For additional genomics, metabolomics, or other analyses, a small but representative subsample of plants can be used.
- Plants to be used in the experiments should be as homogeneous as possible
- Use a minimum of 10 psyllids and 2 tissue pieces per plant for psyllid transmission and graft transmission of CLas, respectively. Number of psyllids and tissue pieces may be adjusted based on the size of experimental plants. Budstick grafting is also a suitable method for inoculation. Provide information on percentage of infection of psyllid colony and titer levels of plant variety used for inoculation. Use standardized PCR methods and provide Ct-values and DNA concentration of plants from which inoculation material was obtained.
- Experiments must define the source of CLas used and reference to any previous publications or work with the same source.
- Researchers must do one of the following:
    - Use a CLas strain that is maintained in the exotic pathogens collection of citrus at USDA-ARS, Beltsville, MD.

- Use a strain that has been sequenced or extensively genotyped.
  - Maintain the strain that they use.
  - Maintain the strain that they use as -80 frozen tissue for future sequencing or other analysis.

Data collection:

- One or more measures of plant size must be recorded at beginning and end of the experiment:
  - Stem diameter (preferred). For non-grafted trees measure at 10 cm above soil level. Height above graft union for measuring stem diameter of grafted trees is preferred at 5 cm but can vary depending on factors such as site of graft inoculation. Must be defined and consistent within an experiment.
  - Plant height or, if plants were pruned, the sum of the length of all branches after regrowth. Indicate times and frequency of pruning.
  - Biomass at the end of experiment. May be separated into shoot, leaf, and root portions.
- Greenhouse conditions and management practices should be recorded in as much detail as possible, including pot size, potting medium, nutritional program, temperature ranges, light levels, and any trimming or training of plants.
- Conduct foliar disease symptom ratings at different time intervals throughout the experiment using a scale from 1 to 5, with 1 = no foliar disease symptoms, 2 = foliar symptoms on less than 25% of leaves, 3 = 25-50% of leaves with symptoms, 4 = 50-75% of leaves with symptoms, 5 = more than 75% of leaves with symptoms.
- Document type of foliar symptoms (chlorosis, blotch mottle, reduced leaf size, vein corking, etc.).
- Collect at least 3 leaves (number may vary based on plant size) at different time intervals for CLas detection (may have this coincide with disease ratings). Choose mature leaves randomly from different areas throughout the canopy. Pool tissue for analysis.
- Use petioles/midribs for CLas detection.
- If CLas testing of roots is to be part of the experiment, fibrous roots ($\leq$ 2mm) should be used.
- Use the "Li primers" (Li et al., 2006) for real-time PCR detection of CLas. New guidelines on primers may follow.
- Report DNA concentration, Ct-values and percent of infected plants. If the Ct values are used for classification of which trees are infected and which are not infected by CLas, the cutoff should be clearly indicated on reports.
- Duration of experiment and time intervals for disease ratings will vary depending on age of plants used. Duration of experiments should be a minimum of 6 months following inoculation, but preferably 12 months. Time intervals for PCR detection may vary based on resources and main purpose of the experiment.

Early-stage field trials

Experimental design

- Use the largest number of plants possible per variety.

- Experimental design should be randomized or randomized blocked. Design will depend on number of rows available, row length, and tree spacing.
- As much as possible, all trees to be compared in a particular trial should come from the same nursery and be planted at the same time.
- As much as possible, a trial should be planted on uniform soil and have uniform irrigation and drainage conditions. Otherwise, variability of soil and irrigation conditions should be taken into account in the experimental design (blocking).
- A minimum of 6 replicates should be used, but more replicates are better. Depending on the purpose and space available, replicates can be single tree, 3 trees, or more; a minimum of 3 trees is preferred. Generally, increasing the number of replications will improve the power of the comparison more than increasing the number of trees per replication. However, increasing the number of trees per replication rather than the number of replications will often improve the convenience of data collection, especially for yield. The relative balance of number of replications and number of trees per replication may vary according to the particular situation.
- Plant border trees at end of rows, and in adjacent rows on each side, when possible.

Data collection

Data to be collected from a field trial may vary by trial purpose, conditions, and resources available. The following metrics should be used:

- Tree size. Measure at one or more time intervals before the completion of the trial.
    - Trunk diameter for scion and rootstock. Measure at 5 cm above and below graft union. Be consistent and return to the same spot on the trunk every year. Measure in two perpendicular directions and use average. Alternatively, trunk circumference can be measured, and trunk diameter calculated using the formula [circumference/π]. Report trunk cross sectional area (TCSA) using the formula [π x $(\text{diameter}/2)^2$].
    - Tree height to top of canopy (do not include height of vigorous shoots that extend significantly past the top of the canopy).
    - Canopy diameter (parallel and perpendicular to the row).
    - If hedging and/or topping are done to the block, this needs to be clearly noted, and may significantly change the value of subsequent canopy size measurements.
- Once tree height and diameter are measured, calculate canopy area and/or volume. Measure canopy diameter parallel and perpendicular to row.
- Calculate standard canopy volume according to the formula: [(diameter parallel to row x diameter perpendicular to row) x height]/4, modified from Wutscher and Hill (1995).
- If nutrition is part of the study, determine leaf macro and micronutrient concentrations annually during July-August from 12 mature, 6-month-old spring flush leaves from each or a subset of trees depending on experimental design.
- Report percentage of dead trees periodically or at the end of a trial period. Dead trees should be excluded from further ratings and analyses, or if included, this should be noted. Inferred or hypothesized cause of tree death may be noted. In many cases, trees that die in the first year are not the result of CLas effects and may be excluded from HLB-associated assessments.
- If a trial is located in an HLB-endemic environment, conduct foliar disease ratings using a scale from 1 to 5, with 1 = no foliar disease symptoms, 2 = foliar symptoms on less than 25% of leaves,

3 = 25-50% of leaves with symptoms, 4 = 50-75% of leaves with symptoms, 5 = more than 75% of leaves with symptoms. Calculate disease index as described below based on tree size and age:
  - For very small trees, rate the entire canopy as one unit. The maximum score per tree will be 5.
  - For medium trees, divide canopy into two sectors and apply ratings to each sector. The maximum score per tree will be 10.
  - For larger trees, divide canopy into 4 sectors and apply ratings to each sector. The maximum score per tree will be 20. If trees are very large, divide into 8 sectors for a maximum score of 40.
  - To standardize ratings across trees sizes, divide the total score by the number of sectors used, so that all tree ratings are expressed on a 1-5 scale.
- Conduct canopy thickness and color ratings using a scale from 1-5 as described below. Apply ratings to one, two, four, or eight sectors of the canopy depending on tree size, with a maximum score of 5 for smallest trees and 40 for large trees. To standardize ratings across trees sizes, divide the total score by the number of sectors used, so that all tree ratings are expressed on a 1-5 scale. Dead trees are not to be scored for canopy thickness or canopy color, and so will not affect average values in analyses.
  - *Canopy thickness*
    1 = very thin canopy, 2 = thin canopy, 3 = medium canopy, 4 = thick canopy, 5 = very thick canopy. It is recommended to illustrate differences between ratings photographically.
  - *Canopy color*
    1 = very yellow unhealthy canopy, 2 = yellow unhealthy canopy, 3 = moderately healthy canopy, 4 = healthy green canopy, 5 = very healthy dark green canopy. It is recommended to illustrate differences between ratings photographically.
- Document foliar diseases not associated with HLB if commercially relevant (e.g. canker) particularly when evaluating different scion varieties.
- Foliar disease and health ratings should be conducted at the same time of year. In Florida and Texas, fall is recommended for scoring disease symptoms, as that is the time they will usually be most pronounced (once temperatures are dropping). Additional ratings during spring and/or summer can provide important information and are recommended, particularly when evaluating new scion varieties.
- Tree appearance may be documented photographically using a measuring pole as reference.
- If PCR evaluation of trees for CLas is to be done:
  - Collect mature leaves from most recent flush and use petiole/midribs for CLas detection. Depending on tree size, collect one or more leaves randomly from each of the four cardinal directions.
  - Collect fibrous roots ($\leq$ 2mm) for CLas detection. Depending on tree size, collect fibrous roots from a minimum of two different cardinal directions, avoiding zones of overlap between adjacent trees.
  - Conduct leaf and root sample collections annually or at the end of the evaluation period (such as the end of four years of harvest). May coincide with disease and health ratings.
- Use the “Li primers” (Li et al., 2006) for real-time PCR detection of CLas. New guidelines may follow.

- Once trees reach maturity, collect fruit yield and fruit quality data each season, as possible. Conduct yield and fruit quality assessment at dates that are standard harvest times for that cultivar, or harvest times that are proposed for new cultivars. Report date of assessment.
    - Yield - assess directly by weighing fruits per replicate or indirectly by counting number of fruits per tree. Report as fruit weight per experimental unit. Alternatively, yield can be measured as boxes of fruit per tree.
    - Fruit weight – determine from random subsample of fruits from each tree, or group, depending on what is practical.
    - Fruit size - determine from subsample of fruits from each tree, or group, depending on what is practical for the situation. Measure the horizontal or vertical diameter (as appropriate) of the subsample of fruit collected for determination of fruit weight.
    - Fruit quality – depending on the type of fruit and trial purpose, determine percent juice, brix, acid, brix/acid ratio, external color, and juice color from subsample of fruits according to standard laboratory methods.
    - Sampling time will vary based on scion variety maturity and other factors. Select time that is most appropriate for the scion variety under evaluation.
    - If appropriate, assess percentage of visually abnormal putatively greening-affected fruit per tree.
    - If appropriate, assess fruit drop pre-harvest. Report as percent drop from fruit number data.

If conducting field evaluations on larger mature trees

- Follow the same guidelines described for new field plantings as appropriate.

Addendum

The following definitions to define tolerance or resistance are suggested:

- **Tolerance**. The ability of a tree/plant to grow well and be productive even when infected with CLas. This is a relative measure that should be expressed in comparison to some other "standard" cultivars or rootstocks under the same conditions. This should be assessed over a defined time period, and under controlled inoculation or endemic disease pressure. CLas titer and symptoms may not be important for tolerance (except to demonstrate that trees were exposed/infected), and focus would be on tree growth, yield and fruit quality.
- **Resistance**. The ability of a tree/plant to exclude/reduce CLas populations. This is not as much a relative measure (as tolerance), but still should be expressed in comparison to some other "standard" cultivars or rootstocks under the same conditions. This should be assessed over a defined time period, and under controlled inoculation or endemic disease pressure. CLas titers provide important information, but it must also be demonstrated that it goes along with superior tree growth, yield and fruit quality. CLas titer information will be of particular importance in California, as titer reduction may affect disease spread.