

Research Project Progress Report

Unforbidden fruits: preventing citrus smuggling by introducing varieties culturally significant to ethnic communities

David Karp, Tracy Kahn, Toni Siebert, Robert Krueger, Richard Lee and Georgios Vidalakis

Before long, as you are driving down a country road, you may be puzzled to see plantings of unfamiliar citrus and citrus relatives such as curry leaf, bael and etrog, perhaps grown in greenhouses or on trellises. It might be even more surprising to learn that the Citrus Research Board has had a hand in the diffusion of these esoteric crops.

The rationale is unusual but compelling: Although these crops could be profitable for a few nurseries that sell the trees, and for the farmers that grow them, far more important is the benefit they could bring to California's entire citrus industry by *avoiding* economic damage from smuggling. As we know all too well, illicit imports pose a grave danger of introducing and spreading exotic pests and diseases, notably huanglongbing (HLB) and its vector, the Asian citrus psyllid (ACP).

Just look at the headlines. In July 2009, a specially trained dog found curry leaves (*Bergera koenigii*) in a package at a Fresno FedEx facility that was carrying ACPs, which tested positive for the bacterium associated with HLB.

The problem is far-reaching. According to a recent study by the USDA's Economic Research Service, citrus and citrus relatives accounted for eight of the top 14 categories of fruits smuggled into the United States from 2002 to 2006 (Peyton Ferrier, *The Economics of Agricultural and Wildlife Smuggling*, USDA-ERS, 2009).

Federal and state agencies strive mightily to stop smugglers, but it's impossible for them to catch them all. Only a small percentage of agricultural cargo is inspected, and in any case many of those who smuggle citrus do so for religious and cultural purposes, not fully understanding the potential impact. Unfortunately, these culprits are unlikely to be deterred by conventional interdiction strategies.

Complementary to interdiction, there's another approach -- reducing demand -- that can play a crucial role in suppressing smuggling. The concept is simple: if a product is readily available in California, smugglers won't bother to bring it in. The implementation is trickier, however, because in many cases there is no pathogen-tested budwood in the system for nurseries to start with to propagate trees. This is mandated by state and federal regulations for all commercial citrus source material.

The scientists at the University of California at Riverside (UCR) and the USDA who are responsible for securing California's citrus germplasm resources have long been aware of this and have made an effort to release varieties and species that were smuggled or illicitly propagated, like yuzu and sudachi, two forms of Japanese acid citrus, or kafir lime (*Citrus hystrix*), whose leaves are indispensable in Southeast Asian cooking. All were processed at the Cali-



Curry leaf, *Bergera koenigii*, CRC 3165, at the South Coast Research and Extension Center in Irvine, CA, 12/1/08. (Right) Curry leaf trees in an insect-protected structure at the USDA-ARS National Clonal Germplasm Repository for Citrus and Dates, Riverside, 8/24/12. Photos © David Karp.





Curry leaf plants grown by Thomas Law of Law Tieng's Farm LLC, which ships fumigated curry leaf to California from Hawaii. © David Karp.



Victor Bhatti of Betel Garden, a leading grower and shipper of curry leaf from Hawaii, 9/23/11. © David Karp.



Two types of curry leaf (small leaf, with abundant fruits, in front; large leaf, supposedly from Indonesia, at rear) at Frankie's Nursery in Waimanalo, Hawaii. © David Karp.



Annapurna Duvvuri with small-leaved (left) and large-leaved forms of curry leaf, in Satya and Annapurna Duvvuri's garden in Riverside. 9/13/10. © David Karp.

fornia Citrus Clonal Protection Program (CCPP), and their budwood was made available to nurseries.

Other non-citrus precedents include tejocote (Mexican hawthorn, *Crataegus pubescens*) which was the fruit most often smuggled into the United States, for use in Christmas punches and ristras. After a substantial planting in Pauma Valley started to produce, the smuggling stopped.

An unusual project is born

As the pressure from new citrus pests and diseases has increased in recent years, it became clear that a full court press was needed to determine which types of citrus were being smuggled and what could be done about it from a germplasm standpoint.

Thus, in spring 2010, a three-year project was born with the ungainly name "Unforbidden Fruits: Preventing Citrus

Smuggling by Introducing Varieties Culturally Significant to Ethnic Communities" – UFF for short. Funded by the Citrus Research Board (CRB), it draws on the expertise of six team members: Tracy Kahn (principal investigator), Toni Siebert and David Karp of the Department of Botany and Plant Sciences at UCR, Richard Lee and Robert Krueger of the USDA's National Clonal Germplasm Repository for Citrus and Dates (NCGRCD), and Georgios Vidalakis of the CCPP.

Our first task was to determine which species and varieties were being smuggled, and why. We learned that there is a little-known database compiled by the USDA-APHIS Smuggling Interdiction and Trade Compliance (SITC) program listing seizures of citrus and citrus relatives being smuggled from foreign countries, including the plant parts concerned, the quantities, the countries of origin, and the states where the items were seized.



“Consulting for Production Agriculture”

At Leffingwell Ag Sales we understand the risks you take to grow a successful crop. Our experienced PCA's are prepared with the latest research and technologies to help growers deal with any existing concerns or threats to your crops. Please call or come by and visit with one of our PCA's. Hold us to the task of helping you succeed.

Locally owned
*Servicing the citrus belt
for over 60 years*

11 PCA's with over
350 combined years
of experience

3 Convenient Locations:

Ivanhoe
798-1153

Lindsay
562-4946

Terra Bella
535-4461

Securing access to this information proved only slightly less arduous than obtaining a list of CIA undercover operatives, but we received it in November 2010.

Interpreting the data proved more problematic. In many cases, seizures were described simply as “citrus leaves” or “citrus plants,” although in some cases we could assume the possible identity based on country of origin as in the case of kaffir lime leaves from Thailand. The most-smuggled citrus commodity was listed as limes from Colombia, which were probably sweet limes illicitly shipped at a season when the fruit was not in season here.

Meanwhile, by reviewing the scientific literature and interviewing interdiction specialists, specialty produce purveyors, and end users, we researched the background of the most-smuggled species and varieties in order to understand the context in which smuggling takes place: their traditional uses, the availability of germplasm here, their HLB and ACP host status, the current quarantine situation, economic demand, and the prospects for their cultivation in California.

Based on this information, we decided to focus first on two Citrus relatives that are important for their leaves – curry leaf and bael (*Aegle marmelos*) – since their leaves are prime host material for ACP and HLB and can easily transmit them in smuggled shipments.

Curry leaf: indispensable Indian flavoring

The most high-profile of the two, curry leaf, is native to the Indian subcontinent and is commonly used in many dishes as an aromatic ingredient, like bay leaf. Ask any Indian, Sri Lankan, or Bengali; if a dish that requires curry leaf doesn't have it, it just doesn't taste right.

Curry leaf trees flourish in citrus-friendly parts of California, although they may grow slowly at first. Many Indians cultivate them in their gardens and share leaves and cuttings with relatives and friends. There are several different kinds, differing considerably in vigor, the size of the leaves, and their aromatic properties; some users strongly prefer one kind over another.

Most significantly for California's citrus growers, there is a substantial demand for curry leaf that is unmet by those who don't have direct access to trees, or from commercial users like restaurants and food processors.

Previously, shipments from plantings in Florida and Hawaii were the primary sources for curry leaf in California. However, Florida is no longer allowed to ship curry leaves to other states because of federal quarantines imposed after the discovery of HLB in 2005.

Hawaii, which has ACP but is not known to have HLB, is now the main source of supply with several growers on the island of Oahu who cultivate perhaps 20 acres. Much of the harvest is flown to an irradiation facility on the island of Hawaii, where the dose of 400 gy is administered. This amount is sufficient to sterilize most insect pests but does not always kill them. That is good enough for the USDA to allow irradiated curry leaves to be shipped to non-citrus producing states but not sufficient for California because even one live ACP could do incalculable damage if it harbored or spread HLB.

Curry leaf intended for shipment from Hawaii to citrus-producing states must be fumigated with methyl bromide, a process that is expensive and drastically shortens the product's shelf life from a few weeks to roughly five days. Under-

standably, retailers and customers are less than enthusiastic about fumigated leaves. Also, in the winter and early spring the supply from Hawaii is insufficient to meet demand, and buyers without good connections can find themselves cut off.

Pros and cons of curry cultivation

The UFF team carefully considered the pros and cons of encouraging curry leaf cultivation in California. On the downside, curry leaf is a preferred ACP host, so it can serve as source of infestation and infection; more trees could also lead to increased shipments within California that violate ACP and HLB quarantines. On the other hand, the demand for curry leaf is not going to go away, and a number of propagators, sometimes below the radar of regulators, have sprung up to supply trees.

It is better to have supervised sources, where the trees and leaves can be tested. Evaluating the benefit of protecting California's high-quality fresh fruit citrus against a few acres of curry leaf trees lead us to believe curtailing smuggling is a huge advantage. The CRB accepted this reasoning and asked us to develop a protocol for distributing curry leaf propagating material to California citrus nurseries.

However, conventional vegetative methods of propagating mother germplasm, such as air layering and grafting, are not readily available for curry leaf. It is not in the genus *Citrus* or closely allied genera, so no rootstocks or disease indexing procedures have been developed. To get material out as quickly and as phytosanitary as possible, we chose to pursue distribution via seed, one of the standard methods used in India.

Seed transmission of pathogens has been reported for a limited number of citrus pathogens: *Citrus psorosis virus*, *Citrus leaf blotch virus*, *Xylella fastidiosa*, and possibly *Candidatus Liberibacter asiaticus*, the pathogen associated with HLB.

To make sure that the original seed material did not carry any known seed-transmissible pathogen of citrus or any graft-transmissible pathogen of regulatory significance such as *Citrus tristeza virus* or citrus viroids, NCGRCD and CCPP scientists tested curry leaf seed mother trees in the Riverside collections in late 2011 and early 2012. The results were negative for all tested pathogens and trees.

In addition, we established six curry leaf trees in an insect-resistant screenhouse at the NCGRCD facilities to serve as seed trees for the future. These measures, and the whole protocol underlying safe seed distribution for curry and other citrus relatives, were described in a comprehensive document, "Standard Operating Procedures for Nursery Owned Source Plants of Citrus Relatives," that we submitted to federal and state regulators in January 2012.

Overcoming regulatory snags

Phytosanitary authorities agreed with the science supporting the pathogen testing and distribution protocols, but regulatory obstacles remained at both the state and federal levels. Citrus nurseries interested in propagating curry trees had to keep them in the insect-resistant structures mandated for their commercial citrus mother and increase trees by the CDFA's Citrus Nursery Stock Pest Cleanliness Program. However, this program is limited to the genus *Citrus* and allied genera, and curry leaf trees were not allowed to



800-992-2304

The
SOURCE
for all your
citrus tree
needs

TreeSource
CITRUS NURSERY L.L.C.

SuperCitrus Trees
B&B Trees • Seedlings
Starter Trees/Citrus Liners
Rootstock Seed
Budwood of all Types

WOODLAKE **www.citrustreesource.com** **PORTERVILLE**

be present (unless in an approved compartment) in a State-approved facility.

UFF team members and interested nurserymen conferred with CDFA, and on March 30, 2012 an interdepartmental permit, No. QC 1334, was issued which authorizes “seeds of bael and curry plants to be planted inside departmentally approved insect-resistant structures,” according to the protocol proposed by the UFF team. On June 14, the Citrus Nursery Stock Pest Cleanliness Program circulated the permit to California citrus nurseries.

The problem from the USDA regulatory standpoint was slightly different: commingling curry leaf and bael with pathogen-tested and therapied citrus mother and increase trees is prohibited by the current regulations for the “Inter-state Movement of Citrus and other Rutaceous Plants for

Planting from Areas Quarantined for Citrus Canker, Citrus Greening, or Asian Citrus Psyllid”.

After much discussion, on July 11 the USDA replied to the UFF team inquiries that “Based on the current status of citrus greening in California, the Subject Matter Experts would be ok with the conditions you outlined.”

The road forward

We have sent curry leaf seeds to four nurseries that have submitted requests and will soon be collecting seeds from this season’s fruits. Once nurseries establish a clean source in their insect-resistant structures, they will be allowed to propagate by root cuttings, air layering, or whatever works. At least one nursery has expressed interest in propagating curry plants by tissue culture, which would require the de-



Bael fruits (*Aegle marmelos*) for sale in a market in Lucknow, 5/13/08. © Richard Campbell.



Very old bael trees at the USDA’s National Clonal Germplasm Repository in Miami, 1/18/11. © David Karp.



Bael fruits and foliage, *Aegle marmelos*, on its own roots, CRC 3140, at the Citrus Variety Collection, University of California, Riverside, 9/13/10. Tree planted in 1984. (Inset) Distinctive leaves from bael tree, *Aegle marmelos*, on its own roots, CRC 3140, at the Citrus Variety Collection, University of California, Riverside, 9/13/10. Tree planted in 1983. Photos © David Karp/Citrus Variety Collection.



On Mondays, in the room devoted to the worship of Shiva at the Hindu Society of the Inland Empire temple, Shri Lakshmi Narayan Mandir, in Riverside, worshipers pour milk or ghee over the lingam and offerings, including bael leaves from the UCR Citrus Variety Collection, 9/13/10. © David Karp.



Nordox® 30-30 WG

High Performance Crop Protection



Grow with Brandt.co

The proud sponsor of the #31 Chevrolet driven by NASCAR Nationwide Series championship contender, **Justin Allgaier**.

Introducing NORDOX 30-30 WG, a new fungicide/bactericide that provides long-lasting, effective protection. NORDOX 30-30 WG is the most concentrated copper-zinc granular available today, providing more disease control with less product.

- Unique retention and superior rainfastness
- Easy to mix, dust-free formulation stays suspended
- Low re-entry time (REI)
- Less personal protection equipment needed

Get an expert's opinion. Talk to your crop consultant about NORDOX 30-30 WG today.



Monterey AgResources
P.O. Box 35000
Fresno, California 93745
559 499 2100
www.brandtmonterey.co

**BRANDT
MONTEREY**

velopment of a specific procedure but could greatly expedite multiplication of the plants.

It will be up to California farmers to decide whether and how to grow curry leaf, but at least two issues remain if commercialization is to be viable. Growers in ACP quarantine zones including most of Southern California – (this could easily expand to new areas if and when the insect is found) – are not allowed to ship leaves outside those zones unless they are fumigated with methyl bromide. An alternative protocol that calls for washing the leaves with a surfactant is under study by USDA scientists, but it is not clear if or when it will be approved.

Washing the leaves wouldn't help a grower whose trees were in an HLB quarantine zone, of course, at least as regulations currently stand. Serious commercial growers might con-

sider raising curry leaf in insect-resistant structures, such as the ones that nurseries are constructing so that they might be able to continue shipping citrus trees if an HLB quarantine is imposed in their area. In order for growers to ship screen-house-protected leaves out of an HLB quarantine zone, however, the current regulations would need to be amended.

Bael: the leaf sacred to Shiva

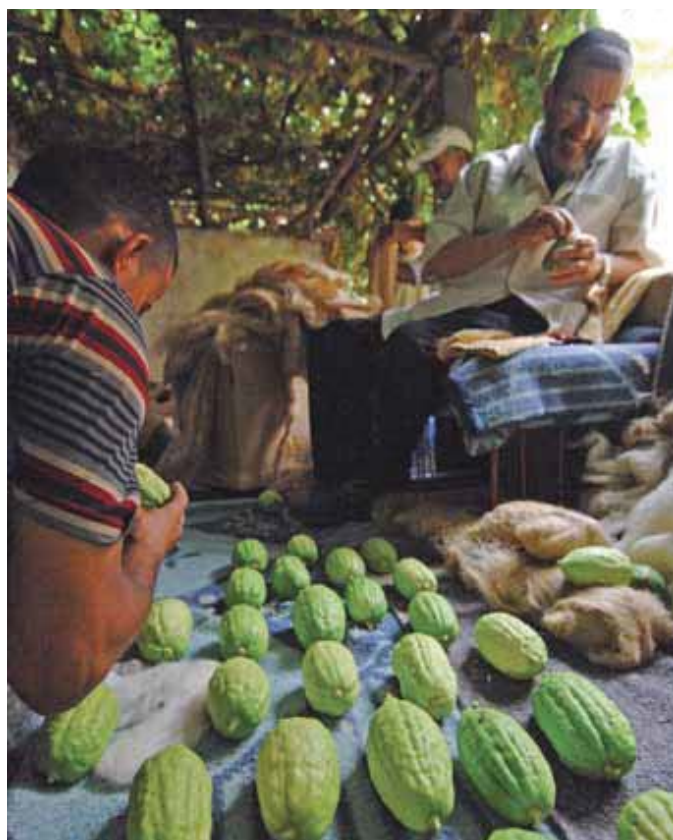
The other of the two citrus relatives on which we are focusing is bael, native to the Indian subcontinent. The hard-shelled fruits are exquisitely aromatic and are used in India for the making of juice and preserves, but its trifoliate leaves are the primary concern. Known in Hindi as "*bilva*," they are used for rites of the Hindu deity Shiva, particularly in the Maha Shivaratri festival held annually in February



Ultra-Orthodox Jews carefully select etrogim for use in their Sukkot ceremonies at a store in Crown Heights, Brooklyn, New York, 9/9/07. © David Karp.



'Assads' citron, grown from seed from never-grafted stock, at the UC Riverside Citrus Variety Collection, 1/26/12. © David Karp.



Rabbi Yasher Levy sorts and wraps sacred 'Assads' etrogim in the home of Aknouz, his supplier. Dumdir, Morocco, 8/31/08. © David Karp.



Porters carry packing materials up the valley to the 'Assads' citron plantings in Dumdir, in the Anti-Atlas Mountains of southern Morocco, 8/31/08. © David Karp.

or March, and to a lesser extent during weekly services.

Each year, local worshipers write to the Citrus Variety Collection requesting bael leaves from its trees. On occasion, as a favor and for research purposes, we have supplied the leaves and attended the ceremonies, watching as worshipers place the leaves on a black stone *lingam*, pour milk or ghee on them, and recite prayers. At least one correspondent has acknowledged smuggling bael leaves from India when they were unable to find a legal source; others have illicitly imported rooted trees.

In India, virtually every Hindu temple has a garden with one or more bael trees, and priests in California say they'd like to do the same thing here. The variety collection trees flourish in Riverside, so there seems to be no reason why they could not be grown in Southern California. However, because no disease-tested propagating material is available to California nurseries, the trees are difficult if not impossible to find in California.

Therefore, as for curry leaf, bael seeds from disease-tested trees at the CVC/NCGRCD in Riverside are being made available to California nurseries in the hope of jump-starting the cultivation of pathogen-free plants.

Etrog: the sacred fruit

Our third focus is citron (*Citrus medica*), one of the three original species of cultivated *Citrus* along with pummelo and mandarin. Native to southwestern China and Northeastern India, it was brought more than 2,300 years ago to the Middle East where it was adopted by the Jews for a crucial role in their autumn harvest festival, Sukkot.

For a fruit to be suitable for Jewish ritual use, it must be of certain traditional cultivars and meet many requirements, including size, shape, color, and freedom from cosmetic blemishes. \$50 is a typical price in the United States, and perfect specimens can fetch \$500 or more from exigent Ultra-Orthodox Jews. Most citrons for Jewish use, called etrogs, are imported from Israel, Italy, or Morocco, but there is one commercial grower in California, and in recent years a number of others have started plantings. There is also a moderate but increasing demand from observant Jews and synagogue gardeners who wish to grow their own trees and want the particular cultivars, which have not been publicly available in California.

The tricky part is that for an etrog to be valid for Jewish ritual use, it must be harvested from a tree that grows on its own roots rather than being grafted, as are virtually all other commercial citrus trees. Not just that, but all of the parents of the tree, dating back centuries, are supposed to have been own-rooted. Therefore, only certain traditional cultivars whose non-grafted pedigree has been attested by generations of rabbinical authorities, are acceptable. This creates a dilemma: if a tree and all its ancestors must be grown from seeds or cuttings rather than grafted, that rules out using micro-shoot-tip grafting, the standard technique to eliminate pathogens. The Etrog accession currently in the CCPP is disqualified by this criterion, and, indeed, the whole concept of budwood doesn't work for citrons intended for Jewish ritual use.

However, despite the seeds being monoembryonic and strictly sexual, because of certain reproductive peculiarities,



New Optional Citrus Tower!

New LectroBlast Tower – Increase your total coverage and efficiency.

LectroBlast®
By Progressive Ag Inc.

Progressive Ag Inc.
1336 McWilliams Way, Modesto, CA 95351
209-567-3232 • www.proaginc.com • 800-351-8101

etrogs generally come true to type from seed. It is possible, with the proper permit, to import seed of citron from the countries in the Mediterranean where they are grown.

In 2008, David Karp ventured to a remote region in the Anti-Atlas Mountains of southern Morocco where the



The 'Assads' variety of citron typically has no seeds when grown in isolation; it also has sweet flesh and correspondingly, white flowers, without purple. At Simon Lévy's etrog parades (farm) in the small settlement of Akridiss, Morocco, 8/26/08. © David Karp.

prized 'Assads' citron has been grown for centuries for Jewish ritual use, and he sent back seeds with a permit to the USDA. Trees derived from these seeds and growing at UC Riverside started fruiting last season. Seeds were harvested and distributed to interested nurseries. Trees derived from another elite ritually valid strain, 'Morning Song Temoni,' were recently planted in the field. Since citron typically fruits just a year or two after plant-

ing, we hope to be able to offer seeds of this accession before too long.

It is unlikely that these germplasm lines will be used by commercial growers aiming at an Ultra-Orthodox clientele, but less exacting Jews should be pleased to have access to ritually valid and pathogen-free etrog trees for the first time.

Acknowledgements

We would like to thank the Citrus Research Board for funding this research. We also sincerely thank all the individuals from USDA-APHIS/PPQ, USDA-APHIS/PPQ SITC, and the CDFA for all their support toward making this project possible.

CRB research project reference number 5100-129. ●

KEY TERMS

The mission of Plant Protection and Quarantine's (PPQ's) Smuggling Interdiction and Trade Compliance (SITC) Program is to detect and prevent the unlawful entry and distribution of prohibited and/or non-compliant products that may harbor exotic plant and animal pests, disease or invasive species.

SITC focuses its anti-smuggling efforts at the ports of entry and markets to prevent the establishment of plant and animal pests and diseases, while maintaining the safety of our ecosystems and natural resources. (Visit www.aphis.usda.gov/international_safeguarding/sitc/index.shtml.)

Plant Protection and Quarantine (PPQ) is a program within the USDA's Animal and Plant Health Inspection Service.

Monoembryony – when only one seedling emerges from a seed. In some citrus, the nucellar cells -- cells that surround the embryo sac -- divide and develop into embryos (nucellar embryony).

Air grafting is a method of cloning a fruit tree. A small branch is wounded and then wrapped tightly in sphagnum moss and polyethylene film until a large mass of roots develops. The "air layer" is then excised from the parent plant

just below the root mass (may take a month to a year). The new plant is then potted.

Sukkoth or Sukkot is a Jewish harvest festival beginning on the 15th of Tishri and commemorating the temporary shelters used by the Jews during their wandering in the wilderness. The connection to citrus is the "Four Kinds" of which citron or etrog is one. The others include a palm frond, myrtle twigs, and willow twigs. The Four Kinds are used nightly when reciting blessings. They represent the diversity of the community of Israel.

Bilva – Lord Shiva's Tree is another name for "bael" (Aegle marmelos), a citrus relative. The leaves of this plant are used as decoration during the festival of Maha Shivaratri. It is believed to have medicinal properties; one's most terrible karma ends when a bilva leaf is offered to Lord Shiva.

Maha Shivaratri – "The Night of Shiva" is a festival celebrated in the Hindu religion; special prayers are offered to Lord Shiva, the Lord of Destruction. It falls on a moonless February night.

Field Guide to ACP and HLB Hosts

In keeping with the purpose of the Unforbidden Fruits project, four members of the UFF team (Siebert, Krueger, Karp and Kahn) have compiled a flip-book, *Field ID Guide to Citrus Relative Hosts of Asian Citrus Psyllid and Huanglongbing*, soon to be published by the Citrus Research Board.

This publication consists of 54 pages of text and photographs concerning those species and types of citrus relatives most likely to be present in California and which could serve as hosts of ACP and HLB. Photos depict the trees, leaves, fruit and flowers of these genotypes; the text includes scientific and common names, descriptions, uses, what is known about the ACP and HLB host status (derived both from a review of the scientific literature and research conducted by UFF team member Lee and his colleagues), and an estimate of the danger presented to California citrus.

It will be distributed shortly as a laminated flip-book, a convenient format for use by phytosanitary professionals, citrus growers, and the general public.

Contacts for the Unforbidden Fruits team

Registered nurseries interested in obtaining seeds of curry leaf, bael or etrogs should contact Robert Krueger of the USDA National Clonal Germplasm Repository for Citrus and Dates, at robert.krueger@ars.usda.gov or (951) 827-4399.

Growers who might be interested in obtaining trees of these crops should contact their nurseries or members of the UFF team: David Karp (dkarp@ucr.edu) or Tracy Kahn (tracy.kahn@ucr.edu).

Do you have suggestions for citrus or citrus relatives for which there is a specialized demand, but no budwood in the CCPP system (ccpp@ucr.edu)? Contact Kahn, Karp or Krueger at the email addresses above.