Taxonomic Revisions in Citrus and Why They Matter

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What is plant taxonomy?

- **Plant** (Kingdom Plantae) **diversity is divided by scientists into categories**

- **From largest group to smallest:** Phylum (Magnoliophyta for Citrus); Class (Magnoliopsida); Order (Sapindales); Family (Rutaceae); **Genus (Citrus); and finally Species**

- there are various subgroups at most levels

- These categories are defined so that naming is consistent around the world and everyone will know what is being discussed
Why a taxonomic revision?

- From genomic data, most citrus types are now known not to be true species and it is inaccurate to refer to them as such.

- For example: *Citrus sinensis* is NOT a true species; the original hybrid was comprised of ~60% mandarin and 40% pummelo.

- Nomenclatural rules require the first established name that is compliant to be used; "known hybrids must be circumscribed to include only offspring of the progenitor species" = the name must be based on the progenitor species.
What will the new names likely be?

-Most citrus cultivars in Florida are introgression hybrids solely derived from *C. maxima* and *C. reticulata*-all will be *Citrus × aurantium*. Actually already this is the correct name

-all *Citrus sinensis* will be *Citrus × aurantium var. sinensis*

-the taxonomic level “variety” is based on phenotype (appearance, taste, etc.,) so all citrus that is solely derived from *C. maxima* and *C. reticulata*, and has a sweet orange-like phenotype, will be properly called *Citrus × aurantium var. sinensis*
Other major Florida cultivars?

-Since all of our current grapefruit, tangerines, tangors, and tangelos are solely derived from *C. maxima* and *C. reticulata*-all will be *Citrus × aurantium*

-those with a tangerine phenotype will be *Citrus × aurantium* var. *chrysocarpa*

- those with a grapefruit phenotype will be *Citrus × aurantium* var. *racemosa*. True pummelos will remain *C. maxima*, but hybrids like Sweetie and Parana will be *Citrus × aurantium* var. *racemosa*

-tangors like Temple, Murcott, etc. are close enough to tangerine phenotype so *Citrus × aurantium* var. *chrysocarpa*
Where does it get wonky?

- Genotypes derived solely from *C. maxima*, *C. reticulata*, and *C. trifoliata* (yes no longer *Poncirus*)-all will be *Citrus × insitorum*

- so Swingle, Carrizo, US-912, US-942, UFR5, etc. all will be *Citrus × insitorum*

- US-802 is *C. maxima × C. trifoliata* with no *C. reticulata*, -so not *Citrus × insitorum*, maybe *Citrus × indioensis*

- Genomic data suggest that SunChuSha is pure *C. reticulata*, while the very similar Cleo has 1-3% *C. maxima*. So Cleo is *Citrus × aurantium* var. *chrysocarpa*, while SunChuSha is *C. reticulata*

- For the most part only scientists care about taxonomic distinctions, but they are often used in regulatory language, but seldom for rootstocks
When might it matter?

- As we breed for HLB-tolerance, we have taken advantage of other genera for their disease resistance.

- According to nomenclatural rules anything which has even a hint of *C. trifoliata*, in an otherwise *C. maxima* & *C. reticulata* background, will be designated *Citrus × insitorum*, like Carrizo and most other rootstocks, even if phenotypically identical to sweet orange.

- If regulatory wording specifies that Orange Juice is from *Citrus × aurantium* var. *sinensis*, then most of our new sweet orange-like hybrids CAN be used, but not hybrids containing even small amounts of other species.

- BUT, citrus cultivar groups to the rescue......
Others have noted the wonkiness of taxonomy applied to cultivated plants:
Hetterscheid, van den Berg, and Brandenburg (1996) argued:
• “Classifications of cultivated plants and wild plants have different goals.
• Whereas wild plants are classified in a system that seeks to clarify evolutionary relationships, cultivated plants are (or should be) classified according to special purpose user-defined criteria, with stability of names as primary, requiring a totally different classification philosophy.” Others have made the same argument
• For this reason, the International Society for Horticultural Science established the idea of International Cultivar Registration (ICR)
  • The “ICR Authority” (ICRA) for each crop establishes descriptions and lists of members for each cultivar group
• These operate under the International Code of Nomenclature for Cultivated Plants
An International Cultivar Registry for Citrus

• An assigned Citrus ICRA is needed
• USDA/ARS is in discussion about creating an International Cultivar Registration Authority for Citrus, possibly with the Citrus Genebank in Riverside as the ICRA
• We will also coordinate an effort to publish a refereed paper outlining the rationale for use of “culton” names (analogous to the term “taxon” in taxonomy) in Citrus, to further establish the authority of the approach (meaning, to provide justification for use in commerce etc.)
• As just one example, Citrus Sweet Orange Group could encompass all citrus types which are very sweet-orange-like, regardless of parentage
HLB-Tolerant Hybrids: potential for supplementing Florida OJ production?

A collaborative effort of members of the Florida citrus industry and research community

Ed Stover, Fred Gmitter, Mikeal Roose, Liz Baldwin, Jude Grosser, Jinhe Bai, Yu Wang, Peter Chaires, Juan Carlos Motamayor, Kristen Carlson

You have all been part of this discussion, and this is why the taxonomic considerations are very important. To quickly refresh.................
Sugar Belle®: In UF blending trials, SugarBelle blends scored very well, better than commercial OJ standard.
We showed considerable differences in HLB-tolerance in existing plantings. What if trees are exposed to CLas at planting?

> 6 yr replicated trial, scion/rootstock comparison

> CLas titers not significantly different HortScience 51:127-132

Some scion/rootstock combinations continued to develop even with high titers of CLas and and strong mottle symptoms

Sugar Belle®/Sour had significantly higher mottle than others

Not “tolerant” rootstocks used so likely a scion effect

<table>
<thead>
<tr>
<th>Scion/Rootstock</th>
<th>Mortality (%)</th>
<th>Fruit/tree Oct 2015 (no.)</th>
<th>Health Oct 2015 (3 pt)</th>
<th>Change in diam. (mm)</th>
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<td>Fallglo/Kinkoji</td>
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<td>28.4 b</td>
<td>1.9 cd</td>
<td>23.8 b</td>
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<td>Hamlin/Cleopatra</td>
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<td>18.6 bc</td>
<td>2.2 bc</td>
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<tr>
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<td>1.6 d</td>
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<tr>
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<td>81.3 a</td>
<td>2.9 a</td>
<td>46.1 a</td>
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<tr>
<td>Tango/Kuharske</td>
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<td>2.9 a</td>
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<tr>
<td>Temple/Cleopatra</td>
<td>18 a</td>
<td>35.6 a</td>
<td>2.3 ab</td>
<td>23.8 b</td>
</tr>
</tbody>
</table>
US SunDragon

Like Navel in alligator-hide

Strong tolerance to HLB at many locations

Released with focus on dooryard/niche/breeding

Scored highly in sweet orange juice trial at USHRL and major processor

Used in many crosses.

Hybrids starting to fruit!
Low seeded selections of Irradiated FF-5-51-2 (Clementine x Orlando)
- Seedy original hybrid growing many places and appears to have useful HLB-tolerance, with no evidence of HLB-affected fruit
- Good midseason tangerine (late Nov early Dec)
- Easy peeling, rich flavor, segments dry when separated. Dancy+ size.
- Appears to require cross pollination
- Trialing all 3 selections in case one has problems
- May release parent 2019
• HLB-tolerance in some but not all mandarin types, even if closely related.
• 5-51-2 is Clementine x Orlando and Early Pride is Temple x (Clementine x Orlando), Sugar Belle® is Clementine x Minneola, Sunburst (C x O) x (C x O)
• SO we need to understand the genetics of HLB-tolerance
An unprecedented collaborative efforts between citrus processors and the USDA, UF, and UC-Riverside citrus breeding programs.

-The Coca Cola Company has funded establishment of a 15-acre top-work trial with 200 genetically diverse selections, selected by the breeders, replicated on trees already HLB-infected but maintained to a high standard of health

-Extensive data will be collected on fruit quality, yield, and HLB-tolerance.

-These data combined with genome resequencing, also funded by industry, will permit use of a modern breeding technique, called Genomic Selection (GS) to accelerate identification and release of new HLB-tolerant cultivars.
An unprecedented collaborative efforts between citrus processors and the USDA, UF, and UC-Riverside citrus breeding programs.

- GS will even drive choice of parental combinations for future breeding cycles.

- This is vital work, and the industry / research consortium, under the CRAFT umbrella, has just submitted a new NIFA grant proposal to fund the next five years of this effort.

- This will be a paradigm-shift in citrus breeding, joining crops like corn and soybeans in leveraging genomic science advances to directly benefit our industry, and ushering in an era of unprecedented HLB-tolerant citrus scions, including greatly improved sweet orange and grapefruit-like hybrids.