# Taxonomy of citrus fruits

Dirk Frettlöh

11. Februar 2019

The taxonomy of citrus fruits is a complex and controversial topic [Wik]. Even the seemingly simple question about the difference (resp. relation) between mandarin orange (*dt. Mandarine*) and the clementine (*dt. Clementine*) has several distinct answers. The following image shows a small part of the family tree of some citrus fuits, left according to the German wikipedia, right according to the English wikipedia.
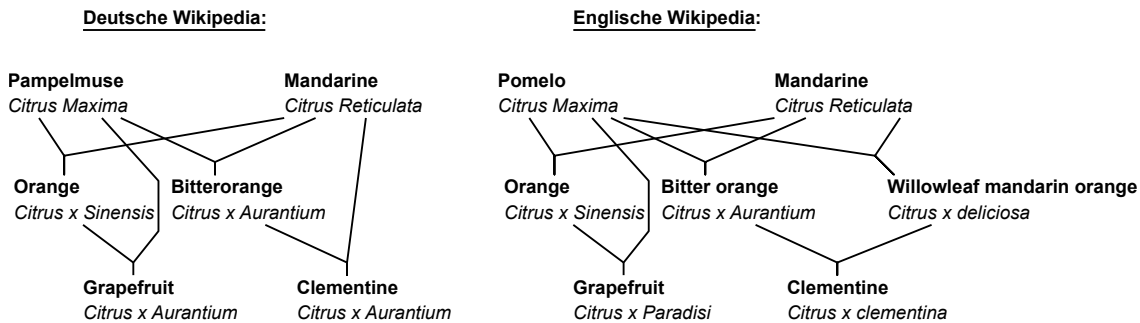

Note that this family tree is not really a tree in the mathematical sense, since it contains several loops. In fact, it is not possible to draw the entire family tree of citrus fruits as a graph. The family tree of the citrus fruits is closer to a dense object than to a discrete one. This is due to the fact that there are several ways to produce new species of the genus *citrus* from old ones, for instance by hybridization *(dt. Kreuzung)*, by grafting *(dt. Veredelung duch Pfropfen)*, or by cultivation *(dt. Züchtung)*; and that all these methods were practiced intensively on members of the citrus genus in the past.

Several genetic studies imply that there are ten original wild forms of the genus *citrus*, seven of them originating in Asia: pomelo (*citrus maxima, dt. Pampelmuse*), mandarin orange (*citrus reticulata, dt. Mandarine*), citron (*citrus medica, dt. Zitronatzitrone*), Ichang papeda (*citrus ichangensis, dt. Ichang-Zitrone*) and Nagami kumquat (*fortunella margarita* or *citrus japonica var. margarita*[1]); and three originating in Australia: the desert lime *(citrus glauca, dt. Australische Wüstenlimette*), round lime *(citrus australis)* and the finger lime *(citrus australasica)*. As a side remark: citrus fruits did not respect the Wallace line, dividing the flora and fauna of Asia from the one of Australia.

Most commercial citrus fruits descended from one or more of the first five of them (pomelo, mandarin orange, citron, Ichang papeda, kumquat). Among them, most descended from one or more of the first three ones. Hence it is tempting to illustrate the relations among the species in

---

[1]The two distinct names are reflecting the fact that it is undecided whether kumquats are part of the citrus genus, or are a genus on its own. In the latter case, it is undecided whether this genus consists of several different species, or of only one species with several varieties.

the citrus family in a family tree like this one:
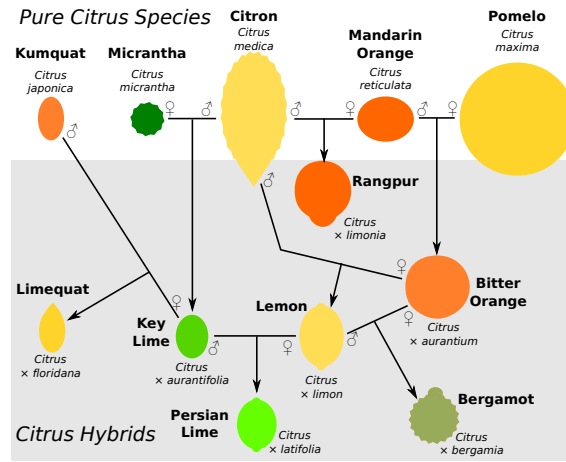
However, this is misleading. Considering all citrus fruits is more like looking at a diffraction pattern of a quasicrystal: Some bright spots dominate the picture (mandarin, lemon, pomelo), but if you look closer, you see also less bright spots (clementine, tangerine, satsuma), and even closer you see even darker spots (willow-leaved mandarin orange, dancing tangerine, Iyokan) spots between the brighter ones. An honest image thus uses a simplex in two, three or four dimensions, where the citrus fruits are represented in barycentric coordinates with respect to their three, four or five original ancestors. Here is an example of the two-dimensional citrus simplex:
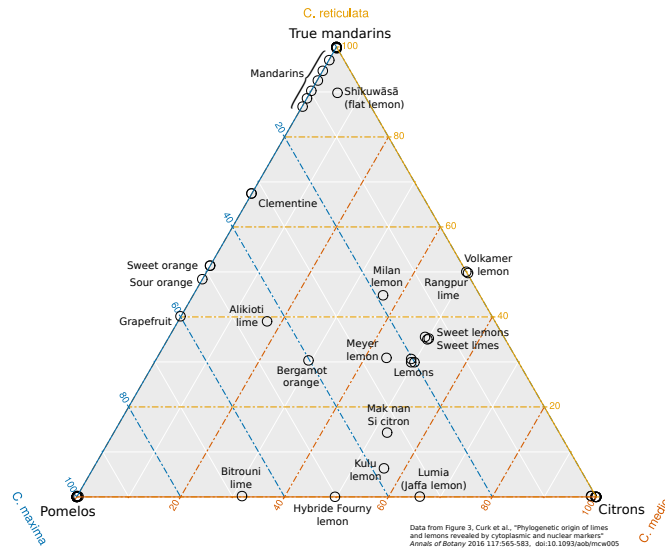

The image aims to show the descendants of pomelo, mandarin and citron. For instance, the common sweet orange is half mandarin, half pomelo. Thus its barycentric coordinates in the pomelo-mandarin-citron coordinate system are about $(0.5, 0.5, 0)$. The barycentric coordinates of most lemons are about $(0.2, 0.3, 0.5)$. The hybrid of some fruit with coordinates (a, b, c) and another one with coordinates (a', b', c') is a citrus fruit with coordinates $(\frac{a+a'}{2}, \frac{b+b'}{2}, \frac{c+c'}{2})$. Starting from mandarin, pomelo and citron, we can realize each point in $\mathbb{Z}[\frac{1}{2}]^2$ (in an appropriate coordinate system) by iterating such hybridization. Hence it is possible to approximate each point in the simplex by iterated hybridization of citrus fruits arbitrarily close. As a side remark: note that the

images also contains a Meyer lemon, in honor of Yves Meyer and his work on Meyer sets, their epsilon-duals providing such a good metaphor for the family tree of the citrus fruits.

Some citrus fruits are not contained in this diagram, since they have kumquat or papeda as ancestors. The following image shows a three-dimensional simplex, for all descendents of pomelo, mandarin, citron, and papeda (here not the Ichang papeda, but *citrus micrantha*)
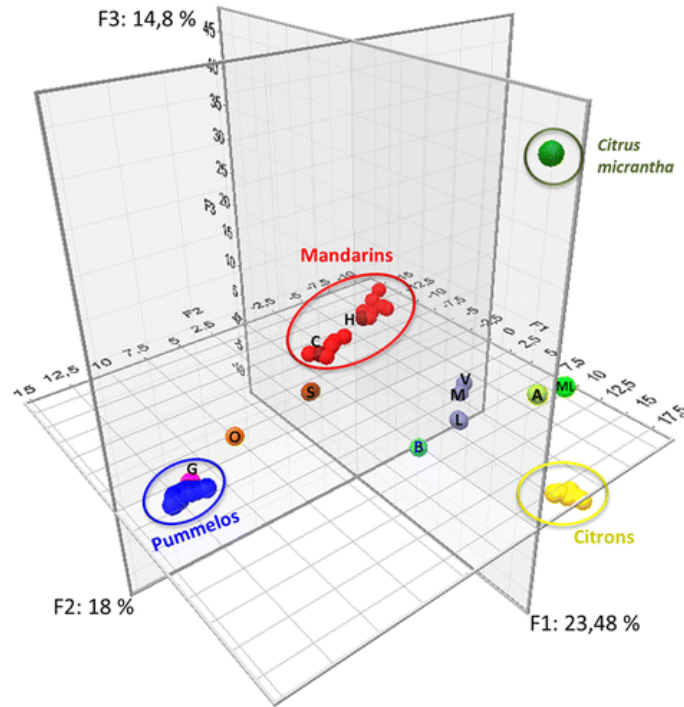
Note that the image again contains the oranges (O), bitter oranges (aka sour orange, S), clementines (C), lemons (L), and the Meyer lemon (M).

Some citrus fruits like the calamansi ($\times$ *citrofortunella microcarpa*) from the Philippines require a four-dimensional simplex, since among their ancestors there is also the kumquat.

Acknowledgements. All images but one are from wikipedia.

Literatur

[Wik] Wikipedia: Citrus taxonomy, online `https://en.wikipedia.org/wiki/Citrus_taxonomy`