



Cooperative Extension
University of California
County of San Diego
Farm and Home Advisor Office
5555 Overland Avenue, Suite 4101
San Diego, CA 92123

Gary Bender, Ph.D.
Farm Advisor, Subtropical Horticulture
Tel: 858-694-2856
E-mail:gsbender@ucdavis.edu

Mysteries of Mandarins **Sex, Seedlessness, and New Varieties**

Authors: Tracy L. Kahn¹ and C. Thomas Chao²

Department of Botany and Plant Sciences, University of California, Riverside

Mandarins and tangerines are receiving a lot of attention lately. But what is a mandarin and is it different from a tangerine? Some people incorrectly think that whatever comes in a can are mandarins and the rest are tangerines. Still for other people in the U. S. the words "mandarin" and "tangerine" are often terms used interchangeably to designate the mandarin group. This is not completely correct because the term tangerine was coined for "Dancy" mandarins which were imported from Tangiers and subsequently called tangerines. The word tangerine became associated with mandarins with orange-red rind color like "Dancy" and later in the U. S. for the whole mandarin group. Yet the term "mandarin" is an older term that is used throughout the world to represent the entire group.

Mandarins are known to be able to produce hybrids by crossing with other mandarins or with other types of citrus such as sweet oranges which are designated "tangors" or with grapefruits (pomelo) or pummelos which are designated "tangelos." Recently the terms "tangerine" and "mandarin" have been used together along with the terms "tangor" and "tangelo" to represent all mandarins and mandarin hybrids that resemble mandarins. Several of the new hybrids such as Yosemite Gold™ mandarin hybrid are not hybrids between two types but are more complex. Yosemite Gold™ is a hybrid between "Temple" (Royal) tangor, a mandarin x sweet orange hybrid, with two other mandarins, "Dancy" and "Encore." There are also mandarin hybrids such as Cocktail "grapefruit," a hybrid of "Frua" mandarin and a low acid pummelo (CRC 2240), that does not resemble a mandarin, nor is considered as a mandarin.

What makes this even more complicated is that recent genetic data proposed that there are only three primordial or fundamental citrus species in the Citrus subgenus: the mandarin (*C. reticulata* Blanco), the citron (*C. medica*) and the pummelo (*C. maxima*). All other types of citrus such as the sweet oranges arose from single or sequential crossing events, which produced hybrids between these three fundamental species or their offspring. Lemons, limes, sour oranges, sweet oranges and grapefruit types are now thought to have arisen as hybrids of these three primordial species and papedas and kumquats. Simply, all mandarins and hybrids such as tangors, tangelos and complex hybrids that resemble mandarins are best categorized as mandarin and mandarin hybrids.

WHAT MAKES A MANDARIN A MANDARIN?

Mandarins alone, without including the hybrids that appear like mandarins, is a large and varied group. Mandarin trees are small to medium in size with slender twigs and small branches. The leaves are dark green in color, with long slim simple leaf blades with smooth leaf margins. The leaves have long petioles, the structure that connects the leaf to the stem, with very small wings that resemble small leaves on each side of the petiole. The fruits are almost always flattened and depressed at the stem and stylar (opposite) ends of the fruit. At maturity, mandarin fruit have a hollow core and the segments tend to pull away from each other. The peel of mandarin fruit is loose at maturity, which explains why they are sometimes called a "zipper skinned" fruit. In the past they were also called "kid glove" oranges because the pickers needed to use gloves so as not to damage these fruit that tend to be more delicate than sweet oranges, like Navel oranges. Also mandarins have a greater tendency to alternate bear than Navel oranges. Alternate bearing means that they will produce a larger than normal crop one year followed by a lighter than normal crop the next year.

Mandarin varieties also vary greatly in their ability to produce seeds unlike all of the different Navel orange varieties. When grown in either a mixed or single variety block planting, some mandarin varieties will produce fruit with no seeds, some will have few, and others will have as many as 40 seeds per fruit. To understand why certain mandarin varieties will produce seedless or seeded fruit, one needs to know a few basics about citrus sex.

¹ Dr. Kahn is the curator of the Citrus Variety Collection and conducts research on seedlessness and the commercial potential of new citrus varieties to California in the Department of Botany and Plant Sciences, UC Riverside.

² Dr. Chao is the Assistant Cooperative Extension Specialist and Assistant Horticulturist, Department of Botany and Plant Sciences, UC Riverside. Dr. Chao's extension and research at UCR focuses on issues related to mandarin production and management in California and new mandarin cultivar production evaluation.

CITRUS SEX AND SEEDLESSNESS

Most citrus flowers have both sexes within a single flower. The pollen within the anthers holds the male sex cells or sperm. The pistil is the female part of the flower in the center with the ovary or spherical structure at the base. Within the ovary, which will develop into the fruit, are the ovules that will become seeds if pollination and fertilization occurs.

Varieties that produce few or no pollen and few or no functioning ovules will be very low seeded or seedless no matter what other citrus varieties are growing around them (See Table 1). Examples of varieties that have no functioning pollen and none to very few functioning ovules include all Navel orange and Satsuma mandarin varieties. "Midnight" and "Delta" Valencia oranges, and "Pixie," "Gold Nugget" and "Seedless Kishu" mandarins have none to very few functioning pollen and ovules. The UCR developed varieties Shasta Gold™, Tahoe Gold™, Yosemite Gold™ mandarin hybrids, as well as "Oroblanco" and "Melogold" that are grapefruit x pummelo hybrids are triploid meaning that these varieties have three copies of the chromosomes instead of the normal two. This makes it very difficult to produce functional pollen and ovules, but will occasionally produce a few. So these varieties and especially the Navel and Satsuma varieties which produce no functioning pollen, have a very low ability to serve as a pollen source to make other varieties seedy (Table 1).

Some citrus varieties have numerous functional pollen and ovules. Self-pollination within one of these citrus varieties will cause the fruit to be seedy no matter whether they are grown in an isolated single variety block or in a mixed variety block (Table 1). One example is the Florida "Honey" ("Murcott") mandarin which will be seedy no matter where it is grown. While other varieties that have many functional pollen and many functional ovules, but are self-incompatible and they will be seedless only if grown as an isolated single variety block (Table 1). Self-incompatibility is a genetically controlled system specific to certain mandarin varieties such as Clementine varieties, "W. Murcott Afourer" mandarin, "Page" mandarin, "Minneola" tangelo and pummelo varieties such as "Chandler" and "Reinking." Pollination within and between flowers of these varieties that are self-incompatible will not result in fertilization or seed development and as a result they will be seedless. However, if these varieties are grown near others varieties that can cross-pollinate them, then fruit of these self-incompatible varieties can be very seedy (Table 1).

THE ISOLATION OF SELF-INCOMPATIBLE VARIETIES TO PROMOTE SEEDLESSNESS

Isolating self-incompatible varieties may not be easy in a state like California that produces hundreds of crops, many requiring cross-pollination by honeybees in order to set fruit or produce seeds. Honeybees that are the most common pollinator of citrus flowers are also common in California during the blooming period for mandarins. In order to have isolated single variety block plantings of a self-incompatible mandarin like the Clementine varieties, one would need to carefully select a site that would isolate the Clementines from other citrus. Or one would need to have large plantings as a solid block to create

enough isolation, prevent cross-pollination and produce seedless fruit. Or another possible way to isolate a self-incompatible variety would be to plant Navel oranges or Satsuma mandarins as a buffer surrounding a self-incompatible variety since they produce no functional pollen. Recent experiments conducted by C Thomas Chao in 2002-2003 using two California mandarin orchards has found that the number of "buffer" rows needed to isolate a self-incompatible mandarin variety was much higher than the original recommendation of 5-20 rows in California. Greater than 116 rows of a "buffer" variety such as Satsuma or Navel variety may be needed to prevent cross-pollination and assure that seedless fruit will be produced. And even greater empty space between compatible varieties would be needed to prevent cross-pollination.

NECESSITY OF A STIMULUS FOR FRUIT SET VARIES AMONG MANDARIN VARIETIES

Most flowering plants require pollination and fertilization in order for the fruit to develop. Yet some citrus varieties are to produce fruits without the stimulus of pollination and fertilization that is responsible for seed development. For example Navel orange varieties that do not make functional pollen and make none to few functional ovules are still capable of setting fruit. Research conducted by Tracy Kahn, C. Thomas Chao and others has shown that the tendency to produce fruit in the absence of pollination and fertilization varies among mandarin varieties. Satsuma varieties are also capable of producing fruit without seeds like Navel orange varieties, but Clementine selections and other self-incompatible varieties such as "Minneola" and "Orlando" will have low fruit yield when cross pollination and seed set is prevented. They will produce greater yield when cross pollination occurs. Unfortunately, with cross pollination, the fruit of these varieties would be seedy. Yet with cross pollination the fruit will also tend to be larger. Self-incompatible varieties grown in isolation or surrounded by "buffer" varieties may produce low yield. Gibberellic acid is often required in the absence of cross-pollination to increase fruit set in these cases.

Throughout the world seedlessness is an important characteristic for marketing citrus fruit. The desire for seedless fruit is influencing growers' choices about which cultivars to plant. Among the different mandarin cultivars available, the Clementine selections are now the most popular in the world. Many superior cultivars have become commercially important in Spain, Morocco and South African in their local markets and in the export market. During the past few years in California, there has been an increase in acreage of newly introduced Clementine selections to help capture this market. According to the Bureau of Census, DOC, during the past decade there has been both an increase in importation and consumption of mandarins in the U.S. yet the consumption of imported mandarins has also increased. The increased importation of Clementine mandarin fruit, which is the largest contributor to importation volume of mandarins from Spain, Morocco and other countries, has encouraged California growers to plant Clementine varieties and other mandarins. According to the California Agricultural Statistic Service (CASS), one of the field offices of the National Agricultural Statistical Services within the USDA, the total acreage of all mandarins and hybrids has increased from 10,094 acres in 1997 to 11,734 acres in 2001. Since 2001 there has

been a substantial increase in acreage of mandarin and mandarin hybrids above these levels. A summary of the 2003 data on mandarin and mandarin hybrid acreage will be released from the CASS in September of 2004 that will quantify this increase <http://www.nass.usda.gov/ca>. Most of the increases in acreage have occurred in Kern and Tulare counties.

NEW MANDARIN VARIETIES IN CALIFORNIA

The greatest increase in mandarin acreage in California is of Clementine varieties. Yet there are also increased plantings of "W. Murcott Afourer" (Afourer), and other mandarin and mandarin hybrids such as the newly released four UCR developed mandarins and mandarin hybrids called Gold Nugget™, Shasta Gold™, Tahoe Gold™ and Yosemite Gold™.

CLEMENTINE VARIETIES

Internationally, the Clementine is one of the most popular groups of citrus varieties in the world. In the 2001 California Citrus Mutual Journal, Dave Gumpf, Robert Krueger and John Bash comprehensively reviewed the origin and characteristics of the different Clementine selections grown currently in California. Of the 16 Clementine varieties currently in California, Algerian Clementine was the most well known and widely grown selection in 2001. In the past few years increased plantings of "Nules" Clementine mandarin (also known as "Clemenules" or "De Nules") is now thought to be the variety of Clementine mandarin most planted in California. Depending upon where they are grown in California, Clementine varieties reach legal maturity between late September and November and are early season mandarins. Clementine varieties produce medium-sized trees, with a fine-textured appearance. The fruit are round to flattened on each end. The dark orange rind has a pebbled texture due to the presence of prominent oil glands and is fairly easy to peel. The flesh is bright orange, finely textured, and juicy. The flavor is sweet and very rich. As mentioned earlier, Clementine varieties (all except the variety "Monreal" which would be seedy in both single and mixed block plantings) are self-incompatible and must

TABLE 1 - Preliminary Pollination and Seediness Guide

Citrus Group	Varieties	Ability to serve as a pollen source to make fruit seedy	Low seeded or seedless grown in a mixed variety	Low seeded or seedless when grown in a single variety
			block planting with other varieties that serve as pollen source	block planting
NAVEL ORANGES	Atwood	very low	yes	yes
	Fisher	very low	yes	yes
	Fukumoto	very low	yes	yes
	Beck	very low	yes	yes
	Washington (Parent)	very low	yes	yes
	Cara Cara	very low	yes	yes
	Lane Late	very low	yes	yes
	Powell	very low	yes	yes
	Chislett	very low	yes	yes
	Autumn Gold	very low	yes	yes
	Summer Gold	very low	yes	yes
	Barnfield	very low	yes	yes
VALENCIA ORANGES	Olinda	moderate	no	no
	Frost	moderate	no	no
	Delta	very low	yes	yes
	Midnight	very low	yes	yes
CLEMENTINE MANDARINS	Algerian	high	no	yes
	Fina Sodea	high	no	yes
	Marisol	high	no	yes
	Clemenules or Nules	high	no	yes
	Caffin	moderate	no	yes
	Oroval	moderate	no	yes
SATSUMA MANDARINS	Owari	very low	yes	yes
	Okitsu Wase	very low	yes	yes
	Kuno Wase	very low	yes	yes
OTHER MANDARINS AND HYBRIDS	W. Murcott Afourer	very high	no	yes
	Cold Nugget	very low	yes	yes
	Pixie	very low	yes	yes
	Seedless Kishu	very low	yes	yes
	IDE 2 Shasta Gold™ hybrid	low	yes	yes
	TDE 3 Tahoe Gold™ hybrid	low	yes	yes
	TDE 4 Yosemite Gold™ hybrid	low	yes	yes
	Nova	high	no	yes
	Page	moderate	no	yes
	Minneola	high	no	yes
GRAPEFRUIT AND HYBRIDS	Fairchild	moderate	no	no
	Star Ruby	very low	yes	yes
	Rio Red	low	yes	yes
	Marsh	low	yes	yes
LEMONS	Oroblanco	low	yes	yes
	Allen Eureka	moderate	no	no
	Frost Lisbon	moderate	no	no
	Limoneira 8A Lisbon	moderate	no	no
PUMMELOS	Meyer	high	no	yes
	Chandler	high	no	yes
	Reinking	high	no	yes

be grown in isolated single variety block plantings to be seedless. If cross-pollination occurs by a compatible variety such a "W. Murcott Afourer" or others (Table 1), the fruit will be seedy.

W. MURCOTT AFOURER OR AFOURER MANDARIN IMPORTED FROM MOROCCO

The mandarin variety "W. Murcott Afourer" (also called "Afourer") was first noticed by W.W. Bitters during his visit to the Kenistra Research Station hosted by El Bachir Nador in May of 1982. The friendship that developed on this trip and subsequent meetings led to importation of several citrus varieties including this one after a number of failed attempts. In July of 1985, the variety "W. Murcott, Afourer," PI 539533, was received for quarantine in Glenn Dale, Maryland, then was subsequently forwarded to the Citrus Clonal Protection Program. The name "W. Murcott, Afourer," came from Dr. Nador's assumption that this variety arose as an open pollinated seed of Murcott (Florida "Honey"), the coordinates for this experimental plot, "INRA W" and "Afourer" which was the name of the town nearby the station. "Afourer" also became the local name for this variety. AH original experimental plots of INRA W were pulled out due to excessive seed numbers in adjacent Clementines and "Ortanique" orchards. In California, the CCP first released "W. Murcott, Afourer" from quarantine which allowed nurseries to buy bud-wood of this variety in January 1993.

It is known now based on the use of DNA markers in Mikeal Roose's lab-oratory at UC Riverside, that "W Murcott, Afourer" ("Afourer") is not the same as the variety "Murcott" which issold as "Honey" in Florida. Fruit of "Murcott" and "Afourer" differ in shape, rind color and flavor. "Murcott" fruit are seedy in both mixed and single block plantings because the flowers are self-compatible. In contrast, "Afourer," like the Clementine varieties are self-incompatible. "Afourer" fruit will be seedless to low seeded when grown in isolated single block plantings, but seedy when the flowers are cross pollinated and it can be a very strong pollinizer for other mandarins such as Clementines. The tree is moderate in size and vigor and the fruit is usually flattened on each end with a thin, smooth, slightly orange rind that is easy to peel. The flesh is orange-colored and juicy, with a rich and sweet flavor. The fruit matures from late January to March depending on the locations and environment and holds on the tree very well.

GOLD NUGGET MANDARIN DEVELOPED AT UCR

In August of 1999, the UC Riverside Citrus Breeding Program directed by Mikeal Roose released a new seedless mandarin variety called "Gold Nugget." This UCR developed late season mandarin is a hybrid of "Wilking" x "Kincy" mandarins. The initial selection was made in 1975 by R. K. Soost and J. W. Camerons and during most of its evaluation it was called "Pixie-like" because of its similarities to the mandarin variety "Pixie." The current name, "Gold Nugget" reflects the external appearance of the fruit. Gold Nugget fruits are usually medium in size and only slightly flattened in shape with a somewhat bumpy rind. The aromatic rind is moderately easy to peel. The flesh of the fruit is bright orange and finely-textured. The fruit will be seedless when

grown in either single or mixed variety block plantings, unlike Clementine varieties and "W. Murcott Afourer." The flavor of "Gold Nugget" fruit is rich and sweet. The fruit usually matures by early March, but holds exceptionally well on the tree, with summer-harvested fruit still being of good quality.

SHASTA GOLD™ (TDE2), TAHOE GOLD™ (TDE3), AND YOSEMITE GOLD™ (TDE4) MANDARIN HYBRIDS DEVELOPED AT UCR

The most recent releases from the UC Riverside Citrus Breeding Program are three complex mandarin hybrids. These new hybrids which are often collectively called "TDE" hybrids since it reflects the pedigree of these three hybrids which is [("Temple" tangor x 4n "Dancy" mandarin) x "Encore" mandarin]. In addition to the patented "TDE" names ("TDE2," "TDE3" and "TDE4"), each of these mandarin hybrids was given a trademark name as well: Shasta Gold™ (TDE2), Tahoe Gold™ (TDE3), and Yosemite Gold™ (TDE4).

All three produce seedless to very low seeded fruit with attractive dark orange rinds and a rich sweet flavor. These varieties will be seedless to very low seeded when grown in either a single or mixed variety plantings, unlike "W. Murcott Afourer" and the Qementine varieties. The trees of all three grow vigorously and are some what spreading in form. The three differ in a number of characteristics. Shasta Gold™ and Yosemite Gold™ produce large, "Mammoth" fruit with a moderately flat shape. Tahoe Gold™ fruit are medium-large "Jumbo" and the fruit are slightly flat in shape. Shasta Gold™ fruit are fairly easy to peel, have a smooth to slightly pitted rind texture with depressed oil glands and a deep orange color to the rind. Tahoe Gold™ fruit are moderately easy to peel and the rind is rather smooth to slightly grained with conspicuous oil glands and a very deep orange rind color. Yosemite Gold™, the easiest to peel has smooth rind with conspicuous oil glands and a very deep orange rind color.

Tahoe Gold™ fruit mature the earliest of the three, maturing between November and January depending on location. Shasta Gold™ and Yosemte Gold™ fruit mature slightly later with Shasta Go ld™ maturing between December and March and Yosemte Gold™ maturing between December and January depending where they are grown. If you would like more information about these three varieties, a description of each is available on Mikeal Roose's web page (<http://plantbiology.ucr.edu/peo-ple/faculty/roose.html>) or there is a link to these descriptions on the Citrus Variety Collection web site: <http://www.citrusvariety.ucr.edu>

The availability of new mandarin and mandarin hybrid varieties with many favorable characteristics offers California growers new opportunities to compete on the global fresh citrus fruit market. Unlike Navel oranges, mandarins are more variable in their ability to produce seedless fruit. For those varieties that are self-incompatible, one needs to carefully select the planting site based on the proximity to potentially compatible pollen sources to ensure the production of seedless mandarins.

Citrus Variety Collection

Authors: Tracy L. Kahn

Since 1910, the Citrus Variety Collection has been a resource for research, citrus breeding and educational extension activities initially for the UC Citrus Experiment Station and now for the expanded College of Natural and Agricultural Sciences at UC Riverside. As one of the most diverse collections of citrus varieties and related types in the world, this collection currently has three locations, the central one at UC Riverside and two smaller collections of citrus relatives at South Coast Research and Extension Center in Irvine, CA and the Coachella Valley Agricultural Station in Thermal, CA. The collection consists of approximately 1800 trees representing two trees of each of the 900 different types of citrus and citrus relatives. Approximately 640 of the types are within the sub-genus *Citrus*. Most commercial citrus varieties such as the different mandarin varieties are classified botanically in the sub-genus *Citrus* of the genus *Citrus*. The collection has 167 different mandarin and mandarin hybrid types including 14 Clementine selections, W. Murcott Afourer, and the UCR developed mandarin hybrids Gold Nugget and the Shasta Gold™, Tahoe Gold™ and Yosemite Gold™ mandarin hybrids. Commercial types that are exceptions to this include the kumquats, which are in the genus *Fortunella* and the Trifoliate oranges commonly used as a rootstocks or as parents for hybrids which are in the genus and species *Poncirus trifoliata*. The genera *Fortunella* and *Poncirus* as well as the 30 other genera related to the genus *Citrus* are classified within the subfamily Aurantiodeae of the Rutaceae plant family. The UC Riverside Citrus Variety Collection has 900 types within 28 of the 33 genera of the subfamily, Aurantiodeae of the Rutaceae.

The Citrus Variety Collection has varieties that were incorporated into the collection since the early 1900s and newer varieties that were recently imported into California from other parts of the world through the efforts of the UC Citrus Clonal Protection Program. The diversity in the collection is apparent visually by types with fruits of unusual shapes, sizes, colors, and tastes growing on trees of varying heights, forms, and foliage characteristics. There are types with fruit as big as one's head and ones as small as a green pea. This living collection also produces fruit with variation in the chemical compounds of the rind and flesh noticeable by the great differences in tastes, textures, and aromas. One type that

has recently received attention is the Australian Fingerlime or *Microcitrus australasica* which has fruit flesh composed of small round juice vesicles that look like caviar and have a flavor and aroma reminiscent of lime. Underlying all of this visible and tangible diversity is genetic diversity, which can and has been manipulated, combined, and transferred for the improvement of citrus crops for productivity, taste, and disease and environmental tolerance or resistance and the development of new food and horticultural crops.

The range of diversity within this collection makes it a valuable resource for research for the California Citrus Industry. Currently, the collection serves as a genetic resource for an array of research projects conducted by researchers from UC Riverside and other Universities, which range from scion and rootstock breeding for the improvement of commercial varieties to the study of the biological activities of citrus limonoids as anticancer agents. Since 1997 over 40 different projects have utilized trees in the Citrus Variety Collection. The USDA-ARS National Clonal Germplasm Repository for Citrus and Dates (NCGRCD) in Riverside situated adjacent to the collection, uses the Citrus Variety Collection as its field site to help fulfill its mission to acquire, preserve, distribute, and evaluate genetic diversity within Citrus, and the 32 related Aurantioideae genera.

The Citrus Variety Collection also serves as a resource for many extension activities. California citrus growers, nursery owners, and other industry representatives, as well as students and teachers from local public schools, the University of California, and the California State College campuses visit the collection to evaluate potential commercial citrus varieties and learn about citrus diversity. In addition to tours, the staff of the Citrus Variety Collection provides fruit displays and oral presentations on the performance of various citrus cultivars at CRB and UC Cooperative Extension sponsored growers meetings, at the Sunkist Annual Meeting, the World Ag Expo, and the Orange Blossom Festival in Riverside, CA. The fruit for the various fruit displays and the citrus display and tasting at the Riverside Orange Blossom Festival that is visited by thousands each year, is picked from the collection.

In March 2003, the Advisory Committee for the Citrus Variety Collection established an endowment fund for the Citrus Variety Collection with funds from the Foundation account for the Citrus Variety Collection. The goal is that the portion of the endowment fund that is expendable will in the future provide major support for the maintenance and activities of the Citrus Variety Collection as state funds become more limited. If you would like to know more about the Citrus Variety Collection or learn how you can help support the collection, contact Dr. Tracy L. Kahn (909-787-7360 or tracy.kahn@ucr.edu) or visit the Citrus Variety Collection web site: <http://www.citrusvariety.ucr.edu>

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