Chapter

Horticultural Classification of Citrus Cultivars

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Abstract

Globally, citrus fruits are grown over an area of 11.42 million ha with 179.0 million tons production. China with 82.7 m tons production is the major producer of citrus fruits followed by Brazil (18.14 m tons) and India (10.53 m tons) (FAOSTAT, 2019). All commercially used scion and rootstock cultivars belong to the genus Citrus, except kumquats, Fortunella spp., and *Poncirus trifoliata*, which are used as rootstock only all over the world. Worldwide citrus cultivars divided into four, reasonably-well-defined horticultural groups: the Sweet oranges, the mandarins, the grapefruits and the pummelos and the common acid members. The true *or 'biological'* citrus, including species of *Citrus (C. reticulata, C. maxima and C. medica)*, share certain characteristics, however, these are clearly differentiated according to the morpho- taxonomic traits. Hundreds of different citrus cultivars are available. Many varieties were chance finds from natural populations, and not the product of intentional breeding efforts. Other varieties in common use have originated from planned citrus hybridization and breeding efforts from worldwide. Most of the readers will be well acquainted with the cultivated types of Citrus scion and rootstocks. This chapter provides ripening season information for worldwide, farmers/gardeners have had success with citrus in many different regions of world where tropical/subtropical climatic conditions occur.

Keywords: true citrus species and its relatives, commercial cultivars

1. Introduction

Generally, there is a strong demand for citrus varieties of superior eating and processing quality. A shortage of supply of consumer-preferred varieties and high prices are the dominant market forces responsible for the revitalisation of the fresh citrus sector. The general demand is for sweet, low acid fruit, with an aromatic flavor. The shortage of supply has meant the acceptance of a range of varieties, some with marginal quality, which it is expected will have a limited commercial potential. Growing citrus in your own backyard and field can be both enjoyable and rewarding! Beautiful green foliage, fragrant blossoms, and delicious, healthful fresh fruit readily available at your doorstep make citrus excellent garden trees. You can choose a citrus variety according to the climate in your area. While this chapter provides ripening season information for worldwide, farmers/gardeners

have had success with citrus in many different regions of world where tropical/subtropical climatic conditions occur. In general appearance and other respects, the citrus fruits of principal commercial importance fall into four, reasonably-well-defined horticultural groups: the Sweet oranges, the mandarins, the grapefruits and the pummelos and the common acid members. The true *or 'biological'* citrus fruit trees, including species of *Citrus (C. reticulata, C. maxima and C. medica)*, share certain characteristics, however, these are clearly differentiated according to the morpho- taxonomic key of Swingle [1, 2]. Wu et al. [2] found that several named genera (*Fortunella*, *Eremocitrus* and *Microcitrus*) are in fact nested within the citrus clade. These and other distinct clades that they have identified are therefore more appropriately considered species within the genus *Citrus*. The pulp vesicles contain droplets of oil, which are more abundant in Poncirus, Microcitrus, and the papedas. Fruits of the true citrus species are segmented and fruits of the genera other than *Citrus* are smaller than those of Citrus itself.

Fortunella and Eremocitrus have ovaries with three to five locules, each of which has only two ovules, whereas Citrus, Microcitrus, and Poncirus have ovaries with six to eight locules, each of which contains many ovules. Members of the true citrus fruit trees are generally cross and graft compatible with other members of the group [3–5]. Fortunella (Kumquat) trees, leaves, flowers, and fruits are generally smaller than those of Citrus. Kumquats are adapted to climates that are marginally cool for most of the other members of the subfamily Aurantioideae, they require less heat to achieve fruit maturity and have a certain level of winter dormancy [1]. Eremocitrus and Microcitrus are both endemic to the Oceania region. Both differ from Citrus in having dimorphic foliage and free stamens; however, Microcitrus has an ovary with four to eight locules, whereas Eremocitrus has an ovary with three to five locules. The cold hardiness of Eremocitrus stated in Swingle [1] and Swingle and Reece [6] is in error; Eremocitrus can probably tolerate temperatures as low as −5.5 °C, consistent with the original description of the genus in 1914 [3, 7, 8]. Microcitrus, on the other hand, is considered semixerophytic and able to withstand prolonged periods of drought [1, 6]. Trifoliate orange was considered as a mono-typic genus for many years, represented by *Poncirus trifoliata* [1], with distinctive trifoliate leaves (unique among the true citrus fruit trees) and deciduous growth habit. This gives to trifoliate oranges the highest degree of cold hardiness among the true citrus fruit trees, surpassing that of kumquats. The adaptation of Poncirus to cold conditions led Swingle [1] to speculate that the remote ancestor of the true citrus fruit trees originated in a tropical or semitropical climate. While the other genera of the true citrus fruit trees remained in these climates, *Poncirus* (or its ancestors) "migrated" to the temperate climate of Northeastern Asia, during which time it developed the adaptations to colder winters mentioned previously. In addition to cold tolerance, Poncirus exhibits many other characteristics that have been and continues to be used in citrus rootstock breeding, notably disease tolerance (including citrus tristeza virus immunity) and dwarfing. For a more complete utilization of Poncirus, the reader is referred to Krueger and Navarro [3, 9, 10]. Relatively recently, a new species, *Poncirus polyandra*, was published [11, 12], which differs from *P. trifoliata* by its larger leaves, some floral differences, and most notably, being evergreen. Perhaps, this latter characteristic is related to its habitat in Yunnan, the southernmost province of China. Clymenia is a very distinctive member of the other true citrus fruit trees. Clymenia was separated from Citrus by Swingle [1] based upon the structure of the pulp vesicles, which are short, plump, blunt, ovoid or sub-globose, sessile or very short stalked, and attached to the side walls of the 14–16 locules. **Table 1** summarizes the correspondence between the proposed classification and the former most important ones of Tanaka [13], Swingle and Reece [6], and Mabberley [22] revised by Zhang and Mabberley [14]. Commercially

Phylogenomic classification	Tanaka (1961) [13]	Swingle and Reece (1967) [6]	Zhang and Mabberley (2008) [14]	Common names (examples)	Phylo-genomic references
C.cavaleriei H. Lev. ex Cavalerie	*C. ichangensis* Swingle	*C. ichangensis*	*C. cavaleriei*	Adsae	[2]
C. maxima (Burm.) Merr.	*C. maxima*	*C. maxima*	*C. maxima*	Pummelos (Pink, Deep Red, Timor, …)	[2, 15]
C. medica L.	*C. limonimedica* Lush.	*C. medica*	*C. medica*	Etrog citron	[2, 15, 16]
	C. medica			Citrons (Corsican, Diamante, Buddha's hand, Humpang)	[2, 15, 16]
C. micrantha Wester	*C. micrantha*	*C. micrantha*	*C. hystrix* DC.	Small-flowered papeda, small-fruited papeda	[2, 15, 16]
C. reticulata var. austeraSwingle		*C. reticulata* var. austere	*C. reticulata* Blanco	Sun-Chu-Sha-Kat mandarin	[2]
C. reticulata var. tachibanained.	*C. tachibana* (Makino) Tanaka	*C. tachibana*	*C. reticulata*	Tachibana mandarin	[2]
C. × *amblycarpa*	*C. amblycarpa*	*C. reticulata* hybrid		Nasnaran mandarin	[15]
C. × *aurantiifolia* var. aurantiifolia	*C. aurantiifolia*	*C. aurantiifolia*	*C.* × *aurantiifolia*	Mexican, Key, West Indies limes…	[2, 16, 17]
C. × *aurantiifolia* var. macrophyllained.	*C. macrophylla* Wester	*C. aurantiifolia* (Christm.) Swingle		Alemow	[16]
C. × *aurantiifolia* var. auratained.	*C. aurata*Risso	*C. limon* (L.) Burm. f.	*C.* × *aurantium* L.	Adam's apple	[16]
	C. excelsa Wester	*C. aurantiifolia*		Excelsa and Nestour lime	[16]
C. × *aurantium* var. L. var. aurantium	*C. aurantium*	*C. aurantium*	*C.* × *aurantium*	Sour orange, Bouquetier	[2, 15, 16, 18, 19]
	*C. myrtifolia*Raf.			Myrtle-leaf orange, Chinoto	[15]
C. × *aurantium* var. clementinained.	*C. clementina* hort. ex Tanaka	*C. reticulata*		Clementine	[2, 15, 18, 19]

Phylogenomic classification	Tanaka (1961) [13]	Swingle and Reece (1967) [6]	Zhang and Mabberley (2008) [14]	Common names (examples)	Phylo-genomic references
C. × *aurantium* var. deliciosained.	*C. deliciosa* Ten.	*C. reticulata*	*C. reticulata*	Willowleaf, Chios mandarins	[2, 15, 18, 19]
C. × *aurantium* var. erythrosained.	*C. erythrosa* hort. ex Tanaka	*C. tachibana*	*C. reticulata*	Fuzhu and San huhongchu mandarins	[19]
C. × *aurantium* var. kinokuniined.	*C. kinokuni* hort. ex Tanaka	*C. tachibana*		Kinokuni, Kishu, Huanglingmiao mandarins	[2, 19]
C. × *aurantium* var. nobilisined.	*C. nobilis* Lour.	*C. reticulata* hybrid	*C.* × *aurantium*	King mandarin	[2, 15, 19]
C. × *aurantium* var. paradisiined.	*C. paradisi*Macfad.	*C. paradisi*	*C.* × *aurantium*	Star Ruby, Marsh, Duncan, etc.	[2, 15, 17, 19]
C. × *aurantium* var. paratangerinained.	*C. paratangerina* hort. ex Tanaka	*C. reticulata*		Ladu Mandarin	[19]
C. × *aurantium* var. sinensis L.	*C. sinensis* (L.) Osbeck	*C. sinensis*	*C.* × *aurantium*	Sweet oranges (Valencia, Washington Navel, Tarroco, etc.)	[2, 15, 18, 19]
C. × *aurantium* var. suhuiensisined.	*C. suhuiensis* hort. ex Tanaka	*C. reticulata*	*C. reticulata*	Szibat and Se Hui Gan mandarins	[19]
C. × *aurantium* var. tangerinained.	*C. tangerina* hort. ex Tanaka	*C. reticulata*	*C. reticulata*	Dancy, Beauty mandarins	[2, 15, 19]
C. × *aurantium* var. temple ined.	*C. temple* hort. ex Yu. Tanaka	*C. sinensis*		Temple tangor	[19]
C. × *aurantium* var. unshiuined.	*C. unshiu* Marcow.	*C. reticulata clone*	*C. reticulata*	Satsuma mandarins	[2, 15, 17, 19]
C. × *latifolia* var. nov. 1				India lime	[16]
C. × *latifolia* var. nov. 2				Kirk lime	[16]
C. × *latifolia* var. latifolia	*C. latifolia*	*C. aurantiifolia*	*C.* × *latifolia*	Bears, Tahiti, Persian limes	[16]
C. × limon var. bergamiained.	*C. bergamia*Risso and Poit.	*C. aurantiifolia*	*C.* × *limon*	Fantastico, Femminello, Castagnaro bergamots	[16, 17]
C. × *limon* var. meyeriiined.	*C. meyerii* Yu. Tanaka	*C. limon*	*C.* × *limon*	Meyer lemon	[16]

Phylogenomic classification	Tanaka (1961) [13]	Swingle and Reece (1967) [6]	Zhang and Mabberley (2008) [14]	Common names (examples)	Phylo-genomic references
C. × *limon* var. limettioidesined.	*C. limettioides* Tanaka	*C. aurantiifolia*		Palestinian and Brazil sweet limes and Butnal sweet lemon	[16, 17]
C. × *limon* var. limettained.	*C. limetta* Risso	*C. limon*		Marrakech limonette	[16]
C. × *limon* var. limon (L.) Burm. f.	*C. limon* (L.) Burm. f.	*C. limon*	*C.* × *limon*	Lemons (Lisbon, Eureka, Verna, Luminciana, Interdonato, etc.)	[2, 16]
C. × *limonia* var. nov. 1				India sweet lime, Indian lemon	[16]
C. × *limonia* var. jambhiriined.	*C. jambhiri* Lush.	*C. limon*	*C.* × *taitensis*Risso	Rough lemon	[2, 16, 17]
C. × *limonia*Osbeck var. limonia	*C. limonia*	*C. limon*		Rangpur lime	[2, 16]
	C. karna Raf.			KhattaKharna lime	[16]
C. × *limonia* var. nov. 2				Voangiala	[16]
C. x limonia var. volkameriana Pasquale	*C. limonia* Osbeck	*C. limon*		Volkamer lemon	[16]
C. × *lumia* var. nov. 1				Bitrouni lime	[16]
C. × *lumia* var. nov. 2				Fourny hybrid	[16]
C. × *lumia* var. lumia	*C. lumia* Risso and Poit.	*C. limon*		Jaffa lemon	[16]
C. × *lumia* var. pyriformis ined.	*C. pyriformis* Hassk.	*C. limon*	*C. maxima*	Ponderosa lemon	[16]
C. × *microcarpa*	*C. madurensis* Lour.	*C. reticulata* hybrid	*C.* × *microcarpa*	Calamondin, Calamansi	[16]
C. × *pseudolumia*ined.				Borneo, Barum, Baboon lemons	[16]

Reference: [20, 21].

Table 1.
Correspondences between the new phylogenomic classification and the former classifications of Tanaka, Swingle and Reece, and Mabberley revised by Zhang and Mabberley.

grown citrus trees such as the varieties discussed in this publication are not grown from seed but are grafted or budded onto a seedling of a rootstock variety. Varieties that are used as rootstocks provide a number of important qualities to the entire tree such as disease tolerance, cold hardiness, soil adaptation, and, to a certain degree, tree size. In the world, most citrus nurseries do not label or identify the rootstock of a tree, but they do select rootstocks that protect trees from important diseases of commercial citrus and are adapted to a range of regions and soil conditions.

2. Varietal groups

Four main varietal groups are distinguished in the international market:

2.1 *Citrus sinensis* (L.) Osbeck

Sweet orange is the main group which is used both for fresh fruit and processing. It probably originated in China but its major center of diversification is the Mediterranean Basin (**Figure 1**). Major cultivars in this group are classified as navel oranges (Washington Navel, Navelina, Navelate, Powell, Rhode Navel, Cara Cara), blonde oranges (Shamouti, Valencia Late, Hamlin, Pineapple, Trovita, Salustiana, Delta Valencia, Pera), and blood oranges (Tarocco, Moro, Sanguinelli, Maltese).

2.1.1 Navel oranges

Washington (Riverside, Bahia, Baia or Baiana): Is considered to be a limb sport of a variety 'Selecta' in Bahia, Brazil. Tree medium in size and vigor, crown round topped, anthers are without pollen. Rind medium thick tender flesh deep orange, firm less juicy, rich in flavor and taste. Processing quality poor, ships and stores well. Seedless.



Figure 1.
Sweet orange varieties.

Navelencia: In growth characters is less vigorous than Washington. Flesh light in color (as rind) firm more juicy, flavor good more than Thompson. Fruit matures earlier than Washington and after Thompson, and hangs well on tree, almost seedless.

Thompson: Limb sport of Washington. Tree compact semi dwarf type, less in vigor than Washington. Rind and flesh less colored, rind smooth glossy pitted finely, flesh firm more juicy, taste and flavor good. Ripens early, seedless.

2.1.2 Blonde oranges

Shamouti (Palestine Jaffa, Jaffa, Chamouti): Tree upright moderate in growth and vigor, branches thick and thornless, petioles with narrow wing. Rind thick leathery smooth pitted, oil glands faint, flesh light orange, firm juicy fragrant and sweet in taste, peels easily. Shipping and storage very good. Mid-season cultivar. Seedless or nearly.

Valencia (Valencia Late, Hart's Tardiff, Hart Late): Has wide adaptation with alternate bearing, tendency to be heavy cropper. Tree large upright vigorous. Matures late. Storage and transportation qualities are very good and hangs well on trees. Seeds few to none.

Hamlin (Norris): Originated as chance seedling and named after the owner of the orchard AG Hamlin. Tolerate cold better than most oranges, productive. Tree medium large with moderate vigor. Matures very early in the season, seeds few to none.

Pineapple: Chance seedling very sensitive to frost, very productive and excellent for processing. Tree medium large with moderate vigor. A mid-season ripening cultivar. Has two limb sport which are seedless. Seedless Pineapple and Blaquemines.

2.1.3 Pigmented or blood oranges

This group of oranges differ from the common sweet orange in that the fruit generally has pink or red coloration on the rind, in the flesh and juice and also has distinct flavor.

Ruby (Ruby Blood): This cultivar was introduced from Mediterranean region. Plants are compact, not very large, moderate in vigor and production. Ripens in mid-season. Rich in flavor and few seeds.

Spanish Sanguinelli (Syn. Sanguinelli, SanguinellaNegra): Originated as a limb sport of Doblefina. Tree foliage light green, spineless, productive small medium in size. Fruit large very attractive with persistent style, late to mid-season in maturity, shipping and storage qualities very good.

Torocco (Tarocco dal Muso, Taracco di Francofonte): An Italian cultivar. Tree medium in size, irregular in bearing but moderate production. Fruits are quite large, variable in shape. Shipping and storage quality good and has mid-season maturity, does not retain quality if left for long on trees. Seeds few to none.

Doblefina (Oval Sangre, Blood Oval): Tree small poor in growth, branches spreading, crown open, foliage light green. Precocious and heavy bearer. Shipping, storage quality good but does not hang well on tree, almost seedless.

Blood Red (Blood Red Malta): Origin unknown probably came from Mediterranean basin. Grown widely and commercially in India and Pakistan. Good coloration is generally attained in the submountain region.

Maltaise Sanguine (Portugaise): Origin of this variety is uncertain but the Egyptian variety Baladi Blood introduced from Malta is said to be Maltaise Sanguine. Likewise Maltase Blood and Bloodred Malta seems to be a clone of this cultivar.Trees are very productive, medium large moderate in vigor. Rind soft easy to peel, taste and flavor excellent, seeds few, storage and shipping quality poor.

2.1.4 Sugar or Acidless oranges

Maltaise Meski: Originated in Tunisia, a non-acid orange cultivar. For all plant, foliage, flower and fruit characters it is like the parent cultivar Maltaise Blonde.

Shamouti Maski or Shamouti Moghrabi: It is a Labenese cultivar which is indistinguishable from Shamouti (Palestine Jaffa) baring that it is acid less (insipid in taste) and more seedy in nature.

2.1.5 Other sweet oranges

Jaffa (Florida Jaffa): It is a clone of Palestine beledi seedling group. Flesh pale orange, tender juicy with pleasant flavor, seeds few. Has good shipping quality but does not hang well on tree.

Joppa: Resembles Jaffa for number of characters and is different in that it starts bearing early and prolifically, branches are stiff and thornless, branchlets are stout. Flesh light orange, soft juicy with rich aroma. Mid-season cultivar, seeds few.

Foster: Tree medium in growth semi spreading foliage dense. Seeds large oval, maturity mid to late season.

Marrs (Marrs Early): Precocious and heavy bearer matures very early. Flesh orange well colored juicy, sweet in taste, acid very low. Fruits hang well on tree and maintain the quality. For good quality and high juice picking should be delayed. Seeds moderate in number.

Parson (Parson Brown): Originated as a chance seedling. It is an early maturing and relatively more seedy. Trees are large vigorous and productive. Rind pitted and pebbled moderately, flesh orange, firm juicy highly flavored.

2.1.6 Indian continents

In India, Mosambi and Sathgudi are invariably placed under sweet oranges as the acid content is very low.

Mosambi (Mosambique): A very popular variety grown commercially in India, early in maturity. Rind quite thick, stripes faint with longitudinal ridges and grooves. Flesh light yellow juicy, acid low, tastes insipid, seeds few.

Sathgudi: Origin is unknown and a popular cultivar grown extensively in India. Tree vigorous produces moderately. Flesh orange, juicy flavor fair sweet in taste, acid very low, mid-season cultivar, moderately seedy.

2.1.7 Sequenced oranges

Chinese box orange (*Severinia buxifolia* (Poir.) Tenore) is native to China and grows as a compact tree or a small shrub. Among the trees related to citrus is the hardiest one. It produces small fruits that have no commercial value and it is used as an ornamental species (IVIA-147).

Amber sweet orange, [(An unnamed hybrid of Clementine mandarin x Orlando tangelo) x unnamed midseason sweet orange seedling], is a variety released by the USDA because of its resemblance to sweet orange, early maturity and deep flesh color. It is the only such hybrid ever legally designated as a "sweet orange", so that its juice could be used to blend with true sweet orange juice, according to juice industry regulations in Florida. All other known sweet oranges are derived only by somatic mutation, not by sexual hybridization, so Amber sweet is not a true sweet orange [23, 24]. There is one true sweet orange (*C. sinensis*) from which many somatic mutants are derived, including Washington navel and blood

orange. The Amber sweet orange is a mandarin x sweet orange hybrid, and not a true sweet orange, as noted above.

2.1.7.1. Sour oranges

Wu et al. [2] reserved the name "sour orange" (*C. aurantium*) to refer to the genome from which cultivar Seville and other somatic mutants are derived. It is the maternal parent of lemon (*C. limon*). The two sour oranges from South China [24] represent two different genomes both unrelated to sour orange (*C. aurantium*).

2.2 Lemon and lime

Lemon and limes are included in the second group. Two main types of limes are distinguished: the small diploid and seedy lime (Mexican) and the big seedless triploid lime (Tahiti, Bears). Several lemon cultivars having major contribution in the world production include Lisbon, Verna, Eureka, Feminello, Fino and Primofiori.

2.2.1 Lemon (C. limon*)*

There are some distinct fruits in which lemon characteristics are evident, however the differences are to such a magnitude which warrants their separate characterization and classification. In this group, the most important are the karna, the galgal or hill lemon and jambhiri or rough lemon and all of them are widely grown in India. Meyor lemon and the limettas are also lemon like fruits, described below.

Hill lemon (Galgal) C. pseudolimon: An ancient Indian citrus whose origin is unknown and is commonly called as hill or kumaon lemon, grown extensively in the submountain areas along the foothills of Himalayas and in Punjab as a substitute for lime or lemon. It is indigenous to North India grown in sub-Himalayan region. Plant is tall, vigorous, upright and spreading with an irregular and loose crown, fruit ovate oblong, yellow, apex nipped, base rounded or nippled, rind medium, axis hollow, segments 7–11, seed 25–50. Ripening during October–December.

Karna (*C. karna* Raf): Karna Khatta, Karna Nimbu, Khatta Nimbu. A very old Indian citrus fruit of unknown origin, moderately polyembryonic. Considered to be a natural hybrid between rough lemon and sour orange, as the characters exhibited resemble the two species. Widely employed as a rootstock in northern India, second only to rough lemon. Flowers and fruits only once a year. Rind quite thick adhere tightly, golden yellow to deep orange, smooth or ribbed. Flesh orange, texture coarse, semidry, acidic in taste, flavor sour orange like. Seedy, cotyledons white.

Rough Lemon (*C. jambhiri* Lush.), Jatti Khatti, Lemon, Citronelle [Red rough lemon (*C x jambhiri* (Lush)) Wu et al. [2]. The species is regarded to be native of Himalayan foothills in India, where even today it grows wild. It was thought to be a natural hybrid between citron and lemon. However, Wu et al. [2] was reported that it originated from an F_1 cross *C. reticulata* x *C. medica* by whole genome sequence comparison and is not a true lemon. It is presumed that Portuguese while returning home introduced it in the southeast Africa. Later towards the end of the fifteenth or early sixteenth century it was brought to Europe from where it reached new world. Fruits are acidic, medium sized, shape variable, usually oblate to elliptic oblong. Rind lemon yellow to brownish orange in color, medium thick, surface typically deeply pitted, bumpy (sunken oil glands) deeply pitted or ribbed, separates readily. Flesh pale yellow to pale orange, acidic in taste, juice moderate, segments 10, hollow and large. Seeds many, small highly polyembryonic, cotyledons light green in color.

Eureka (*C. x limon* L. (Burm. f.))**:** Carvalho et al. [25] were sequenced cultivar Eureka and related somatic mutants. Its seed parent is sour orange and pollen parent

is an unknown citron. It is one of the most important commercial varieties around the world [2]. It is seedling selection of Sicilian lemons. Tree is medium, spreading and having few thorns. Its fruit color is lemon yellow, surface rugose, pitted, shape obovate, size medium, apex round, rind medium thin axis small, solid, segments 8–10, juice acidic with excellent flavor and quality. Eureka is heavy yielder and begins bearing at early age. It has tendency of tip bearing. Rind semi thick pitted, oil glands sunken. Fruiting more in winter, spring and early summer. Seeds few to none.

Lisbon: Originated in Portugal. Its appearance and yield is superior to Eureka. It is resistant to frost, heat and high wind velocity. Tree is large and vigorous with spreading shoots. It has upright thorny growth, lemon yellow fruit color, smooth surface, medium size, pitted rind, small axis, solid, 6–10 segments with 0–8 seeds. Rind quite thick adherence tight, pitted surface smooth and less ribbed than Eureka.

Lucknow seedless: It is hardy, medium, vigorous, spreading drooping, dense foliage, thorny, fruit color yellow, smooth, nippled apex, base round, thin rind, hollow axis, segments 10–12 maturity during November–February.

Plant lemon: Fruit size medium, juicy, heavy fruiting, tolerant to pests and diseases.

Villafranca lemon **(CRC 280)**: It belongs to Eureka group and was introduced into Florida from Europe in about 1875. Originated in Sicily. Commercially not very important compared to Eureka and Lisbon. Tree characters resembles to that of Lisbon, but the plants are more erect or upright in growth, foliage less and with few thorns. In fruit characters, it is similar to Eureka but fruits more during winter like Lisbon.

Nepali oblong (Assam, Nimber or Pat Nebu): An ever bearing lemon cultivar. Plant medium sized, hardy, spreading drooping with irregular crown, fruit shape oblong, color lemon yellow, segments 10–12, the fruit ripen during December–January. Rind relatively thick, greenish yellow, glossy and smooth. Flesh fine grained, greenish yellow, juicy, not too acidic, seeds none to few.

Meyer lemon: Flowers throughout the year, but more so in spring. Tree semi dwarf, thornless, spreading, cold resistant, fruit color light orange, smooth surface, finely pitted, shape obolate or oblong base rounded, rind thin, axis small, 8–10 segments and 8–12 seeds. Rind thin, adhere tightly, surface smooth yellowish orange to orange, flesh light orange yellow, soft, very juicy and typical lemon flavor.

2.2.2 Limes

Like the citron and lemon, the limes likely have originated in north eastern India. Limes are generally of two forms- Small fruited acid limes (*C. aurantifolia*), West Indian lime and the large fruited acid limes (*C. lantifolia*). In its natural habitat, several forms are recognized which differs markedly in size, form, shape, spine and seediness character etc. The West Indian or Mexican lime is the Kagzinimbu and has number of vernacular names. Australian desert lime (*Eremocitrus glauca* (Lindl.) Swingle, *C. glauca* (Lindl.) Burkill) is native to Australia and produces fruits of sour taste that can be used as condiment. It is drought tolerant and has very few soil requirements (UCR-12B-38-01). Eremorange, Australian desert lime hybrid (*Eremocitrus glauca* x *C. sinensis*) (SRA-871). Australian finger lime (*Microcitru saustralasica* (F. Muell.) Swingle, *C. australasica* F. Muell), native to Australia, develops elongated finger-shaped fruits of different colors. Juice vesicles that can be broken down and separate very easily are of sharp acid flavor. It is used as a food seasoning (UCR-18B-16-04). Australian finger lime is an accession that we find has Australian round lime admixture. BC2 backcross. (SRA-1002). Australian round lime (*Microcitrus australis*, (Swingle), *C. australis* (A. Cunn. ex Mudie)) native to Australia produces rounded green fruit although at full maturity they become yellow. The pulp has low cohesive juice vesicles as the Australian finger lime. It is used as a food seasoning (UCR-18A-32-01).

Acid lime (*C. aurantifolia* (Christm.) Swingle.)*:*

West Indian (Mexican sour lime): It is native of India and widely cultivated in the tropics. Rouiss et al. [26] reported that it is a natural hybrid between micrantha and citron. It is tenderest species among all the citrus species. Tree medium sized, hardy, semi vigorous, upright growth, thorny, fruit round to oblong, yellow apex rounded and slightly nippled, base round, rind thin, papery, 8–10 segments and seeds both. Rind thin, surface fine, smooth, adhere tightly, greenish yellow. Polyembryonic with few seeds, aroma characteristic, flesh greenish yellow, fine, soft juicy, very acidic.

Tahiti lime (Persian lime) C. lantifolia.

Cold resistant, same as that of lemons. It is large fruited acid lime. Flowers throughout the year more in spring. Purple pigmentation present on shoot and flowers. The plants are large, spreading, cold resistant, thornless, fruit large, seedless, triploid and produce non-viable pollen. It is considered as hybrid between lime and lemon. Fruit color orange yellow, smooth surface and 8–10 segments. It is late variety. Rind thin lemon yellow, adherence tight, flesh greenish yellow, tender juicy acidic. Usually 10 segments.

Rangpur lime (C. limonia* Osbeck):***

Rangpur lime (*C. x limonia* (Osbeck)) produces non-commercial small and very acidic fruits of orange color. It is indigenous to India and is commonly used as rootstock. Rangpur lime is mainly grown for home consumption and ornamental purpose [2]. Fruits are used for making limeade. It is also known as Marmalade orange. It has loose rind, easily separable segments and pulp is light orange yellow. It is very cold hardy.

Sweet lime (C. limettioides):

In north-eastern India to which it is native it is said that sohsynteng of Assam is the acid form of this fruit. Like acid limes, the Indian sweet lime is the mithanimbu and number of its forms differing in fruitfulness, fruit shape, size and with or without nipple etc. are easily recognized. Generally, sweet lime is grown as a rootstock and for its non-acidic fruits.

Vikram: It was developed at MAU, Parbhani, fruit medium size, heavy fruiting, fruit color golden.

Pramilini: It was also developed at MAU, Parbhani, high yielder, golden fruit color, tolerant to canker.

Sai Sarbati: It was developed at MPKV, Rahuri, high yielder, suitable for summer cropping, tolerant to canker and tristeza.

Jai devi: It was developed at FRS, Periakulum, high yield, juicy, thin peel and pleasant aroma.

2.3 Mandarins

The easy peeling mandarins are becoming more important in the fresh fruit market. Principal in importance in the Orient are the Mandarins, a large, distinctive, and highly varied group that includes some of the finest and most highly reputed citrus fruits. These fruits are commonly referred to as loose-skin oranges. Clementines are the most important mandarins in the Mediterranean Basin, while Satsumas predominate in Japan. Other commercial mandarins include intraspecific or interspecific hybrids such as Fortune, Kinnow, Minneola and several chance seedlings such as Ponkan, Ellendale, Ortanique, Murcott, and Nadorcott (**Figure 2**). In the United States, where the name tangerine first came into common usage, mandarin and tangerine are used interchangeably to designate the whole group. Since mandarin is the older and much more widely employed name, its use is clearly preferable. Presumably because of the orange-red color of the Dancy variety, which originated in Florida and was introduced in the markets as the Dancy tangerine, horticulturists have tended to restrict the use of term tangerine to the mandarins of similar deep

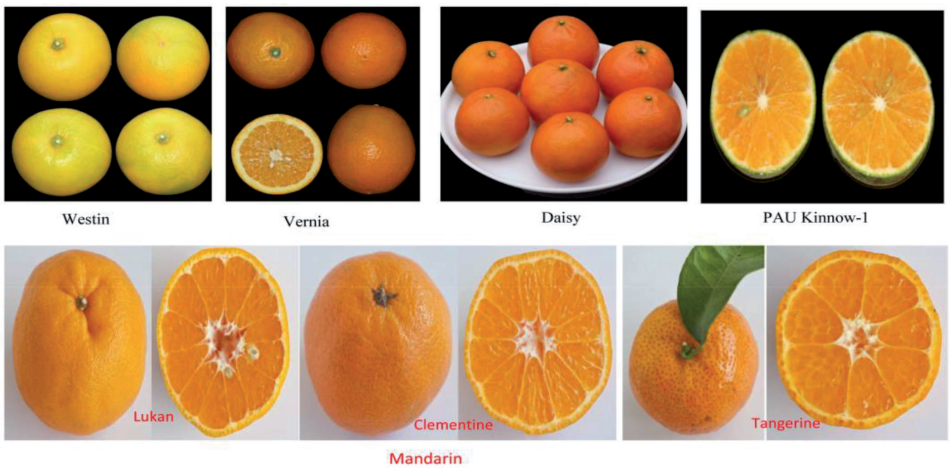


Figure 2.
Mandarins varieties.

color. Tangerine is applied more strictly to those varieties which produce deep orange or scarlet fruits. Mandarin is known as the mikan of Japan, the suntara or sangtra (numerous modifications) of India, mandarino of Italy and Spain and the mandarine of French-speaking countries.

Due to remarkable diversity of mandarins and the writer's lack of firsthand knowledge of many of the Oriential members, considerable difficulty was experienced in developing a satisfactory horticultural classification for this group. Webber (1948) has separated the mandarin oranges into (a) King group (b) Satsuma group (c) Mandarin group (d) Tangerine group (e) Mandarin-Lime group (f) Mitis group. In this treatment, therefore, the mandarins are presented as the following classes.

2.3.1 The Satsuma mandarins

The Satsuma mandarins (unshiu) mandarin, cv. Owari (UNS) (*C. unshiu* [(Mak.) Marc]; *C. reticulata* (Swingle)) is a commercial midseason, sterile and parthenocarpic, easy peeling mandarin. Satsumas are a group of commercial varieties with relatively high tolerance to low winter temperatures. It is a Japanese variety that was introduced in Florida in 1876. It is also resistant to canker, gummosis, scaly bark and melanose. Plant is thornless having spreading growth habit, orange fruit color, rough surface, oblate to spherical shape, medium size, thin and easily separable rind, flavor rich and seedless. Ripens early than any other oranges as its heat requirement is very low. Number of segments is 10–12, axis hollow and capillary membranes are loose. Fruits should be picked quickly when mature otherwise quality deteriorates and it stores well.

2.3.2 The King mandarins

The King mandarins (C. nobilis (Lour.), C. reticulata (Swingle)) is thought to be a natural tangor, i.e., a hybrid between mandarin and orange, that originated in Vietnam. However, this conventional wisdom is evidently wrong, as Wu et al. [2] was reported that whole genome sequence analysis shows that sweet orange is not a direct parent of King mandarin. King mandarin was first introduced from Cochin China into California in 1882. The king is a prolific bearer, frost resistant and

produces high quality fruit. Fruits have had much commercial interest since they are large, develop good flavor when ripe and are of late harvest.

2.3.3 Tachibana mandarin

Tachibana mandarin (*C. tachibana* (Mak.) Tanaka, *C. reticulata* (Blanco)) is thought to be native to Japan and surrounding islands. It develops easy peeling, small fruits of pale-yellow-orange color and acid flavor. Although taste is not completely unpleasant the fruit is not palatable.

2.3.4 Sunki mandarin

Sunki mandarin (sour mandarin, suanju) (C. sunki (Hayata, Hort. ex Tanaka, C. reticulata (Blanco)) produces easy peeling, very acidic small fruits, of an attractive orange color. Its fruits are not palatable and the plants are used as rootstocks.

2.3.5 Cleopatra mandarin

Cleopatra mandarin (C. reshni (Hort. ex Tanaka), C. reticulata (Blanco)) is native to India. It produces unpalatable, small and very acidic fruits. It is widely used as a salt tolerant rootstock and also as an attractive ornamental because of the deep red color of the peel. Plant is thornless with dense top. Fruits are produced singly or in bunch, fruit color is dark orange red, shape oblate, flattened at both ends, size is small with12–15 segments.

2.3.6 The Mediterranean mandarins

The Mediterranean mandarins (C. deliciosa Tenore), which is of principal importance in the Mediterranean Basin. It differs from other mandarins as seeds are plumb and spherical, leaves are small narrow lanceolate and aroma of oil glands and juice is very aromatically flavored.

Willow leaf mandarin (C. deliciosa): The tree is willowy in growth, almost thornless, fruits usually born singly at the tip of slender branches. Fruit color orange, surface smooth, glossy, frequently slightly lobed, necked base, apex depressed, wrinkled, rind thin with 10–12 segments. It is an early variety. Trees are cold hardy but at the ripening time rind separates rapidly and lacks storage ability.

2.3.7 The common mandarins

The common mandarins (*C. reticulata* Blanco), which have worldwide importance and are represented by numerous varieties.

2.3.8 The small-fruited mandarins

The small-fruited mandarins, which are of considerable importance in the Orient and consist of many varieties.

2.3.9 Clementine (Algerian Tangerine)

Clementine (Algerian Tangerine) C. clementina Hort.ex Tanaka: It is a tangerine and is probably an accidental hybrid of the mandarin and sour orange which originated in Algeria. Fruit color is deep orange, shape globose to elliptical, size medium

with depressed apex, rind thick and segments are 8–12, adhered slightly. It is an early variety. Cotyledons are green in color and seeds are monoembryonic.

2.3.10 Kishu mandarin

Kishu mandarin (Kinokuni mandarin) (*C. kinokuni* Hort. Ex Tanaka). The seeded form of this small tangerine grows in southern China and also in Japan, where it was introduced. We sequenced the seedless mutant known in Japan as Mukakukishu; sweet, juicy, and easy to peel, it is appreciated because of its pleasant taste and wonderful aroma. Whole genome sequence comparison shows that it has the same base genotype (i.e., is a somatic mutant of) Huanglingmiao1 mandarin.

2.3.11 Dancy mandarin

Dancy mandarin, Dancy tangerine (*C. tangerine* (Tanaka), *C. reticulata* (Swingle)) is an easy peeling commercial late harvesting variety of excellent color and good size and perdurability on the tree. Originated in 1867 from a chance seedling. In USA, dancy is the best known and highly prized of all the mandarin oranges. Tree is large, nearly thornless and has upright growth. It has tendency towards alternate bearing and seeds are polyembryonic.

Fallglo [Hybrid of Bower mandarin (Clementine mandarin x Orlando tangelo) x Temple tangor, a presumed mandarin-sweet orange hybrid of unknown parentage], a seeded, early maturing and large fruited mandarin hybrid, developed by the USDA and produced primarily in Florida, USA [24].

2.3.12 Calamondin (C. madurensis *(Lour.))*

Calamondin (C. madurensis (Lour.))**:** Tanaka has recognized it as a loose skinned orange group. It has less value as a fruit but hangs well on tree and is widely used as an ornamental fruit. It is very cold resistant true citrus fruit and as hardy as Satsuma. Fruit color is orange to deep orange, smooth and glossy surface, pitted shape oblate, size small with flattened base having 7–10 segments.

Sun Chu Sha Kat mandarin (*C. reticulata* (Blanco), *C. reticulata* var. austere (Swingle), *C. erythrosa* (Tanaka)) is characterized by small flowers, small but narrow leaves and small fruits. These are broader than long, peel color may change from yellow to deep red and taste is acidic or acidic-sweet. It is used as rootstock.

Changsha mandarin (*C. reticulata* (Blanco)) produces small, juicy, puffy, brilliant orange-red and seedy fruit. The taste is sweet or acidic-sweet. The tree is rather tolerant to frost and yields heavy crops. It is also grown as an ornamental (UCR-12B-23-07).

Wilking [It is a sister hybrid of Kinnow mandarin both having King mandarin x Willowleaf mandarin parentage], developed by the University of California, Riverside in 1915. Fruit are small, quite fragrant and richly aromatic. Because it produces monoembryonic (zygotic) seeds, it has been used in breeding programs, but not grown commercially to any great extent [24].

Feutrell's early: It is an old variety of New South Wales. Its parents are unknown. The fruit characteristics indicate that it may be a natural tangore and those of the three suggest the possibility that medaterian or Willow leaf might have been the mandarin parent.

Coorg orange: It is an important variety of South India particularly in Coorg and Wynad tracts. Fruits are medium to large, bright orange color, oblate to globose in shape, finally papillate and winkled, glossy with 9–11 segments.

Deshi mandarin (Pathankot): This variety is mainly grown in Punjab hills. The tree is large with semi-upright growth habit with compact foliage and spineless.

Fruit is ovoid to sub globose, color uniformly cadmium, surface pitted, semi glossy and finally wrinkled, rind medium, adherence slight with 7–10 segments.

Khasi mandarin: It is commercial variety of Assam. Fruit is depressed, globose to oblate, orange yellow to bright orange, surface smooth, glossy, base even or obtuse, rind thin, soft and 8–10 segments.

Nagpur santra (Ponkan, Warnucro): This variety occupies premier position in Indian market and is one of the finest mandarins grown in the world. It is also known as Ponkan. Tree is large, vigorous, spineless with compact foliage. Fruit size is medium, cadmium color, smooth surface, glossy, rind thin, soft, and slightly adhered with 10–12 segments.

Kinnow mandarin: It is first generation hybrid between the King and Willow leaf mandarin that was developed by H.B. Frost at the California Citrus Experiment Station in 1915. It was introduced into Indian Punjab from USA. Tree is vigorous, large, top erect, dense symmetrical with few scattered thorns. Fruit color resembles of King, deep yellowish orange, surface smooth, glossy, very shallow pitted, shape slightly oblate, size medium with flattened base, rind thin, peel tough and leathery, 9–10 segment easily separable and 12–24 seeds. It is a late variety, cold resistant, has strong alternate bearing tendency and seeds are polyembryonic.

PAU Kinnow-1: It is bud mutant of Kinnow mandarin and is low seeded compared to Kinnow.

Tengors: The mandarin-like fruits include the synthetic tangors; the so-called natural tangor, Temple. Kiyomi [Hybrid of Miyagawa-wase satsuma mandarin x Trovita sweet orange], developed by the Okitsu Branch Fruit Research Station, now known as the Okitsu Citrus Research Station, National Institute of Fruit Tree Science. This is a large fruited juicy tangor, with aroma closely resembling sweet orange, and is seedless in the absence of cross pollination. It produces abundant monoembryonic (zygotic) seeds when cross pollinated and has been used as a scion breeding parent in Japan and elsewhere [24].

Temple mandarin: It is a hybrid between Tangerine and sweet orange. Temple mandarin is most beautiful and highly flavored fruit of the citrus group. Tree is medium, thorny, spreading with deep orange to reddish fruit color, rugose glossy surface, medium to large, depressed or nearly flat apex, loose rind, solid axis with 10–12 segments and orange pulp. It is late in maturity.

Dweet: Evolved from a cross between Mediterranean Sweet Orange and Dancy Tangerine. Late in maturity. Tree character intermediate of the two parents. Fruits do not hang well on tree. Fruit reddish-orange in color, globose-oblate, neck distinct, medium to large, surface pebbled. Rind adherence tight and peels very poorly, also puffs, flesh orange, firm very juicy, flavor rich, seeds numerous.

Mency: Originated from a reciprocal cross of Dweet. Fruits ripen early, do not hang well on tree, susceptible to sunburn, small, reddish orange, somewhat oblate and necked, surface pebbled due to oil glands. Rind adherence is not tight and peels easily. Flesh is orange colored and juicy with acidic flavor. Seeds are many.

Tangelos: The mandarin-like fruits include the synthetic tangelos; the so-called natural tangelo, Ugli. Hybrids of mandarin, grapefruit and pummelo are designated as tangelos. They exhibit characters of both the parents.

Clement: It is a hybrid between Duncan grapefruit and Clementine mandarin. Tree and foliage characters are intermediate and productive. Fruit is subglobose to oblong, light orange yellow in color and medium large. Rind is quite thick, pebbled and peels easily. Flesh is dull yellow soft and moderately sweet. Fruit is early to medium in ripening.

Minneola: It is hybrid of Duncan grapefruit and Dancy tangerine. Less cold hardy than Orlando, requires cross pollination for regular and higher yields. Maturity midseason. Rind deep reddish orange, smooth, medium thick, adherence moderate, surface pitted.

Orlando: A hybrid of Duncan grapefruit x Dancy tangerine. Early in maturity. Fruit broad oblate to subglobose without neck, medium large. Rind, thin orange in color, adherence quite tight, does not peel easily, pebbled. Flesh orange, very juicy tender, somewhat sweet seedy.

Seminole: Parentage is same as that of Orlando and Minneola. More fruitful. Late in maturity, trees are productive, medium large, leaves small to medium, rounded and cupped. Fruit broad oblate deep reddish orange in color. Rind adhere moderately, thin, pebbled, peelable, axis usually hollow. Flesh dark orange, juicy soft, somewhat acidic in taste, seedy.

Page: An early ripening cultivar obtained from a cross between Minneola tangelo x Clementine mandarin.

2.4 Grapefruit and Pummelo

The last group is grapefruit which is divided into the yellow flesh cultivars (Marsh, Duncan) and the red flesh cultivars ('Hudson', 'Star Ruby', 'Ray Ruby' 'Rio Red'). In the Southeast Asia and the Pacific, pummelo (*C. maxima*) and many traditional local mandarin cultivars are still important in the domestic market.

2.4.1 Citrus paradisi *Macf. Grapefruit*

It is closely related to pummelo, originated in Barbados (West Indies), as old records refer to 'forbidden fruit' (**Figure 3**). It has become popular as a breakfast fruit because of its typical flavor and mild bitterness of the juice. Grapefruit is regarded to be either an interspecific hybrid of pummelo and sweet orange or a hybrid or a mutant of pummel Wu et al. [2]. Seeds are polyembryonic. The fruit is also called as small shaddock, obtained from pummelo, and the name has been derived from the fact that it bears in clusters, and flower resemble that of grape. Like pummelo, grapefruit is also of two types- the common and pigmented grapefruits. The varieties obviously differ in a number of characters i.e., maturity time, seedless or seedy and flavor etc. Important cultivars grown worldwide are described briefly. It is a hybrid between a pummelo and sweet orange. The Cocktail grapefruit is not a true grapefruit.

Common Grapefruit Varieties:

Marsh: (Syn. White Marsh, Marsh seedless, (*C. x paradisi* (Macfadyen)). It is most extended varieties of grapefruit, originated as a chance seedling around 1860



Figure 3.
Grapefruit varieties.

in Lakeland, Florida. It is a late-ripening, self-incompatible variety that shows long tree storage capability and very good behavior during postharvest. It comes under pallid pulp group of grapefruit. It is bud sport from cultivar Marsh. Fruit color light yellow, surface smooth, shape oblate to globose, size medium to large, basal area small, rind thin, segments 12–14 and 2–5 seeds. It is a late cultivar. Cultivars more significant value is its seedlessness character and its late ripening. Fruit medium sized, spherical or oblate, light yellow, areole ring almost absent. Rind surface even, smooth semi thick, flesh light yellow, soft very juicy, with pleasant flavor, but less than that in seedy cultivars. Has very good storage quality and fruit hangs for long on the tree. Seeds few to none.

Duncan: It was developed as chance seedling in Florida. It is the hardiest variety for cold, fruit color yellow, surface smooth, shape oblate to globose, size large, basal area depressed, apex round, rind medium thick, firm, axis medium in size segments 12–14 and 25–50 seeds. Plants are large, very vigorous and productive early to medium in ripening and also among the few which are cold hardy. Rind surface even/ smooth, glossy, medium in thickness. Flesh light yellow/ buff, soft very juicy, flavor very characteristics strong and pleasant.

Pigmented Grapefruit Cultivars

Foster (Foster Pink): It belongs to pink or red pulp group and originated as bud sport of Walters grapefruit by R.B. Foster in 1906–1907. Fruit color is light yellow, surface smooth, oblate or globose shape, size medium large, base rounded, apex round, rind medium thick with 12–15 segments and 50 or more seeds. It matures during November–December. Cultivar is said to be the first pigmented grapefruit variety that ripens in mid-season, originated as a limb sport of cv. Walters. Fruit medium large in size, round flat to spherical, light yellow overlaid by pink blush, which is also seen in the albedo (mesocarp), areole inconspicuous, furrows at base are small and diverging. Rind smooth, medium thick, flesh light yellow, pink under favorable conditions, soft, flavor good.

Red blush (Syn. Ruby, Red Marsh, Red Seedless): It belongs to pink or red pulp group. It originated as bud sport from Thompson. Deep red color which uniformly distributed throughout pulp. Fruit resembles Thomson for most of the characters except intense pigmentation of the flesh, albedo/ mesocarp also pink with bright red blush on the fruit surface. Hangs well on the tree as the parent cultivar.

Thompson (Pink Marsh): It originated from bud sport to marsh. Fruit color light yellow, surface smooth, 10–12 segments with 2–5 seeds. Plants are very productive large with vigorous growth. Fruits medium sized, spherical-oblate, areole indistinct light yellow, rind relatively thick, smooth and tough. Has excellent storage and shipping quality, fruits hang well for long period of time. Seeds few to none.

Saharanpur Special: Fruit round to oblate, empire yellow, surface small, segments 10–15 and 50–100 seeds. Fruits ripen in November to February.

2.4.2 Citrus grandis *(L.) Osbeck. Pummelo, shaddock*

Seeds are large yellowish and ridged, monoembryonic. It is native of Polinasia and Malaysia and commonly grown in South China. Fruit is pyriform, largest fruit size among citrus fruits, rind thick, juice is acid bitter, juice sacs easily separable. Seeds are monoembryonic. Fruits are of two types (a) elongated pear shaped with neck (b) Oblate or globose, flattened and neckless. In India there is no improved cultivar except Nagpur chakotra.

In all likelihood is indigenous to the Malayan and East Indian archipelago. In respect of fruit characters, the pummelos fall into two major groups the pigmented and the non-pigmented types. The pigmentation in the former types is caused by carotenoid lycopene and varies from pink to deep red some of which are very

attractive with very high in flavor. The non-pigmented (common pummelo) are very variable in number of characters, have moderate to high acid contents and mostly seedy. Description of some known pummelo cultivars is described briefly.

Non-Pigmented Varieties

Banpeiyu: The variety is considered to have originated in Malayan region and is very popular in Japan and Taiwan. Rind thick tightly adhering to vesicles, surface smooth. Flesh pale yellow, soft and juicy, segments many (15–18) central axis solid and large, carpellary membranes thin and tough. Mid-season ripening cultivar, flavor excellent and pleasant taste of acid and sugar, storage quality very good, seedy.

Hirado (Hirado Buntan): Originated as a chance seedling at Nagasaki Prefecture, Japan and rated very highly resistant to cold. Fruit large bright yellow, glossy, oblate both ends slightly depressed, surface smooth, rind medium thick, flesh light green, yellow soft semi dry, flavor pleasant with balanced blend of acid and sugar with some bitterness, segments many, carpellary membranes thin and tough. Seedy.

Kao Phuang: One of the most famous cultivars grown in Thailand. Mid to late in ripening, fruits hang well on tree for long. Tree upright very vigorous. Rind semi thick adherence medium with the vesicles which are firm large and separates easily, juicy, flavor good, capillary membranes semi thick, axis small and compact. Seedy.

Pigmented Varieties

In its place of origin-Orient a number of pink and red fleshed types are present some of which are pomologically described below.

Chandler: Is a hybrid cultivar obtained from a cross between Siamese Sweet x Siamese Pink. Flesh in pink and in other characters it is intermediate between the parents. Rind smooth medium thick, vesicles moderate in juice flesh firm later turns soft, flavor pleasant sub acidic in taste, seeds many.

Ogami (Syn. Egami): This cultivar has performed very well in Florida and other parts of the world. Fruit quite large broadly round flat (oblate), rind smooth shiny and moderate in thickness, pink to deep pink in color, flesh deep pink, pigmentation extends far into the albedo (mesocarp), seedy.

Siamese Pink (Siam): Considered to be one of the finest cultivars in respect of its strong flavor, matures late. Rind adheres tightly medium thick, smooth and glossy. Segments many, carpellary membranes quite thick and tough but open at axis when mature. Almost seedless.

Siamese Sweet: Commonly called as sweet pummelo practically non-acid. Plants are dwarf type, branches drooping, leaves distinctly round pointed. Vesicles separate easily, are large crisp, lack in juice, sweet in taste.

3. Some wild and semi wild species

As north eastern region of India has been recognized as one of the major centre of citrus origin, a number of species are said to be native to this place **Table 1**.

C. indica (Indian wild orange): Specie is found growing in many parts of Assam, Nagaland, Meghalaya and other north eastern parts of India in wild form. Fruit small broad obovoid or subpyriform, appear singly on terminal twigs, about 2 cm in diameter, pedicel very small. Rind very thin, red in color, segments few, orange red in color, inedible, vesicles spindle shaped, very soft, pulp slimy, acidic in taste with unpleasant flavor. Seeds are very large, smooth, monoembryonic and occupy major portion of fruit.

C. assamensis (Adajamir): A very distinct specie known for its peculiar aroma that resembles to ginger or eucalyptus smell that emits from the crushed leaf or from the fruit. A new specie which was indigenous to Assam region. Fruit medium

small, spherical to round in shape, surface smooth, very acidic juice hence has very limited use as fresh fruit.

The other species *C. latipes*, *C. ichangensis* and *C. macroptera* are usually placed under subgenus Papeda which has number of true wild species of citrus.

C. macroptera (Malanesian Papeda): Almost all the species of Papeda group, this species is most promising as a rootstock. Widely distributed in Indo-China, Thailand, Philippines, New Guinea, New Caledonia and Polynesia. All plants parts are with amber colored glands, spine axillary straight. Flowers are like that of orange. Fruit globose, pale yellow, small (2.5 in dia), smooth, glands small, segments 10–12 with 1–2 seed/vesicle. Juice scanty, highly acidic.

C. latipes (Khasi Papeda): Cold hardy. Native of northeastern Khasi hills (India), and Northern Burma. A small spiny shrub or a small tree (10–15 feet), twigs angular with sharp stout spines (1.2–2.5 cm), reduced or absent on flowering twigs. Fruit medium sized, globular, rind somewhat thick, leathery, segments 9, quite large pulp, vesicles few, spindle shaped, well developed. Seeds many 5–7 in each vesicle, round in shape.

C. ichangensis (Ichang Papeda): Native of south western and west central China. This specie is the most cold hardy of all evergreen types. Differs from other Papeda in that it has large flowers, stamens are connate. Small shrub or a tree (12–15 feet), twigs angular, spines stout. Fruit small (3–4 cm dia) glossy, peel rough, bumpy, medium thick, segments 7–9, each with many seeds large and thick, blunt at both ends, monoembryonic.

Micrantha, Biasong (*C. micrantha* (Wester)) it is thought to be native of the Southeast of the Philippines. It produces small, bitter and inedible fruit with a skin comparatively thick and broadly winged leaves (SRA-1114).

Citron (*C. medica* L).

Citron is considered as native of India having probable region of origin in South Western Asia. Citron is often ranked as the first specie to be cultivated in the western world and in China.

Major citron cultivars are divided into two groups:

- Acid cultivars: Diamante is commercially grown in Italy and Etrog is the main cultivar of Israel.

- Nonacid cultivars: Corsican-well established in California. Sarcodactylis is well known in Japan and China, often referred as fingered citron, because fruit split into number of segments (like finger) with very less pulp.

This citrus fruit is most likely to have originated in the north eastern India and the areas nearby. As the fruit is inedible and tree lacks ornamental value, one ponders why the Romans and Greeks liked it so much. This was the first citrus fruit which was known to the Romans, further the fruit fragrance is soft, penetrating and lasting. Features of some citron cultivars grown extensively are described.

Diamante (Cedro Liscio): A very important and commercial cultivar of Italy, origin is unknown. New growth, buds and flowers are distinctly purple pigmented. Fruit is usually large, long oval to ellipsoid, basal cavity furrowed, apex pointed-nipple like and lemon yellow in color. Rind is very thick, fleshy surface lobed or ribbed and smooth. Flesh is crisp, dry, acidic in taste and seeds are many.

Etrog (Atrog, Ethrog): New growth, flowers and flower buds all are purple pigmented. Trees are small, productive and moderate in growth. Fruit is small to medium, ellipsoid, neck distinct, nipple at apex sharp, style persistent and lemon yellow. Rind is fleshy, thick, surface bumpy/ribbed, flesh firm and crisp, acidic in

taste and low in juice content. Citrus is a highly heterogeneous group and its various species hybridize freely with each other in nature.

Humpang citron (*C. medica* L.) fruit is large, oblong or oval, of green color when growing but generally yellow when ripe. The surface usually is smooth, the rind and the albedo are very thick and the segments are filled with acidic pale greenish pulp-vesicles. Citrons were the first citrus fruit to reach the Mediterranean region and are cold sensitive, monoembryonic, unpalatable and very fragrant.

Mac Veu citron (*C. medica* L., *C. lumia* Risso & Poit). Similar to Humpang citron.

Corsican citron (*C. medica* L.) is an acidless citron of unknown origin.

Buddha's hand citron var. Sarcodactylus (*C. medica* L. (Noot.) Swingle) produces a very characteristic fruit usually without pulp and split into a number of finger-like sections. This fingered citron is well-regarded because of its fragrance for perfuming rooms and clothing. It is also grown as a dwarf plant for ornamental purposes.

***Fortunella margarita* Fortunella/Kumquat.**

Kumquats are part of genus *Fortunella*, and in Chinese language the word kumquat means 'Gold orange'. This distinct group of citrus has been named after Robert Fortune, the well-known English horticulture worker.

Other species of *Fortunella* are:

- *F. crassifolia* Swingle (Meiwa kumquat)
- *F. margarita* Swingle (Oval or Nagami kumquat)
- *F. japonica* Swingel (Round or Marumi kumquat)
- *F. hindsii* Swingle (Hongkong wild kumquat)

Pomological description of important Kumquats is briefly summarized below:

Meiwa- Large round Kumquat (*F. crassifolia* Swing.): It is less cold hardy compared to Nagami but considered to be the best as fresh fruit. This specie is the Ninpo, Neiha or Meiwa Kinkan of Japan. A natural hybrid of oval and round Kumquats.

Nagami or Oval Kumquat (*F. margarita* [Lour] Swing): Popularly called as Naga or Nagami Kinkan of Japan. The characteristic features are that fruits are oval, oblong or obovate in shape having fewer number of segments usually 4–5, rind deep orange, both flesh and rind are richly flavored. Tree and leaves are larger in size. Since trees are small and show slow, cold-tolerant growth it is also used as an ornamental. It produces fertile hybrids when crossed with species of the genus *Citrus*.

Marumi or Round Kumquat (*F. japonica* [Thumb.] Swing): Maru or Marumi Kinkan of Japan. Tree is low in vigor with some thorns. Leaves are small and apex is not sharp pointed. Fruit is small round to slightly oblate-obovate. Rind is thin and sweet in taste, segments vary from 4–7.

***Poncirus* and hybrids.**

Trifoliate orange, Poncirus Pomeroy (*Poncirus trifoliata* (L.) Raf.) shows trifoliate leaves and deciduous behavior, two dominant characters that are not present in citrus. The tree also has high resistance to cold. Its fruit has no commercial value and the plant is commonly used as rootstock like its hybrids, especially the citranges, Carrizo and Troyer.

Citranges: It is hybrid between *Poncirus trifoliata* and *C. sinensis* and is hardy than sweet orange. It is nearly deciduous, fruit color varies from yellow to deep orange, surface rough, wrinkled, ribbed or smooth, rind thin, juicy pulp, highly

acidic. It is used as dwarfing rootstock for grapefruit, Satsuma, sweet orange and lemon.

Varieties: Coleman, Etonia, Mortan, Rusk, Cunnigham, Rustic, Sanford, Savage, Troyer.

Citrangequats: It is trigeneric hybrid of Citrange (Sweet orange x Trifoliate orange) and Kumquat. Citranges are subjected to spring frost injury due to its tenderness while Kumquat is tolerant to the spring frost because of their winter dormancy.

4. Sequenced genome of *Citrus* spp. and their varieties

Xu et al. [27] reported Valencia sweet orange (*C. sinensis* cv. Valencia): A model of the sweet orange origin. With pummelo as the female parent crossed with mandarin, the interspecific hybrid was backcrossed with mandarin and produced the ancient sweet orange. Haploid Clementine, Clementine mandarin, Ponkan mandarin, Willowleaf mandarin, W. Murcott mandarin, Chandler pummel, Low-acid pummel, Sweet orange, Seville sour orange [18] **Table 1**.

5. Conclusion

Classification of the Citrus varieties has long been debated by taxonomists and botanists. The reticulate evolution combined with partial apomixis has led to very different classification systems. Earlier classification was very difficult due to lacking of genomic study but recently, phylogenomic data revealed the origins and admixtures of modern cultivars and wild types. Coupled with reproductive biology, phylogenomy supports the inclusion of all true citrus of the Swingle system plus Oxanthera in the genus Citrus. The variety rank is defined by the old independent reticulation events from which groups of cultivars were differentiated by asexual mechanisms. It provides an unambiguous conceptual framework for Citrus classification based on the phylogenomic and genetic data. However, today, the available genomic data remain available for further study and further WGS studies are needed to establish a definitive classification of the Citrus varieties. Commercially grown citrus varieties discussed in this text, are not grown from seed but are grafted and budded onto a seedling of a rootstock.

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Conflict of interest

The authors declare no conflict of interest.

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