CHERIMOYA AND LOQUAT

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Contents

Summary

Cherimoya (*Annona cherimola* Mill.) is a subtropical tree crop that belongs to the Angiosperm family Annonaceae, which also includes sugar apple and soursop. Cherimoya flowers are pollinated by beetles and characterized by a marked protoginous dichogamy. In regions where cherimoya is now cultivated, the lack of native efficient pollinators forces the implementation of hand-pollination, thus increasing local production costs.

Cherimoya is a 5 to 9 meter high tree with a dense foliage. The optimal temperature for growth is between 18° and 25° C in summer and between 5° and 18° C in winter. The

crop adapts well to a wide range of soils. The perishability of cherimoya is a problem for handling and transportation to distant markets.

Loquat (*Eriobotrya japonica* Lindl.) belongs to the Rosaceae family, which also includes other pomes such as apple and pear. It is a subtropical evergreen fruit with a reversed annual cycle: it rests during summer and matures in early spring, being the first fruit crop reaching the market. This fruit earliness allows for high prices early in the season. Optimal temperature for cultivation is 20-30° C; the tree is moderately cold-hardy. Loquat grows in a wide range of soils, provided they are deep and well-drained.

Loquat is benefiting from modern production techniques. Fruit earliness is enhanced by pre-flowering deficit irrigation, a management strategy that saves water and at the same time increases the value of the crop thanks to improved fruit earliness. Fruit size is enhanced by girdling and hand- and chemical fruit thinning. In this chapter, the different procedures to achieve the best fruit size in order to make the crop more profitable are described.

1. Introduction

Annonaceae trees are part of the natural flora in Central and South America, where their medicinal and nutritional values have been exploited by the native populations since time immemorial. In America, many of these fruit species are preserved out of tradition, though a number of them are not yet completely domesticated. Today, annonas, and cherimoya in particular, are multi-use plants with good nutritional food value; they also serve as sources for medicinal and industrial products.

Loquat is indigenous to southern China where it has been cultivated since ancient times for its food value, but also as an ornamental and medicinal plant. Loquat leaves and fruits have traditionally been considered to have high medicinal value and there is formal evidence of pharmaceutically active compounds.

2. Cherimoya

Cherimoya, one of the most important fruits of the Annonaceae family, is recognized by some botanists as one of the three best fruits in the world (National Research Centre, 1989; Gardiazábal and Rosenberg, 1993). The famous 18th century Czech naturalist Thaddäus Haenke considered it “the masterpiece of Nature”.

2. 1. History and Economic Importance

Cherimoya is most probably the indigenous Quiché (Maya dialect from Guatemala) name for the fruit of the *Annona cherimola* tree. Other authors (De Smet *et al*., 1999) believe that the connotation of “cherimoya” comes from the combination of two Quichua words: *chíri* or *círi* meaning cold or cool, and *múyu*, meaning ring, circle or wheel; as a whole this would then refer to a “rounded and fresh fruit”. Cherimoya has not received many names given its limited distribution in the world, and the common names in different countries are just a translation of the Latin species epithet *cherimola*. For example, it is known as “cherimoya” in English, “chirimoya” in Spain, "chérimolier" in France, "cherimoyabaum" in Germany, "cherimolia" in Portugal and "cerimoglia" in Italy.

As happens with its name, there is also some controversy regarding the geographical origin of cherimoya. Popenoe, cited by Perfectti and Pascual (1998), stated that the native home of cherimoya are the inter-Andean valleys where the Marañón River flows between Perú, Colombia and Bolivia before reaching Ecuador. The Ecuadorian province of Loja appears to be more specifically the centre of diversity of plant material, since cherimoya grows in the wild there. Other authors have suggested Central America as a secondary centre of diversity (Perfectti and Pascual, 1998; De Smet *et al*., 1999).

The cherimoya crop has been domesticated a long time ago as demonstrated by the findings of cherimoya seeds in archaeological sites in Perú. Fruits are depicted on pre-Inca pottery, and terra cotta vases modeled from cherimoya fruits were dug up from prehistoric graves in Perú, showing their longstanding history in the area. Ceramic cherimoya-formed vases found in the Ecuadorian Valdivia culture (3,500 - 1,600 BC.), seem to indicate that this early culture played an important role in plant exchanges between Perú and Central America. This suggests that native populations and maybe some animals may be at the origin of cherimoya seed distribution into South Mexico and Central America where the tree is now established as relatively wild plants.

According to this South America origin, cherimoya expanded from its centre of origin to the mountainous regions of Chile and Brazil, and later to the Argentinean province of Tucumán. Cherimoya was brought to Jamaica in 1785, where it mainly developed at about 1000-1500 m altitude. It was established in California in 1871 via Mexico. By the end of the 18th century, cherimoya expanded all around the world. In Spain, it was introduced in 1757 along the Coast of Granada, where it was restricted for a long period as an ornamental tree in backyards. At the end of the first half of the 20th century, the acreage of cherimoya cultivation increased notably and made Spain the world leading producer, a situation that still persists.

The production area of cherimoya in the world is evaluated at some 13,500 ha. With an average yield of 6 t/ha/yr, the world production is estimated at 81,000 tons (PROCIANDINO cited by Pinto *et al*., 2005). More than 75 % of the crop is produced in well-established orchards along the Mediterranean coast of South Spain, in the provinces of Granada and Málaga in particular. Perú is the second producing country with a cultivated area of 1,800 ha and an estimated annual production of 15,000 tons. Chile is third, producing some 12,000 tons over 1,200 ha, but in recent years many cherimoya orchards have been replaced by avocado. Other countries with regular plantations are Ecuador (700 ha), Mexico (500 ha) and USA.

There are also a number of other Annona species under cultivation. Taiwan is the prime producer of *Annona squamosa*, a close relative of cherimoya, while Mexico is considered the mayor world producer of *Annona muricata*. The cultivation of atemoya (*A. cherimola x A. squamosa*) has some interest in Australia (500 ha), USA (135 ha) and Israel (50 ha).

The worldwide marketing of cherimoya is generally weak, except for Spain and Chile which have well established international trading activities. The fruits of other annonas are mostly commercialized in the local markets. The restricted trading of annonas is mainly due to the short shelf life of the product and the poor post-harvest technologies which result in significant transport losses (Pinto *et al*., 2005).

2.2. Taxonomy

Cherimoya (*Annona cherimola* Mill.) belongs to the family of Angiosperm Annonaceae. Though still a matter of controversy, most authors recognize 120-130 genera in the family, and 2,000 to 2,500 species. Many of these genera have commercial utility, but only three include edible fruits. These genera are *Annona*, *Rollinia* and *Asimina*. *Annona* is the genus with the highest number of cultivated species, collectively known as annonas. Some of these species are:

- *A. cherimola* (denominated chirimoya in Spanish and cherimoya in English), the most appreciated for its fruit,
- *A. muricata* (soursop in English, guanábana in Spanish),
- *A. squamosa* (sugar apple in English, anón and saramuyo in Spanish),
- *A. reticulata* (Bullock's heart in English, corazón de buey in Spanish),
- *A. atemoya*, a hybrid between *A. cherimola* x *A. squamosa*, known as atemoya everywhere.

2.3. Plant Description

Trunk - Cherimoya grows fast and may reach a quite impressive size. Under cultivation the tree shows an erect habit with an upright fast growth reaching 5 to 9 m height (Fig. 1). However, its trunk is rather short and in the wild cherimoya seedlings look more like a shrub rather than a tree. The canopy of cherimoya tree is dense, with dark green foliage.

Figure 1. Cherimoya tree.

***Roots* -** The root system of cherimoya trees is superficial and ramified. Seedlings, and trees grafted on them, develop roots at various but rather shallow depths. Root growth in cherimoya concentrates mainly in summer, i.e. after the end of flowering, and is markedly reduced after fruit growth has started. Soil temperatures greater than 20 ºC favor root growth. Cherimoya roots suffer in poorly drained soils.

***Leaves* -** The leaves of cherimoya, alternately disposed on the stem, are obovate or elliptic, dark green in the upper side and light green underneath. The petiole is short and hollow, soon enclosing beneath the axillary buds that are not seen unless the leaf is removed. Both, the abaxial and adaxial sides are covered by pubescence, giving leaves a velvety appearance.

The cherimoya tree is semi-deciduous, meaning that although the tree loses foliage completely, bud break takes place so fast after leaf drop that in some locations the tree never completely lacks vegetation, or does so very briefly. The reason of this behavior is that cherimoya buds (in fact a bud complex) are sub-petiolar and sprout immediately after senescent leaves are dropped.

The cherimoya bud complex contains up to five single independent buds of decreasing size, each one enclosed by two bracts. Very often more than one bud develops from the bud complex over the season. The primary and secondary buds form 1 or 2 flowers, while the third bud commonly adopts a narrower shape indicative of a vegetative condition. The smallest buds show an undifferentiated stage that does not allow them to be labeled vegetative or reproductive. It is not yet clear whether the old leaves drop because the new growth pushes them away or whether the old leaves hamper the growth of repressed sub-petiolar buds (a state called paradormancy). Cherimoya trees are particular in the sense that all leaves drop in April and May, and not in autumn as is common for temperate zone tree crops (Morton, 1987).

***Flowers* -** The cherimoya tree bears its flowers mostly on new and one-year-old wood. Flowers appear as single flowers or in groups of 2-3 arising from the axillary buds. The flowers are fragrant and pendulous (Fig. 2).

Figure 2. Cherimoya flower in its female phase.

The flowers of cherimoya present three small hairy sepals and six glabrous petals disposed in two whorls. One set of petals is minute and not easily visible to the naked eye, leading many people to consider the flower as having only three petals. The other set of petals is very large and light green, with each petal having a shape of a tall triangular pyramid. Cherimoya flowers are bisexual, with the female organs (gynoecia) of the flower in the upper part of a triangular floral receptacle, while the approximately two hundred stamens are arranged at the base. The stamens hold a short filament and longitudinally split dorsifixed anthers that set free the pollen grains in groups of four (tetrads).

Cherimoya flowers have over a hundred carpels arranged helicoidally on the floral receptacle with their free stigmas partially overlapping, most like the tiles of a roof. Each gynoecium is composed of a large stigma, a short style and a small ovary inserted within the floral receptacle and enclosing a single anatropous ovule. Although hermaphroditic, cherimoya flowers exhibit protogyneous dicho-gamy (see reproductive biology), and auto-gamy is rare.

Flowering dates depend on the area of production. In the northern hemisphere, flowering extends from the end of May until mid-August, with June and July as the peak blooming season. In New Zealand and Australia, and the southern hemisphere in general, flowering occurs from November to January. In some parts of India, cherimoya flowers at two different moments in the year: first in summer when vigorous vegetative growth takes place, and second in spring coinciding with the rainy season. Flowering is always closely associated to bud break and shoot growth.

Reproductive Biology - Cherimoya flowers are hermaphroditic, but self-pollination within the flower is complicated because cherimoya has a marked protogyneous dicho-gamy. The cherimoya flower cycle lasts two days only. On the first day, the flower opens as a female and the stigmas are receptive from the early morning hours until noon of the second day. During the female phase, the flowers have their petals slightly open, but from the afternoon of the second day the stigmas usually lose their capacity to adhere pollen grains and are no longer receptive. The flower then enters in its male phase in which the stamens of the flower dehisce and the pollen grains are dispersed. These changes are accompanied by complete spread of the petals. All open flowers of the same tree (or genotype) synchronize their sexual phases. This synchronization is interpreted as a mechanism to avoid geitono-gamy and to promote xeno-gamy (cross-pollination). Nonetheless, if dichogamy fails to prevent the deposition of self-pollen then the pollen tube growth takes place without rejecting the flower's own pollen for fertilization. This finding is relevant for the choice of pollen source in hand-pollination programs (Gonzalez and Cuevas, 2008).

The main pollinators for cherimoya in its native area are small nitidulid beetles. Beetle pollination is termed cantharophily and is commonly associated with basal Angiosperm taxa. Annonaceae flowers do not produce nectar, but the arrangement of their petals creates a so-called "pollination chamber", where the beetles find shelter, food, and a place to mate. Annona flowers attract beetles during the female phase by their sweet scent, which is diffused by the thermo-genesis that these flowers show. Normally, beetles enter flowers during the female phase, in the morning hours, and remain at the base of the petals, crawling around on stamens and stigmas. When the flower reaches the male phase in the afternoon of the second day the beetles abandon the place dusted with pollen, before entering newly open flowers in their female phase.

Unfortunately, the introduction of cherimoya in new production areas has not always been accompanied by a simultaneous transport of pollinators. Under these conditions, natural fruit set is reduced. As a result, commercial yields of cherimoyas in many countries depend on hand-pollination programs in which human intervention replaces the beetles. Tests have been carried out introducing different insects as pollinators, although the results are not fully satisfactory.

***Fruits* -** Cherimoya fruit (Fig. 3) is a concrescence berry formed by the fusion of many carpels and the floral receptacle. Carpel development is only possible if fertilization of the single ovule has taken place. Therefore, good ovule fertilization is needed in order to obtain large, well conformed fruits. Misshapen, deformed fruits as a result of insufficient pollination are often occurring. Incomplete pollination also leads to reduced fruit setting, and to the production of small fruit which are difficult to market. Fruit size has been found to be highly correlated with the number and weight of seeds produced.

Figure 3. Cherimoya fruit.

Pulp weight of an average cherimoya fruit (without skin and seeds) is around 310-320 g. According to the USDA Nutrient Database (2010), 100 g of fresh cherimoya edible pulp contain between 74 and 110 kcal provided by carbohydrates, proteins and fats. The rest of the weight consists of other nutrients, water and indigestible components (Table 1). Cherimoya fruits provide several vitamins, mainly vitamin C and other significant quantities of vitamin B6, riboflavin, thiamin and folate. Cherimoya fruit contains also several essential minerals, and are particularly high in potassium, copper, manganese and magnesium (Table 1).

Water	68-79.39
Energy (kcal)	74-110
Protein (g)	1.54-1.65
Total lipid (g)	0.13- 0.62
Ash (g)	0.64-0.67
Carbohydrate, by difference (g)	17.70-28.8
Fiber, total dietary (g)	2.3
Sucrose (g)	1.30
Minerals	
Calcium (mg)	8-9
Iron (mg)	0.25-0.30
Magnesium (mg)	16
Phosphorus (mg)	24-26
Potassium (mg)	269
Sodium (mg)	4
Zinc (mg)	0.18
Copper (mg)	0.073
Manganese (mg)	0.083
Vitamins	
Vitamin C (mg)	11.5-12.2
Thiamin (mg)	0.091-0.112
Riboflavin (mg)	0.112-0.119
Niacin	0.574-1.02
Pantothenic acid, B5 (mg)	0.237
Vitamin B-6 (mg)	0.212
Folate, total (mcg)	18

Table. 1. Nutrients concentration in 100 grams of fresh cherimoya edible pulp (Source: USDA National Nutrient Database Standard Reference, Release 23, 2010).

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Biographical Sketches

Julián Cuevas has an M.Sc in palinology and a Ph.D. in olive reproductive biology obtained at the School of Agricultural and Forestry Engineering of the University of Córdoba, Spain. He specialized on olive pollination at the University of California, Davis. Since 1995 he gained a position at the University of Almería, where he continues as a full professor in charge of different courses of pomology.
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Mónica González Fernández has a Ph.D. in agronomic engineering and has been working over the past 7 years as a researcher in the Subtropical and Mediterranean Fruit Trees Department of the Experimental Station of Cajamar Foundation. She has specialized in reproductive biology, pollination and fructification of cherimoya. She has focused her research activity on the study of flowering physiology and fruit production of several Mediterranean (olive, almond, table grape) and subtropical fruit trees (cherimoya, loquat, avocado and mango), paying special attention to flower quality and its relation to reproductive success.