# White Sapote (*Casimiroa edulis* La Llave): Botany, Floral Biology, Fruit Development, Cultivar Diversity and Utilization

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## Introduction

White sapote (*Casimiroa edulis* La Llave) is an evergreen subtropical fruit tree belonging to the family Rutaceae. It is native to the tropical highlands of Mexico and Central America and is commonly known as white sapote, Mexican apple and zapote blanco. Despite its common name, white sapote is botanically distinct from sapodilla (*Manilkara zapota*) and belongs to the citrus family, Rutaceae (Yonemoto *et al.*, 2007).

White sapote has attracted considerable scientific interest because of its distinctive fruit quality, substantial cultivar diversity, unusual floral biology and potential as a specialty fruit crop. Research conducted by Yonemoto and co-workers has provided important information on floral morphology, pollen production, pollination, flowering temperature, fruit development, maturity, ripening and genetic diversity (Yonemoto *et al.*, 2000, 2001, 2002, 2005, 2006, 2007).

Although the crop is cultivated in several tropical and subtropical regions, its commercial expansion remains limited by factors such as difficulty in determining optimum harvest maturity, rapid softening after ripening and postharvest losses. These characteristics make white sapote an interesting crop for diversification and specialty-fruit production.

## Botanical Classification

| Taxonomic rank | Classification |
|---|---|
| Kingdom | Plantae |
| Order | Sapindales |
| Family | Rutaceae |
| Genus | *Casimiroa* |
| Species | *Casimiroa edulis* La Llave |
| Common names | White sapote, Mexican apple, zapote blanco |

*Casimiroa edulis* belongs to the Rutaceae, a family that also includes economically important genera such as *Citrus*. The species is taxonomically distinct from the true sapotes belonging to Sapotaceae.

## Origin and Distribution

White sapote originated in the tropical highlands of Mexico and Central America. It has subsequently been introduced into several tropical and subtropical regions, including parts of the United States, Israel, Australia and New Zealand. In Japan, selected cultivars were introduced from California and Florida and evaluated under greenhouse and open-field conditions (Yonemoto *et al.*, 2007). The crop has traditionally been grown in home gardens and small orchards,



while commercial production remains relatively restricted. Its adaptation to subtropical conditions and attractive fruit quality make it a potential candidate for specialty-fruit cultivation.

## Plant Morphology

### Plant habit

White sapote is an evergreen fruit tree that can develop a medium to large canopy under favourable environmental conditions. The tree has a spreading growth habit and produces abundant foliage.

Its evergreen nature and attractive canopy also make it suitable for home gardens and landscape planting in addition to fruit production.



### Leaves

Leaves are palmately compound, with several leaflets arising from a common point. The leaflets are generally green, smooth and relatively glossy. The compound foliage is an important morphological characteristic distinguishing white sapote from many other tropical fruit crops.



**Flowers**

The flowers are relatively small, inconspicuous and generally greenish to greenish-white. They occur in panicles. Although the flowers are structurally hermaphroditic, considerable variation occurs in floral organ development among cultivars. Yonemoto *et al.* (2001), while studying 41 cultivars, reported that the flowers possessed five petals and five stamens. However, some cultivars produced large anthers containing abundant pollen, whereas others had small anthers with little or no pollen.

**Fruit**

The fruit is fleshy and berry-like, generally round, oval or obovoid, with considerable variation among cultivars. The skin is usually green to yellowish-green, while the ripe flesh becomes cream to yellowish and develops a soft, juicy texture.



The ripe fruit is characterized by a sweet flavour and relatively low acidity, making it primarily suitable for fresh consumption. Fruit characteristics differ substantially among cultivars, providing opportunities for selection of superior genotypes.

**Floral Biology and Pollination**

**Floral Types**

The floral biology of white sapote is particularly important because cultivars differ markedly in their pollen-producing ability.



Yonemoto *et al.* (2001) studied floral morphology among 41 cultivars and classified them into three floral types based mainly on ovary, stigma and anther characteristics.

**Type I**

Type I cultivars have:

- Large ovaries
- Large stigmas
- Relatively small, poorly developed anthers
- Little or no pollen production

Cultivars such as 'Florida' and 'McDill' were included in this group.

**Type II**

Type II cultivars possess:

- Smaller ovaries
- Smaller stigmas
- Large, well-developed anthers
- Abundant pollen production

'Suebells' and 'Vernon' are examples of Type II cultivars.

**Type III**

Type III was represented by 'Maltby', which showed a combination of a large ovary and stigma with large, pollen-producing anthers.

Yonemoto *et al.* (2001) suggested that Type I cultivars could be particularly useful for fruit production, whereas Type II and Type III cultivars could serve as pollinizers because of their pollen-producing capacity.

**Pollen Germination**

Yonemoto *et al.* (2000) investigated the effects of artificial medium conditions on *in vitro* pollen germination and storage of white sapote. Their work examined factors such as sucrose concentration, agar medium and temperature and provided basic information on maintaining viable pollen for controlled pollination studies. Such information is useful for breeding programmes and for orchards in which pollen-producing cultivars are deliberately used to improve fruit set.

**Effective Pollination Period**

Pollination efficiency is also influenced by temperature and the physiological receptivity of the stigma. Yonemoto and Hennayake (2002) investigated pollen-tube growth and the effective pollination period in white sapote. Their results showed that pollen-tube growth was strongly affected by temperature, with faster penetration of the ovule at higher temperatures within the tested range. Observations of stigma colour indicated that the effective pollination period continued until the stigma became brown. These findings demonstrate the importance of synchronizing pollen availability with stigma receptivity for successful fruit set.

**Flowering and Temperature**

Temperature plays an important role in flowering and floral induction. Yonemoto *et al.* (2005) investigated floral induction in white sapote cv. 'Florida' under different temperature regimes. Floral induction occurred under relatively cool conditions, while high temperatures during the experimental period suppressed panicle emergence.

The study indicated that floral induction occurred under mean temperatures below approximately 20°C, while day temperatures around 30°C were unfavourable for floral induction under the experimental conditions. Panicle emergence was associated with cooler temperature regimes, demonstrating that white sapote flowering is strongly influenced by temperature (Yonemoto *et al.*, 2005). This information is particularly relevant when evaluating white sapote for production in subtropical environments where seasonal temperature changes can influence flowering.

**Fruit Development**

White sapote fruit development follows a single sigmoid growth pattern. Yonemoto *et al.* (2006) studied fruit development in cv. 'Cuccio' and observed progressive increases in fruit length and width followed by a decline in growth rate during the later stages of development. Soluble solids continued to increase as fruits approached maturity. The study demonstrated that fruit size alone was insufficient for accurately determining harvest maturity, emphasizing the need for physiological and biochemical maturity indices (Yonemoto *et al.*, 2006).

**Fruit Maturity and Harvesting**

Determination of the correct harvest stage is one of the most important challenges in white sapote production. Yonemoto *et al.* (2006) evaluated fruit size, skin colour, seed colour, total soluble solids, sugars, polyphenols and dry matter during fruit development of cv. 'Cuccio'. The researchers found that pulp dry matter was strongly associated with fruit maturity, and a pulp dry matter content of approximately 18% or higher was proposed as a useful maturity index under the conditions of the study.

Total soluble solids also increased substantially during fruit development, reaching approximately 18–20°Brix toward maturity in the studied material. The researchers also examined accumulated temperature, days after pollination and fruit skin colour as potential indicators of harvesting maturity (Yonemoto *et al.*, 2006). Thus, maturity assessment based only on external fruit appearance may be unreliable, and dry matter, TSS and other physiological indicators can provide more dependable information.

**Fruit Ripening**

White sapote exhibits climacteric ripening behaviour. Yonemoto *et al.* (2002) studied changes in respiration and ethylene production in white sapote fruits stored at temperatures ranging from 1 to 35°C. Respiration and ethylene production increased during ripening, and the fruits became soft and edible around the period of peak ethylene production. The relationship between ethylene production and softening explains why fully ripe white sapote fruits are highly delicate and difficult to transport over long distances.

**Postharvest Behaviour and Storage**

Postharvest life is an important limitation to the commercialization of white sapote. Yonemoto *et al.* (2002) found that storage temperature strongly affected respiration, ethylene production and fruit skin changes. Fruits stored at 1°C showed very low respiration and no distinct ethylene production during storage, but they were capable of ripening after transfer to 25°C. Fruits stored at 1°C for up to 46 days subsequently ripened, whereas fruits stored for 63 days showed chilling injury. The study therefore suggested that storage at approximately 1°C could extend storage life to around 46 days under the experimental conditions, although longer storage resulted in chilling injury. This finding is significant for the development of cold-storage protocols, but storage recommendations should be validated for individual cultivars and commercial handling systems.

**Cultivar Diversity and Germplasm**

White sapote possesses substantial genetic and morphological diversity. Yonemoto *et al.* (2007) characterized 39 white sapote cultivars using floral morphology together with random amplified polymorphic DNA (RAPD) and amplified fragment length polymorphism (AFLP) markers. The molecular analysis demonstrated considerable polymorphism among the cultivars. RAPD analysis generated

168 bands, while AFLP analysis generated 286 bands, with approximately 60% of RAPD products and 77% of AFLP products being polymorphic. The molecular markers successfully differentiated the cultivars and revealed genetic groupings that were not always apparent from morphology alone. Several cultivars that appeared morphologically similar were genetically distinct.

This genetic diversity is valuable for:

- Germplasm conservation
- Cultivar identification
- Breeding
- Selection of superior genotypes
- Development of pollinizer combinations
- Protection and authentication of planting material

**Important Cultivars**

White sapote has numerous named cultivars and selections, with substantial variation in fruit and floral characteristics. Some cultivars studied extensively in the Japanese research programme include:

- 'Florida'
- 'McDill'
- 'Suebells'
- 'Vernon'
- 'Maltby'
- 'Cuccio'
- 'Yellow'

These cultivars differ in floral type, pollen production, fruit characteristics and maturity behaviour (Yonemoto *et al.*, 2001, 2006, 2007). Therefore, cultivar selection should be based not only on fruit size and quality but also on flowering behaviour and pollination compatibility.

**Propagation**

White sapote can be propagated through seeds, but seedlings are genetically variable and cannot reliably reproduce the characteristics of a superior mother plant. For commercial production, vegetative propagation is therefore preferred for maintaining selected cultivars. Clonal propagation ensures greater uniformity in fruit characteristics, flowering behaviour, maturity period and other horticultural traits.

Seed propagation remains useful for:

- Breeding programmes
- Rootstock development
- Germplasm conservation
- Production of genetic variability

The extensive cultivar diversity identified by Yonemoto *et al.* (2007) further emphasizes the importance of maintaining genetically true-to-type planting material.

**Climate and Soil**

White sapote is adapted primarily to tropical and subtropical climates, particularly regions with moderate temperatures. The crop performs best where sufficient warmth is available for vegetative growth but seasonal temperature reduction can occur to support flowering. The temperature studies of Yonemoto *et al.* (2005) demonstrate that excessively high temperatures can interfere with floral induction. Well-drained soils with adequate depth and fertility are preferable. Waterlogging should be avoided because prolonged soil saturation can adversely affect root growth.

**Harvesting**

Harvesting should be based on physiological maturity rather than relying solely on external skin colour.

The research of Yonemoto *et al.* (2006) demonstrated that pulp dry matter and soluble solids can be useful indicators of maturity in cv. 'Cuccio'. Fruits harvested at an appropriate physiological maturity stage can subsequently ripen to acceptable eating quality. Because ripe fruits soften rapidly, careful harvesting and handling are essential to minimize bruising and mechanical injury.

**Uses**

**Fresh consumption**

The principal use of white sapote is fresh consumption. The ripe pulp is soft, sweet, juicy and creamy, making it suitable as a dessert fruit.

- **Beverages-** The pulp can be utilized in the preparation of a variety of refreshing and value-added beverages, including smoothies, milkshakes, fruit beverages, nectar and other blended drinks.
- **Desserts-** Because of its creamy texture, the fruit can be incorporated into a variety of value-added food products, including ice cream, frozen desserts, fruit creams, puddings and yogurt preparations, where it contributes a smooth consistency, rich mouthfeel and pleasant flavour.
- **Value-added products-** Surplus fruits can be effectively utilized through processing into a range of value-added products, including pulp, puree, jam, jelly, frozen pulp, fruit beverages and various dessert preparations. Such processing helps reduce postharvest losses, extends the shelf life of the fruit and enhances its economic value.

Value addition could be particularly useful because processing can provide an outlet for fruit that cannot be marketed as premium fresh produce.

**Nutritional and Functional Potential**

White sapote is primarily appreciated for its sweet flavour, low acidity and soft edible pulp. Yonemoto *et al.* (2006) reported substantial increases in soluble solids during fruit development, contributing to the characteristic sweetness of ripe fruit.

The species has also been associated with traditional medicinal uses, and its phytochemical composition has attracted scientific interest. However, medicinal claims should be interpreted cautiously because traditional use does not establish clinical efficacy. Further studies on nutritional composition, antioxidant activity, bioactive compounds and functional-food applications could increase the value of white sapote as a specialty fruit.

**Commercial Potential**

White sapote possesses several characteristics that make it attractive as a specialty fruit:

- Distinctive sweet flavour
- Soft and creamy pulp
- Low acidity
- Considerable cultivar diversity
- Potentially high fruit yield
- Adaptation to subtropical environments
- Potential for fresh and processed products

Research conducted by JIRCAS and other institutions has demonstrated that the crop can be systematically evaluated for flowering, pollination, maturity and postharvest management, providing a scientific basis for further commercialization.

However, commercial expansion is constrained by:

- Short postharvest life after ripening
- Soft texture
- Difficulty in judging harvest maturity
- Limited awareness among consumers
- Limited availability of standardized planting material
- Need for suitable pollinizer combinations

Consequently, future commercialization should emphasize elite cultivar selection, appropriate pollination management, maturity standardization and postharvest technology.

Conclusion

White sapote is an important underutilized subtropical fruit crop of the Rutaceae family with considerable potential for specialty-fruit production. Its attractive fruit quality is complemented by substantial variation in floral biology, reproductive behaviour, fruit development and genetic composition.

Research by few scientists has generated valuable information on the crop's floral morphology, pollen biology, effective pollination period, temperature-dependent flowering, fruit development, maturity, ripening, storage and genetic diversity.

The identification of reliable maturity indicators, particularly pulp dry matter and soluble solids, is important for improving harvest and postharvest management. Similarly, understanding the differences in floral type and pollen production is essential for selecting appropriate cultivars and pollinizers. With systematic cultivar evaluation, clonal propagation, pollination management, maturity standardization, improved postharvest handling and value addition, white sapote has strong potential for development as a diversified specialty fruit crop.

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