

north-west exposure. The leaders tend to crawl over the citrus in a south-westerly direction which was also the general orientation of the main body of foliage of the mature vines on the Montgomery estate.

#### CONCLUSIONS

Although further investigations must be made, the results to date do not indicate that *Strophanthus sarmentosus* in South Florida will be developed into an economically workable crop plant in the near future.

The response to hand pollination was successful from a breeding standpoint but not from a commercial standpoint. Breeding and selection of self-fertile, high-yielding plants is the only rational solution to the problem; then clone plantings will be the first commercial step. Such a program would require large areas to grow the numerous seedling generations and a long term breeding set-up.

#### SUMMARY

*One.* In accord with the results obtained with *S. gratus* in Indonesia, *S. sarmentosus* shows varying degrees of self compatibility, ranging from incompatibility to relative compatibility when individuals are mutually compared.

*Two.* Intraspecific cross-pollination is possible.

*Three.* Hand pollinations have increased the fruiting response, but not to an extent that is commercially feasible.

*Four.* The possibility of finding self-pollinating individuals exists as Table 1 indicates.

*Five.* On mature vines only one blooming period was observed.

*Six.* Fruit on mature vines developed only on strong leader shoots.

*Seven.* In South Florida the fruit requires one year to ripen.

*Eight.* Two-year-old cuttings of a self compatible plant could be brought to fruit by hand pollination.

*Nine.* Possible correlation with fertilizing

with sulphur powder, NKP, minor elements with increased magnesium applications and heavy mulching is indicated.

*Ten.* Scattered flowering throughout the year was observed on cuttings.

*Eleven.* In general, the results of these orientative investigations are disappointing from a time element viewpoint. For commercial utilization self-compatible naturally-fruiting high-yielding strains will have to be bred, which requires a long term breeding selection program.

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## REVIEW OF INVESTIGATIONS ON THE ANNONA SPECIES

JOHN C. NOONAN  
Sub-Tropical Experiment Station  
Homestead

The edible anonas, indigenous to the Western Hemisphere, are probably as widely distributed in the tropical parts of the world as any other New World fruit. Frost and extended cool weather are recognized as the

main climatic factors limiting the distribution of the annonas. In Florida, annonas have been grown on the coastal areas south of Stuart and Bradenton. The pond apple is a native in the swamps, both brackish and fresh water, of south Florida. A related plant, known as the papaw has been reported to be growing as far north as New York (13).

In the United States, cultivated annonas are classed as novelty fruits and some doubt that Americans in general will enjoy them. The odor of the fruit is rather pleasant in contrast to the odor of many other tropical fruits of minor importance. The fruit is made up of many carpels, joined together into one fleshy, roundish, edible fruit, with a muricate, scaled, or nearly smooth and netted skin. Each carpel normally contains a rather large, bean-shaped seed. (23).

#### HISTORY

There is little doubt that annonas had an important role in the life of the peoples living in the sub-tropical regions of the Americas. Terra-cotta vases modeled after cherimoya fruits have been dug from prehistoric graves in Peru (18).

Annonas are reported in historical accounts of the discovery of the Americas; Popenoe writes:

"The historian Gonzolo Hernandez de Oviedo in his 'Natural History of the Indies,' written in 1526, describes the soursop (*Annona muricata* L.) at some length, and he mentions having seen it growing abundantly in the West Indies as well as on the mainland of South America."

It is thought the annonas were then introduced to Egypt, India and other tropical countries by these early explorers (10). Wester (22) states that Annonas were first introduced into the United States in 1833 by Dr. H. Perrine. Reasoner (13) in his "Condition of Tropical and Subtropical Fruits in the U. S." written in 1887, described four of the *Annona* species which were then found in southern Florida. Since that time numerous introductions have been made from the Bahamas, Cuba and other sources.

#### DESCRIPTION

Fortunately, there is very little confusion in

botanical nomenclature, although the family, *Annonaceae* and the genus *Annona* are sometimes spelled *Anonaceae* and *Anona*. The family contains more than forty genera, of which only two beside *Annona* produce edible fruit. The biriba, *Rollinia deliciosa* Saff., is highly regarded in northern Brazil, and may be of value in sections of India which are free from frost. The papaw or pawpaw, *Asimina triloba* Dunn., is a wild fruit of temperate United States with some possibilities for improvement (7).

The genus *Annona* contains more than fifty species, of which five produce edible fruits of some importance. A number of others may have value in breeding or as root stocks. Most of the members of the genus, including all of the fruiting species, are indigenous to America (7). Those producing edible fruits in Florida are: *Annona cherimola* Mill., cherimoya; *Annona diversifolia* Saff., ilama; *Annona muricata* L., soursop; *Annona reticulata* L., custard apple; *Annona squamosa* L., sugar apple and an *Annona* hybrid, Atemoya (8). The wild pond apple, *A. glabra* L., bears an inferior fruit with a resinous flavor.

Cherimoya trees have made poor growth in Florida and have borne few fruit, most of which is poorly shaped and of indifferent quality. The fruit is variable in size and appearance, irregularly heart-shaped, greenish or yellowish with areoles more or less distinct. The flesh is whitish, sweet, subacid, rich and melting. It is a tall shrub or small tree, with ovate-oblong leaves. The cherimoya is cultivated with limited success in California where a number of varieties have been propagated. Many of these are under trial in Florida, but thus far none has shown much promise of being adapted to Florida conditions (8, 22).

The ilama (Figure 1) is now represented in southern Florida by a number of fruiting trees, and many young plants have been distributed in recent years (8). The tree resembles the cherimoya in size and habit; the fruit is also similar. The skin is whitish-green often with a pinkish tinge; the flesh is white or pinkish (11). It is sometimes called "the cherimoya of the lowlands." Its hardiness is comparable to that of the sugar apple. The ilama has proved a shy bearer thus far under Florida conditions (8).

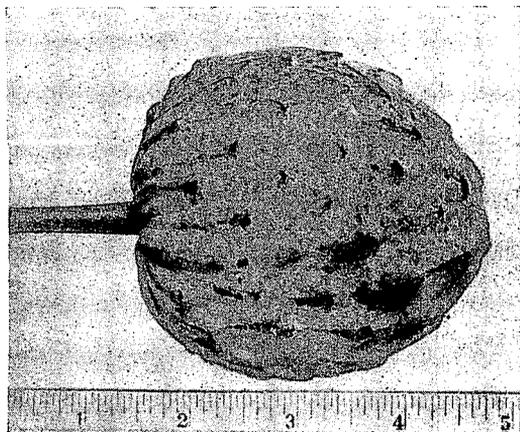


Figure 1. *Annona diversifolia* Saff., Ilama

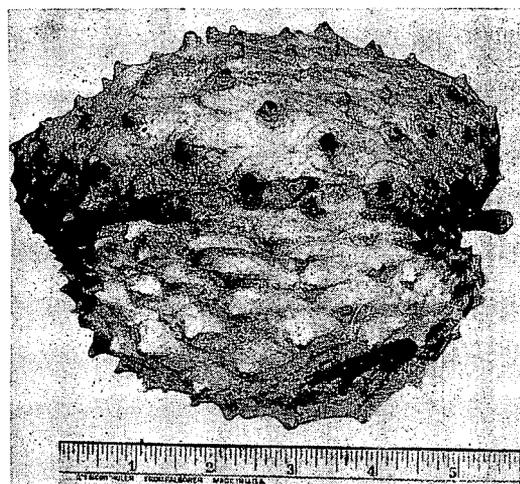


Figure 2. *Annona muricata* L., Soursop.

The soursop (Figure 2) has succeeded fairly well as a dooryard tree on the Lower East Coast but most specimens are shy though continuous bearers (8). It is a small handsome tree with dark green and shining, oblong-ovate or obovate leaves. The fruit is ovate-oblong or conical, greenish, with short, soft spines; the flesh is white, rather fibrous, juicy subacid, and well flavored (22). Cold winds, near-freezing temperatures or severe drought may cause defoliation, and light freezes kill twigs and smaller branches (8). It succeeds best in frost-free Key West where there is a small commercial use of the pulp in ice cream.

The custard apple (Figure 3) succeeds only in the extreme southern portion of the state. The fruit matures during late winter and early spring. It is a small tree, with lanceolate

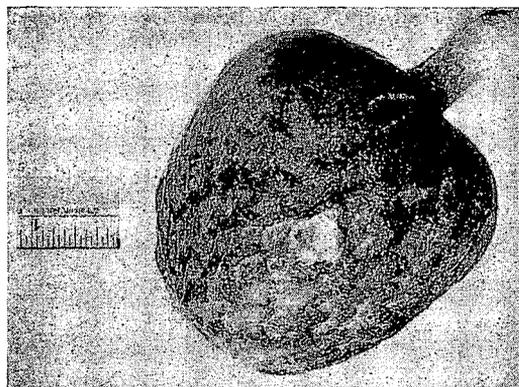


Figure 3. *Annona reticulata* L., Custard Apple.

leaves. The fruit is cordiform, fairly smooth, tan or yellowish in color with reddish reticulations. The flesh is melting, slightly granular, creamy white, rich, sweet with a slight trace of acidity (22). Generally the quality is rather poor but chilling improves the sweet or rather insipid flavor. Some confusion has arisen because in Cuba and Australia and in some countries of Central America this fruit is known as "cherimoya" (8).

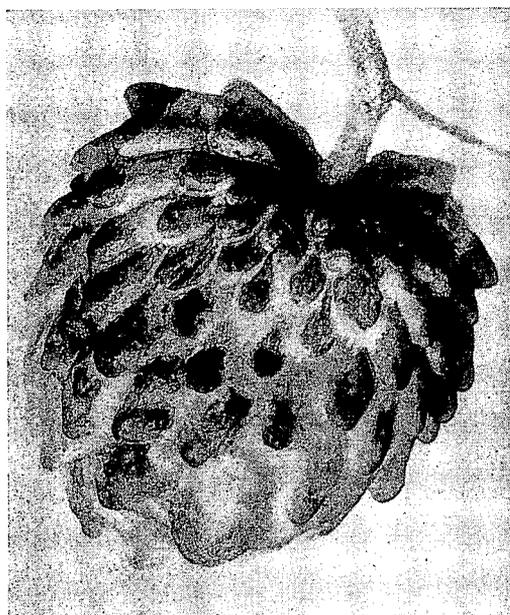


Figure 4. *Annona squamosa* L., Sugar Apple.

The sugar apple (Figure 4) is grown to a limited extent in the southern counties and is the most successful of the annonas in Florida (8). It is a tall shrub or small tree with thin,

oblong-ovate leaves which are sparsely hairy. The fruit is irregularly heart-shaped, tuberculate, greenish; the flesh is white, sweet and delicately flavored (22). The season begins in mid-summer and lasts for about three months, the fruits ripening irregularly. They are used almost wholly as a fresh fruit and are commonly chilled before eating. During the season the fruit may be found on local markets in southern Florida, but on account of the characteristic splitting of its rind as it ripens or separation of carpels it seldom reaches its destination in good condition when shipped long distances (8).

The sugar apple and the custard apple have fruited fairly well in Florida; the sugar apple frequently coming into bearing the third year from seed (8).

A hybrid between the cherimoya and the sugar apple has been named "Atemoya" (Figure 5) and has proved quite satisfactory for

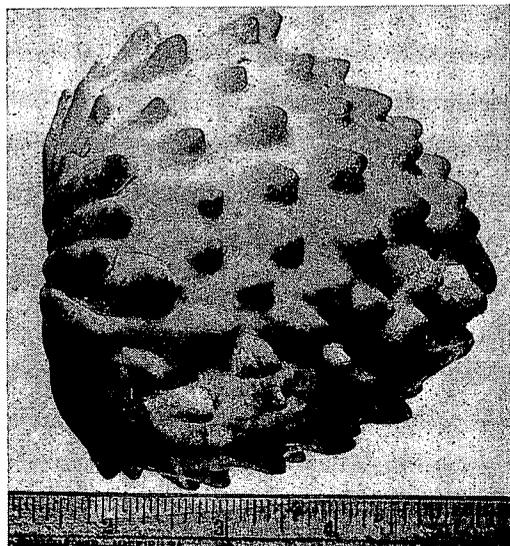


Figure 5. *Annona* hybrid, Atemoya.

southern Florida. The atemoya is eaten only as a fresh fruit, and the juicy, white pulp is of agreeable flavor and custard-like in consistency. The Page Atemoya has proved to set more fruit and to have dependably better quality than the cherimoya under Florida conditions (8).

#### POLLINATION

Ahmed (2) reports that the yield of most annonas can be greatly increased by hand

pollination. Flowers on the extremities of branches or weak flowers in clusters are unlikely to set fruit, so these are collected and used for pollen. Pollen is applied with a camel's hair brush before the stigmas have a chance to dry out. Only as many flowers are pollinated as the tree can carry to maturity. Hand pollination is very satisfactory in Egypt, but in India, at least under certain conditions, it is not entirely successful because the early flowers produce no pollen.

Construction of the flowers and their fragrance suggest that they are pollinated by insects, and in the course of Wester's observations it was discovered that they are protogynous. As the flowers mature, a viscid fluid is secreted that covers the stigmas and which appears to be most abundant twenty-four hours before the pollen is shed. Until the shedding of the pollen the petals assume an almost perpendicular position to the twig and leave a small opening facing downward, permitting the entrance of pollen-bearing insects. As the time approaches for the discharge of the pollen, the petals spread out and upward so rapidly that movement is readily perceived; this phenomenon is accompanied by emanation from the flower of a fragrance similar to that of well-ripened bananas or pineapple. The fragrance is also noticeable in the flowers twenty-four hours previous to the shedding of the pollen. The stigma is now readily approached by large as well as small insects and if the stamens and stigmas were synchronous, self-pollination by insects or the wind might be effected (21).

It has been demonstrated that the sugar apple hybridizes readily with the cherimoya, custard apple and pond apple; the cherimoya has also been successfully crossed with the pond apple. So far, the attempts to cross the soursop with the cherimoya, sugar apple, and custard apple have failed (21).

#### CLIMATIC AND SOIL REQUIREMENTS

The soursop is the most tropical of all the annonas. It is very susceptible to cold and should be planted where it may be protected from the cold north and northwest wind (18).

The cherimoya is considered to be the hardiest of the annonas. A small tree thriving at higher altitudes, it is not successful near sea level. It has become well established in upland areas throughout the warmer regions

of the world. The tree grows fairly well in southern Florida but fruits poorly (18).

Aside from the question of frost, or too much cool weather, the sugar apple and the custard apple are not particular as to climate. They are said to prefer a dry climate, at least during the flowering season, but in northern India they ordinarily set no fruits until the beginning of the rainy season, even though flowers are produced during the hot dry weather. Low humidity apparently interferes with pollination in parts of Egypt. Although they are known to thrive under dry conditions, and withstand drought well, they should be irrigated during fruit development. While the trees will withstand drought, they do so to the detriment of developing fruit by going dormant and sometimes shedding their leaves (7, 18).

The Annonas are tolerant of a wide range of soil conditions. The fact that they grow well on rocky soils has been commonly noted, in India, and in other countries. This does not mean, as some have thought, that the tree requires such stony ground for its best growth. The trees are rather shallow rooted so do not require a deep soil, but drainage must be good, as they suffer from water logging (7).

The soursop develops best in deep, rich, well-drained soil and is not as tolerant of lime soils as are some of the other species of Annonas. It has a shallow fibrous root system close to the surface so that a good mulching is necessary, as well as frequent irrigation during dry spells (18).

#### IMPROVEMENT BY SELECTION

The quality and flavor of fruit from individual trees of the edible Annonas is highly divergent, some being sweet and others acid, some distinguished by attractive coloring of their exterior and flesh, others possessing a hard shell-like rind that enhances the shipping qualities of the fruit, while in still others aroma and flavor are highly developed. Certain species grow at high altitudes and are cold resistant—an invaluable characteristic in subtropics visited by frosts; some possess unusual vigor; and still others inhabit swampy and inundated regions incapable of growing other fruits, while others succeed on high well-drained ground (22). A program of selection and evaluation will be of major importance in obtaining Annonas which have desirable features.

The fruit produced on inferior seedlings has given an adverse impression to those who have tried them without having had the opportunity to sample good specimens (14). As is often noted, the seedlings produced from seed of good fruit do not always produce fruit equal to the original; but fortunately the Annonas are reasonably easy to root and graft so improvement could result from selection of wood from trees of known superiority.

No superior strains or horticultural varieties of the Annonas have so far been propagated commercially in this state with the exception of Page Atemoya. Some excellent seedlings are to be found among some of the earlier plantings which might deserve propagation. Observations suggest cultural practices affect not only the vigor and yield, but also fruit quality.

#### PROPAGATION—ROOTING AND GRAFTING

Healthy branches of mature wood are used for rooting. The wood is taken during the period of dormancy and made into cuttings 5 or 6 inches in length and varying  $\frac{3}{8}$  to  $\frac{1}{2}$  inch in diameter. These are set in sand to a depth of  $\frac{4}{5}$  of their length, having at least one bud exposed above the surface. With bottom heat, a large percentage was sufficiently rooted in 28 days for transplanting into pots of soil (12).

At the Sub-Tropical Experiment Station cherimoya, atemoya, ilama, soursop, and sugar apple have been successfully veneer grafted on one-year-old stock of several species of Annonas including sugar apple and pond apple. The pond apple (*Annona glabra* L.), is used for a root stock because of tolerance to flooding.

#### VALUE AND USES

The food value is principally due to the richness in sugars; glucose and sucrose being found in almost equal proportions (18).

Most of the better seedlings can be eaten as fresh fruit which may be improved by chilling before eating. The strained pulp makes an excellent drink when mixed with milk. In employing the pulp for ice cream it should be added to the cooled custard just before putting it into the freezer (16).

Annonas should be harvested while still firm and, with the exception of soursop, after the skin between the segments has turned a creamy yellow and may have begun to crack.

This requires going over a tree every day or two. When ripe they are very delicate and must be handled with utmost care. This means that the fruit should reach the consumer within a few days of picking, and makes transport to distant markets difficult. If picked prematurely, the skin holds together better even after the pulp is soft, but the quality is damaged (7).

Among the native peoples of the tropics the sugar apple is reputed to be of medicinal value. Tea made from the roots is highly purgative, while that made from the leaves is mildly laxative and is also considered to have a general tonic effect on the digestive tract (18). In some parts of its range, leaves of this species are rubbed over floors or placed in hen's nests to keep away vermin and the seeds are said to have insecticidal properties (15).

#### INSECTS AND DISEASES

The trees are commonly attacked in Florida by several species of scale insects, by mealybugs and by a lace-wing bug. The fruits are sometimes attacked and destroyed by larvae of a chalcid fly (8). In Trinidad, fruits are infested by several lepidopterous insects whose larvae tunnel into the fruit (5).

The incidence of anthracnose (*Colletotrichum gloeosporioides* Penz.) on the *Annonaceae* in Puerto Rico seems to be correlated with high relative humidities. Experiments have shown that Annonas are seriously attacked by anthracnose fungus in the north-eastern and wet inland region of Puerto Rico. The disease is responsible for a constant drop of flowers and fruits, a die-back of twigs and branches, and a damping-off of the seedlings (6).

The disease appears on young leaves, as small, light, green spots, which, under high humidity, expand until the whole leaves are scorched and may finally drop. From the leaves, the organism may grow into the young twigs which may be killed resulting in the condition known as die-back (6).

Young infected fruits drop and either rot or mummify. On mature fruits the characteristic lesions consist of small, inconspicuous spots on the skin of the fruits. When such fruits are cut open, a dry rot, without accompanying bad odor, is found in the pulp (6).

In Florida, the leaves of the *Annonaceae* are attacked by a rust fungus, *Phakopsora cheri-*

*moliae* (Lagh.) Cum. This disease is often severe enough to cause premature defoliation. The cherimoya is probably more severely attacked than the other annonas (8).

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