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CARAMBOLA PRODUCTION IN FLORIDA

C. W. CAMPBELL
University of Florida, IFAS
Tropical Research and Education Center,
18905 SW 280 Street,
Homestead, FL 33031

R. J. KNIGHT, JR.
USDA
13601 Old Cutler Rd.,
Miami, FL 33158

R. OLSZACK
J. R. Brooks and Son
P. O. Drawer 9,
Homestead, FL 33031

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Abstract. **The carambola, *Averrhoa carambola* L., was introduced to Florida long ago, but has been grown commercially for only a short time. Currently there are 60 acres of orchards, with additional 70 acres planned. The tree is best adapted to a hot lowland tropical climate, but can be grown well in warm subtropical areas free of severe freezes. Freezes limit carambola plantings in Florida to the southern part of the peninsula. Of the many cultivars in Florida, those presently available in nurseries are 'Arkin', 'Fwang Tung', 'Golden Star', 'Maha', 'Newcomb', and 'Thayer'. Superior cultivars must be propagated vegetatively; veneer grafting and chip budding are the preferred methods. Growers now plant at densities of 116-170 trees/acre. Topping and hedging appear to be suitable methods of size control. The principal nutritional problem is deficiency of micronutrients in soils of high pH. Pests and diseases are not of major importance at this time. Twelve-year-old trees will produce 300-400 lb. of fruit per year. Most orchards in Florida are young and maximum yields have not yet been determined. The industry will continue to expand rapidly for some years to come.**

Carambola, *Averrhoa carambola* L., like many tropical fruits which have attained commercial status in Florida only recently, was introduced to this state long ago (12,18). Carambola trees were offered for sale by the Royal Palm Nurseries of Manatee, Fla. in 1887 (18). Most early introductions of seed produced trees with small, sour fruits. People in Florida were intrigued by the unique star shape of the fruit, but did not find it palatable, so the tree remained a rare curiosity, grown in botanical gardens, experiment stations, and the gardens of collectors of rare plants.

The carambola has been cultivated since ancient times in Asia and many superior selections have been propagated there. In 1935 Dr. H. S. Wolfe introduced seed from Hawaii and grew a number of trees at the University of Florida's Subtropical Experiment Station, Homestead (now the Tropical Research and Education Center). From those trees the first 2 carambola selections to be named in Florida were made, 'Golden Star' (2) and 'Newcomb'. Subsequently other superior cultivars have been introduced from several countries by the U.S. Department of Agriculture (3, 11). Introductions and local selections have been made also by private individuals and groups. From a collecting trip to Malaysia and Thailand sponsored by the Rare Fruit Council International in 1973 one of us (R. J. K.) brought back 'Fwang Tung' as a grafted plant, and seeds that later yielded 'Arkin', 'Star King', and 'Thai Knight'.

During the late 1950s and the early 1960s a few individuals in southern Florida harvested carambola fruit from home garden plantings and sold them in restaurants and stores. (R. J. Knight, Jr. and J. F. Morton, personal communications). This marked the beginning of commercial interest in the carambola in the United States, although it had long been a commercial crop in Asia. Planting of commercial orchards in Florida began in the 1960s. Some research was done on handling and shipping of fruit at that time (10, 20). In 1971 Campbell (4) reported about 10 acres of orchards in Dade County. A local organization, J. R. Brooks and Son, was the principal buyer and distributor of fruit at that time and has remained so up to the present.

As interest in carambola grew the area planted in orchards increased, reaching an estimated 30 acres by 1980 (5) and 40 acres by 1984 (15). In Sept. 1985, there were approximately 60 acres of orchards in Dade County, with an additional 70 acres planned for the near future. The current demand for trees exceeds the supply available in plant nurseries.

As in any new horticultural industry, research is lacking on many aspects of carambola culture. Growers find it difficult to obtain the information they need to establish and maintain their plantings. This paper reviews the status of the carambola industry in Florida and the cultural information available at this time.

Description

The carambola tree in Florida grows to a height of approximately 25 ft and a spread of 20-35 ft. The dark green leaves are odd-pinnately compound, with 5-11 leaflets 1-3 inches long (2,19). The flowers are pink to purplish pink, with a diameter of ¼ inches. They are borne in clusters laterally on old or young branches, or occasionally terminally on young twigs. The carambola is heterostylous, some trees bearing flowers with long styles and short stamens, and other trees bearing flowers with short styles and long stamens. The trees are self-incompatible to varying degrees (12,13).

The fruit is ovoid to ellipsoid, with 4-6 prominent longitudinal ribs corresponding to the carpels. The fruit is distinctly star-shaped in cross-section (19). Length of the fruit is 4-6 inches or more, with color varying from whitish to a deep golden yellow. The skin is smooth, translucent and waxy. The pulp is juicy, varying in texture from very soft to firm and crisp. Flavor varies from very sour with little sugar to very sweet with little acidity. Acidity varies from 2-10 mg/100 g tissue; solids vary from 5-14% (21). Other flavor components make considerable variation in the palatability of fruit of different cultivars. The fruit is a good source of vitamin C (1).

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Climatic Adaptation

The carambola tree is best adapted to a hot lowland tropical climate with medium to high rainfall (7,9). It can be grown well in warm subtropical areas if it is not subjected to severe freezes. Temperatures in Florida are suitable for most of the year, but the cold periods which occur occasionally in Dec., Jan. or Feb. affect the trees adversely. Freezes are the most important limiting factor to the northward distribution of carambola plantings in Florida, essentially limiting them to the coastal areas from Sarasota County and Martin County southward and to warm locations in the interior of the Florida peninsula (7).

Tender young leaves are likely to be killed at air temperatures of 30-32° F. Young trees and the mature leaves and twigs of older trees will be killed at 27-29° F. Mature trees will have damage to small branches at temperatures in the mid-20s. Temperatures in the low 20s will cause death of large branches and if prolonged will kill the trees (8). Trees in a condition of active growth will be more susceptible to cold injury than trees which are dormant.

In warm areas like Dade County, sprinkler irrigation has proved to be the most effective method of cold protection. In areas where water quantity or quality are not suitable for this method or where freezes are too severe for sprinkler irrigation to be effective, commercial production probably is not feasible. Home garden trees in these areas can survive freezes if protected by banking with soil or by use of tree wraps, covers, or heaters.

Cultivars

There are many cultivars in Florida, but only a few are available in nurseries and fewer still have been evaluated thoroughly for commercial production potential. Important characteristics of a commercial cultivar include high productivity, good eating quality, medium fruit size, good yellow color, resistance to handling damage and ability to maintain good quality during storage and marketing (21). The cultivars available in nurseries include 'Arkin', 'Fwang Tung', 'Golden Star', 'Maha', 'Newcomb', and 'Thayer'.

These cultivars are also the principal ones in commercial production. The 'Arkin' is currently the most popular cultivar for new plantings because of its excellent flavor and resistance to handling damage. The 'Golden Star', 'Newcomb', and 'Thayer' are widely planted also because they are productive, have good color, and can be sold readily. The 'Fwang Tung' and 'Maha' are not popular because their fruit has poor color, is easily damaged in handling, and seems to be susceptible to cold damage in refrigerated storage. Figure 1 shows cross-sections of the fruits of these cultivars, and illustrates their shape and their relative size. It can be generalized that the ones with thick, fleshy ribs are more resistant to handling injury than those with thinner ribs. Table 1 contains information on several characteristics of these and other carambola cultivars which are grown in Florida.

Propagation

Carambola trees grown from seed are variable in their characteristics. In order to reproduce cultivars true to type it is necessary to use some form of vegetative propagation. Veneer grafting and chip budding are the most popular propagation methods used in Florida. Carambola seedlings in a state of active growth are used as rootstocks. Most nurseries use seedlings grown in containers, with stems of ¼-⅜ inches diameter.

Seedlings of some cultivars are more vigorous than those of others. Experiments by Knight (14) showed that plants grown from seed of local selections ('Golden Star', M-18960) grew better in the limestone soils of southern Florida than plants grown from seed of some introduced cultivars ('Dah Pon', 'Fwang Tung'). It is advisable to use seed of cultivars adapted to local conditions if possible. At present the supply of seed in Florida is limited, so nurserymen use seed from whatever cultivars they can find.

Graftwood should be taken from vigorous, firm shoots which have leaves and on which the bark has not yet become corky. Preparation of the graftwood by removal of the leaves 3-4 days ahead of time (5-7 days in cool weather) assures virtually 100% success in grafting or budding, because it forces the buds into active growth.

Air layering has met with limited success in Florida. Nurserymen report successful rooting of only 20-30%. Root formation is slow and weak, and excessive callus often develops without formation of roots. Trees produced by air layering are often slow to become established in the field. Therefore air layering is not recommended for propagation of carambola in Florida.

Successful methods for tissue culture propagation of carambola were determined by Litz and Conover (16), but these methods are not being used commercially in Florida at this time.

Planting, Spacing, and Pruning

Young carambola trees are susceptible to damage from strong, dry winds and low temperatures. It is best to plant trees in the field at the beginning of the rainy season in May or June so they will have several months of good growing conditions in which to get established before they are subjected to the harsh conditions of winter.

Spacing of trees depends upon many factors. There has been no research on the subject in Florida, but some information is available from field observations. It is important to note that shading of the tree canopy will reduce fruit production; therefore trees should be planted in full sun.

The growth habit of the tree makes it adaptable to size control by periodic pruning. Annual topping to limit the height of trees to 12-13 ft has been done by several growers with success. Limbs which are pruned severely require about 8 months to resume production on the new growth. We have not evaluated the effect of hedging to reduce canopy width. Hedging appears to be feasible, but most growers have spaced tree rows as much as 25 ft apart, making hedging unnecessary. It appears to be feasible to space rows as close as 20 ft and still maintain good light on the sides of the tree canopies by hedging occasionally.

Spacing of trees in the row depends upon whether the grower wishes to develop" hedgerows" or to maintain the tree canopies separate from one another in the row. If hedgerows are desired, a spacing of 10-12 ft should be satisfactory. Some growers choose to plant at that spacing and then to remove alternate trees when the trees become crowded. Others make the original planting at the ultimately desired spacing. This can be wasteful because it

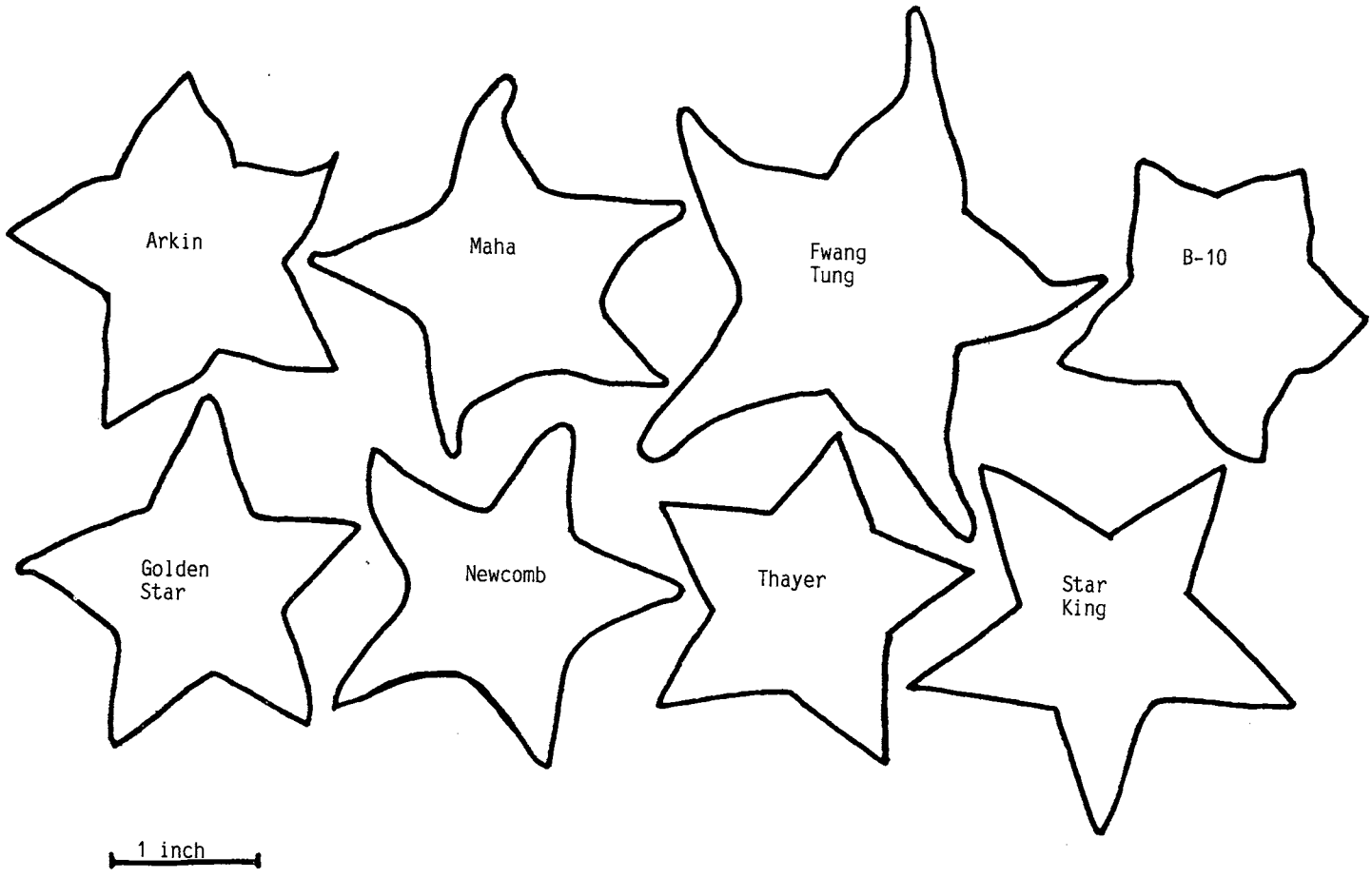

Fig. 1. Cross-sections of fruit of carambola cultivars.

takes the trees 10 years or more to grow and occupy the available space in the orchard.

Some growers have chosen to interplant carambola with other tree crops or with herbaceous crops like papaya. In such cases other spacings of the carambola trees may be desirable, depending upon the size and longevity of the companion crops.

Soils, Fertility and Irrigation

The carambola tree grows well in a variety of soils, provided that they are well drained and have a pH in the range of 5.5-7.0. The tree will survive occasional flooding, but will not grow and bear fruit well in waterlogged soils. The tree is not tolerant of high salinity in soils or irrigation water.

Trees growing in soils of pH 7-8, such as the limestone soils of Florida, often have iron, zinc and manganese deficiencies. These can be prevented by regular application (2-3 times/yr) of materials containing these elements. Iron is applied to the soil in chelated form. Some growers also use chelated Zn and Mn applied to the soil, but others use foliar sprays of inorganic Zn and Mn compounds.

Most growers use mixed fertilizers containing N, P, K and Mg in formulations such as 6-6-6-3, 8-8-8-4 or 8-3-9-4. Applications of 500 lb./acre are made 4-6 times/yr.

As discussed earlier, the carambola tree grows best in areas of medium to high rainfall. Growth and fruit produc-

Table 1. Characteristics of carambola cultivars grown in Florida.

Cultivar	Fruit size	Color	Style type	Flavor		Commercial desirability
				Sugar	Acid	
Arkin	medium	orange/yellow	long	high	low	excellent
B-10	medium	orange/yellow	short	high	low	good
Dah Pon	small/medium	pale yellow	long	medium	low	poor
Fwang Tung	large	pale yellow	short	high	low	poor
Golden Star	medium	orange/yellow	long	medium	medium	good
M-18960	medium	yellow	short	medium	low	fair
Maha	medium/large	pale yellow	long	medium	low	poor
Newcomb	medium	orange/yellow	long	medium	medium	good
Star King	medium	yellow	long	medium	high	poor
Tean Ma	medium	light yellow	long	medium	low	poor
Thayer	medium	orange/yellow	long	medium	medium	good

tion are adversely affected by drought. Determination of the water requirement of the tree has not been made. When trees are in active growth, growers apply 1-2 inches of irrigation water after 7-10 days without rain.

Diseases and Pests

Three pathogens have been reported to cause leaf spot diseases of carambola in Florida (22). These include *Cercospora averrhoae, Phomopsis* sp., and *Phyllosticta* sp. These have not been considered to cause important damage in the past. Some growers feel that leaf spot damage is increasing, so it may become necessary to apply control measures.

Anthracnose disease, caused by *Colletotrichum gloeosporioides,* occurs on the fruit of carambola (22). Another problem is a blemishing of the fruit surface by what appears to be a "sooty mold" fungus. This seems to be most severe in the summer and occurs even in trees which apparently do not have infestations of insects or mites sufficient to cause the development of sooty mold on their excretions. The nature of this disease needs to be determined because it causes otherwise sound fruit to be culled at the packinghouse.

Pests are not considered major problems to carambola in Florida. Leaf miners occasionally cause blemishing of the surface of the fruit of the summer crop. No control measures have been applied for this pest. Occasionally infestations of scale insects build up to damaging levels, but they are confined to limited areas and require only localized application of pesticides. Infestations of the reniform nematode (*Rotylenchulus reniformis*) have been associated with decline of trees in certain orchards.

In some locations carambola fruit are disfigured by raised spots which seem to develop at the sites of puncture wounds caused by stinkbugs. Some growers believe that such damage is most severe near plantings of herbaceous crops which attract these insects. Work is needed to determine the cause, extent and control of this problem.

Another disorder of unknown cause is the darkening and breakdown of the area of the fruit between the ribs. In some years the disorder does not occur at all, but at other times up to 10% of the fruit are affected.

Flowering and Fruit Production

The carambola, like some other tropical trees, produces some fruit sporadically throughout the year. The majority of fruit production in Florida, however, is concentrated in 2 main crops. The first, maturing in Aug., Sept. and Oct., develops from a bloom which occurs from April to June. The second crop, maturing in Dec. and Jan., develops from a bloom in Sept. and Oct. The interval from flowering to fruit maturity is about 70 days.

The choice of cultivars to plant is a difficult one at this time because not enough is known about some characteristics of available cultivars. One important factor is that of fruitfulness. Knight (12) indicates that all carambola cultivars are self-incompatible to some degree. The best fruitset resulted when pollen from short-styled cultivars was placed on the stigmas of long-styled ones, or when short-styled cultivars were pollinated by long-styled ones.

This would indicate that for best fruit production it is necessary to plant more than one cultivar in the orchard, to assure cross-pollination and subsequent production of fruit. 'Golden Star' has proved to set a satisfactory crop when grown without other cultivars nearby. 'Golden Star' has only partial self-incompatibility (14). The experience of growers in Florida indicates that other cultivars may produce a satisfactory crop in this manner as well. More information is needed before a satisfactory answer to this matter is obtained. Probably the best solution is to choose 2 cultivars which have saleable fruit, different flower types and similar time of blooming, (e.g. 'Arkin' and 'B-10') and plant them together in a pattern in which no tree is more than 1 or 2 rows away from a tree of the opposite flower type.

Good carambola cultivars are quite productive. Trees given good care will begin bearing as early as the third year after planting. After 5 years, yields of 100 lb. per tree have been obtained. Trees 8-10 years old can produce 200-300 lb. of fruit per year. Trees 12-13 years old will produce 300-400 lb. or more of fruit per year. Most orchards in Florida are young, so we have not determined maximum production.

Uses of the Fruit

The carambola crop of Florida is sold as fresh fruit. It can be eaten fresh, cut up in fruit salads, squeezed for juice, and made into various sauces, preserves or jellies. The fruit can also be preserved by pickling or drying (1, 6).

An important question facing growers is which cultivar to plant based on consumer acceptance. Until recently this was a moot point, since tart cultivars, 'Golden Star'; 'Newcomb'; and 'Thayer' were the only ones available. They were therefore the most widely planted. As sweet cultivars, 'Arkin'; 'Maha'; and 'Fwang Tung' became available, it was obvious that many consumers preferred them to the tart ones and many people began to plant them.

The amount of sweet fruit available for sale has been small, so there has been little differentiation between sweet and tart fruit in the market. Growers now tend to prefer the sweet cultivars for planting, but also plant tart varieties to extend the season of fruit availability.

Future of the Industry

The carambola industry of Florida is small but flourishing and profitable. The demand for nursery plants and for fruit exceeds the supply, and new plantings are being established at a rapid rate. Growers are now planting more trees of sweet cultivars, but there appears to be a place in the market for both sweet and tart fruit.

Most of the orchards in Florida are young, so production will increase rapidly for some years to come. As more orchards are planted, some pest and disease problems appear to be increasing. Research is needed on these and other aspects of culture as well as on handling, storage and marketing. It appears that this interesting new industry will continue to expand for some time in the future.

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PAPAIN IN SEEDLINGS OF PAPAYA

MARGARET J. MUSTARD
Department of Biology,
University of Miami, Coral Gables, FL 33124

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Abstract. **Two types of articulated anastomosing laticifers occur in stems and hypocotyls of seedling papayas (*Carica papaya* L.), which have attained a height of 4.0 to 22.5 cm above ground level. Small laticifers occur between the parenchyma and collenchyma cells of the cortex, parenchyma cells of the vascular rays and to a lesser extent parenchyma cells adjacent to the primary xylem. Large laticifers occur principally in the cortex but also occur in the vascular rays. Formation of large laticifers appears to be associated with tubular structures which extend through the transverse walls of series of cells. The tubes have indistinct pores in their lateral walls and frequently appear to be attached to the lateral walls of the enclosing series of cells by loops. It is suggested that following rupture of the tubes, the enclosing series of cells enlarge, their walls rupture and large articulated anastomosing laticifers develop. The abundance of laticifers in seedling papayas suggests the possibility of their utilization as a commercial source of papain.**

The papaya, *Carica papaya,* is the source of papain, a proteolytic enzyme used as a meat tenderizer, in the brewery industry, and for various medical purposes. Commercial papain is obtained from the skin of immature papaya fruit. The fruit is scratched with a sharp instrument and the latex collected, dried, and powdered. Balls (1) found that papain could be obtained from all parts of the papaya plant except the roots and suggested that extraction of papain from the whole plant is feasible.

Laticifers in mature papaya trees are articulated and anastomosing (4,5,6,7,8,10). A literature survey revealed no specific information pertaining to laticifers in seedling papayas. This investigation was undertaken to determine the stage in papaya seedling development in which lacticifers occur.

Materials and Methods

Seeds were planted approximately 2.5 cm apart in potting soil in shallow flats and grown in a greenhouse. Papaya seedlings are epigeal, therefore measurements of above ground height include hypocotyl as well as epicotyl or young stem. Preliminary studies were made with freehand sections of seedlings ranging from 4.2 to 5.5 cm in height and were found to contain papain in their hypocotyls. Seedlings measuring 4.0 to 4.5 cm, 10 to 10.5 cm, and 16.8 to 22.5 cm above ground level were used for this study.

Specimens were fixed in FAA, evacuated, dehydrated and embedded in paraffin-plastic. Transverse, tangential, and radial serial sections were stained with Foster's tannic-acid ferric chloride and counterstained with safranin and fast green.

The following observations are based on a study of transverse and longitudinal sections prepared from seedlings ranging from 4.0 to 22.5 cm in height and presented as composite data.

Results

Two types of articulated anastomosing laticifers occur in papaya seedlings. Small laticifers occur between the parenchyma and collenchyma cells of the cortex, parenchyma cells of the vascular rays and to a lesser extent the parenchyma adjacent to the primary xylem. Large laticif-

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