IICA

PRE-PRODUCTION, PRODUCTION AND POST-HARVEST HANDLING OF CARAMBOLA

Carl W. Campbell
Rafael J. Marte

IICA OFFICE IN BARBADOS

WHAT IS IICA?

The Inter-American Institute for Cooperation on Agriculture (IICA) is the specialized agency for agriculture of the inter-American system. The Institute was founded on October 7, 1942 when the Council of Directors of the Pan American Union approved the creation of the Inter-American Institute of Agricultural Sciences.

IICA was founded as an institution for agricultural research and graduate training in tropical agriculture. In response to changing needs in the hemisphere, the Institute gradually evolved into an agency for technical cooperation and institutional strengthening in the field of agriculture. These changes were officially recognized through the ratification of a new Convention on December 8, 1980. The Institute's purposes under the new Convention are to encourage, facilitate and support cooperation among the 32 Member States, so as to better promote agricultural development and rural well-being.

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INTRODUCTION

As many of the lesser countries fight against the economic crisis affecting them, the search is being intensified for alternative crops to replace traditional ones. Agricultural diversification has become an important goal for those countries in which the economy is strongly related to agriculture.

The growing preference for health foods in most international markets has boosted the demand and opened opportunities for new crops. The demand for exotic crops has grown steadily with the advantage of attractive prices and less competition. For example, "organic" fruits cannot meet the present demand and prices being paid are significantly higher than for chemically treated products.

Carambola, an exotic fruit still unknown to a large portion of the world's population, has the necessary characteristics to become one of the alternative crops in the diversification plans of several countries in the Caribbean. The successful attempt to commercially produce carambola in the region and the acceptance by the ethnic and non-ethnic markets in the USA, Europe, Canada, Japan, Hong Kong, Singapore and the Middle East, have stimulated a great interest among potential producers.

Only a few countries can be considered commercial producers of carambola. Taiwan (2875 ha), Malaysia (500 ha), Indonesia and the USA (176 ha) are among the major producers.

Guyana with an estimated 500,000 seedling trees scattered in dispersed plantings, and Brazil with 300 ha of seedlings in backyard orchards, have also been able to develop some commercial production and occasionally ship fruit or sub-products to international markets. However, the high variability in fruit quality produced in these two countries has been a major limitation to market penetration. Given the limited demand for carambola for processing, the majority of the fruits go to waste. Top-working of the tart seedling trees, with selected sweet cultivars, may be an alternative to change this situation.

A few orchards can also be found in Australia, Colombia, Hawaii, Israel, and Guam. In the Caribbean islands, plans are currently underway to establish a fair amount of land under carambola cultivation. Dominica, Trinidad, Barbados, and Grenada have already initiated plans for expansion and plants are being propagated to satisfy the demand by farmers.

A deficit in the supply of carambola is recognized in the international market. Prices for fresh fruit have been very attractive, and although a price drop is expected the demand is also expected to increase as more people get acquainted with the exquisite flavor and alternative uses of Carambola.

This audio-visual package has been developed by the Inter-American Institute for Cooperation on Agriculture (IICA) with the goal of assisting Caribbean Governments in the planning of the expansion of carambola production. It is directed to technicians, farmers and students.

We now invite you to sit back, relax and join us to review three important aspects of Carambola production:

PART 1: Generalities, Propagation and Nursery Management

PART 2: Planting and Post planting Care, and

PART 3: Harvesting and Post-harvest Handling

PART I: GENERALITIES, PROPAGATION AND NURSERY MANAGEMENT

1.1 Botanical aspects:

Carambola trees are of small to medium size, with height and width approximately the same. Under favorable conditions their height reaches 10-12 m in about 15 years. Some cultivars grow faster than others. There is a flush of vegetative growth after each harvest period. In the initial stage of growth the tree makes only a few strong branches, soon after it begins to make many lateral branches and develops a dense canopy. Two types of shoots are formed. Some are short, lateral branches which begin to flower relatively soon. Others, sometimes called water sprouts, are strong, nearly vertical branches which grow very fast and remain juvenile for a prolonged period. These are the branches which later form the framework of the tree.

The root system of the carambola tree is relatively shallow, especially under conditions of stress, such as that caused by a high water table. As with other fruit trees, the tap root is atrophied during the early stages of the propagation phase. Consequently a lateral root system is developed.

Individual flowers are small in size and pink in color. They are borne in clusters laterally on both small and large branches. Most of the flowering occurs on branches 2 years or older. Branches have the capability to flower throughout their life. Flower clusters may have as many as 15 flowers. The flowers are attractive to honey bees, which facilitate good pollination. One hive of bees per acre (0.4/ha) is recommended.

Research indicates that most cultivars are self-incompatible; that is, plants of the same cultivar are incapable of pollinating themselves. Consequently, plants need pollen from a different cultivar for successful fertilization. To facilitate cross-pollination it is recommended that 2 compatible cultivars be planted together. For example, in Florida B-10 is thought to be a good pollinator for 'Arkin', presently the most important cultivar. In Malaysia B-2 is used as a pollinator for B-10. In spite of what has been said, solid plantings of cultivars such as 'Arkin' and 'Golden Star' produce satisfactory yields in Florida, without the presence of other cultivars as pollinators. Research is in progress to determine the economical need for interplanting with pollinating cultivars.

The period from fruit set to maturity is 70 to 80 days. Fruit growth is relatively uniform through this period.

1.2 Cultivars:

Although the majority of world production is from un-selected seedling trees, most commercial production comes from selected cultivars. The high variability of fruit from seedling trees is a disadvantage when marketing fresh fruit. Although several cultivars have been selected, only a few are of commercial importance.

The tremendous potential of regions like Guyana, Brazil, and Southeast Asia for clonal selection is recognized. Nevertheless, little effort has been made to take

advantage of the genetic resources available. Characteristics needed for a particular selection to be successful in the market place are attractive appearance of fruit, high yield, and good internal quality, and resistance to the stresses resulting from picking, packing, storage and transport. One of the most important factors of internal fruit quality is the flavor. In practical terms the fruit can be categorized as either sweet or tart. Perceived sweetness depends upon the relative amounts of sugars and acids. A fruit may have a high level of sugar and still be insipid because of low acidity. The most desirable fruit is one having high sugar content and sufficient acid to enhance the flavor. The most important cultivars listed by country are:

Malaysia:

B-10: It is the most popular and widely grown, making up 82% of commercial plantings. The fruit is sweet with Brix 8-10%, large in size (about 12-14 cm long), yellow to reddish golden in color, and juicy with a smooth shiny surface. The ribs of the fruit are thick and therefore resistant to handling damage. Storage life is good (4 weeks).

B-17: Locally known as 'Crystal Honey'. The fruit is very sweet with Brix 15-18%, of medium to large size, golden in color, and cylindrical in shape, and with thick ribs.

B-2: This cultivar makes up 2.5% of the total commercial area. The fruit is sweet with Brix of 7-8%. Color is greenish yellow becoming yellowish white when ripe. The fruit is juicy, bruises easily and has a short storage life. The main importance of B-2 is as a pollinator for other cultivars.

Taiwan:

The most important cultivars are 'Meeshi', 'Er-lin', 'Soft Sih' and 'Cheng-Tsey'. 'Cheng Tsey', also know as 'Chun Choi', is a sweet, low-acid fruit with large size and yellow orange color. 'Er-lin' is used mainly as a pollinator.

United States:

Although 'Golden Star' was the first improved selected cultivar to be planted, the 'Arkin' is now by far the most popular cultivar in Florida, occupying 94% of the planted area. The 'Arkin' fruit is sweet with a Brix of 7.2% but low in organic acids (.2%). Fruit size is medium to large, with golden yellow color. The fruit has thick ribs and resists handling damage well. Storage life is approximately 4 weeks. The 'Golden Star' produces a tart fruit (high acidity). The fruit is of medium to large size, golden yellow in color, and has a smooth, waxy surface. The ribs of the fruit are thinner than 'Arkin' and not as resistant to handling damage. Storage life is also about 4 weeks. In spite of the high productivity of this cultivar, it is not very important in Florida today because the preference is for sweeter cultivars.

Other cultivars being grown on a small scale are 'Dah Pon', 'Fwang Tung' and 'Hew 1' from Thailand, 'Maha' and B-10 from Malaysia, 'Newcomb' and 'Thayer' from Florida.

1.3 Propagation:

Carambola can be propagated sexually (by seed) or asexually (vegetatively). Although sexual propagation is easier, vegetative propagation has great advantages for commercial planting, for example earlier fruit production, smaller trees, and uniformity in characteristics of trees and fruit.

Sexual propagation

Fruits are obtained from trees that are preferably selected for their proven adaptability to the environment where the orchard is to be established, then allowed to ripen fully. It is not recommended to pick up fruit which have been on the ground for

a long time since the seed may be affected by pests, reducing their germination potential. The fruit is cut open lengthwise and the seeds are removed from the locules. The seeds are rubbed against a screen to remove the gelatinous material (aril) which surrounds them. They are allowed to dry on newspaper or toweling paper, away from direct sunlight for 1 or 2 days. To improve germination the remaining part of the seed coat should be removed. The seed now is ready to be planted or to be stored. Seed to be stored should be treated with seed treatment chemical and placed in a plastic bag. Refrigeration of the seed will prolong the viability for several weeks.

Planting the seeds: When planting the seedbed it is always preferable to use fresh seed. Seed stored longer than 2 months is not recommended. Seeds can be planted in a seedbed or directly in containers. Containers such as plastic bags, pots, leach tubes, and peat pots may be used.

For the preparation of the seedbed, locally available material including clean soil, sand, sawdust, wood chips, or compost may be used. Where economical, artificial media such as peat moss, vermiculite, perlite and others are recommended. When soil is used it is advisable to sterilize it to reduce the chance of pest infection and weed contamination. The same media can be used for growing plants in containers. The important thing is to have media that provide good drainage for the young plants. Seeds may be broadcast in the seedbed or alternatively sowed in rows. In the latter case, spacing should be 10 cm between rows and 3-5 cm between seeds (Fig 1.). In both cases the seed should be covered to a depth of no more than 2 cm. Germination should occur within 2 or 3 weeks in seedbeds or containers.

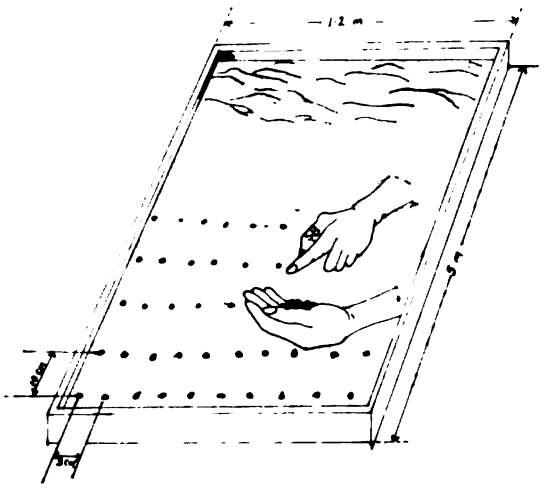

Fig 1. The Carambola Seed-bed. Seeds may be broadcast or planted in rows.

Care of young plants involves removal of weeds, watering, fertilization and pest control. Weeds are controlled entirely by hand. Ideally, irrigation is done with low volume sprinklers, but it can also be undertaken with a watering can or a hose with a 'rose nozzle'. Care should be taken to avoid washing away the media covering the roots. Fertilization of young seedlings can be done by application of granular fertilizer directly to the media, application of soluble fertilizer through the irrigation system or by spray application to the leaves. The most common pests are ants, birds, rodents, and fungi. Carbofuran e.g. Furadan, gives protection against ants and other insects. Screens may be used to protect against birds and rodents. Fungicides such as Benomyl and Ridomil are used to control diseases like damping-off.

Asexual propagation:

Different methods of asexual propagation:

Vegetative propagation of carambola may or may not use rootstock. Propagation which involves the use of a rootstock results in a 2-parted tree. Those propagated on its own roots, are referred to as one-part trees.

2-parted trees:

These consist of a scion and a rootstock joined together by a graft union. The scion forms the top of the tree and the rootstock forms the lower trunk and the root system (Fig. 2). Vigorous, healthy seedlings with single straight stems are selected for rootstocks. There is evidence

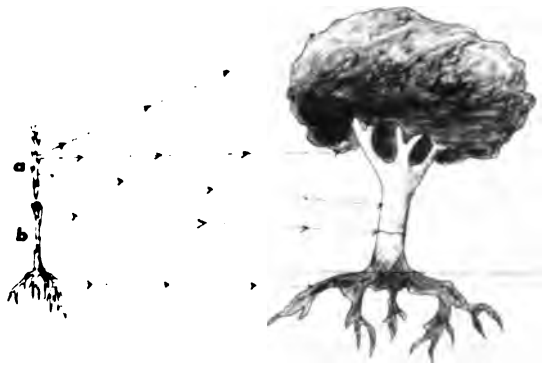

Fig 2. 2 Parted Trees. The scion (a) forms the top of the tree and the rootstock (b) forms the lower trunk and the root system.

that in calcareous soils, seed from some selections, e.g. 'Golden Star' and 'M-18960,' produce plants which grow better than other selections. More research is needed before definite recommendations can be made. Until more information is available the best procedure is to use seeds from the most vigorous local selections available for the production of rootstock.

Efficient nursery practice calls for using rootstock plants with stems of a diameter similar to a pencil at the point where the graft is made. Grafts should be made 10-25 cm above the soil level depending on soil conditions in the area to be planted.

Scionwood is selected from actively growing leafy stems with smooth, non-corky bark. The buds should be well-formed and swelling. Dormant buds can be forced into active growth by removing the leaves from the stem 3 to 7 days before the scions are to be cut from the tree.

There are two main methods for making 2-parted plants; these are budding and grafting:

Budding:

This method is characterized by scions with a single bud. Two main techniques are used, chip budding and 'T' budding. For the selection of scionwood (budwood) relatively straight stems of 3-5 cm diameter with long internodes are best, because straight scions with a single bud are to be cut from them.

'Chip' budding process:

A scion 2-3 cm long, with the bud approximately in the center, is removed from the stem. A shallow cut is made the full length of the scion down to, or slightly into, the wood on the side opposite the bud. A shallow cut of approximately the same length is made on the rootstock. The scion is bound to the rootstock with plastic tape A small gap in the tape is left at the site of the bud so that it can grow without being impeded by the grafting tape (Fig. 3).

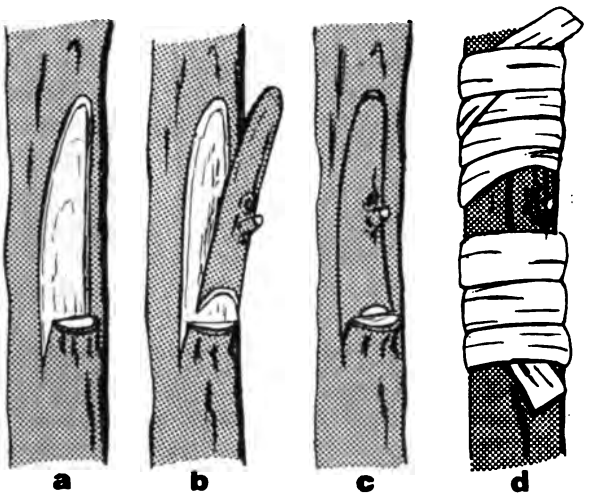

Fig 3. The "Chip" Budding Process. (a) A section of bark is sliced off the stock to form a lip at the bottom. (b) A chip bud of the same size and shape is sliced from the budstick. (c) The chip bud is set so that the lip made in the stock will hold the bud in place (d) Wrapping around the stock from the bottom upward finally secures the chip bud in place.

'T' budding process:

A scion 2-3 cm long is prepared by removing a single bud with an oval shield of bark with a shallow flat cut slightly into the wood. A single vertical cut through the bark of the rootstock is made with the point of the budding knife, followed by a short transverse cut at the upper or lower end of the vertical cut, in the form of an erect or inverted letter 'T'. The bark at the juncture of the cut is opened with the point of the knife and the scion is inserted into the vertical cut under the bark (Fig. 4). The success of this method depends on having rootstocks in active growth, so the bark separates easily from the wood. If the bark is not "slipping" in this way, it is preferable to use the 'chip' budding method. The scion is covered with plastic grafting tape, leaving a small gap for the bud to grow as is done in chip budding.

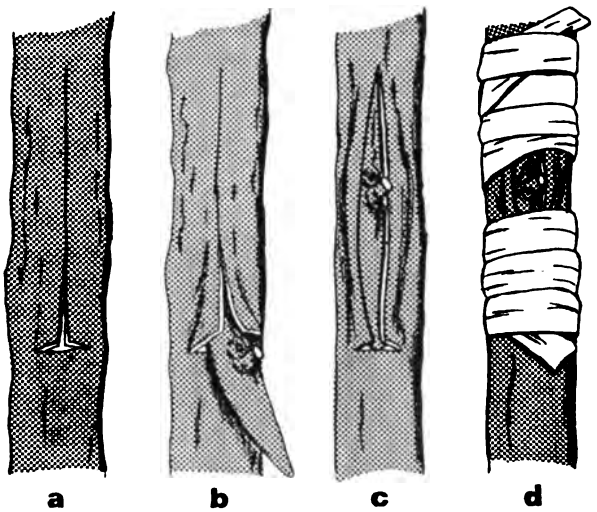

Fig 4. The 'T' Budding. (a) A vertical cut followed by a short transverse cut is made through the bark of the rootstock to form a 'T' (b) The two sides of the bark are gently lifted and the shield-shaped bud pushed inside. (c) The bud is fitted inside the bark (d) A piece of plastic is wrapped from the bottom upward leaving the bud-eye free.

Grafting:

Different from budding, where only one bud is used, this method utilizes scions with multiple buds. The grafting of carambola is mainly done by two methods, veneer grafting and cleft grafting. To prepare the scionwood, also called the graftwood, actively growing leafy stems are chosen. Since the scions have more than one bud, graftwood with relatively short internodes is preferable to that with long internodes.

Veneer grafting:

A scion 6-10 cm long is cut from the stem. A long, straight, shallow cut is made on one side of the scion through the bark and slightly into the wood. The length of the cut will usually be 1/2 to 2/3 the length of the scion. A shallow cut of similar length is made on the rootstock. The two cuts are joined so that the cambial tissues of the scion match those of the rootstock as well as possible. Carambola scions are seldom completely straight, so it may be necessary to bend the scion to make it match well with the cut on the rootstock. The scion is bound with plastic grafting tape. As in budding, small gaps are left so the buds can grow without interference. It is advisable to cover the full length of the scion with grafting tape to prevent it from drying out (Fig. 5).

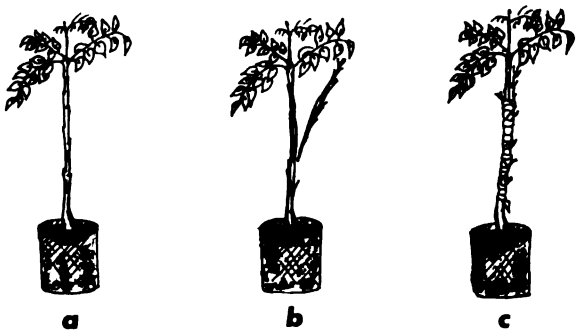

Fig 5. Veneer grafting. (a) leaves are cut off from the trunk of the stock leaving the one at the top. (b) A long, straight, shallow cut is made on one side of the scion through the bark and slightly into the wood. A similar cut is made on the rootstock and the two cuts are joined matching the cambial tissues. (c) The scion is bound with plastic tape, leaving small gaps so the buds can grow.

Cleft grafting:

This method is sometimes called wedge grafting. Slender, terminal scions 6-10 cm long are used. The lower end of the scion is cut on two sides to form a wedge about 3-4 cm long. A rootstock plant 25-35 cm tall is used. The plant is cut off at a height of 20-30 cm above the soil level. The cut stump is split down the middle and the wedge of the scion is inserted into the cleft of the rootstock. They are bound together with plastic tape (Fig. 6). A small plastic bag is used to cover the remaining uncovered part of the scion. This bag should be removed as soon as the buds sprout. This happens within 10-15 days from the time of grafting.

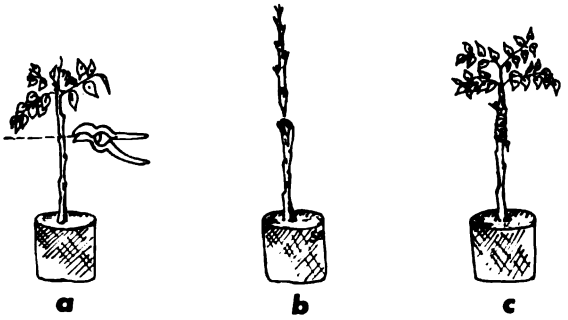

Fig 6. The Cleft Grafting Process. (a) The rootstock is cut off at a height of 20-25 cm. (b) The stump is split down the middle and a scion 6-10 cm long with the lower end cut on two sides to form a wedge, is inserted into the cleft of the stock.

Topworking:

Often growers wish to graft selected cultivars on seedling trees in the field, or convert grafted trees over to different cultivars. This can be done by the 'bark' grafting method (fig. 7). The main limbs on the rootstock trees are cut back to stumps, at a height convenient for grafting. Relatively large scions with multiple buds are used. A cut is made on one side of the scion in the same manner as for a veneer graft, or alternatively, the scion is prepared in the form of a wedge, as in cleft grafting. A single vertical cut is made through the bark of the cut stump of the rootstock. The bark is separated from the wood and the scion is inserted between the bark and the wood. If the bark is thick and stiff it may be necessary to make two vertical cuts close together; remove the bark between them

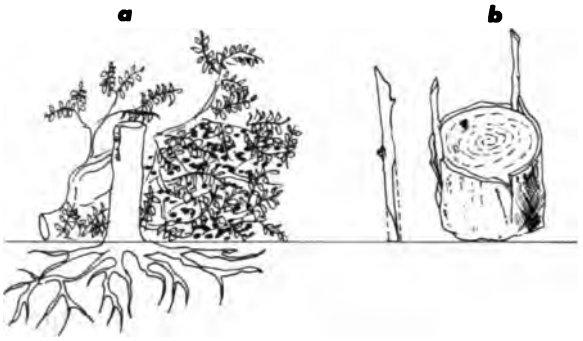

Fig 7. Topworking a Mature Carambola Plant. (a) The main limb is cut back to stump (b) Large scions with multiple buds are prepared with one cut as for the veneer grafting, or to form a wedge as in the cleft grafting.

and fit the scion into the opening thus created. In the past, the scion was then covered with grafting wax to prevent it from drying out. Nowadays this is considered necessary only if conditions are very dry and windy. As an alternative, the scion and rootstock stump may be covered with a plastic bag to prevent dehydration. Some shade should be provided to prevent the air inside the bag from becoming hot enough to damage the scion. Some grafters like to put 2 or 3 scions on a single stump, to assure the success of the graft and to hasten healing of the stump, and later remove all of the grafts but one.

It is not recommended to leave more than one graft on a single stump because a very weak crotch would be formed.

An alternative method of topworking is to cut back the limbs of the large tree, let new shoots sprout from the stumps and then veneer graft or bud with scion of the new cultivar on the shoots.

One-parted plants:

These plants are propagated without the use of a rootstock. Several methods are used to induce the formation of root shoots on plant parts from the desired cultivar. The most important methods for carambola are marcottage, cuttings, and tissue culture.

Marcottage (air layering):

Healthy, upright branches produce the best results in the shortest time. A branch with a stem diameter of 1-2 cm is selected. The stem is girdled by removal of a ring of bark 2 to 3 cm in width. It is preferable to scrape the surface of the wood in the girdled area to remove the cambium; otherwise the area can heal quickly and fail to form roots. The girdled area is then covered with a ball of moist sphagnum moss or other moisture-retaining material such as shredded coconut fiber. The moss is covered with a sheet of aluminum foil twisted tightly shut at each end. Alternatively a sheet of plastic tied at each end with string may be used (Fig. 8). Callus tissue forms at the upper end of the girdled area and then roots are initiated from the callus. The process takes 6-8 weeks in warm, rainy weather. Root-inducing compounds containing indolebutyric acid (IBA) or other auxins can be used to increase the number of roots formed and reduce the time required. When the roots are well formed, the branch, called a marcot, is cut from the tree, planted in a container of soil, and kept in a nursery area for a few weeks until new shoots begin to grow. Then it can be planted in the field.

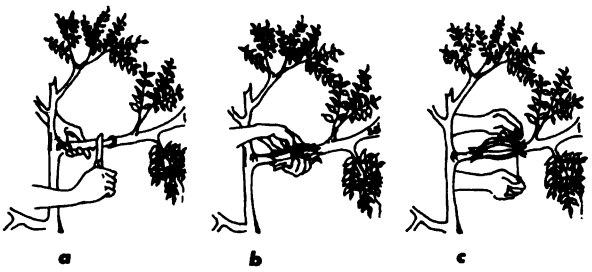

Fig 8. Propagation by "air layering". (a) The stem of the selected branch is girdled by removing a ring bark 2-3 cm in width. (b) The girdled area is covered with a ball of moist spahgnum moss or similar material (c) The moss is covered with aluminum foil or plastic and twisted or tied at each end.

Marcottage has been used successfully for a long time in Southeast Asia to propagate carambola. In tropical America it has not been so successful. In Florida, for example, often only 25% to 30% of the marcotted branches will form roots. The reasons for the regional differences have not been determined. In tropical America budding and grafting are considered better methods of propagation for carambola than marcottage.

Cuttings:

An alternative method of propagation is the rooting of cuttings. This is a method not yet well developed for Carambola. The percentage of cuttings forming roots is very low. Work is underway to study the influence of hormones, media, hot beds, and other techniques on rooting. Healthy, vigorous shoots 20-30 cm long are cut from the tree. The leaves are removed from the lower 1/3 to 1/2 of these cuttings and the leafless parts of the stems are stuck into the moist

rooting medium in containers or beds. Well-drained, well-aerated artificial media are essential for good results. Suitable media include mixtures of sand, vermiculite, peatmoss or similar materials.

The cuttings are kept moist by intermittent application of a fine spray of water from mist nozzles or by covering the containers or beds with bags or sheets of plastic. Roots should form at the lower ends of the cuttings in 6-8 weeks under good conditions. When roots have formed, the cuttings are transplanted to containers of soil and placed in a nursery area until they have grown large enough to be planted in the field. Up to now this method has given erratic results for Carambola. More research is needed to make the method dependable.

Tissue Culture:

In experiments with tissue culture of carambola in Florida and Trinidad, callus cultures grown from leaf tissues readily differentiated shoots but not roots. Until further research is done, tissue culture cannot be considered a successful method for propagation of carambola trees.

1.4 Care of young trees in the nursery:

Fertilizer: Light applications, about 28 gr, of granular fertilizer, should be made on the soil in the containers every 4 to 6 weeks. Occasionally, chlorosis occurs on the leaves. It can be corrected by a spray application of soluble fertilizer to the leaves. A dilute solution of ammonium sulfate applied to the soil will also help in correcting chlorosis.

Irrigation: Water should be applied on a regular basis as needed. Under normal conditions watering once per day is sufficient.

Weed control: Weeds should be removed by hand from the containers when they are small to prevent competition for water, nutrients and light.

Pest control: Except for scales and occasional fungal leaf spots, pests are not an important problem at the nursery stage. Monthly application of a scabicide and a fungicide will prevent buildup of these problems.

1.5 Release of plants from the nursery:

Timing:

With good care rootstock plants can be ready for grafting or budding in 4 to 8 months. After grafting, trees can be ready to plant in the field in 4 to 6 months more.

Recommended standards:

Trees ready for planting should be 80-120 cm in height with a well-developed central stem and a crown of several branches. Some growers plant trees which have only a single stem and let the secondary branches develop in the field. The root system should be developed well enough that the soil is held together when the plant is removed from the container but it should not be "pot-bound". The leaves should be large, with medium green to dark green color. Avoid releasing plants from the nursery with tender new growth.

PART 2: PLANTING AND POST-PLANTING CARE

2.1 Planning the orchard:

Several factors must be considered in the location and design of the orchard. Topography is of great importance in determining the planting pattern for the trees and in affecting soil erosion. Other important factors are wind velocity and direction; amount and distribution of rainfall; availability and quality of irrigation water; depth, fertility, drainage, and aeration of the soil and amount of sunlight exposure. Often growers must use

sites in which conditions are not optimal for the crop because they have no other land. In such cases they must take advantage of all available technology to produce the crop profitably.

Another factor to consider is whether the Carambola will be grown in a pure stand - also called monoculture - or together with other crops on the same land - called multi-cropping planting. Monoculture is more common in plantations on flat land where a high degree of mechanization with trucks, mowers, pruning machines, sprayers, etc. can be used. Under Monoculture production practices are easier and more cost effective. Monoculture has the disadvantage that pest and diseases build up more than when the carambola trees are interspersed with other crops.

2.2 Establishment:

After the planning of the orchard is completed, clearing of the land may be necessary. This can be done mechanically or by hand, depending upon the land area and the density of the existing vegetation. In flat or gently sloping terrain, cultivation is normally done mechanically. Plowing and rotation are the most common cultivation methods. In hilly land, where mechanization is not feasible, planting sites about 1 m in diameter are prepared by digging the soil with a hoe. Then, individual "eyebrow terraces" are made where the planting hole is to be established.

Layout:

Three main planting systems are recognized: square, rectangular, and triangular (Fig. 9). The first two are used mostly on flat land. The triangular pattern is more common for planting on hillsides. Planting distance should be related to the management of the orchard and the cultivar to be used. Where mechanical equipment is to be used, the rows must be farther apart than where the operation is to be entirely manual. Some cultivars have a larger canopy than others, e.g., 'Golden Star' is larger than 'Arkin', and B-2 is smaller than B-10. In Malaysia carambolas are planted with a spacing of 5 x 5 m (400 plants/ha) and 6 x 6 m (278 plants/ha.) In Florida, trees are planted in rectangular designs from 4 to 4.5 m x 6 to 7.5 m, giving populations of 250-300 trees/ha. Square patterns are also used, at about 6 x 6 m. For triangular patterns spacings of 6 x 6 x 6 m or 7 x 7 x 7 m are recommended, giving a population of 640 to 470 plants/ha.

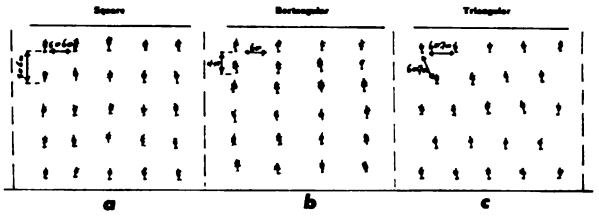

Fig 9. The Three Main Planting Systems for Carambola. (a) Square (b) rectangular (c) triangular.

High density plantings are feasible during the first few years. Eventually the trees become crowded and thinning becomes necessary. High density planting is recommended for places where land is scarce and expensive.

As a general rule the planting hole should be twice the width and depth of the container in which the plant is grown (Fig. 10). In shallow soils, keep the topsoil separate from the subsoil. It is recommended to incorporate a mall amount of a complete mineral fertilizer and about 2 pounds of well decomposed manure with

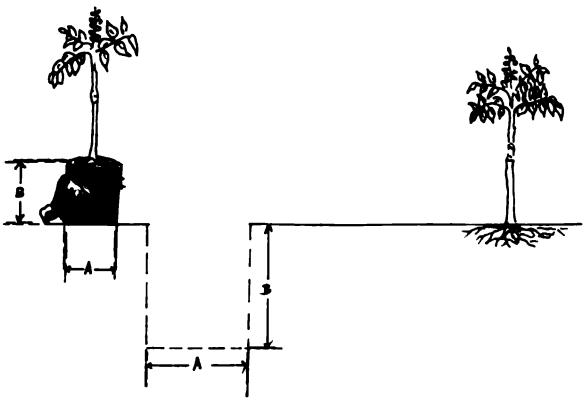

Fig 10. The Planting Hole. As a general rule the planting hole should be twice the width and depth of the plant container.

the topsoil. This mixture is used to fill the area below and around the soil ball of the tree being transplanted. Remove the container, taking care not to disturb the root system. The surface of the soil ball should be slightly lower than the surface of the soil around the planting hole.

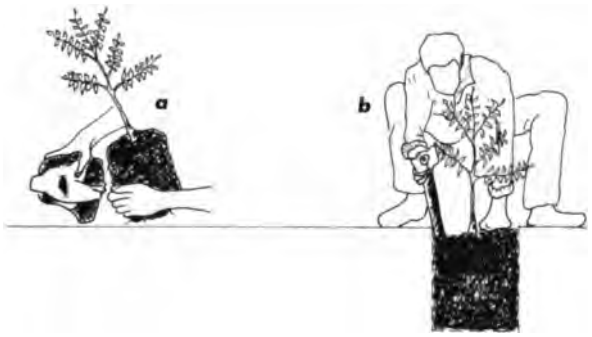

Fig 11. Planting In The Field. (a) Be sure to remove the container, taking care not to disturb the root system. (b) With the help of a stick, add soil and water to fill empty spaces thus eliminating all air pockets. Ensure that the surface of the soil ball is slightly lower than the surface of the soil around.

Planting on Flat Land:

Carambola trees are usually planted in a square or rectangular pattern on land that is flat or gently rolling. These designs facilitate the use of mechanical equipment. The rows should be oriented so as to favor maximum exposure of the tree canopies to sunlight and the passage of winds through the orchard.

Planting on Hillside:

A large percentage of the land in the Eastern Caribbean has slopes of 20 % and over, thus soil and water conservation are important issues to consider when planting any crop. Under these conditions carambola trees should be established on triangular patterns and ideally on terraces. The construction of large terraces is an expensive operation. Planting in individual "eyebrow" terraces which accommodate one tree at a time can be very useful to control erosion at a relative low cost (Fig. 12). Live

Fig 12. Individual "eyebrow" terraces. Accommodate only one tree but are very useful to control erosion at a relatively low cost.

grass barriers such as those made with pachouli and lemon grass, provide extra protection to the soil from erosion. These barriers are established every three to five rows depending on the steepness of the slope. The orientation of the rows should allow for a maximum use of sunlight, and a

free passage of the wind, while providing protection against erosion (Fig. 13).

Fig 13. Live grass barriers. Grasses are established every three to five rows to provide extra protection from erosion.

Intercrop:

Agriculture in most of the Caribbean islands is characterized by multi-cropping systems. The combination of root crops, food crops and fruit trees is a normal pattern found throughout the region. The carambola tree can be adapted to these multi-cropping conditions, but the system is more efficiently managed if the orchard is planned prior to the establishment of the trees. Carambola trees can be inter-planted with bananas, nutmeg, citrus, avocados, mangoes, papayas, annonas and other fruit trees. With cocoa and coffee care should be taken not to over-shade the carambola tree since the yield and quality of the fruit may be significantly reduced. Inter-cropping with food and root crops is also feasible. However the planting of root crops should be done so as to avoid the root development area of the carambola tree. This can be achieved by concentrating the planting of the temporary crops to areas outside the "drip area." Crops with vines, such as curcubitaceaes, e.g. squash and cucumbers, should be avoided since it is difficult and costly to maintain the vines away from the trees.

Windbreaks:

Although the wood of the carambola tree is relatively flexible, when planting in areas exposed to high wind intensity, such as coastal areas, protection should be provided by the establishment of windbreaks. This helps to reduce wind-scar damage to fruit which is one of the most important causes of post-harvest rejections. Temporary windbreaks can be provided with pigeon peas, sugar cane, bananas or plantain. For permanent wind-breaks, fruit trees such as mangoes and jamoons can be used. Casuarinas and other forest trees may also be used as permanent windbreaks for carambolas.

2.3 Orchard management:

Care of the trees in the orchard is different for non-bearing and bearing trees. Care includes fertilization, irrigation, weed control, pruning and pest management.

Fertilization:

The fertility of the soil must be considered in the development of the fertilization program. A soil analysis is helpful in determining the initial requirements of the carambola trees. Two types of fertilizer are recommended, organic (manure) and inorganic (mineral). In the first few years a balanced formula high in nitrogen, phosphorus and potassium e.g. 15-15-15, is normally required.
Magnesium is frequently required and can be applied in the mixed fertilizer or separately. Frequent applications, e.g. every 6-8 weeks, are made to young trees.

Although the amounts required will vary from one place to another, the program in most places is initiated with 100-200 g per tree per application gradually increasing to 400 g by the third year. The frequency of application is reduced to 3 or 4 times a year when the trees reach about 4

years of age. As with other tree crops, applications of phosphorus to older trees is reduced because phosphorus accumulated in the soil recycles and gradually becomes available to the carambola tree.

Sometimes deficiencies of minor elements appear. Iron deficiency normally is corrected by application of chelated products (e.g. Sequestrene 138, Sequestrene 330). Applications of 50-100 g are made by drenching in the soil. As an alternative, small amounts (10-15 g/tree) are applied through the drip or micro-sprinkler irrigation system every 2-4 weeks. Zinc and manganese are applied as inorganic compounds (zinc sulfate, nitrate, manganese sulfate) to the soil or as neutralized inorganic compounds sprayed on the leaves to prevent damage.

Weed control:

Weed control can be done manually, mechanically, chemically, or by a combination of these methods. Manual weeding is done with a hoe or a cutlass. Mechanical weeding is done with a mower or by shallow cultivation with a rotovator or disk plow. Normally, mechanical methods are used to control weeds in the space between rows and, if the tree spacing is wide enough, between the trees in the row. Weeds near the tree trunk need to be controlled manually or chemically to prevent damage to the tree. Herbicide may be applied in a circle under the tree or in a continuous band in the row. These chemicals can be applied with a tractor-mounted boom sprayer, a knapsack sprayer or mist blower, or with a "Chemi-hoe", the method used may vary with the size of the orchard.

The most common herbicides used are Paraquat, Roundup, and Diuron.

Pruning:

Under favorable conditions the carambola tree grows vigorously and pruning is often needed to control tree size and to remove dead limbs which interfere with cultural practices or movement of vehicles in the orchard. When the canopy becomes dense and interferes with light penetration and aeration, some overlapping branches should be removed. Usually, heavy pruning is not needed until about the fifth year of age.

Pruning for size control facilitates harvesting, bagging of the fruit and pest control and can be done by hand with loppers or saws, or by mechanical pruning machinery. In Florida, pruning for size control consists mainly of topping the trees back to a height of 3-4 m. Eventually, as the trees become more crowded in the rows it is expected that periodic mechanical hedging will be necessary.

Growers in Taiwan train the trees to a desirable shape by a combination of pruning and trellising. In Malaysia bending and tying of branches are used to control tree size, to increase flowering and to facilitate bagging and harvesting of fruit.

Pest Management:

In designing a pest control program, producers must consider the requirements of the intended markets for the fruit. Some countries, such as the USA and Japan, have more stringent regulations than others concerning pesticides residues and quarantine requirements. Production for the organic food market restricts the use of synthetic pesticides and inorganic fertilizers. In any case, an integrated pest management (IPM) system is always recommended. Little research information is available on IPM of carambola. In Malaysia and Taiwan bagging of the fruit is a common technique used to prevent female fruit flies from laying eggs in the fruit. It also protects the fruit from damage caused by bats, birds, and other pests. The fruits are bagged about 3 weeks after fruit set when they are 4-5 cm long. Paper bags 20x30 cm are used.

Fruit thinning:

Fruit produced during the first year after transplanting should be removed from the tree to stimulate vegetative growth. After the second year, fruit thinning may be done to select 1 or 2 fruits per inflorescence to increase fruit size and quality. All irregular-shaped fruit should be removed.

2.4 Causes, effects and control of factors affecting yield and fruit quality in the field:

Under good management practices carambola trees begin to produce fruit in the second year, and production increases rapidly with age until about the ninth or tenth year. Yield of trees at various planting ages in Florida and Malaysia are presented in Table 1.

Of the several factors affecting yield or fruit quality in the field, the most important are related to pests, the environment, physical or chemical damages, and nutritional aspects.

Pests:

In tropical America pest problems are not as important as those of Southeast Asia. Pests can be divided into those affecting vegetative parts of the tree and those affecting primarily the fruit. The carambola tree is affected by scale insects, mealybugs and fungal leaf spots. Of these, the most serious are the leafspots, which can cause leaf drop affecting yield and fruit quality. Where it is permitted, regular sprays of benomyl should prevent their occurrence. Scale insects and mealybugs may be controlled with sprays of broad spectrum insecticides. Pests which feed on the fruit include fruit flies, mealybugs, stinkbugs, orthoptera insects (grasshoppers, crickets, katydids, snails), slugs and birds. Fruit flies are the most important pests, not because of the damage to the fruit, but because of their importance in international quarantines. Birds prefer sweet, soft fruit to sour, firm fruit, possibly because they are more juicy. It has been reported that bird damage is most severe during the dry season, when water is scarce. Soft rot of carambola fruit is caused by several fungi, including Alternaria, Colletotrichum, Phoma, and Phomopsis. Damage develops principally after harvest, in stored fruit which has been crushed or bruised. The best way to prevent this is to avoid damage to fruit during harvesting and handling. Frequently sooty mold, caused by the fungus Leptothyrium sp., develops on the surface of the carambola fruit. This is one of the major causes of rejection at the packinghouse. Sooty mold can be eliminated by washing or wiping the fruit, but most packers avoid doing this because of the expense involved and because it reduces the natural waxy gloss of the fruit and shortens storage life.

Table 1. Yield at Various Planting Ages in Florida and Malaysia

Country	wt. of fruit	Years after planting 2	3	4	5	6	7	8	9	10+
Florida	kg/tree	10	25	50	100	150	200	250	300	350
Malaysia	kg/tree	60	100	150	175	180	200	220	240	240
Florida	Mt/Ha	3	7.5	15	30	45	60	75	90	105
Malaysia	Mt/Ha	16.5	27.5	41.5	49.5	50	60	61	66.5	66.5

Sources: After Campbell, C. (1989) and Wahabngah, A. Ahmad and A. Hassan (1989).

Environmental Factors:

Three environmental factors are most important in carambola production. These are wind, water and light. Strong winds cause defoliation, flower and fruit drop, water loss and wind scarring of fruit. The defoliation is especially important with young trees, and in extreme cases can cause death of the newly planted trees. Establishment of wind breaks is recommended in exposed areas. Water stress and water logging are both detrimental to yield and fruit quality, and in extreme cases can kill the plants. Carambola trees are best adapted to areas with medium to high rainfall. Supplemental irrigation is needed every 7-10 days under dry conditions. Well drained soils are necessary for good performance of trees.

The carambola tree grows well under shady conditions, but it will not produce a good crop and fruit quality is lower than that of trees growing in full sun.

Physical and Chemical factors:

Physical damage to the fruit and the tree can be caused by machinery, harvesting tools, containers and fingernails. Growers should train their workers to drive carefully inside the grove, handle fruit gently during and after harvesting and avoid overloading or dropping the containers. High concentrations of pesticides and drifting of herbicides can cause damage to the fruits and the leaves of carambola trees. Careful management of chemical products is essential.

Nutritional Factors

A balanced fertilization program is essential for good yield and high fruit quality; deficiencies in minerals (nutrients) as well as excesses will reduce both. For example, in Florida, fruit which normally would have a golden yellow color will be pale yellow and unsalable on trees with severe iron deficiency. Deficiency of nitrogen will invariably reduce tree and fruit growth. Few studies have been conducted to determine the effect of deficiency or excess of other elements.

PART 3: HARVESTING AND POST-HARVEST HANDLING

3.1 Harvesting:

Factors:

The carambola fruit is easily injured and must be handled with care during harvesting. The fruit is picked from the tree by hand or with a short picking pole. It is best to maintain the trees short enough that workers can pick the fruit while

standing on the ground. Undersized or deformed fruit is culled out (eliminated) during the harvesting operation and left on the ground in the orchard.

Tools and Equipment:

The picking pole consists of a short metal or wood pole about 3m long, with a cloth bag at one end which catches the fruit as it is detached from the stem. Several designs are available. Some growers use ladders or hydraulic lifts to assist in reaching the fruit, but most consider it preferable to keep the trees short so the use of these is not necessary. The fruit is placed in containers of about 10-12 kg capacity as it is picked from the tree. Plastic boxes or buckets are preferred in Florida to metal and wood containers, or cloth and plastic bags, because they cause less injury to the fruit. The boxes are carried directly to trucks by the workers or stacked in wooden bins and placed on the truck with a mechanical forklift. It is important to avoid as much as possible the transfer of fruit from one container to another because this usually involves some damage to the fruit. In Florida, for example, the fruit is placed in one container at harvest and the fruit remains in that container until it is packed in the shipping cartons at the packing house.

Maturity Index:

Color of the fruit is considered the best index of maturity. Fruit size is too variable to be dependable in determining maturity. Fruit that is to be stored and shipped for long distances should have changed from green to yellow color on 1/2 to 3/4 of the surface. Fruit at this stage will have a post-harvest life of about 3 weeks, and will continue to change color until it is completely yellow. Fruit for local sale can, of course, be more fully colored than fruit intended for shipping. Carambola fruits that are harvested prematurely do not ripen to full flavor and color.

In Malaysia five color indices are being used:

Index 1: Full Green
Index 2: Traces of yellow to less than 25% yellow
Index 3: 25-75% yellow
Index 4: 75-100% yellow
Index 5: Full orange

Index 1 and 2 are for unripe fruit, index 3 and 4 for ripe fruit and index 5 for fruits which are overripe.

3.2 Post-harvest handling:

Field-Handling:

It is essential to handle the fruit carefully at all stages to avoid large post-harvest losses. Containers of fruit should be kept out of full sunlight in the field, to prevent the fruit from being injured by high temperature. It should be carried to the packinghouse as soon as possible. Fruit should be deposited gently in the containers. Bruising will easily occur if fruits are dropped onto others already in the container. Where carambola is bagged for protection against the fruit fly, the bag with fruit inside is removed from the tree and placed in a field in containers. The bags help protect the fruit until they are unbagged at the packing house. Some farmers prefer to pack the fruit in the field in small sheds constructed in the orchard. If the fruit has been bagged, for protection from pests, the bag is removed and the fruit is arranged in the boxes following the same procedure as in the packinghouse.

Transportation to Packing house:

Harvest containers should be stacked carefully on trucks and carried directly to the packinghouse.

Receiving:

Upon arrival at the packinghouse fruit is customarily weighed and recorded. If cooling facilities are available it is best

to cool the fruit immediately to remove field heat. Some packinghouses are equipped to wash the fruit upon arrival. Washing is done in water containing 10% of a disinfectant like sodium hypochlorite (household bleach 5%). Concentration of 1%, or higher, has been found to reduce fruit storage life. If the fruit is clean, some packers prefer not to wash it, because washing removes some of the waxy covering which is essential to good fruit appearance and retards moisture loss. Other packers prefer to wipe the fruit using soft sponges to free them from dirt or foreign matter.

Sorting and Grading:

Some packinghouses are equipped to carry out the packing operation simultaneously with the sorting of the fruit. The harvest containers of fruit are brought to the packing table on a slow moving canvas conveyor belt. Packers take the plastic boxes from the conveyor belt one at a time and place them on the packing table. There, the packers eliminate undesirable fruit as they pack the good fruit in the shipping box. Where the conveyor belt is not available this operation can be done on fixed sorting tables.

Sizing, Grading and Rejecting:

Some countries such as Malaysia have a system of standards for carambola to be shipped. These grading requirements are used to ensure uniform sizes, clean fruit with minimal damage and uniform maturity in each carton.

Poorly shaped, immature or undersized fruit that was not culled in the field must be eliminated in the packinghouse. The most important cause for rejection in the packinghouse is crushing or bruising. Damaged fruit must be eliminated because it is highly susceptible to soft rots caused by fungal infection. Other defects include damage by insects and birds, wind-scarring of the fruit surface and sooty mold. Rejection rates normally reach 25 to 35% when shipping for the export market.

Packing:

The most popular shipping container is a cardboard fiber box (CFB). Many designs of carton are used. The most common designs in Florida hold 3.5 kg of fruit in a single layer or 8 kg of fruit in a double layer. The fruit is placed in the cartons by hand. Various methods are used to protect the fruit in the carton. Individual fruits are wrapped in tissue paper, often waxed to reduce water loss. Cardboard or foam plastic dividers or cushions can be used to keep the fruit from rubbing against one another. A foam pad is placed on the bottom and on top of the fruit. The important thing is to prevent fruit movement in the container during shipment, any movement invariably causes some damage. In Malaysia two sizes of CFB are used. One is 45 x 32 x 28 cms and holds approximately 68 carambolas and weighs about 14 kg. The other, usually used for the European market, holds up to 18 carambola fruits and weighs 3.5 kg. In the latter, each fruit is individually wrapped with paper and the CFB is lined all around with sponge. All cartons should be identified with the number of fruit, gross and net weight, size, treatments and country of origin.

Storage:

Cold storage is an excellent method for extending the storage life of the fruit. A temperature of 5°C is recommended for storage and shipment. Fruit stored at 5°C can last 3 weeks or more without significant reduction in quality. Atmospheric humidity should be kept in the range of 85-90% to reduce water loss and shriveling of the fruit. Carambola is often shipped in mixed loads with other fruit.

In Florida Carambolas are shipped with avocados at 7°C and with limes or mangos at 12-13°C. Storage life is not as long at the higher temperature as it is at 5-7°C.

Shipping:

Shipping of carambolas can be done by air, land or sea. Air shipment is quick but expensive. Air-freight is mainly used to market the highest quality fruit which can attain attractive prices and allow the recovery of freight charges. Land transportation is used for local markets. To reduce transportation costs to overseas destinations, some shipments are being made by sea. The perishability of the fresh fruit necessitates careful handling during shipment. Fresh fruit must be refrigerated to obtain long storage life. Some processed products must be refrigerated also, but for many of them this is not necessary. Since most of the processed products are less easily damaged than fresh fruit, the handling and storage of processed products are easier.

Quarantine Requirements:

Although most reports have shown that carambola is not one of the fruits preferred by the Caribbean Fruit Fly (Anastrepha suspensa) it is listed under the host list for this fruit fly in the USA.

A recent development is the use of post-harvest treatment with low temperature to destroy fruit fly larvae in infested fruit. This treatment is being used within the United States to satisfy the requirements of the state of California, which has a quarantine against fruit from Florida, where there is an infestation of the Caribbean Fruit Fly. Carambola fruit must be held at 1°C for 15 days. This treatment method has only been cleared, to date, for the 'Arkin' cultivar.

3.3 Uses of the fruit

The carambola can be used in many ways. Although the current emphasis is on fresh fruit in world markets, many processed products can be made from the fruit as well. Processing contributes added value to a fresh fruit industry by allowing the utilization of low quality fruit which cannot be marketed fresh, thus improving grower returns.

Fresh fruit uses:

The fresh fruit may be eaten out of hand, but most frequently is cut into pieces and served with other foods. Slices make an excellent addition to fruit salads, or may be used as a garnish with meats or cocktails. Research has shown that vacuum-packed fresh slices are a good product which can be stored under refrigeration for 6-9 weeks.

Processing:

Canned carambola juice can be used alone or blended with other fruit juices to make excellent drinks. Carambola juice or puree can be incorporated into sherbets or ice cream. Whole fruit, fruit parts, or puree can be dehydrated in solar driers or with artificial heat. Sliced or diced fruit can be canned in syrup or made into conserves, marmalades or jellies. Whole fruits or slices can be preserved with sugar as glaced products. The whole or sliced fruit can be pickled with vinegar or salt. Wines and liqueurs are also made from the fruit.

3.4 Nutritional Value

The composition of 100 grams of the edible portion of carambola is presented in Table 2. As can be noticed, the carambola fruit is low in calory and fat but is relatively rich in minerals and vitamins A and C.

Table 2. Composition of 100 grams of edible portion of Carambola

Water	90.4%
Food & Energy	35.0 calories
Protein	0.7 g
Fat	0.5 g
Carbohydrate:	
Total	8.0 g
Fibre	0.9 g
Ash	0.4 g
Calcium	4.0 mg
Phosphorus	17.0 g
Iron	1.50 g
Sodium	2.00 mg
Potassium	192.00 g
Vitamin A	1200.00 Iu
Thiomin	0.04 mg
Riboflavin	0.02 mg
Niocin	0.30 mg
Ascorbic acid	35.00 mg

Source: Handbook of the Nutritional contents of Foods, USDA. 1975

3.5 Markets

There are many possibilities for selling carambola fruit, and the producer should take advantage of as many of them as possible. The local fresh fruit market in the production area can usually absorb a relatively small volume of fruit, and prices are likely to fluctuate a lot. An advantage of local marketing is that some fruit which is not suitable for shipping to distant markets can be sold locally. For example, fruit too ripe to ship may be preferred locally because of its superior eating quality. Processing factories may be located in the local production area, and can utilize an important part of the crop. The lower price received for processing fruit is partly offset by the lower cost of transportation and handling.

Regional markets also offer opportunity for sale of carambolas. Presently in the Caribbean the volume of fruit sold in the regional market is relatively small. Potential consumers of carambola include not only the local populace but tourists visiting these Islands. In countries like Antigua and Barbuda, Barbados and Trinidad and Tobago the growing tourist industries offer good opportunity for sale of exotic tropical fruits like carambola. This is well recognized and some development of orchards is already in progress.

Extra-regional marketing of carambola has attracted much attention in recent years. The fruit is now known in Europe, the United States, Canada, Japan, Singapore, Hong Kong, and the Middle East. Producers and packers who intend to participate in the export trade need to be aware that they can succeed only if they maintain high standards of quality and handle the fruit very carefully. Prices in the export market are good at this time. Although world production is increasing, consumption of the fruit is increasing also and it is expected that carambola production will remain a profitable business in the future.

In 1988 Malaysia sold 13,022 mt to international markets, Hong Kong being the main destination. The Malaysian government has estimated a deficit in supply which will reach 13,298 mt by 1990. By 1995 and 2000 this deficit is expected to increase to 21,436 mt and 27,652 mt, respectively. Wholesale prices for Malaysian carambola in the main markets ranged from US$ 1.00 to as much as US$ 3.60 Kg. In the USA wholesale prices in 1989 ranged from US$1.75 to US$5.25/kg. It is expected that prices will drop in the international markets as more countries develop a sustainable supply. Nevertheless, it is also expected that the demand will increase significantly as more people taste the exquisite flavour of this exotic fruit.

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