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CULTIVATION OF NEGLECTED TROPICAL FRUITS WITH PROMISE

Part 1. The Mangosteen

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Cultivation of Neglected Tropical Fruits with Promise. Part 1. The Mangosteen.

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NOTICE TO READERS

Most countries regulate the use of pesticides and establish the amount of pesticide residues permitted on raw agricultural commodities. In the United States, the Federal Insecticide, Fungicide, and Rodenticide Act, as amended, governs the use of pesticides; and the Food, Drug, and Cosmetic Act, as amended, governs pesticide residues. The Environmental Protection Agency (EPA) administers the former Act and the pesticide-residue provisions of the latter Act. At this writing, the pesticides mentioned in this publication are not registered by EPA for use on the mangosteen nor have residue tolerances been established. Individuals interested in cultivating the fruit commercially or in exporting it should check the pesticide regulations of the importing country.

CULTIVATION OF NEGLECTED TROPICAL FRUITS WITH PROMISE

Part 1. The Mangosteen

By Narciso Almeyda and Franklin W. Martin¹

ABSTRACT

In spite of the many species of fruits provided by the Tropics, only a relatively few are widely known. The most exquisite of the rare fruits is the mangosteen, *Garcinia mangostana* L., considered by many to be the most delicious fruit of the Tropics. Although cultivated for centuries in Southeast Asia, the mangosteen has been difficult to introduce to the Western Hemisphere because of the problem in transporting the seeds, the viability of which is short, and the difficulty of establishing the tree during its first years. The best known method for the propagation of the mangosteen is by seeds. Asexual techniques, especially bud grafting and approach grafting, have been partially successful, and approach grafting produced excellent results in one experiment. Transplanting the mangosteen must be done delicately because of the sensitive taproot. Able to grow in almost any kind of soil, the mangosteen should be planted at the beginning of the rainy season. Once planted, the trees should be given some shade, fertilized, and kept free of weeds. Cover crops, such as pigeonpeas, bananas, and plantains, afford light shade, enrich the soil, and act as windbreaks. In commercial plantings, the mangosteen requires little pruning, which should be done, when needed, in the fall after the harvest. The few diseases and insects found to attack the mangosteen can be controlled with readily available commercial fungicides and insecticides. The mangosteen begins to bear in an average of 8 to 10 years, and an adult tree yields from 500 to 1,500 fruits. Careful handling and packaging will allow a shipping time of up to 3 weeks. The mangosteen is normally used principally as a fresh fruit, but the seed is also edible, the wood makes fine furniture, and the tree will fit well in ornamental landscapes. **KEYWORDS:** fruit, fruit cultivation, mangosteen, mangosteen cultivation, tropical fruit, tropical fruit cultivation.

INTRODUCTION

Thanks to a mild climate, the Tropics are enriched by an immense variety of plants that grow exuberantly throughout the year. Thousands of species yield products of an economic value, and, of course, hundreds produce edible fruits of a

wide variety of forms, colors, and flavors. In spite of the great quantity of fruits provided by the Tropics, only a few are widely known. The use of many of the rich fruits of the Tropics has been limited, and other fruits have not been recognized for their potential importance.

With respect to the attention that has been given to tropical fruits, we can recognize three principal groups:

1. Fruits that are well known and that are used almost daily. These fruits are normally cultivated

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commercially and have received sufficient scientific attention. This group includes the majority of the citrus fruits, pineapple, avocado, mango, papaya, and guava.

2. Fruits that are less well known and that are only rarely found in the market. These are fruits that often have a fairly narrow growing season, making them unavailable throughout much of the year. Generally, they are not cultivated commercially, and scientific investigation of them has been inadequate. This group includes fruits such as the custard apple, soursop, cashew apple, spanish lime, marmalade box, sapodilla, star apple, and others.

3. Fruits that are little known or in some cases completely unknown by the public. These are called exotic fruits, in some cases because they have been introduced from far away places only recently, or because their distribution has proceeded very slowly. Very little or no scientific attention has been given to these fruits. This group includes the mangosteen, langsat, carambola, ceylon gooseberry, durian, velvet apple, akee, jackfruit, rambutan, and many others. We shall discuss this third group in this series, because we believe that the great richness of the Tropics is lost because of a lack of knowledge and appreciation of these unusual fruits, often of exquisite flavor and of high nutritional value.

There are a number of reasons that explain the ignorance of these important tropical fruits. First, many people have never had the opportunity to familiarize themselves with these fruits. Such fruits are extensively cultivated in their countries of origin and recognized as important but outside of such areas they are represented only by a few scattered trees or a specimen or two in an experiment station. Secondly, the apathy of the general public has hindered the development of these fruits. People are accustomed to the fruits that they have eaten all their lives, and they are not curious about new fruits offered to them. When one tries a new fruit, it is important first to have an appropriate attitude towards the fruit. There should be an attitude that the fruit can be enjoyable, but that the flavor may not be immediately agreeable because of a lack of experience with it. If only a small amount is tested at the beginning with the attitude that with time the flavor will be acceptable, there is a good chance that the fruit will eventually be relished, and later sought after.

In order to introduce a new fruit to the public

successfully, a program of education is necessary. Such a program could be done by means of printed material, such as this publication, the newspapers, or radio and television. Another technique is to introduce the fruit by means of the supermarket system, giving opportunities to test the fruit and to obtain trees for planting.

This publication would be too extensive if we considered all of the exotic fruits that appear adapted to the Tropics. We plan to prepare a series of bulletins, each of which treats specifically the cultivation of a single species. This publication introduces the fruit considered the most exquisite of the Tropics, the mangosteen, *Garcinia mangostana* L. It would be worth every effort to make this fruit well known, especially in the Western Hemisphere. The Mayagüez Institute of Tropical Agriculture (MITA) can provide limited quantities of seeds of this fruit during the normal seasons of production in summer and late fall.

The mangosteen has been considered the most delicious fruit of the Tropics. Many have said it is "the queen of fruits," or "the finest fruit of the world" (7, 9, 25, 26).² The exquisite flavor of the fruit is cited among the marvels of the Far East by the earliest of plant explorers. The flavor has been likened to that of nectar or ambrosia. Popenoe believes that the combination of its beautiful color and its delicate flavor make it without doubt the most valuable fruit of the Asiatic Tropics (25). The mangosteen compares well with the best fruits of the Temperate Zone, such as peaches, pears, and nectarines. It is one of the few fruits that does not require a positive attitude in order to appreciate it, because virtually everyone who tries the fruit likes it.

THE MANGOSTEEN

Origin

In spite of arguments concerning its origin, by far the bulk of the literature suggests that the mangosteen originated in Indonesia or Southeast Asia (21). It is to be found growing wild in the Malay Peninsula, Burma, Thailand, Cambodia, Vietnam, the Sunda Islands, and the Moluccas. It has been planted on a large scale in Ceylon, the Philippine Islands, and in the south of India. Nevertheless, the major part of the fruits marketed in these countries come from wild trees

²Italic numbers in parentheses refer to items in "Literature Cited" at the end of this publication.

or from small plantings, for there are few, if any, systematically developed mangosteen orchards.

The introduction and distribution of the mangosteen to this hemisphere has been difficult because of the problem of transporting the seeds, the viability of which is short. A few trees have been well established in Jamaica, the Dominican Republic, Trinidad, Central America, Surinam, and Puerto Rico. In Honduras, the United Fruit Company has in production more than 20 acres of mangosteens. We believe it is the largest such commercial planting in the Western Hemisphere. In the Canal Zone of Panama, commercial-size plantings have been established. In Puerto Rico, there are only a few isolated trees throughout the island. There are various scattered trees and a small orchard of about 100 trees on the grounds of MITA (27) (figs. 1 and 2). Many of these trees have already produced an abundance of fruit, and their condition is excellent. In the Agricultural Experiment Station of the University of Puerto Rico, Río Piedras, there is a small planting of 25 trees about 20 years old. The success of this planting shows that, in spite of the few trees that exist in the Western Hemisphere, the culture of the mangosteen is certainly possible in this region.

The explanation usually given for the relatively poor distribution of the mangosteen in the Western Hemisphere is the belief that this species requires too much special attention. In addition,



FIGURE 1.—Orchard of about 100 mangosteen trees in production at the Mayagüez Institute of Tropical Agriculture, Mayagüez, P.R. The soil is alluvial, near a small creek, and with natural shade.

it is commonly believed that the tree requires 20 years of growth before it produces. Both explanations are far from the truth. Numerous experiments carried out in Central America and at MITA (26, 27) have demonstrated that the culture of mangosteen is simple in this part of the world, and that the time required for production is less than 10 years.

Nevertheless, various trials made to cultivate this tree in the north of the Philippine Islands, Australia, and Florida, have failed (18). The trees suffer severe damage when the temperature goes below 5° C. Other sensitive fruits have been cultivated at such low temperatures when they have been grafted on rootstocks resistant to cold. If this could be done with the mangosteen, it might be possible to cultivate it in the south of Florida.

Botanical Description

The mangosteen is a broad-leaved evergreen that belongs to the family Guttiferae. To this family belong a number of well-known plants of the Tropics, such as the signature tree (*Clusia rosea* Jacq.), the mammee apple (*Mammea americana* L.), and the tree called María (*Calophyllum brasiliense* Camb.). In the same genus there are many other fruit-bearing species, but none so flavorful as the mangosteen.

The tree has a short columnar or pyramidal form, of medium size, reaching 9 to 12 m in diam-

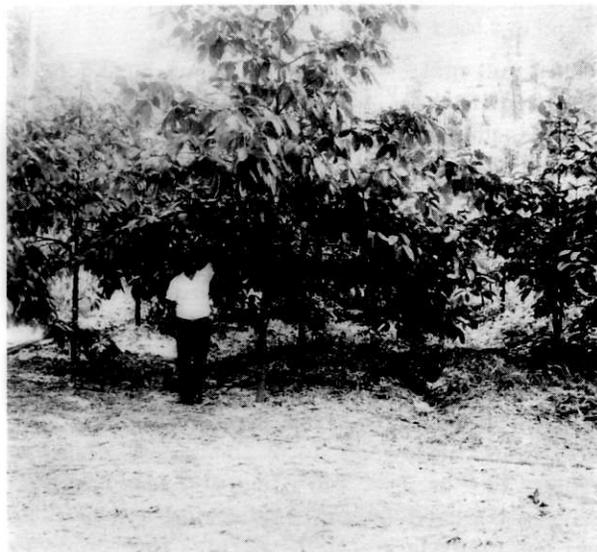


FIGURE 2.—Another view of the mangosteen orchard at the Mayagüez Institute of Tropical Agriculture, Mayagüez, P.R.



FIGURE 3.—Mangosteen tree more than 40 years old on the grounds of the Mayagüez Institute of Tropical Agriculture, Mayagüez, P.R. Its production is high, up to 2,500 fruits per year.

eter at full maturity, with trunk up to 0.6 m in diameter (fig. 3). The central trunk is upright and branched symmetrically. The bark is of a dark brown color, somewhat rugose, and often showing protuberances that have been produced by previous branches.

The leaves are simple and opposite, of an oblong, elliptical form, and vary in size from 15 to 25 cm in length by 7 to 13 cm in width (fig. 4). They are thick and leathery, but smooth and free of pubescence. The color of the upper surface is an olive green that shines, especially in full sunlight, and the lower side of the leaf is a yellow green. The central vein is pale green and is markedly raised on both sides of the leaf. The leaf has many lateral veins parallel to each other and perpendicular to the principal vein, a characteristic that, together with thickness, is common to many of the trees of Guttiferae. The pedicels are short but thick, from 1.3 to 2.5 cm in length,

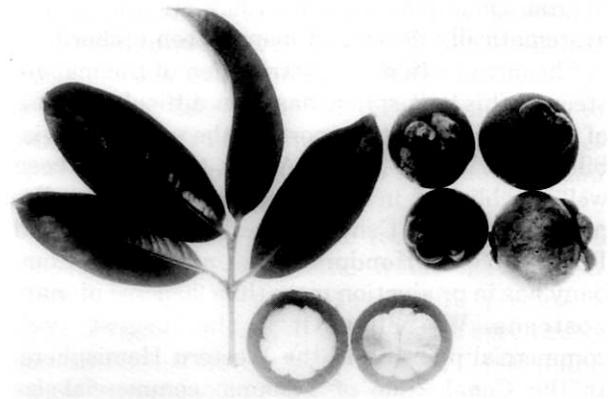


FIGURE 4.—Foliage and fruits of the mangosteen. Observe the delicious white pulp of the fruit that makes this the best fruit of the Tropics. Observe also that the sepals and pedicel remain attached to the fruit.

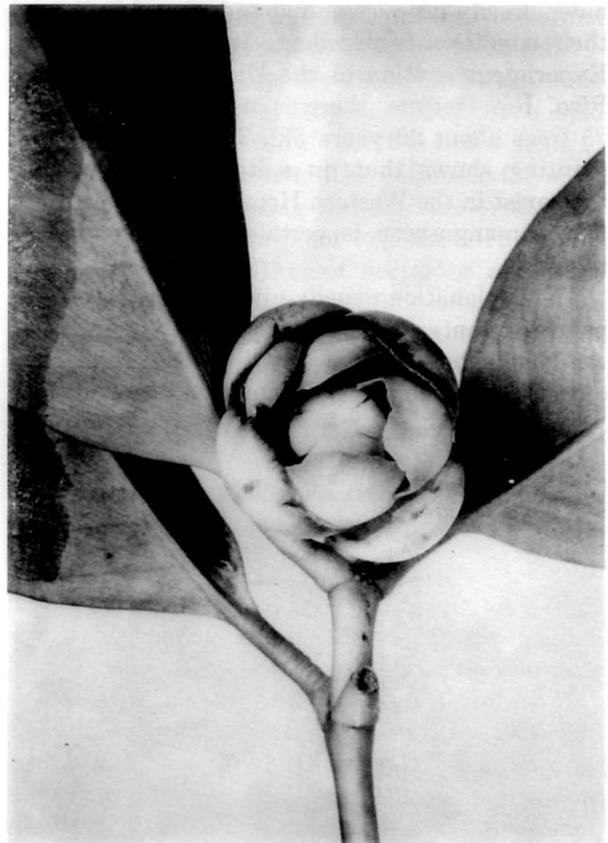


FIGURE 5.—Flower of the mangosteen beginning to open.

and can be broken easily. When they are damaged they exude a yellow latex. The margin of the leaf is entire and the tip is cuspidate.

The flowers of mangosteen are solitary or paired, and develop at the extremes of the branches (figs. 5-7). Only trees with female

flowers are found in cultivation. The male form has not been described and may no longer exist. Nevertheless, seeds are formed apomictically. These have been shown to form from a cell of the gametophyte, for the sporophytic mechanism never develops in the female flower.

The flowers have four sepals and four petals. The sepals are arranged in two series of two each, with the external series 2 cm in length, yellow green, covering the shorter internal pink sepals. The petals are thick, obovate, 2 to 3 cm in length, and yellow green with pink borders. In the center there is a globose ovary with a thick stigma divided into four to eight lobes. The petals drop a day after anthesis, and the fruit begins to develop immediately. No pollination or other stimulation is necessary (fig. 7).

The fruit is in the form of a small tangerine, flattened a little above and below, about 6 to 7 cm in diameter, with a smooth cortex of clear green that changes to reddish purple when the fruit is completely mature (fig. 4). It is similar in appearance to the fruit of the signature tree, except that the latter matures to a light brown color. Normally the four sepals are enlarged and concave. At the distal tip can be observed four to eight remnants of the stigmatic lobes that persist until the fruit ripens. The number of lobes is indicative of the number of segments of the fruit.

When a circular cut is made around the equator of the fruit, it may be separated into two parts. The cortex is 0.6 cm in thickness, fibrous in consistency, and purplish red in color. The interior is composed of four to eight white segments that can be easily separated from each other. These segments are not always uniform, for those that contain seeds are larger than the others. About half of the fruit contain seeds, and there are normally only one or two. Fruits with more than two seeds are rarely found. Seeds have the size and shape of a shelled almond; they are 2 to 2.5 cm long, 1.5 to 2 cm wide, and 0.7 to 1.2 cm thick, brown in color and covered with white pulp that adheres lightly. The pulp is white externally but grayish to transparent near the center of the fruit. It is so soft that it almost melts in the mouth, and it has an indescribably sweet, delicate flavor.

Little scientific effort has been spent on study of the root system of mangosteen (17). When this is well known it may be possible to understand the mangosteen better. The taproot is strong and



FIGURE 6.—Flower of the mangosteen completely open. The flowers have four thick sepals and four petals.

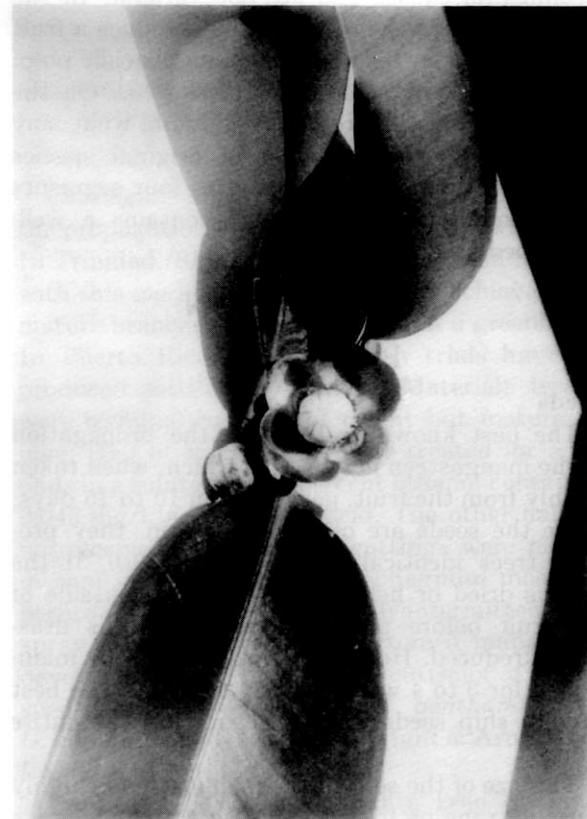


FIGURE 7.—Flower in which the petals have now fallen and the fruit is beginning to form. Observe that the sepals remain attached to the fruit.

deep. Although there are lateral roots, these have few or lack completely the root hairs normally necessary for absorption of water and nutrients.

Varieties

Although the mangosteen has been cultivated for centuries in Southeast Asia, varieties are unknown. As previously noted, the seed is an asexual propagating organ, and therefore the evolutionary process of this fruit has stopped. The descriptions of the mangosteen made in the Malay Peninsula, Burma, the Moluccas, Indonesia, and the New World are in complete agreement regarding its characteristics. We conclude that there are no varieties of the mangosteen (8, 12, 16, 22).

In the south of the Philippine Islands, a form of the mangosteen called Jolo is cultivated, which bears fruit somewhat larger than those of the Malay Peninsula (16). The seeds are reputedly larger and the pulp more acidic and more delicious than the more common form. It is possible, however, that these differences result from environmental causes and are not varietal. In the Sulu Islands, trees are found that produce a fruit with a thicker cortex and a much more acidic pulp, but the flavor is said to be inferior (3). On the island of Borneo, there has been found what may be considered the precursor or original species (16). The fruit of this tree contains four segments about equal in size, and each contains a well-developed seed.

CULTIVATION

Propagation

Seeds

The best known practice for the propagation of the mangosteen is by seeds, which, when taken freshly from the fruit, germinate in 10 to 15 days. Since the seeds are of asexual origin, they produce trees identical to the mother (10). If the seed is dried or held for several days outside of the fruit before planting, germination is drastically reduced. However, the seeds can be maintained for 3 to 4 weeks within the fruit. The best way to ship seeds is by transporting the entire fruit.

The size of the seed of the mangosteen is highly variable, ranging from 0.1 to 2.2 g with an average of about 1.0 g. This difference in weight results in strong differences not only in germination but also in later growth and survival. In care-

fully controlled tests in Puerto Rico, the percentage of germination and rate of growth have been shown to be related to seed size (fig. 8). Apparently the ability to germinate and to grow successfully is related to the amount of food stored in the seed. It is recommended, therefore, that new plantings be established only from the larger seeds, those that weigh 1 g or more. This simple selection can prevent many problems later as the new trees develop.

Seeds should be planted in a medium that is high in organic material. Sometimes the seeds are germinated in a mixture of dried leaves, sand, and charcoal. Other mixtures recommended include equal parts of alluvial topsoil with well rotted sugarcane-filter press cake (cachaza), a mixture of perlite with sphagnum moss, a mixture of topsoil and sphagnum moss, or sphagnum moss alone. With moss, perlite, or mixtures, the seedlings suffer little when removed from the seedbeds for transplanting.

Germination can be done in seedbeds, in which case bare-root transplanting will be necessary, or in individual containers, in which case the plant can be transplanted with an intact ball of soil. In case of germination in a seedbed, transplanting should be done when the plants have only two leaves. In studies at MITA (15), survival of transplants has decreased rapidly as the size of the transplant has increased.

Sometimes two plants, or rarely three, are produced from a single seed. When multiple seedlings are produced, they are smaller and weaker than normal and should be discarded. Smaller plants are also produced by seed that germinate later than normal. Vigorous plants should be chosen at an early stage after germination to avoid slow-growing trees.

One of the most serious problems in the cultivation of the mangosteen is the slow development of plants after germination. It is frustrating to wait a year or more for the development of a pair of leaves. After 2 years many seedlings do not reach more than 15 cm in height. Many plants die during this growth period, but surviving plants grow about as rapidly as those of other tree species.

The poor growth during the first years of seedling life has been attributed to poor growth of the root system during this period (17). The root system consists of only the taproot and is usually free of lateral roots and of root hairs. This problem requires more careful investigation.

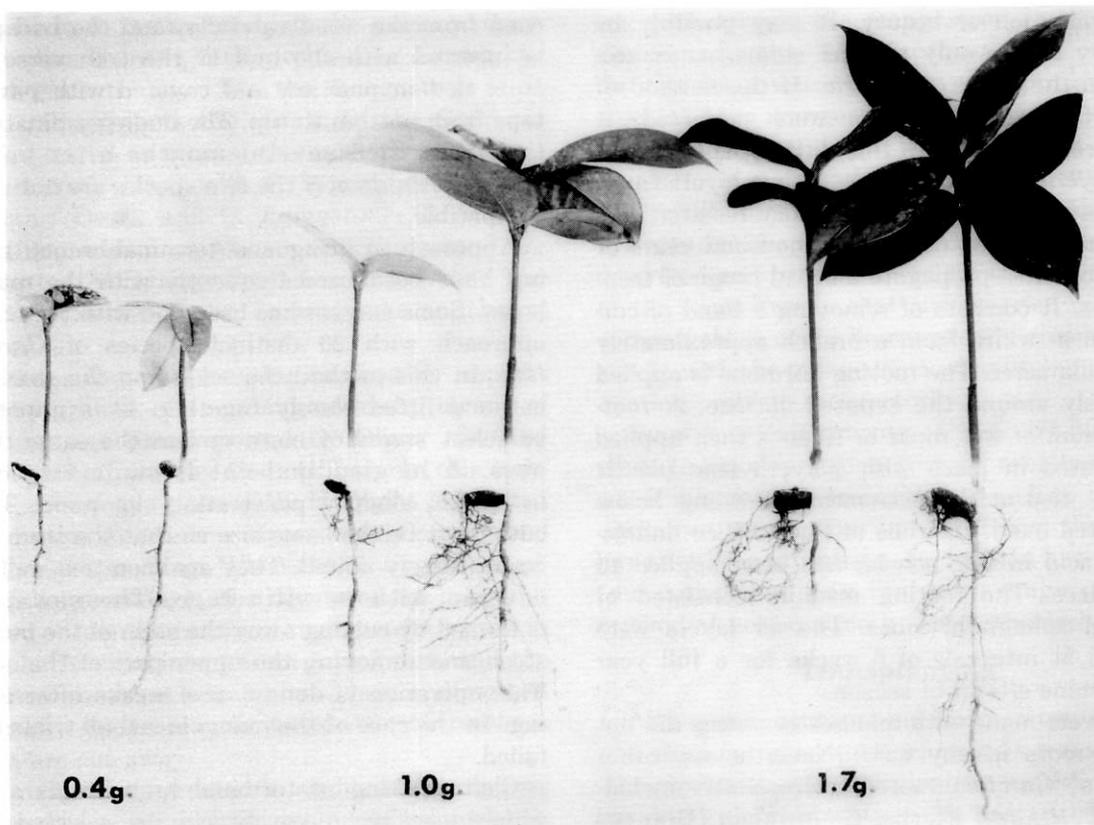


FIGURE 8.—Differences in development of the mangosteen resulting from differences in the weight of the seed. The larger plants resulted from the heaviest seed. Note also that root development is related to the weight of the seed. Plants from small seeds have poor root systems.

Various types of trials have been made to stimulate root production. Some investigators (16) have used yeast extract, in the belief that vitamin B-1, which is essential to root development, might stimulate growth. Plants grown in sphagnum moss and watered with the yeast extract grew more rapidly and produced more leaves than plants that received only control treatments. The use of artificial lights during the night in order to stimulate the growth of plants has not produced positive results. Neither have different types of fertilizers and classes of containers solved the problem. The critical 2 years can be considered one major barrier to the culture of the mangosteen.

Asexual methods

Various asexual methods have been tried to resolve the problem of poor root development and poor seedling survival. The use of cuttings, air layering, and systems of grafting have proved useful with other fruit species in developing new and productive trees of appropriate form in relatively short times.

Cuttings.—Many studies have been made on the propagation of the mangosteen from cuttings. In Trinidad (8), partial success has been reported with this method: propagation was achieved with mature branches planted in sand in a greenhouse. In Puerto Rico, however, such trials have not produced satisfactory results. Materials treated were terminal cuttings of recent but mature foliage. Half of the cuttings were treated for 5 seconds in a solution of 50 percent ethanol containing 0.043 mg/l indolebutyric acid. The other half did not receive treatment. The cuttings were planted in sand or in a mixture of sphagnum moss and perlite and kept moist with an intermittent mist spray. None of the cuttings from a mangosteen developed roots, even though cuttings of related species of *Garcinia*, such as *G. benthami* Pierre, *G. cornea* L., and *G. spicata* (Wight & Arn.) Hook. f. produced roots in quantity.

Pennock (24) stated that a tree obtained through cuttings utilizing flat lateral branches turned out to be markedly asymmetric and slow growing, and therefore not promising for either

fruit production or beauty. It may possibly be necessary to use only vertical stems, as is necessary in the genus *Araucaria*. If the method of propagation from cuttings were perfected, it would prove useful with this difficult species.

Air layering.—Propagation by air layers (marcots) has not produced satisfactory results. This technique has been used for a thousand years or more in order to propagate a broad range of tropical trees. It consists of removing a band of cortex 2 cm in width from a branch approximately 2 cm in diameter. The rooting hormone is applied generously around the exposed surface. A rooting medium of wet moss or fiber is then applied and secured in place with polyethylene plastic sheeting, tied at the extremes above and below the treated band. In trials in Puerto Rico, indolebutyric acid in talc powder has been applied to the surface. The rooting medium consisted of shredded sphagnum moss. The air layers were prepared at intervals of 6 weeks for a full year to determine effects of season.

Air layers made with mangosteen trees did not develop roots in any case. Nevertheless, other species of *Garcinia* rooted successfully, including *G. benthami* Pierre, *G. binucao* (Blanco) Choisy, *G. cochinchinensis* (Lour.) Choisy, *G. cornea* L., *G. livingstonei* T. Anders., and *G. spicata* (Wight & Arn.) Hook f.

Grafting.—Propagation by budding or bud grafting has not produced satisfactory results, in part because the accumulation and fermentation of the latex on opening the cortex to receive the bud. To avoid this, the opening has been made up to 6 days before budding, but without success.

Pennock was partially successful using the Forkert method on a stock of *Garcinia tinctoria* (D.C.) W. F. Wight (24). This method has worked in the case of species that exude latex from fresh cuts, and when the cortex can be removed easily from the stem. The technique consists of removing a bud piece that includes a new bud as well as a small amount of the wood. The technique consists in making two parallel vertical cuts at the side of the bud, about 1 cm apart, entering the wood to a depth of about 2 mm. Two horizontal cuts, about 4 cm, are made at the side of the bud to release the patch. The wood is then removed carefully from the bud piece, care being taken to leave the cortex undamaged. The stock is prepared by making two parallel vertical cuts approximately 10 cm long and a transverse incision that slightly penetrates the wood. The cortex is loos-

ened from the wood carefully, and the bud piece is inserted with the bud at the transverse cut. It is tied in position and covered with paraffin tape from bottom to top. The buds germinated at first, but died several months after having "taken." Apparently the two species are not graft-compatible.

Approach grafting and terminal-branch grafting have been used frequently with the mangosteen. Some success has been had with the former approach with 20 distinct species of *Garcinia* (29). In this method the scion and the stock are cut and fitted closely together. It is important to select stems of more or less the same thickness. A longitudinal cut is made 5 to 8 cm in length, slightly penetrating the wood. These cuts must be the same size so that the stems can be intimately united. They are then tied well and covered with paraffin tape. The new plant is formed by cutting away the stem of the mangosteen and removing the upper part of the stock. This operation is done 3 or 4 weeks after grafting. In the case of the mangosteen, all trials have failed.

Cleft grafting of terminal branches is also a widely used technique. Stocks are selected from 1 to 1.5 cm in diameter, although thicker stems up to 3 years old can be used. The graft is prepared by removing completely the upper part of the stock by a horizontal cut 20 to 25 cm from the soil. A vertical cut is made into the wood about 4 cm from the top towards the bottom. The scion is obtained from the tip of a branch of approximately equal diameter and 7 to 10 cm in length. The base is cut in the form of a wedge by means of two opposite cuts not less than 2.5 cm in length. The scion is inserted in the vertical cleft of the stock in such a way that there is a union of cambial layers. This union does not have to be perfect at all points. It is tightened a bit on both sides in order to hold it firmly in the correct position, tied with a rubberband, and covered with paraffin tape.

When this method was used with many species of *Garcinia*, two species of the related genus *Calophyllum*, *C. antillanum* (Britton) Stone, and *C. brasiliense* Camb., and one species of *Clusia*, *C. rosea* Jacq., none of the grafts were successful, in part because of differences in growth rates. In some cases the stock developed more rapidly than the scion, and in other cases the reverse was true. At times the scion failed to accept the stock but developed adventitious roots that established

themselves in the soil and left the stocks to eventually die. There is little problem in getting the initial graft to take, but the mangosteen scion eventually rejects the stock. Of the *Garcinia* species tested as stocks, the most promising are *G. tinctoria* (D.C.) W. F. Wight, *G. morella* (Gaertn.) Desr., and *G. livingstonei* T. Anders. The first, known as Matau, and the second are native to the Malay Peninsula and India. The third, known as Imbe, is native to southeast Africa.

Perhaps the most exciting method for improving the growth of the mangosteen by means of grafting was first reported by Oliver (23) and recently confirmed by Campbell (5). In this technique, *Garcinia tinctoria* W. F. Wight is planted in the same container with an already established mangosteen seedling. When the *G. tinctoria* seedling is large enough, the two trees are approach grafted. Stem diameters of mangosteen varied in Campbell's experiment from 5 to 7 mm, and the *G. tinctoria* stems were about 3 mm in diameter. After the graft union is sealed, the *G. tinctoria* stems are cut away.

A mangosteen treated in such a fashion grows vigorously in comparison to ungrafted controls. However, the principal growth of the root system is that of the mangosteen itself. During the crit-



FIGURE 9.—View of a seedbed of mangosteens about 0.6 meter in height. From this seedbed trees are transplanted directly to the permanent planting site.

ical period when the mangosteen root is underdeveloped, the *G. tinctoria* root supplies the necessary water and serves as principal rootstock. As the mangosteen roots develop the plant becomes progressively less dependent on the *G. tinctoria* roots and more able to sustain itself. The results now need trial on a field scale.

Because 175 species of *Garcinia* alone have been described and because there are still other genera of the same family that can be tried as stocks, some of these could be completely compatible as stocks with the mangosteen, simplifying the propagation problem satisfactorily.

Numerous experiments (5, 23, 27) have been made to develop stronger, more rapidly growing small mangosteen trees, and to reduce the time until fruit production, but until now the results have not been promising. No method has yet been found that has any real advantage over the method of propagation by seeds themselves.

Transplanting

Although the mature mangosteen tree is strong and durable, it is weak when it is transplanted. The operation of transplanting is delicate and requires careful attention. No damage should be done to the roots, since there is always the possibility that they will be killed outright or that growth will be even further retarded. Once the plant has wilted, there is no way to help it to recuperate. The long taproot is delicate and easy to disturb, and the few lateral roots cannot replace it.

The method of transplanting is highly variable. In Honduras and Panama, the seed is germinated in small pots, and when the seedling has only two leaves it is transplanted to shaded seedbeds (13, 14) (fig. 9). The seedbeds should be deep and provided with abundant organic material. Shade is provided by branches, dried leaves of coconut, or species of bamboo cut longitudinally into two or more sections. Materials should be selected that are resistant to rapid deterioration of the Tropics and to insect attacks. The species of bamboo, *Bambusa tulda* Toxb., has been highly recommended for this purpose. The mangosteen plants are transplanted to their permanent sites when they reach a half a meter or a little more in size by digging out the tree below the expected root level (figs. 10 and 11). The ball of earth is covered with well-fitting cloth sacks or tightly fitted cloth in order to avoid loss of soil (fig. 12). If the soil falls away,



FIGURE 10.—Method of transplanting mangosteen trees about 0.5 meter in height. Observe that the ball is somewhat narrow but long, so that the full taproot is included. Note also the shade provided by bamboo.

it is difficult to save the plant. The problem with this technique is that the plant is transplanted twice, once as a small seedling and secondly as a small tree, and is thus exposed to a double risk.

In Burma, the recommendation is to plant the seed in a container 0.3 to 0.4 m deep. The plant continues to grow in such containers until it reaches a height of 0.6 m, when it is transplanted to its permanent site (18).

In order to reduce the shock of transplanting, various practices have developed. An improvement in the percentage of survival of 2-year-old trees transplanted directly from the seedbed was achieved with a special compound, Goodrite (28). Applied as a spray 1 day before digging and transplanting, this latex reduced the loss of water by transpiration. Although the transplanting problem was not completely solved, the results suggest that the technique is useful as part of the routine protection necessary.



FIGURE 11.—Method of sewing the cloth or sack around the ball of earth. This operation is done carefully in order to avoid loss of the soil.

The development of polyethylene bags from 4 to 12 l in size makes still another approach possible (fig. 13). It is possible to plant seeds directly into these bags or to transplant to them seedlings of no more than two leaves. Within the same year, the entire ball of earth can be transplanted to the permanent site. Although the bags of 4 l are the most convenient, those of 12 l permit better development, carry more soil to the field on transplanting, and are less critical with respect to the appropriate transplanting time. Of course, on planting them the polyethylene must be eliminated, for it does not rot in the soil. When the bag is left in the soil or cut by a knife to permit roots to escape, the plastic continues to limit expansion of roots and thus the growth of the plant.

Various other types of containers have been tried (20). One of these is to unite end to end two or three 4-l cans with strips of wood that are easy to remove. Still another method is to unite in a



FIGURE 12.—Mangosteen trees prepared for planting at their permanent sites.

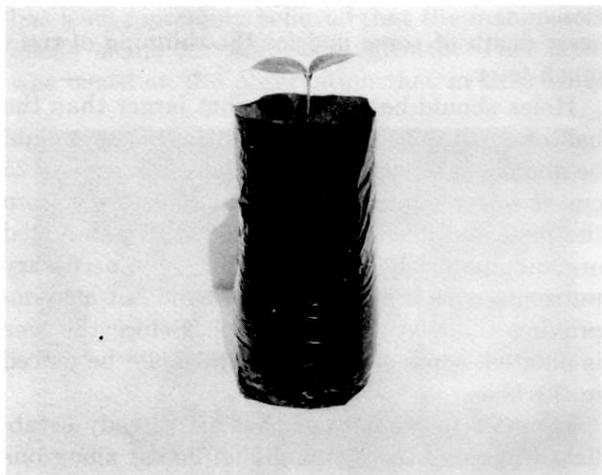


FIGURE 13.—Use of polyethylene bags for the planting of seeds or seedlings of two leaves.

cylinder thin sheet metal, lining the interior with polyethylene (fig. 14). The sheet metal is difficult to remove, but on doing so, the polyethylene remains, and the roots are not injured.

As a soil mixture, two parts of alluvial topsoil, one part of sand, and one part of well-rotted organic material can be recommended. Regardless of the technique used, it is of utmost importance to carry out all transplanting operations with a minimum of damage to the roots.

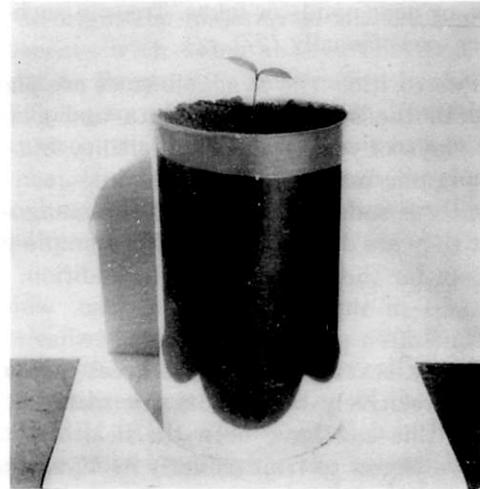


FIGURE 14.—Mangosteen plant in sheet-metal container lined with polyethylene.

Soils

The mangosteen is not demanding in its soil requirements and is found growing in almost all types of soils. It prefers a deep soil with a high content of organic material and good drainage. In orchards of Ceylon, India, and Panama, trees are often grown in soils that are thoroughly wet throughout the year (11, 13). In such soils it has been necessary to construct irrigation canals so that the high water table and runoff can be controlled. The roots in such soils can be considered to be bathed in water constantly, with a minimum of aeration, but the water is not stagnant, for a constant flow is maintained. The success of the mangosteen in such areas is attributed to the fact that the soil never dries and that a permanent and abundant water source exists within a few centimeters of the surface of the soil.

In contrast to this condition, there are trees in Hawaii in perfect condition and fruiting abundantly in areas where the annual rainfall is only 15 cm a year (9). In this case the trees are irrigated twice each month, even though it has been demonstrated that the trees can resist considerable drought without loss of leaves.

The mangosteen does not do well in alkaline soils or in soils of low fertility. In such soils growth is even slower than normal, and the percentage of survival is reduced.

A water table about 2 m from the surface of the soil is thought to be ideal. The mangosteen is especially suited for planting along river banks,

canals, or near ponds or lakes. Trees in such sites prosper exceptionally (27).

In Puerto Rico, the available trees are planted chiefly in the soil series Humata and Cialitos, acidic clays of low to medium fertility but with some organic material. The most important feature of these soils with respect to the mangosteen is that they are deep soils and afford ample growing room for the long taproot. In addition, trees are found in the alluvial soil Coloso, which is deep, but often poorly drained, somewhat acidic, and of fine texture. It has the great advantage of being relatively high in organic material. The trees in this soil have been the healthiest seen and have begun to fruit as early as 7 years from planting (fig. 15).

On the island of Puerto Rico, there are a large number of soils suitable for the production of the mangosteen, since various series of soil combine the necessary characteristics. Among these series are Aibonito, Alonso, Catalina, Consumo, Daguey, Lares, and Anones. They have great depth, good drainage, acidic reaction, reasonable permeability, and some fertility. Suitable soils should be able to be found throughout the hot humid Tropics.

Planting

Planting should be done at the beginning of the rainy season to assure the humidity necessary to stimulate new root formation. In Puerto Rico, this season is June, July, and August. The preparation of the soil is simple. If the trees are to be planted in a mixed culture, practically a necessity because they grow so slowly, the soil should be plowed twice. Before planting, lines are traced on the soil, and the positions of the future trees are marked. Perfect alignment facilitates later operations such as cultivation and harvest. When only the mangosteen trees are to be planted, it is not necessary to plow the soil. After a good cleanup, the lines and tree sites are marked. As a minimum, the site should be well cleaned from 1.2 to 1.5 m in diameter around the planting hole.

Planting distances vary from 5.5 to 7 m between trees, depending on soil fertility and the size of tree expected. A convenient planting distance is 6 by 6 m, which gives 280 trees per hectare. This planting distance affords sufficient space for operations such as cultivation and harvest, but also results in enough trees to compensate for



FIGURE 15.—Mangosteen trees growing in alluvial soils of the Coloso series in Puerto Rico. These trees developed without shade protection and began to fruit at the age of 7 years.

early death of some and for the thinning of trees much later.

Holes should be dug somewhat larger than the ball of earth expected with the tree. They should be about 0.6 m wide and 0.6 m deep. The first 25 cm of soil should be maintained separately from the rest, and it should be mixed with well-rotted organic material, providing not only necessary nutrients over a long period of time but also improving the texture of the soil. Before the tree is planted, some of this mixture should be placed in the hole.

In order to plant trees that are already established in cans, the metal should be cut along one or two sides, caution being taken to avoid damage to roots. Polyethylene is much safer, for it can be easily removed after cutting the bag along one side with a knife.

An important detail in planting the tree is to place it at the same depth as it was in its previous container or planting site. It is also important to place the soil mixture carefully around the roots and to see that the soil is firm and does not trap bubbles of air around the roots. Such bubbles dry and kill the tender roots of the tree. Gently tamping the soil around the roots while it is being added to the hole and watering well helps to avoid this condition.

About 0.5 kg balanced mineral fertilizer should be applied at the time of planting. This fertilizer can be mixed with the soil as the hole is filled and the soil is tamped into it. A slight depression should be left after filling the hole to facilitate irrigation.

Once planted, the tree should be given some shade. Partial shade is desirable during the first years of growth, for it reduces the loss from premature death (30). The dried fronds from palms, including the coconut palm (fig. 16) or saran cloth (fig. 17), are especially valuable for this protection. When the shade is provided by the coconut-leaf cover, the plant gradually grows through the structure and accustoms itself to the sun. With time the trees will no longer need shade, and the protection can be completely eliminated.

It is important to watch the growth of the plant so that the terminal bud does not reach the saran cloth or shade-bearing structure. If this happens, the bud is likely to be damaged, resulting in distorted growth. Once so disturbed, many months or even years are required for the tree to recuperate and grow normally. For many years it has been commonly believed that the mangosteen needs shade for successful growth. This belief was based on the observation that in their coun-

tries of origin the majority of the trees grow in the forests with some shade. The first trees brought to Puerto Rico were grown in this manner, helping to reinforce the belief. Nevertheless, trials since that time have demonstrated not only that trees without shade can develop normally, but also that such trees bear earlier than shaded trees.

Fertilization

Little has been written concerning the fertilization of the mangosteen. Generally, this tree is not fertilized in the majority of the plantings of the world (2, 6). The application of liquid fertilizers to small seedlings in the nursery has been tried in the same manner that has been used for other seedlings. For this purpose, a commercial mixture of 20-20-20 containing trace minerals was applied at the rate of 1 tsp (5 ml) per 4 l of water to the foliage as well as the soil each 15 days.

At MITA, a fertilizer experiment was carried out with 4-year-old trees. Manure was used as a mulch 2.5 cm thick, or mineral fertilizer 10-10-9, 280 kg/hectare, or a combination of both. There was only a slight response to fertilizer, visible as an increased growth rate.

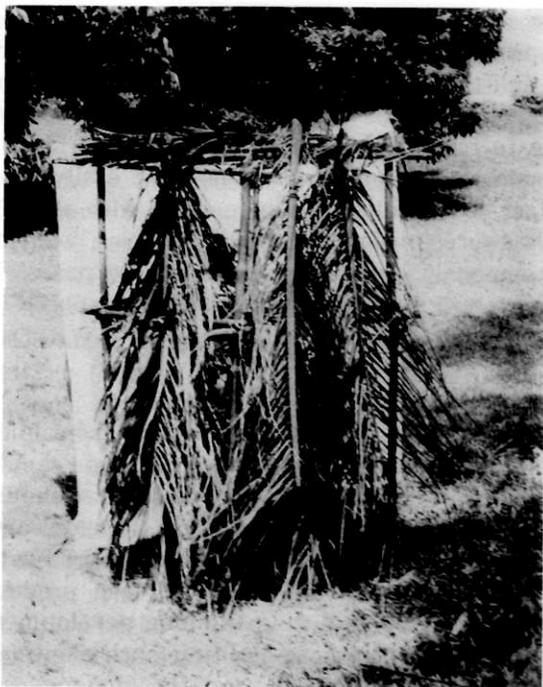


FIGURE 16.—Method for providing shade by means of fronds of a coconut palm. It is a cheap and efficient technique.

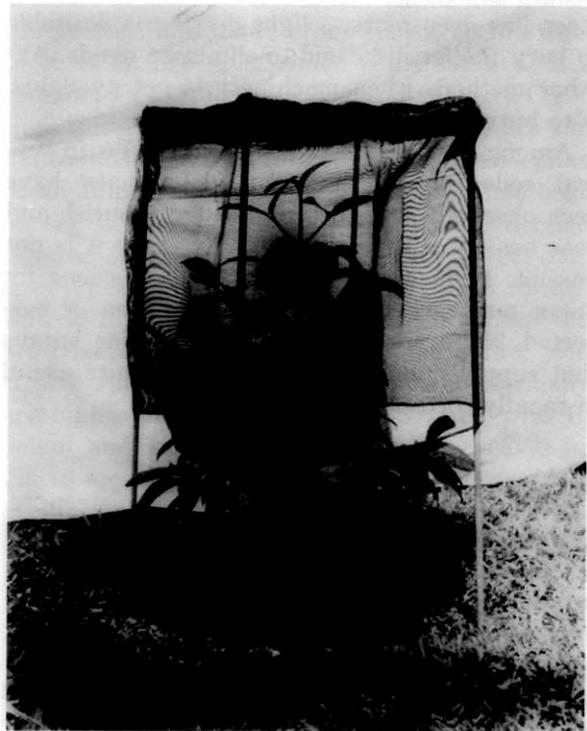


FIGURE 17.—Method for providing shade using saran cloth.

From the knowledge of the fertilizer requirements of other trees, it is possible to make some recommendations for the mangosteen. Regular fertilization of trees should begin about a month after transplanting. Because soils vary, it is difficult to specify a formula, but a 10-10-9 mixture should have general applicability. Two applications should be given, the first in March or April and the second during October or November. In areas where irrigation can be used, the fertilizer can be applied in any season if it is watered in well. With each application half of the recommended yearly treatment as shown below, should be given.

<i>Age of tree (yr)</i>	<i>Fertilizer (kg)</i>
1-2	0.25
2-4	.5
4-6	1.0
6-8	2.0
8-10	4.0

Trees in production should receive higher quantities of fertilizer. A large mature tree in full production needs about 7 kg of fertilizer per year.

Fertilizer is normally scattered in a wide band below the cup of the tree, but not within 15 cm of the trunk. The object is to cover the entire surface underlain with roots. Since the mangosteen has deep roots, a light disking is desirable to bury the fertilizer and to eliminate weeds. Another method, when machinery is not available, is to bury the fertilizer in small holes.

Among the trees established at MITA in several soils, no micronutrient deficiencies have been observed, and the trees in fact flourish and bear heavily with neglect. At this time it is not possible to make clear-cut recommendations for minor nutrients. If deficiencies are seen or suspected, there are several types of foliar sprays that supply minor elements and are quite useful in rapidly correcting deficiencies.

Pruning

In commercial planting, the mangosteen requires little pruning (19). In the first 3 years of growth no attention at all need be given. Later, pruning is done chiefly to improve the appearance and condition of the tree. It is customary to remove the smaller branches in the interior of the tree. Old trees that have not fruited well for several years flower and fruit abundantly after such pruning. It is also a good practice to prune away old, diseased, and damaged branches

and any suckers that grow up from the base of the main trunk. Those branches that touch the soil or interfere with the application of fertilizer, pruning, and so forth should be removed after fruiting. Such branches serve as an easy access for rodents that damage the fruit. Branches that are weakly developed or that have not developed fruit should be thinned to permit further growth. It is not desirable that the growth be so dense that light does not penetrate to all parts. A tree that is too dense will produce fruit only at the tips of the branches, and much of the total fruiting capacity will be lost.

Severe pruning is never desirable with the mangosteen and will severely limit production. The removal of growing tips of branches or of only half of a branch is also injurious and should be avoided.

Although there is no special time for pruning, it is better to do so when the tree does not have flowers, fruits, or flushes of new leaves. The most favorable time is the fall after harvest. If it is necessary to remove thick branches, much care should be taken to avoid damage as they are cut away. The cut should be begun with a pruning saw on the underside of the branch about 15 cm from the trunk. This cut should penetrate about half way through the branch. A second cut made from above and 15 cm still further from the trunk will then permit the branch to break away without splitting to the trunk itself. Then, a fine cut should be made as close to the main trunk as possible to remove the short stub. This cut should be smooth so that water runs off it easily. The surface of the cut should be painted with a liquid asphalt preparation, a layer of grafting wax, or a commercial paint made for such purposes. If the cuts are not treated, they remain exposed to fungi that destroy wood.

Care

In order to stimulate rapid and continued growth of the trees, mangosteen orchards should be well cared for. The area around the tree should be maintained free of weeds, and, if necessary, the land among the trees should be covered with a cover crop or a crop plant that can produce something of value during the long developmental period of the trees. In addition, such plantings help to conserve the soil, and the mangosteens can benefit from the fertilizer given to the secondary crop. Almost any short-term crop that does not grow too close to the trees themselves

or give excessive shade can be planted. A planting of pigeonpeas affords high shade, especially during the hottest months of the year. Such plantings also enrich the soil by means of fixation of nitrogen and serve as windbreaks. Other useful crops include bananas, plantains, and vegetables. Crops should not be planted less than 1.5 m from the trees themselves. Bananas and plantains should be spaced from 2.4 to 3.7 m apart, a greater distance than that usually recommended for these crops.

Cover crops planted among the trees, but not too close to the trunks are useful. The principal species are *Crotalaria*, cowpeas, velvetbeans, horsebeans, and tropical kudzu. Types with low growth are preferred. Tropical kudzu has frequently been used as a cover crop, for it is an excellent forage for cattle and it grows vigorously. Nevertheless, the plantation should be examined frequently to see that the vines do not reach and cover the young trees.

The area around the trees should be weeded at least twice a year, care being especially necessary during the rainy season. When the dry season begins it is useful to cover the area around the tree with a mulch, which reduces the evaporation of water from the soil and keeps the weeds under control. During harvest the mulch also catches the fruit that falls, preventing damage.

In some areas it is useful to maintain a mulch during the entire year. The mulch can be obtained from the cover plants or from the weeds removed from around the trees, but other sources of mulch will usually be necessary. A thin (2.5-cm) mulch of manure is useful after the rainy season.

Irrigation is necessary during the first few years of growth when roots are not extensive enough to take advantage of all the water in the soil. During the dry season it is advisable to water twice a month. Trees growing near ponds or streams, however, may not need irrigation.

DISEASES AND INSECTS

Few diseases have been found to attack the mangosteen, and only a few insect pests damage the tree. One is a small ant, *Myrmelachista ramulorum* Wheeler. This common pest of coffee plantations has a yellow thorax and a blue-black head and abdomen and lives in large colonies in the new branches of the tree and in old fallen branches and trees. It bores long irregular tunnels through the center trunk and into living branches and

often damages the growing tips of the plant, stimulating the development of dense foliage.

Ant infestations can be treated first by trimming dead branches and by removing dead trunks from the field. The living trees can be sprayed with malathion (diethyl mercaptosuccinate S-ester with *O,O*-dimethyl phosphorodithioate).³ Beginning with the 54.8-percent concentrate, mix 0.7 l with 380 l of water, or on a smaller scale, 2 tbsp (28 ml) in 3.8 l. For best results add to this a sticker-spreader of a commercial type at the rate of 60 to 180 ml per 3.8 l of solution. Malathion spraying should be suspended 14 days before the beginning of harvest.

Once in a while, the fruit is attacked by mites that damage the surface and make the fruit unattractive for the market. Because these mites are about 0.16 cm in size, they are difficult to detect with the naked eye. The major part of the damage comes from the small bites of these pests and from the scratches they make. Chemical controls would prove costly, and cannot be recommended. Dicofol [1,1-bis(*p*-chlorophenyl)-2,2,2-trichloroethanol] plus malathion could be used in the same concentration as suggested above.

In Puerto Rico, the disease commonly called thread blight has been seen frequently. This disease, found also on coffee, cacao, the Indian rubber tree, and many other plants, occurs when there is an excess of shade and humidity. It is caused by the fungus *Pellicularia koleroga* Cooke (fig. 18). The symptoms of this disease are similar to those found on coffee. The vegetative phase of the fungus occurs as filaments that first begin on the smaller stems. This part of the infection, however, does not appear to cause any real damage. When the fungus reaches the leaf, it forms a whitish film over the blade. Young branches, too, are covered by the filament. Some fruits, principally those that have not matured normally, are highly susceptible and are covered with filament and killed in a short time. The leaves begin to lose their luster, turn a clear brown, and eventually a dark brown or even black. In this stage they absciss from the tree but remain suspended by threads resembling a spider web. This is the most characteristic feature of the disease, and the one that makes diagnosis easy.

The disease occurs principally in plants of abundant vegetative growth, especially in areas of

³Regarding the use of pesticides on the mangosteen, see "Notice to Readers" on page iv.

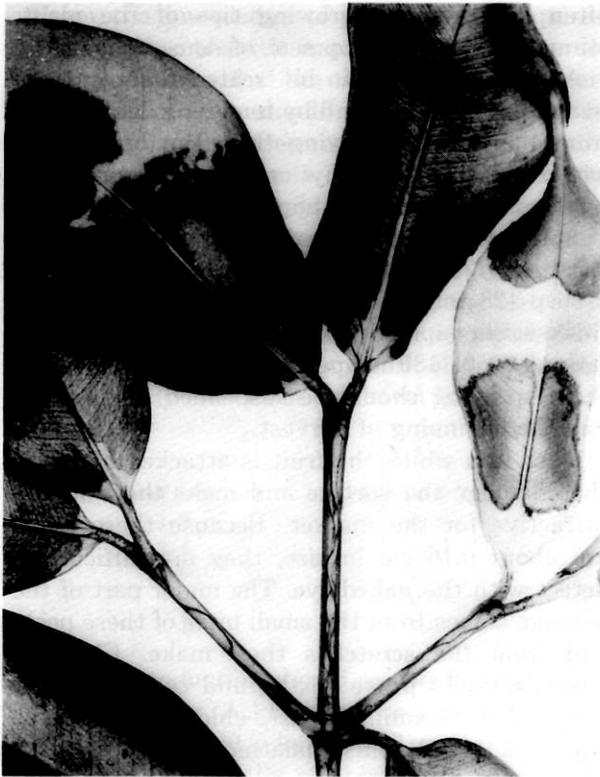


FIGURE 18.—Infection caused by the fungus *Pellicularia koleroga* Cooke. The leaves turn clear brown and loose luster. Observe the fungal filaments on the young leaves.

the tree that are too shaded and humid. This fact suggests that the best remedy for the disease is to remove part of the shade and drain well the soil around the tree in order to reduce the humidity. The fungus is susceptible to bordeaux mixture [copper sulfate (monohydrate)+excess of hydrated lime (calcium hydroxide); mixture formed in presence of moisture on plant surface] and to other fungicides that contain copper, and excellent control can be obtained with these materials. Two applications of bordeaux mixture (5-5-30) at an interval of 3 weeks are generally recommended. The same result can be obtained with almost any copper-based fungicide on the market. For best results, a sticker-spreader should be used so that the fruit and the foliage are well covered.

A fungus on the Malay Peninsula caused by *Zignoella garcineae* P. Henn. causes the formation of tubers on the new stems, which are later seen as mature tubers of the older wood (1). As the disease increases in force, it causes wilting or death, first of the leaves, then branches, and then of the whole tree. To combat the disease,

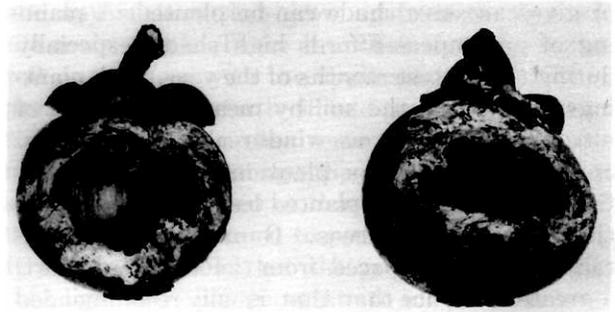


FIGURE 19.—Damage caused to mangosteen fruits by rats and bats.

cut and destroy the tree to avoid spread to still other trees.

Rats and bats (fig. 19) damage many fruits by eating not only the pulp but also the seeds. The best way to combat them is to maintain the orchard as clean as possible and to use traps with an appropriate rat poison, such as warfarin [3-(*α*-acetonylbenzyl)-4-hydroxycoumarin].

HARVEST

The time of first production is an important limiting factor in mangosteen cultivation. For many years the idea that 20 or 22 years of growth were required for fruiting has discouraged the establishment of new plantings. As has been noted, however, many well-tended trees have begun to fruit at 7 years of growth, the average time to production being 8 to 10 years. It would, of course, be useful to develop techniques to shorten this period. The most promising technique for accomplishing this would be to find an appropriate stock for grafting the mangosteen.

As in the case of almost all fruits, the mangosteen produces little during the first year, but each year a larger production can be expected. Each harvest of the adult tree yields from 500 to 1,500 fruits depending on the development of the tree. Although each tree produces only one crop each year, the time of production varies. The time of flowering and of fruit production is affected by external factors such as elevation and the presence or absence of shade. In low areas of Sri Lanka, the harvest extends from May to July. In higher elevations of the same country, the crop matures from September to October. In Mayagüez, P.R., production occurs during July and August if the trees are not shaded, but from November to December in the case of trees grown in the shade.

The fruits of a tree mature more or less at the same time, giving little opportunity for spreading out the harvest. Since the mature fruit falls from the tree when ripe, the harvest is indeed simple, but should be frequent. Once the fruit has ripened, the keeping quality is limited.

The harvest can also be made before the fruits fall. The appropriate stage is apparent from a change in color of the fruit from a green-brown to a dark brown or reddish purple. In addition, the fruit softens a bit. The fruit is picked with the peduncle attached. Since the purple fruit is already ripe and will soften rapidly, it is likely to rot and is not recommended for shipping. For the shipping of fruit or the storage of fruit for 7 to 21 days, it is necessary to pick light or dark brown fruits. Picking of fruits of an appropriate stage is an art that must be learned. Trials of the ripening time of fruits of different colors are necessary to establish an appropriate scale for judgment.

Before ripening, some fruits contain a variable amount of yellow latex. As the fruits mature, this latex gradually disappears and is uncommon in fully ripened fruits.

Since a large mangosteen tree may reach 35 feet, collection of the fruits directly from the tree is often difficult. A variety of simple tools has been used to remove the fruits, from simple bamboo poles, with or without an attached basket, to a commercial grabber. Often these techniques scratch or damage the surface of the fruit. Special care should be taken at the moment of harvest because the greatest loss occurs at this time. After harvest, the fruit should be handled and packed with care, especially to avoid damage from the still attached peduncle. Another factor that influences harvest damage is the falling of the fruit onto hard ground or onto ground with excessive slope, which permits the fruit to roll. Advance preparation of the land can prevent this problem.

It is necessary to prepare well in advance of the harvest. Such preparation includes obtaining appropriate tools, sacks, boxes, and packing materials. Among the tools necessary should be folding aluminum ladders with legs adjustable for irregularities in the soil. Shipping boxes used so far are much like those for the shipping of tomatoes. Some shippers wrap each fruit individually in paper, but there is no advantage to this technique. The fruit heats up more rapidly in this fashion, hastening maturity and subse-

quent rotting. The normal rot observed is not a soft rot; rather, the cortex of the fruit dries, and the pulp disintegrates.

Shipments to distant regions have been successfully arranged. These have taken as many as 20 days, without loss of quality. The cortex of a well-packaged fruit has remained soft and the pulp indistinguishable. The United Fruit Company has pioneered in the shipments of mangosteen in this hemisphere. A shipment from Cochin, China, to Paris, France, was reported to be successful (4). In this case, the surface of the fruit had been disinfected. It is a wise practice to treat the surface of the fruit with bordeaux mixture in order to avoid rot during shipping.

The shipment should insure that the fruit arrives at the market near or at maturity, free of cuts and scratches. The ideal fruit should be mature, dark red or purple, completely free of fungus infections, and upon opening it, the pulp should be white, uniform, and flavorful.

USES

The mangosteen is normally used principally as a fresh fruit. While used at any time of the day, it is especially agreeable as a dessert fruit. Various trials have been made to preserve the fruit in the form of a nectar, but the mangosteen is delicate and the flavor is easily lost. The addition of sugar masks completely the flavor (3). Fresh milkshakes made with the pulp are delicious, but still something of the flavor is lost. In London (3), preserves of the pulp including seeds have been tried but are not considered successful. Other kinds of preparations have similarly failed. In the Sulu Islands, the pulp has been conserved in brown sugar, but references concerning their technique do not mention anything of the flavor (3). A good method must be developed to conserve the flavor in a process and product.

The seed is edible after being boiled in water. The cortex of the fruit contains a tannin that is used as a commercial dye. The dry pulverized cortex is also used in a decoction as an astringent in cases of dysentery and chronic diarrhea. An infusion made from the leaves has been used in the treatment of wounds. The wood of the trunk is a dark brown color and has been used in the construction of furniture. It is hard and heavy and is worked up well by machine tools.

Landscape architects in many countries are

always looking for ornamental trees that give shade but do not destroy sidewalks, foundations, and other structures with their roots. The mangosteen is ideal for such purposes, for it produces a deep taproot and few lateral roots. This and the hardness of its wood make it resistant to hurricanes. It is a beautiful tree, whose long-lasting leaves are of a reddish color when developing and later a brilliant green. The symmetrical cylindrical or pyramidal form and the large number of lateral branches arranged symmetrically add to the attractiveness of the tree. For the person who wishes to cultivate the best, there is no substitute for the mangosteen, for in addition to its beauty for homes and parks, it produces the finest of the tropical fruits.

LITERATURE CITED

- (1) Belgrave, W. N. C. 1915. A disease of mangosteen trees. *Agric. Bull. Fed. Malay States* 3(6-7): 218-285.
- (2) Bourdeaut, J., and Moreuil, C. 1970. The mangosteen, possibilities of its culture in the Ivory Coast and Madagascar. *Fruits, France* 25(4): 223-245.
- (3) Burkill, I. H. 1935. A dictionary of the economic products of the Malay Peninsula. Vol. 1, pp. 1052-1054. University Press, Oxford.
- (4) Cadillat, R. M. 1970. The trade in tropical fruits in the Common Market. *Proc. Conf. Trop. Subtrop. Fruits, London, September 15-19, 1969*, pp. 37-45.
- (5) Campbell, Carl W. 1966. Growing the mangosteen in southern Florida. *Fla. State Hortic. Soc.* 79: 399-400.
- (6) Chevalier, A. 1919. Les cultures fruitières en Indochine. *Bull. Agric. Inst. Sci. Saigon* 1(4): 97-111.
- (7) Dahlgren, B. E. 1947. Tropical and subtropical fruits, pp. 21-23. Chicago National History Museum.
- (8) Evans, Frank. 1908. The mangosteen. *Bull. Misc. Inf. Trinidad* 60: 40.
- (9) Fairchild, David G. 1915. The mangosteen, queen of fruits. *J. Hered.* 6(8): 338-347.
- (10) Feilden, G. St. Clair (compiler). 1936. Vegetative propagation of tropical and subtropical fruits. *Imp. Bur. Fruit Prod. Tech. Commun.* 7: 67.
- (11) Grant, J. W. 1936. Burma fruits and their cultivation. *Bull. Dep. Agric. Burma* 30: 103.
- (12) Gregory, Luis E. 1965. El cultivo de algunas frutas exóticas en Puerto Rico. *Rev. Agric. P.R.* 52(1): 163-164.
- (13) Higgins, J. E. 1938. Annual reports of the Canal Zone experiment gardens for the fiscal years 1933-1934. 59 pp.
- (14) ———. 1939. Annual reports of the Canal Zone experiment gardens for the fiscal years 1935 and 1936. 56 pp.
- (15) Horn, C. L. 1940. Stimulation of growth in juvenile mangosteen plants. *J. Agric. Res.* (61): 397-400.
- (16) ———. 1941. Existence of only one variety of cultivated mangosteen explained by asexually formed seed. *Science* 92: 237-238.
- (17) Hume, E. P., and Cobin, Milton. 1946. The relation of seed size to the germination and early growth of the mangosteen. *Proc. Am. Soc. Hortic. Sci.* 48: 298-302.
- (18) ———, and Cobin, Milton. 1947. Difficulties in mangosteen culture. *Trop. Agric. (Trinidad)* 24(1-3): 32-36.
- (19) Lindsay, Walter R. 1941. Mangosteen cultivation. *Canal Zone Exp. Gard. Annu. Rep. 1940*: 25-28, 33.
- (20) Macmillan, H. F. 1935. *Tropical planting and gardening*. 4th ed., pp. 237-238. Macmillan and Co., London.
- (21) Molesworth, Allen B. 1967. *Malayan fruits*, pp. 68-71. Donald Moore Press Ltd., Singapore.
- (22) Naik, K. C. 1944. Mangosteen propagation. *Indian J. Hortic.* 2(1): 43-44.
- (23) Oliver, G. W. 1911. The seedling-inarch and nurse-plant method of propagation. *U.S. Dep. Agric. Bur. Plant Ind. Bull.* 202, 245 pp.
- (24) Pennock, W. 1972. Técnicas para injertar plantas tropicales. *Estac. Exp. Agric. Río Piedras P.R. Bol.* 229, pp. 16-19.
- (25) Popenoe, Wilson. 1938. Importantes frutas tropicales. *Union Panamericana. Of. Coop. Agric. Publ. Agric. Nos.* 130-131: 24-25.
- (26) ———. 1952. Central American fruit culture. *Ceiba Esc. Agric. Panam.* 1(5): 349-351.
- (27) Puerto Rico Agricultural Experiment Station. 1941. Plant introduction and distributions. P.R. (Mayagüez) *Agric. Exp. Stn. Rep.*, pp. 53-59.
- (28) ———. 1952. Food crop investigations. P.R. *Agric. Exp. Stn. Rep.*, pp. 6-7.
- (29) Webster, P. J. 1926. Edible garcinias and possible mangosteen stocks. *J. Dep. Agric. P.R.* 10(3-4): 283-305.
- (30) Winters, H. F. 1953. The mangosteen. *Fruit Var. Hortic. Dig.* 8(4): 57-58.

* 1976-G.P.O.-1750-S/771-040/7