MANGOSTEEN AND RAMBUTAN

Bryan R. Brunner and **J. Pablo Morales-Payan**
Department of Crops and Agro-Environmental Sciences, University of Puerto Rico-Mayagüez Campus, Mayagüez, Puerto Rico

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Contents

Summary

Mangosteen and rambutan are common fruit crops in tropical Asia, but are still regarded as exotic new crops in the western hemisphere, where both crops hold the promise of being highly profitable as compared to traditional fruit crops. As global markets for these two crops grow in developed countries, production in Asia and elsewhere is bound to expand, and it is currently undergoing rapid expansion in Central and South America, and the Caribbean islands.

Prospective mangosteen growers may be deterred by the difficulties and length of its juvenile period, but economic return seems to compensate successful growers. Shortening the juvenility of mangosteen remains a challenge for horticultural researchers. Once established, mangosteen and rambutan are relatively easy to grow and have few important pathogens and pests, as compared with other tree fruit crops such as mango and banana. Nevertheless, much remains to be studied in terms of their crop husbandry to use resources more adequately. As with many tropical fruits, the highly

perishable nature of mangosteen and rambutan is an important factor in post-harvest operations for fresh fruit markets.

The future of both crops seems bright, and expansion of areas under production and improvement of production practices should continue in the near future in response to growing demand for both fruits in non-producing areas.

1. Introduction

Sometimes called the natural staple food of man, fruit crops are an important source of nutrients, mostly vitamins and minerals. Many fruit crops also have medicinal and industrial uses as well. Mangosteen and rambutan are well known in Southeast Asia but are relatively newcomers in the fruit crop industry of tropical America, Africa and Oceania. Both are profitable fruit crops that can be grown in environments that are too wet for many other tropical and subtropical fruit crop species, and the expansion of their production in many tropical areas is expected in the near future. For mangosteen, the appeal resides in its 'mystery fruit' and nutraceutical reputation, whereas for rambutan the 'exotic' label and its looks are its main presentation cards.

2. Mangosteen

Called "the queen of fruits", mangosteen (*Garcinia mangostana* L., synonym *Mangostana garcinia*, Clusiaceae, Dicotyledones) is an economically important tropical tree fruit species. The name mangosteen comes from the Malay *manggistan*. Its relative scarcity in markets in the Western hemisphere contributes to its status as an enigmatic fruit. In spite of their similar names, the mangosteen and the mango (*Mangifera indica*) are not botanically related; the mango belongs to the Anacardiaceae family.

Currently, mangosteen is widespread in humid tropical regions of Asia and Oceania, and can be found growing in several countries in tropical America and Asia. However, for many centuries it was an almost inaccessible exotic fruit for consumers in most countries outside tropical Asia.

In Western Europe and the USA the mangosteen has been known at least since the 17th century and has become a sensation since the late 20th century because of its properties reputed to enhance human health. In the African and American tropics, the mangosteen was introduced several times since the 17th century, but the fruit still remained relatively scarce even in local markets.

The European markets are mainly supplied by exports from Asia, in particular Thailand, Indonesia and the Philippines. Although several commercial products based on mangosteen have become available to consumers in the USA during the last 20 years, the fresh fruit has only recently become available thanks to orchards starting to bear fruits in Puerto Rico.

Nowadays, mangosteen fruits are also exported from Thailand after gamma irradiation treatment. There is a relatively small but increasing business of exporting fresh and

frozen mangosteen from various Asian countries to the main importing markets of continental China, Taiwan and Japan.

2.1. Origin and Distribution

It is believed that mangosteen originated in the Sunda Islands (currently part of Brunei, East Timor, Indonesia and Malaysia), and the Moluccas or Spice Islands (currently part of Indonesia) in tropical Asia. From Malaysia it arrived in the Philippines, Burma and India, and from there was further dispersed to other parts of the world. There are records of 17th century Dutch settlers in Indonesia praising the mangosteen as a delightful fruit, and in 1770 the famous English explorer Captain Cook described mangosteen fruits he found in Jakarta. The mangosteen plant was introduced in England in 1789, and shortly afterwards, mangosteen and breadfruit (*Artocarpus altilis*)were taken to the Pacific islands and Antilles. Mangosteen was introduced in Sri Lanka in 1800.

Legend has it that Queen Victoria of England (1837–1901) offered a handsome reward or even knighthood to whomever could bring her a fresh mangosteen. From seeds introduced from India in 1833, mangosteen trees were grown in heated glasshouses in England, and fruits were harvested in 1855. The Victorian legend continued with a sample of those mangosteen fruits being sent to the Queen, but there is no evidence that she ever received or tasted the fruit. Apparently England-grown fruits remained extremely scarce, for the distinguished English horticulturist James Herbert Veitch mentioned in his publication "Hortus Veitchii" that he visited Java in 1892 for the purpose of eating mangosteen.

Seedlings were introduced to Australia in 1854. There are records of mangosteen orchards in India during the last decade of the 19th century, and in Madagascar in 1901. In the Western hemisphere there have been successive attempts to establish the crop, including large orchards in Lancetilla, Honduras, by the United Fruit Company, and small plantings or introductions to botanic gardens and private collections in many other American countries throughout the 18th to 20th centuries.

It seems that the now famous phrase “mangosteen, the queen of tropical fruit” or “queen of fruits" was uttered in 1903 by the famous horticulturist David Fairchild. However, it must be said that the same title of nobility has been bestowed upon many other fruits, among them the pineapple, the orange, the peach, and the mango. As with many other things, it is a matter of personal preference.

Mangosteen is found throughout the tropics. Most of the organized, commercial production occurs in Southeast Asia (mostly Indonesia, Malaysia, the Philippines, and Thailand) and a few locations in America (mainly Costa Rica, Honduras, Panama, Peru, Colombia, Brazil, Hawaii, and Puerto Rico) and Australia. Even so, most of the fruit marketed in Asia comes from backyard trees and from traditional orchards where many fruit species grow together with little management. In Asia, mangosteen is commonly found intercropped with chempedak (*Artocarpus integer*), durian (*Durio zibethinus*), jackfruit (*Artocarpus heterophyllus*), langsat (*Lansium domesticum*), and rambutan (*Nephelium lappaceum*). Many prospective growers shy away from starting new mangosteen orchards because the time between planting and commercial harvesting

may take 5 to 10 years, depending on growing conditions (bin Osman and Milan, 2006). This time can however be reduced by grafting the trees.

Information on the area dedicated to mangosteen and its production is scarce. In the year 2000, Thailand had approximately 11,000 hectares of mangosteen with a production of about 46,000 tons, valued at approximately $46 million; the same year the Philippines reported 1,354 hectares, with a production of 4,700 tons. In 1998, Malaysia had approximately 7,632 hectares, and Indonesia 10,750 hectares. In 1998, the combined commercial production in Thailand, Malaysia, the Philippines, and Indonesia was estimated at more than 150,000 tons. In 2007 there were approximately 350 hectares dedicated to mangosteen production in the Brazilian states of Pará and Bahia, with an annual harvest of 300 tons (Sacramento *et al*., 2007). There are approximately 50 hectares of commercial production in northern Australia, supplying about 10 tons of fruit to the Sydney market, at an approximate retail price of $1.5-2.0 per fruit.

2.2. Economic Importance

Most of the production is consumed in the grower countries. Puerto Rico has started commercial harvesting recently, with small amounts being sold to selected restaurants in the USA for as much as $10-15 per kg. International trade of mangosteen is still small as compared to other tropical fruits, but there is a trend of increasing exportation from the main producer countries. The largest importers are continental China, Taiwan, Japan, Australia, Europe, the USA and Canada.

Because of quarantine regulations, some countries like Japan traditionally import only frozen mangosteen, either whole or in pulp. Similarly, frozen fruit may be the preferred form of mangosteen exportation to the USA and parts of Europe to satisfy the quarantine requirements against the threat of accidental importation of fruit flies, and to avoid prohibitive air freight shipping costs. Nevertheless, Indonesia regularly exports fresh mangosteen fruits to Singapore, Saudi Arabia, Japan, continental China, Taiwan, and Europe, in amounts of up to 350 tons per month, with a value of $350,000 (bin Osman and Milan, 2006).

2.3. Taxonomy and Plant Description

The mangosteen belongs to the genus *Garcinia*, within the family Clusiaceae (formerly Guttiferae). The genus was named after the French botanist Laurent Garcin, who described mangosteen and other related species in their natural habitat. Taxonomists recognize around 100 species in the genus *Garcinia*, the majority of which originated in tropical Asia, including *G. dulcis* (mundu), *G. indica* (wild mangosteen), and *G. xanthochymus* (yellow mangosteen) while others originated in the Americas, such as *G. humilis* (wild mammee). About 30 of those species produce edible fruits.

The mangosteen tree (Fig. 1) has a straight trunk that commonly grows from 7 to 25 meters in height, with dark-brown and heavy timber. The tree crown is rounded, pyramidal and symmetrically branched. When wounded, the stem, branches, leaves and the developing fruit exude a bitter yellowish latex that is typical of the Clusiaceae

family. The leaves are thick and leathery, opposite, elliptical, bright green in coloration, about 15-25 cm long by 7-13 cm wide, with short and thick petioles.

Figure 1. Mangosteen tree.

The tree has a very long juvenile phase, commonly between 10 and 20 years. The flowers are apical, with white-pinkish coloration, and usually up to 5 cm in diameter. All known trees produce only female flowers, with non-functional male parts. Because there is no pollen, true seeds cannot be produced, and the ovary of the flowers undergoes a process called apomixis or agamospermy, in which the ovary lining turns into the fruit segments and produces asexual seeds, a clone or copy of the mother plant.

Figure 2. Mangosteen: open and whole fruit.

The fruit is round, slightly flattened and ovoid, with a pointed tip. The exocarp or rind is thick, firm, and spongy; the outer surface is of a very pale green when very young, then enlarges for 2 or 3 months, becoming darker green and hard until it ripens very quickly (10 days) and turns reddish to purplish. The edible flesh or pulp (aril) is divided in 4 to 8 segments (Fig. 2). It is aromatic and contains compounds such as hexyl acetate, hexenol, and and α-copaene, with a delicious flavor described as "sweet and tangy", or "sweet and sour" with hints of citrus and peach. One student in the Exotic Fruit Crops course at the University of Puerto Rico, tasting mangosteen for the first time during a visit to a local farm, told me "professor, now I know what love is. I have tasted a mangosteen".

Nutrient	**Units**	**Fresh**	**Canned in syrup**
Water	g	80.7	80.9
Energy	kcal	n.a.	73.0
Protein	g	0.5	0.4
Total lipid (fat)	g	0.5	0.6
Carbohydrate	g	13.0	17.9
Dietary fiber	g	1.4	1.8
Calcium, Ca	mg	7.9	12.0
Iron, Fe	mg	0.17	0.3
Magnesium, Mg	mg	13.9	13.0
Phosphorus, P	mg	9.2	8.0
Potassium, K	mg	61.6	48.0
Sodium, Na	mg	6.4	7.0
Zinc, Zn	mg	0.1	0.2
Copper, Cu	mg	0.1	0.1
Manganese, Mn	mg	0.1	0.1
Vitamin C (total ascorbic acid)	mg	5.7	2.9
Thiamin	mg	0.05	0.05
Riboflavin	mg	0.03	0.05
Niacin	mg	0.3	0.29
Pantothenic acid	mg	n.a.	0.03
Vitamin B-6	mg	n.a.	0.02
Folate	µg	n.a.	31.0
Vitamin A, RAE	µg	n.a.	2.0
Beta carotene	µg	14.0	16.0
Alpha carotene	µg	n.a.	1.0
Beta cryptoxanthin	µg	n.a.	9.0
Vitamin E	IU	0.6	n.a.
Vitamin A	IU	<50.0	35.0

n.a. = not available.

Table 1. Nutrient values for 100 grams of mangosteen pulp (Sources: USDA National Nutrient Database for Standard Reference,Release 22 (2009), and J. Morton, 1987. Fruits of Warm Climates (http://www.hort.purdue.edu/newcrop/morton/mangosteen.html)

In spite of its famous flavor, mangosteen has little nutritional content (Table 1). The pulp does not contain pigments, its content of antioxidants is very low, and there is no proof that it has medicinal effects. The part of the fruit that has medicinal properties is the reddish-purplish exocarp or rind. It contains a vast number of polyphenolic acids, among them xanthones and tannins, which are responsible for the astringent nature of the outer part of the fruit.

Each fruit may contain up to 7 large (1.3 cm diameter) flattened adventitious embryos commonly called seeds, of which one is generally viable. The seeds usually weigh 1-2 g, and lose viability almost as soon as they dry out. Generally, seeds older than one week, when left at ambient conditions, fail to germinate. However, seeds may be preserved for a few weeks keeping the seeds inside the fruit, or extracting them from the fruit and putting them in damp moss or similar material, although at the risk that the seed will germinate in moist storage.

In Puerto Rico, the first fruits of a new orchard weighed on average 113 grams, of which approximately 29% was the edible portion. The high levels of acidity (pH 3.5) and sugars (almost 19% Brix, mostly due to sucrose, fructose, and glucose) in the pulp of the fruit partly account for its appeal. The pulp is a good source of potassium and magnesium, and contains vitamin C.

2.4. Breeding and Varieties

Mangosteen is thought to be a polyploidy, resulting from natural hybridization between *Garcinia hombroniana* and *G. malaccensis*. Conventional breeding of mangosteen is complicated by the fact that it does not need sexual fertilization to produce fruits and, hence, the plants propagate clonally by seed. With no new genetic combinations resulting from the seeds, there is little genotypic variation from which to select, and thus there are few varieties or cultivars. However, not all mangosteen trees and populations are genetically identical, apparently due to infrequent natural mutations.

Collections of selected, apparently distinct trees are kept in Brunei, Indonesia, Malaysia, Papua New Guinea, the Philippines, Thailand, and the USA. The Malaysian Department of Agriculture has identified 16 accessions which show variation for fruit size and shape, seed number, shelf life, fruiting precocity and external coloration, and has released the clones GA1 and GA2. The commercially available Malaysian cultivar ‘Mesta’ is seedless and has a smaller fruit size than typical mangosteen.

Protocols have been developed for mangosteen tissue culture for preservation, multiplication, and potential genetic manipulation (Ferwerda, 2003), and mutation induction projects have been undertaken in Indonesia. Moreover, crossing mangosteen with the closely related species *G. hombroniana* to create new varieties may be possible (bin Osman and Milan, 2006).

Desirable traits in new mangosteen cultivars include longer seed viability, easier propagation, faster growth rate in nursery, shorter juvenile period, higher tolerance to lower environmental humidity, and higher fruit yield.

2.5. Ecology and Growing Conditions

Mangosteen is often called an ultra-tropical species, due to its stringent warm temperature and humidity requirements. Seeds germinate well at temperatures near 25° C and with adequate soil moisture.

Prolonged temperatures of 38° C or higher may be lethal to the tree. Mangosteen produces the highest yields at temperatures between 25° and 35° C, with a relative air humidity at or above 80%. Growth and yield performance are lower but are still good at 20-25° C. Vegetative growth is slow at temperatures under 20° C, and commercial production is not recommended in places with temperatures of 15° to 20° C. The tree may die at temperatures below 4° C. It commonly grows better at altitudes up to 500 meters above sea level and on slopes of less than 15%, and may even attend 1000 meters providing the minimum temperature remains above tolerable values; growth rates at high altitude are however much slower. Young trees need a shaded environment, but after the first 2-4 years the shade may be removed.

Deep, porous soils rich in organic matter and nutrients, with good drainage and acidic pH seem to be best for mangosteen. Generally the tree does not grow well in limestone and other alkaline soils. The crop has a high water requirement. The soil must have adequate moisture year-round, provided either by rainfall or irrigation. The most successful orchards receive at least 1200 mm of rain annually. Dry periods should not be longer than 15 days. Drought for 30 days is associated with induction of flowering, and watering may be necessary to prevent undesired flower production. Mangosteen thrives alongside fresh water bodies such as streams and canals. Occasional short dry periods are tolerated, but may have a negative impact on yield.

2.6. Crop and Land Husbandry

2.6.1. Propagation

Propagation of mangosteen by layering and cuttings is rarely successful. Mangosteen is usually propagated by seeds, which are recalcitrant and die if allowed to dry. The seeds may start germinating as soon as they are removed from the fruit, if maintained in a moist environment. Seedlings grow at a very slow rate, and small seeds are known to have slow growth rates, which make them undesirable for commercial propagation. The slow growth rate of mangosteen has been partly attributed to the lack of root hairs which limits nutrient uptake.

Also, for the first six months after germination, the seedlings depend largely on seed reserves and make little use of soil fertilizers. Hence, the seedlings do not tolerate high concentrations of salts or fertilizers in the soil, and respond better to low fertilizer rates or to slow-release organic fertilizers. Grafting onto rootstocks of *Garcinia venulosa*, *G. xanthochymus* and *G. hombroniana* is possible, potentially reducing the juvenility period and the size of the trees; however, incompatibility may be a problem.

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Biographical Sketches

Bryan R. Brunner studied plant science at Rutgers University, New Jersey (1985), and completed a master's degree in tropical agriculture in the Department of Agronomy and Soils at the University of Puerto Rico, Mayagüez (1989), and a doctorate in plant breeding and genetics at Michigan State University (1992). He taught graduate plant breeding and was Head of the Horticulture Department at the University of Puerto Rico, Mayagüez (1999-2003). He currently works as a horticultural researcher at the Agricultural Experiment Station of the University of Puerto Rico in Lajas. His research interests include germplasm management of tropical and subtropical fruits, and organic agriculture. He has advised numerous graduate and undergraduate student research projects, and authored or co-authored more than 50 scientific publications and three books in the areas of tropical fruits, ornamentals and organic agriculture.

J. Pablo Morales-Payan is currently professor at the University of Puerto Rico, Mayagüez Campus. He obtained a M.Sc. in Horticulture in Rutgers University (1989) and a Ph.D. in Horticultural Sciences (weed science and plant pathology) at the University of Florida-Gainesville (1999). His current research and teaching is focused on the use of exogenous substances for physiological regulation; on practices for sustainable/organic production systems for horticultural crops with emphasis in weeds and pests; and on disease ecology and management. He has led many research projects and has served as thesis chairman of numerous graduate and undergraduate plant science students in several academic institutions in the Dominican Republic and in Puerto Rico.

Dr. Morales has been National Director of the Agricultural Research Department of the Dominican Republic, Chair of the Agronomy Department at UNPHU, President of the Dominican Society of Agriculture and Forestry Researchers (SODIAF), and President of the Caribbean Division of the American Phytopathological Society. He also served as Research Director of the Dominican Team with the Network for Vegetable Research and Development of Central America, Panama, and the Dominican Republic (REDCAHOR). In 2007 he received the 'Eugenio de Jesus Marcano' award, the highest distinction bestowed by SODIAF, for his contributions to research and education in agricultural sciences.