

Cultivation of Neglected Tropical Fruits With Promise

Part 7. The Durian

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Cultivation of Neglected Tropical Fruits With Promise

Part 7. The Durian

By Simón E. Malo and Franklin W. Martin¹

ABSTRACT

The durian, *Durio zibethinus* Murray, is the most controversial fruit of the Tropics because of its strong, offensive odor and its rich, filling taste. It is a fruit tree of the tropical rain forests of the Malaysian Archipelago and adjoining areas and is popular in many parts of Southeast Asia. The fruit is a large, spiny capsule that opens into five segments containing seeds covered with a pulpy, edible aril. The durian is highly prized both as a fresh fruit and as processed dishes and sweet preserves. The plant is cultivated only where the rainy season is long and well distributed without a marked dry season. Seed viability is short, and superior cultivars have to be propagated by grafting. The tree needs at least 12- by 12-m spacing and a well-drained soil that should be maintained constantly moist. Grafted trees produce in as little as 4 years, but seedlings may take as long as 10. When mature, the fruit drops to the ground, but it can be carefully harvested before this occurs and ripened in 4 to 6 days. The durian is an exceptionally nutritious fruit with a high protein, carbohydrate, and vitamin content. It merits large-scale trials in the Tropics of the Western Hemisphere, where it is known to be well adapted to many humid localities. **KEYWORDS:** botany, durian (*Durio zibethinus*), fruits, horticulture, plant cultivation, tropical agriculture (fruits).

INTRODUCTION

The durian, *Durio zibethinus* Murray, is one of the most remarkable fruits of the rain forests of tropical Asia. Its unique appearance, flavor, and aroma have been the subject of curiosity and amazement in the western world since 1869, when Alfred Russel Wallace (37),² the British naturalist, extolled its

virtues in his writings about the Malay Archipelago. When ripe, the fruit emits an intensely pungent smell that can be overpowering. The aroma strikes people in different ways and has been compared to a variety of things, some not complimentary. Although difficult to describe, the odor at first suggests garlic, onion, or strong cheese, but later a pleasant aroma or fruity smell is detected. The taste of the large pulpy aril that surrounds the seeds also defies description, but perhaps an appropriate one is Wallace's: "Like a rich butter-like custard highly flavored with almonds . . . intermingled with it come wafts that call to mind cream-cheese, onion-sauce, brown-sherry and other incongruities."

It takes a hardy spirit to surpass the initial odor

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

and taste the durian for the first time. But once this barrier is overcome, the experience of eating a good durian is unforgettable. A visitor to the Southeast Asian Tropics cannot really boast of an acquaintance with these exuberant lands if he has not tasted this uncommon fruit.

The durian merits wide distribution in the Western Hemisphere. It is exceptionally nutritious, with a high protein, carbohydrate, and vitamin content. It would be somewhat controversial but welcomed by many people. Fortunately, it has adapted well in many tropical American countries.

THE DURIAN

ORIGIN AND DISTRIBUTION

The durian has long been grown and appreciated as a seasonal dessert fruit in the Malaysian region, including the Malay Peninsula, Indonesia, and the Philippines. The durian has been intimately associated with the folklore, customs, and beliefs of the ancient Malaysians and other aboriginal people who have inhabited the islands, large and small, of the Sunda Shelf. This area has been covered by the oceans only recently in geological time (24). As recently as 10,000 years ago during the ice ages of the Pleistocene Epoch, the Sunda Shelf was a great expanse of tropical land enclosing all of Indo-Malaya, Sumatra, Java, and Borneo. This area, including Celebes and the small islands to the east of the Makassar Strait, gave rise to the great majority of plants and animals that predominate in the present rain forests.

Species of *Durio* are found throughout the forests of western Malaysia, but the majority of them, including the durian, seem to be native to Borneo. This island has a greater number of native *Durio* species than any other place and seems to be the center of distribution for the durian (27). Many speculations have been made on the identity of the ancestral parents of the wild durian of Borneo. However Soegeng-Reksodihardjo (27) believes that there is at present no genetic evidence to substantiate this ancestry. Moreover, the majority of the forests where genetic evolution could have been traced have disappeared, probably as a result of violent volcanic upheavals (24, 27).

The durian is grown intensively and commercially for its fruit only in Indonesia, Malaysia, and Thailand. Its popularity in Cambodia, Vietnam, and Burma is restricted to the extreme southern regions of these countries. In the Philippines, it is still

considered an exotic fruit in Luzon but is well known in Mindanao and the Sulu Islands. In both Burma and Thailand, it does not grow further north than latitude 18° N. (12, 16). In Thailand, its northernmost range seems to be the district of Uttaradit, where in winter wild and cultivated durian trees are affected by the occasional cold fronts from the north, but where the temperature seldom if ever goes below freezing. North of Lampang, Thailand, no durian trees are found, and the valley of Chiang Mai is at times too dry and cool for durian trees to prosper. The climate in Chiang Mai is typically of the monsoon type, with intensely dry months from November through May and a rainy season from late May through October.

Many efforts have been made to introduce the durian to the Tropics of the Western Hemisphere. Because the seeds are short lived, only potted seedlings have succeeded in shipments of plants, and predictably only in the high-rainfall areas of the Americas. The first durian to fruit outside Asia was in 1894 in Dominica (Lesser Antilles) from plants sent from the Kew Botanical Gardens, England (1). These trees were the source of plants for subsequent introductions to Trinidad, Jamaica, and other Caribbean islands. Today there are many fruit-bearing trees in the American Tropics, especially in dooryards of knowledgeable plantmen and in the few botanical collections of the region, such as the Lancetilla Experimental Gardens in Honduras. There are, however, no large orchards or commercial plantings. The reception of the durian in the American Tropics has been mixed, many people spurning it at first because of its strong smell, but an increasing number of people, particularly young people, have become fond of it.

COMMON NAMES AND BOTANICAL RELATIONSHIPS

The specific epithet, *Durio zibethinus* Murray, is derived from the Italian "zibetto" for civet, a catlike animal known for its musky smell. The generic name, as well as the vernacular names in many Indo-Malaysian languages, is derived from the Malayan "durian" (9, 27), also the name in many European languages.

Botanically, the durian belongs to the family Bombacaceae, and the species has well-known American counterparts, such as those in the genera *Ceiba* and *Bombax*, which produce kapok (silk cotton), and *Ochroma* (balsa), the source of the lightest of woods. Another fruit tree, the less known South American sapote, *Quararibea cordata* (H. & B.)

Garcia-Barrega and Hernández, is also a relative of the durian.

Of the more than 27 species of *Durio*, at least 6 are edible, but besides *D. zibethinus*, only the lai, *D. kutejensis* (Hassk.) Becc., is grown for its fruit. It is considered by many to be as good as or better than the durian, although less sweet in most cases. The kerantongan, *D. oxeyanus* Griffith, is grown occasionally in isolated villages of Borneo, and *D. dulcis* Beccari is rarely planted (27). Most of the members of the genus *Durio* are small to large trees, strongly buttressed in some cases. The majority produce racemelike inflorescences, either on the large branches (ramiflorous) or on the main trunk (cauliflorous), or down to the bottom of the trunk in some species. The undersurface of the leaves of all species is covered by stellate hairs or minute scales that give them either a silvery or a ferruginous appearance, which contrasts with the shiny, light-green upper surface. The elliptical flower bud of *Durio* species is covered in all cases with a fleshy epicalyx that cracks open when the flower develops. When

this happens it exposes an urceolate (vase shaped) calyx, five petals, and numerous stamens around a sessile ovary that has five locules in most cases. The fruit in all species of *Durio* is a capsule, variable in size and shape but always spiny outside. The seeds are enveloped in an aril that is fleshy in the edible forms and thin in others.

BOTANICAL DESCRIPTION

The tree

Durio zibethinus Murr. is a medium to large tree, depending on soil depth and fertility, which grows up to 40 m in some unusual cases in the forest. However, grafted orchard trees seldom grow over 12 m, more commonly 8 to 10 m. The leaves are simple, alternate, leathery in texture, elliptic to oblong, 8 to 20 cm long, with a characteristic silvery-brown or rusty undersurface scurfy in texture and a light-green, smooth, upper surface (fig. 1). The foliage is peculiarly attractive, changing color and texture with the breeze much in the same



FIGURE 1.—Durian leaves.

manner but less pronouncedly as the two-color foliage of the cainito (*Chrysophyllum cainito* L.). Young grafted trees in commercial orchards are uniform if well cared for, tending to be conical in shape, like some conifers. This symmetrical shape is maintained until the orchard becomes crowded with age, when the growth habit changes to irregular forms, but even then the upper portion continues to exhibit the conical shape, a reflection of the strong apical dominance of the central leader.

Isolated, old seedling trees are tall and erect with branches that show a characteristic horizontal, sometimes gnarled appearance. The bark is brown, rough, and flaky. The wood is brittle, grainy, dark brown to reddish, with the heartwood conspicuously darker than the sapwood. It is reported to make an undesirable lumber, because it shrinks in drying and is short lived in humid conditions (6).

Flower development and biology

The durian has an interesting flower biology (9, 36). Seedling trees start blooming around the seventh year, and flowering in grafted trees is initiated in the fourth year or sooner if the young trees are growing vigorously. The flowers are borne in corymbose (some call them cymose) inflorescences that are even topped, with stalks that have ordinarily branched twice. The stalks are purplish green or greenish and are covered with minute scales, as are many young shoots, which give them a texture like sandpaper. The inflorescences arise in clusters from floral cushions, normally along the main branches. The pedicel of each flower is 5 to 8 cm long, and the branched inflorescence stalk can reach 16 cm and is as thick as a pencil. Each cluster may contain as many as 25 flowers, but ordinarily few set fruit that develop to maturity, although fruit clusters of 10 have been recorded by the senior author. In these cases, the fruit is smaller than usual.

Each flowerbud is neatly covered by a shell-shaped, fleshy epicalyx that splits open into halves at the beginning of flower development. The cracking of the epicalyx marks the beginning of anthesis or expansion of the flower, followed by a series of rapid events that culminate in the falling of anthers and the corolla. From anthesis to petal fall, it may take from 24 to 72 hours (3, 9, 36), depending on temperature and weather conditions. As the epicalyx opens, the first flower part to emerge is the tubular calyx, which is usually flattened at the base, followed by five whitish petals. Immediately afterward, a "shaving brush" cluster of stamens begins

protruding. The stamens are grouped in 5 distinct bundles, or phalanges, each containing as many as 12 filaments united at the base with reniform anthers that dehisce by a slit. The ovary is superior with a long style capped by a yellow stigma. The manner in which the anthers dehisce, by a slit or by a pore, has been used as a major taxonomic character to separate two broad categories of *Durio* species (17, 18).

At full anthesis, which occurs between 4:00 and 6:00 p.m., the flowers begin to emit their characteristic sour-milk odor and attract insects like bees and flies in the late afternoon (3), and nectarivorous bats and moths at night (2, 21, 22, 30, 36). Bees are not effective agents of pollination, because the process of pollen shedding often starts after sundown when bees are inactive (36). By midnight, most of the pollen has been shed, and subsequently stamens and corollas begin dropping as a unit, so that by dawn the ground is covered with the remains of the flowers that opened the previous evening.

Because there are only a few hours when pollination takes place, moths and bats are probably the most important agents (2, 30, 36). Artificial pollination can be performed shortly before the flowers open in late afternoon, when the stigma of the pistil becomes sticky. Pollen can be stored in good condition for 24 hours in a refrigerator and used to hand-pollinate flowers emasculated a few hours before dusk. If pollination does not occur, the pistil will hang on for 4 to 5 days longer, ultimately dropping. If pollination and fruit set has occurred, the ovary begins enlarging in a few days. Valmayor et al. (36) have found that isolated seedling trees have a high degree of self-incompatibility and have to be cross-pollinated to set fruit. Their studies explain why isolated trees in the American Tropics and other areas where durian trees are uncommon are unfruitful. No floral biology studies have been conducted with the well-known cultivars of Thailand, Malaysia, and Indonesia. It is not known whether self-incompatibility is also a common phenomenon with productive commercial selections.

The durian is a typically chiropterophilous (bat-loving) plant; many studies and observations in Malaysia, Indonesia, and Central America have confirmed the dependence of its pollination upon bats. The most important species in Malaysia is *Eonycteris spelaea* Dobson, although species of *Macroglossus* seem to act as occasional pollinating agents also (30). Although durian evolution has apparently been dependent upon Old World nectarivorous bats in the suborder *Megachiroptera*, its

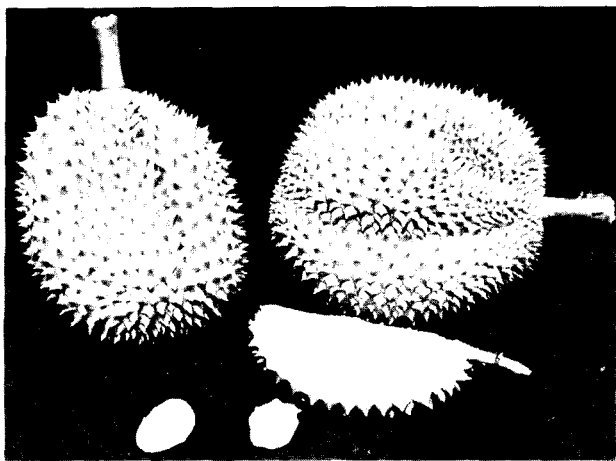


FIGURE 2.—Durian fruit. Small seeds, as the ones shown here, are desirable.

flowers have also proven attractive to the New World bats in the suborder *Microchiroptera* (3), when it was introduced to the American tropics.

The fruit

The durian fruit is a large, five-shouldered, thorny, ovoid to ellipsoid capsule, uniformly shaped but sometimes highly ridged in cross section, depending on the cultivar. Some fruits reach 30 cm in length, and they are seldom less than 5 cm. A durian fruit ordinarily weighs 1.5 to 2.5 kg, but the largest ones may reach 7 or 8 kg. The color is normally a dull olive green for most varieties but varies from a light rusty tone to a light yellowish green. The outside of

the fruit is impressively well protected with a cover of stout pyramidal spines 1.0 to 2.0 cm long with three to seven sides at the base, making it difficult or even dangerous to handle with the bare hands, except by the thick (1.5 to 2 cm), long (10 to 30 cm) fruit stem (fig. 2). The fruit makes a formidable weapon.

It takes between 3½ to 4½ months from fruit set to maturity. Development is rapid, compared to that of other fruits. During the first week, the fruit grows slowly, and after the second week of fruit set it grows faster. Growth slows during the last 4 weeks before maturity. Once the fruit is mature on the tree, it abscises at the articulation of the pedicel with the inflorescence stalk and takes from 2 to 4 days to ripen after that. The first indication that the fruit is ready to eat is when it starts emitting its characteristic aroma, faint at the beginning but stronger as the capsule splits open at the stylar end along the five sutures that are barely visible in the fruit.

Each of the five interior compartments of the capsule has smooth walls and contains one to six seeds 2 to 6 cm long. The seeds are larger in unselected types and smaller in improved cultivars (fig. 3). A fleshy, edible aril completely surrounds each seed (figs. 4 and 5), especially if the seeds are abortive, small, and rudimentary, as in the good cultivars. Seed color is usually creamy, but colors range from light to dark tones, sometimes a distinct light orange, which is preferred by most people. Directly above the large hilum patch of the seed, the aril is mealy and lighter in color (8). This area cor-



FIGURE 3.—Durian seed (actual size).



FIGURE 4.—Interior compartments of durian fruit, showing uniform arils.

responds to the funiculus and to the side of the aril facing the central core of the fruit. On one side of the seed there is a large, light-colored hilum that in some cases occupies one-third of the seed surface. The seed is also enveloped with two papery seed-coats or reddish-brown integuments. Fruits with attractively colored arils are usually displayed in the markets of Thailand with a window cut in the capsule to expose them to the passers-by, but they are carefully wrapped in cellophane to protect the shiny pulp from dust and dirt.

The taste of the aril has been described both in derogatory terms and in complimentary terms. The aroma of some unimproved types is offensive, but the smell of the best cultivars is comparatively mild and no worse than the pungent odor of ripe guavas. However, a ripening durian in closed quarters becomes unbearable. The odor lingers for days, sticking to walls and clothing, and it is noticeable on the breath of people. Two or three large arils are enough to satisfy most people, because the taste is rich and cloying. Eating a durian gives a feeling of internal warmth, followed by a glowing sensation difficult to describe. Apparently, it is for this reason that people have ascribed aphrodisiacal qualities to the durian.

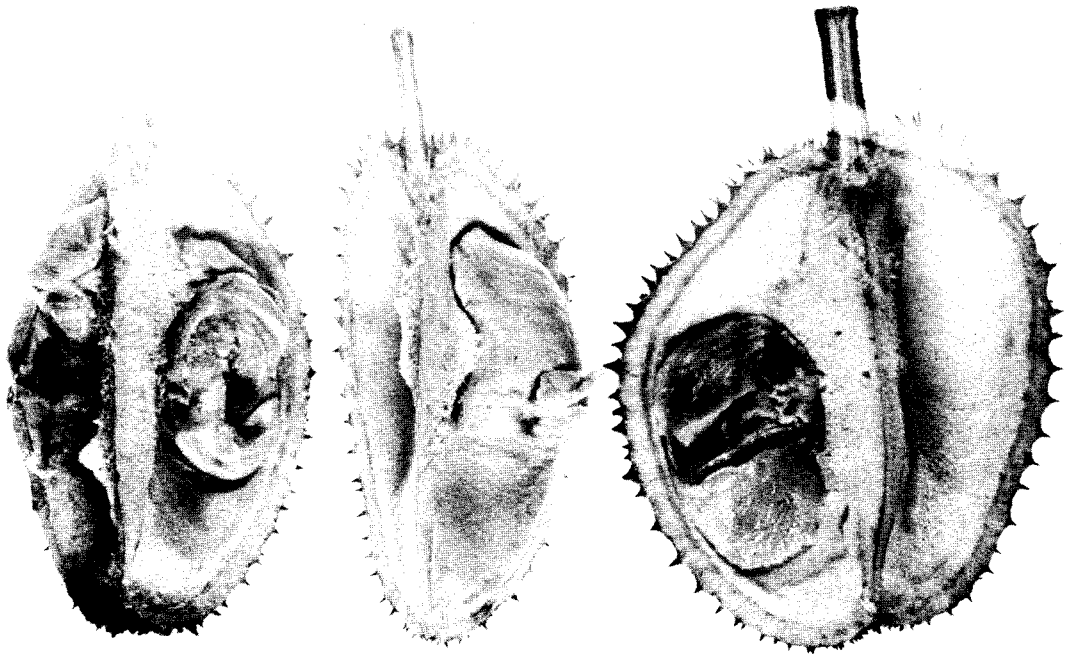


FIGURE 5.—Interior compartments of durian fruits, showing poorly developed and uneven arils.

CULTIVARS AND MATURITY

The durian has received little scientific and pomological attention from trained horticulturists. Most of the trees in Indonesia, Malaysia, and Thailand—the three countries that excel in durian production—are still found in dooryards in cities and villages, receiving little or no cultural care. Malaysia and Thailand have planted many hundreds of hectares of commercial orchards since the end of the Second World War, yet the demand is increasing faster than the supply, as reflected by the high prices of the fruit. Thailand alone reportedly had 900,000 trees producing fruit before 1970 (31), but the number of grafted trees sold every year in nurseries indicates that this figure has probably increased at least three-fold in recent years.

Despite the rapid increase in planting area, little is being done in the way of systematic selection of superior cultivars. The annual fruit festivals of Thailand, encouraged and assisted by government technicians, do give growers an opportunity to exhibit and compete with their outstanding durian selections. As many as 300 named varieties have been exhibited at these contests, but only a fraction of these are propagated by commercial nurseries. Some of the most outstanding Thai cultivars and a few from Malaysia and Indonesia are listed in table 1. No complete pomological descriptions of these

cultivars have apparently ever been written. Valuable research has been conducted with the durian at Kasetsart University, Bangkok, particularly cytological studies on fertilization and embryo development. This information is unfortunately in the Thai language.

There are marked differences in flavor, aroma, and other fruit characteristics among Thai varieties, which are readily distinguishable even in a cursory evaluation. Those with better market demand have less of the objectionable garliclike flavor than others, especially when the fruit is fully ripe. This garlicky flavor is somewhat disagreeable even to the populace, who as a rule are not discriminating when it comes to the durian. Cultivars with a high demand, such as 'Chanee' (fig. 6), meaning gibbon in Thai because it tends to bear on top of slender branches, and 'Kanyao' (fig. 7), meaning long peduncle, are quite mild in flavor and aroma. The best varieties also have a high incidence of small abortive seeds surrounded by thick, fleshy arils.

All cultivars seem to have a short shelf life, for they ripen in 2 to 4 days after they drop by themselves and spoil quickly thereafter. Some fruit will

Table 1.—Selected durian cultivars

Country	Cultivars
Indonesia:	
East Java	'Bojol', 'Krikil'.
West Java	'Badak', 'Ketan', 'Kuning', 'Ngebel', 'Parung', 'Serang', 'Sito Kong', 'Tjipatat'.
Malaysia	'Batu', 'D24', 'D117' 'Eddy's Special', 'Gombat', '96', '97 (Foo)', '123'.
Thailand	'Chai Mafi', 'Chanee', 'Chat Tong', 'Chok Loy', 'Chompu Sri', 'Ela', 'E-Live', 'E-Tui', 'Kam Pan', 'Kam Pun', 'Kampun Luang', 'Kanyao', 'Karaked', 'Knok Jip', 'Kob Chainam', 'Kob Champa', 'Kob Hemaraj', 'Kob Kkun-Pan', 'Kob Leb Yeiw', 'Kob Mae Tao', 'Kob Phuang', 'Kob Picul', 'Kob Takham', 'Kra Toey', 'Kradoom', 'Kradoom Tong', 'Luang', 'Luang Tong', 'Med Nai', 'Mon Kiew', 'Mon Tong', 'Tong Suk', 'Tong Yoi', 'Tong Yoi Chat', 'Yam Mawad', 'Yam Plaei'.



FIGURE 6.—Large fruit of the cultivar 'Chanee' (approximately 30 cm long).

split simultaneously as they ripen; others remain in one piece even when fully ripe. Growers have learned that they can harvest fruit before the natural drop occurs and still obtain adequate quality at ripening. The durian, like most avocados, displays no exterior changes to indicate maturity. Thai growers, however, claim that a rap with the hand on the sharp spines or dragging the edge of a knife over the spiny exterior will give a characteristic sound indicating that the fruit is near maturity. This noise resembles the tight drum or hollow ring given by a watermelon or pineapple when ripe. Fruit picked in this manner will take longer to ripen and consequently have an extended shelf life, compared to fruits that drop from the tree. Another method that is claimed to extend shelf life is to harvest the fruit with its peduncle plus as much of the original inflorescence stalk as possible, and wrap the latter with a green banana leaf to keep it cool and fresh. *Musa balbisiana* Colla leaves are preferred for this because they are not brittle and because they withstand handling without tearing.

The durian season is characteristically short; most varieties mature within a few weeks of each other. This short season is always a potential problem, because a glutted market usually means low prices. Low prices seldom occur, however, because demand for durian fruit always seems to be higher than the supply. In the Bangkok markets, as well as those in other large cities such as Kuala Lumpur, Malaysia, and Jakarta, Indonesia, choice varieties command exorbitant prices, as much as the equivalent of US\$5 or more for a single medium-sized fruit (31). Fruit starts appearing in Thai markets at the beginning of May, slowly at first, increasing in volume steadily through June and July, and coming abruptly to an end during August. After that time, a few fruit trickle into the Bangkok market from off-blooms in remote areas, and later there is a much smaller fruit season from late November through January and even part of February. It is not clear whether this second-season production comes from the same trees that bore fruit during the past summer or from different ones, which because of their alternate bearing behavior did not have any fruit during the regular summer season. The amount of fruit on a single branch in the on year of the cycle can become so heavy that the fruit must be propped to avoid breakage (fig. 8).

The main bloom in Malaysia and Thailand extends from November through the early part of March, depending on the location, because this region covers almost 18° of latitude from Singapore (0°) to



FIGURE 7.—'Kanyao', or 'Karn Yao', durian fruit. This cultivar has perhaps the longest peduncle (15 cm or more) of any commercial Thai cultivar.

Uttaradit (18° N.) in Thailand. In Java (6° S.), the blooming and fruiting seasons are reversed, with flowering occurring from late June through early September, depending on altitude, and with the main crop coming from October through February (20). Trees are seldom seen above 300 m in Malaysia and Thailand (2), although it has been reported that they will grow at an elevation of 800 m in Java (20). Many named Indonesian durian varieties are available in the Javanese nursery trade (26). The bulk of nursery trees in Java are grown for the dooryard trade, in contrast with Malaysia or Thailand, and fewer orchards are being planted because of high land prices associated with recent housing and industrial developments in Indonesia (25). Most varieties in Java are well known only to nurserymen and technical people. According to Burkill (6), an old Dutch publication of 1866 listed approximately 20 varieties from this island; presumably some of these are still available and propagated.



FIGURE 8.—Branches so heavy with fruit that they must be propped with bamboo stakes to prevent breakage.

CULTIVATION

SEED MORPHOLOGY, GERMINATION, AND PROPAGATION

The seed of the durian is typically monoembryonic and sexually produced (zygotic). This gametic embryo, in contrast to the nucellar or apomictic one, is subject to genetic segregation and therefore produces a variable progeny. The durian has to be propagated asexually to obtain uniform trees with the characteristics of the desired cultivar.

The seeds are variable in size, ranging from small, abortive ones with abnormally shrunken cotyledons, to those as large as a hen's egg, with massive cotyledons and except for the large hilum, similar in size and texture to those of the Mexican avocado. The seed is notoriously short lived and is affected by high temperatures. Even a short exposure to direct sunlight will damage it, and it will lose viability in about a week even if stored in a cool place (14). It seems to have a fast metabolism that is quickly triggered into activity as soon as the aril is removed, because it starts germinating shortly thereafter, especially if kept in a plastic bag. The embryo, depending on the size of the seed, is large, measuring approximately 1.0 cm in length by 0.5 cm in width. When germinating, the radicle, or pri-

mary root, pushes hard and fast into the soil, lifting the cotyledons out of the ground. This process represents the characteristic epigeal germination of the durian seed.

In recent years, several hundred seeds have been brought to the Western Hemisphere. The seeds were carefully packaged and stored in plastic bags with slightly dampened paper. The majority of these seeds have germinated surprisingly well even after a 2-week storage period.

GRAFTING

Because rooting of cuttings and marcottage are not successful (19), grafting is the most practical method of propagation. Large, healthy seeds are planted with the flat side down in a suitable well-drained soil, if possible directly in plastic bags or containers with approximately 8 l of soil. This volume of soil sustains enough roots to grow a good-sized tree for transplanting to the field. It is important to emphasize good aeration in the potting media, because the more friable the soil, the better the seedlings will grow. Appropriate mixtures of clean sand, peat or muck, compost, wood shavings, and ground coconut fiber will have to be prepared locally, depending on the availability of materials. Germination and subsequent growth are relatively fast, producing a good-sized seedling suitable for grafting in about 2 months.

Young, vigorously growing seedlings with a diameter thicker than a pencil near the ground are preferred for grafting. The modified Forkert method, a modification of patch budding, is the best procedure to follow (20), and it is the one presently used in Thailand, Malaysia, and Java. The bud is cut off from the scionwood of a relatively young branch about the thickness of a pencil, as if it were for shield or chip budding. The thin slice of wood behind the bud is carefully removed so as not to pull off the base of the bud, leaving a shield of cortex containing the bud. The rootstock cortex is carefully lifted out after one basal and two lateral incisions are made into the wood. This flap of cortex should be slightly wider than the scion, which is immediately slipped under it. The two surfaces of cambium are pressed together. The flap of the rootstock is cut so that it slightly overlaps and covers the top of the scion shield. The graft is covered, preferably with a strip of polyethylene, leaving the small bud of the scion slightly uncovered, or covered carefully and loosely.

All trees propagated in Thailand and Malaysia are on *D. zibethinus* stock, which is susceptible to a root-rot disease caused by *Phytophthora palmivora* (Butl.) Butl. (32-35). Studies conducted in search of a resistant stock in Thailand have shown that durian intergrafts well with *Durio malaccensis* Planch. and apparently grows well on stocks of this species, because the graft union is smooth and normal, at least for the first few years. It is possible that graft compatibility of the durian with other species could be widespread, because many species, like *D. malaccensis*, are morphologically similar to *D. zibethinus*. Were it not for a slightly larger leaf with a more silvery undersurface, young *D. malaccensis* plants could be confused with the durian.

NURSERY HANDLING AND PLANT CARE

Within 25 to 30 days, the scion should have united with the stock, and it usually begins to grow. Otherwise, the stock should be regrafted immediately before it gets too woody. The probabilities for success decrease gradually with the age of the stock. The young bud grows rapidly after the polyethylene is loosened, and a stake is soon necessary to support and train the growing scion. The stock is gradually pruned as the scion grows and develops more foliage.

Growers in Thailand believe in providing artificial shade for young durian plants, and bamboo slat

houses are used for this purpose. More often than not, however, too much shade is used, slowing down plant growth. Malaysian nurserymen, on the other hand, do not give any shade at all, because on the average Malaysian days are cloudier than those in central Thailand. Depending on the locality, a light shade for young plants is desirable, particularly if the midafternoon sun is bright. Direct sunlight is occasionally known to scald the leaves of young durian plants.

Proper irrigation is crucial with young potted plants, particularly during the dry season. Irrigation must be done daily to keep the relative humidity high and the soil in the containers moist. Because the potting medium for the durian is light and friable, adequate irrigation is doubly important. It is also desirable to have a 5- to 10-cm layer of sawdust on the ground of the nursery to keep a constant humidity, improve drainage, and minimize the weed problem. Another important requirement is protection against strong winds. Because the durian is a rain-forest native, the young plant is susceptible to desiccation.

Young plants in containers need to be fertilized often and lightly by hand. About 5 g (1 tsp) of a mineral fertilizer mixture containing 6-6-6 (never a higher analysis than 8-8-8) should be used monthly, and one should be careful not to use more than this amount, because young durian trees can be burned easily. This sensitivity is also the reason why the fertilizer mixture should at least have 30 percent of its nitrogen from organic sources. It is also desirable that the person fertilizing should pull out weeds that might be growing in the containers.

The durian is seldom pruned in the nursery prior to transplanting. The plant usually acquires a desirable pyramidal shape by itself, and it gradually needs more space as it grows. Depending on care and climatic conditions, an 8-l container will produce a plant ready for field transplanting in 14 to 16 months.

ENVIRONMENT, SITE CHOICE, AND CARE OF YOUNG PLANTS

The durian, like many other fruit trees, is highly susceptible to poorly drained soils that lead to root asphyxiation. Under these conditions, soil-borne fungi such as *Phytophthora* spp. are important limiting pathogens. Sandy or loamy soils are best, especially in alluvial conditions; however, in these soils provisions for irrigation water will be necessary.

Trees thrive best in soils where aeration is good

and where soil moisture is both constant and adequate throughout the year. The site should not have a tendency to flood or to remain too dry for long periods. The permanent site should also be chosen on the basis of the rainfall, because the distribution and the total amount of precipitation are equally important for the durian. A rainfall regime of 2,000 mm annually seems to be a bare minimum for satisfactory growth and production, with apparently no maximum limit.

It is a characteristic of the durian that it cannot tolerate more than 3 months of an intense dry period without suffering irreversible damage. In alluvial plains and delta regions with a high water table, such as the region around Bangkok, Thailand, the amount of annual rain can be as low as 1,500 mm, provided it is fairly well distributed throughout the year. Fruit trees in these areas are grown in raised beds, which together with an ample system of canals, offer the double opportunity of waterways for drainage and for irrigation. However, delta regions are also risky, because they flood periodically, making it impossible to drain the soil properly in periods of high water.

Once the proper site has been found, the next priority is the planting distance. Grafted durian trees bloom and set fruit precociously, compared to seedlings. The earliest for the latter would be around 7 years (9), and grafted plants of productive cultivars often begin production at the fourth year if properly grown. A 12-year-old tree at its peak of production will need a circle of space about 10 m in diameter. It is thus desirable to have a planting distance varying from 12 by 12 m in shallow soil to 14 by 14 m in deep soils, where trees will grow larger. Depending on the value of the land, an option to the grower is to plant on a 6- by 12-m spacing, with the idea of eliminating one-half of the trees later in order to have the preferred 12- by 12-m distance. This arrangement necessitates careful planning and attention to how the trees are growing. The grower must thin the orchard when it becomes clear that close planting is forcing the trees into an upright spindly growth.

TRANSPLANTING

Arrangements for securing an irrigation system, whether it is gravity flow, sprinkler, or drip irrigation, and its installation should have been completed before the trees are set out. The system should be reliable and applicable to local conditions such as labor, availability of equipment, and so forth.

The planting of the durian orchard follows the

same order and principles applied to any other fruit crop: (1) holes are dug at the proper distance, slightly wider and deeper than the plant's container; (2) a handful of superphosphate is put in the bottom of the hole and mixed thoroughly with loose soil; (3) plants are set in so as not to disturb the roots, and plastic bags are carefully removed by cutting them open with a knife; (4) the soil around the young tree is well packed and a small basin is built around it; and (5) the soil is thoroughly soaked with 15 to 20 l of water. About 200 g of an 8-8-8 fertilizer mixture may be spread around the young tree at this time.

CARE OF YOUNG ORCHARDS

Trickle irrigation, a relatively new system, should be tested with the durian, because this system maintains the constant, adequate soil moisture needed by the durian for maximum growth. Preliminary experiments with oil palm (*Elaeis guineensis* Jacq.), another crop requiring constant adequate soil moisture for maximum production, are encouraging (11). Because low pressures are required (seldom over 15 lb/in² or 1.0 atm), small pumps, preferably electric, are used with polyvinyl chloride (PVC) pipe for the mains and polyethylene hoses for the laterals. The only difficult or mechanically sophisticated aspect is the necessary filtration of the water.

Keeping the soil around the young plant free of weeds is important for maximum growth, particularly during the first year. Weeding can be done, depending on the location, either by hand or with approved herbicides. If a herbicide is used, protect the young plant with a rectangular shield of tin or aluminum sheeting (0.60 by 1.2 m) that has been folded in half, in V-shape fashion. The shield is put around the tree on two or three sides while the weeds around it are sprayed.

Areas between rows should be kept periodically mowed to promote a short grass cover, or they should be planted with a legume cover crop suitable for the area. This cover crop should be neither so vigorous that it requires much labor to keep it in check nor so weak that it does not cover the ground completely. Good crops for this purpose are *Dolichos lablab*, the hyacinth dolichos, *Canavalia ensiformis* (L.) NC., the jackbean, and *Stizolobium deeringianum* (Bort.), the velvetbean, if it is carefully managed.

The fertilization of young durian trees has to be conducted carefully, because they are susceptible to high concentrations of salts in the soil. Too much nitrate or potassium salts will burn the young plants

and reduce their growth considerably. The young trees should be fertilized frequently with a low-analysis mixture, and with small amounts that should be increased gradually. According to the natural fertility of the soil, young trees should start receiving about 200 g of a 6-6-6 or 8-8-8 mixture at planting time. This amount should be increased by 50 g every 2 months for sandy soils with poor fertility, and by 25 g for fertile soils. This regime should be continued for the first 4 years (trees in infertile soils should be receiving a total of approximately 1,400 g, and those in fertile ones 800 g at the end of this period). This gradual increase in fertilizer for these contrasting types of soils can be modified for soils of intermediate fertility. This fertilizer schedule is designed to give a maximum amount of growth during the period of juvenility before the trees enter the flowering and fruiting phase. It seems that the faster the initial period of growth, the quicker a fruit tree outgrows its juvenility and begins blooming.

CARE OF PRODUCING ORCHARDS

Until precise knowledge based on research on the durian is available, the following tentative recommendations may be carried out. They are based on the West Indian avocado, a crop with a similar metabolism, fruit analysis, and in some ways bearing behavior.

After young durian trees begin producing fruit, their growth rate should be slowed so that there is little vegetative growth after the eighth year. This goal requires some changes in the fertilizer mixture. First, the phosphorus content should be reduced to 2 or 3 percent in the fourth year through the eighth year and totally eliminated thereafter, or until leaf analysis shows that it is necessary again. Second, depending on the natural fertility and the potassium content of the soil, this element may be lowered or sometimes even eliminated. Volcanic soils, such as those of Central America, are unusually high in potassium, and even bananas, which require large amounts of this element, do not react favorably to additional applications. It should be emphasized, however, that durian trees, like most other crops with a high potassium content in their fruits, such as bananas and avocados, will need plentiful amounts of this element in the soil to replace what the fruit removes from the tree. Third, the annual amounts of nitrogen supplied to bearing trees, considering soil fertility and age, should vary between 0.5 and 2.0 g per tree. Nitrogen is the

most critical element in commercial fruit production. It is the only element stored principally in the soil organic-matter fraction, which is susceptible to oxidation and ultimate depletion under tropical conditions. In commercial operations in tropical regions, this element cannot be ignored, eliminated, or even reduced in cultural programs, without rapidly noticing the effects upon yield.

DISEASES, INSECTS, AND OTHER PESTS

Several minor insect pests are found occasionally on the durian. As with most crops formerly grown in dooryards or sporadically as isolated trees in a semiwild condition, major insect pests have not yet had an opportunity to develop to a destructive level. Natural biological control usually keeps pace with pests, and a desirable equilibrium is maintained. Insects may become a nuisance at times, but they do not attain sufficient economic impact to require control measures. However, this situation may change in Thailand and Malaysia as the number of commercial durian orchards increases. Insects are expected to become important enough for growers to consider chemical controls. Such measures will slow but will not eliminate insect pests and may destroy the current natural biological equilibrium.

Observations of commercial orchards in Thailand revealed some leaf-eating insects such as several lepidopterous larvae of undetermined genera, particularly on young growth. Larvae of root weevils of various species destroy roots, and the adults damage the foliage. The adults can destroy young durian orchards. Several types of armored scales have been observed on the fruit. Although no study has indicated what kind of damage is done to the tree, scales render the fruit unsightly, lowering their acceptability and price.

The most important disease of the durian at present is root rot caused by *Phytophthora palmivora* (Butl.) Butl. (32-35). This disease kills the tree quickly or in just a few months after the first symptoms appear. The pathogen seems to be widely distributed not only throughout Malaysia and Thailand but also in virtually every other humid tropical area. It is apparently common on the durian on the island of Penang just off the west coast of Malaysia (Andaman Sea) and on the island of Samui off the east coast of Thailand (Gulf of Siam). Many trees with typical symptoms of the disease have been observed in both localities.

Symptoms and the development of the disease

are similar in many ways to root rot of avocado caused by *Phytophthora cinnamoni* Rands. As in avocado, durian root rot cannot be controlled once the trees are infected and show typical symptoms. Characteristically, the fungus seldom strikes a great number of trees at one time or in one location in an orchard, but scattered sick trees appear sporadically. Only occasionally are there dead or dying trees grouped in a large area. It is apparent that trees become more vulnerable to the fungus after reaching a certain size and age, because young trees are seldom killed by the disease.

Knowing that there is no effective control, chemical or otherwise, Thai growers periodically inarch seedlings to the main trunk of a mature tree. This practice apparently works well because, trees treated in this manner seldom die, even though they are still infected.

Perhaps, the juvenility of the seedling conveys a



FIGURE 9.—Inarches made to prolong the life of the main trunk of a durian tree infected with *Phytophthora palmivora* (Butl.) Butl. Note the graft union in the main trunk with a slight overgrowth of the scion.

measure of tolerance to mature trees, or seedling roots are still in well-aerated soil, whereas roots of older trees have grown into poorly aerated zones. Once this phase is outgrown, the tree needs fresh inarches. The cultivar 'Chanee' is preferred for grafting, because some growers believe that it is more tolerant to root rot. This belief is questionable, because durian seedlings are variable.

After successive years of inarching, some orchards look like mangrove forests, for each tree has several lateral supporting stems growing in twisted, strange ways (figs. 9 and 10).

There has been some testing for tolerance involving other species of *Durio*. Results of laboratory experiments show that roots of *Durio malaccensis* Planch. (13) and possibly *Durio mansoni* (Gamble) Bakh. (27) do not attract zoospores of *Phytophthora palmivora* (35). This tolerance has to be confirmed in field experiments in infested soils. Both of these species of *Durio* seem to be graft compatible with the durian.



FIGURE 10.—Durian tree that has lost its main trunk and is supported by the stems of three inarches.

Table 2.—Composition of the durian aril according to several sources

Component	Fresh			Dry ⁴
	(¹)	(²)	(³)	
Water	58.1	52.0–68.0	59.5	18.0
Protein	2.8	2.4–2.7	2.0	.....
Fat	3.9	2.9–4.3	1.2	3.0–6.0
Sugars	12.0	.....	.....	37.0–43.0
Carbohydrates (total)	34.0	27.8–32.3	36.1	8.0–13.0
Minerals:				
Calcium	10	.....	18	.....
Iron	1.0	.....	1.1	.....
Phosphorus	50	.....	56	.....
Total minerals	1.2	0.91–1.2	.....	3.0
Vitamins:				
Ascorbic acid	25	.....	.....	.....
Carotene	20	.....	.....	.....
Niacin	⁵ 0.70	.....	.....	.....
Riboflavin	⁵ 0.20	.....	.....	.....
Thiamine	⁵ 0.24	.....	.....	.....

¹Wealth of India (7), except for niacin, riboflavin, and thiamine.

²Bauchau (5).

³Intengan et al. (15).

⁴de Bussy (10).

⁵Wu Leung (39).

Phytophthora palmivora is a primary parasite of durian rootlets, according to Tsao (35), who studied this problem in several durian-growing areas of Thailand. The fungus spreads to the collar and trunk, destroying the phloem and killing the tree by girdling the stem. No effective control has been found, except possibly by using a tolerant stock, as outlined above, or perhaps by a refinement of the tedious inarching procedure, using only tolerant *Durio* species instead of durian cultivars. However, the key for successful durian culture in orchards infected with *Phytophthora* is to maintain a well-aerated soil by providing adequate drainage ditches or by improving existing facilities.

CHEMICAL ANALYSIS, FOOD VALUE, AND USES

The few available chemical studies of the durian show that this highly unusual fruit also has an unusually high food value. The most often consumed part of the fruit are the arils that surround the seeds, although the seeds are also edible when fried, roasted, or boiled. Table 2 gives information on the food value of the aril, indicating that the durian is a nutritious fruit, comparable to the avocado in many ways. Vitamin E, relatively high in avocados but seldom found in other fruits, is found in considerable

amounts in the durian and reportedly is not destroyed in processing (12). The vitamin B content is high, and the vitamin C content is fair. Total protein and carbohydrate are extremely high, and when the fruit is fully ripe almost all of the carbohydrates occur as soluble solids.

Some preliminary work has been done to characterize the volatile flavor and aromatic compounds of the aril (4, 28, 29). The overall smell of the ripe fruit has three distinct, readily distinguishable aromas. The first two seem to develop, normally, one being strong, onionlike or garliclike, and the other delicate and fruity. The third aroma is more pronounced in its development and easier to perceive when the ripe fruit is held in a closed container. It is the most fetid and objectionable of the three aromas. The intensity of the garlicky note is apparently related to different concentrations of thiols and thioethers, and the fruity smell is mainly because of esters. The compounds that seem to be at least partially responsible for the offensive smell are hydrogen sulfide and diethyldisulfide. Synthetic mixtures of propanethiol and ethyl α -methylbutyrate give a similar odor but not precisely the same as the durian. Baldry et al. (4) have found that there are wide differences in the relative amounts of the volatiles, which seem to change according to the source and the cultivar and determine the relative pungency of the fruit. This finding agrees with observations of

many durian devotees who know that there is a wide variety of flavors and intensities of aroma, indicating the potential for the selection of even milder forms with less offensive smell.

Nothing in the literature points to the compounds or the group of compounds that is responsible for the afterglow effect of eating the arils. This warming effect is readily noticeable and has undoubtedly led to the belief that the durian has aphrodisiacal qualities.

The seeds consumed either roasted or boiled have a distinctive flavor reminiscent of chestnuts. They also make good appetizers when sliced and fried in coconut oil. The seeds are nutritious and like those of most Bombacaceae are high in carbohydrates (mostly starch), oil (10 to 45 percent), and protein (28). Uncooked seeds may contain a poisonous substance "which makes one short of breath," according to Kostermans (17).

The pulp is used to make a variety of conserves and delicacies. Some, like "dodol durian," are mixtures with such old favorite standbys of the Tropics as coconut milk, glutinous rice, palm sugar (mainly *Arenga pinnata* (Wurmb.) Merr.), and pili nut (*Canarium* spp.) or peanuts. Several types of hard, sugary cakes are also popular and sold under various names according to the recipe. Dairy companies make a respectable durian ice cream, popular from Bangkok to Jakarta.

For preserving the durian, there are several homemade and commercial methods that are useful when the market for fresh fruit becomes glutted: sweet preparations made by soaking the pulp in sirup ("lampog"); spicy, salty, relishlike preserves ("tempojak"); and fermented pulp concoctions of an objectionable smell which are kept in earthen jars or bamboo joints ("tape duren") (27). The unripe arils are used in the making of soups (20), and young fruits are also consumed as a vegetable.

The populace and the aboriginal people of the Malaysian region credit the durian with numerous pharmacological properties. These ideas and folklore are well ingrained in their native customs and way of life. For instance, a decoction of roots is used to treat fevers (23). Decoctions of leaves and fruit valves are used to reduce swellings, arrest infections, prevent abortion, control jaundice, and so forth (6, 27).

The aril and seeds of the durian represent, depending on the cultivar, from 14 to 22 percent and from 18 to 22 percent of the fruit weight, respectively (38). The pulp is notorious for losing its quality and spoiling shortly after the fruit has reached

full ripeness. The fruit is markedly seasonal, being available at two times of the year but for relatively short periods. Studies have been undertaken in Malaysia to preserve durian pulp as a processing ingredient (5). Although the aril can be kept for about 3 months by quickfreezing at a temperature of -24°C without changes in flavor, it is not a practical method for the Tropics, mainly because it is costly and because of the general lack of adequate refrigerating facilities in these areas. On the other hand, the manufacture of durian powder or flakes by spray drying or drum drying as a flavoring ingredient for beverages, pastry, ice cream, and so forth is more feasible and amenable to local handling and application. The powder absorbs moisture from the air and must be adequately protected and packed to insure its lasting value.

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