



Durian in Thailand

A Success Story



Asia-Pacific Association of Agricultural Research Institutions

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Foreword

Durian, the most favourite fruit of Thailand, is popularly known as the “King of Fruits”. Its popularity is not only due to its excellent taste but also its specifically strong odour. Thailand is the world’s largest producer and exporter of high quality durians, followed by Malaysia and Indonesia. The exported quantity of durian was 122,664 metric tons (14.75 % of total production valued at 2,241.219 million Baht (US\$ 67.64 million) in 2004. The area planted under durian in Thailand in 2004 was about 873,643rai (139,782.88 ha.) with 831,182 tons annual yield. Majority of the fruit is grown in eastern and the southern regions, i.e. about 52 and 41 per cent, respectively. There are approximately 200 durian cultivars in Thailand. Out of these, only 60-80 cultivars have been commercially grown. There are only five cultivars commonly found in the market which are ‘Chanee’, ‘Kradum Thong’, ‘Mon Thong’, ‘Kan Yao’ and ‘Phuang Mani’, with Mon Thong’ being the most popular.

During the period of 20 years (1997-2017), the cultivation area shrunk at the rate of 0.88 per cent per year, with the production volume declining at a rate of 2.54 per cent per year. The price of durian has been very low especially during the peak season. that caused the farmers to shift to other crops such as rubber and oil palm that resulted in the decline of the production area to only 641,359 rai (102,617.44 ha.), with production of about 569,313 tons in 2013. In 2013, Thailand exported fresh durian to the extent of about 64.48 per cent of the total production. Also, the export of fresh durian and its products was about 381,414 metric tons valued at 8,528.898 million Baht in 2013. In 2016, Mon Thong variety was about 63 Baht/kg, while the Chanee variety was priced at about 42 Baht/kg. The fresh durian fruits export was about 403,634 metric tons valued at 17,505.762 million Baht which was 77.92 per cent of the total production. The export of fresh durian and its products was about 425,060 metric tons valued at 20,049.976 million Baht in 2016 which was 82.06 per cent of the total production.

The area planted with durian in Thailand in 2017 was about 762,776 rai (122,044.16 ha) with an annual total yield 616,121 tons. 503,205 metric tons (81.67 per cent of total production) were exported. Mon Thong’ occupied the largest area of about 83 per cent of the total planted area in 2017. Moreover, some of the farmers increased the area under cultivation, especially for new varieties developed by the Department of Agriculture (DOA), Thailand and the farmers themselves. The new hybrid durian varieties recommended and released by DOA, Thailand were Chanthaburi 1,

Chanthaburi 2, Chanthaburi 3 in 2006; Chanthaburi 4, Chanthaburi 5, Chanthaburi 6 in 2013; and Chanthaburi 7, Chanthaburi 8, Chanthaburi 9 in 2016, respectively.

This comprehensive publication on durian embodies information of diversity and distribution; present status of cultivation and production; collection, characterization and conservation; breeding of varieties; cultural practices and propagation; processing and value addition; economic importance, market status and commercialization; problems, constraints and limitations; and prospects. The publication will be immensely useful to policy makers, researchers, technologists, farmers, marketing personal and other stakeholders involved in the area of production, processing and marketing. I congratulate Dr Songpol Somsri, former Senior Advisor (Plant Production), Department of Agriculture (DOA), Thailand for his sincere efforts in synthesizing very valuable information on durian. Also, the efforts of Dr Bhag Mal and Fai Collins of APAARI in improving and editing this publication are much appreciated. It is our expectation that APAARI members, stakeholders and other readers will find this important publication both informative and useful.



Ravi Khetarpal
Executive Secretary
APAARI

Acronyms and Abbreviations

APAARI	Asia-Pacific Association of Agricultural Research Institutions
BAP	Benzylaminopurine
BIOTROP	Southeast Asia Regional Centre for Tropical Biology
DOA	Department of Agriculture
IBPGR	International Board of Plant Genetic Resources
IPGRI	International Plant Genetic Resources Institute
K	Kinetin
NAA	Napthalene Acetic Acid
WPM	Woody Plant Medium
2, 4-D	2, 4-dichlorophenozyacetic Acid

1 Introduction

Durian (*Durio zibethinus* Murr.) is one of the popular fruits and most preferred by consumers in Southeast Asia. Durian has a long history of production in the tropical Asia for more than hundred years. It was first introduced to the western world during the 16th century by a Dutch tourist Linschoten who recorded that "Durian is a fruit with excellent taste and considered as the most outstanding among any other kinds of fruits in the world". A.R. Wallace, a British, also wrote in several famous tourist journals that in his journey around the world, there was one part of the journey he considered as valuable when he had the chance to taste durian fruit (Allen, 1967).

Among the different kinds of fruits in the world, there has never been any fruit that has been recorded and described on the specific feature of smell and taste more than durian fruit. Foreigners have described durian as a fruit with a very strong smell. Its smell was disliked by those who had never eaten and tasted the fruit. Durian fruit has high nutritive value, and even animals like elephants, tigers, squirrels, dogs and cats like the taste of it. Several articles about durian have been written by the French during the reign of King Narai in 1682 A.D. Thais have high preference for eating the durian fruit (Vangnai, 1995).

A survey conducted by Patra (1991) shows that 72 per cent of the Thais prefer to consume durian fruit especially the Mon Thong variety, due to its sweet and creamy taste, with soft and fine flesh and mild smell.

1.1. Chemical Composition

The durian flesh is rich in food nutrients and vitamins: 100 g of the Mon Thong variety flesh contains moisture (62.5 g), protein (2.1 g), fat (3.3 g), carbohydrate (31.2 g), fibre (1.4 g), ash (0.9 g), calcium (29 mg), phosphorous (34 mg), iron minerals (1.1 mg), beta carotene (46 mg), Vitamin A (8 mg), thiamine (0.16 mg), riboflavin (0.23 mg), niacin equivalent (2.5 mg), and Vitamin C (35 mg). The varieties, Kratum Thong, Kanyao and Chanee (Department of Health, 2007) once ripe have their own specific natural distinct smell which is actually caused by the presence of sulfur or different kinds of substances such as Thioles, Thioethen and Esters that have tiny volatile molecules (Nanta, 1991).

1.2. Botanical Characteristics

1.2.1. Tree characteristics

Durian is a tall and big perennial tree, which has a long life of 80-150 years. The tree trunk attains a diameter range from 50-120 cm. The bark of the trunk is dark brown and can hardly be separated from the trunk but splits vertically along the trunk. The wood is soft and the branches spread in all directions. The tree canopy may be straight or spherical in shape depending on the variety and responsiveness to daylight.

1.2.2. Leaf characteristics

Durian is a dicotyledonous plant, with simple and alternate leaves. The length of the leaf ranges from 15-20 cm, with a width range of 5.0 -7.5 cm. The leaf is dark green with smooth and glossy upper surface, and brown scales at the bottom. The leaf petiole is round with a length of about 1.5 cm. The tip of the leaf is pointed acuminate. The young shoot in the first stage does not spread out though the leaves will spread out in the later stage.

1.2.3. Root characteristics

The durian tree developed from the seedling has a primary tap root that grows from the trunk plummet to the surface soil with secondary roots that come out from the primary tap root. The tertiary roots come out from the secondary roots. The durian tree propagated from the vegetative parts does not have primary tap root, but secondary roots that develop from the lower portion of the trunk and does not have root hairs. The roots that absorb moisture and the nutrients come out from the secondary roots or the tertiary roots. The adventitious roots grow only on the surface soil at a depth of not more than 50 cm.

1.2.4. Flower characteristics

The flower of durian develops in clusters on the branches or trunk. One cluster may be comprised of 1-45 flowers. The flower is complete with male and female parts together in one flower. Once the outer petal splits, the stigma will come out first, then during the late afternoon and evening, the flower will be in full bloom and will spread a fragrant smell indicating that the stigma is receptive and the ovary is ready for fertilization. The anthers burst and spread the pollen during night time (Fig. 1).

The durian inflorescence will be in full bloom during 16.00-16.45 hrs, and the anthers burst and shed the pollen grains during 17.45-19.00 hrs. However, at 19.30 hrs, the ability for the pollen grains to germinate is low and the rate of germination is the best during 20.30-21.30 hrs. Therefore, the self-fertilization inside the flower would be difficult, because when the ovary is ready to be fertilized, the anthers would



Fig. 1. Durian flowers

still be inside the flower and not yet shed the pollen grains. When anthers come out and shed the pollen grains, the stigma starts drying- up and does not remain receptive to pollen grains. The range of natural self-pollination in durian Chanee variety was observed to be 0-6 per cent, while in the Kan Yao variety it was 7-21 per cent. However, if the pollination is done manually, the fertilization percentage is higher. About two weeks after the pollination using pollen from other varieties, the percentage of fertilization in the Chanee variety enhanced by 30-79 per cent, whereas in the Kan Yao variety, the fertilization rate enhanced by 87-90 per cent. The cross-pollination with other varieties enhanced the fruit setting, increased the fruit size, better fruit shape and higher pulp content (Songpol, 1987, Songpol and Hiran 1992).

1.2.5. Fruit characteristics

Durian is a fruit that has aril seed. The fruit pericarp or fruit shell has pointed spikes and each fruit has about five carpels, with some carpels filled whereas some may be empty. This could be attributed to the degree of success in the pollination and fertilization, which is dependent on type of varieties. The flesh of the fruit starts developing from the fourth week after pollination in the form of a very thin white layer that later grows in size covering the seed. Once the fruit is fully developed and matured, the colour of the flesh turns yellow or dark yellow depending on the variety. The flesh is soft when fully matured (Fig. 2).



Fig. 2. Fruit and flesh of durian

1.2.6. Seed characteristics

The seeds of durian have oblong shape with varying colours depending on fruit maturity and variety. Normally, the colour is brown or reddish brown once fully matured (Fig. 3).



Fig. 3. Seeds of durian have oblong shape with brown or reddish brown colours.

2 Origin, Diversity and Distribution of Durian Varieties

Durian (*Durio zibethinus* Murr.) is a tropical fruit tree that belongs to the family Bombacaceae (Durian Family) and is comprised of about 30 genera and more than 200 species distributed along the tropical zones all over the world (Soegeng-Reksodihardjo, 1962). Out of these, 27 species are distributed along the Indo-China and Southeast Asia. The native durian (*D. zibethinus* Murr.) has a widespread plantation from Sri Lanka, Southern Burma, Southern Philippines, up to Java (Kostermans, 1958; Zeven and Zhukovsky, 1975), also distributed up to Australia, Northern Queensland and Northern Territory, including United States of America, Florida and Hawaii (Zainal *et al.* 1996) (Fig. 4).

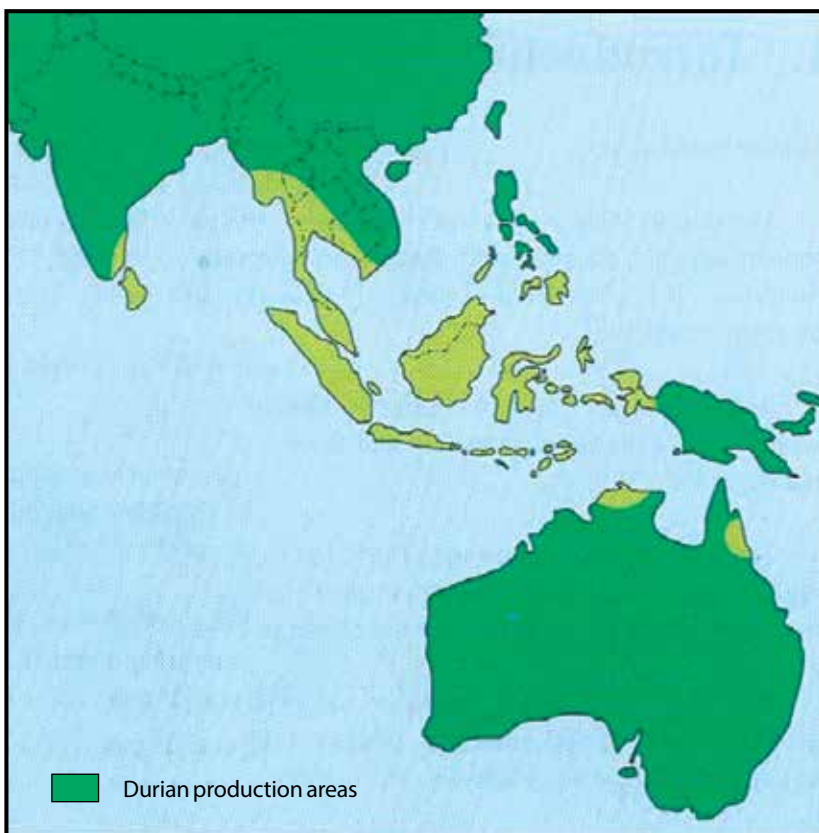


Fig. 4. Area of distribution of durian varieties along the countries in the tropical Asia and in the Northern part of Australia

It was believed that durian is a native of Malaysia (Kostermans, 1958; 1992). Zeven and Zhukovsky (1975) report that durian originated in the center of diversity in Borneo and Sumatra. They also note the discovery of 19 species in the Borneo Island, though there are 14 species that are considered local and wild species, 14 from Sabah, 16 from Sarawak, 7 from Sumatra Island, and 11 from Malaysia, in which 5 species are considered local and native.

The genus *Durio* contains at least 6 different kinds of edible species such as wild durian (*D. dulcis* Becc.), durian with mounted pedicel type (*D. graveolens* Becc.), wild durian (*D. kutejensis* Becc.), durian with long spikes type (*D. oxleyanus* Griff.), durian tortoise type (*D. Testudinarum* Becc), and the native durian type (*D. zibethinus* Murr.) (Fig. 5).

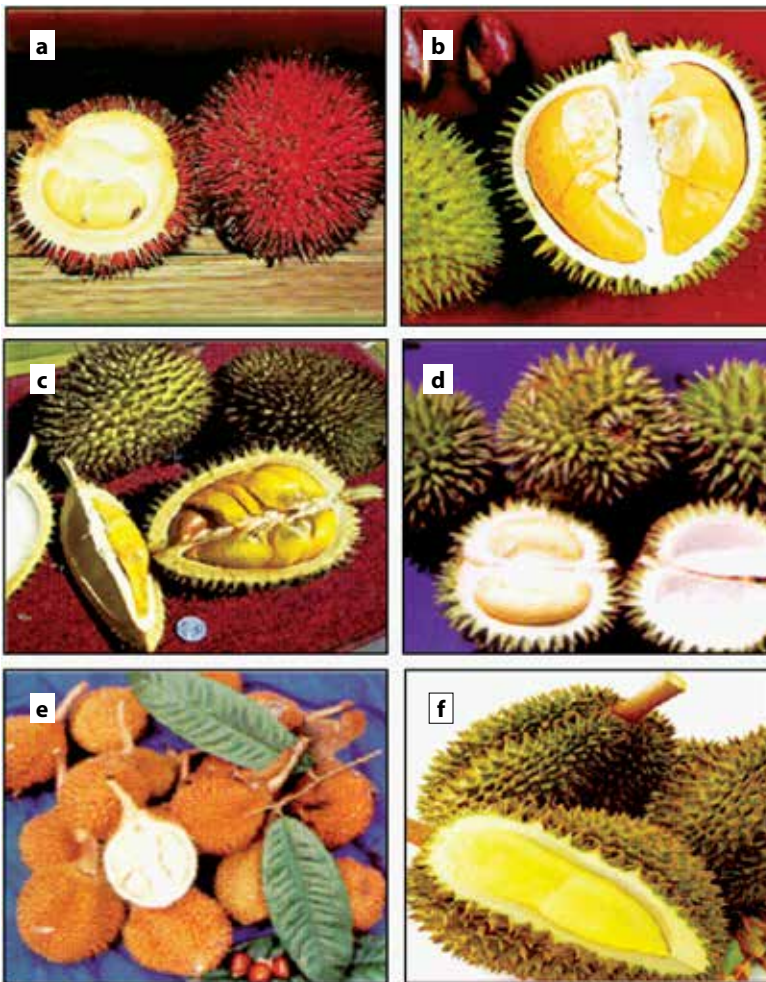


Fig. 5. Six edible species of genus *Durio*

(a) wild durian (*D. dulcis* Becc.)

(c) wild durian (*D. kutejensis* Becc.)

(e) durian tortoise (*D. testudinarum* Becc.)

(b) durian mounted pedicel (*D. graveolens* Becc.)

(d) durian long spikes (*D. oxleyanus* Griff.)

(f) common durian (*D. zibethinus* Murr.)

Non-edible durian has little or no flesh covering the seed which is used for seed base. Zainal *et al.* (1996) report on the characteristics of six edible durian species as follows:

- ***D. dulcis* Becc.** This species is rare and could only be found in the deep forests of Borneo. The fruit has pointed and sharp spikes and is red in colour. The pointed end of the spike is black, the flesh is thin but with sweet taste and strong smell, the whole seed is glossy black, and the flesh has the efficacy of an aphrodisiac.
- ***D. graveolens* Becc.** This species of durian which is found in Borneo Island, has high heterogeneity similar to the common durian species. The colour of the fruit is diverse; ranging from green and yellow; brown and red. The colour of the flesh also varies from red to white, the taste is sweet and has no smell; with the seed colour varying from light brown to black. This variety is highly preferred in Brunei Darussalam and considered to be better than the common variety.
- ***D. kutejensis* (Hassk) Becc.** This is a kind of durian variety that has low heterogeneity. The leaves, flowers and fruits develop during the late season. The colour of the flower is red but Alim (1990) has reported the flower as white with the traits of the trunk, fruit and taste similar to the common durian. During the flowering stage, the flower exudes fragrant smell that attracts insects. The fruit is small in size, green to yellowish in colour; the spikes are soft and the fruit is easy to open. The flesh is thick and golden yellow in colour, sweet taste and creamy, with fine flesh, mild smell, small seeds with brownish and black colour.
- ***D. oxleyanus* Giff.** This species is homogenous. The tree is tall with large canopy, green fruit with sharp and pointed spikes. This variety is found in Borneo Island and Malaysia. It is not similar to other durian species because the fruit is small and round, with four carpels, the flesh is yellow, sweet taste and the smell is similar to the common durian.
- ***D. testudinarum* Becc.** This is a peculiar type of durian, as the flowers and the fruits develop from the trunk or the base of the tree near the ground, which is different from other kinds of durian in which the fruits are developed from the branches. The common name of this durian-species is Kwa Kwa or Tortoise Durian. The species is homogenous, because it is self-pollinated by natural means. The fruit shape is oval, with brown fruit colour but green when it is still immature but turns brownish to yellow when mature. The flesh is thick with creamy yellow colour, sweet taste, strong smell and the size of the seed is relatively big.

- ***D. zibethinus* Murr.** The common durian (*D. zibethinus* Murr.) is a kind of durian which has economic importance, since the yield is high and the species heterogeneous. The seedlings that were planted from seeds have high variation with regard to the traits of the trunk, fruit and the flesh. The fruits vary from green to reddish yellow. The colour of the flesh also varies from white to dark yellow and yellowish orange. The size of the seed is from small to big with brownish colour. Its growth and production depend on variation in the season, flowering, fruiting, and harvesting period.

The durian plants could grow well in the high temperature up to 46°C as is the case in some regions of Thailand and India (Watson, 1984), but the growth will be hindered when the temperature is less than 22°C. when the temperature is lower than 10°C, the leaves will drop. Aside from the discovery of durian in Borneo, Indonesia, Malaysia, Thailand, Southern Burma, and the Philippines, it is also found in New Guinea (Knight, 1980), Solomon Island (Anon, 1968), Papua New Guinea (Bettencourt *et al.*, 1992), Ponape Island (Kanehira, 1935), Mindanao and The Sulu Archipelago of the Philippines, Northern Australia (Watson, 1993), India at a height of 760 meters above mean sea level (msl), and Sri Lanka (Mac Millan, 1909), especially *D. ceylanicus* Gardn. which could grow at the height of 910 meters above the sea level . Therefore, durian may grow at a temperature range between 10-46°C, with rainfall not less than 1,600 mm/year, humidity at 30 per cent, at a latitude range between 16°N to 17°S and at above mean sea level range from 0-910 meters. Climatic conditions, geography and the soil types have significant influence on the growth of durian.

However, there is no confirmation about the ancestors of the common durian (*D. zibethinus* Murr.). Kostermans (1958) cites that the common variety (*D. zibethinus* Murr.) has close similarity with *D. wyatt-smithii* Kosterm, which is a wild type found along the Malaya. However, Soegeng-Reksohirdjo (1962) believes that the ancestor of durian varieties that is widely grown at present came from the wild varieties of common durian (*D. zibethinus* Murr.), and not from any other kind of species, and also reports that more than half of the wild durian cultivation was found along Batak, in the Northeastern Sumatra, especially Sulawesi and Ambon-Ceram (Moluccas) and distributed through human activities, and hence called wild durian. The seeds were dispersed in different forest areas where humans passed by or in the areas along the community villages, and the varieties later spread to different countries through travelers and tourists. In Thailand, Phengkai (1978) and Tem (1980) report that there are six different kinds of durian found as Durian Nok (*D. griffithii* Bakh.), Durian Nok (*D. lowianus* Scoff. Ex King.), Durian Don (*D. malaccensis* Planch. Ex Mast.), Durian Charian (*D. masoni* Bakh.), Wild Durian (*D. pinangianus* Ridl.), and Common Durian (*D. zibethinus* Murr.).

2.1. Distribution in Thailand

The durian has been introduced from its traditional area to several other countries. It was reported by Monsieur de la Loubre, French consulate in 1687 that Thai people have high preference for eating durian fruit in spite the very strong smell. It is reported that durian cultivation in the central part of Thailand was started by King Narai in the Ayudhaya Era, over 330 years ago (Hiranpradit, 2004) and the fruit came from southern part of Thailand. It is believed that the distribution in Thailand was in 2 ways: from northeastern part of Burma and southern part of Thailand. It is also believed that native durian cultivars came to Thailand from Malaysia in 1787 (Bhusiri, 1970 and Vangnai, 1996). Good cultivars of *D. zibethinus* Murr., were from Thonburi province in 1854,, now a part of Bangkok Metropolitan. In the beginning of this period, the propagation started from seeds, and then developed to marcotting and seeds from three good cultivars, namely, E-Batr, Thong Suk and Karaket. This resulted in the development of many good open pollinated cultivars. From this area, durian cultivars were distributed to Bangkok, Nonthaburi and Smutsongkram. The trees thrive well in these areas, especially in Nonthaburi. It is believed that Nonthaburi was the first commercial growing area in Thailand, and subsequently it spread to the other areas in the East and North.

Durian progeny are very heterozygous in all attributes. Most durian seedling trees have a high degree of self- incompatibility and flowers must be cross-pollinated from other trees in order to set fruit (Valmayor *et al.*, 1965; Malo and Martin, 1979; Somsri, 1987). This would add to the genetic diversity. However, in Thailand a number of clonal selections have resulted in many cultivars which are self-compatible. The phenomenon is supported by pollination studies by Soepadmo and Eow (1977) and Somsri (1987).

Durian cultivars in Thailand differ from one another in terms of tree form, vigour and leaf size; flowering intensity and frequency, fruit size and shape, rind colour and thickness; aril volume, colour, aroma, texture and flavour; and seed number and size.

There are only five original durian cultivars in Thailand and the off springs arising from them are as follows:

- **'Luang' Original:** Offsprings - 'Luang Khiao', 'Chanee', 'Chomphu Si', 'Yam Mawat'
- **'Karaket' Original:** Offsprings - 'Kop Maetao', 'Kop Phuang', 'Chom Kop', 'Kop Kop', 'Kop Lep Yiew', 'Yam Pe'
- **'Thong Suk' Original:** Offsprings - 'Kan Yao', 'Si Suwan', 'Kan Yao Wat Sak'
- **'Thong Yoi Doem' Original:** Offsprings - 'Thong Yoi Chat', 'Nom Sawan', 'Sin Samut', 'Chat Si Nak', 'Chat Ngoen', 'Chat Si Thong', 'Thorani Wai'
- **'Kampan' Original:** Offsprings - 'Kampan Luang', 'Chai Mafai', 'Kampan Si Nak'

Boonyakome (1955) classified durian cultivars in Thailand into the following 6 main groups, including about 82 cultivars:

1. **Kop Group** - 23 cultivars: Jorm Kop, Kop Maetao, Kop Lebyiew, Kop Boonnak, Kop Takhum, Kop Hemaraj, Kop Chomphu, Kop Thongkom, Kop Khunpaen, Kop Phrawai, Kop Ngoy, Kop Jaokhun, Yampleh, Sood Sakhom, Luang Hokepoo, Kop Plichumpon, Chat Thong, KleeB Samut, Kop Tachaem, Kop Yaclub, Kop Tanoi, Kop Loynam, Jorm Yota.
2. **Thong Yoi Group** - 17 cultivars: Thong Yoi Chat, Nom Sawan, Sin Samut, Chat Ngern, Phuang Chat, Chat Si Nak, Chat Si Thong, Chomphu Noot, Thong Sawat, Thong Yoi Si Nak, Thoranee Wai, Erung, Seesook, Kammayi Bangbon, Nok Yib, Daeng Rasamee, Tubtim.
3. **Kan Yao Group** - 7 cultivars: Kan Yao, Sri Suwan, Kan Yao Wat Sak, Kan Yao Namyai, Chomphu Phan, Kan Yao Si Nak, Kan Yao Boonyoung.
4. **Kampan Group** - 11 cultivars: Kampan Khao, Kampan Luang, Kampan Daeng (short-leaved), Kampan Daeng (long-leaved), Kampan Daeng, Tagluay Looklek, Sucreep, Kampan Si Nak, Maled Faw, Takay, Chai Mafai.
5. **Luang Group** - 10 cultivars: Luang Khiew, Luang Thong, Luang Loom, Luang Neuadaeng, Leang Sompoy, Laweng, Yam Mawat, Chompu Si, Chanee, Si Chomphu.
6. **Miscellaneous Group** - 13 cultivars: Karaket Maetao, Karaket Si Nak, Phuang Malai, Krapook Thong, Daeng Tanoi, Thosagun, E-nak, Thong Daeng, Mai Thongyib, Khua Yi, Krapook Thongdee, Kathoei Neau Daeng, I-ad.

Fruit characteristics of the original durian cultivars as recorded by Bhusiri (1970, 1984) and Vangnai (1976, 1983) are as follows:

- **Luang:** The fruit is medium-sized, oval in shape with 20-25 cm length and 16-20 cm width , yellowish-green in colour at maturity, 4-5 lobes with slight depressions. The medium-spaced spines are small, short fruit stalk. The rind is medium thick. The aril is medium thick, yellow in colour, coarse texture and sweet. The fruit has 5 locules, each locule contains 1-6 pulp units.
- **Karaket:** The fruit is ovoid, medium to large with 25 cm length and 21 cm width . Skin surface is greenish brown in colour covered with curved, sharp-pointed spines. The spine is about 2 cm long. There are 5 conspicuous lobes with depressions run from base to apex of the fruit. The aril is thick, fine texture, dark yellow, very sweet and nutty, strong odour. Each locule contains 2-3 pulp units.

- **Thong Suk:** The fruit is round, 20 cm long and 19 cm wide, with 5 unobtrusive lobes. The rind is rather thick covered with dense brownish-green spines, 1-1.5 cm long. Fruit stalk is 12-15 cm long. The fruit has 5-6 locules with 3-5 pulp units each. The aril is medium thick, fine texture, yellow in colour, sweet and creamy richness, and mild odour.
- **Thong Yoi Doem:** The fruit is oblong, medium to large, 27 cm long and 21 cm wide with protrusive apex. The skin surface is yellowish red at maturity covered with large-base spines, greenish brown in colour. There are 5 conspicuous lobes with depressions which run from the base to the apex of the fruit. The aril is thick, dark yellow in colour, sweet and nutty with aroma.
- **Kampan:** The fruit is rather round, medium to large with 20 cm length and 18 cm width; Fruit shoulder is enlarged tapering toward apex. Fruit apex is round. The fruit has 5 lobes and the skin surface is greenish-brown in colour with reddish-brown depressions. The spine is thick, short, straight and angled, greenish-brown in colour. The fruit has 5 locules with 1-2 seeds each. The aril is thick with pale yellow to white in colour, very fine texture, strong smell, and very sweet.

The selection of good cultivars, which has been based largely on fruit quality, was done through chance seedlings by the farmers in the early times, and subsequently perpetuated from chance seedlings as clones. As a result of this practice, 1884, there were about 68 good durian clones in Nonthaburi and its vicinity. Now, about 200 durian-clones are recognized.

3 Present Status of Cultivation and Production of Durian

3.1. Cultivation

Based on the history of its introduction, it is well established that the geographic and climatic conditions are suitable for the cultivation of durian in Thailand, and the keen interest of farmers on the selection of varieties, and propagation through the government support, contributed to the widespread distribution of varieties in every region of Thailand. The major growing areas that are highly suitable for its growth are in the Eastern and Southern regions of Thailand. However, in the Northern and Northeastern regions, durian could also be grown at commercial scale in provinces like Utharadit, Nakornpanom, Srisaket, etc. (Fig. 6).

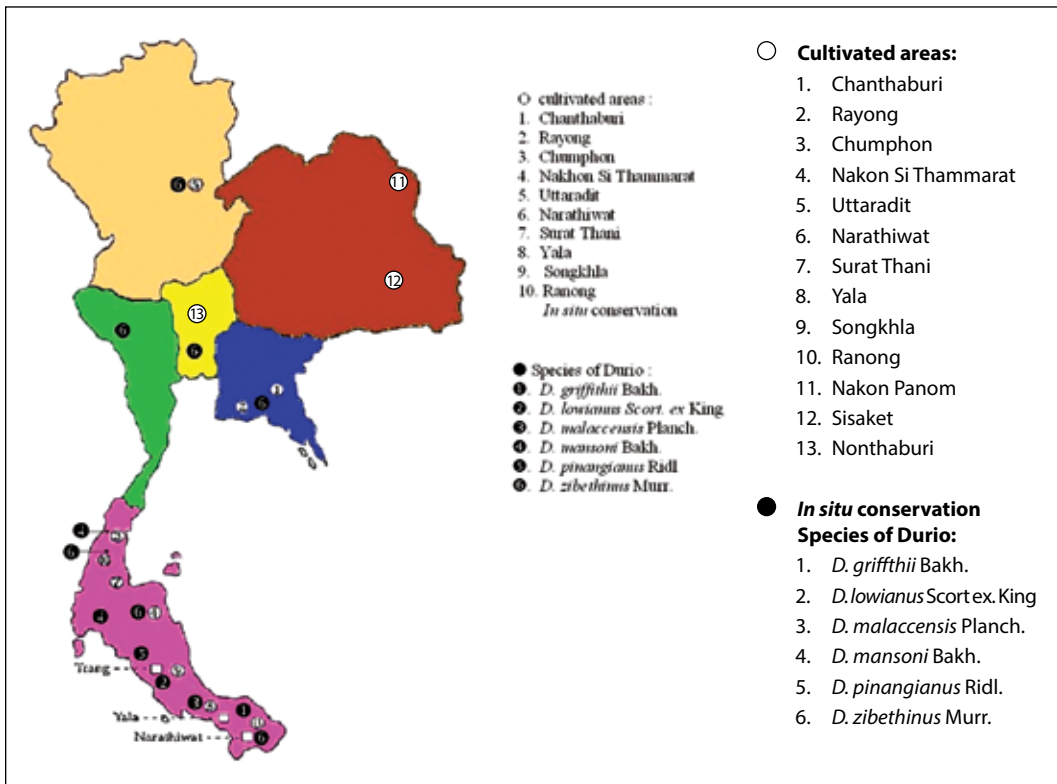


Fig. 6. Durian distribution and production areas in Thailand

Source: Tem (1980) and Vangnai (1995)

3.2. Production

The total cultivation area of durian in Thailand in the year 1997 was 676,393 rai (108,222.88 ha) with total production of about 916,025 tons with yield average of 1,487 tons/rai (9.29 tons/ha). During the period of 20 years (1997-2017), the cultivation area declined at the rate of 0.88 per cent per year, with the production volume declining at a rate of 2.54 per cent per year. The price of durian has been very low especially during the peak season and has caused farmers to shift to other crops like rubber and oil palm and this resulted in the decline of the production area to 641,359 rai (102,617.44 ha), with production of about 569,313 tons in 2013 (Table 1).

The production of commercial varieties of durian includes Mon Thong (46.33%), Chanee (31.13%), Kan Yao (4.56%), Kradum Thong (2.39%), and other varieties (15.58%). Durian can be harvested within 4-5 years, and the production peak is 15 years after planting. The major growing areas are Chanthaburi (34.7%), Rayong (14.7%), Chumporn (11.27%), Trad (5.24%) and Nakorn Sri Tammarat (4.36%) of the total production area. Chanthaburi province has the highest production with 51.45 per cent of the total production, followed by Rayong, Chumporn, Trad, and Nakorn Sri Tammarat with 17.20, 4.74, and 4.16 per cent of the total production, respectively (Department of Agriculture Extension, 2004). However, owing to a better price in 2013 and 2014, some of the farmers increased the area under durian cultivation, especially for new varieties that were developed by the Department of Agriculture and the farmers themselves.

At present, the area planted under durian in Thailand in 2017 is about 762,776 rai (122,044.16 ha) with an annual total yield of 616,121 tons (Table 1). 'Mon Thong' has the largest area of about 83.12 per cent of the total durian area in 2017 along with Chanee 7.79 per cent, Kan Yao 1.2 per cent, Kradum Thong 1.78 per cent, Phuang Mani 0.09 per cent and others 6.02 per cent.

Table 1. Planting area, production and yield of durian during 1997-2017

Year	Total Cultivation Area (rai)			Production (tonnes)	Average Yield (kg/rai/year)
	Fruiting stage	Growing stage	Total		
1997	616,022	60,371	676,393	916,025	1,487
1998	564,783	193,675	758,458	712,992	1,262
1999	605,432	174,156	779,588	804,090	1,328
2000	654,691	150,032	804,723	889,685	1,359
2001	694,400	128,952	823,352	884,570	1,274
2002	717,835	110,266	828,101	962,859	1,341

Contd...

Table 1 contd...

Year	Total Cultivation Area (rai)			Production (tonnes)	Average Yield (kg/rai/year)
	Fruiting stage	Growing stage	Total		
2003	733,379	106,300	839,679	738,585	1,007
2004	748,824	124,819	873,643	831,182	1,110
2005	716,809	115,674	832,483	650,960	908
2006	700,357	114,945	815,302	622,934	889
2007	683,044	88,301	771,345	750,683	1,099
2008	667,437	58,518	725,955	637,790	956
2009	628,244	52,683	680,927	661,665	1,053
2010	611,206	50,864	662,070	568,067	929
2011	604,477	54,984	659,461	509,424	843
2012	581,684	56,198	637,882	524,469	902
2013	577,235	64,124	641,359	569,313	986
2014	570,602	95,704	666,306	631,775	1,107
2015	573,293	113,289	686,582	601,884	1,050
2016	581,659	133,682	715,341	517,955	890
2017*	592,750	170,026	762,776	616,121	1,039

Source : Office of Agricultural Economics, 2017

*2017 Estimated Value; 1 hectare = 6.25 rai

4 Collecting, Characterization, Evaluation and Conservation of Genetic Resources

4.1. Ex Situ Conservation

For durian germplasm collection, the first variety collection centre in Thailand was established at Plew Horticultural Research Station in Chanthaburi province in 1956 (Tongyu, 1982). Later, wild durian from southern Thailand and Indonesia were collected and maintained at Khaochong Rubber Experiment Station, Trang province (Polprasid *et al.*, 1969). From 1967-1969, Mr. Supit Marayong collected 68 grafted durian varieties from different places in Klung, Laemsing, and Meuang districts. They were kept in the nursery and later planted at Plew Horticultural Research Station in Chanthaburi between 1969 and 1970. In 1976, Mr. Pairoje Polprasid and his team were granted financial support from the Southeast Asia Regional Centre for Tropical Biology (BIOTROP) to conduct survey and collect tropical fruit species both at domestic and international sources including wild species of durian, native durian from the Southern Thailand and Indonesia, and were planted at the durian varieties collection center at Khao Chong Rubber Research Station in Trang province. In 1980 and 1983, Mr. Songpol Somsri planted different species of *Durio* at Plew Horticultural Research Station in Chanthaburi province, namely, Durian Don (*D. malaccensis*), Durian Nok (*D. lowianus*) from Malaysia, Durian Rakka (*D. kutejensis*) from Yala province, Durian Charian (*D. mansoni*) from the Southern Thailand, Spikeless Durian (*Durio sp.*) from the Philippines, wherein Mr. Pairoje Polprasid brought the buds from Davao Agriculture Station in Mindanao in October, 1981, Long spike Durian (*D. oxleyanus*) grown from the seed, brought from Kina Guatamaru Sabah in February, 1982, Mounted Pedicel Type Durian (*D. graveolens*) grown from the seed which was brought from Dawu, Southern Sabah in February, 1982. Moreover, durian collections were also established at Trang, Surat Thani, Narathivat, krabi Research Centers (Department of Agriculture, 1995).

Germplasm collection

Some durian cultivars and species collected and maintained at Chanthaburi Horticultural Research Center

Chanee	Chomphu Si	Chat Si Thong
Chai Mafai	Chai Mang Khut	Daeng Sao Noi
Foi Thong	Kan Yao Wat Sak	Kampan Daeng
Kob Hemaraj	Kob Lepyiew	Kob Kanparn
Kob Suwan	Kob Si Nak	Kob Champee
Kob Nasan	Kob Ratsamee	Kob Wat Kluai
Kob Ta Ho	Kob Yaiploy	Kob Ta Pun
Kob Thong Kham	Kan Yao Si Nak	Krapuk Tong
Kratoei Nuea Daeng	Kratoei Khao	Klib Samut
Khun Thong	Long Lablae	Mon Thong
Nom Sawan	Nok Krachip	Phuang Mani
Rang Thong	Sao Chom	Sin Samut
Taparb Nam	Thong Kham	Thong Kham Ta Pruat
Thong Gone	Thong Suk	Thapthim
Thorani wai	Yindi	Yam Mawat. etc.

In addition to the following 8 planted species: *D. graveolens*, *D. griffithii*, *D. kutejensis*, *D. lowianus*, *D. malaccensis*, *D. masoni*, *D. oxleyanus*, and *D. sp.* Also, three species of wild durian maintained at Trang Horticultural Research Centre are: *Durio lowianus* Scort. ex King *D. malaccensis* Planch. *D. masoni* Bakh.

The collection of durian varieties between 1967-2005 (318 accessions) and between 2006-2010 (316 accessions) was carried out in the country following the programme on durian genetic resources conservation. In 2014, the variety collection reached 634 accessions located at the Chanthaburi Horticultural Research Center. In addition, over 200 accessions were collected in the southern research centers. At present, survey and collection of durian varieties/cultivars are still being conducted in order to assemble diverse germplasm.

4.2. In Situ Conservation

Durian germplasm is conserved under natural conditions at the Plant Genetic Resources Conservation Areas, National Wildlife Parks, and Botanical Gardens, which are under the management and control of the Forestry Department. The wild species are found in the Peninsular Thailand; while the species *Durio malaccensis* Planch. ex Mast., *D. griffithii* Bach., *D. pinangianus* Ridl are found in the areas below Kra Canal. viz. ,Yala, Narathiwat provinces. Most of the wild species are usually conserved *in situ* in forest reserves. Wild and local varieties include Durian Don (*D. malaccensis*), Durian Nok (*D. griffithii*), Wild Durian (*D. pinangianus*), and Durian Nok (*D. lowianus*)

that are found in the natural forests in Yala and Narathiwat provinces of Thailand (Phengklai 1978, Tem 1980, Vangnai, 1996, Department of Agriculture, 1995).

4.3. *In Vitro* Conservation

A study on the conservation of durian genetic resources under *in vitro* conservation. Prayong (1983) conducted a study on embryo culture for Durian Nok (*D. lowianus*) at Murashige and Skoog media, with application of 2,4-dichlorophenoxyacetic acid (2,4-D) at 0.2 mg/litre, and once the tissues developed, these were transferred to a media naphthaleneacetic acid (NAA) and kinetin (K). The results showed that all treatment concentrations were able to stimulate callus formation, but were unable to develop a plantlet and roots.

Prayong (1985) conducted embryo culture for Durian Nok using woody plant medium (WPM) with Benzylaminopurine (BAP) at 1 and 3 mg/litre, and at culture media Vieitez and Vieitez (1980) with BAP at 1 mg/litre for a period of 2 months. Once the tissues had grown into callus, it was found that the application of hydrogen peroxide at 6 per cent for a period of 20 minutes could sterilize the tissue of the end part of the mature shoot from a variety resistant to root and stem rot disease. Once the tissues were grown in growth medium WPM, applied with N6 – (4- isopentenyl) adenine (2ip) at 0.5, 1, 2 and 4 mg/ litre, the tissues from the end part of the shoot showed a good growth, but all the shoots died in the media applied with 2ip at 8 and 16 mg/ litre. When the growth media at concentration of 1.5 and 2.0 times the WPM with sugar at 30 g/ litre, the end part of the mature shoot grown for a period of 3 months showed better growth than when grown in the growth medium WPM with sugar at different levels. With regards to the end part of the shoot from the trunk grown at 1.5 times of the WPM with sugar at 30 g/ litre showed that an addition of 10 per cent coconut water, or 5 per cent coconut water with 2ip 0.2 mg/ litre for a period of 3 months, the tissue of the end part of the shoot from the seedlings recorded the highest growth, and the growth was better than the tissues at the end part of the mature branch from the tree of a variety resistant to root and stem rot disease.

4.4. Activities and Future Directions for the Conservation and Utilization of Durian Genetic Resources

- 4.4.1. Undertake survey and collection of durian genetic resources both common durian and local varieties, including location mapping of genetic resources.
- 4.4.2. Exchange of durian genetic germplasm among Bioversity International (formerly, IPGRI) networks or international organizations for breeding purposes, in accordance with the existing national laws and regulations.

- 4.4.3. Establish national field genebanks and accelerate conducting studies on the conservation of genetic resources through *In vitro* conservation.
- 4.4.4. Accelerate the creation of databases on durian germplasm in Thailand.
- 4.4.5. Accelerate research on biotechnology, taxonomy and identification of durian germplasm possessing traits for quality improvement such as the thickness of the flesh, flesh colour, seed size, maturity, resistance to root and stem rot disease through molecular techniques, etc.
- 4.4.6. Utilization of durian germplasm for the development of varieties with specific traits such as dwarf varieties, small fruit size for export, easy to harvest, resistance to root and stem rot disease through breeding programmes and development of new varieties with the following characteristics:
 - For the breeding of dwarf durian, the variety Durian Rakka (*D. kutejensis*) which is a dwarf variety could be used as parent material.
 - For early fruiting varieties or varieties fruiting at five years after planting, mounted pedicel type (*D. graveolens*) variety which is an early fruiting variety could be used as parent material.
 - For developing mild smell durian variety, *D. graveolens* variety which has a mild smell may be used as parent material.
 - For developing varieties with fewer spikes which are handy and convenient to transport, the *D. kutejensis* variety which has soft and elastic spikes, or non-spike varieties such as *Durio* sp. may be used as parent materials.
 - For breeding of varieties tolerance to environmental stress due to floods, the *D. carinatus* or *D. graveolens* that are flood-tolerant could be used as parent materials.
 - For resistance to root and stem rot disease, the Durian Nok (*D. lowianus*) or Durian Charian (*D. mansonii*), Durian Rakka (*D. kutejensis*) could be used as a root stock or as parent materials.
 - For easy harvesting, the variety Tortoise Durian (*D. testudinarum*) with fruits attached to the trunk could be used as parent materials.

4.5. Characterization and Evaluation of Durian Germplasm

4.5.1. Study on characteristics and evaluation of durian germplasm

Songpol *et al.* (1983) conducted a study on the germplasm characteristics of different durian varieties which were planted at the Plew Horticultural Research Station using the IBPGR references and found out the following:

Different durian varieties have differences in the width of the leaves, ranging between 3.6-5.6 cm and the length of the leaves ranging from 9.0-17.7 cm. Flower arrangements are similar in all varieties, but the size of flowers and the number of pollen slightly differ in each variety. The characteristic of the fruit is similar in every variety which is a simple fruit, weighing from 1.6 kg such as Kob Si Nak variety, and Kob Ta Pun variety to about 4.8 kg. Most of the fruits have oblong shape, however, some fruits may be round, with colour of the fruit pericarp as yellow or yellow-green. The thickness of the pericarp ranges from 0.6 cm to 2.0 cm, and the thickness of the flesh ranges from 1.0 cm to 2.2 cm. The colour of the flesh could be classified into two groups: yellow and yellow-orange. The flesh texture ranges from fine to rough and semi-rough. The taste of fruit varies from sweet to creamy, and sweet-creamy. The shape of the seed is oblong with seed size relatively similar in all varieties, with width of 3 cm and length 5.5 cm. The aborted seeds may vary from 0-100 per cent. The weight proportion between the flesh and the seed at the maximum is 11.75:1 in Yam Mawat variety and the lowest at 2.16:1 in See Nak variety.

Songpol *et al.* (1983) conducted a study on the genetic characteristics of four durian commercial varieties, namely, Chanee, Kan Yao, Mon Thong, and Kradum Thong. The morphological characteristics studied using the reference of International Board of Plant Genetic Resources (IBPGR), which later became the Plant Genetic Resources Institute (IPGRI) and now Bioversity International revealed that the structure of the leaf, leaf fibre, leaf shape, leaf apex, leaf margin, leaf petiole, and leaf arrangement, have no significant difference among the varieties. However, there were differences in terms of the size of the leaf, the width, and the length with Mon Thong variety having the largest leaf size. The flower structure and arrangement were quite similar among the varieties but there were differences in the size of the flower, length of the flower pedicel, and the length of filament, length of style, and size of stigma. The size of the fruit, shape, length of fruit peduncle, thickness of pericarp, flesh, flesh texture, taste, smell, size of seeds, and the percentage of aborted seeds varied among the four varieties studied. Mon Thong variety had the thickest flesh (2.2 cm), the highest percentage of aborted seeds (75.29%) and the highest ratio of flesh weight to seed weight (8.29:1).

Songpol *et al.* (1983) conducted a study to compare the quality of fruit in different varieties planted at the Plew Horticultural Research Station and found that some of the durian varieties had outstanding characteristics in terms of fruit flesh, colour, taste and fine flesh texture, bright yellow flesh, sweet and creamy taste, thick flesh, thin pericarp, and high percentage of aborted seeds and these could be used as parent materials in the breeding programmes. These varieties are Thong Kon, Kob Suwan, Kob Ratsamee, Chat Si Thong, Kan Yao Wat Sak, Nok Yip, and Kob Maetao.

Moreover, the study also revealed that some of the varieties have outstanding traits such as the sticky and fine flesh with sweet and creamy taste such as the Foi Thong, Kob Suwan, Kob Rastamee, Chat Si Thong, Kan Yao Wat Sak, Yindi, and Nok Yip.

Durian varieties with bright yellow flesh at a range between Y016D-Y021D are Thong Kon, Foi Thong, Kob Ta Pun, Kob Suwan, Daeng Sao Noi, Kob Ratsamee, Bang Khun Non, Kob Kluay, Chat Si Thong, Thapthim, Kob Ta Tuam, See Thong, Kan Yao Wat Sak, Yindi, Nok Yip, Kob Ta Ho, Kampan Nuea Daeng, Luang Thong, Kob Ta Kham, Kob Ta Jaem, Kob Si Nak, Kob Maetao and Thong Muan.

Varieties that have high flesh weight ranging from 0.71-1.64 kg are Kob Champee, Thong Kon, Nom Sawan, Kob Ta Pun, Daeng Sao Noi, Kob Ratsamee, Kampan Lueang, Kathoei Nuea Khao, Chai Mangkhut, Taphab Num, Nok Yip, Kathoei Nuea Daeng, Yam Mawat, Kob Bao, and Plew 64. The varieties with more than 50 per cent aborted seeds are Foi Thong, Kob Ta Pun, Kob Suwan, Kob Ratsamee, Bang Kun Non, Kob Kluay, Kathoei Nuea Khao, Thapthim, Kob Ta Thuam, Taphub Num, See Thong, E-leep, Yindee, Kob Ta Ho, Kampan Kao, Kathoei Nuea Daeng, Kob Ta Maetao, Yam Mawat, Kob Bao, Thong Muan, and Kob Takhum.

Hiran *et al.* (1986, 1988) conducted a study on durian varieties that are almost extinct which showed that the total number of cultivated durian varieties nearing extinction was about 227. A survey conducted in durian growing areas in Chanthaburi, Rayong, Trad, Prachinburi, Nakorn Nayok, Nonthaburi, and Bangkok, showed that a total of 112 varieties were studied for the genetic traits. The evaluation of different mother plants that were surveyed based on IBPGR Fruit Descriptors showed that the characteristics of the leaves, fruits and spikes have distinct genetic traits that differ among varieties and are not influenced by the climatic conditions. This could be used as category for classification into 6 groups, namely, Kob group, Luang group, Kan Yao (long pedicel) group, Kampan group, Tong Yoi Group and others.

5 Breeding of Durian Varieties

The breeding programmes in durian were undertaken to develop new varieties which possess good quality and high yield traits in accordance with the demand of the farmers and consumers. The following are details of breeding history and the efforts made at different stages.

5.1. Taxonomical Studies of Durian Varieties

Information on genetic resources is extremely important for breeding programmes. The history of durian germplasm including wild species, native, cultivated and all types of durian varieties and the correlation between durian species is not yet well known. Zeven and Zhukovsky (1975) reported that durian (*D. zibethinus* Murr.) has $2n=56$ chromosomes, while Soepadmo (1979) reported that the number of chromosomes of durian vary between $2n=54-69$ such as *D. zibethinus* Murr. $2n=56$, *D. griffithii* Bakh. $2n=60$, and *D. oxleyanus* Griffith. $2n=56$, etc. The chromosome number is an important parameter as this contributes towards the development of improved varieties through breeding. The number of chromosomes differs among varieties, which may adversely affect the pollination and fruit setting or create difficulty in developing the hybrids.

5.2. History and Stages of Breeding of Durian Varieties

The breeding and development of fruit tree varieties through breeding was practiced long time ago since the reign of King Narai about 300 years ago. The Thai Government during that time collected tax for every fruit tree but the amount differed based on the kind of fruit tree. The tax on durian tree was four cents, whereas on mango, mangosteen, and wax apple, the tax collected was one cent per tree. It was made mandatory that replanting should be done immediately to replace the dead trees otherwise a penalty will be imposed. This attributed to the large scale planting of fruit trees. Another contributing factor was the attitude of the Thai people during that time and even at the present time to offer the best fruits to the monks, village heads or respected high ranking officials. The offering of good quality fruits contributed to the development of the better fruit varieties by the farmers. Therefore, the selection of good quality varieties was in practice already for several decades resulting in a number of good quality fruit varieties in Thailand (Polprasid, 1992).

During the past, most of the durian varieties came from the farmers' selection from the seed that incidentally came out to be good varieties. These selections were

the products of natural breeding and hence the varieties were named after their distinct characteristics, the shape of fruit, colour of the flesh, person who made the selection or the place where the said variety was found. Some of the varieties might have mutated or may slightly differ from other varieties, and hence, more than 200 durian varieties have been recorded to be developed from the selection and breeding programmes in the past.

5.2.1. Research and development relating to durian breeding during the past 50 years

Durian breeding and improvement includes introduction, collection, characterization, evaluation and selection of the various varieties, cross-breeding of durian from the evaluated and selected varieties, evaluation and selection of durian F1 hybrids, testing of durian varieties that were already selected, and the release of recommended varieties. The production and propagation of recommended varieties by the farmers since 1956 up to the present stage are given below:

- 1956 : The first durian collection plot was established at Plew Horticultural Research Station in Chanthaburi province. However, the number of varieties collected and established is still unknown.
- 1967-1969 : Survey and collection of the different durian varieties from different districts in Chanthaburi province, followed by grafting resulted in 68 varieties that were established at the Plew Horticultural Research Station, Chanthaburi.
- 1969-1970 : Durian varieties that were planted at Plew Horticultural Research Station were evaluated
- 1980-1989 : Conducted study on the genetic traits, evaluated and selected durian varieties that were used as the parent material for the breeding of hybrid durian
- 1980-1986 : Conducted study on 42 durian varieties to characterize their inherent genetic traits, and morphological characteristics including leaves, flowers, fruits, seeds, in accordance with the records and reference of International Board of Plant Genetic Resources (IBPGR), including various outstanding traits of each variety to be used as parent material for breeding purposes.
- 1987-1989 : Breeding of durian varieties through selection of clones from commercial durian varieties and grown from the seeds.

5.2.2. Selection of durian clones for commercial purposes

A study conducted for the selection of durian clones planted for trade which

presently have four varieties, namely, Chanee, Mon Thong, Kan Yao, and Kradum Thong indicated the quality of these clones is relatively good. However, there are still some variations in terms of quality, and the yield within the same variety which might have been resulted from the outstanding genetic trait which is specific to each durian tree. Durian variety that has outstanding traits in terms of yield and quality has to be used as elite clone in the breeding programme. The propagation of durian varieties for distribution to farmers is one of the means to increase the yield with good quality traits for sale in domestic and international markets.

The selection of clones for commercial purposes was done through competition of four commercial varieties and using the quality traits as criteria for judging. The competition was conducted for three consecutive years (1987 - 1989) to confirm the outstanding traits of the varieties.

From the competitions for the selection of good clones, it was possible to produce varieties, namely, Chanee (10 trees), Mon Thong (8 trees), Kan Yao (7 trees), and Kradum Thong (5 trees) that were winners of the competition. The proposal was submitted to the Department of Agriculture (DOA) which certified the following three varieties:

Mon Thong San variety

The outstanding traits of Mon Thong variety of durian developed by Mr San Suwankamaneer include thick flesh, with high flesh and fruit weight (40%), bright yellow flesh colour which is more concentrated than the other varieties, good flesh quality, sticky flesh, less fibre, creamy taste, and uniform fruit ripening. Evaluation of the original variety showed that the highest yield was 120 fruits per tree and showed resistance to root and stem rot disease in the tree.

Chanee Chanchai variety

The Chanee Chanchai variety of durian was developed by Mr. Chanchai Manatawee. The outstanding traits of this variety include thick flesh, sweet taste, creamy, dry flesh, less fibrous, and high percentage of aborted seeds. The original tree showed resistance to root and stem rot disease, and the highest yield of 120-130 fruits per tree.

Kan Yao Aree variety

The outstanding traits of Kan Yao variety developed by Mrs. Aree Areeket include big fruit size, round shape, bright yellow flesh, good taste, less fibrous, very fine flesh, sweet creamy taste, resistance to root and stem rot disease, and high yield (Hiran *et al.*, 1998).

Selection of clones was also done for new varieties which were planted from the seed from the winners of the competition. The clones have the specified qualities as per the criteria and the outstanding traits as required.

5.2.3. Selection of the durian varieties planted from seeds in the Eastern region

Durian is a crop that was improved by cross breeding. The reproduction of varieties by using seed has the possibility of producing new varieties which have some of the outstanding traits as required by the breeder like yield quality, resistance to insect pests and diseases, tolerance to environmental stress and improper management, flower and fruit initiation during the start and end season in order to attain uniform distribution throughout the production season, or its suitability for the processing industry. The selection of durian clones planted from the seed as required would be useful for the breeding of varieties which could replace the commercial varieties that may have problem of production in the future.

Competition is one among the several means for the selection of new durian varieties which are planted from the seeds based on demand. The breeding lines that were selected will have quality in accordance with the standard of durian as specified and have outstanding traits based on the target purposes, with at least one condition that is, the selected breeding lines from the competition have to be planted and subjected to evaluation. Once the outstanding traits have been confirmed, the variety will be certified following the standards of the Department of Agriculture (DOA), Thailand.

The selection of new durian clones planted from the seed from the competition showed that the clones that were selected will have quality in accordance with durian standards as specified and with at least one outstanding traits based on the objectives. The competition resulted in the selection of three varieties in 1987, and five varieties in 1988 (Hiran *et al.*, 1998).

For the development of durian varieties through hybridization during the period December 1985 - September 1990, a strong base on various stages of durian varietal improvement as shown below (Fig. 9) was made, using parent material that comprised 18 varieties. In order to produce hybrid durians having good quality and with various required traits efforts were made to develop varieties with early or late maturity, good quality, high yielding, suitable for processing industry. This was done by using the mother plants namely; Chanee, Kan Yao, Mon Thong, Kradum Thong, E-Nak, Thong Yoi Chat, and Chomphu Si, and cross bred with the following male plant Chanee, Kan Yao, Mon Thong, Kob Pikul Thong, Kob Suwan, Kob Ta Kham, 'Phuang Mani, E-Leeb, Kradum Thong, Nok Yip, Kathoei, Chomphu Si, Yam Mawat, Foi Thong, Kob Nasan, and Kob Maetao at Chanthaburi Horticultural Research Center and in the farmers' field in the Chanthaburi province. From 1985 to 1990, hybridization of durian varieties was undertaken and it resulted in the development of a total of 55 hybrids and production of 17,240 hybrid seeds which produced 7,634 durian seedlings.

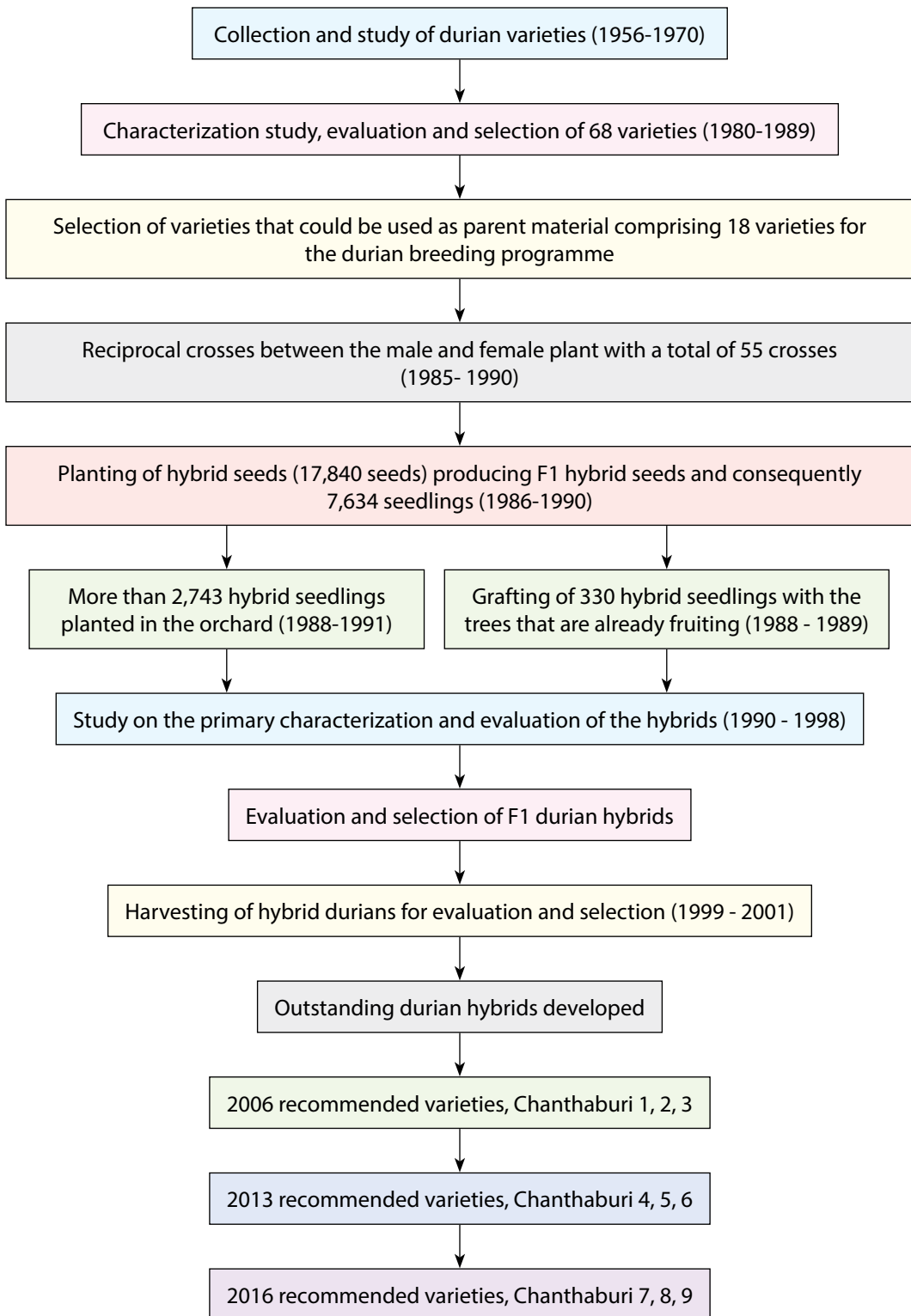


Fig. 7. Various stages of durian varietal improvement

From 1988 to 1991, 330 hybrid durian seedlings were grafted with 10 years old Chanee variety which is already fruiting, and another 2,743 hybrid seedlings were planted at a distance of 3 × 8 meters in the experimental plots of the Chanthaburi Horticulture Research Center within the Tung Pel Rubber Experiment Station in Chanthaburi province. The soil texture of the experimental plot was sandy loam to clay loam, with the lower layer soil being clay with medium fertility, good drainage, and the pH range from 4.5-5.5 Phuket soil series, or classified under soil group 26 (Land Development Department, 1998), with the highest average temperature of 32°C, the minimum temperature of 21°C, and the average rainfall of 3,407.16 mm/year.

During the period 1988 - 1998, a study was conducted on the evaluation and selection of F1 durian hybrid varieties. The study and evaluation of hybrid varieties were developed from the cross breeding of durian varieties through side-grafting/ inarching on top of the durian tree that was already fruiting. The hybrids were planted in the plots at a planting distance of 3 × 8 meters, pruned, trained to retain only the side branches and were properly maintained, protected from insect pests, diseases and weeds, and managed with proper irrigation and fertilizer application. Once the trees started fruiting, they were subjected to quality inspection and preliminary evaluation for physical characteristics both inside and outside, including the flowering and fruiting behaviour, for the selection of varieties based on specific/target purposes.

5.2.4. Evaluation, selection and testing of hybrid durian varieties (1999-2007)

Durian hybrids grafted on a fruiting tree and planted in the plots started flowering and there was fruit set in 193 trees developed from the 19 crosses in 1,999, 224 trees from 20 crosses in 2000 and 326 trees from 21 crosses in 2001. The study and F1 selection were conducted by inspection of the quality of durian hybrids as compared with the parent lines for 774 fruits in the year 2000, 705 fruits in 2000, and 1089 fruits in 2001, respectively. According to fruit and other agricultural characteristics comprising 26 traits, studies were conducted with emphasis on the specific important qualities like fruit weight, thickness of the flesh, percentage proportion of the flesh to fruit, taste quality, and the percentage of aborted seeds for use in the selection of F1 hybrid durian. Moreover, data on three traits, viz., age to maturity, fruit setting percentage, and yield were also collected and were used as criteria for the selection. From 2002 – 2007, after the outstanding durian hybrids were selected, a comparative study was conducted with the commercial varieties, and the results were submitted for certification as recommended varieties which could be grown on larger scale by the farmers.

5.2.5. Criteria for the selection of outstanding durian F1 Hybrids

The criteria for good taste, quality and suitability for export or domestic consumption, by using the Thai Durian Standard B. E. 2541 (Department of Agriculture, 1999) was modified to be used in the selection of durian hybrids.

Moreover, the selection of hybrid varieties was done in order to have varieties that could be harvested during early, middle, and late season, and the selection criteria used was based on the information on the classification of early, medium and late maturing varieties from the list of Thai fruits (1976) (Vangnai, 1976), which could be modified for the selection. The selection of durian hybrids was also done in order to have varieties that have high weight proportion between the flesh and fruit suitable for the processing industry. The criteria used for selection for setting-up the standard for durian in Thailand B.E. 2541 specifically for the Mon Thong variety, wherein at present the criteria is used for durian consumed as fresh and processed for trade purposes.

The selection of hybrid durian varieties that possess outstanding traits continued for 2-3 years, with high percentage of fruit setting, with harvesting period based on each purpose, by comparing with the present commercial varieties such as Kratum Thong variety for early season; varieties Chanee, Mon Thong for the middle season; varieties E-Nak, and Thong Yoi Chat for the late season; and the Chomphu Si variety for processing purposes.

Once the selection of hybrid durian with most outstanding traits for each is carried out according to taste, quality, age of maturity (early, middle and late season varieties) then followed taste, quality and percentage proportion between the weight of the flesh and the fruits for processing purposes, the hybrid varieties are identified for certification and recommended for cultivation.

5.3. Improvement of Durian Varieties by Breeding and Selection

5.3.1. Selection, evaluation, and testing of F1 hybrid durian varieties having good potential and with high market demand

- (i) The selection of hybrid durian from 1999 – 2001 for the outstanding varieties in terms of taste, consumption quality, consistent for at least 2-3 years or with similar qualities or better than the standard varieties in some of the traits that are presently used commercially (Chanee, Mon Thong), and with high percentage of fruiting , revealed that the following hybrid varieties possess these qualities: Hybrid Nos. 10-251-8-2, ICNxM 5-1-1, 11-241-9, 11-341-1, 6-152-5 and ICN 7-5-2-2.

In summary, the selection of hybrid durian varieties during the period 1999 - 2001, resulted in the identification of hybrid varieties with outstanding

characteristics in terms of taste, good eating quality, short, medium and late maturing, with high weight proportion between flesh and fruit suitable for processing. The 29 breeding lines thus identified were compared and tested with other varieties from different locations in terms of quality, and yield, and were released as recommended varieties.

(iii) The evaluation and testing to confirm the quality of the F1 durian hybrids during the period 1999 - 2007, revealed that the durian hybrids with outstanding traits in terms of eating quality and with high standard suitable for export and consumption in Thailand were identified. The traits used as important criteria for the selection were fruit weight, thickness of the flesh, eating quality, taste, percentage of aborted seeds, and percentage proportion of the flesh and the fruit and age of maturity less than 105 days after flowering. The following durian hybrids that have a shorter maturity period are suitable and recommended for early season:

- Hybrid No. 5-222-12
- Hybrid No. 9-69-5
- Hybrid No. ICN x M 5-1-1
- Hybrid No. IIICN 5-4-3-6
- Hybrid No. IIICN 6-2-4-7
- Hybrid No. 10-251-8-1
- Hybrid No. 10-251-8-2
- Hybrid No. 10-432-6
- Hybrid No. ICN 7-5-2-2
- Hybrid No. IIICN 6-3-1-5 (Songpol, 2005)

These durian hybrids may be used as a substitute to native varieties such as the Chanee variety planted in the local area in Chanthaburi, Rayong, and Trad, and these varieties were confronted with problems of price and market, in order to distribute the volume of production that could be harvested during the months of March- April. Hence, there is a need for a study to test the varieties under the local conditions and in different production areas.

5.3.2. Study and testing of new durian hybrid varieties that have high market potential and demand

Based on the project on the breeding of durian for the development of hybrid varieties undertaken from December 1985 to September 1990, followed by the

evaluation and selection of hybrid varieties that were harvested during 1998 - 2001, it was possible to produce 29 outstanding hybrids that have better quality and good standard suitable for the export and domestic consumption with early, medium and late maturity, and also suitable for processing. However, at the same time varietal trials were also conducted with 20 breeding lines, for evaluation and testing of the quality of fruit, as compared with other commercial varieties in order to confirm its outstanding traits from 2002 – 2007 which revealed their good quality. Besides, a study on the inherent traits of the varieties was conducted including the study and testing of the variety in terms of the growth in the production areas in the Eastern and Southern regions like the Chanthaburi Horticultural Research Center (Tung Pel Experimental Plots), Surathani Rubber Research Center (Kuntulee), and Trang Horticultural Research Center, including the study and testing for the resistance to *Phytophthora palmivora* which is the pathogen for the root and stem rot disease. Subsequently, all the data collected were verified for consideration as recommended durian hybrid variety of the Department of Agriculture (DOA), Thailand.

5.3.3. Study on the inherent characteristics of first batch of outstanding durian hybrids for consideration as recommended varieties

From the study on the inherent characteristics of the hybrid durian varieties from 1999 to 2007, the outstanding hybrids that possess characteristics such as early, medium, and late maturity, breeding lines suitable for early season, mid-season and late season, and breeding lines good for processing were identified. These included at least 29 breeding lines. However, the varieties identified were specific with characteristics as the early season varieties as recommended varieties of the Department of Agriculture, in order to be used in the project for the improvement of durian implemented under the Ministry of Agriculture and Cooperatives. The three outstanding hybrids are Chanthaburi 1 (ICNxM 5-1-1), Chanthaburi 2 (ICN 7-5-2-2) and Chanthaburi 3 (10-251-8-1) which are early season varieties (Songpol *et al.*, 2007). Between 2007 – 2013, the selection process was followed using the same criteria as used for the varietal selection for Chanthaburi 1,2,3, and produced another three hybrid varieties, namely, Chanthaburi 4 (11-341-1), Chanthaburi 5 (12-21-1), and Chanthaburi 6 (11-241-9), which are early and mid-season varieties, with desired botanical and agricultural traits (Songpol *et al.*, 2011). Moreover, Chanthaburi 7 (10-432-6), Chanthaburi 8 (5-451-5), and Chanthaburi 9 (5-441-13) are newly released varieties recommended for cultivation in 2016 for early season, mid-season and late season with good quality, thick flesh suitable for processing, and high yield.

5.3.4. Recommended hybrid varieties of the Department of Agriculture

The inherent traits of new selections of hybrid durian varieties proposed for recommendation of the Department of Agriculture and were already certified as

recommended varieties of the Department of Agriculture on 9 October 2006 and 1 December 2013. The first six recommended hybrid varieties of durian are Chanthaburi 1, Chanthaburi 2, Chanthaburi 3, Chanthaburi 4, Chanthaburi 5, and Chanthaburi 6. Also, Chanthaburi 7, Chanthaburi 8, and Chanthaburi 9 are newly released varieties recommended for cultivation on 7 November 2016.

Chanthaburi 1 (Hybrid durian breeding line ICN x M 5-1-1)

Salient characteristics: This is a hybrid between the mother Chanee variety and male parent Mon Thong variety has the following characteristics; round fruit shape, full carpels, long peduncle (7.79 cm), fruit weight (2.20 kg), pericarp thickness (1.47 cm), flesh thickness (0.75 cm), proportion between the fruit weight to flesh weight 20.15 per cent, aborted seeds 42.30 per cent, fruit setting four weeks after flower bloom 4.69 per cent (average of 3 years) which is 79 per cent higher than the Chanee variety, days to harvesting 103.86 which is 6.52 per cent longer than the Kradum Thong variety. The outstanding characteristics are bright yellow flesh (Y 11A-YO 13C), good flavour, sweet creamy, fine flesh, very mild odour, the flesh stays intact longer after the peduncle separates from the fruit, and the high percentage of sterile seeds (Fig. 8).



Fig. 8. Fruit and flesh characteristics of durian hybrid Chanthaburi 1

Chanthaburi 2 (Hybrid durian breeding line ICN 7-5-2-2)

Salient characteristics: This is a hybrid between the mother Chanee variety and male parent Phuang Mani variety with relatively small fruit shape, long oval shape, long fruit peduncle 60.00 cm, fruit weight 1.76 kg, thickness of the fruit pericarp 1.98 cm, thickness of flesh 0.91 cm, the proportion between fruit weight and flesh weight 14.89 per cent, aborted seeds 5.28 per cent, fruit setting at four weeks after flower blooming 4.93 per cent (three years average) which is 88.18 per cent higher than the Chanee variety, days to harvesting 92.67 which is 4.95 per cent shorter than the Kradum Thong variety. Outstanding characteristics are bright yellow flesh (YO 16B – YO 17C), good taste, sweet creamy, fine and sticky flesh, and mild odour (Fig. 9).



Fig. 9. Fruit and flesh characteristics of durian hybrid Chanthaburi 2

Chanthaburi 3 (Hybrid durian breeding line 10-251-8-1)

Salient characteristics: A hybrid between the mother plant of Kan Yao variety and male plant Chanee variety, with relatively round fruit, full carpels, long fruit peduncle 8.35 cm, fruit weight 2.77 kg, fruit pericarp thickness 1.94 cm, flesh thickness 0.98 cm, proportion between the fruit and flesh 23.36 per cent, aborted seeds 8.83 per cent, fruit setting at four weeks after flower bloom 4.37 per cent (three-year average) which was 66.79 per cent higher than the Chanee variety, days to harvesting 99.43 which is 1.98 per cent higher than the Kradum Thong variety. Outstanding characteristics are deep yellow flesh (YO 14 B – YO 15 A), good taste, sweet creamy, fine flesh, with slight aroma, and high fruiting ability (Fig. 10).



Fig. 10. Fruit and flesh characteristics of durian hybrid Chanthaburi 3

Chanthaburi 4 (Durian hybrid breeding line 11-341-1)

Salient characteristics: A hybrid between the mother plant Kan Yao variety and male plant Mon Thong variety, with round fruit shape, long fruit peduncle 6.56 cm, fruit weight 2.36 kg, fruit pericarp thickness 1.34 cm, flesh thickness 1.11 cm, proportion between the flesh and fruit weight 27.05 per cent, of aborted seeds 28.76 per cent, days to maturity 114, medium harvesting age between 112-116 days after flower bloom or an average of 114 days (five years average). Outstanding traits are yellow flesh (YO 13B), sweet creamy taste, very sticky and fine flesh, and mild odour (Fig. 11).



Fig. 11. Fruit and flesh characteristics of durian hybrid Chanthaburi 4

Chanthaburi 5 (Hybrid durian breeding line 12-21-1)

Salient characteristics: This is a hybrid between the mother plant Kan Yao variety which was subjected to open pollination. This hybrid possesses round oval fruit, long fruit peduncle 5.33 cm, fruit weight 3.42 kg, pericarp thickness 1.66 cm, flesh thickness 1.20 cm, proportion between the flesh and fruit weight 25.35 per cent, aborted seeds 28.07 per cent, early maturity 104 days which is 8.33 per cent higher than the Kradum Thong variety, fruit setting between 1.32-6.45 per cent at four weeks after flower blooming, or at an average of 3.89 per cent (five years average), harvesting between 100-109 days after flower bloom, or at an average of 104 days (five years average), with flower blooming during the month of January, and harvested during May. The outstanding characteristics are bright yellow flesh (YO 14 C), very sweet and creamy taste, fine and medium stickiness flesh, and mild odour (Fig. 12).

Chanthaburi 6 (Hybrid durian breeding line 11-241-9)

Salient characteristics: A hybrid variety with mother plant Kan Yao variety and male parent Mon Thong, with round oval fruit, long fruit peduncle 7.63 cm, fruit weight



Fig. 12. Fruit and flesh characteristics of durian hybrid Chanthaburi 5

2.90 kg, pericarp thickness 1.73 cm, flesh thickness 1.45 cm, proportion between the flesh to fruit weight 31.38 per cent, aborted seeds 21.63 per cent, days to maturity 115 (fiveyears average), flowers bloom in mid January, and harvested during late May, fruit setting between 5.31 – 11.22 per cent at four weeks after flower bloom or an average of 8.27 per cent (fiveyears average). The outstanding characteristics are yellow flesh (Y 11B), very sweet and creamy taste, fine and sticky flesh, and mild odour (Fig. 13).

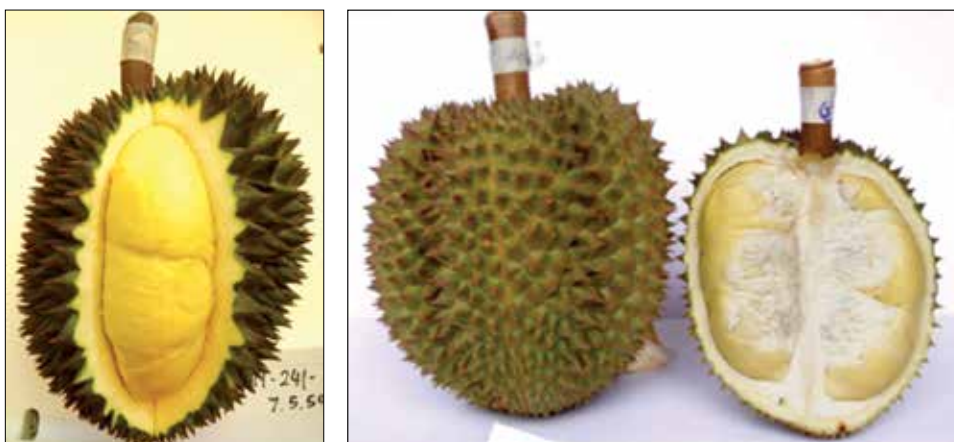


Fig. 13. Fruit and flesh characteristics of hybrid durian Chanthaburi 6

Chanthaburi 7 (Hybrid durian breeding line 10-432-6)

A hybrid variety with mother plant Kan Yao variety and male parent Chanee, with round oval fruit, long fruit peduncle 6.96 cm, fruit weight 2.30 kg, pericarp thickness 1.63 cm, flesh thickness 0.96 cm, proportion between the flesh to fruit weight 19.56 per cent, aborted seeds 16.6 per cent, days to maturity 95 (three years average), flowers bloom in mid January, and harvested during early May. The outstanding characteristics are yellow flesh (YO 14C), very sweet and creamy taste, fine and sticky flesh, and mild odour (Fig. 14).



Fig. 14. Fruit and flesh characteristics of hybrid durian Chanthaburi 7

Chanthaburi 8 (Hybrid durian breeding line 5-451-5)

Salient characteristics: A hybrid variety with mother plant Chanee variety and male parent Mon Thong, with round oval fruit, long fruit peduncle 5.42 cm, fruit weight 2.24 kg, pericarp thickness 1.05 cm, flesh thickness 1.46 cm, proportion between the flesh to fruit weight 38.83 per cent, aborted seeds 69.89 per cent, days to maturity 114 (three years average), flowers bloom in mid January, and harvested during mid April- May. The outstanding characteristics are yellow flesh (Y 11C), very sweet and creamy taste, fine and sticky flesh, and mild odour (Fig. 15).



Fig. 15. Fruit and flesh characteristics of hybrid durian Chanthaburi 8

Chanthaburi 9 (Hybrid durian breeding line 5-441-13)

Salient characteristics: A hybrid variety with mother plant Chanee variety and male parent Mon Thong, with round oval fruit, long fruit peduncle 6.23 cm, fruit weight

3.43 kg, pericarp thickness 1.59 cm, flesh thickness 1.30 cm, proportion between the flesh to fruit weight 19.01 per cent, aborted seeds 41.16 per cent, days to maturity 138 (three years average), flowers bloom in mid January, and harvested during late May- June. The outstanding characteristics are yellow flesh (Y 10A), very sweet and creamy taste, fine and sticky flesh, and mild odour (Fig. 16).

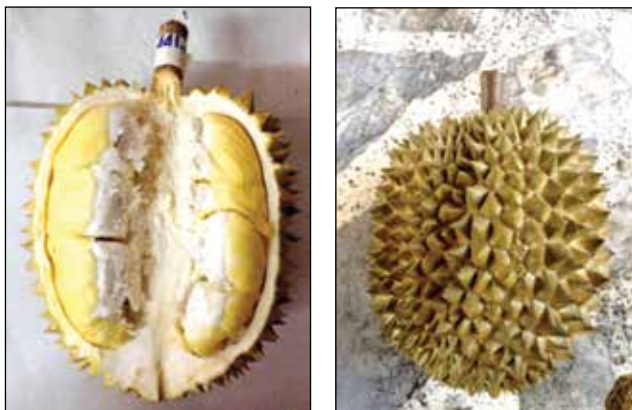


Fig. 16. Fruit and flesh characteristics of hybrid durian Chanthaburi 9

5.4. Use of New Recommended Hybrid Durians

Six varieties of durian were proposed to the Department of Agriculture with recommendation for their release for cultivation by farmers. Out of these, three varieties, namely, Chanthaburi 1, Chanthaburi 2, and Chanthaburi 3, were certified by the Department of Agriculture on 9 October 2006, and the remaining three Chanthaburi 4, Chanthaburi 5 and Chanthaburi 6, were certified on 1 December 2013. The varieties Chanthaburi 1, Chanthaburi 2, Chanthaburi 3, and Chanthaburi 5 are early maturing varieties, with short maturity period, whereas the varieties Chanthaburi 4 and Chanthaburi 6 are medium maturity varieties, with fine flesh, good taste and good eating quality, especially the Chanthaburi 1 with very mild odour. In fact, in the media, it is called as “odourless durian”, which is considered good for consumers who prefer durian with mild odour. First time durian eaters would prefer this variety. The target is to introduce this variety to new markets such as the United States of America, Europe, Japan, Korea and other new niche markets, as a new option for consumers, and a new variety for the farmers that could be a substitute to the traditional varieties like the Chanee variety that has a problem of low price for the past more than ten years. If this variety is accepted by the consumers, these six outstanding hybrid durian varieties could be used for improving the production of durian as a substitute to the traditional varieties and increase the production during the early period of durian season, or as a means to distribute production throughout the growing season in order, to improve the income of the farmers. The six durian varieties were propagated and 5,000 saplings were distributed to more than 4,000 farmers in the province of Chanthaburi as well as other provinces between 2008 - 2013. (Songpol, 2005, Songpol, *et al.*, 2007, Somsri, *et al.*, 2006. It is noteworthy that the Chanthaburi 7, Chanthaburi 8, and Chanthaburi 9 are newly released varieties recommended for cultivation on

7 November 2016. They will be propagated and distributed to the farmers in the same way as was done for earlier recommended and released varieties, namely, Chanthaburi 1,2,3,4,5,6 (Fig. 17)..

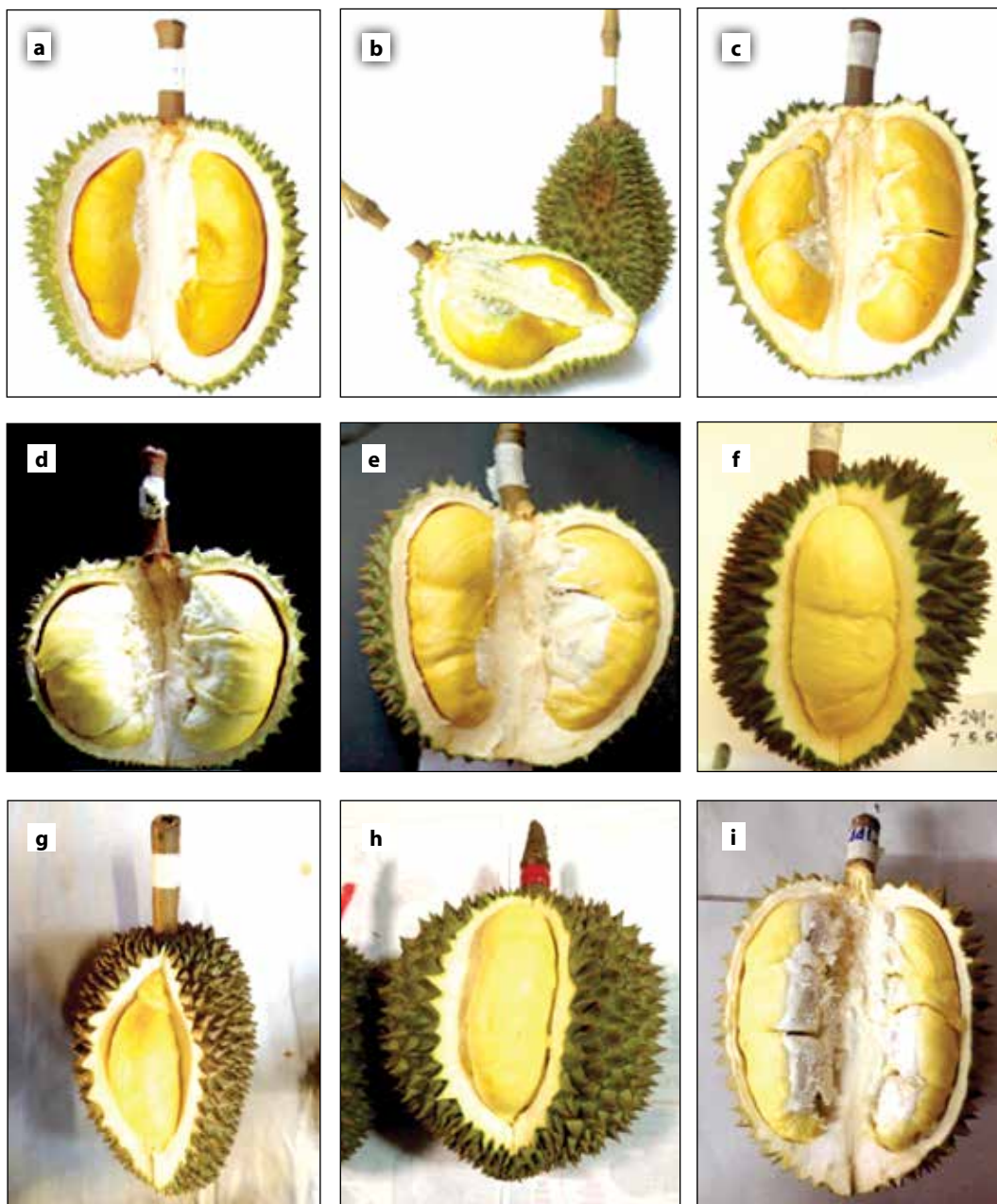


Fig. 17. The shape, size, flesh colour of nine new durian hybrids:
 (a) Chanthaburi 1, (b) Chanthaburi 2, (c) Chanthaburi 3, (d) Chanthaburi 4, (e) Chanthaburi 5,
 (f) Chanthaburi 6 (g) Chanthaburi 7, (h) Chanthaburi 8, (i) Chanthaburi 9

6 Cultural Practices and Propagation of Durian Varieties

6.1. Propagation of Durian Varieties

The propagation techniques preferred at present is the asexual propagation by cleft grafting, and marcoting. However, the cleft grafting is the most preferred technique. For the rootstock, the Chanee variety or traditional variety is used. If the rootstock is used from the wild durian species such as the Don durian variety (*D. malaccensis* Planch. Ex Mast.), Cha Rian durian variety (*D. mansonii* Bakh.), and Nok durian variety (*D. lowianus* Scort. Ex King), the life span of the durian tree could be increased due to the resistance to root and stem rot disease caused by the fungi *Phytophthora palmivora* (Butler) Butler. However, the use of these rootstocks with scion from good varieties, especially Mon Thong will have a better growth than the rootstock, unlike in the Chanee and Kradum Thong variety (Fig. 18).

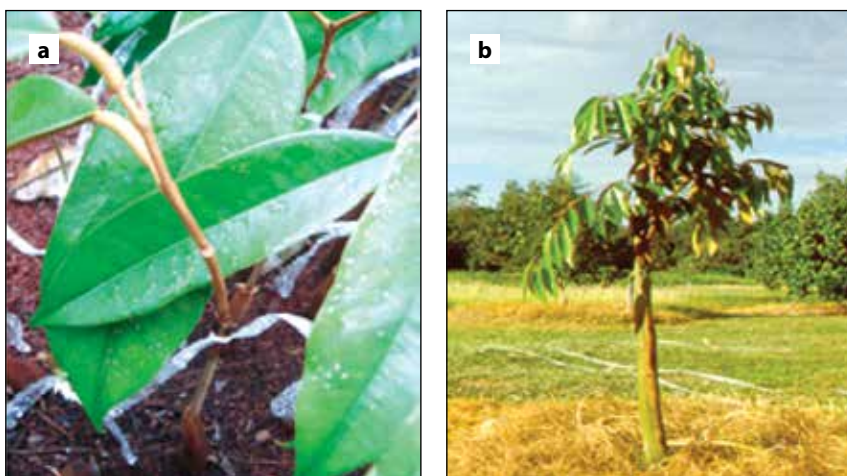


Fig. 18. Propagation of durian varieties: (a) propagation of durian variety by cleft grafting technique; (b) sion of Mon Thong variety grafted on rootstock of Durian Nok variety (*D. lowianus* Scort. Ex King)

6.2. Production and Maintenance of Durian

Durian production in Thailand, faces a number of problems relative to production, and adoption of production technology, production inputs, including the varieties of durian still lacking efficiency in the utilization of inputs, resulting in the low volume of production, yield per rai (1 ha=6.25 rai), and the quality of

production still below export standards as required by the market. The production cost is high and there is no uniformity in the distribution. Climatic factors equally have an impact on the yield and quality of the harvest.

Durian is a tropical fruit that needs hot and humid environment, with temperature ranging from 10-46°C and the relative humidity of less than 30 per cent, rainfall at least 2,000 mm/year for proper growth and yield. The water requirement for the growth ranges between 3,750 – 5,000 cubic meters/ha, with irrigation not more than three months per year, in areas with water evaporation rate between 4.9-9.5 mm/day. The water should be clean and free from organic and inorganic compounds that could be toxic contaminants such as the water from the irrigation canals, rivers, waterways, and at water pH between 6.0-7.5, with soluble salts not more than 1,400 millimole (Chanthaburi Horticultural Research Center, 2004). Durian grows well in sandy and clay loam soil with good drainage, soil surface fertility at a depth more than 50 cm, ground water level of more than 75 cm, soil pH between 5.5-6.5, and heavy clay soil, as durian roots are sensitive to the flood and susceptible to the diseases especially root and stem rot diseases.

Durian can grow well and give better yield in the areas with an elevation above the mean sea level between 0-910 meters. However, it is not advisable to grow durian at an elevation of more than 300 meters above sea level. The areas suitable for durian production are between the latitude 15°North to 17°South, , planting distance of 8 × 10 meters, and the plant population of about 100 – 156 trees/ha. The grafted seedlings start bearing fruits at the age of 4-5 years after planting and the peak production period is between 15-20 years after planting.

Once the tree starts bearing, the first fertilizer application should be carried out after harvesting to improve the growth of the tree. The fertilizer N: P: K 16-16-16 should be applied at a rate of 2-5 kg/ tree and could be supplemented by cow and chicken's manure at a rate of 20-50 kg/tree, in order to improve soil fertility, and add soil microorganisms. The second dose of fertilizer application should be done when the young shoots start maturing, by applying fertilizer N: P: K 12-24-12 or 8-24-24 at a rate of 2-5 kg/tree, in order to stimulate flowering. The third fertilizer application should be done when the fruits attain a size as big as a betel nut, by applying fertilizer N:P:K 12-12-17-2 at a rate of 1-3 kg/tree in order to enhance the growth of the fruit, and the quality of the fruit flesh. In the case where the application of soil fertilizer is still not sufficient, the application of urea and other essential nutrients by foliar spray could be done as necessary.

During the drought period of about three months, watering should be done during the young fruit stage, and enough irrigation water should be applied for the growth of the fruits, however, it is not recommended to apply excessive water as young shoots may develop the problem of fruit drop.

6.3. Flower Stimulation by Foliar Spray

From the studies on the stimulation of durian flowering by foliar spray using the chemical compound Paclobutrazol at a rate of 1,000 ppm, it could stimulate flowering up to 83 per cent and the flowering could be initiated faster than the untreated trees by 14-45 days. Besides the increase in the number of flowers per tree between 29-64 per cent (Chandraparnik *et al.*, 1992), the foliar spray of Paclobutrazol has an effect on the flower initiation, specific to variety. The recommendation on the use of this chemical to farmers should be made only if they have the knowledge and understanding of the guidelines on the care and maintenance of the yield and the impact of the use of the chemical and this technology on the yield performance at the farmers fields which should be carefully considered.

6.4. Pollination and Fruit Development

The nature of the plants that are sexually propagated should have a fertilization to induce fruiting and could be propagated by seeds. Fruiting, therefore, would depend on pollination which is dependent to related factors such as the pollen, stigma and the vectors that help in the pollination.

Durian has relatively sticky pollen after it bursts from the anther which makes insects important pollinators which could be moth, bats, bees, mints or honey ants etc. A study conducted by Somnuek (1992) indicated that insect pollinators include honey bees, stingless bees or *Tetragonula* sp., bees belonging to Apidae family such as the *A. cerana*), *A. florea*, etc. Songpol (1987) reported that the pollen is round with three holes serving as a passage opening for the pollen tube (Fig. 19). The vitality of the pollen is relatively high in the five varieties, after the flower bloomed between 1-20 hrs with vitality ranging between 95.92-98.73 per cent in Chanee variety, 88.0 – 88.88 per cent in Mon Thong variety, 85. 71-94.87 per cent in Kan Yao variety, 80.0-94.66 per cent in Kob Pikulthong variety, and 85.45-95.35 per cent in Kathoei variety, but the germination of pollen is not high. After keeping

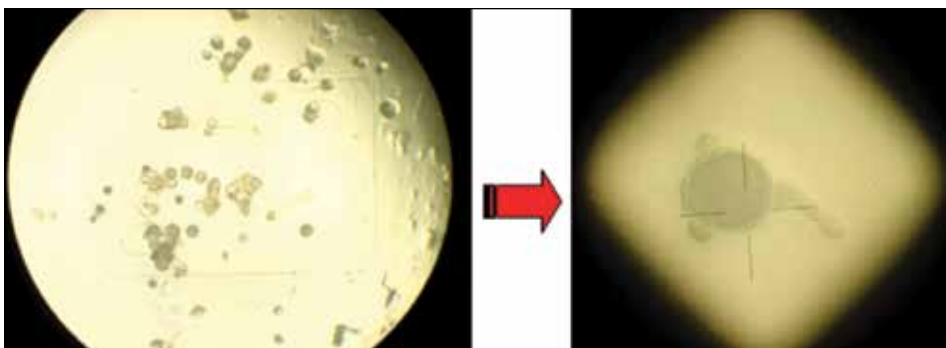


Fig. 19. Shape of the pollen showing 3 holes for germination

the pollen for two hours and 30 minutes, the germination is between 16.66-27.27 per cent, with sucrose content between 10-15 per cent in Chanee variety, and 48-59.77 per cent with sucrose content between 15-25 per cent in Kathoei variety (Songpol, 1987), whereas Salakpetch, *et al.* (1992) reported that the vitality of the male durian in commercial varieties is between 83-96 per cent one day before or during the flower bloom, and the vitality is not less than 70 per cent in two days after flower bloom. The vitality is 75, 77, 92 and 93 per cent in Mon Thong, Kratum Thong, Chanee and Kan Yao varieties, respectively.

Songpol (1987), and Songpol and Hiran (1992) reported that the percentage of fruit setting for Chanee variety increased when it received male pollen from a suitable variety; the fruit setting increased by 30.1-79.46 per cent, at two weeks after pollination by pollen from different variety, especially from the variety Mon Thong. Salakpetch, *et al.* (1992) reported that more pollen grains that were captured by the stigma will increase the percentage of germination of the pollen and there will be more fruits developed.

Therefore, durian growers could easily pollinate durian in order to help in the pollination of durian specifically with the Chanee variety without making the flowers male sterile by removing the pollen from the flower, or without covering it with white thin cloth bag after pollination by using the following techniques:

Method 1: Cut the flower of Mon Thong variety or any other variety while in bloom and is ready for pollination, by observing the abundance of white pollen spores on top of the anther at about 19.00 – 19.30 hrs., then bring the flower that contains the white pollen spores and touch it with the stigma that is round shaped and yellowish in colour of the flower of Chanee variety that is presently in bloom. This will ensure pollination and fruit setting.

Method 2: Cut only the set of the stamen of the male plant. The durian flower has 5-6 sets of stamen, and each set comprises of 5-18 filaments. At the tip of the filaments are the anthers. Then hold the filament with the anther that has white pollen spores and then gently touch it on the stigma of the mother plant.

Method 3: Cut only the anthers from the flower of the male parent plant that has the white pollen spores, put them in a plastic bottle, then use brush to tap the pollen and brush it directly on top of stigma of the mother plant.

If growers want the durian fruits to mature at the same time or almost at the same time, for convenience in harvesting, this could be done by removing the flowers during the time between 09.00 – 12.00 hrs and leaving only the unbloomed flowers which will bloom that night and will be ready to be pollinated in the morning of the next day. The flowers should be removed in such a way that only 2–10 flowers

are retained per cluster, and about 10-20 clusters per branch, leaving an appropriate distance between clusters. The flower clusters located at the tip of the branch should all be removed. The flowers to be pollinated should be selected on the big and lower branches, in order to be able to carry the weight of the fruits. For the upper branches, it is not necessary to help in pollination, as the flowers in upper branches could be pollinated by natural means.

Method 4: If durian growers wish to pollinate the flowers in the upper branches, the procedure is to collect the pollen spores from the male plant, then use a rope to tie a bottle and hang it on the neck of the person who has to undertake the pollination. The pollinator then climbs the tree and does the pollination by using a brush tap on the pollen spores from the bottle, then taps it on the mother plant. Pollination can be done as needed in the upper branches that are reachable.

Method 5: Collect the pollen spores of the male plant, put them in the plastic bottle, tie the soft brush in a long pole, then tap the brush with the pollen spores from the plastic bottle and then brush it on the stigma of the flowers on the mother plants that are located on the upper branches as needed.

Method 6: In case of using a different variety as the male plant that is at some distance from the mother plant, use a brush attached to a long pole, tap the brush with pollen from the male plant, then tap it on the tip of the stigma of the mother plant or could be done alternately to help in the pollination (Songpol, 1989).

6.5. Harvesting and Maintenance

In general, durian can be harvested when the fruit is about 3-5 months after the flower bloomed, depending on the variety. The early maturing varieties can be harvested at about 95-105 days, medium maturing varieties at about 105-135 days, and late maturing varieties at about 135-150 days after the flowers bloomed. The harvest period of different commercial varieties, counted from the flower bloom to harvesting are given in Table 2.

Table 2. Days from flower bloom to harvest in different varieties of durian

Varieties	Days from flower bloom to harvest
Kradum Thong	90-100
Chanee	100-110
Mon Thong	120-135
Kan Yao	120-135
Kob	120-135
E-Nak	140-150

The harvested fruits can be stored at a temperature of 30°C for 2-9 days, and at temperature of 20°C for 5-12 days. Durian fruits kept at a temperature of 15°C at relative humidity of 85-90 per cent can be stored for about 2 weeks, depending on fruit maturity. Immature fruits will show signs of chilling injury if stored at a temperature lower than 15°C, showing blackish or brownish skin in between the spikes, which would enlarge until it covers the whole fruit, then the flesh will be unripe and would shrink in size.

Once durian flesh is taken out, it should be kept in low temperature, such as in the cold storage, because the durian flesh has a strong odour. The durian flesh can be kept as long as 3 weeks at a temperature of 15°C. Bauchau (1972) reported that the flesh of durian could be kept for as long as three months at a temperature of -24°C by using the quick-freezing technique, without changing the flavour, with atmospheric condition with O₂ at 5-10 per cent and/or combined with CO₂ not exceeding 20 per cent. Aside from this, the use of modified atmosphere by waxing the fruits can also reduce the splitting of the fruit and the fruit flesh can stay intact but soft and reduce the fruit smell (Thongdee, 1992).

The waxing of the durian fruit during the storage at temperature of 22°C or at 18°C will help in reducing the water evaporation. The weight loss would depend on the type of wax used and the concentration used in waxing. The movement of the gas passing in and out of the fruit pericarp will cause the CO₂ inside the fruit to be high, while O₂ low and the C₂H₄ low, as compared to the fruits that are not waxed. The rate of transpiration and the circulation of the C₂H₄ will be reduced in the waxed fruits, aside from this, the sulphurous odour of the ripe durian will also be reduced, wherein in some instances, the ripeness of the durian could be hindered in some or the entire parts. Therefore, the wax FMC SF 7055 is used to allow the exchange of gases and reduce the rate of ripening in durian (Ching Ching, *et al.*, 2000).

6.6. Yield of Asexually Propagated Durian Trees

Asexual propagation of durian can be done by budding, grafting, inarching and marcotting. The asexually propagated plants start bearing fruits at about 4-5 years after planting, depending on the variety. The yield is about 10-40 fruits per tree and if the tree has already reached six years fruiting age or when the tree is about 10-11 years, it will yield about 100 fruits per tree. At tree age of 15 years and above, the tree can produce 200 fruits per tree. However, the yield is dependent on the maintenance and the growth of the tree, pest and disease control, and the application of good agricultural practices.

6.7. Insect Pests and Diseases of Durian

6.7.1. Major diseases of durian

The most important is the root and stem rot disease which is caused by the fungus *Phytophthora palmivora* (Butler) Butler. The symptoms of the disease can be



Fig. 20. Symptoms of the root and stem rot disease along the base of durian tree

observed along the tree trunk (Fig.23). Other common diseases are *Rhizoctonia* leaf blight disease, anagal disease, fruit rot disease, powdery mildew disease, *Anthraxnose* disease, *Fusarium* wilt disease, *Cercospora* leaf spot disease, etc. (Songpol, 1988; Teanjai, *et al.*, 2002).

Root and stem rot disease

It infects the roots, the base of the tree, the trunks and the branches, affecting tree growth; the leaves turn yellow and then drop, the branches get dried up, and finally the tree dies. Symptoms of the disease are shown in Fig. 20. The disease is serious in susceptible varieties such as the Kradum Thong, Mon Thong, and the Kob varieties. The disease outbreak is prevalent during the end of the rainy season.

Control measures

- Clean the base of the tree to make it free from weeds, and remove the infected barks, and then treat the infected barks with red lime or cupravit.
- Use a disinfectant metalaxyl, ridomil at 25 per cent WP at a rate of 50-60 g/ litre of water, then spread it on the wounded bark and pour the mixture on the soil within the tree canopy, or apply efosite aluminum, aliette at 80 per cent WP at a rate 80-100 g/litre of water, spread it on the wounded bark. Besides, apply microorganisms such as *Trichoderma harzianum*, *Chaetomium cupreum*, *C. gloosum*, and *Bacillus subtilis* as biocontrol agents.
- Spray phosphorous acid mixture mixed with water in a proportion of 1 : 1 at the base of the tree.
- Destroy the disease vectors, especially the stem borers.

Rhizoctonia leaf blight

It is caused by a fungus *Rhizoctonia* sp. occurring in leaves that are crowded and dense. The leaves appear to have bruises similar to brownish bruise like hot water

scald, then the leaves drop leaving only the branch. Infestation is prevalent during rainy season.

Control measures

- Appropriate pruning of branches, keeping enough moisture in the tree to allow good growth and development. If there is enough moisture in the tree canopy it will ward off disease organisms.
- During the vegetative growth, regular surveillance of the disease should be done, and once the disease symptoms are found on the leaves or stems, cut the infested area and burn outside the orchard area, then spray with pesticides such as carbendazim, thiabendazole, captafol+copper+zinc, copper oxychloride, and nitroaniline+captan, along the trunk base for 1-2 times or until the leaves turn mature.
- Collect and burn all the infected leaves that have fallen around the tree base, in order to reduce the population of disease causal organisms, and to help reduce the degree of infestation for the next cropping season.
- In the orchards with high moisture where there is regular occurrence of the disease, fertilizer with low nitrogen should be applied in order to reduce the vegetative growth of the durian tree.

Angal disease

It is caused by an algae *Cephaleuros virescens* occurring on leaves and trunks appearing as gray spots on a green surface of the leaves, and once matured turns into red brownish with resemblance to velvet that will make the tip or the end part of the stem to be wounded or bruised affecting the growth of the tree and the stems to be dried until it dies.

Control measure

Spray with chemical cupravit, synapse and dithane M-45 as per the DOA recommendation manual guide.

Fruit rot disease

It is caused by the fungus *Phytophthora palmivora* resulting in small spots on the skin of the fruit and then it spreads to enlarge circles, causing the splitting of the carpels, and in some cases fruits will get rotten along the end part of the fruit.

Control measure

Spray chemical fosetyl-aluminum, captafol or metalaxyl one month before harvesting the fruit as per the DOA recommendation manual guide.

Powdery mildew disease

It is caused by the causal organism *Oidium sp.* occurring in young fruits resulting to white powder in between the durian spikes, hampering the development of the young fruits and consequently resulting in fruit drop.

Control measure

Spray with chemicals, sulfur powder, benomyl as per the DOA recommendation manual guide.

Anthracnose disease

It affects the leaves and the fruits of durian during the rainy season and can be controlled by spraying of benomyl during the early stages of disease infestation as per the DOA recommendation manual guide.

Fusarium wilt disease

It could be controlled by spraying of copper oxychloride.

Cercospora leaf spot disease

During the early vegetative stage, it could be controlled by spraying of the chemical difolatan as per the DOA recommendation manual guide.

6.7.2. Major insect pests of durian

The major insect pests of durian include red mites, durian psyllids, mealy bugs, fruit borers, seed borers and stem borers (Songpol, 1988 , Saruth and Manita, 2004, Sudhi-Aromna *et al.*, 2006) (Fig. 21).

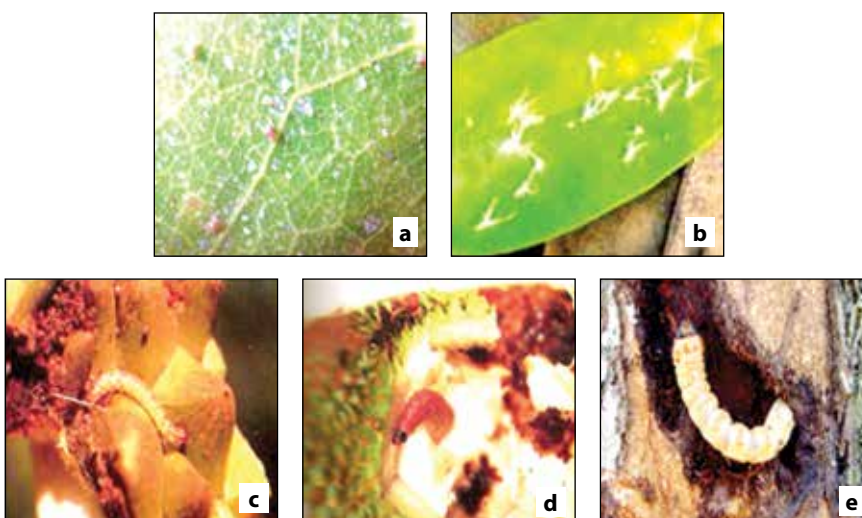


Fig. 21. Major insect pests of durian: (a) red mites, (b) durian psyllids, (c) fruit borer, (d) seed borer, (e) trunk borer

Red mites

Red mites suck the water from the leaves and young shoots causing the drying of the infected leaves, which are dropped later although sometimes the leaves are still green. The surface layer of the leaves has grayish spots in the form of dust and the outbreak of the red mites usually occurs during the months of August – September and during dry season or when there is late rainy season.

Control measures

- Conserve natural enemies of red mites such as predaceous mites, lady beetles, long-legged fly, spiders
- If an outbreak of red mites is found in the orchard, spray the tree canopy in order to reduce the outbreak of red mites
- The best control measure is to spray the trees with guzathion, parathion, and as a protection measure to spray with chemicals sulfur powder, keltan, omite, ecomite.
- When it is found that the population of red mites has increased, count the number of red mites on top of the leaf and with an average of 10 per leaf, apply the following chemicals
 - Propagite 30 per cent at the rate of 30 ml per 20 liters of water
 - Hexythiazox 2 per cent W/V EC 2 per cent at the rate of 40 ml per 20 liters of water (apply after spraying; propagite when eggs and larvae of red mite are still found)

Durian psyllids

Durian psyllids suck the water from the young leaf shoots of durian, inhibiting the leaf growth with the result that the leaf will be smaller than the normal, curl and finally drop. The symptoms are prevalent during the young leaf shoot formation.

Control measures

- Conservation of natural enemies of durian psyllids to control naturally, such as the aphidophagous ladybird beetles (*Menochilus sexmaculatus*), orange lady beetle or *Micraspis discolor* (Fabricius), lady beetle *Coccinella transversalis*, antlion, wasps, and spiders
- To stimulate durian tree to develop young shoots at the same time, the N:P:K 46-0-0 fertilizer should be applied at the rate of 2 kg/tree to protect the tree by shortening the period of infestation and to eradicate the pests at the same time.

- Survey the young shoots and the young leaves of the durian tree, and when durian psyllids are found, use yellow sticky trap to attract the adult moth, or spray water on top of the young shoots that are already open in order to reduce the population of the durian psyllids. Once the number of infected shoot reaches to about 4 shoots per tree, apply chemicals as follows:
 - Cyhalothrin 25 per cent at the rate of 10 ml per 20 litres of water
 - Endosulfan 35 per cent at the rate of 50 ml per 20 litres of water
 - Carbosulfan 20 per cent at the rate of 50 ml per 50 litres of water

Mealy bugs

The mealy bug sucks the sap from the young fruits through the help of the black ants, leaving black patches along the infested areas. The control measure is to spray with chemicals parathion, malathion, and sevin 85 per cent.

Fruit borers

Fruit borers are the larvae of the small moth with yellow wings with black spot, and they infest all sizes of durian fruits from small to big. The adult moth lays eggs outside durian fruit. At the first stage, the larvae will hatch from the egg cocoon, and will feed on the pericarp of durian fruit, and once it matures, it will feed on the inside part of the fruit. If the larvae feeds on the durian flesh, the flesh of the infested part will become rotten. Once the fruits ripen, the droppings from the larvae become visible on the outer part and juice exudes from the fruit. Once the fruit is almost fully mature, the larvae will infest the fruits nearby more than the fruits that are isolated because once the larvae hatches out from the egg, it then habituates in these open tracts.

Control measures

- Conservation of natural enemies for the control of the fruit borer such as Assassin bugs (*Sycanus collaris*), Predaceous stink bug (*Eocanthecona fuscillata*), spiders, parasitoids, *Anagyrus dactylopii* (Howard) (Hymenoptera: Encyrtidae).
- Use the black blue light bulb to attract the adult moth for eradication.
- Pruning of branches of durian to avoid crowding of branches and very close branches or use other materials such as coconut husks or use twigs to be placed in between the fruits to protect the fruits from the insect pest infestation or to provide an alternate host to the adult moth.
- After the fruits are thinned the third time, and still found infested areas are sprayed with chemical specific to the infected tree as follows:
 - Cyhalothrin 2.5 per cent at the rate of 20 ml/20 litres of water

- Carbosulfan 20 per cent at the rate of 50 ml/20 litres of water
- Chlorpyrifos 40 per cent at the rate of 50 ml/20 litres of water

The rotten and dropped durian fruits should be collected and destroyed by burning and should be buried in the soil.

Seed borer

Seed borer is the larvae of the brown caterpillar *Mudaria luteileprosa* Holloway with yellowish spots or alternate white and yellow spots. Adult moth is usually found inside the orchards, when durian fruits are about two months old. The fully-grown adult will lay its eggs on top of durian fruit near its peduncle, later the larvae will enter inside the fruit and feed on the seed without causing damage to durian flesh, except a small trace of entrance between the flesh and the fruit pericarp. This type of larvae drill inside the seed to feed and excrete outside, causing the flesh of the durian smeared and damaged. The full-grown larvae at about 4 cm in size are ready to cocoon and make a hole to come out from the fruit then drop to cocoon under the soil and become a moth in the next season. The damaged durian fruits have comparatively low market value and preference.

Control measures

- Light traps should be used in order to attract the moth to reduce the population and to observe the time when the moths will appear to determine the proper time of spraying
- Use the chemicals carbaryl, endosulfan, or metamidphosphos to spray after the first detection of moth in the light trap.
- In transporting the durian seeds from the infected area with seed borers to be used as root stock for varietal propagation, should be soaked first with chemical carbaryl before they are transported in order to eradicate the worms that infected the seeds.
- Maintain the cleanliness of the orchard, and closely conduct surveillance in durian orchards at fruiting stage and once symptoms and damage caused by the pest are found in the fruits or there are fruit drops in the orchards with outbreak of the seed borers, the fruits that fell on the ground should be collected and destroyed daily, because after the durian fruit has fallen, in less than no time, the worms inside the seeds will bore a hole to come out to cocoon under the ground.

Long horn beetle or stem boring grub (*Batocera rufomaculata* De Geer.)

At present, it has become a major durian pest and causes severe destruction in different varieties of the fruit. However, Mon Thong is the variety that is usually

affected with the trunk being the affected area resulting in the death of the tree, and the farmers are not yet able to control this pest problem (Sudhi-Aromna *et al.*, 2006).

Control measures

- Problem of dying durian tree could be solved by spraying with imidacloprid (confidor 100 SL 10 % SL) at the rate of 30 ml per 20 litres of water two times every two weeks. This treatment will be able to kill all the worms. The tree can be protected from the pest to lay eggs again by wrapping a fish net around the trunk of the infested tree, then use a pointed knife to scrap the eggs inside the infested tree barks.

7 Processing and Value Addition

Durian harvest with inferior quality fruits and not considered good for consumption or have some drawbacks such as the fruit size being too big or too small and not within prescribed standard, splitting fruits, damaged by pests and diseases, over ripe fruits with symptoms of wet core, dry flesh, etc. are processed into various products such as durian paste, crispy fried durian, powdered durian, durian ice cream, oven dried durian (durian chips), durian cake, durian candies, durian desserts, etc. The flesh of durian could be stored for a longer time by freezing and once put under normal temperature can be processed and eaten.

In the past, the important product of durian was durian paste which was the local product of farmers. Durian farmers normally process durian paste by adding sugar in required proportion in an open pan then cook it using charcoal and firewood until it boils while stirring until the moisture evaporates. Suwantha *et al.* (1988) reports that the flesh of durian weighing 11.3 kg used for making durian paste using the process above will take about 1.5 hours, and 4 kg durian flesh will produce 1 kg of durian paste. Durian French fries is a new durian processed product and a study by Pacharee *et al.* (2007) reports that the moisture content, starch and sugar content differ depending on the maturity period of durian fruits. The suitable age for processing durian French fries is about three days before fruit ripening which is the period when durian fruit has the highest starch content. The temperature for frying has an effect on the oil absorption, moisture content, and the form of French fries. This product has the potential to be developed and exported to the Asian market. However, the fried crispy durian which is processed



Fig. 22. Various durian products: (a) fried durian, (b) freeze dried durian, (c) powdered durian, (d) durian ice cream, (e) durian snacks, (f) durian paste, (g) durian cookies and cakes, (h) durian moon cakes

from a raw durian has also gained popularity in recent times, both in the plastic and canned packages (Fig. 22).

Durian Chips

Durian chips are made from unripe durian that is thinly sliced or grated and then deep fried in vegetable oil. They are so popular in Thailand that even the 7-11s and supermarkets stock them on shelves. The durian chips are produced both in large factories and in family homes. Since the chips are made from immature fruits, they lack the strong odour and flavour that is sometimes repugnant to those not yet in love with durian. Instead, they are similar in flavour and texture to potato chips, but with a difference of only being sweeter.

Ingredients

- 2 lb unripe durian (sliced)
- 1 tsp salt
- 3 cups vegetable oil

Preparation of recipe

- Slice durian fruits into thin pieces, using a mandolin, grater, or carefully cut with a knife. Make sure the slices are of the same thickness so that they will cook at the same pace.



Fig. 23. Monthong durian chips

- Heat a frying pan or wok and pour vegetable oil in it. Use a medium flame.
- When the oil is ready, fry the durian slices. Flip frequently to prevent burning.
- When durian chips have darkened in colour to yellow or golden, remove from the pan with a sieve and place on paper towels to dry.
- If desired, sprinkle salt over the chips and allow to cool.

Freeze Dried Durian

Unlike frozen durian, which is mushy and slushy, freeze dried durian is always sweet and funky having typical durian flavour. In addition, it is crunchy. Freeze drying would probably never happen to durian or other tropical fruits. It occurs naturally at high elevations (Andes mountains), where a combination of low-atmospheric pressure and volatile temperatures cause a magical thing called sublimation to occur. This is when frozen ice turns directly into gas, bypassing the liquid stage of being water, turning them into foamy, crunchy, styrofoam nuggets that are lightweight and great for hiking.

Freeze drying is now done by machines like the ones at Sunshine Durian Factory, Chanthaburi province (Fig. 24), the place that produces the Fruit King brand freeze dried durian (Fig. 25).

Freeze drying of durian is a fairly standardized process, but companies do find ways of making their own recipes. Smaller machines are also available for home use.



Fig. 24. Freeze drying machines at Sunshine Durian Factory, Chanthaburi

Sunshine International's packing house and freezing facilities in Chanthaburi, Thailand was the very first durian company to invest in freeze drying machines, back in 2005, which probably makes them the first ones to make freeze dried durian in the whole world. The durian pieces are irregular, crunchy and dissolves into wet powder. The flavour is pretty strongly durian and can smell it as soon as one rips open the package.

Durian Powder

Durian powder is prepared from durian fruit that has been freeze dried, then ground into a powder with particles measuring between 40 mesh and 60 mesh. This product has a maximum moisture content of 5 per cent. Durian powder is the most commonly used in baked goods and culinary applications. Selects of various types of high-quality Thai fruits, through peeling, vacuum drying and rapid freezing, grinding and other standard operating procedures, make fresh fruit powder from fresh fruits. Fruit powder made by Sunshine Company from raw materials to end products, contains absolutely no additives, preservatives and flavourings. It is not only more delicious, but its nutrients remain the same and is ideally suited for the beverage shops, ice shops, food processing, and hotels.

There are a few other products which are produced on a limited scale and using the similar methods as used for other fruits.

These durian products are examples of value addition for durian. In 2007, the volume of export for processed durian reached 9,906 tons; valued at 491.84 million Baht. The export attained 1,061 tons valued at 372.97 million Baht in 2016. The production of value added products is one way to help find a market outlet in case there is over supply of durian fruits. It was found that the export volume and value of processed products were reduced but the fresh and frozen durian were increased.



Fig. 25. Freeze dried durian (Fruit King brand)

8

Economic Importance, Market Status and Commercialization

8.1. Economic Importance

The traditional local community has a culture and tradition, in the form of an integrated production with balanced agro-ecosystem, by adopting the integrated farming system, with intercropping with different kinds of fruit trees such as durian, mangosteen, rambutan, langsung, longkong, duku, salacca, and other kinds of fruits. The durian trees during the ancient times were planted from the seeds of traditional varieties which were tall varieties reaching to about 30-40 meters high with trunk diameter of 1.0 – 1.5 meters and 4-5 persons were required to embrace the tree trunk.

The other kinds of durian are wild species, or traditional varieties or local varieties which are still not popularly known. However, some varieties might have good fruit quality, good yield potential, and resistance to pests and diseases, which could be used for breeding new varieties in accordance with the requirement of durian growers and the consumers.

In the recent times, these traditional varieties were grafted or were replaced by good varieties such as Mon Thong and Chanee. The Mon Thong variety is popular for its thick flesh, good taste and with good price reaching to about 60-100 Baht/kg, whereas Chanee variety, which is popular among the local community, normally weighs to about 2-5 kg giving good profit especially the Mon Thong variety as compared to other varieties.

However, the local community needs to maintain this culture and tradition for adopting the integrated orchard which promotes the conservation of genetic resources of fruit trees, and the community could be benefited from the local plants sustainably, including durian for the livelihood improvement by consuming as ready-to-eat food. This shows that the local community knows the methodology for the postharvest and storage practices of durian and can develop wide variety of durian products such as durian paste, durian candies, etc. Aside from the durian flesh that could be used as food ingredients, it could be used as desserts, especially durian with coconut milk. The durian seeds could be boiled, roasted and eaten as it contains high carbohydrates.

Ripe durian is eaten fresh after meal, whereas the raw durian could be used as a variety of food delicacies such as a dish, fried, salad, and at present, new products are

being developed from a mature durian to the extent of 75-80 per cent, by using the flesh cut in thin slices and then fried as crispy durian. These products are sold in the local market and also exported to other countries and are gaining much popularity among the consumers. Therefore, the profit from durian has a significant effect on the development of the economy of the country and the well being of the society of the local community.

8.2. Market Status and Export of Thai Durian

The local retail merchants or the local collectors collect all the harvests from the orchard owners and send to the merchants to be sold to the local central market of the other provinces such as in the Neansung Market in Chanthaburi, then the produce will be distributed to the retailers in Bangkok or sold to merchants in other provinces. There are some orchard owners who send their produce for sale directly to wholesale merchants or send to markets in Bangkok such as Talad Tai, Si Mum Meang at a market share of 50 per cent of the total volume sent to Bangkok market outlets.

It has been reported that the retail merchants in the local market in the provinces and retail merchants from other provinces have the market share of about 44 per cent, whereas, the share of retailers in Bangkok is about 44 per cent and the remaining 12 per cent of durian harvest is brought to processing for domestic consumption, or exported to other countries (Anonymous 1988; Fig. 26).

The major market of durian was the local market with an approximately 77.36 per cent and exported 22.64 per cent of the total production in 2007. The fresh durian

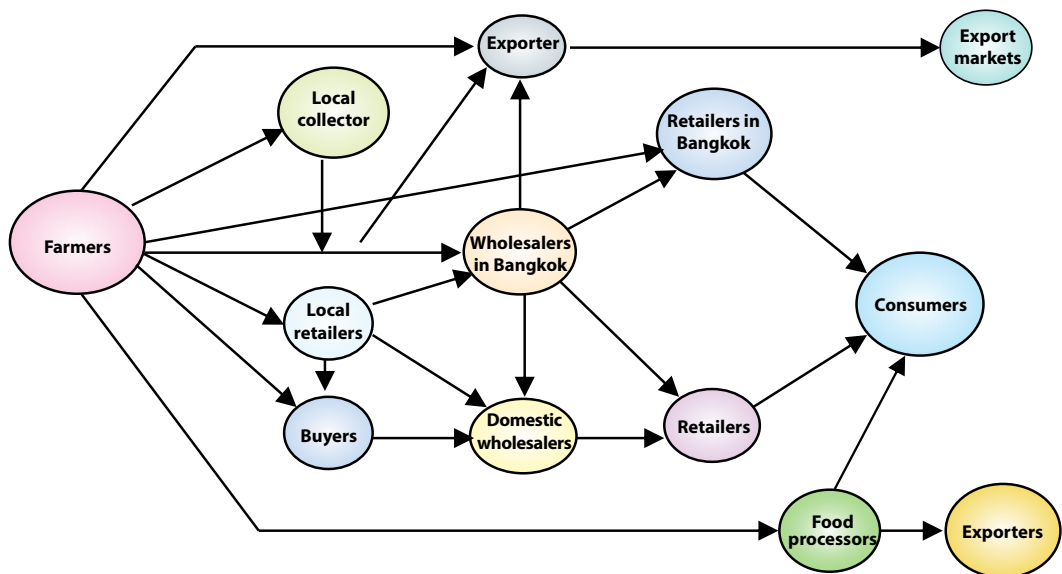


Fig. 26. Market chain for durian in Thailand

fruits export was about 157,474 metric tons valued at 2,568.26 million Baht in 2007 which was 20.97 per cent of the total production (Table 3). The export growth rate has increased by 5.95 per cent per year during the past 10 years during 1997 – 2007. The volume of fresh durian export and products totaled to 169,948 metric tons valued at 3,486.4 million Baht in 2007. During 2008 – 2013, The price of durian that the farmers used to sell in 2013 for Mon Thong variety was about 39.42 Baht/kg, while the Chanee variety was priced at about 15.14 Baht/kg. In 2013, Thailand exported fresh durian to the extent of about 64.48 per cent of the total production. Also, the export of fresh durian and its products was about 381,414 metric tonnes valued at 8,528.898 million Baht in 2013. During 2014-2016, Mon Thong variety was about 63.00 Baht/kg, while the Chanee variety was priced at about 42.00 Baht/kg. The fresh durian fruits export was about 403,634 metric tonnes valued at 17,505.762 million Baht which was 77.92 per cent of the total production. The export of fresh durian and its products was about 425,060 metric tonnes valued at 20,049.976 million Baht in 2016 which was 82.06 per cent of the total production (Table 3, 4) (Office of Agricultural Economics, 2017). The export growth rate has increased by 10.34 (for fresh), 28.85 (for frozen) and decreased by -26.95 (for paste) and -5.21 (for oven dried durian) per cent per year during the past 10 years 2007-2016. At present, the area planted to durian in Thailand in 2017 is about 762,776 rai (122,044.16 ha) with annual total yield 616,121 tons. The exported quantity of durian was 503,205 metric tonnes (81.67 per cent of total production) (Table 1, 3). 'Mon Thong' has the largest area of about 83.12 per cent of the total durian area in 2017.

Table 3. Volume of durian production, domestic consumption and export (2007-2017)

Year	Production (tonnes)	Domestic consumption (tonnes)		Export (tonnes)	
		Farm	Farm	Ports	
2007	750,683	528,477	222,206	169,948	
2008	637,790	410,703	227,087	209,381	
2009	661,665	377,627	284,038	263,918	
2010	568,067	332,690	235,377	214,978	
2011	509,424	211,156	298,268	280,006	
2012	524,469	152,523	371,946	365,912	
2013	569,313	182,567	386,746	381,414	
2014	631,775	238,766	393,009	387,554	
2015	601,884	213,362	388,522	381,470	
2016	517,955	86,230	431,725	425,060	
2017	616,121	105,698	510,423	503,205	

Source: Office of Agricultural Economics, 2017

Table 4. Volume and value of export of fresh durian and products (1997 – 2016)

Volume and value of export of fresh durian and products (1997 – 2016)										
Year	Fresh durian		Durian paste		Frozen durian		Oven dried durian		Total	
	Volume (tons)	Value (million Baht)	Volume (tons)	Value (million Baht)	Volume (tons)	Value (million Baht)	Volume (tons)	Value (million Baht)	Volume (tons)	Value (million Baht)
1997	73,043	1,400.652	34	3.304	1,401	333.999			74,478	1,737.955
1998	87,542	2,065.195	33	4.428	2,065	543.250			89,640	2,612.873
1999	111,250	2,126.014	17	2.565	2,126	602.101			113,393	2,730.680
2000	87,607	1,625.885	104	8.783	1,626	742.219			89,337	2,376.887
2001	116,674	2,057.870	163	14.072	2,058	585.587			118,895	2,657.529
2002	85,814	1,737.114	152	19.221	1,737	584.063			87,703	2,340.398
2003	73,342	1,324.214	182	17.104	1,324	675.414			74,848	2,016.732
2004	120,886	1,635.866	142	14.182	1,636	590.817	1	0.354	122,664	2,241.219
2005	132,780	2,190.871	617	43.025	2,191	462.604	15	12.781	135,603	2,709.281
2006	137,390	2,726.860	1,154	72.873	2,727	464.227	33	28.558	141,304	3,292.518
2007	157,474	2,568.265	9,224	415.139	2,568	426.327	682	76.704	169,948	3,486.435
2008	203,127	3,131.902	2,598	152.552	3,132	416.726	524	123.050	209,381	3,824.230
2009	256,172	4,114.406	3,142	182.488	4,114	510.740	490	144.755	263,918	4,952.389
2010	207,501	3,690.338	3,421	234.482	3,690	560.644	366	142.441	214,978	4,627.905
2011	271,949	4,662.525	3,071	229.169	4,663	565.814	323	131.689	280,006	5,589.197
2012	351,124	6,195.219	501	44.172	6,195	734.375	394	193.708	358,214	7,167.474
2013	367,057	7,344.686	230	28.554	7,345	876.563	465	279.196	375,097	8,528.999
2014	369,602	12,435.702	455	58.079	17,143	1,131.328	353	217.521	387,553	13,842.630
2015	358,192	13,246.388	690	82.423	22,187	1,944.775	401	289.652	381,470	15,563.238
2016	403,634	17,505.762	720	90.092	20,365	2,171.233	341	282.889	425,060	20,049.976

Source: Office of Agricultural Economics, 2017

Durian fruits once harvested from the tree could be safely kept for about one week and during this short period, some fruits are processed to be other products. A part is exported to major markets such as China, Hong Kong, Indonesia Taiwan, Vietnam, United States of America, Japan, Malaysia, Singapore, Republic of Korea, Europe and Russia (Tables 5, 6, 7, 8; Fig. 27). The major problem of market for durian including export is the relatively short shelf life. The bad smell of durian fruit is also a great hindrance during the transportation. The smell and taste of durian are two factors that are not preferred by consumers, and hence it was recommended to the consumers who dislike fresh durian to taste durian products such as ice cream, or other desserts from durian. Besides, the frozen durian products and ready-to-eat durian are also other means to promote the export of durian products (Fig. 28).

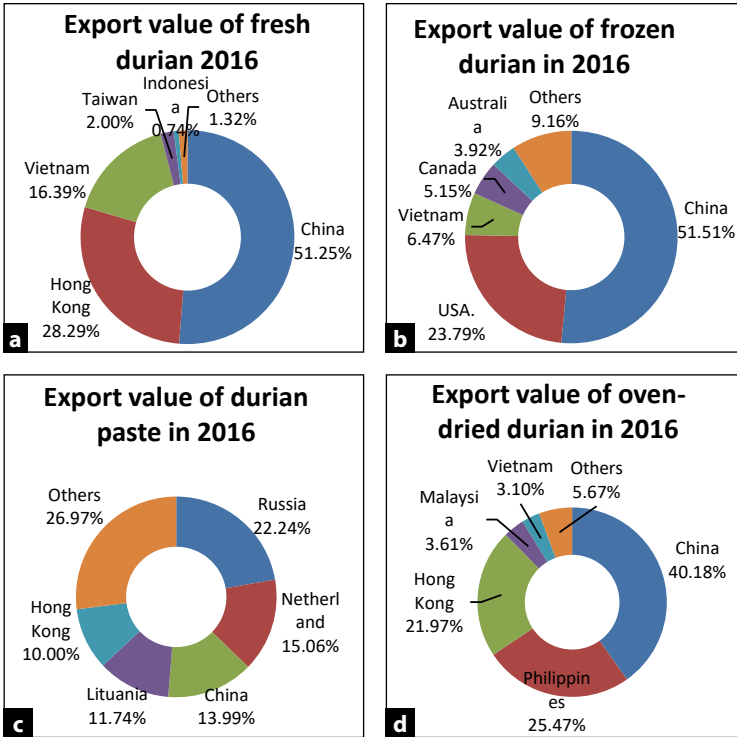


Fig. 27. Export value of (a) fresh durian (b) frozen durian (c) durian paste, and (d) oven dried durian in major countries in 2016.



Fig. 28. Durian export products in supermarkets in other countries: (a) durian packaged in cartons for export to China; (b) durian fruits in carton package for export to China; (c) frozen durian in a supermarket shelves in Seoul, Republic of Korea; (d) ready-to-eat durian flesh in supermarket shelves in Seoul, Republic of Korea

Table 5. Volume and value of export for fresh durian (2007 - 2016)

Volume (tons) and value (million Baht) of fresh durian export in major markets during 2007– 2011										
Country	2007		2008		2009		2010		2011	
	Volume	Value	Volume	Value	Volume	Value	Volume	Value	Volume	Value
China	75,182	1,342.260	93,889	1,551.750	123,892	2,039.932	124,784	2,227.822	142,618	2,500.200
Hong Kong	41,475	536.477	61,513	734.489	86,090	1,180.767	47,708	759.299	84,686	1,225.390
Taiwan	17,857	228.064	20,477	257.014	15,818	195.266	10,254	109.425	13,667	177.632
Indonesia	20,912	380.332	24,071	452.139	27,820	585.503	21,897	470.850	26,305	624.654
Vietnam	65	0.695	118	1.095	66	0.772	98	1.562	148	1.972
Cambodia	-	-	314	4.115	34	0.349	-	-	43	0.606
USA	928	44.703	1,174	68.940	787	46.865	952	56.485	739	47.746
Republic of Korea	32	1.471	10	0.649	50	2.799	58	2.445	120	6.407
Japan	190	10.183	187	11.846	177	11.611	175	11.118	186	9.271
Myanmar	110	1.135	365	3.347	613	11.139	288	12.066	185	5.314
Others	657	21.407	1,009	46.134	826	39.404	1,285	39.265	3,250	63.043
TOTAL	157,407	2,566.720	203,127	3,131.520	256,172	4,114.406	207,501	3,690.338	271,948	4,662.240

Volume (tons) and value (million Baht) of fresh durian export in major markets during 2012– 2016										
Country	2012		2013		2014		2015		2016	
	Volume	Value	Volume	Value	Volume	Value	Volume	Value	Volume	Value
China	204,586	3,944.479	198,875	4,305.396	149,949	5,167.058	158,792	6,575.045	158,081	8,972.544
Hong Kong	111,048	1,524.247	147,803	2,569.083	190,339	6,369.507	164,615	5,475.791	146,321	4,953.194
Taiwan	15,290	227.915	11,364	188.809	11,065	326.017	9,627	351.485	7,740	350.446
Indonesia	18,083	424.004	4,763	136.104	7,271	284.642	5,718	256.082	1,959	129.939
Vietnam	389	7.312	2,377	69.659	9,820	220.261	18,233	491.121	84,850	2,869.429
Cambodia	255	3.315	664	18.505	18	0.747	63	2.683	13	1.116
USA	126	11.929	143	14.204	156	12.550	303	42.118	435	68.964
Republic of Korea	70	4.970	126	8.672	118	8.991	210	14.117	244	18.986
Japan	317	16.013	107	8.672	105	12.417	55	6.021	68	8.076
Myanmar	295	4.185	523	6.461	325	5.993	109	1.320	78	1.269
Others	667	26.849	312	19.122	438	27.519	467	30.606	3,844	131.800
TOTAL	351,124	6,195.219	367,057	7,344.686	369,602	12,435.702	358,192	13,246.388	403,634	17,505.762

Source : Office of Agricultural Economics, 2017

Table 6. Volume and value of exported frozen durian in major markets during 2007 – 2016

Volume (tons) and value (million Baht) of frozen durian export in major markets during 2007– 2011										
Country	2007		2008		2009		2010		2011	
	Volume	Value	Volume	Value	Volume	Volume	Value	Volume	Value	Volume
USA	4,559	185.480	2,756	130.84	3,292	165.101	2,655	165.949	1,812	128.155
China	2,751	29.259	9,165	99.367	11,469	155.52	7,580	147.186	6,998	171.563
Australia	1,506	66.551	1,256	58.763	1,133	61.812	1,200	72.460	1,205	82.268
Canada	1,264	55.653	1,320	58.744	916	49.515	1,022	63.331	1,186	69.852
Taiwan	765	15.545	1,015	14.827	1,463	17.208	1,528	30.191	2,272	45.687
ROK	308	17.498	346	16.303	310	14.02	461	26.856	355	25.955
Hong Kong	1,120	13.200	28	2.745	33	4.068	33	5.083	87	8.669
New Zealand	112	4.931	89	4.263	77	3.596	92	5.338	53	3.185
France	45	9.588	60	7.973	78	11.52	73	11.241	44	7.181
Netherland	136	9.700	117	8.991	92	7.888	103	8.067	95	9.366
Others	344	14.041	159	13.906	904	20.491	693	24.943	217	13.932
TOTAL	12,909	421.449	16,311	416.722	19,768	510.739	15,440	560.644	14,323	565.814

Volume (tons) and value (million Baht) of frozen durian export in major markets during 2012– 2016										
Country	2012		2013		2014		2015		2016	
	Volume	Value	Volume	Value	Volume	Volume	Value	Volume	Value	Volume
USA	3,290	280.497	3,404	328.419	3,163	303.980	3,392	413.130	3,248	516.628
China	4,603	153.487	4,764	198.673	8,288	411.348	13,392	1,114.113	12,496	1,118.362
Australia	1,063	88.643	1,222	116.572	1,077	105.268	573	92.521	358	85.154
Canada	608	48.294	847	78.555	980	122.355	731	103.682	497	111.742
Taiwan	3,438	69.482	2,316	52.149	2,012	48.874	2,053	50.760	1,269	27.978
ROK	345	26.823	402	28.429	431	36.612	287	31.002	109	14.134
Hong Kong	77	15.410	185	24.479	68	19.885	373	42.257	275	65.564
New Zealand	106	7.378	126	12.422	98	8.881	74	8.673	96	20.515
France	68	14.996	47	11.455	56	14.401	48	11.011	51	17.386
Netherland	134	13.365	72	9.413	97	11.823	87	13.109	59	11.940
Others	163	16.000	279	15.987	874	47.901	1,177	64.517	1,906	181.831
TOTAL	13,895	734.375	13,662	876.553	17,143	1,131.328	22,187	1,944.775	20,365	2,171.233

Source : Office of Agricultural Economics, 2017

Table 7. Volume and value of durian paste exported to major markets during 2007 – 2016

Volume (tons) and value (million Baht) of durian paste export in major markets during 2007– 2011										
Volume	2007		2008		2009		2010		2011	
	Volume	Value	Volume	Value	Volume	Volume	Value	Volume	Value	Volume
Russia	2,309	83.885	526	29.757	724	41.886	1,415	92.803	1,046	74.514
Hong Kong	33	4.332	27	5.937	30	6.640	11	6.788	10	4.210
Singapore	31	2.201	10	1.688	11	1.813	12	2.378	17	2.453
USA	1,526	88.400	407	25.099	916	45.438	210	12.012	39	3.291
Ukraine	731	25.120	45	2.803	38	1.877	48	3.005	19	1.542
China	17	0.473	2	0.218	1	0.067	2	0.332	8	1.164
Malaysia	2	0.781	15	0.847	31	1.693	9	0.473	0.40	0.162
Myanmar	-	-	-	-	-	-	-	-	8	1.547
Denmark	19	1.491	-	0.004	0.30	0.076	0.10	0.011	0.30	0.138
Australia	244	12.416	294	16.450	342	18.777	327	19.725	338	22.173
Others	4,310	196.040	1,270	69.749	1,048	64.221	1,386	96.955	1,586	117.976
TOTAL	9,224	415.139	2,598	152.552	3,142	182.488	3,421	234.482	3,071	229.169

Volume (tons) and value (million Baht) of durian paste export in major markets during 2012– 2016										
Volume	2012		2013		2014		2015		2016	
	Volume	Value	Volume	Value	Volume	Volume	Value	Volume	Value	Volume
Russia	168	9.689	158	11.750	131	10.253	244	21.081	199	20.037
Hong Kong	6	5.373	8	7.195	17	9.670	15	7.938	14	9.013
Singapore	10	2.331	7	1.533	2	0.496	13	2.123	18	3.199
USA	7	1.279	6	1.511	13	2.954	5	1.241	4	0.410
Ukraine	-	-	16	1.278	2	0.134	-	-	5	0.608
China	11	1.922	3	0.900	4	0.847	6	1.059	72	12.601
Malaysia	1	0.350	1	0.739	2	1.178	0.36	0.280	1	0.130
Myanmar	10	2.062	3	0.676	7	1.722	0.02	0.031	-	-
Denmark	-	-	4	0.580	0.20	0.058	36	4.320	-	-
Australia	65	4.362	5	0.495	24	2.338	2	0.772	2	0.775
Others	222	16.772	19	1.896	253	28.430	369	43.577	405	43.319
TOTAL	501	44.139	230	28.554	455	58.079	690	82.423	720	90.092

Source : Office of Agricultural Economics 2017

Table 8. Volume and value of oven-dried durian export in major markets during 2007 – 2016

Volume (tons) and value (million Baht) of oven-dried durian export in major markets during 2007– 2011										
Country	2007		2008		2009		2010		2011	
	Volume	Value	Volume	Value	Volume	Value	Volume	Value	Volume	Value
China	118	28.871	311	75.429	97	76.465	141	84.576	133	75.509
Hong Kong	114	26.240	124	33.185	166	43.993	85	30.387	101	31.049
Philippines	0.15	0.058	-	-	3	0.072	0.10	0.001	0.03	0.0003
Malaysia	15	2.125	0.40	0.208	12	2.704	34	6.023	45	8.131
Myanmar	-	-	-	-	1	0.004	1	0.005	5	3.175
Singapore	31	4.548	18	2.630	15	3.746	20	9.000	2	2.259
Taiwan	30	2.633	10	1.302	119	2.954	54	1.558	3	1.486
USA	22	2.667	22	4.058	24	6.599	14	3.854	20	5.193
ROK	18	0.990	17	1.697	30	2.237	1	1.145	0.30	0.107
Netherland	-	0.017	-	-	-	-	-	-	-	-
Others	334	8.555	23	4.543	22	5.981	16	5.893	14	5.065
TOTAL	682	76.704	524	123.052	490	144.754	366	142.441	323	131.973

Volume (tons) and value (million Baht) of oven-dried durian export in major markets during 2012– 2016										
Country	2012		2013		2014		2015		2016	
	Volume	Value	Volume	Value	Volume	Value	Volume	Value	Volume	Value
China	148	106.272	235	175.841	204	155.936	185	139.026	164	113.677
Hong Kong	142	39.780	90	34.050	15	19.612	23	32.520	41	62.152
Philippines	10	6.399	25	18.304	-	-	93	70.904	90	72.041
Malaysia	40	11.862	39	13.628	13	10.390	6	6.643	7	10.217
Myanmar	14	12.425	17	11.898	46	19.129	67	22.613	9	5.285
Singapore	8	5.447	27	9.255	1	1.962	1	1.312	1	1.041
Taiwan	1	0.859	2	4.613	1	1.774	2	3.328	5	4.350
USA	20	5.708	11	3.202	1	0.686	6	4.717	1	0.610
ROK	0.02	0.039	1	1.508	0.50	0.814	0.21	0.309	0.35	0.321
Netherland	0.10	0.053	3	1.412	2	1.059	-	-	0.10	0.049
Others	10	4.697	15	5.484	69	6.159	17	8.279	23	13.147
TOTAL	392	193.540	465	279.196	353	217.521	401	289.652	341	282.889

Source: Office of Agricultural Economics, 2017

9 Problems, Constraints and Limitations

In the past, the tropical fruits were given the least priority. However, at present significant attention is being given to tropical fruits due to the advancement in technology, and the development of improved varieties for enhancing production as well as value addition and development of new products. However, there are still several problems that need to be addressed. One of the major problems is the extinction of genetic resources. Although different kinds of durian could be conserved in the natural environment in the national parks to protect the plant genetic resources from extinction, there are also programmes for the collection and conservation of genetic resources in experimental plots in different horticultural research centres such as the Chanthaburi Horticultural Research Center, in which there is a collection of eight different species of durian such as *D. graveolens*, *D. griffithii*, *D. kutejensis*, *D. lowianus*, *D. malaccensis*, *D. masoni*, *D. oxleyanus*, and *D. zibethinus*. Also, there exists a collection of 600 durian varieties.

But, the *in situ* conservation of durian would require a lot of space, maintenance cost, intensive labour, and risk for pests and diseases, climatic uncertainty, problem with the storage of durian genetic resources in the long-term which is still unsuccessful due to the fact that durian seeds are recalcitrant and inhibit germination at low moisture content. The durian varieties, Chanthaburi 1, Chanthaburi 2, and Chanthaburi 3, were recommended and released by the Department of Agriculture in 2006, and were already patented. These varieties were multiplied by establishing in the propagation plots, then propagating the plants by cleft grafting in the Chanthaburi Horticultural Research Center, and selling the saplings of these recommended varieties at a price of 25 Baht per sapling. Besides, since 2007 the saplings were distributed to farmers at the rate of 5 seedlings per farmer and thus distributed 5,000 saplings of the varieties, Chanthaburi 1, Chanthaburi 2, and Chanthaburi 3.

The production has not yet reached the market, thus, there is not enough data available to work out the profits. The saplings were distributed to farmers and were planted about 4-5 years ago. Some of the durian trees have just started producing fruits in the first year, and still have very low yields and are consumed at home. The production is not enough to be marketed and, hence there is no available data yet on the consumer's acceptance and preference. However, in March 2016, some export of Chanthaburi 1, Chanthaburi 2, Chanthaburi 3 and other varieties was done first to China. There was consumer acceptance for these varieties and continued to import for 2017. Also, some of them were put on shelf in the local market at Chanthaburi and in the supermarket at Bangkok.

10 Future Prospects

For the conservation and tissue culture of the plants with recalcitrant seeds especially in the tropical fruit trees like durian, there is an urgent need to have a tissue culture genebank, in order to save the space required for conservation and maintenance. However, the technique for conservation that is most significant is conservation of plant genetic resources that have recalcitrant seeds or cryopreservation at a temperature of -196°C , which is a long-term storage (Roberts *et al.*, 1984). Withers (1980) and Bajaj (1985) recommend that the seeds have short life, and therefore the methodology that is most successful for the conservation of genetic resources is the use of cryopreservation of the embryos. Another important methodology is the conservation of plant genetic resources through the establishment of seedling banks in which the seedlings or saplings will be kept in the nurseries with low light, and low temperature, in order to slow down the growth of the seedlings similar to bonsai. Once brought under normal conditions and provided with suitable sunlight and suitable temperature, the seedlings can grow normally.

Therefore, concerted research efforts need to be made for the conservation of genetic resources, use of biotechnological approaches and breeding of new varieties resistant to root and stem rot and other diseases, insect pests such as the seed borer, stem borer, and at the same time having good quality with desirable characteristics in accordance with the requirements of market, consumers or suitability for processing and product development with increased nutritive value.

For varietal improvement, the normal methods of selection and breeding should be continued especially in developing new varieties. Sincere efforts need to be made to popularize already certified and recommended varieties of the Department of Agriculture such as the new hybrids Chanthaburi 1, Chanthaburi 2, Chanthaburi 3, Chanthaburi 4, Chanthaburi 5, Chanthaburi 6, and Chanthaburi 7, Chanthaburi 8, Chanthaburi 9 through expanding the planting area to replace the old varieties like Chanee variety that fetches low price in the market. The cultivation of variety Chanthaburi 1 that has a mild odour and is referred to as "Odourless Durian" should be expanded to increase the volume of production for the new market for consumers that dislike durian odour in countries such as the USA, Europe, Japan, Republic of Korea, etc.

Besides, the research and development on the production system, processing, value addition and product development, value chain and effective marketing system, the traceability system, efficient packaging and transportation for maintaining the quality and longer shelf life are also very important so as to make available the quality products at the destination of consumers so as to sustain the production of durian on a long-term basis.

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Asia-Pacific Association of Agricultural Research Institutions

Asia-Pacific Association of Agricultural Research Institutions (APAARI) was established in 1990 at the initiative of Food and Agriculture Organization of the United Nations and most of the National Agricultural Research Systems (NARS) of the Asia-Pacific region. Its mission is to promote the development of National Agricultural Research Systems in Asia-Pacific region through facilitation of inter-regional, inter-institutional and international partnerships.

APAARI's vision is that Agricultural Research for Development (ARD) in the Asia-Pacific region is effectively promoted and facilitated through novel partnerships among NARS and other related organizations so that it contributes to sustainable improvements in the productivity of agricultural systems and to the quality of the natural resource base that underpins agriculture, thereby enhancing food and nutrition security, economic and social well being of communities and the integrity of the environment and services it provides.

The overall objectives of APAARI are to foster the development of agricultural research in the Asia-Pacific region so as to:

- Promote the exchange of scientific and technical information
- Encourage collaborative research
- Promote human resource development and capacity building
- Build up organizational and management capabilities of member institutions
- Strengthen cross-linkages and networking among diverse stakeholders

APAARI's strategic thrusts are:

- Building research partnerships
- Regional research networking
- Policy advocacy for ARD
- Information dissemination
- Human resource development
- Technology transfer

To know more about APAARI, please visit: <http://www.apaari.org>

Important APAARI Publications

Expert Consultations/Meetings/Training Programs

- Scaling Conservation Agriculture for Sustainable Intensification in South Asia – Proceedings and Recommendations (2017)
- Expert Consultation on Best Practices in Agri-food Innovations in Asia and the Pacific – Proceedings & Proceedings (2016)
- 14th General Assembly, 3 November 2016 – Proceedings
- High Level Policy Dialogue on Investment in Agricultural Research for Sustainable Development in Asia and the Pacific, 8-9 December 2015 – Proceedings
- The Executive Committee Meeting of APAARI, 8 September 2016 – Proceedings
- The Executive Committee Meeting of APAARI, 10 December 2015 – Proceedings
- Workshop on Development of Communication Strategies for Adoption of Agri-Biotechnology in the Asia-Pacific Region, 28-29 September 2015 – Proceedings
- Capacity Development Workshop On Planning, Monitoring and Evaluation towards Measuring Outcomes and Impacts, 3-7 August 2015 – Proceedings
- Expert Consultation on Assuring Food Safety in Asia-Pacific, 4-5 August 2014 – Proceedings
- 13th General Assembly Meeting, 1 November 2014 – Proceedings
- 12th Asian Maize Conference 'Maize for Food, Feed, Nutrition and Environmental Security', 30 October-1 November 2014 – Proceedings
- Expert Consultation on Promotion of Medicinal and Aromatic Plants in the Asia-Pacific Region, 2-3 December 2013 – Proceedings
- Asia-Pacific Symposium on Molecular Breeding 1-3 October 2013 – Proceedings
- Regional Workshop on Youth and Agriculture: Challenges and Opportunities : Proceedings (2013)
- Expert Consultation on Strengthening Linkages between Research and extension to Promote Food and Nutrition Security : Proceedings (2013)
- NARS-CGIAR Interactive Session for Strengthening Partnership in South Asia : Proceedings (2013)
- National Workshop on Outscaling Farm Innovation : Proceedings (2013)
- International Conference on Innovative Approaches for Agricultural Knowledge Management: Global Extension Experiences: Proceedings (2013)
- Training Workshop on Open Access Publishing Using Open Journal Systems: Proceedings (2013)
- Foresight and Future Pathways of Agricultural Research Through Youth: Proceedings and Recommendations (2013)
- Expert Consultation on Managing Trans-boundary Diseases of Agricultural Importance in the Asia-Pacific: Proceedings and Recommendations (2013)
- Stakeholders' Dialogue on Biosafety Regulations in the Asia-Pacific Region Proceedings and Recommendations (2013)
- Regional Consultation on Agricultural Research for Development : Proceeding and Recommendations (2013)
- Regional Consultation on Collective Actions for Opening Access to Agricultural Information and Knowledge in the Asia-Pacific Region: Proceedings (2012)
- Prioritization of Demand-driven Agricultural Research for Development in South-Asia (2012)
- Regional Consultation on Improving Wheat Productivity in Asia: Proceedings and Recommendations (2012)

- Workshop on Climate-Smart Agriculture in Asia: Research and Development Priorities: Proceedings and Recommendations (2012)
- First Global Conference on Women in Agriculture (GCWA): Proceedings (2012)
- Regional Workshop on Implementation of Suwon Agrobiodiversity Framework: Proceedings (2012)
- Regional Dialogue on Conservation Agriculture in South Asia: Proceedings and Recommendations (2012)
- Expert Consultation on Agricultural Biotechnology, Biosafety and Biosecurity: Proceedings and Recommendations (2012)
- Workshop on Moving Beyond Strategy to Improve Information and Knowledge Management for Agricultural Development in the Pacific Islands Countries and Territories: Proceedings (2012)
- Stakeholders' Interface on GM Food Crops : Proceedings and Recommendations (2011)
- Expert Consultation Meeting on Postharvest and Value Addition of Horticultural Produce – Strengthening Technologies for Linking Farmers to Market : Proceedings and Recommendations (2011)
- International Symposium on Sustainable Agricultural Development and Use of Agrobiodiversity in the Asia-Pacific Region (2010)
- APAARI-ADB Asia-Pacific Consultation on Agricultural Research for Development (AR4D) in Asia and the Pacific-The Way Ahead (2009)
- Expert Consultation on Biopesticides and Biofertilizers for Sustainable Agriculture (2009)
- Symposium on Global Climate Change : Imperatives for Agricultural Research in Asia-Pacific (2008)
- Expert Consultation on Agricultural Biotechnology for Promoting Food Security in Developing Countries (2008)
- Workshop on Development and Management of ARD Information Resources (2008)
- Asia-Pacific Regional Workshop on Agricultural Research for Development (2008) (for establishment of NGO Consortium-NAARAP)
- Expert Consultation to Review Progress of Agricultural Research Networks and Consortia in Asia-Pacific (2007)
- ICT/ICM Sensitization and Awareness Building Workshop for NARS Leaders and Senior Managers (2007)

Success Stories

- Success Stories on Information and Communication Technologies for Agriculture and Rural Development (2015), Gerard Sylvester
- ITC e-Choupal – Innovation for Large Scale Rural Transformation : A Success Stories (2014), Joyoti Chaliha and Shoma Bhattacharya
- Wax Apple Industry in Taiwan : Success Stories (2014), Chi Cho Huang *et al.*
- Agricultural Information and Knowledge for All : Success Stories on ICT/ICM in AR4D in Asia and the Pacific Region (2013)
- Linking Farmers to Market: A Success Story of Lettuce Export from Chinese Taipei (2012), Min-Chi Hsu *et al.*
- Biofuel Growers Market Network (2012), K. Narayan Gowda
- Success Stories on ICT/ICM in AR4D in Asia and the Pacific Region, Malcolm Hazelman and S. Attaluri
- Short Duration Mungbean: A New Success in South Asia (2010), M.L. Chadha
- Taro Improvement and Development in Papua New Guinea (2009), Abner Yalu *et al.*
- Cotton-Wheat Production Systems in South Asia: A Success Story (2008), C.D. Mayee *et al.*
- Linking Farmers to Market: Some Success Stories from Asia-Pacific Region (2008), Rosendo S. Rapusas *et al.*

- Rainbow Trout (*Oncorhynchus mykiss*) Culture in the Himalayan Kingdom of Nepal (2005/1), A.K. Rai *et al.*
- Sustaining the Green Revolution in India (2004/3), S. Nagarajan
- Lentil Improvement in Bangladesh (2004/1), Ashutosh Sarker *et al.*
- Success Story on the Control of Newcastle Disease in Village Chickens (2003/1), Robyn Alders
- Hybrid Rice in China - A Success Story (1994), Lou Xizhi and C.X. Mao
- Tilapia Farming in the Philippines - A Success Story (1994), Rafael D. Gurrero III
- Dairying in India - A Success Story (1994), R.P. Aneja

Status Reports

- Jackfruit Improvement in the Asia-Pacific Region: A Status Report (2012)
- Information and Communication Technologies/Management in Agricultural Research for Development in the Asia-Pacific Region : A Status Report (2011)
- Strengthening of Plant Genetic Resources for Food and Agriculture: Conservation and Utilization in the Pacific (2011)
- Bt-Cotton in India – A Status Report (2nd Edition) (2009)
- Production and cultivation of Virus-Free Citrus Saplings for Citrus Rehabilitation in Taiwan (2008)
- Biosafety Regulation of Asia-Pacific Countries (2008)
- Micropropagation for Quality Seed Production in Sugarcane in Asia and the Pacific (2008)
- Commercialization of Bt-Corn in the Philippines (2005)
- Information and Communication Technologies in Agricultural Research for Development in the Asia-Pacific-Region (2004)

Other Publications

- Webinar with Universities on Capacity Development for Agricultural Innovation, Bringing System-wide Change in Asia-Pacific : Synthesis Report (2017)
- High Level Policy Dialogue on Investment in Agricultural Research for Sustainable Development in Asia and the Pacific : Papers Presented (2015)
- High Level Policy Dialogue on Investment in Agricultural Research for Sustainable Development in Asia and the Pacific : Abstracts of Presentations (2015)
- High Level Policy Dialogue on Investment in Agricultural Research for Sustainable Development in Asia and the Pacific : Scoping Paper (2015)
- 12th Asian Maize Conference 'Maize for Food, Feed, Nutrition and Environmental Security' : Extended Summary (2014)
- 12th Asian Maize Conference 'Maize for Food, Feed, Nutrition and Environmental Security' : Abstracts (2014)
- Benchmarking Agricultural Research Indicators Across Asia-Pacific : ASTI Regional Synthesis Report
- Training Workshop on Open Access Publishing Using Open Journal Systems
- APAARI on CD
- Priorities for Agricultural Research for Development in South-Asia
- Improving Wheat Productivity in Asia
- Fifteen Years of APAARI - A Retrospective
- APAARI Vision - 2025
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