THAILAND’S BANANA, COCONUT, MANGO AND PAPAYA INDUSTRIES: A COUNTRY REPORT

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ABSTRACT

Thailand has the privilege of having a stable warm season which is ideal for cultivating a wide variety of tropical fruit throughout the year. Banana, ‘Aromatic Coconut’, mango and papaya could be grown practically anywhere in Thailand. The main growing areas of these fruit crops are mainly at the central region of Thailand. Mango and ‘Aromatic Coconut’ are the important economic crops of the country. These fruit have been exported to China, Japan, and USA earning impressive export value.

In Thailand, there are only a few names of growers with big pieces of land. Majority of tropical fruit growers are small land growers, some owning even smaller than 0.8 hectare (5 rai). Although with limited resources, they organize themselves together, collaborate production efforts and assure consistent product supply, share knowledge and improve quality, and eventually receive better returns. The Thai Government realizes the importance of these fruit crops and set up new strategies and budget for supporting the tropical fruit industries with new product development, new market development, production technology, etc.

As an example, the Department of Agriculture worked together with the industries and set up the heat vapor treatment to eliminate the egg of oriental fruit fly in mango fruit. Since then Thailand exports million tons of fresh mango fruit to Japan.

The tropical fruit market demands for better quality products. Thai growers improve their techniques on propagation, cultivation and production, and protect the quality of true-to-type planting materials and fruit products.

Good Agricultural Practices (GAPs) is still not well developed and practiced in Thailand, even with the government setup which promotes the streamlined ThaiGAP. However, growers involved in export trade, like mango growers and coconut growers are actively joining the program with an obvious incentive.

In 2010, there was a big invasion of coconut hispine beetle in the coconut growing area. In 2012, coconut black-headed caterpillar also destroyed many plants and caused a big damage in the ‘Aromatic Coconut’ growing area in Thailand. Oriental fruit fly is another constraint to mango, papaya and banana in Thailand. Thai growers still apply chemicals to combat these pests and diseases. Few growers in the coconut industry develop bio-control methods to control the constraints. Government organizations setup training programs and help growers in raising their parasite insects by themselves. The industries aim for less chemical contamination and better food safety. Droughts and floods become more unpredictable abiotic constraints. The 2011 big flood destroyed large areas of mango and coconut plantations in the central region of Thailand. Many young plants were destroyed.

Harvesting tropical fruit is very labor intensive. Very soon, the ‘Aromatic Coconut’ industry will have to confront with labor shortage from fruit picking skills to trimming and polishing duties. Transporting and exporting fresh fruit are always a challenge. ‘Aromatic Coconut’ industry manages to repack the coconut juice into modern packaging, like tetra pack. An innovative idea applies a pull-tab on a polished coconut fruit, with the coconut juice consumed easily like soft drink. Mango and banana export is now limited to fresh fruit; recently the industries explore value-added fruit products, like banana syrup, and address the changing consumer preferences.

Keywords: Tropical fruit, banana, coconut, mango, fruit production, fruit processing
INTRODUCTION

Mango is one of the most important economic fruit crops of Thailand. It occupies the largest production area all over the country. In 2012, yielded growing area of mango was 327,405 hectares (2,046,280 rai), with the 2,985,530 tons of fresh fruit produce and export value was more than $US67 million (2,000 million baht).

Banana is another fruit crop that can be exported. Baby banana or 'Kluai Kai' in Thai, is exported. About 18% of its fresh fruit produce is exported mainly to China, and the demand is continuously increasing.

'Aromatic coconut' is a very popular fruit crop, due to its remarked high nutrition value as well as its good taste. This makes the booming of 'aromatic coconut' business in Thailand. The new growing area is also increasing rapidly to meet the demand.

Papaya production in Thailand is growing bigger in volume and is now ranked as number 8 in the world, but the export value is still very low (FAO, 2013). Besides, the growing area is decreasing due to the invasion of insects and diseases. However, if these obstacles could be removed or decreased, it should become a promising new crop which has high potential in the export market.

METHODOLOGIES

All information in this report were summarized from primary and secondary data sources. No delegated data collection was planned and no primary data were specific to this report. The primary data sources were mostly summarized from the author’s research works on ‘Aromatic Coconut’, mango and other tropical fruit, under the research projects of Kasetsart University. These were collective information including interviews with growers, collectors as well as fruit exporters. The secondary data sources were mostly generic institutional data from Thai Government sections, including the Department of Agriculture (DAO), the Organization of Agricultural Economics (OAE), the Department of Agricultural Extension (DAE) and the National Bureau of Agricultural Commodity and Food Standards, which is under the Ministry of Agriculture and Cooperatives. Other government sections are the Custom Bureau, and the Ministry of Commerce. Sources of primary data and secondary data were not cited in this report, and could be available upon request.

BANANA

Banana is a common fruit crop in Thailand. Other than commercial banana plantation for fresh fruit production, banana also grows naturally and randomly in the warm and humid tropical climate everywhere in the country. Thai people consume almost every part of the banana plant, ripe banana fruit is consumed as fresh fruit; raw banana fruit is used as vegetable in Thai food; mature banana fruit is grilled or sun-dried and eaten as popular Thai snacks. Banana flowers, banana leaves, banana pastes and banana chips are used as everyday ingredients in Thai cooking.

Recently Charoen Pokphand Group (a Thai food industry) introduced an individually packed single banana in the 7-11 stores (Fig. 1).

The main varieties of Thai banana are 'Hom' banana, especially the 'Hom Thong' variety (Gros Michel; AAA group), 'Kai' banana or baby banana (AA group) and 'Namwa' banana (AB group) (Fig. 2). The Hom Thong banana and the Kai banana are mostly grown for export; the 'Namwa' banana, on the other hand, are mainly grown for domestic consumption.
Thailand National Bureau of Agricultural Commodity and Food Standards developed a quality standard for banana fresh fruit that sorts the quality of banana into three classes:

- extra class - no flaw at all
- class I - a little bit of flaw
- class II - more flaw but not more than 4 cm² and only at the skin but not in the flesh

The quality standard also describes the general characteristics of banana as follows:

- whole complete fruit
- firm fruit flesh
- true-to-type cultivar
- no visible contamination
- no bruise on the skin
- no abnormal shape, end of stem does not wilt nor has fungi
- no pest or disease
- no dried part of flower attached
- no injury symptom from low or high temperature
- no obvious moisture on the skin
- no abnormal smell or taste

**Yield and trade**

The production of the 'Hom Thong' banana is quite steady for some years. The production of 'Kai' banana was badly damaged by the 2011 flooding, and the growing area was affected.

Banana growing brings good financial benefit in relatively short growing cycle. In the domestic market, prices of banana varieties are slightly different. In terms of price, 'Hom Thong' banana and 'Kai' banana are higher, from 25 to 40 baht; 'Namwa' banana is from 10 to 20 baht. Products for export are generally in higher quality and marked in much higher pricing; for example, in 2012, 'Hom Thong' banana for export was priced about five times for domestic consumption.
Most Thai growers channel their products for domestic trade; only few growers aim for the export market. Although 'Hom Thong' banana has higher export price/ton than that of the 'Kai' banana; yet 'Kai' banana has an increasing trend of high export demand, especially for the China market in which 'Kai' banana is locally called 'Ti Huang Jiao, 天皇蕉'. Table 1 shows the domestic and export yield and trade of the 'Hom Thong' banana; while Table 2 shows those of the 'Kai' banana. Most Thai banana growers are small land farmers; some may have small piece of land not more than 0.8 hectare. However, small growers setup coop system and organization that allow them to compete with good quality and sustainable quantity. In Petchaburi province, the main area of the 'Hom Thong' banana growing area, via the coop system, many small growers reach the quality for export trade.

### Table 1. Yield and trade of 'Hom Thong' banana (Source: Commodity 55, OAE)

<table>
<thead>
<tr>
<th></th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>No. of growers</strong></td>
<td>15,301</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Yielded area (ha)</strong></td>
<td>13,832</td>
<td>13,704</td>
<td>13,768</td>
</tr>
<tr>
<td><strong>Yield /ha (kg)</strong></td>
<td>449</td>
<td>431</td>
<td>434</td>
</tr>
<tr>
<td><strong>Domestic (ton)</strong></td>
<td>235,579</td>
<td>240,771</td>
<td>231,031</td>
</tr>
<tr>
<td><strong>Domestic (baht/ton)</strong></td>
<td>5,038</td>
<td>4,905</td>
<td>5,587</td>
</tr>
<tr>
<td><strong>Net price (baht/ton)</strong></td>
<td>4,611</td>
<td>5,359</td>
<td>5,065</td>
</tr>
<tr>
<td><strong>Export (ton)</strong></td>
<td>6,740</td>
<td>4,632</td>
<td>2,169</td>
</tr>
<tr>
<td><strong>Export (baht/ton)</strong></td>
<td>14,112</td>
<td>17,720</td>
<td>26,404</td>
</tr>
<tr>
<td><strong>Export value (baht)</strong></td>
<td>95.12 millions</td>
<td>82.07 millions</td>
<td>57.26 millions</td>
</tr>
</tbody>
</table>

| Export country           | Japan, Hong Kong, Singapore |
| Competition              | Philippines, Ecuador        |

Source: Office of Agricultural Economy

### Table 2. Yield and trade of 'Kai' banana

<table>
<thead>
<tr>
<th></th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>No. of growers</strong></td>
<td>11,471</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Yielded area (ha)</strong></td>
<td>9,374</td>
<td>5,166</td>
<td>5,072</td>
</tr>
<tr>
<td><strong>Yield /ha (kg)</strong></td>
<td>457</td>
<td>446</td>
<td>447</td>
</tr>
<tr>
<td><strong>Domestic (ton)</strong></td>
<td>153,005</td>
<td>74,397</td>
<td>73,129</td>
</tr>
<tr>
<td><strong>Domestic (baht/ton)</strong></td>
<td>3,861</td>
<td>3,953</td>
<td>4,815</td>
</tr>
<tr>
<td><strong>Net price (baht/ton)</strong></td>
<td>8,514</td>
<td>9,003</td>
<td>9,012</td>
</tr>
<tr>
<td><strong>Export (ton)</strong></td>
<td>14,490</td>
<td>15,503</td>
<td>15,471</td>
</tr>
<tr>
<td><strong>Export (baht/ton)</strong></td>
<td>6,953</td>
<td>data error</td>
<td>8,955</td>
</tr>
<tr>
<td><strong>Export value (baht)</strong></td>
<td>101 millions</td>
<td>data error</td>
<td>138.54 millions</td>
</tr>
</tbody>
</table>

| Export country           | China, Hong Kong, Vietnam |
| Competition              | no information            |

Source: commodity 55, OAE
In Chantaburi province, the main area of the 'Kai' banana growing area, the growers have good knowledge and experiences in growing tropical fruit such as durian and mangosteen for some decades; they support each other and now manage exporting 'Kai' banana to China.

Government setup legislation that banana is one of the crops in which propagation must be retained within the country. Government agricultural strategy focuses on ‘Hom Thong’ banana and ‘Kai’ banana for their export trade, especially to China and Japan; ‘Namwa’ banana is kept for domestic consumption. For export, there will be challenges on postharvest technology, logistics and transportation. Details of the strategies are listed in Table 3.

Table 3. Government agricultural strategy on ‘Hom Thong’ and ‘Kai’ banana

<table>
<thead>
<tr>
<th>Strategies</th>
<th>Goal</th>
<th>Present status</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Increase production efficiency by deploying GAPs</td>
<td>1. All year product, in every part of Thailand</td>
<td></td>
</tr>
<tr>
<td>2. Promote contract farming</td>
<td>2. ‘Hom Thong’ banana main production areas are Chantaburi, Chumporn, Petchaburi, Nongkai, Saraburi, Nonthaburi, Nakhon Sawan provinces</td>
<td></td>
</tr>
<tr>
<td>3. Export more to China and Japan in the free trade under JTEPA (Japan-Thailand Economic Partnership Agreement) quota</td>
<td>Develop quality and expand exports</td>
<td>3. ‘Kai’ banana main production areas are Chantaburi, Kamphaeng Petch provinces</td>
</tr>
<tr>
<td>4. Develop packaging for long distance logistics</td>
<td>4. Main variety ‘Hom Thong’ banana; ‘Kai’ banana is catching up</td>
<td></td>
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</tbody>
</table>

In Thailand, most banana plants are propagated by either whole suckers or sucker division. Tissue culture is not popular for banana propagation since it is expensive and needs higher skill. Planting materials for banana are propagated by fruit tree nurseries in the country. They are easily available everywhere. Some growers choose to prepare their own planting materials for meeting specific production needs.

Most commercial available suckers are about 30 cm in height, true-to-type, with no disease and no contamination (Fig. 3-1). Price of the suckers for the ‘Hom Thong’ banana is about 40 baht; that for the ‘Hom Karieng’ and ‘Hom Chan’ banana are about 120 baht; and 20- to 50 baht for the ‘Kai’ banana; while that for the ‘Namwa’ banana is about 20 to 50 baht.

In fruit nurseries, growers select the whole sucker with narrow leaves, that is usually a bigger sucker and will grow faster in planting. When planting materials are not enough, growers will divide the whole sucker by themselves, into four smaller longitudinal pieces (Fig. 3-2). Growers will also treat the suckers with fungicide and root promoting substances. About 20 to 30 days after the set into the media, the new banana plants will grow accordingly, in slightly different timing.

** Cultivation **

Due to the warm and humid climate in Thailand, banana grows rapidly and steadily. From planting to first harvest, ‘Hom Thong’ banana and ‘Kai’ banana take about eight to nine months, while ‘Namwa’ banana takes about 12 months. Fruit bearing life span in ‘Kai’ banana is about two years for three crops. Some growers keep the banana plant for four years if the tree is still fertile. From flowering to harvest, ‘Hom Thong’ banana takes 13 to 15 weeks, ‘Kai’ banana takes 6 to 8 weeks, and ‘Namwa’ banana takes 14 to 16 weeks.

Although banana can grow all-year in Thailand, it grows better during the rainy season. Banana prefers
well drainage soil with pH 4.5 to 7.6, and watering three to four days per week. Fertilizers, manure or compost and chemical fertilizers such as 46-0-0 and 15-15-15 or 16-16-16 are also applied to banana plants. In ‘Kai’ banana, fertilizer is applied four times, 1) one to two months after planting; 2) three to four months after planting; 3) five to six months after transplanting; and 4) about seven months after transplanting which at this stage banana will start to flower. Generally, phosphorus and potassium are always available in the soil since the growers use to apply 15-15-15 or 16-16-16 formula.

Planting density for ‘Hom Thong’ banana is 3.5x3.5m; that for ‘Kai’ banana is 2x2m or 2.5x2.5m; and that for ‘Namwa’ banana is 2.5x2.5m or 2.5x3.0m. For growing suckers, a 50x50x50cm ground hole is recommended. When the planting material is from the whole sucker, then new leaf grows after 15 days after planting. Four months after planting, only one to three healthy suckers will be kept, for decreasing food reserve competition. After fruit setting (with five to six expanded hands), the tip of inflorescence will be removed. Then banana bunches will be bagged to protect the fruits from insects.

Pests and diseases

The diseases often found in Thai banana plantation are as follows:

1) Yellow sigatoga is the most damaging disease that is caused by fungus (*Pseudocercospora musae*) in Thai banana, especially the ‘Kai’ banana. Severe damage during the rainy season and can also occur at any growth stage of the banana plant. It is always found in the lower leaves of the banana plant with a brown scar.

2) Root rot is also a damaging disease in ‘Kai’ banana. It is also caused by fungus (*Fusarium oxysporum*). Growers perform preventive diagnosis of this disease at the young stage of the banana plant while the plant is in the fruit nursery. If specific wilting symptom is identified (part of the root changing from white to brown), then the complete plant will be destroyed.

Other diseases that have been found in Thai banana plantations are:

3) Crown rot caused by fungus (*Colletotrichum musae* and *Fusarium* spp). This disease is found at the harvest time and the banana fruit is in the ripe stage.

4) Cordona leaf spot caused by fungus (*Cordona musae*).

5) Fruit anthracnose caused by fungus (*Colletotrichum musae*).

6) Enlarged leaf spot caused by *Pestlotiopsis palmarum*.

7) Brown spot caused by *Nirospora musae* or *Curvularia* sp.

8) Phaeoseptoria leaf spot caused by *Phaeoseptoria musae*.

9) Panama disease caused by *Fusarium oxysporum* f. sp. cubense. This disease will be spread easily in clay soil or bad drainage soil.
**Insect pests**

1) Banana weevil borer (*Cosmopolites sordidus*) destroys root and sucker. This is a serious current problem in Thai banana plantations.
2) Banana stem weevil (*Odoiporus longicollis*).
3) Banana leaf and fruit beetle (*Nodostoma viridipennis*).
4) Hawaiian flower thrips (*Thrips hawaiiensis*) destroys fruit skin.
5) Leaf roller, banana skipper (*Erionota torus torus* or *Erionota thrax*).
6) Leaf eating caterpillar (*Orgyia poetica*).
7) Common cutworm (*Spodoptera litura*) eating leaf blade.
8) Case worm or bag worm (*Macarea corbetti*).
9) Oriental fruit fly (*Bactocera dorsalis*).

Fruit brown spot symptom is often found in ‘Kai’ banana. This is a biochemical change when the fruit starts to ripe. The brown spot is quinone that is caused by the reaction of phenolic compound and polyoxidase enzymes. Keeping the fruit at the temperature 12 to 18 °C would delay this symptom in about five days. Other methods are wrapping the banana fruit with PVC plastic bag, waxing or heat shock treatment by putting the banana under 42 °C for 18 hour; these methods will decrease the fruit brown spot symptom. (Trakulnaleumsai et al., 2006; Promyou et al. 2008).

Some growers protect the ‘Kai’ banana plants by removing old and dried leaves frequently when the plant is about four months old until harvest. This effectively prevents the spread of yellow sigatoga disease.

Other methods also applied in the Thai banana plantation, like dipping young banana plant in fungicide before planting that prevents the plant from root rot disease; and spraying insecticide during blooming to prevent the young banana fruit from thrips. For export quality, Thai growers wrap the ‘Hom Thong’ banana and ‘Kai’ banana fruit with bags (Fig. 4). In case of severe invasion, related government organizations will deploy actions and regulations to cease the damage by diseases and insects.

Implementing Good Agricultural Practices (GAPs) will effectively manage the quality of the plantation as well as the constraints from diseases and insects. Currently, GAPs is not mandatory in Thailand. Thai Government organizations set up the Thai GAP that is endorsed by and is equivalent to the Global GAP. Government organizations persuade growers joining the Thai GAP with incentive on less cost and simplified procedure.

Growers also understand the advantages of adopting the GAPs while aiming at the export trade. Growers who aim for the domestic market, however, also see the increasing concerns on healthy, clean and quality fresh fruit products. The implementation of GAPs and Q-mark will be increased.

The most serious abiotic constraint come from storms and strong winds that damage the plant and decease the yield dramatically. Some ‘Kai’ banana plantations in the south region are facing these problems. Growers plan their planting cycle so that they can harvest before the storm season comes.
Other abiotic constraints are droughts, floods and unpredictable cold weather; especially those banana plantations in the northern region. Month long abiotic constraints will retard growth and significantly decrease the yield of banana.

**Harvest and postharvest**

From flowering to harvest, ‘Hom Thong’ banana takes 13 to 15 weeks. ‘Kai’ banana takes 6 to 8 weeks, and ‘Namwa’ banana takes 14 to 16 weeks. When the fruit bunch grows to five to six expanding hands, then flower tip will be cut and then bagging will be applied. Twenty-eight days after bagging, the banana fruit is ready to harvest.

For exports, the banana fruit will be picked at 65 to 70% of maturation while the fruit angle is still visible. For domestic consumption, the banana fruit will be picked at 90 to 95% of maturation and the banana fruit is completely round.

When cutting the fruit bunch, growers avoid them touching the ground so that they will not be contaminated. Then the fruit will be transported to the packing house where they will be separated into individual hands. They will then be trimmed, clean and sorted onmp grades. For export, the banana fruit is packed and transported by cool trucks to the export facility. For domestic consumption, calcium carbide is applied for even ripeness.

**AROMATIC COCONUT**

Coconut is practically in every part of Thai living. Thai people consume coconut juice, coconut flesh and coconut shoot as ingredients in Thai food, coconut oil for cooking, and other parts of the coconut plant for everyday articles. Coconut plants are available everywhere in Thailand as natural vegetation and as commercial plantation.

Thai growers used to grow mixed varieties of coconut plants together, such as variety for consumption as young coconut for juice and flesh, and variety for coconut oil and coconut milk. About 50 to 60 years ago, Thai growers separated a variety of coconut for juice consumption and that carries good fragrance in its juice. Thai growers cultivate this unique coconut variety further and it becomes today’s ‘Aromatic Coconut’, or the ‘Nam Hom’ - fragrant water, in Thai language (Fig. 5).

‘Aromatic Coconut’ is the main coconut variety which is consumed as young coconut in Thailand today, and is solely for juice consumption. In Thai market, the whole coconut fruit could be consumed as a fresh fruit when the coconut fruit is young (six to seven months after pollination). The juice is sweet with a specific aroma and the flesh is tasty and tender. Also very popular to the Thai food hackers are grilled or boiled coconut fruit which have different flavors of aroma and sweetness.

Thai growers also export ‘Aromatic Coconut’ as fresh fruit to USA, Canada, China, Taiwan, Singapore,
Australia, the Netherlands, etc. Over the last six years, the amount of export increases by 20% per year. In 2013, Thai growers exported 22,511,925kg of ‘Aromatic Coconut’ to USA, and the export value was 410,018,786 baht, about US$13,667,000 (OAE, 2014). Besides exporting ‘Aromatic Coconut’ as fresh fruit, Thai companies also exported processed coconut juice to many countries.

Coconut juice is rich in nutrition, antioxidant substances, minerals, especially potassium. Coconut juice is considered as a supplementary food as well as a sport drink. Some Thai researchers also found that coconut juice could help retard Alzheimer’s development in elderly people.

‘Aromatic Coconut’ belongs to the dwarf type of coconut variety. It grows slower than the tall type of coconut. The base of the trunk or the stem (usually called ‘bole’) is smaller than the tall type coconut. When the ‘Aromatic Coconut’ gets older, it becomes taller gradually with a maximum height of about 12m tall. In the fruit bearing stage, one tree can have 15 to 17 bunches of coconuts a year, with an average of seven to eight coconut fruits per bunch. In some cases, one bunch could carry 14 to 15 coconut fruits. The fruit size of the ‘Aromatic Coconut’ is about two kg in weight, and the shape is round with a bit longitudinal height. ‘Aromatic Coconut’ contains a specific natural fragrance that is composed of a chemical substance called 2-acetyl-1-pyrroline (2-AP). It is the same substance in other aromatic plants, like that in jasmine rice and pandanus leaves.

In 2010, the Thai Government consolidated the ‘Aromatic Coconut’ industry as a new agricultural industry, and separated it from the ‘mainstream’ coconut industry. Thai Government organization also setup new strategies and approved a new budget of 118 million baht (US$4 million). The new strategies support the ‘Aromatic Coconut’ industry in four structural changes: 1) plans to increase production; 2) product development and diversity; 3) organization support; and 4) market development. The new strategies also setup new legislation that ‘Aromatic Coconut’ propagation and plantation must be kept inside the country. However, ‘Aromatic Coconut’ has already been grown in many countries.

Coconut plants can be grown in all parts of Thailand. The main growing area of ‘Aromatic Coconut’ is in the central region that includes Ratchaburi, Samut Sakorn, Samut Sonkram, Nakhon Pathom and Cha Sheng Sao and Pathum Thani provinces. Since ‘Aromatic Coconut’ is becoming popular, there are new plantations in other parts of the country, mainly at the northern and northeastern regions. Small coconut orchards start from a small piece of land of 0.8 hectare (5 rai) to big exporting coconut plantations with big piece of land 80 hectares (500 rai).

Propagation

In old agricultural practice, Thai growers used to plant varieties of coconut plants together, and cross-pollination between different varieties was not controlled. Today, growers of ‘Aromatic Coconut’ want the true-to-type planting materials that carry the unique fragrant characteristic; but true-to-type materials are not always guaranteed. Growers examine the planting materials by different methods – smell the young root of the seedling, rub the young leaves of the seedling, etc. These methods demand individual experience and is considered time consuming. They are also proven to be ineffective in the production environment.

In Thailand, although ‘Aromatic Coconut’ could be propagated anytime of the year, Thai growers usually propagate ‘Aromatic Coconut’ from December to July. From February to May, the ‘Aromatic Coconut’ plants will have a lot of old coconut fruit and they are good for propagation. May is the best timing for propagating coconuts, so the new seedlings are ready to grow in the rainy season from August to September.

Thai growers propagate ‘Aromatic Coconuts’ by seeds. For preparing planting materials, growers identify true-to-type ‘mother’ plants from big plantations that grow single variety ‘Aromatic Coconuts’, to avoid possible cross-pollination. Growers check the quality of the ‘mother’ plants – bearing coconuts that with good sweetness, good fragrance, good yield and good fruit size.

Growers keep healthy 11 to 12 months old coconut fruit on the tree, until the fruit skin color turns to a bit brown. The healthy coconut fruit have good food reserve inside - thick flesh and sufficient juice.

Thai growers pick the old coconut fruit for propagation. They cut the upper part of the coconut fruit, for letting the new plant develop easily through the thick shell. Then the coconut fruit will be soaked in water for 10 to 15 days to enhance germination. After that, the soaked coconut fruit will be relocated to the propagation bed, with the cutting part up and covered with sand or sandy soil. The place for propagation bed should have at least 60% sunlight (Fig. 6).

With warm climate and high humidity in Thailand, in 15 to 20 days, the coconut fruit will start to
germinate. In cool season, it may take a bit longer. Percentage of germination of ‘Aromatic Coconut’ is about 65 to 70%. The older, bigger fruit with good food reserve will germinate earlier, and will be considered as good seedlings. When the new shoot develops to three to 10 cm, the coconut fruit will be relocated to another propagation bed and the coconut fruit will be spaced at 40x40 cm or 50 x 50 cm. Manure or compost is applied to enhance the growth.

After transplant of the germinated fruit to the new propagation bed for three months, the seedlings are ready to be planted in the production orchard. The seedling will have about three to five true leaves and their height should be about 30 cm. The seedlings will be planted immediately within 10 days.

Some Thai growers buy seedlings from fruit nurseries. A three-month old seedling will cost 25 to 30 baht (about US$0.8 to 1.0).

**Cultivation**

The ‘Aromatic Coconut’ bears fruit three to four years after planting, which is faster than the tall coconut that may take six to seven years. From the early growth stage till seven to eight years old, the plant’s fruit bearing capacity is still low. Mature ‘Aromatic Coconut’ plants could bear fruit till 35 to 40 years old. However, Thai growers may grow new seedlings after the ‘Aromatic Coconut’ plants are about 30 years old, since the plants maybe too tall to harvest.

In the central region of Thailand, the bedding system is popular since the central area is low land, and the system takes good advantage of the irrigation canal. Thai growers plant ‘Aromatic Coconut’ in 6x6m or 6x7m square or triangular system. The ground hole is about 30x30x25cm and with manure at the bottom.

At the early growth stage of the ‘Aromatic Coconut’ plants and before their bearing fruit phase, Thai growers utilize the space between coconut plants and other plants for growing cash crops – banana, papaya, aloe, pandanus, etc.

‘Aromatic Coconut’ is relatively easy to grow and easy to manage, compared with other tropical fruit. After planting, weekly irrigation (Fig. 7), monthly fertilization and basic sanitation are required.

‘Aromatic Coconut’ grows well in alluvium soil. In Thailand, growers also plant ‘Aromatic Coconut’ in other soils, as long as good drainage is provided and soil pH is at about 6.5 to 7.
In the ‘Aromatic Coconut’ growing area at the central region of Thailand, the annual rainfall meets the coconut growing requirement, ranging from 1,500 to 2,000 mm per annum, and not less than 50 mm in three consecutive months. In the dry season (November to May), Thai growers water the plants at least once a week.

In the first three months of planting, Thai growers apply high nitrogen fertilizers to enhance vegetative growth, like 21-0-0 or 46-0-0. When the coconut plant is in its growing stage, Thai growers apply different fertilizer formula, like 15-15-15, 13-13-21 and 8-24-24, at a rate of less than four kg per tree in two applications. Manure is also applied, either from cow, pig, duck or chicken.

Thai growers only perform seasonal orchard sanitation, removing dried leaves or dried bunches from the plants, to avoid the accumulation of insects and diseases.

Since coconuts are sold by the number of fruit and their sizes dictate their price, the growers who manage and take good care of their plantations earn more returns.

For improving the quality of managing the coconut plantations, many growers especially those who aim for the export trade, engage themselves in following GAPs and even the GlobalGAP. Some coconut factories and packaging houses, also study, learn and follow the Good Manufacturing Practices (GMPs) and the HACCP.

Organic coconut farming is not a mainstream practice. Some Thai growers try to change their plantations to organic coconut, to earn higher margins and higher returns in the niche market.

**Pests and diseases**

In 2010, there was a big invasion of coconut Hispine Beetle (*Brontispa longissima* Gestro) in the coconut growing area in the southern region of Thailand. This later spread to other regions, including some areas in the central region which is the main growing area of ‘Aromatic Coconuts’. In the same year, about 40,000 hectares (250,000 rai) of coconut plantations in 19 provinces were destroyed. This insect destroys the young leaves at the top of the plants and those that have been infected have white leaves at the top of the plants. Thai growers call it ‘grey hair coconut disease’.

In 2012, coconut black-headed caterpillar (*Opisina arenosella*) also destroyed many plants and caused a big damage in the ‘Aromatic Coconut’ growing area in Thailand. The insect’s larvae damage the lower leaves of the coconut and it hides in tunnels, like termites. It kills the coconut plant. If the plant survives, it would take years to recover resulting in a markedly decrease in yield.

After these incidents, the Thai Government setup warning system in the coconut growing areas that alerts growers on any insect invasion.

Another damaging insects in Thai coconut plantation are Asiatic rhinoceros beetle (*Oryctes rhinoceros*), palm weevil (*Rhynchophorus ferrugineus*) and two color coconut leave beetles (*Plesispa sispinae*). The first one penetrates the new shoots. Then the damaged leaves will be cut and will look like a fishtail or shaped like a fan. After the coconut rhinoceros beetle damaged the coconut plants, the two color coconut leave beetles penetrate into the coconut plants through the scar made by the coconut rhinoceros beetle. It damages the young inner shoot and the plant dies.

Termite is another common problem in the propagation bed and destroys the young coconut seedling. Besides insects, some rodents like mice and squirrels also destroy many coconut fruit just by their mere bites or their making holes in the coconut fruit. Thai growers use baits to poison them or sometimes even shoot them using rifles and guns.

**Bio-control**

Although most Thai growers still apply chemicals in combating coconut pests and insects, few growers avoid chemicals and develop bio-control methods in their coconut plantations. For example, coconut hispine beetle can be controlled by using *Asecodes hispinarum* for larval parasites, or *Tertrastichus brontispae* for pupal parasites. Black-head carterpillars can be controlled by *Goniozus nephantidis*, or by bacillus bacteria (*Bacillus turingiansis*). In the case of coconut rhinoceros beetles, at their larva stage, a fungus *Metarhizium anisopliae* has been found to effectively kill them.

Government support organizations used to provide these parasite insects to the coconut growers, but over the years, the demand has increased significantly. Now government organizations setup training and
help growers raise their parasitic insects by themselves. Few growers develop it further and raise these insects to other growers.

Other than pests and diseases, drought is a critical abiotic constraint especially for ‘Aromatic Coconuts’. Drought decreases the amount of yield, size of fruit, therefore the amount of juice, and most importantly, the quality of the juice.

Flood is another abiotic constraint, although coconut plant tolerates light floods. The 2011 big flood in Thailand also damaged some ‘Aromatic Coconut’ growing areas in the central region. The flood came at the season of propagating seedlings and none of the seedlings could survive when they are submerged in water for months.

**Harvest and postharvest**

A mature ‘Aromatic Coconut’ plant supplies new fruit bunches constantly over time. Thai growers harvest ‘Aromatic Coconuts’ about every three weeks. In big plantations, harvest activities are carried out on a daily basis.

Although ‘Aromatic Coconuts’ are grown all-year round, in the Thai summer season from March to May, due to high demand and less supply, the price of ‘Aromatic Coconuts’ is about 15 to 16 baht per fruit. In the rainy season from June to September, a small less than two kg coconut fruit may just sell half the price. At this time, some growers choose to keep the coconut fruits on the tree and grow them into mature coconuts with thicker flesh, then sell them.

‘Aromatic Coconuts’ are grown for juice consumption and are harvested when the coconut fruit are young. At the age about five to six months after the pollination, the sweetness and the unique fragrance start to develop in the coconut juice. For consumption as fresh fruit, Thai growers harvest the coconut fruit as early as six to seven months after pollination. At this stage, the coconut fruit is still young, the fruit shell is still green but brittle, juice is clear and sweet, at about 7 to 8° Brix. The unique fragrance is very fresh.

‘Aromatic Coconuts’ could also be consumed as grilled or boiled fruit. Thai growers harvest the coconut fruit at about eight months after pollination. The fruit shell is more developed and is heat tolerant. The sweetness of the juice is about the same, and the unique fragrance is a bit stronger.

The normal tall type coconut fruit is picked at the mature stage and the fruit shell is much stronger; then the traditional monkey pick-and-drop method could be applied. Since ‘Aromatic Coconuts’ are young and delicate, the coconut fruit are picked by workers who tie the coconut fruit bunch with a rope and descend it to the ground. In coconut plantations located at the central region, coconut plants are grown on beddings with surrounding irrigation canals; then workers pick and drop the fruit into the canal (Fig. 8).

![Fig. 8. Cutting and throwing the coconut bunch into the water canal](image)

The coconut fruit will be transported to the packing house or the factory. Then the fruit shells will be removed and the fruit will be trimmed or polished to decreasing their volume and weight during transportation. Workers also dip the coconut fruit into sodium metabisulfite solution (SMS), to protect the fruit from fungi and keep their white color.

Coconut production and harvesting, especially those for ‘Aromatic Coconuts’ are very labor intensive
and depends on special skills – from hand picking coconuts, to trimming and polishing. Thai growers had already foreseen shortage of labor in the future.

At the point of consumption, cutting and handling coconut fruit are not easy – cutting, for one, requires a heavy knife at a specific location. Instead of selling the fresh fruit, some companies extract the coconut juice from the coconut and repack the juice in tetra packs or other modern ways of packaging. This significantly reduces the transportation cost, and at the same time lengthen the shelf by more than a two months.

One innovative idea requires the application of a pull-tab on a grilled coconut fruit (Fig. 9). This is easy as consuming the fruit juice like a softdrink. A laser-cut circular imprint allows opening the shell further for fresh consumption.

Some companies develop added-value products from coconut juice and flesh, like coconut pudding, coconut jelly and coconut ice cream (Fig. 10).

Recycling gurus also turn the leftover coconut shells and coconut bunches into manure fertilizers.

![Coconuts with a pull tab](image1)

![Coconut jelly and coconut pudding](image2)

**MANGO**

Mango is one of the most ancient fruit crops of Thailand. Thai people have grown and made use of mangoes for a long time. Thai growers ingeniously developed new varieties through the selection of chance seedlings and bud sports. At least 172 varieties have been recorded in Thailand and about 10 have been grown commercially. Today, mangoes have played an important role as an important economic crop. New varieties and techniques of production have been developed, many of which are unique to Thailand. Several mango
products are also available exclusively in Thailand. Thai people consume a lot of fresh mangoes at their raw and ripe stages. Raw green mango is a popular vegetable that adds fresh and sour taste to the food. Raw mango as snack has a crispy, crunchy and nutty taste, and a bit of sweetness. Sweet ripe mango, on the other hand, served with glutinous rice is a signature Thai dessert. Mangoes are also processed into many products like ice cream, dried mangoes, juices, pickles, pastes and jams, etc.

Due to the off-season technique, mango is available all-year round. Nevertheless, the best mango season is from March to May, the hot and dry season in Thailand. The mango price varies according to season, varieties and fruit quality. For example, when the fruit are in season the farm gate price is around 15 to 20 baht per kg; while the price for off-season rises to 35 to 40 baht per kg or higher. The export quality is kept at higher price, like 80 to 90 baht per kg.

Mango grows well in every part of the country. There is high number of mango growers and they occupy a large area of agricultural land in the country. The return for growing mango is also good (Table 4). Besides, among fruit growers in Thailand, mango growers are quite advanced. They organize well to set up their groups to help each other on technology, finance, market support, etc. Those mango growers who aim for export trade, adopt GAPs and even developed a traceability system for individual mangoes. Some mango growers own big pieces of land for their mango plantations, like 3.2 to 8 hectares (20-50 rai) or bigger.

Table 4. Mango growing area and production in Thailand from year 2010 to 2012.

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<th></th>
<th>2010</th>
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<th>2012</th>
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<tr>
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<td>-</td>
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<td>Yield (ton)</td>
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<td>Farm gate value (baht/ton)</td>
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<td>18,000</td>
<td>17,773</td>
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<tr>
<td>Net value (baht/ton)</td>
<td>10,326</td>
<td>13,075</td>
<td>12,815</td>
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</table>

Source: OAE, 2013

Major varieties

Mango for raw consumption

1) "Kieo saweoi" is a late variety. The fruit has oblong shape, dark green skin with white flesh when mature. The taste is sweet, juicy and nutty. The taste is similar to persimmon when consumed just before ripening. The fruit weight is about 250 to 350g.

2) "Raet" is an early variety. The fruit is oblong shaped, some fruit have short horn at the shoulder of basal end. The skin color is light green, and flesh color is rather yellow. The taste is nutty and sweet and has good taste when it is ripe. The fruit weighs about 250 to 300g. This variety is also exported to Japan as ripe mango. The volume is not that big.

3) "Phimsen man" has an oblong fruit shape with obtuse fruit end. The fruit skin color is light green with cream color pulp. The taste is nutty with scanty fiber. The fruit weighs about 280 to 300g.

4) "Kaew" has an ovate oblong shape. The fruit skin color is light green and it turns yellow when ripe. When it is green then it is used for cooking; when ripe it has sweet, and sour taste. The fruit weighs about 200 to 300g. This variety grows well in every part of Thailand. It is the main variety for food processing, like pickles, pastes, candies, etc. It is also used as rootstock since it adapts well in all climates. Besides, the seeds can be easily collected from the factories that use this variety for processing.

Mango for ripe consumption

1) "Nam Dok Mai" is divided into two clones.
1.1) "Nam Dok Mai Si Thong" is the main variety for export. The fruit shape is ovate with sharp pointed tip. The fruit skin color is golden yellow. It has a lot of flesh since the seed is very thin. The taste is sweet and scented. The fruit weighs about 280 to 300g (Fig. 11).

Fig. 11. ‘Nam Dok Mai Si Thong’ (middle), ‘Maha Chanok’ (right), ‘Kieo Saweoi’ (left)

1.2) "Nam Dok Mai #4" has similar character as ‘Nam Dok Mai Si Thong’. In fact, it is sweeter than "Nam Dok Mai Si Thong"; but the skin color is still green when it is ripe, this makes it less attractive. The skin is also thinner and is not suited for long distance transportation. It can also be easily attacked by the anthracnose disease. It is possible to export this variety but in smaller amount.

2) "Maha Chanok" requires a little bit cool weather to enhance its red color cheek on the skin. The fruit shape is oblong with curved and tapering tip. The skin is thick, bright yellow skin, sometime with the touch of pink. The flesh is yellow, juicy and fiberless, with pleasant aroma when ripe. "Maha Chanok" is an export variety, especially to Japan. The fruit weighs about 350 to 400g.

3) "Choak Anan" bears fruit all-year round. It can be consumed in both their raw and ripe stages. The fruit shape is oblong. When ripe, the fruit skin’s color is golden yellow. The flesh is yellow, firm and fiberless. The taste is sweet and sour with pleasant aroma. The fruit weighs about 300 to 400g.

4) "Ok Rong" ia an old variety that used to be eaten with glutinous rice in the past, now it is replaced by ‘Nam Dok Mai’. The fruit shape is oblong with small size fruit. Pale green skin color will pale yellow flesh. The taste is sweet and mildly scented when ripe and contains much fiber.

New mango varieties are increasing, by chance seedling or from various breeding programs. Some new varieties were introduced from overseas, like the R2E2 from Australia. Its red skin color attracts attention in the domestic market. Jin Huang (in Thai ‘Nual Kham’) from Taiwan, grows and adapts well in Thailand. Mango builds a substantial export trade. Mango’s main export market is Japan, with a required volume of 1,200 tons and a value of 480 million baht (about $US16 million) each year. The main export variety is ‘Nam Dok Mai Si Thong’ which occupies about 90% of the export volume.

Thai Government’s strategy for Thai fruits for 2010 to 2014 is focused on increasing mango exports especially on the ‘Nam Dok Mai’ mango variety. Budgets were approved for supporting the Thai mango growers on technological know-how and on quality improvement.

Since there are stringent requirements on importing fresh fruits into Japan, in 1999, the Thai Government’s Department of Agriculture supported the industries with the technology of heat vapor treatment that eliminates the egg of oriental fruit flies in mangoes. Since then, export of mango fresh fruit to Japan became possible.

Recently, Thai government builds real-time information database that supports mango growers on managing their products according to the customers’ need. ‘Just in Time’ is the code name of the system, and is now collecting data about mangoes in the country.

Thai government organizations provide different levels of technology transfer and training to the mango growers, on product development and quality improvement. They also support the mango growers in qualifying GAPs and GMPs programs.
With the support from the mango export community, government organizations also persuade mango growers to participate in contract farming to ensure sustainable returns.

Therefore, under the Thai Government legislation and the Thai Act on Plant Materials, the mango propagation is restricted inside the country.

**Propagation**

Although mangoes can be propagated sexually it is rarely used in Thailand. The asexual method by far is regarded as the more popular way of propagation. The asexual method controls the true-to-type characters of mango, and it also shortens the flowering time of the mango tree.

Thai mango growers apply inarching technique in the commercial propagation (Fig. 12). The inarching method allows both scion and rootstock to still have their own roots while grafting. It supports a higher chance of success in the propagation. Usually, the scion shoot attaches to the parent plant while grafted onto a seedling rootstock of ‘Kaew’ mango by side veneer method. In four to five weeks, a new plant is developed.

![Fig. 12. Mango propagation by inarching](image)

In another method, the 1 to 1.5 year-old rootstock is pre-planted in the plantation prior to the actual propagation. The scion is therefore brought for grafting; and the complete propagation process is applied at the planting site. This method significantly costs lower than buying an inarching plant - the rootstock costs only 6 to 10 baht per tree, vs. a 60 cm inarching plant of normal variety which costs between 30 and 40 baht. Mango growers can prepare the new plant by themselves or they can also buy it from fruit tree nurseries.

**Cultivation**

Mango trees that were propagated by asexual method bear fruit in three years after planting. On the other hand, mango trees which were propagated by seeds take at least five years to bear fruit. The fruit bearing life span of a healthy mango tree is more than 30 to 40 years; and the highest yield when the tree is about 8 to 10 years old. At the fruit tree’s peak, yield may reach from 50 to 100kg per tree per year. For mango trees that are older than 15 years, hard pruning is required to re-activate the plant and make it productive again. Nevertheless, Thai mango growers consider replacing mango trees older than 20 years, since its yield starts to decrease.

In Thailand, the recommended planting density for mango trees is 6x4m. The ground hole is about 30 x 30 x 30cm.

Training is necessary for growing mango trees and this can be done in many styles to control the size of the trees, enhance yield, decrease pests and diseases, etc. In Thailand, ‘open center’ is a popular training pattern for mango trees; with at least three main branches that will be kept at 70 cm height from the ground.

After harvest, pruning is needed to keep the size of the tree not so tall. This is done by cutting back about 60 cm every time. Old and weak twigs will be removed to let the light penetrate inside the tree. Mango
growers sometimes put the cut shoots under the tree for mulching, as long as there are no insects or diseases. During flowering and fruit set, when the inflorescence is about two-three cm long, mango growers apply insecticide to control the insects. However, they stop using insecticide during the blooming stage, to promote the pollinators, like bees. Once the fruit setting has started, mango growers apply insecticides again until the fruit bagging stage.

About 35-40 days after fruit setting, wherein the fruit size is about one and a half (1.5) to two cm in width and four to five cm in length, mango growers apply fruit thinners. The “thinned” fruit is small, abnormal, attacked by insects or diseases and usually a non-fertilized fruit (no seed inside). In Thai mango plantation, only one to three fruit per inflorescence will be kept for its optimum size. Mango growers may skip the thinning if the number of fruit per tree is not too much.

When the young fruit is about the size of a lime, mango growers will immediately wrap the fruit with bags to protect them from fruit flies (Fig. 13). The bagging also enhances a richer skin color of the fruit. The most popular bagging material is the brown paper bag with carbon coating inside. For cost saving, mango growers re-use the paper bag in the next season. After bagging, mango growers also stop applying insecticides.

Off-season mangoes

Inducing mango flowering for off-season crop is now common for Thai mango growers. They apply growth retardants such as paclobutrazol to make mango crops available almost all year round. Mango growers apply growth retardants to the tree by collar drench in the soil. Before applying, growers clean the soil under the tree from weeds and have enough moisture to increase the efficiency of the chemical, since the chemical go inside the plant via xylem.

The amount of the chemical is 10g of active ingredient for the tree with one meter of canopy diameter. However, mango growers adjust the concentration of this chemical to the tree condition. Trees that have been applied with this chemical in consecutive years may not need to apply the same amount like in the previous year, since the tree may carry some chemical residue coming from the soil. The residue of paclobutrazol depends on the type of soil. Soil that has good drainage like sandy soil has less chemical residue compared with clay soil.

The key success factors to this technique include appropriate preparation to obtain healthy trees, and the proper stage of tree development at which the chemical is applied. The success of induction may vary among mango varieties. For example, ‘Nam Dok Mai Si Thong’ and ‘Nam Dok Mai #4’ are much easier to induce off-season flowering than ‘Kieo Sawoei’, since ‘Nam Dok Mai’ has the habit of off-season while ‘Kieo Sawoei’ is of the late variety type.
Fertilization

Mango growers apply both organic and chemical fertilizers in their plantations. For organic fertilizer, growers usually apply manure once a year, and they adjust the amount of manure depending on the age of the mango tree.

Chemical fertilizers generally apply to mango trees are 15-15-15, 16-16-16, 30-20-10 or 8-24-24. Mango growers apply these fertilizers about twice a year. When the trees are still not bearing fruit, 15-15-15 or 16-16-16 are applied. When the trees start bearing fruit, they still use 15-15-15 or 16-16-16, sometimes formula like 30-20-10 and 8-24-24 will be applied.

Thai mango growers also add a lot of supplementary nutrients to their mango trees, like sugar, extracted seaweed and some nutrients like calcium and boron.

Water is necessary for mango trees especially during the time of flowering to the time of fruit development. Mulching is applied to keep moisture of soil during the dry season.

Insect pests

Insects that attack mango trees or mango fruits:

1. Thrips (chilli thrips: *Scirtothrips dorsalis*) insect damages young shoots, flowers and fruits. The damaged leaves will be small, curly or drooped. In case it attacks the inflorescence, it makes the flower dry which leads to a reduction in the fruit setting.

2. Mango leaf hoppers or mango jassid, has two species - 1) *Idioscopus clypealis* and 2) *I. niveosparsus*. This insect also damages flowers by sucking the sap from flower inflorescence. Sometimes it completely damages all the inflorescence and reduces fruit setting.

3. Leaf eating weevil (*Hypomeces squamosus*) eats the young leaf of the mango. This decreases the efficiency of photosynthesis.

4. Mango leaf cutter (*Deporaus marginatus*) cuts only the leaf blades. So the leaf blade will drop, but the petiole and the base of the leaf are still attached to the tree.

5. Oriental fruit fly (*Bactrocera dorsalis*) penetrates the fruit skin and lays egg inside the fruit. Later the egg becomes worm and eats the flesh of the fruit. This insect is a serious obstacle to mango exporters for a long time. Bagging is used to prevent this insect; and after harvest, heat vapor treatment (45 °C) for 10 minutes or longer is applied to kill the eggs inside the fruit.

Disease

1. Anthracnose is the main disease that plagues Thai mangoes. It is caused by fungi *Colletotrichum gloeosporioides*. This disease occurs at every growth stage and every part of the mango tree. The serious problem is when it comes to the fruit. The symptom of this disease is that fruit have black spots spread on the skin and these spots will become bigger. Dipping the mango fruit in warm water (50°C) for five minutes and then dipping them in cold water immediately will decrease this symptom. Another alternate solution is to dip the mango fruit in the solution mixed with fungicide.

2. Powdery mildew, with a fungi pathogen (*Oidium mangifera*) causes pale yellow spots on the leaves which later, will become bigger. The color of the lower part of leaves becomes pale and would look like they have been covered with white powder.

3. Black mildew; *Meliola mangifera* usually comes after the attack of mango jassid. It makes the mango inflorescence and leaves look like they have been covered with black dust. In severe cases, the inflorescence is unable to set fruit.

Control of diseases and insect pests

Some prevailing diagnostic tests can be performed in mango trees to decrease the invasion of pests and diseases. For example, mango growers check the insect population on the sticky trap, then decide the timing and dosing of insecticide - an efficient method to control the pests and diseases in mango plantations. Other physical means like bagging and netting are also effective solutions. In principle of decreasing the use of chemicals, some mango growers use the right amount and right frequency of bait with pheromone (like
methyl eugenol) to decrease the fruit fly population. For good orchard sanitation, it is recommended to prevent the accumulation of insect and fungi inside the tree. Some mango growers clean the trunk by spraying insecticides (before pruning); and they apply copper compound solutions, like copper hydroxide or copper oxychloride (after pruning).

**Abiotic constraints**

Drought is the abiotic constraint that decreases the growth and yield of mango production, especially if it occurs at the time of flowering and fruit setting. If the flood lasts more than a month, mango trees cannot survive being submerged in water for too long. Besides, hailstorms (which often attack in March and April) also cause fruit drop and damage the fruit. For off-season mango production, too much rain also decreases the off-season flowering rate since the tree have new leaves flush instead of inflorescence.

**Harvest and postharvest**

Summer (March-June) is considered to be the best mango season in Thailand with minor timing variation in the northern region and the southern region of the country. Since off-season inducing technique is commonly applied, varieties of mangoes are now available all-year round. Harvesting index for mangoes is usually 105 to 115 days after full bloom; or 55-60 days after bagging in ‘Nam Dok Mai’. Some mango growers also experiment with other methods and indexes, like specific gravity, or size and shape or skin color, etc.

For mango plantation aimed at the export market, mango fruit will be harvested at 85% maturation. Thai mango workers carefully hand pick mango fruit from the tree, to avoid bruises and scratches. The mango still has a long stalk attached and with the wrapping bag. The workers transport the mango to the packing house immediately. At the packing house, fruit stems will be cut to 3 to 5 cm long from the fruit basal end to avoid the gum drop on the fruit skin; then the bag will be removed. Then mango fruit will be graded and the one that meets the export quality will be separated while the other remaining fruit will be re-graded again for the domestic market.

Mango growers will apply additional steps on mango fruit that are prepared for export, in order to meet the export requirements. The fruit size for export is about 300 to 600g, depending on the order specifications. Workers will clean the skin of the mango so there is practically no dirt and no dust. Also visual checks will be done to ensure that there is no sign of anthracnose, pests, flaws or bruises. After this, the stem can be removed completely.

The fruit will be given a traceable code, and will undergo vapor heat treatment. Before packing, the mango fruit will be air-dried in the shade. There will be a last quality check before the mango fruit will be boxed and transferred to the export facility in the cool truck.

**PAPAYA**

Papaya is a basic tropical fruit in Thailand and is available everywhere all-year round. Ripe papaya as fresh fruit consumption is about 30%; and Thai people prefer dark red papaya flesh which has very sweet taste. Thirty-eight percent of Thai food use raw papaya as vegetables and Thai people like green crispy flesh but not hard. Papaya for processing, like papaya for making canned fruit, juice, sauce, and dried fruit, etc. is about 16%.

The papaya growing area in Thailand in 2007 was 16,795 hectares (104,968 rai) and it slightly increased to 17,981 hectares (112,381 rai) in 2010. But in 2011, the growing area decreased to 9,537 hectares (59,604 rai) (Table 5). The main cause for the decrease in the growing area was the invasion of virus. In 2010, Thailand ranked number eight in papaya production in the world with a yield of 211,594 tons (OAE, 2013; FAO, 2013). However, in that year, the export volume was only 630 tons with 27 million baht (about US$9 million). In 2011, the export volume increased to 995 tons with 50 million baht (about 16.7million) (FAO, 2013). From these figures, it could be understood that most of papaya production in Thailand is used for domestic consumption. Even the growing area in 2011 decreased by almost 50% from the previous year, but the yield increased. This was due to the fact that in 2014, the growing of ‘Holland’ papaya increased and this papaya variety had higher yield than the local variety. ‘Holland’ papaya fitted well for the domestic as well as the export markets. It had higher price than the local variety as well.
About half of the papaya growing area in Thailand are the small land orchards, smaller than 0.8 hectare (1-5 rai). These papaya growers organize themselves to have enough product volume for the market. Small papaya growers produce only three tons of papaya, just enough to fill up a small truck. Some papaya growers have big piece of land more than four hectares (25 rai) that are mainly located in the west region and the south region of the country, in the neighborhood of some food factories.

**Farmgate value**

The farmgate value of papaya from 2007 to 2011 is shown in Table 5. The price of papaya was increasing every year. Among all varieties, ‘Pluk Mailai’ or ‘Holland’ got the highest price, average 7.5 to 12.4 baht per kg. From July to October papaya production is less, and the price increased to 18 to 30 baht per kg. The second one was “Khaek Dum”, five to 10 baht per kg. While “Khaek Nual” and papaya for food processing factory was around 3 to 5 baht per kg.

Since papaya production in Thailand is mostly for the domestic market, the growing varieties match the preferences of the domestic market. There are also some varieties for processing factories. Listed below (Fig. 14) are the main papaya varieties in Thailand:

![Fig. 14. ‘Khaek Dum’ (left), ‘Khaek Nual’ (middle), ‘Pluk Mailai’, or ‘Holland’ (right)](image)

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<tr>
<th>Year</th>
<th>Growing area (hectare)</th>
<th>Yielded area (hectare)</th>
<th>Yield (ton)</th>
<th>Farm gate value (baht/kg)</th>
<th>Total value ($US million)</th>
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<td>2010</td>
<td>17,981</td>
<td>12,366</td>
<td>211,594</td>
<td>12.50</td>
<td>88.2</td>
</tr>
<tr>
<td>2011</td>
<td>9,537</td>
<td>4,721</td>
<td>227,946</td>
<td>27.58</td>
<td>209.6</td>
</tr>
</tbody>
</table>

Source: OAE, 2013
1. "Khaek Dum" is the main variety for ripe consumption (60%). This variety fits only for the domestic market and not for exports, since the fruit is too big and the skin is too thin and is considered not good for transportation. The fruit shape is long cylindrical, with the stem end and the bottom end almost equal. It has very sweet taste, the flesh is not too hard and has dark red color. Due to the unintentional cross-pollination with other varieties, the flesh color becomes less red. Visually, it is considered of inferior quality.

2. "Khaek Nual" is mainly consumed as vegetable when the fruit is still green (18%), like the shredded papaya in Thai ‘Som Tam’ salad. The fruit shape of this variety is similar to ‘Khaek Dum’ but the fruit skin is smooth and is light green in color. It is also eaten when ripe like ‘Khaek Dum’, the flesh also dark red in color and when ripe has a good taste.

3. "Pluk Mailai" or "Holland" (8%) is increasing in snowing area (8%) since it has higher yield than ‘Khaek Dum’ or ‘Khaek Nual’ and is suitable for export. The fruit size is small and is ideal for export. The fruit shape is also cylindrical but much shorter than ‘Khaek Dum’. The fruit tip is not pointy. The flesh is very firm, color is red orange and the taste is sweet. Fruit skin turns orange when ripe.

4. Other varieties, both local and abroad are Red lady, Hawaii (Solo), and Coco, etc. (Table 6).

### Table 6. Some characteristics of main papaya varieties in Thailand

<table>
<thead>
<tr>
<th></th>
<th>Khaek Dum</th>
<th>Khaek Nual</th>
<th>Coco</th>
<th>Sainamphueng</th>
<th>Pluk Mailai or Holland</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaf petiole</td>
<td>Green</td>
<td>Green</td>
<td>Purple</td>
<td>Light green, long</td>
<td>Green</td>
</tr>
<tr>
<td>Leave</td>
<td>Thick dark green, 7 to 11 leaflet</td>
<td>Thick dark green, 7 to 11 leaflet</td>
<td>Thick dark green, 7 to 11 leaflet</td>
<td>7 to 9 leaflet</td>
<td>11 leaflet</td>
</tr>
<tr>
<td>Fruit shape</td>
<td>Cylindrical shape with pointed end (0.6 to 2kg)</td>
<td>Cylindrical shape with pointed end (0.6 to 2kg)</td>
<td>The end of fruit is wider than the stem part (1.3 to 2kg)</td>
<td>The end of fruit is wider than the stem part (0.6 to 2kg)</td>
<td>Cylindrical shape, short</td>
</tr>
<tr>
<td>Peel color</td>
<td>Dark green not smooth</td>
<td>Light green smooth</td>
<td>Dark green smooth</td>
<td>Light green smooth</td>
<td>Green smooth</td>
</tr>
<tr>
<td>Flesh color*</td>
<td>Red &lt; 5</td>
<td>Red &lt; 5</td>
<td>Red &lt; 5</td>
<td>Orange 6</td>
<td>Red orange 5-6</td>
</tr>
</tbody>
</table>

Source: Sirikul Wasee, Thailand Vegetative Research Center, Kasetsart University.

* Flesh color is scored by using the color chart developed for Thai papaya by Kasetsart University. The flesh color of papaya that Thai people prefer should be 4, but 5 to 6 is also accepted. If it scores more than 10 then this will not be accepted by the factory for the red flesh papaya. Eleven to 13 is for the yellow flesh papaya.

### Propagation

Papaya in Thailand is used only for seed propagation. There are two variances: i) grow seeds directly in the plantation; and ii) grow seeds separately then transplant the seedling to the plantation. The second method is more popular in Thailand (87%) as it has better control for successful seedling in the plantation. Papaya growers can easily transplant the one to two months old seedlings in the field.

Price of the papaya seed is expensive in Thailand. It starts from 10,000 baht (about US$330) per kg, and the average price is 32,000 to 200,000 baht (about US$1,067 to 6,667) per kg; or 0.5-4 baht (about US$0.1) per seed, depending on the variety and quality.

About 69% of Thai papaya growers collect the seeds by themselves, from the papaya tree that has good traits. Papaya growers pick up the papaya fruit that starts changing color from green to orange. Until the papaya is ripe, they take the seeds, wash them until no mucilage, air-dry them under the shade. Number of
seeds depends on individual papaya variety, usually ranging between 500 and 800 seeds per papaya. Thai papaya growers keep these seeds for two to three years in the cold room or in the refrigerator, at about 10°C and 50 % relative humidity.

Fourteen percent (14%) of Thai papaya growers get the seeds from the papaya buyers or the collectors. Another 10% of the growers buy the seeds from fruit tree nurseries or seed companies. Some nurseries also provide seedlings and the price depends on the size or the age. A 20- to 30-day seedling costs 3 baht (about US$0.1) or more. Elite varieties like ‘Red Lady’, a 3-months old seedling may cost 60 baht (about US$2.0). Recently this method becomes popular since papaya growers have better success on the propagation process, and don’t spend their time and space for preparing plant materials by themselves.

Thai papaya growers look for true-to-type planting materials, since papaya is easily cross-pollinated. They are also interested in the seeds that have three genders. In such cases, the seeds will grow into hermaphrodite trees (Fig. 15).

Cultivation

Planting system is 2.5 x 2.5m if grown as a single crop. When intercrop system is applied and grow together with young para rubber tree, the planting density should be 2 to 2.5 x 4 to 5 m. The size of the ground hole is about 50 x 50 x 50cm with some manure at the bottom.

For papaya growers using transplant seedling, growers first prepare four to five seeds in small plastic bags; in 20 days, growers transplant these seedlings in the plantation. They grow three seedlings in one ground hole, for increasing the chance of getting fruit setting plants.

Two months after planting, the seedlings start to flower. Papaya growers keep only one hermaphrodite seedling per hole, or second choice on the female flower seedling. Fruit from the hermaphrodite plants are more popular and get better price. Fruit from the female plant are also accepted in the market. The male flower seedlings, on the other hand, will be removed.

Soil, fertilization and irrigation

Papaya prefers soil with good drainage property. Growers condition the soil using high organic matter, the soil surface should be deep and the pH level should be maintained between 5.5 and 7.

Fertilizers for papaya can be organic or chemical. Two to three months after transplant, growers apply five kg of organic fertilizer to the young papaya plant by dividing the frequency of fertilization three to four
times. Growers also apply chemical fertilizers, 21-21-21 as foliar spray every two weeks after transplant, for enhancing tree vigor. One month after transplant, the 15-15-15 fertilizer is applied at the rate of 50g per plant. When the papaya plant grows, the amount of fertilizer is increased to 100g per tree. When the papaya tree starts to flower and set fruit, 15-15-15 at 100g per tree is again applied together with 50g of urea. Other fertilizer formula like 13-13-21 or 8-24-24 are also applied to increase yield and yield quality.

After the transplant, papaya growers water a lot to the young plants, every three to five days during the dry season. If there is lack of water during the young seedling development, it will cause stunt growth and the papaya plants may not recover. Growers also water a lot when the plant starts flowering or setting fruit. Insufficient water will decrease the yield and also lower the yield quality.

**Pests and diseases**

Papaya ring spot virus (PRV) is the main disease in Thai papaya. It damages papaya trees at every growing stage. At a young seedling stage, the virus stunts the growth of the plant, leaf blades are not smooth, curled and becomes smaller than normal leaves. Leaves acquire two colors, dark and light green like mosaic. In severe cases, the seedlings die. In big trees, growth is also stunted and the leaves have mosaic and are curled. If it attacks the stem or the pedicel, they cause dark green spots or stripes. If the virus attacks on the flowering plants, fruit setting is lowered. And if it attacks on the fruit, the green ring spot appears on fruit skin and usually the flesh in this part will be hard and has bitter taste. This virus is spread by aphids that suck the plant sap and transfers the virus into the plant. This process takes only 30 seconds. The symptom in the attacked plant will be seen in 15 to 20 days after the infection. From the survey conducted by researchers from the universities in Thailand (funded by Thailand Research fund) it was revealed that most of the Thai papaya growers still do not know that virus can be spread by aphids. And, in case invasion happens, 49% of growers will do nothing, 22% of growers will cut the papaya plants, 16% of growers will use chemicals, 2% of the growers will use bio-control methods while 2% of the growers will use various methods together. When the virus disease is severe, the growers will abandon the place and move to the new area and this is one reason that causes the decrease in papaya growing areas. Genetically modified papaya is said to be tolerant to this virus disease, but it is still not accepted in Thai society. Other means like breeding new varieties that is more tolerant to this virus may be a solution. Other solutions like growing papaya in net houses have also been tried, yet they have been found to be too costly for the growers.

Another disease found in papaya trees is the ‘root and foot rot’, that is caused by fungi *Pythium aphanidermatum* and *Phytophthora palmivora*. This disease is more severe in the rainy season, when temperature and humidity are high. This disease often attacks young papaya seedlings, then the seedling leaves will wilt and will soon drop. When the root system is damaged, the seedling will die later. Using well drainage growing media can minimize this problem. This disease is also found in germinated seeds. In this case, soaking or mixing the seeds with fungicide will protect them from this disease. In big trees, the leaf petiole drops, turns yellow and becomes dry. The fruit on the tree also turns yellow before becoming ripe, the base of the stems rot and are sometimes covered with white mycelium. Adding some microorganism like trichoderma in the soil can control this disease. Other methods may also help like improving the water drainage in the plantation, and increasing the soil pH by applying some lime.

During the rainy season, anthracnose disease can plague papaya trees. The disease is caused by fungus *Colletotrichum gloeosporioides*. If it attacks the papaya fruit, it makes yellow scar with dried brown color at the center and this part will collapse and the orange mycelium will show up. Finally, the whole fruit will be rotten.

Some insects attack papaya trees too, like thrips, spider mites, mealy bugs and scale bugs. In the summer when the weather is hot and dry, these insects are more active. These insects suck the sap of the papaya tree and that will retard or suppress the tree growth. In severe cases, the tree declines and dies later. If they attack the fruit, it makes the papaya skin flawed thus reducing its selling price. If the problem is more severe, the fruit cannot develop normally. Insecticides are used for prevention and it is suggested to remove the host plant of this insect to stop the invasion.

Besides insects, the growing area in the northeast region of Thailand is facing nematode problems in the papaya root. It makes the tree decline causing yield decrease. At this moment, there is still no method or no solution to cope with nematodes.
Abiotic constraint

Storms or strong winds can cause damages in papaya. Since papaya is a herbaceous plant, and the stem has no wooden fiber and hollow inside, it cannot tolerate stress like salinity and flooding.

Harvest and postharvest

Papaya tree bears fruit quite early. Seven to nine months after planting, growers can harvest the first batch of papaya fruit. A healthy papaya plant can bear fruit about three main crops during its life span. Thai papaya growers remove the 1.5 to two years old plant and replace it with a new plant. It is because the old plant may be too tall to harvest.

Ripe papaya as fresh fruit

Workers pick up the papaya fruit when the skin has orange color about 10% or two to three yellow or orange patches. Workers use shears to cut the peduncle close to the papaya trunk. They are not hand picked since it will cause scar that could easily cause diseases to penetrate. The fruit should not also be allowed to touch the ground to avoid fungi infections and bruises.

In "Pluk Mailai" or "Holland", after picking the fruit from the plant, the fruit will be wrapped immediately with newspaper to avoid gum sticking to the skin. Workers keep papaya fruit in a cool place under the shade. In the grading process, workers separate the bigger papaya fruit which are usually 50% ripe and 800g in weight. They are sold in the market immediately. Workers select smaller and less ripe papaya fruit, put them into foam nets and sell them in supermarkets.

In "Khaek Dum", after picking from the plant, the papaya fruit will be wrapped individually. In the packing house, workers grade the papaya fruit, clean and soak them in water with fungicide for a short while. For domestic market, ethylene generator is used for uniform ripening except when the fruit is more than 50% ripe. The fruit will be air dried before they are packed into foam nets and boxes. Cool truck carries the premium quality papaya fruits to the supermarkets.

Raw papaya as vegetables

After picking from the plant, workers load 13 to 15 papaya fruit into a big plastic bag. It is is a bulk container for transporting 10kg of fruit. External visual quality is not much a concern for this sort of papaya fruit.

Papaya for food factory

The food factory needs 10 to 50 tons of papaya fruit per day, and the required volume is 800 to 1,200g of big papaya fruit. Workers sort the red flesh papaya and the yellow flesh papaya for different food preparation process. Workers further check the size and evenness of the shape, flesh thickness and nitrate residue. The fruit will then be peeled, cut, and seeds and placenta will be removed before feeding them into next food preparation process. Some factories also buy raw papaya with white flesh or with light green flesh for different food process.

CONCLUSION

Due to suitable climate condition, Thailand has high potential to produce varieties of high quality tropical fruit which include banana, 'Aromatic Coconut', mango and papaya. Moreover, some decades of knowledge on production techniques, harvest and postharvest management, are important factors leading to the success and the sustainability of the Thai tropical fruit industries. However, there are still many challenges along the value chain of these fruit crops, from the upstream to downstream.

In the case of the upstream chain, growers should update themselves to cope with the field management that becomes more complicated due to the continuous fluctuation of the climate. GAPs should be deployed to ensure the food safety and the benefit for export.

Fruit growers with small land should collaborate with others or should join contract farming. These
allow them receiving better returns. These will also assure the consistency in product supply and quality.

At the downstream level, exporters and factories, should consider the diversity in the new fruit products, instead of converging to fresh fruits as export commodities. Fruit processing increases product value and leads to new market opportunities matching the needs and the lifestyle of consumers. Food processing also helps to extend the product life and to manage the fluctuation between supply and demand. In the case of exports, processed products are also much easier to transport compared with whole fresh fruits. Adapting GMPs would certainly assure food safety in fruit processing.

There will be more competition on tropical fruit crops among ASEAN countries, and other countries in the tropical zone. 'Cost' should not be the keyword as everyone approaches the zero margin. New focus on quality allows the players in the industry to explore new opportunities on premium fruit, organic fruit, and functional fruits in the next market landscape.

Shortage of labor and loss of skills are becoming pronounced in fruit production and fruit processing functions. Recommended solutions should focus on priorities, including development of machines and simplifying fruit production processes.

Government organizations also play important roles in the Thai tropical fruit industries. They make pragmatic strategies and support the industries in all dimensions.

To make a sustainable tropical fruit industry in Thailand, it will have to start from well collaboration between every stakeholders in this value chain, from the upstream and downstream levels to government to trade and to growers. Only then can we be able to share a new vision.

REFERENCES
