PROCEEDINGS:

TENTH ANNUAL INTERNATIONAL TROPICAL FRUIT CONFERENCE

OCTOBER 20-22, 2000

HILO HAWAIIAN HOTEL
Hilo, Hawai'i

sponsored by the
Hawai'i Tropical Fruit Growers
and the
County of Hawai'i,
Research and Development

10TH ANNUAL INTERNATIONAL TROPICAL FRUIT CONFERENCE

October 20-22, 2000

Hilo Hawaiian Hotel • Hilo, Hawaii

FRIDAY, OCTOBER 20
OPENING RECEPTION ~ MOKU'OLA ROOM

5:00pm Registration

5:30 Pupus & No-Host Cocktails

7:00 PROGRAM

Fruit Production in Thailand

Surmsuk Salakpetch,
Chantaburi Horticultural Research Center, Thailand

SATURDAY, OCTOBER 21
10TH ANNUAL TROPICAL FRUIT CONFERENCE ~ MOKU'OLA ROOM

8:00am REGISTRATION
Coffee & Pastries
Sponsored by United Horticultural Supply

8:30 Hawaii Tropical Fruit Growers
Annual Meeting

9:00 Welcome Address

Margarita Hopkins, *County of Hawai'i, Director of Research and Development*

Dr. Jerry Quisenberry, *USDA Pacific Basin Agriculture Research Center*

9:30 ***Rambutan Production in Thailand***

Surmsuk Salakpetch, *Chantaburi Horticultural Research Center, Thailand*

10:30 BREAK

11:00 ***Update on Tropical Fruit Research in Hawai'i***

Dr. Mike Nagao, *UH College of Tropical Agriculture and Human Resources*

12:00pm LUNCH

1:00 ***Durian and Mangosteen Production in Thailand***

Surmsuk Salakpetch, *Chantaburi Horticultural Research Center, Thailand*

2:00 ***Quarantine Pest Research for Hawai'i's Tropical Fruits***

Dr. Peter Follett, *USDA Agriculture Research Service*

2:30 PANEL: Selling Tropical Fruits

Sam Hugh, *Ham Produce*

Donald Sasaki, *Cal-Kona Produce*

Ralph Iwamoto Jr., *Regional Director, International Services, Asia and Pacific Region*

3:30 TROPICAL FRUIT TASTING
Including a sampling of irradiated fruit

DINNER & AUCTION
SEASIDE RESTAURANT, KEAUKAHA

5:30pm No-host Cocktails

6:30 Dinner and Auction

SUNDAY, OCTOBER 22 - TOURS

7:45am Meet at Hotel Lobby

8:15 Pueo Orchards, Wailuku

9:45 Mac Rab of Hawai'i, Papaikou

11:00 Onomea Orchards, Onomea

12:00 -1:00pm LUNCH at Onomea Orchards

1:30 Hawai'i Pride Post Harvest Treatment Facility, Kea'au

3:30 Return to Hotel

Proceedings:
Hawaii Tropical Fruit Growers
Tenth Annual International Tropical Fruit Conference

October 20-22, 2000

Hilo, Hawaiian Hotel
Hilo, Hawaii

Sponsored
by the

Hawaii Tropical Fruit Growers
and the
County of Hawaii, Department of Research & Development

PREFACE

The featured speaker at the 10th Annual International Tropical Fruit Conference is Dr. Surmsuk Salakpetch of the Chantaburi Horticultural Research Center in Thailand. Dr. Salakpetch obtained her Bachelor of Science degree from Kasetsart University in Thailand, a Master of Science degree from the University of Western Australia and her Doctorate in Horticulture from the University of Hawaii. She is currently a research horticulturist who has been conducting research on a variety of tropical fruit crops including rambutan, durian and mangosteen. Dr. Salakpetch's presentations provide an overview of the tropical fruit industries in Thailand, production technologies associated with rambutan, durian and mangosteen and an overview of research findings in Thailand relating to the culture and production of these tropical fruits. Among Dr. Salakpetch's accomplishments are discoveries relating to the involvement of water stress in flower induction of mangosteen and factors affecting the long juvenile period of this crop.

Editor: Mike A. Nagao
Horticulturist
University of Hawaii
College of Tropical Agriculture & Human Resources

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Tropical Fruit Production of Thailand

Surmsuk Salakpetch
Chanthaburi Horticultural Research Center, Chanthaburi, Thailand

1. Introduction

Tropical fruit crops are steadily becoming an important component of agricultural production in Thailand. Since the late 1980's, the fruit industry has developed a small niche in the international export market for fresh longan. Processed pineapple from Thailand has been in the world for decades. The exports of fresh and processed fruits from Thailand have shown upward trends in recent years. In 1996, the export values of fresh fruits and products were US $ 86.7 and US $ 378.4 million, respectively, and increased to US $ 115.5 and US $ 549.6 million, respectively in 1999. The main fruits exported are pineapple (58.7%), durian (10.0%), longan (6.1%), lychee (3.5%), rambutan (1.9%), mango (1.4%) and mangosteen (0.5%), and together these fruits contribute 82% of the total fruit export value (US $ 665.1 million). Fresh durian and longan contribute to 45% and 24% of the total fresh fruit export value, respectively.

This paper briefly describes the fruit industry in Thailand and the cultivars grown commercially in the country. It also highlights some of the potential minor and rare fruit species.

2. Fruit Industry

At present, the country's economy is strongly fueled by the manufacturing industrial sector as the driving force for growth. Agriculture remains important, but has steadily experienced fluctuation in its contribution towards the Gross Domestic Product.

The country's economy is dominated by rubber amongst the plantation crops, rice amongst the food crops, and cassava and corn amongst the field crops. Based on the export values of agricultural products, fruit is still considered as a relatively minor crop for the country. However, this pattern is likely to change slowly in the years ahead due to new climates in world trade. At present, fruit production is probably close to becoming an important component of the total agricultural production based on its priority of importance and scale of operation. The future for fruits is bright because they have the potential to contribute towards the country's earnings, directly as an export commodity and indirectly through import substitution. The fruit industry in Thailand can be expanded in three main areas: 1) the export of tropical fruits; 2) domestic consumption; and 3) processing and its downstreaming activities.

The 5th National Economy and Social Development Plan which was launched in 1985 and active for 4 years, first pointed out the development of the fruit industry. Its importance has been increased consistently until the last year of the 8th Plan, and will continue to be important in the 9th Plan. With the directions from the plans, fruit production was announced as a driving force for development in the agricultural sector.

Encouraging commercial production of fruit for export, local consumption and processing is the main focus of the government's fruit policies. The major policies consist of: improving the quality of fruit production and its products; considering the cost effectiveness in producing quality production; the necessary impetus for marketing system development and accelerated export; and encouraging the usage of the information technology for commercial fruit production and trade. The commercial production of organic fruits was also considered. Although the implementation of such policies was not fulfilled, the growth of the fruit industry increased dramatically from US $ 430 million in 1992 to US $ 665.1 million in 1999. Active participation by the private sectors and growers was involved in the growth of the fruit industry.

The area under fruit cultivation (banana, durian, jackfruit, longan, lychee, mango, mangosteen, papaya, and rambutan) increased rapidly from 633,645 hectares in 1992 to 936,381 hectares in 1999. There has been almost an 81% increase in the area for mangosteen cultivation. At present, mango is the most extensively planted fruit for commercial production in the country, accounting for 35% of the total hectares. However, the trend for expansion has also included durian, longan, lychee, jackfruit and rambutan. The bulk of the present fruit production is produced in medium holdings as well as in large scale commercial cultivation.

3. Future Scenario of the Fruit Industry

Commercial fruit production comes mainly from cultivation areas in the east, the north and the south of Thailand. Commercial orchards which are more efficient in the utilization of resources will be substituted for the traditional style of fruit cultivation which consists of mixed fruits in small acreages in the south of Thailand. The acceleration of development of the fruit industry is ongoing. One of the strategies in the overall development of the fruit industry is to promote cost effectiveness and more efficient economies of scale for present holdings of selected fruits. Another proposal, the reasonable imported taxes for fertilizers and pesticides, including farm machinery should be considered. Export marketing and trades are being improved to serve the fruit traders. E-commerce is also included.

However, making profits out of fruit cultivation is not an easy task. The rapid progress of the fruit industry strongly requires the support of strong and sustained research and development.

4. Fruit Research

The overall objective of fruit research and development is to develop an appropriate package of technologies for improving productivity and quality, enabling the fruit industry to meet domestic and export requirements as well as increasing the benefits to fruit producers. The system of quality assurance (QA) will be studied and introduced to assure quality production and sanitary fruit. Although processed fruits, such as canned pineapple, rambutan, longan and lychee have been industrialized for decades, some governmental agencies have pursued diversification of fruit processing. Fruit species and

other downstreaming activities as well as zoning areas of fruit grown for factories will be emphasized in the future.

5. Tropical Fruit in Thailand

The fruits cultivated in Thailand can generally be categorized into two broad groups, namely: **Non-seasonal fruits** such as banana, guava, citrus, Java apple, papaya and *Salacca* sp. Many non-seasonal fruits do not actually produce continuously throughout the year but exhibit one or several peak bearing periods. The other group is **Seasonal fruits** such as durian, mango, mangosteen, rambutan, longan, lychee, langsat and longkong, and jackfruit.

The main bearing season of many fruits in Thailand is in mid-year or few months before or after. Durian, mangosteen and rambutan often fruit about the same time. The main seasons normally overlap from April to June in the east and few months thereafter in the south (Fig. 1).

5.1 Brief descriptions of some tropical fruit in Thailand

Banana (*Musa* spp.), ***Thai name:*** *Kluai*

There are numerous varieties of banana in Thailand, and the three commercial varieties are Khai (AA group), Namwa (ABB group) and Hom (AAA group). Namwa is the most common banana in the country. It can be seen in the home gardens of most houses in villages. Kluai Namwa of the Pisan Awak type, has an average fruit weight of about 100 g. It has a smoky yellow and moderate thickness rind when it ripens. The firm and sticky flesh is creamy white and sweet, and can be eaten both fresh and cooked.

Kluai Khai, meaning *egg banana*, of the Sucrier type has a very thin rind and is golden yellow when ripens. Although it is similar to Pisang Mas of Indonesia and Malaysia, Kluai Khai is very sweet with an appetizing fragrance and yellowish white flesh. The fruit weight is about 50 g. Kluai Hom, meaning *aromatic banana*, has a special flavour and fragrance compared to other commercial varieties of the Gros Michel type. Although the fruit is bigger than Namwa and Khai, 150 g, it is still smaller than other varieties of the Gros Michel.

Durian (*Durio zibethinus* Murr.), ***Thai name:*** *Thurian*

There are over 100 varieties of Thai durian. Monthong, Chanee, and Kradumthong are three major commercial varieties. Puangmanee and Kanyao are also potential varieties for commercial establishment. Durian is one of the well known and appreciated fruits in Asia and is a gourmet's delicacy. The fruit of the commercial varieties, weighing from 2 to 5 kg with large thorns on the skin, has a sweet, aromatic and creamy pulp with a creamy yellow to golden yellow colour inside. In 100 g of durian pulp is found 29.6 g carbohydrate, 2.1 g protein, 29 mg calcium, 34 μg phosphorus and 46 IU β-carotene. In comparison, banana contains 31.9 g carbohydrate, only 0.9 to 1.5 g

Fruits	Jan	Feb	Mar	Apr	Ma	Jun	Jul	Aug	Sept	Oct	Nov	Dec

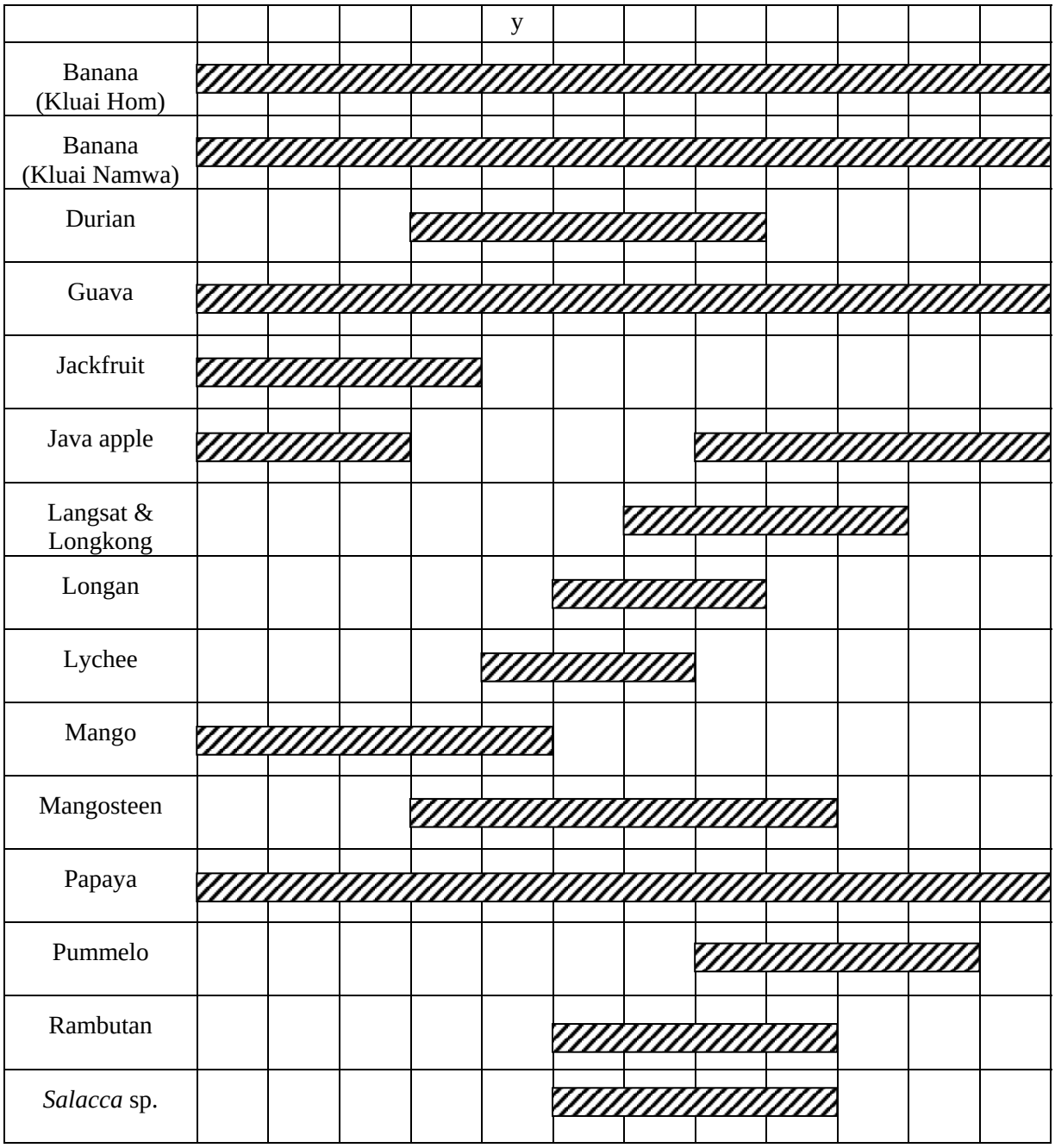

Figure 1 Fruiting seasons of some tropical fruits in Thailand. (Dept. of Agricultural Extension, Ministry of Agriculture and Cooperatives, 1998.)

Table 1 Nutritive values of Thai fruits (Nutritive Values of Thai Fruit, 1987, 1992. Nutrition Division, Department of Health, Ministry of Public Health, Thailand.

	Nutrient Composition per 100 g. Edible Portion																		
	Proximate composition								Minerals			Vitamins							
	Energy	Moisture	Protein	Fat	Carbohydrate	Crude Fiber	Dietary Fiber	Ash	Calcium	Phosphorus	Iron	Retinol	B-Carotene	Total A (RE)	Total A	Thiamin (B_1)	Riboflavin (B_2)	Niacin	Vitamin C
	Kcal	grams					milligrams		micrograms			IU	milligrams						
Avocado	102	79.0	1.1	6.1	13.2	1.0	-	-	12	26	0.7	-	-	-	342	0.05	0.10	1.4	8
Banana (Kluai Khai)	140	62.8	1.5	0.2	32.9	0.4	1.9	0.7	4	23	1.0	-	492	82	-	0.03	0.05	1.4	2
Banana (Kluai Namwa)	139	62.6	1.1	0.2	33.1	0.3	2.3	0.7	7	43	0.8	-	54	9	-	0.04	0.02	1.4	11
Banana (Kluai Hom)	125	66.3	0.9	0.2	29.8	0.3	1.9	0.9	26	46	0.8	-	99	17	-	0.04	0.07	1.0	27
Bael fruit	133	61.5	1.8	0.3	34.7	2.9	-	-	85	50	0.6	-	-	-	92	1.30	1.19	1.1	8
Bilimbi	11	96.9	0.3	0	2.4	0.3	-	0.3	1	6	0.2	-	-	-	267	0.03	0.09	0.7	2
Bread fruit	96	72.9	1.3	0.3	24.7	1.3	-	-	29	40	0.7	-	-	-	17	0.08	0.06	1.2	12
Carambola	34	90.0	0.4	0.1	7.8	0.9	-	0.8	9	15	0.9	-	-	-	123	0.02	0.17	0.8	28
Durian	156	62.5	2.9	3.8	29.6	1.4	-	0.9	49	34	2.0	-	46	8	-	0.16	0.23	2.5	35
Gandaria (Ma-prang)	47	86.6	0.4	0	11.3	0.3	1.5	0.2	9	4	0.3	-	230	39	-	0.11	0.05	0.5	100
Grape	50	86.0	0.5	0.3	12.8	0.9	-	-	9	20	0.6	-	-	-	83	0.10	0.06	0.2	4
Guava	34	89.0	0.6	0.1	7.8	-	2.9	0.5	2	12	0.4	-	21	3	-	0.05	0.11	1.3	187
Jackfruit	113	70.3	1.3	0.4	26.1	1.0	-	0.9	20	22	1.0	-	-	-	233	0.10	0.01	0.4	88
Java apple	24	92.8	0.5	0	5.5	0.4	1.1	0.1	2	18	0.3	-	53	9	-	0.02	0.18	0.6	32
Jujube	41	87.0	1.0	0.1	9.1	0.5	2.2	0.6	14	6	0.4	-	31	5	-	0.01	0.21	1.1	32
Langsat	66	82.9	0.9	0.1	15.3	0.3	-	0.5	5	35	0.7	-	-	-	15	0.08	0.04	1.7	24
Lime	36	91.0	0.5	2.4	5.9	0.3	-	-	13	11	tr.	-	-	-	17	0.03	0.02	0.1	46
Longan	61	83.4	1.1	0.1	14.0	0.2	1.1	0.3	1	12	0.5	-	-	-	29	0.07	0.08	0.9	11
Lychee	57	85.2	0.9	0.1	13.1	0.1	-	0.6	7	41	1.3	-	-	-	0	0.11	0.04	0.3	-
Malay Apple	28	91.7	0.3	0.1	6.5	1.0	-	0.4	2	8	0.6	-	-	-	108	0.01	0.04	0.3	20

	Nutrient Composition per 100 g. Edible Portion		
	Proximate composition	Minerals	Vitamins

	Energy	Moisture	Protein	Fat	Carbohydrate	Crude Fiber	Dietary Fiber	Ash	Calcium	Phosphorus	Iron	Retinol	B-Carotene	Total A (RE)	Total A	Thiamin (B_1)	Riboflavin (B_2)	Niacin	Vitamin C
	Kcal	grams					milligrams			micrograms			IU	milligrams					
Mango (unripe)	60	82.9	0.6	0.4	15.3	0.4	-	-	10	15	0.2	-	-	-	183	0.06	0.05	0.6	62
Mango (halfripe)	69	81.1	0.4	0.6	17.5	0.2	-	-	10	15	0.3	-	-	-	392	0.06	0.05	0.6	48
Mango (ripe)	62	82.6	0.6	0.3	15.9	0.5	-	-	10	15	0.3	-	-	-	3133	0.06	0.05	0.6	36
Mangosteen	76	79.2	0.5	0	18.4	0.3	1.7	0.2	11	17	0.9	-	0	0	-	0.09	0.06	0.1	0
Papaya (ripe)	51	86.9	0.8	0.3	11.3	0.5	-	0.2	12	22	2.5	-	-	-	1308	0.04	0.03	0.3	78
Pineapple	47	87.0	0.7	0.3	11.6	0.5	-	-	17	12	0.5	-	-	-	58	0.06	0.03	0.3	22
Pomegranate	72	80.0	1.0	0.6	17.7	1.1	-	-	13	23	0.7	-	-	-	-	0.07	0.01	0.3	7
Pummelo	39	88.9	0.7	0.3	9.5	0.4	-	-	27	22	0.5	-	-	-	50	0.05	0.02	0.3	53
Rambutan	63	82.9	0.9	0.1	14.5	1.1	-	0.5	3	6	1.8	-	-	-	4	0.04	0.05	0.6	31
Santol	57	84.5	0.4	0.7	13.9	1.0	-	-	9	17	1.2	-	-	-	83	0.05	0.03	0.9	14
Sapodilla	71	77.3	0.3	0.8	15.6	2.5	5.6	0.4	15	6	0.6	-	22	4	-	0	0.01	0.6	47
Strawberry	34	90.6	0.8	0.5	7.6	1.7	-	-	25	30	0.9	-	-	-	17	0.04	0.03	0.4	53
Star gooseberry	28	91.7	0.7	0	6.4	0.6	-	-	5	23	0.4	-	-	-	-	0.01	0.05	-	8
Sugar apple	87	75.2	1.4	0.2	19.9	1.2	2.7	0.6	7	27	0.4	-	0	0	-	0.09	0.09	1.0	tr.
Sweet tamarind	314	12.4	2.9	0	75.6	4.7	-	4.4	141	165	0.9	-	-	-	264	0.46	0.01	1.3	75
Tangerine	37	89.9	0.6	0.4	7.8	0.5	1.3	tr.	30	24	0.8	-	82	13	-	0.04	0.04	0.4	42
Young coconut (flesh)	55	83.1	1.6	2.0	7.7	4.5	-	1.1	13	173	1.0	-	-	-	25	0.06	0.04	1.3	4
Young coconut (juice)	22	94.4	0.2	0.4	4.5	0	-	-	24	18	0.3	-	-	-	0	tr.	tr.	tr.	3

Remark:
- \- = non-analysis
- tr. = trace
- Kcal = kilocalorie
- RE = Retinol equivalent
- IU = International unit

protein, 26 g calcium (Kluai Hom), 45 μg phosphorus and over 50 IU β-carotene (Table 1).

Durian is also known for its strong and pungent odour which can be offensive and nauseating to some people. There is a saying about its taste and aroma, namely *Tastes likes heaven, but smells likes hell*. Thai durian always emits a sweet and very aromatic smell at the proper stage of ripeness. Thailand is the leading producer and exporter of durian. Almost 50% of the total value of exported fresh fruit is due to the value of durian. The total area of durian cultivation is about 137,649 hectares with production of about 797,343 tons.

Guava (*Psidium guajava* Linn.), ***Thai name:*** *Farang*

Guavas are normally eaten when fully ripe elsewhere in the world. However, Thai people prefer to eat green guava instead of ripe fruits. Guava varieties have been developed for being eaten green for decades. Crunchy texture and nutty taste are main criteria of varietal improvement. Green guava contains a very high amount of vitamin C, 187 mg, and 2.9 mg dietary fiber (Table 1).

Jackfruit (*Artocarpus heterophyllus* Lamk.), ***Thai name:*** *Khanun*

Jackfruit is one of the largest fruits in the plant kingdom and is a fast growing monoecious evergreen latex producing tree which may produce fruit all year round. All species of *Artocarpus* are tropical and require a warm humid climate. The jackfruit is the most cold tolerant species as it can withstand some frost. The fruit may weigh as much as 60 kg, depending on varieties. It can be eaten fresh when ripe and cooked when immature. There are two main groups of jackfruit varieties in Thailand; the yellow-fleshed and the yellow-orange-fleshed group. The taste of both groups is sweet and fragrant. Jackfruit contains 88 mg vitamin C, 233 IU of total vitamin A, 20 mg calcium and 22 μg phosphorus in 100 g pulp (Table 1). The market acceptability of jackfruit as a fresh fruit would probably be low in some countries due to the large size and strong smell of fully ripe fruit

Java apple (*Syzygium javanica*), ***Thai name:*** *Chomphu*

Java apple, a pear-shaped, tender and juicy fruit with sweet and pleasant aroma, is a common fruit throughout Southeast Asia. The fruit colour varies from green (Thun Klao) and greenish red (Phet Sai Rung and Phet Sam Phran) to dark red (Thap Thim Chan), depending on varieties. The fruit weighs from 70 to 200 g. Java apple is consumed fresh and is well known among the Thais. Thun Klao (heavy bearing and seedless), Phet Sai Rung (very sweet) and Phet Sam Phran (giant fruit with firm and crispy texture) are Thai varieties which have been developed recently and are popular among growers. The three varieties produce 2 main peaks of fruiting period, April to May and September to February. The propagation is through air layering and cuttings.

Longan (*Dimocarpus longan, Euphoria longan* (Lour.) Steud), ***Thai name:*** *Lamyai*

Longan, one of the popular fruits in the tropics and sub-tropics, has an aromatic flavour and taste. The fruit is consumed fresh or processed into various products such as

canned, sun dried and oven dried longan. Thai may also use longan in a recipe as a main dish or dessert. Longan is widespread in the north of Thailand (about 92% of total hectares under longan cultivation), because it requires cool and dry weather. However, a chemical treatment has been developed recently to promote off-season production. Thai longan and products are exported mostly to the countries where Chinese people reside such as Hong Kong, Taiwan and Singapore as they believe in its nutritive value and dragon-eyed seeds.

Longkong (*Aglaia hybrid*: *A. domestica* Griff. x *A. dookoo* Griff.)

The fruit shape is globular with dull yellow rind. It was stated that *longkong is a recently developed fruit crop, probably derived from a natural hybrid of langsat (A. domestica) and duku (A. dookoo).* Langsat, duku, and other *Lansium* species are native to Malaysia, Indonesia, Thailand and Philippines. The fruits are mostly consumed locally and do not store for long after harvest. The longkong bunch is clustered and the fruit skin is a little darker and thicker than langsat. There is no white latex secreted from the rind when peeled. The skin of both fruits peels easily and cleanly from the clear, white, translucent, and juicy aril. Longkong has almost no seeds and is very sweet with a mild aroma and a perfect combination of a little sourness, which makes the fruit so delicious. Langsat has 1 to 5 seeds, which are firmly attached to the aril. Pollen grains of langsat are sterile, fruits and seeds are respectively autonomously parthenocarpic and apomictic in development.

Mango (*Mangifera indica* Linn.), ***Thai name:*** *Ma-muang*

Mango is one of the popular fruits in Thailand and many other Asian countries. It is widely distributed throughout Thailand. Almost 40% of the total hectares for fruit growing is used for mango cultivation. Thai varieties can be eaten green or fully ripe. Some are suitable for processing such as pickles and dried mango. Thai varieties (Nam Dok Mai, Ok Rong and Nang Klang Wan) which eaten when fully ripe, have a delicate and sweet flesh. They are eaten with glutinous rice (well cooked with coconut milk and sugar) as a delicacy. It is a favorite dessert for Thais and foreigners during the mango season. Khieo sawoei and Rad are varieties unique to Thailand as they are eaten green. Malaysia is a potential market for Thai mango.

Mangosteen (*Garcinia mangostana* Linn.), ***Thai name:*** *Mangkhut*

Mangosteen is widely grown in the east and the south of Thailand. It is established that *there is no genetic variation in mangosteen since it is propagated apomictically*. Mangosteen is often grown as a minor component in mixed crop plantings in most parts of Southeast Asia as it has a long juvenile period and slow growth. In Thailand, there was a noticeable change from growing mangosteen as a minor component in mixed fruits within small acreages to profit-oriented commercial scale monocrop farms, especially in the east of the country. The trees require fairly high rainfall, and humidity and well-drained soils. Although native to Malaysia and distributed to all Southeast Asia countries, Thai mangosteen has attracted lucrative markets in many Asian countries and North America since the fruit can be cared for through proper harvesting and postharvest handling, and the pure white pulp is in perfect condition when consumed.

Taiwan, Hong Kong, Japan and the United States of America are potential markets for both fresh and frozen Thai mangosteen.

Papaya (*Carica papaya* Linn.), ***Thai name:*** *Malako*

Papaya has long been popular not only in the tropical countries but also in the other parts of the world. It was introduced from tropical America over a century ago, and is quite adapted to Thailand and cultivated widely. There are many local and introduced varieties in Thailand. Khaek Dam, Khaek Nuan and Khaek Dam Tha Phra are popular varieties with excellent texture and taste. Unlike other countries, Thai consume both fully ripe and green papaya. Apart from eaten fresh, fully ripe papaya is also processed as canned fruit salad and exported mostly to the EU and the United States of America markets. The green papaya is eaten cooked or as a fresh vegetable. A Thai dish known as Som Tam, spicy salad, made from green papaya is a popular appetizer not only in Thailand but also in Thai restaurants in many countries. At present, the planted area for papaya is about 27,320 hectares.

Pummelo (*Citrus maxima* (Burm.) Merr.), ***Thai name:*** *Som O*

Pummelo is quite a common fruit crop in Thailand. Apart from local consumption, cultivation of pummelo in this country has also found lucrative markets in Hong Kong, Singapore and Canada. Pummelo has some similarity with grapefruit. However, the grapefruit seeds are polyembryonic, the pummelo is always monoembryonic. Pummelo can be grown throughout Thailand, but the main growing area is in the Central Plain of the country. The taste is from sweet and slightly sour to sweet and scented which makes pummelo quite attractive to consumers. Besides this, the fresh fruit can be kept for about one month at 25-30 °C and used to pay respect to Chinese Gods in various Chinese festivals.

Rambutan (*Nephelium lappaceum* Linn.), ***Thai name:*** *Ngo*

Rambutan, a succulent fruit native to Malaysia and Indonesia, has a unique pleasant sweet flavour. The oval fruit has a bright red to yellow skin colour. It is presently in many Southeast Asian countries, and Thailand has become the leading producer of the fruit. The two commercial varieties, Rong Rian and See Chomphu, have a loose seed coat which is easily separated from the juicy aril. Most of rambutan grown in the country is consumed fresh and canned in syrup. Also, rambutan stuffed with a chunk of pineapple and canned in syrup is quite popular because of the two fruits unique blend in taste. The export of both canned products to major markets as Singapore, Taiwan, Hong Kong and China accounted for about US $ 10 to 15 million a year.

Salacca (*Salacca wallichiana* C. Martius), ***Thai name:*** *Sala*

Sala is believed to be selected naturally from rakam, a wild form of *Salacca* in Thailand. A sala clone, named Mo, was then developed and grown near Bangkok until urbanization took place. The chance seedling of Mo, called Noen Wong, was further selected and grown in Chanthaburi province in the east of Thailand over a century ago. Another indigenous rakam group grown in Thailand is sakam (thornless *Salacca*). *Salacca* is a dioecious species and male plants are required as a pollinator. At present, sala Noen Wong is widely cultivated in the east of Thailand. Its growing area has been

extended recently to the south of Thailand. Unlike Noen Wong, large scale cultivation of sala Mo was established only in Phetchabun province in the lower north of Thailand. Sweet with a delicious flavour and distinctive aroma is an attractive characteristic of sala. The propagation is through stem cuttings since plants from seeds always produce more male than female plants.

6. International Fruit Trade

The total export of Thai fresh fruits and products was valued greater than US $ 400 million between 1992 and 1995 while the total value of fruit imported was about US $ 60 million. Since 1996, Thailand has imported about US $ 90 million of temperate fruits and products into the country. These imports were dominated by apples and pears which accounted for 47.5% of the total imported value. Others included grapes (5.0%), nuts, fruit juice and cherries and peaches. Most of the fruit were from the United States of America, China, Australia, New Zealand and Taiwan which together accounted for over 60% of total imported fruits.

6.1 Export of fresh and frozen fruits

The export of fresh and frozen fruits has been an increasing trend between 1995 and 1999 (Table 2). The breakdown on the fresh and frozen fruits exported were durian (49.4%), longan (21.6%), lychee (6.7%), mango(3.0%), mangosteen (2.4%) and rambutan (2.0%). Fruits having a significant increase in exports in recent years include pineapple, banana (Kluai Khai) and pummelo.

Hong Kong, Taiwan, Malaysia, Indonesia and Singapore are major markets for fresh fruits from Thailand. Hong Kong's market accounted for 49.6% of the total exported fresh fruit between 1995 and 1999. Taiwan's market accounted for 21.3%. Apart from importing fresh fruits for domestic consumption, Singapore also re-exports the imported fresh fruits from Malaysia, Thailand and other countries to various fruit markets worldwide. China, Japan, the Netherlands, the United Arab Emires and the United Kingdom are also included in the top ten export markets for Thai fresh fruits.

Over 80% of total frozen fruits was exported to the United states of America, Japan, Australia, the Netherlands and Canada. Frozen durian, longan and mangosteen accounted for over 60% of total value of exported frozen fruits. Although its market share is not as large as the fresh fruits, it had a tendency to increase since 1997. The Middle East is considered as a potential market for fresh and frozen fruits. The Ministry of Commerce through the collaboration with exporters and various trade missions have been developing the Middle East Market.

6.2 Export of processed fruits

The total export value of processed fruits contributed to over 70% of total exports. Pineapple (canned, juice and others) has been the main crop contributing 73.1% of the total value in 1999. Other potential processed fruits included rambutan, longan and lychee. Most of the products were exported to the United States of America, the EU countries, Japan, Australia, Canada, Spain and Taiwan. The export market for the

processed fruits will be expanded to the middle east where canned food and vegetables are successful.

Overall, the United States of America, the EU, Canada and Australia are major export markets for frozen and processed tropical fruit from Thailand, whereas Asian markets, Taiwan, Hong Kong and Singapore for instance are big markets for fresh fruits. The Middle East is a potential market for both fresh and processed fruits.

Table 2 Imported and exported values of fresh and processed fruits, Thailand, 1995 - 1999.

Value: US $ million

Year	Fresh and frozen fruits		Processed fruits		Total	
	Import	Export	Import	Export	Import	Export
1995	62.0	77.4	5.2	380.7	67.2	458.1
1996	86.2	97.7	6.4	367.4	92.6	465.1
1997	85.6	129.0	8.8	340.4	94.4	469.4
1998	66.2	97.4	10.7	376.8	76.9	474.2
1999	84.7	134.4	9.9	530.7	94.7	665.1

Source: Department of Export Promotion, Ministry of Commerce, Thailand.

7. Conclusion

As a consequence of increasing world demand for tropical fruits, an increase in the export markets (both the traditional and the new potential markets) for Thai fruit is expected. Canada, Australia, the Middle East, and South Africa are newly found markets for fresh and processed fruits from Thailand. At present, pineapple, durian, longan, lychee, and rambutan have contributed to the country's exports of fresh and processed fruits. Although tropical fruit is positioned to be another important economic crop in the Thai agricultural sector, the international markets for fresh and processed fruits have been not yet fully exploited.

To sustain the present markets is as important as it is to expand and develop the new potential markets. The important issue for the country is not to focus only on the market development but also on the product development, quality and diversification of fresh fruits and products. Efforts should be made to encourage the participation of producers, traders, and related governmental agencies in the fruit industry in Thailand as well as implementing systemic management and practices to build up the strength of the

industry. The foreign investment in fruit trade should be encouraged in order to establish and capture the overseas markets.

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Rambutan Production in Thailand

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1. Introduction

Rambutan (*Nephelium lappaceum* Linn.) is an evergreen tree native to west Malaysia and Sumatra. It is cultivated widely in Southeast Asian countries; Thailand has become the leading producer and exporter of the fruit. The total area cultivated with rambutan was about 86,440.6 hectares in 1999.

The fruit is globose to ovoid, green in colour while developing and ripens to various shades of pink, red or yellow, depending on the variety. The edible aril is translucent white to yellow-white and eating quality varies according to the varieties. The aril of Thai varieties may or may not peel cleanly from the seeds and contributes to 40 to 46% of the total fruit weight. The seed is elliptic ovoid or oblong. In freestone varieties, the aril usually detaches together with the seed testa. In 100-mg of aril, rambutan can contain 31-mg of ascorbic acid.

This paper briefly describes rambutan production in Thailand and also highlights the management practices employed by growers to produce rambutan. Information on fertilization, irrigation, varieties, and control of flowering are also included in this paper.

2. Area of cultivation and varieties

In 1999, the area of fruit cultivation in Thailand was about 936,381 hectares. The planted area with rambutan for commercial production accounted for 9.2% of the total hectares. The rambutan is grown widely in a 3,000 to 4,000 mm precipitation zone in eastern and southern Thailand, which accounts for 51 and 48% of total area of rambutan cultivation, respectively. At present, Chanthaburi province in eastern Thailand, and Chumphorn and Surathani provinces in southern Thailand are the three most extensively cultivated areas, accounting for 39, 15, and 10% of the total hectares under rambutan cultivation, respectively.

Rambutan seedlings are planted in a 6- to 10-m spacing on a square (about 100 to 280 trees per hectare), with a row of banana or papaya planted between each row of young rambutan. About 5 to 10 kg of compost or animal manure, (chicken manure is always chosen,) is applied every year to add organic matter to the plants. During the first two years after planting, a complete fertilizer, such as 16-16-16 or 13-13-21, is applied three times a year. A reasonable amount of complete fertilizer is 3 kg/plant/year. The fertilizers (which needs to be spread our well) may be applied either to soil, or through irrigation. Plants need 0.6 times the evaporation rate (3.5 to 5 mm/day), or on a 8 x 8 m spacing about 105 to 151 liters/plant/day.

Rambutan production increases from about 20 to 25 kg/tree, 3 years after field planting, to about 250 to 300 kg/tree at 12 years after planting. The rambutan can yield up to 400 to 450 kg/tree in year 30 after planting.

3. Cultural techniques to prepare plants for flowering

A vigorous rambutan tree with fully mature green healthy leaves and prolonged water stress are important factors for flower initiation. To induce a vigorous tree, these cultural techniques should be applied:

3.1 Fertilization and irrigation

A complete fertilizer, 16-16-16 or 13-13-21 of N-P-K-, and chicken manure are applied just after harvest. If the period of plant preparation is in the rainy season, irrigation may be unnecessary. Dry spells in excess of 7 days necessitate irrigation. A suggested watering regime is 60 to 65% of pan evaporation.

3.2 Pruning

Pruning out of all water shoots and dead branches within the tree frame and overlapping side-branches is common. Pruning is always done just after harvest to promote strong vegetative growth. Unnecessary branches within the canopy may be pruned to improve light conditions within the canopy. The top of the canopy may be removed to control the canopy height.

3.3 Pests and diseases

Diseases, which may be present during vegetative growth, are powdery mildew (*Oidium nepheli* Kunze), pink disease (*Corticium salmonicolor* Berk. et Br.) and algal spot (*Cephaleuros virescens* Kunze). These diseases damage leaves and stems.

In Thailand, the leaf eating looper (*Oxyodes scerobiculata* Fabricius) which damages both fully expanded and fully mature leaves, is more serious than the leaf eating caterpillar (*Parasa lepida Cramaer). Hypomeces squamosus* Fabricius which damages both leaves and young shoots is also present in Thailand.

4. Flower induction and development

About 2.5 to 3 months after harvest, a complete fertilizer, 8-24-24 of N-P-K, is applied to the rambutan trees to stimulate the flowering process. Rambutan trees require prolonged water stress for about 2 to 4 weeks to induce flowering. Rambutan is ready to undergo an induction period when the terminal leaves of the latest flush are mature, and the wet season has ended. When the terminal leaves grow upright and both margins are slightly bent upward after the trees have been exposed to water stress, a large amount of water (about 10 mm applied only once) is applied to stimulate flowering. More water may be required if there are strong winds. About 7 to 10 days after irrigation, the terminal shoots will develop and turn from black brown to a golden brown colour. Another 10 mm irrigation is then applied to stimulate flower bud growth.

If too much irrigation is applied to the trees after being exposed to the stress conditions, the terminal shoots will turn to a green brown colour and tend to develop into leaf buds. To stimulate flower development from these vegetative buds, irrigation should be withdrawn until the colour of the terminal shoots becomes golden brown, then 5-mm irrigation will be applied. A recommended irrigation regime is 75% of pan evaporation to

promote flower bud growth and development. The development of panicles from floral bud emergence to full bloom is only 3-4 weeks. Powdery mildew is also found to damage the rambutan panicles. Chilli thrips (*Scirtothrips dorsalis* Hood) is one of the key pests of rambutan grown in Thailand. Apart from the chilli thrips, Haplothrips sp., Megalurothrips sp. and *Thrips hawaiiensis* Morgan are also present during the panicle development.

5. Fruit set and development

Rambutan flowers are small, greenish pubescent (600 to 2,000 flowers per panicle) and usually functionally unisexual. Flower lack of odour, but secrete nectar at anthesis to attract honeybees, which affect pollen transfer. The trees have been generally classified into 3 groups according to flower characteristics.

5.1 Male trees - producing only staminate flowers. About 40 to 60% of any seedling population are usually male trees. These trees are an important pollen source for the fruit set process. Pollen is shed only for 3 to 4 hours in the morning of flower opening.

5.2 Trees produce hermaphrodite flowers, which are functionally female. This type of flowers is receptive at anthesis and remains for up to 48 hours.

5.3 Trees produce hermaphrodite flowers, some of which are functionally female, and some are functionally male. This is the most common form in cultivar selection.

Since the (5.2) type of flower is widely seen in cultivated rambutan, cultural techniques to convert or improve sufficient flowers to a functional male status for adequate pollination are required to improve fruit set.

- Assisted pollination is done by hanging male panicles collected from the male trees directly onto functionally female hermaphrodite panicles when the hermaphrodite flowers are about 50% bloom on each panicle. This is one of the cultural techniques to improve fruit set. The male panicles are left until the fruit are set and start to develop. This technique is labor intensive and requires a large number of male panicles.

- Pollen grains, collected from the male trees, in an amount of 0.5 to 1.0 liter may be mixed in 20 liters of water and sprayed onto the hermaphrodite trees when the panicles develop to 50% full bloom. The second application, a week later, is recommended.

- Another technique to improve adequate pollination is to graft male scions onto the hermaphrodite trees. One grafted tree may provide adequate pollen for about 5 hermaphrodite trees. Planting male trees in a row of hermaphrodite trees with ratios of male: hermaphrodite varying from 1:5 to 1:10 is also recommended in newly established orchards.
- A spray of 1 - naphthylacetic acid (NAA), (4.5% stock solution diluted at a concentration of 1 ml - NAA per 1 liter-water) applied to hermaphroditic panicles located particularly at the top part of the trees about a meter apart at the time of early

bloom (the majority of panicles is 5% bloom) converts the hermaphrodite flowers to functional male flowers. If a dilute concentration of NAA, (1 ml NAA stock solution per10 liter water) is applied to the whole tree when the majority of the panicles is about 5% bloom, all hermaphrodite panicles will be converted to male functional panicles. In this case, the treated tree will act as a pollen source. After the pollen is shed, the treated panicles will be cut off and the new coming panicles will be the (5.3) type and set fruit easily.

Beehives can be placed in the orchard to increase bee activity for pollination. During the development of panicles, an irrigation regime of 75% of pan evaporation is applied to promote their growth and development. The same amount of water is applied until the end of the first week after anthesis to promote growth and development of fertilized ovules. Gibberellin A_3 (GA_3) at 8 to 10 ppm can be applied 1 week after anthesis to promote growth of young fruits.

6. Fruit growth and development

Rambutan trees require irrigation regimes at an amount of 80% and 85% of pan evaporation when fruits are 2 to 5 weeks and older than 6 weeks after anthesis, respectively. Regular and consistent watering regimes are crucial for fruit growth and to prevent fruit split. Fruit splitting always occurs after heavy rain if irrigation is not adequate and inconsistent during various stages of fruit growth.

The fruit size may be increased if a single panicle retains about 8 to 10 fruits only. Therefore, fruit thinning is recommended. The thinning should be made and completed not later than the fourth week after anthesis. A complete fertilizer, 13-13-21 of N-P_2O_5-K_2O, should be applied to the soil during this period of fruit development. The period from anthesis to fruit maturity is normally 3.5 to 4 months.

Pesticides can be applied, if required. Diseases present during fruit growth and development are powdery mildew, sooty mold (*Capnodium* sp.), black fruit rot (*Gliocephalotrichum bulbilium* Ellis & Hesseltine), and brown fruit rot (*Phytophthora botryosa* Chee).

Mealy bug (*Ferrisia virgata* Cockerell, *Planococcus lilacinus* Cockerell and *P. minor* Maskell) damage can be the most problematic during fruit growth. The fruits can sometimes be destroyed by chilli thrips, whose natural enemies are *Amblyseius* sp. (Phytosiidae, Acarina) and *Stethorus* sp. (Coccinellidae, Coleoptera).

Fruit maturity is determined by development of rind colour and aril taste. Hooked knives or small scissors on poles are used to detach the panicles. Individual fruit are normally detached prior to sale. The whole panicles may be bunched, weighing about 1 kg/bunch, and presented for sale in a bunch of panicles. The fruit shelf life is extremely short. The fresh fruit usually stays marketable for only 3 to 4 days at room temperature, (25 to 30 °C). This is one reason why the export of processed rambutan is larger than the fresh fruit.

7. Export of rambutan

Thailand exports rambutan as both fresh and processed fruits. Fresh rambutan accounted for only 2% of the total export of fresh fruits. Malaysia, Taiwan and the United of Arab Emires are major markets for fresh rambutan from Thailand. In Thailand, rambutan fruits are processed as rambutan stuffed with a chunk of pineapple and canned in syrup. Both types of processed rambutan can be exported to Singapore, Taiwan, Malaysia, the United States of America, China and Australia. The EU markets, Australia and Canada are also potential top ten markets for processed rambutan. The export of processed rambutan accounted for US $ 10-15 million a year.

Discussion

Rambutan is one of the most popular tropical fruits in Thailand, because it produces a very attractive fruit, that has an acceptable texture and flavour. Apart from produced as a fresh fruit; there is a significant canning industry, especially in Thailand. Thailand can export both fresh and processed fruits mostly to Malaysia and Singapore. Other potential markets include Taiwan, China, Australia the United States of America, Canada and the United Arab Emires. The EU markets are also of interest. The economic benefit from the export of processed rambutan is about 10 times greater than the fresh fruit. Postharvest technology is being studied to prolong the shelf life of the fresh fruit. In the meantime, diversification of processed rambutan is also emphasized. Appropriate postharvest technology and packaging, and varieties of processed rambutan are ideas that may contribute towards an increase in the market share of Thai rambutan in foreign markets.

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Mangosteen Production in Thailand

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1. Introduction

Garcinia mangostana Linn., mangosteen (manggis, Malaysia; mangkhut, Thailand) is a highly regarded fruit in tropical Asian countries. It is a broad-leafed evergreen tree, with a pyramidal shape and is native to the Malay Archipelago. Mangosteen is grown in most parts of Southeast Asia, often as a component of a mixed crop planting. It is a slow growing tree and may be up to 10 to 25 meters high. Mangosteen has a long juvenile period. The trees begin to bear fruits 10 to 12 years after seeding.

Quality mangosteen fruit, which is required by lucrative markets, should weigh greater than 80 g. Insect or mechanical damage and yellow latex should not be visible on the fruit skin. The inferior fruit quality, especially translucent flesh and latex exudation is unacceptable. Therefore, technology to improve mangosteen production has been established and transferred to mangosteen growers. Once the technology was fully applied, the growers could increase their marketable yield to 50% of total production.

The technology and descriptive information of mangosteen production in the country as well as foreign markets are described in this paper.

2. Cultivated area and export markets

The cultivated area in Thailand dramatically increased from 13,508 hectares in 1987 to 34,127 hectares in 1994 and to 46,817 hectares in 1999. The major planted area is in the south and the east of the country, which accounts for 68 and 31% of total area under mangosteen cultivation. Chumphorn and Nakhon Sithamarat provinces are major areas for mangosteen cultivation in the south, whereas Chanthaburi province is the major producer in the east. The production obtained from the cultivated areas in the south contributed 51% of the total production of the country (155,044 tons in 1999), whereas only one province in the east, Chanthaburi, produced up to 34.7% of the total production. Mangosteen is grown as a component in mixed crop planting in southern Thailand while growers in the eastern part of the country, especially Chanthaburi, changed from the traditional style of fruit cultivation as in the south to commercial scale monocrop farms.

The production season in the east of the country starts from April to June, but in the south continues from July to September, which is the rainy season. Since the translucent flesh and inside-fruit-latex exudation are caused by the rainfall about 1 to 2 weeks before harvesting, inferior fruit quality is observed in the production from the southern part of the country.

Mangosteen seedlings should be grown in a highly fertile potting mix and under 50% shade in the nursery for 2 years. Irrigation with an amount of water that is about 75% of daily pan evaporation should be applied daily. Both soil and foliar fertilizers should also be applied regularly to maintain normal growth. Plant growth regulators, thiourea + dextrose, or extended daylength, 2-hour-photoperiod extension may be applied thereafter to accelerate growth of mangosteen seedlings under the nursery conditions. The plants will then produce the secondary branches and increase in leaf area before transplanting.

After field transplanting, the plants should be grown under 50% shade conditions for about a year. An irrigation regime with an amount of water that is about 60% of the daily pan evaporation should be applied regularly. Mangosteen seedlings are planted at a 6 to 10-m spacing. There always is a row of papaya or banana between each row of young mangosteen. A complete fertilizer, 16-16-16 of N-P_2O_5-K_2O, and chicken manure are also recommended to promote the growth of young mangosteen. The plants should also be kept well protected from the major pests: leaf miner (*Phyllocnistis* sp. and *Acrocercops* sp.); and leaf eating caterpillars (*Stictoptera columba* (Walker), *S. cucullioides* (Guene), and *S. signifera* (Walker)).

Mangosteen production increases according to tree age. The 200-years-old trees grown in eastern Thailand can produce about 1,000 to 1,500 kg/tree. Yield of mangosteen recorded in Thailand is about 100 to 120 kg/tree at 20 years old after seeding at a 7 x 7 m spacing and the tree height and diameter are controlled at about 6 meters. If the canopy size is not controlled, the 20-years-old mangosteen trees may yield up to 250 kg/tree in a 10 x 10 m spacing.

Mangosteen is excellent as a fresh fruit. Thailand exports mangosteen to many Asian countries, and Taiwan and Hong Kong are major markets for fresh mangosteen. Markets accepting Thai fresh mangosteen fruits include China, Japan, and Canada. Thailand also exports frozen mangosteen to Japan, the United States of America, and Taiwan. The export of fresh mangosteen increased about 2 times in 1999 compared to that of the last 5 years, whereas the export of frozen fruit has been steady. The country exported about 4 times more fresh fruit than the frozen fruit, and only 3 % of total production can be exported.

3. Flowering process in mangosteen

Poonnachit et al. (1996) suggested that duration of water stress, age of apical buds, and plant vigor are three main factors involved in the flowering process of mangosteen. Once the three factors are in place, an appropriate water management is needed to trigger flower development.

Trees should exhibit a high degree of vigorous vegetative growth, which is apparent in a healthy tree with bright color and shiny leaves. Damage from pests on leaves should be about 6 to 10% of the total leaf. The mechanical and/or pest damage on branches can be more than 5% but less than 10% of total branch number. The apical buds should be at least 9-weeks-old or older following emergence of the latest flush when

the trees are exposed to stress conditions. The tree should be kept under the stress conditions until the last internode is noticeably wilted and the last pair of leaves is bent slightly downward. The leaf water potential measurement is then about -1.1 MPa. After being subjected to water stress, floral buds of mangosteen require irrigation to emerge.

4. Cultural practices to prepare mangosteen for flowering

After harvesting, the tree should be manipulated to produce maximal photoassimilates together with synchronized leaf flushing at a specific time to allow apical buds to be old enough for flower induction. These cultural techniques should be conducted to prepare mangosteen trees for the flowering process.

4.1 Fertilization and irrigation

A complete fertilizer of 16N-16P_2O_5-16K_2O and cow or chicken manure is applied to the soil immediately after harvest. Trees can be irrigated with 60% of the daily pan evaporation only when the rainfall ceases for longer than 7 consecutive days. Pruning is always done at the same time or after fertilization. Apart from soil fertilizer, an additional foliar spray of (600 g dextrose + 30 ml humic acid + 60 g of a complete foliar fertilizer) per 20 L water may be applied to trees with a heavy fruit load in the previous year. The trees should produce synchronous leaf flushing about a month after fertilization and pruning. A combination of 2,500 mg l^{-1} thiourea and 3,000 mg l^{-1} dextrose or 100 to 200 g of urea in 20 L water may be foliarly sprayed to induce leaf flushing.

4.2 Pruning

In Thailand, growers normally cut off only dead and mechanicaly damaged branches from heavy fruit loads and from harvesting. Water sprouts developing near the main stem are always removed. In order to induce early synchronous leaf flushing, pruning should be done just after or at the same time of fertilization. Unnecessary branches can be cut off to allow more light to penetrate into the canopy. One of the purposes of pruning is to improve the light conditions for remaining branches and to adjust the framework of the canopy. The side-branches and the top of the canopy can be removed to control the canopy size. The overlapping side-branches may result in a reduction in fruit production.

4.3 Pests and diseases

A number of major pests appear to attack mangosteen during the vegetative development stage. These are thrips, leaf miner, and leaf eating caterpillar, the same species that is present during the development of young mangosteen plants.

Leaf spot (*Pestalotiopsis flagisetula* Guba) occurs only in the wet season. Leaf blight (*Colletotrichum* sp.) and Helminthosporium leaf spot (*Helminthosporium garcinae* Petch) can also be expected.

5. Flower induction and development

As mentioned in section 3 '*Flowering process in mangosteen*', mangosteen trees should exhibit a high degree of vigorous vegetative growth and the apical buds should be

at least 9-weeks-old or older following emergence of the latest flush before being exposed to stress conditions. After being subjected to an optimum level of water stress (leaf water potential of about -1.1 MPa), mangosteen trees require irrigation to allow floral buds to emerge. A suggested water management regime to promote growth of the floral buds is a single application of 35 to 40 mm/tree followed by half of that amount (17.5 to 20 mm) applied at 7-day-intervals until flowering. Approximately, 7 to 10 days after the onset of irrigation, the first flower can be observed. After the emergence of the floral buds, 80% of daily pan evaporation is applied to stimulate normal development to anthesis. The development of mangosteen flowers from floral bud emergence to full bloom is only 3 to 4 weeks.

Flowers are terminal and creamy-colored, with 4 green sepals, 4 petals and a globose ovary with a thick stigma divided into 4 to 8 lobes. At flower opening, the stigmatic lobes are creamy with a faint pink color towards the periphery of the lobes and turns a deep pink to dark brown the following day. Staminodes carry aborted anthers, which are devoid of pollen. The ovary starts to enlarge directly after petal fall. The fruit is formed parthenocarpically so the seeds are apomictic in origin. The practice of growers is to raise mangosteen from seeds. The seeds are highly viable but are short lived.

Both chilli thrips (*Scirtothrips dorsalis* Hood) and mangosteen thrips (*S. oligochaetus* Karny) are found to damage the mangosteen flowers. If they attack the flowers at anthesis, a brown scar will be left on the ovary which becomes the fruit.

6. Fruit growth and development

Fruits that weigh greater than 80 g per fruit with a fresh and complete green calyx, unbroken peduncle and free from gamboge (internal latex) as well as translucent flesh are indices of superior or marketable quality mangosteen. Also, fruit should be clean and free from defects including excessive skin abrasions caused by thrips or by rough handling, hardened fruit, and insects on the fruit skin. To obtain fruits weighing in the quality indices range, an optimum number of fruit should be retained on the tree. Since the fruit is formed parthenocarpically, manipulations to optimize flower number should be done.

When flowers on about 10 to 15% of total terminal shoots are detected, an irrigation regime of about 8 to 10 mm/day should be applied to promote the development of the initiated flowers, but may inhibit some of the flowering of the remaining buds. The remaining buds may consequently develop to vegetative buds. After the emergence of the vegetative buds, an irrigation regime should be reduced to 75 to 80% of pan evaporation to stimulate normal growth of flower and vegetative buds. This water management technique can lead to an optimum number of flowers, 30 to 35% of the total number of shoots, and consequently an optimum number of marketable fruit size.

6.1 Fertilizer management

It has been reported that the developing mangosteen fruit at an age of 6 to 12 weeks after anthesis acts as a stronger sink when compared to the younger and older stages of development (Figure 1). Poor fertilizer management may cause undersized

fruits with inferior quality. A complete fertilizer (13N-13P_2O_5-21K_2O) should be applied when the fruit is in the first stage of development, 0-4 weeks after anthesis. In addition, a mixture of a complete foliar fertilizer with minor and trace elements and humic acid is also foliarly sprayed on a weekly schedule when the fruit is at 2 to 4 weeks after anthesis. This results in an increase in the growth rate of developing fruit, and results in a high proportion of marketable yield.

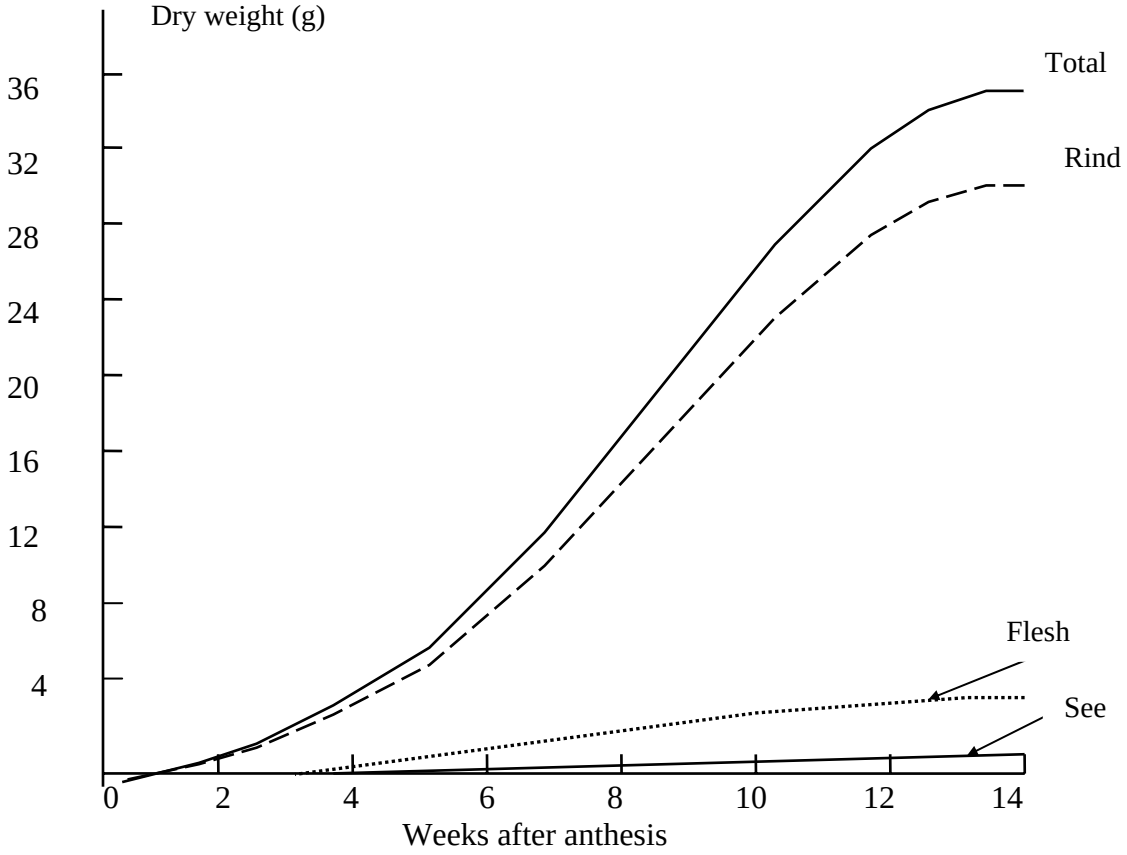

Figure 1 Growth pattern of mangosteen fruit after anthesis, Chanthaburi, Thailand.

6.2 Water management

A wilting symptom in the fruit end, fruit cracking, internal latex exudation, and translucent flesh may be found during the development of fruits if inappropriate water management is applied. A regular and consistent irrigation of 80 to 85% of pan evaporation is recommended to obtain normal growth of fruits until harvest. The wilting symptom at the fruit end will be eliminated and the severity of other physiological defects can be reduced to level where they are absent.

6.3 Pests and diseases

The major pests during fruit development are chilli thrips and mangosteen thrips. Fruit piercing moth (*Othreis fullonia* Clerck) may be present in some years.

6.4 Harvesting

In Thailand, hand harvesting or using an appropriate harvesting tool is the method to harvest mangosteen for marketing. When a pink blush develops on the light green yellowish fruit, mangosteen is said to be best for harvesting. Four to five days after harvest, the fruit turns from green yellowish to reddish purple, which is acceptable for eating quality. The best eating quality is the stage when the rind develops to a dark purple color. Mature fruits drop, and fruits, which are harvested at full maturity, readily spoil. If harvested too soon, fruits do not develop full flavor. During harvesting and postharvest handling, mechanical damages due to impact (equivalent to a drop from higher than 20 cm on a hard surface) and compression (pressure greater than 5 kg) should be avoided otherwise a large number of hardened fruit will result.

7. Conclusion

Mangosteen, *Garcinia mangostana* Linn., one of the outstanding fruits of the Guttiferae family, is excellent as a fresh fruit. It is grown widely in tropical Asian countries and in South American countries, and among these, Thailand is the leading producer and exporter. Thai mangosteen is shipped to Taiwan and Hong Kong, the major markets for fresh mangosteen. The markets for frozen mangosteen include Japan, China, and Canada. Only 3% of total production can be exported. Growth of mangosteen business will emphasize both sustaining the old markets and expanding to new markets.

The technology and cultural techniques to improve mangosteen production have been developed and transferred to growers. Accelerated research to improve the cost effectiveness for producing quality mangosteen is ongoing.

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Durian Production in Thailand

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1. Introduction

Durian, *Durio zibethinus* Murr., is one of the best known fruits in tropical Asia. Its natural distribution is peninsular Malaysia, southern Thailand, Indonesia and Borneo. The fruit is stalked, pendulous, and round to oblong with large thorns on the skin. The fruit is a capsule that is split into 3 to 5 segments. Each segment contains 1 to 5 seeds, each of which is embedded in a sweet, aromatic and rich creamy pulp (aril) with a creamy yellow to golden yellow color. It is also known for its strong and pungent odour, which can be offensive and nauseating to some people.

Durian is probably one of the most nutritious fresh fruit. The food energy of 100 g of durian pulp is about 156 kilocalories. The protein (2.9 g), fat (3.8 g), calcium (49 mg), iron (2.0 mg), and vitamin A (8 mg total A, 46 IU (β-carotene)) are very significant. Vitamin C content is also significant, 25 to 62 mg depending on varieties, and is comparable to grapefruit. About 8 kinds of amino acid, including methionine and lysine are contained in 100 g durian pulp. In Thailand, durian is one of the fruits with the highest export value. Besides consumption as a fresh fruit, durian is also processed into various products such as chips, French fried, sugary cakes, candies and a flavoring powder in ice cream, biscuit, and others including a main ingredient of Thai cuisine recipes.

The information contained in this paper includes general characteristics of durian, cultural techniques to improve its production, postharvest knowledge and the current status of its trade potential.

2. Cultivated area and export markets

Durian cultivation lies mainly in the eastern region, 49% of total cultivated area, and the southern region, 44% of the total durian cultivation. The total cultivated area of durian in Thailand was about 137,649 hectares in 1999. Chanthaburi and Rayong provinces are major cultivation areas in the east, whereas Chumporn is a major area in the southern part of the country. The total production was approximately 927,194 tons in 1999, and the production from the cultivated area in the eastern part of the country contributed to 75% of the total production, with about 50% produced in Chanthaburi province. The fruiting season starts from mid March to early July with a peak around April to June, in the eastern region. In the south of Thailand, fruits are produced between August and October, mainly the Monthong variety. The popular varieties being planted include Monthong, Kra dum thong, Chanee, and Puang manee. Monthong is highly praised and is the most prized of all. Kra dum thong is classified as an early season variety, Chanee and Puang manee are the mid-season varieties, and Monthong is a late-

season variety. In Thailand durian is commonly propagated through the approach, whip, and wedge grafting method, and approximately 90% of the trees grown in the country are produced by such grafts. Seedlings of any variety can be used as rootstocks, but seedlings of Chanee variety are the most popular.

Durian seedlings are planted at a 8- to 10-m spacing on a square (about 100 to 156 trees per hectare). The major pests during seedling and vegetative development are durian psyllids (*Allocaridara maleyensis* Crawford), African red mites (*Eutetranychus africanus* Tucker), shot hole borer (*Xyleborus fornicatus* Eichhoff), and a white grub, which damages the root system of durian. The most serious disease is patch canker caused by *Phytophthora palmivora*. The soil organism is a primary parasite of durian roots and the canker may develop on the trunk, branches and young shoots. Other important diseases are pink disease (*Coticium salmonicolor* Berk & Br.), anthracnose (*Colletotrichum zibethinum* Sacc.), leaf blight (*Rhizoctonia solani* Kuehm), and algal spot (*Cephaleuros virescens* Kunze). Durian trees start to produce the first fruit about 3 to 4 years after field transplanting, but are not yet at commercial production. The production increases from about 60 to 80 kg/tree at 6 years after transplanting to about 180 to 200 kg/tree at 12 years after planting on an 8 x 8 m spacing. The economic life of yielding durian trees is until about 20 to 25 years after planting.

Thai durian is exported both fresh and frozen, and as other products to many Asian countries. About 96% of the total exported fresh durian was transported to Hong Kong, Taiwan, and Malaysia. The United States of America, Canada and China are also the potential markets. Thailand also exported frozen durian to the United States of America, Australia, Hong Kong, Canada, and Taiwan. The EU and the Middle East markets are emphasized in the market expansion plan since only about 20 to 30% of total production can be exported.

3. Flowering process and flower development in durian

Durian trees should be healthy trees with bright color and mature shiny leaves. Damage from pests on leaves should be less than 5% of the total area. Mechanical and/or pest damages on branches should be less than 5% of total branch number. The trees must be free from Phytophthora disease. These types of trees exhibit a high degree of vigorous vegetative growth and are ready to flower when an appropriate inductive treatment is applied. A dry period for 7 to 14 consecutive days, about -0.8 MPa leaf water potential, is needed to trigger the emergence of flower buds. After the emergence of floral buds, irrigation of 60% of the daily pan evaporation is required for about a week to promote growth during an initial stage of floral development. To enable normal growth of the later stages of flower development, a suggested irrigation amount is 75 to 85% of the daily pan evaporation. Irrigation is reduced to one-third of the suggested irrigation regime at about 1 week before anthesis.

Durian flowers are borne in clusters on main and lateral branches, not on the trunk. Each inflorescence contains 8 to 20, or more, large pendulous flowers. The flowers take about 2 months from emergence to full bloom. At opening, the green epicalyx splits to reveal 5 slightly golden united sepals and 5 yellowish white petals. A

large receptive stigma which is covered with stigmatic fluid protrudes at about 1 p.m., about 2 hours before flower opening, and remains so until the following morning, approximately 18 to 20 hours after being receptive. Durian flowers usually open in the late afternoon, but anther dehiscence does not occur until about 6 to 7 p.m. or later depending on varieties. By midnight, all flower parts including stamens, excepting the pistil, fall to the ground. However, all flower parts may remain attached until the following morning if the recommended the water management regimes mentioned above are applied during the stage of development.

During the development of flowers, the trees should keep protected from African red mites and chilli thrips. *Phytophthora palmivora* may damage the flowers and other parts of the tree if the microclimate is humid.

4. Fruit set and development

Durian pollen is released singly or in clumps, indicating no distribution by wind. Moths may be involved in pollen transfer. In Thailand, hand-crossed pollination is a common practice to improve durian fruit set. The process of fruit set takes about 3 days from anthesis. After the fruit has been set, irrigation should be increased gradually to about 60% of pan evaporation within 3 weeks after anthesis to promote normal growth of young fruits.

The fruits of the commercial varieties in Thailand normally take about 90 to 135 days between anthesis and physiological maturity, depending on varieties, position of a fruit on a tree, conditions of cultural techniques, as well as environmental conditions. A complete fertilizer, 12N-12P_2O_5-17K_2O-2MgO or 8N-24P_2O_5-24K_2O or 13N-13P_2O_5-21K_2O is applied when the fruits are at about 5 to 7 weeks after anthesis. When fruits are at 9 to 10 weeks after anthesis, 0-0-50K_2O fertilizer should be applied. Water management regimes to enable normal growth of durian fruits are 70% of pan evaporation at 3 to 5 weeks after anthesis, 75% at 5 to 8 weeks after anthesis, 85% at 8 to 10 weeks after anthesis, and reduced to 75% and 60% at 10 to 12 and older than 12 weeks after anthesis, respectively. In Thailand, fruit thinning is another important cultural technique to promote growth, shape, and quality of fruit. The first thinning should be applied not later than the 8^{th} week after anthesis.

Durian seed borer (*Mudaria luteileprosa* Holloway), fruit boring caterpillar (*Conogethes punctiferalis* Guenee), mealy bugs (*Planocoocus minor* Maskell and *P. lilacinus* Cockerell) are major pests found during the development of durian fruit. Fruit rots caused by *Phytophthora palmivora* Butler, *Phomopsis* sp., *Colletotrichum* sp., and *Lasiodiplodia* sp. are also present.

Fruits drop when ripe. In Malaysia, fruits are allowed to fall on the ground and picked up daily. However, Thai growers detach the fruit at the stage of physiological maturity. The fruit will ripen to excellent eating quality about 3 days after harvesting. Days from full bloom to harvest is one characteristic indicating fruit maturity. Indices of maturity may be observed by changes in rind color, from waxy fresh green to slightly rusting, a dry look or freckles, and browning at ridges between fruits. Tips of spines may

turn to a brown color, slightly drying up, and shape and stiffness of spines (by observation or finger feeling) may also change. Changes also occur to the fruit peduncle; swelling of a portion of peduncle close to the break point; roughening (sand-feeling) on the peduncle surface; increase in stiffness of the peduncle-stem (by holding and swinging the fruit). The aril will turn from off-white to pale yellow, creamy, or yellow depending on variety. The color of the seed will also turn to a reddish brown. The acoustic method of tapping the fruit where the tapping sound changes from tight to loose can be used.

The fruit is highly sensitive to chilling temperatures lower than 14°C. Chilling causes discoloration of the rind and failure of the aril to soften. The optimum storage temperature and relative humidity are 14 to 16°C and 85 to 90% RH for mature-green durian. The fruit may be kept for about 2 weeks under such conditions.

5. Conclusion

Durian, a large tree native to western Malaysia, is grown throughout Asia for its large edible fruit. It is obvious that both domestic and overseas markets possess great potential for exploitation and further expansion of Thai durian. The development of an appropriate technology package to increase durian productivity and quality has been made to meet domestic and export demand. After the technology was transferred and fully applied to durian orchards, the production of quality durian increased dramatically. Consequently, the total export of durian increased dramatically from about 3% ten years ago to about 20% of total production in 1999.

At present, more emphasis will be given to cost effectiveness in producing quality fruits and in the production and diversification of durian products. These efforts will provide the impetus for greater exploitation and expansion of potential foreign markets for Thai durian.

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Effect of Winter Tip Pruning on Flowering of Kaimana Lychee

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Introduction

Critical to lychee (*Litchi chinensis* Sonn.) flowering is a period of cool temperature that is preceded by a resting phase when vegetative flushing of terminal branches is kept in check. Experiments with 'Kwai Mi' plants have shown that plants exposed to 13.9^{o} C (57^{o} F)night temperatures produced flowers buds within 56-91 days, whereas plants maintained at 22.2^{o} C (72^{o} F) tended to produce vegetative flushes instead of flowers (Nakata and Watanabe, 1966). The floral induction period for lychee in Hawaii occurs between November to April when cooler temperatures prevail, however, in many locations the cool season is often accompanied by heavy rainfall, which encourages vegetative flushing (Yee, 1972; Zee et al., 1999).

Irrigation studies indicate that when soil moisture stress was imposed during fall and early winter, shoot growth was arrested and increased flowering occurred (Nakata and Suehisa, 1969; Stern et al., 1998). Leaf nitrogen can also play a critical role in regulating flushing just prior to panicle emergence. By restricting leaf nitrogen levels prior to panicle emergence to below 1.75-1.85%, flowering was promoted in sub-tropical environments where heavy rainfall occurred in autumn (Menzel et al., 1988).

Earlier and increased flowering of 'Hak Ip' trees in Florida was observed when flushes emerging during the fall (August-October) were pruned (Campbell, 1994). Increased flowering was associated with the production of panicles at more than one node per branch and from multiple panicles per node. Although the use of Kaimana lychee which is adapted to Hawaii conditions has been helpful in overcoming erratic bearing, vegetative flushing in late autumn can result in irregular flowering during spring and inconsistent yields (Zee et al., 1999). The purpose of this study was to determine if pruning of vegetative flushes emerging on 'Kaimana' trees in early winter could enhance flowering.

Materials and Methods

The study was conducted on 7 year-old air-layered 'Kaimana' lychee trees growing in a Papai stony Aa lava soil in the Panaewa district near Hilo, Hawaii. Trees

were spaced 5.2 m between trees and 11.0 m between rows. The mean height of the trees was 1.7 m and the mean canopy diameter was 4.0 m.

On December 5, 1999, 15 trees were selected and divided into 2 groups (10 trees on which the terminal buds were undergoing vegetative flushing and 5 trees on which the majority of the terminal buds were at rest). On 5 of the flushing trees, all terminal shoots undergoing vegetative flushing were tip pruned, while the remaining 5 trees exhibiting a similar flushing behavior were left unpruned. Flushing terminals were pruned by clipping the shoot approximately 1.0 cm above the latest mature flush. On each of the pruned, resting and non-pruned trees, 10 terminals were tagged and panicle development and fruit set monitored. In addition, the overall flowering behavior of the trees was assessed at monthly intervals by estimating the percentage of flowering terminal buds within the entire canopy.

Results and Discussion:

Over the duration of the flowering season, significantly greater flowering occurred on the tagged branches when flushing terminals were tip pruned compared to flushing branches that were left unpruned (Table 1). Inflorescences were produced on 70% of the pruned branches and on 67% of the resting terminals compared to only 24% from the non-pruned flushing terminals. Pruning also increased the number of panicles developing on the pruned branches (Table 1). On those terminals that produced panicles, the resting and flushing terminals had an average of 1.1 panicles/terminal compared to 3.1 panicles on the pruned branches. This increase resulted from the production of inflorescences from multiple nodes located immediately below the pruned terminal. A significantly higher percentage of the panicles from the pruned treatment had fruit set compared to the flushing branches that were left unpruned (Table 1). Fruit set occurred on 36% of the pruned branches, on 18.2% of the resting terminals and on only 4% of the non-pruned flushing terminals.

Table 1. Panicle development and fruit set on flushing, resting and pruned lychee branches over the entire flowering season.

Treatment	Terminals Flowering (%)	Number of Panicles Developing/Terminal	Terminals with Fruit Set (%)
Flushing	24.0a[z]	1.1a	4.0a
Resting	67.4b	1.1a	18.2ab
Tip Pruned	70.0b	3.1b	36.0b

[z] Mean separation within columns by Waller-Duncan K-ratio *t* test, K-ratio=100 ($P \leq 0.05$).

By monitoring the flowering pattern of the entire tree canopy, it appeared that flowering in all treatments began in early February and reached a maximum by late February (Fig. 1). On February 25, flowering panicles were present on 68% of the canopy for the pruned trees, on only 14.5% of the canopy for the flushing trees, and on 61.5 % of the canopy for the resting trees. Thus the length of the flowering season was not altered, however, the intensity of flowering was increased.

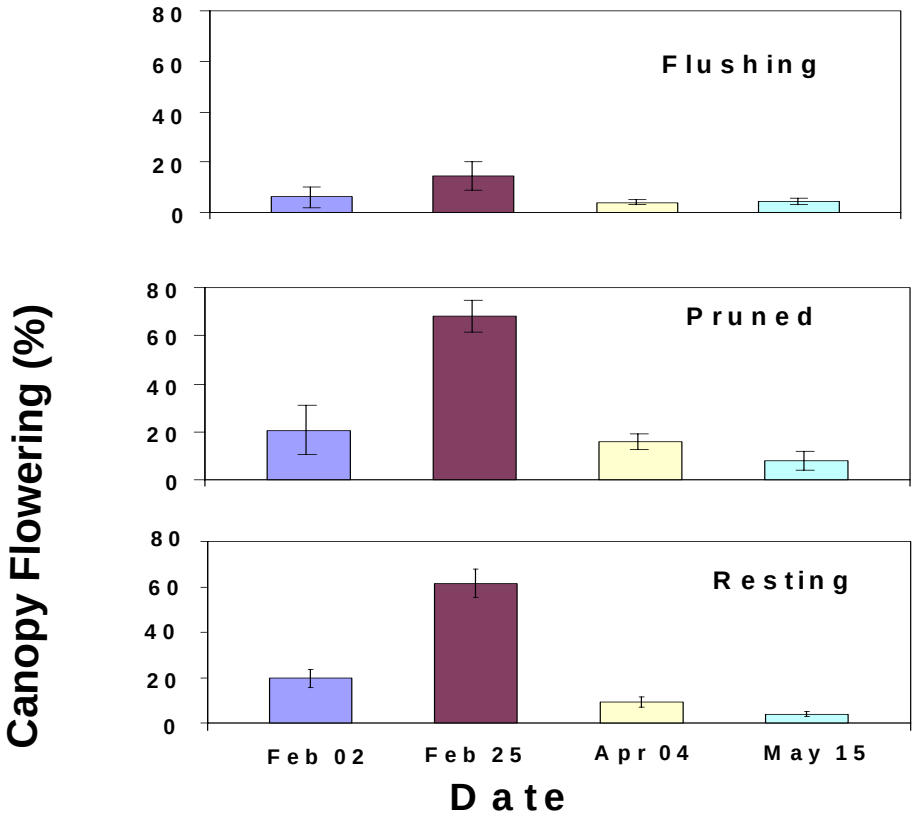

Fig. 1 Flowering pattern of flushing, pruned and resting lychee trees. Vertical bars represent standard error of the means (SE).

The results of this study confirmed earlier studies that a resting period during early winter is conducive to floral initiation in lychee. These results also showed that vegetative flushing during the winter reduced flowering of Kaimana and that pruning of young flushes, which emerged during early winter, could stimulate flowering. Pruning also increased the number of panicles that developed on each branch (Table 1).

A consistent problem with lychee production in Hawaii is irregular flowering, which can lead to inconsistent yields. Continuous vegetative flushing during the winter and the absence of a dormant or resting phase during this period reduces flowering. By pruning vegetative flushes that emerge during the winter rest period, it may be possible to induce flowering and overcome some of the inconsistencies associated with lychee trees growing in Hawaii conditions.

Although flowering was increased in the pruning treatments, fruit set was not similarly increased in all pruned trees due to the low rainfall experienced during the entire month of February (Fig. 2). Increased flowering may not necessarily result in greater yields, as low soil moisture and low humidity during blooming and fruit set can cause abscission of flowers and fruitlets and reduce yields (Menzel et al., 1986). Thus it is imperative that sufficient irrigation is available to trees during flowering and fruit set to

obtain maximum yield. The economics of employing the tip pruning treatment in a commercial setting are not known. However, vegetative flushing during the winter will reduce flowering, while tip pruning of vegetative flushes will offer the possibility for obtaining increased bloom and fruit set.

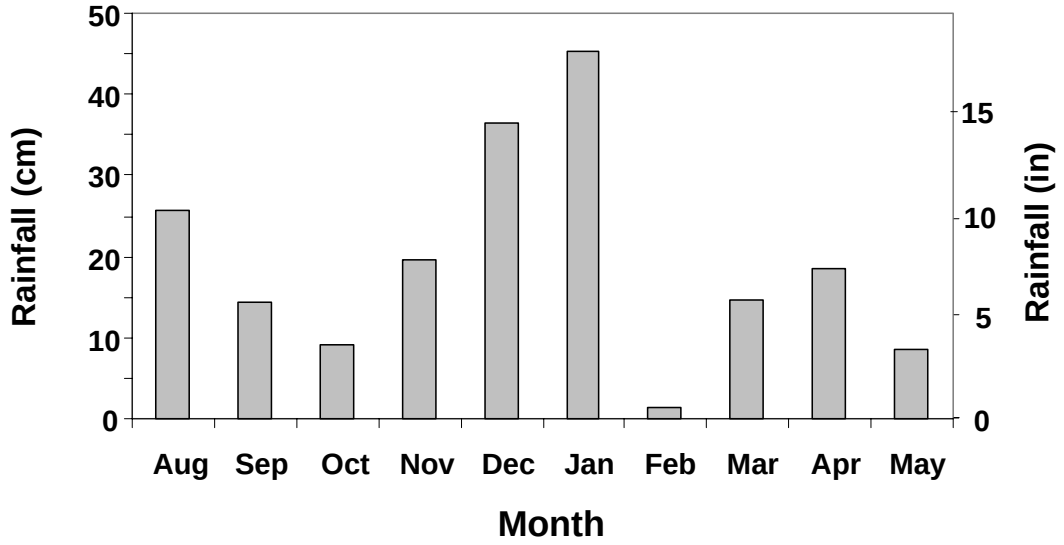

Fig. 2. Rainfall pattern between August 1999 to May 2000.

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Stimulating Flowering of Longan In Hawaii

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Introduction

Longan (Dimocarpus longan (Lour.) Steud.) is generally grown in subtropical environments where cool dry winters and wet warm summers prevail or at higher elevations in the tropics (Nakasone and Paull, 1998). Under these environmental conditions flowering tends to more regular. According to Tindall (1994) winter temperatures ranging from 15-20^{o} C (59-68 ^{o} F) are conducive for flowering, and once fruit set has occurred, night temperatures should not exceed 20-25 ^{o} C (68-77 ^{o} F). An annual rainfall of 150-200 cm (59-79 in) is necessary for good fruit development. Flowers are borne on terminal inflorescences, which possess both functional male (staminate) and female (pistillate) flowers on the same panicle (Subhadrabandhu, 1990). Generally there is enough overlap of the flower types to insure pollination and fruit set. Fruit development usually takes about 100 days, and productive trees, which are generally weakly branched, can vary from 5 to 20 meters in height.

Dr. Chung-Ruey Yen of the National Pingtung University of Science and Technology in Taiwan reported at the 9th Annual International Tropical Fruit Conference in Hawaii that potassium chlorate ($KClO_3$) drenches around longan trees could stimulate off-season flowering. A 10 to 20% solution applied as a drench or as a soil injection to depth of 50 cm effectively delivered the treatment to the roots (Yen, 2000). The effect of potassium chlorate ($KClO_3$) on flowering was independent of temperature or developmental maturity of the shoots, as both newly emerged as well as mature terminals were responsive to the treatment. The objectives of this study were to determine if soil applied potassium chlorate and foliar sprays were effective for inducing flowering of longan in Hawaii.

Materials and Methods

The first study was conducted on 7 year-old air-layered longan trees growing in a Olaa silty clay loam soil near Kurtistown, Hawaii. The soil treatments consisted of evenly broadcasting 0, 250 or 500 g $KClO_3$ on November 19, 1999 under the canopy of each tree in an area extending to about 1.5 meters away from the trunk. All leaves and loose organic matter were removed from under the canopy prior to application, and trees were immediately irrigated to deliver the $KClO_3$ to the root zone. Four longan varieties, ‘Kohala’, ‘Sri Chompoo’, ‘Biew Kiew’, and ‘E-Wai’, were used in the trial. The experimental units consisted of 9 single tree replicates arranged in a randomized complete block design. Each treatment consisted of 1 ‘Kohala’, 2 ‘Sri Chompoo’ 4 ‘Biew Kiew’, and 2 ‘E-Wai’ trees. The overall flowering and fruit set of the tree

canopies were assessed at monthly intervals by estimating the percentage of terminal shoots with flowering panicles or with fruit set.

In a second study 10 year-old air layered 'Kohala' trees growing in the same location were treated on December 20, 1999 with a foliar spray consisting of 0 or 2.0 g/l $KClO_3$ applied to run-off. Experimental units consisted of 3 single tree replicates on which $KClO_3$ was applied to the lower branches on one side of each tree with the opposite side of the tree serving as the control. The number of panicles developing in the treated and the control sections of the trees were determined at 2 months after treatment.

Results and Discussion

Panicles on control trees were found on less than 9% of the terminal shoots in January but increased to 61% by May (Fig. 1). Maximum anthesis on the control trees was observed in mid April. More synchronous panicle development was evident in trees treated with 250 and 500 g $KClO_3$ (Fig. 1). In the 250 and 500 g/l treated trees, panicles were evident on 74% and 86% of the terminal shoots at 2 months (January 19) after treatment. By mid February, at 3 months after treatment, 91% and 97% of the terminals were flowering with the 250 and 500 g/l $KClO_3$ treatments, respectively. Maximum anthesis occurred near the beginning of March for both $KClO_3$ treatments, and flowering was completed by the beginning of May. All varieties responded similarly.

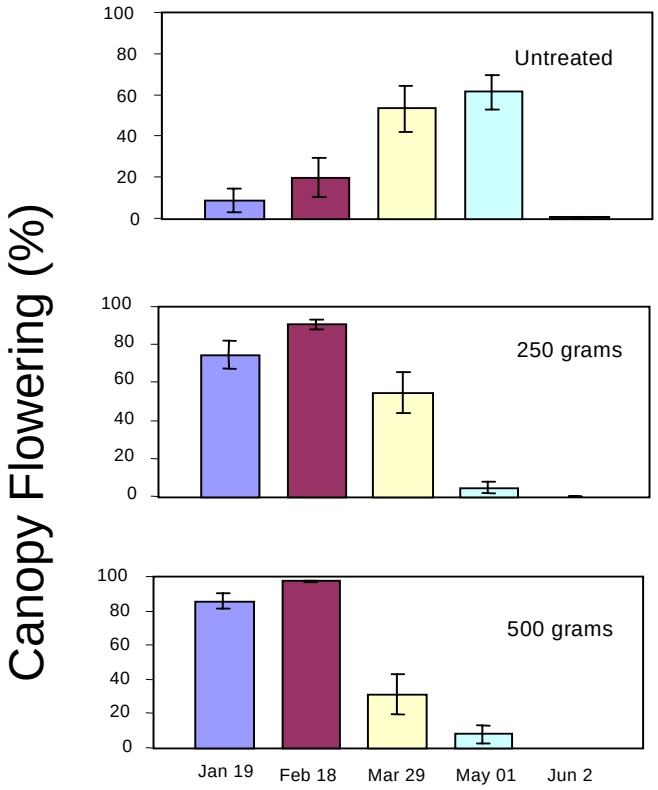

Fig 1. Flowering pattern of longan trees after soil treatment with 0, 250, and 500 g potassium chlorate. Vertical bars represent standard error of the means (SE).

In the control trees about 49% of the terminals within canopy had fruitlets by the beginning of June, whereas at the beginning of May the 250 and 500 g treated trees had fruit set on about 82% of the terminals within canopy Fig 2). For the duration of the fruit development period, fruit set was maintained on about 44% of the terminals in the untreated trees as compared to 84% and 86% of the terminals with the 250 and 500 g treatments.

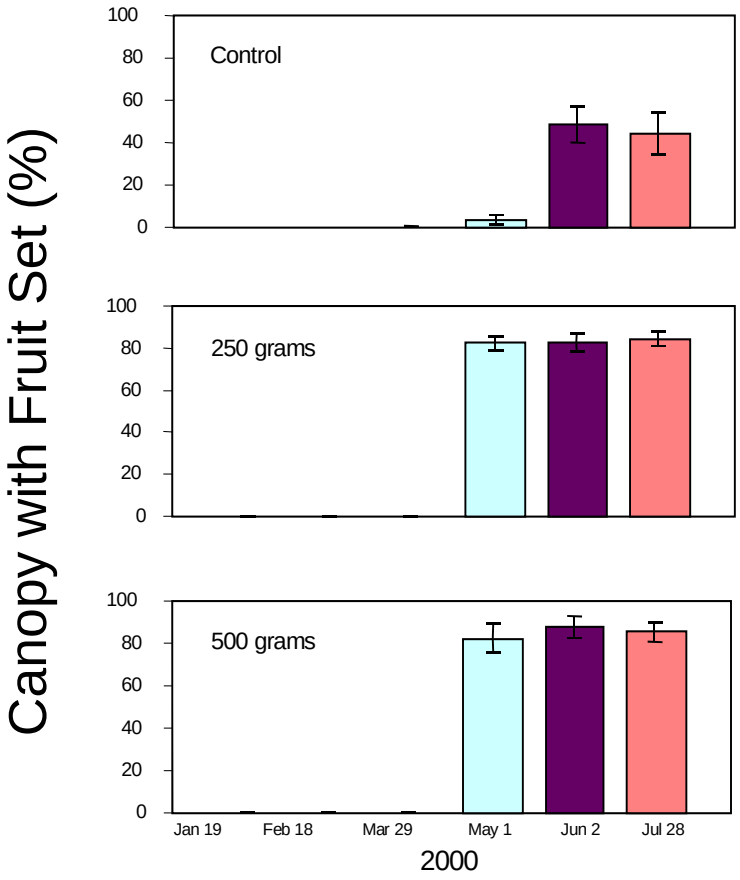

Fig 2. Fruit set pattern of longan trees after soil treatment with 0, 250, and 500g potassium chlorate. Vertical bars represent standard error of the means (SE).

Foliar applications containing of 2.0 g/l $KClO_3$ stimulated flowering within 2 months after application (Table 1). None of the control branches exhibited flowering during this period, and evidence of phytotoxicity was not observed on any of the branches receiving the foliar treatments.

Table 1. Effect of 2.0 g/l $KClO_3$ applied as a foliar spray on 'Kohala' longan branches. Treatments were made on December 20, 1999 and flowering observed on February 23, 2000.

	Total Panicles/Tree ± sd
Control	0
2.0 g/l $KClO_3$	9.0 ± 2.2

Soil applications of 250 and 500 g potassium chlorate effectively stimulated flowering of longan trees within 2 months after application. Potassium chlorate application resulted in earlier, more profuse and more synchronous flowering, and resulted in a greater amount of fruit set within the canopies of the treated trees. As reported by Yen (2000) flowering was independent of developmental maturity of the shoots, since both newly emerged as well as mature terminals were responsive to the treatment. In some instances flowering occurred from axillary buds situated below the cut surface of a pruned branch. Phytotoxicity symptoms were not evident in any of the treatments.

Foliar application with 2.0 g/l potassium chlorate also induced flowering at about 2 months after treatment, however, flowering was not as profuse as with soil applications. Later studies using foliar applications also showed that 4.0 g/l was effective for stimulating off-season flowering (data not shown). Phytotoxicity symptoms including defoliation and leaf scorching were observed when 8.0 g/l concentrations were applied.

Since flowering was more synchronous with potassium chlorate than in untreated trees, fruit maturation was also more uniform. Under these circumstances fruit maturation in treated trees should be monitored closely so that trees are harvested when fruits attain optimum quality. Over maturation can result in less than optimal fruit quality (reduced brix, off-flavor, fruit cracking).

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Fruit Quality of 'Egami' Longan

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Longan (Dimocarpus longan (Lour.) Steud.) is a popular tropical fruit crop that is believed to have originated in the lowlands of Sri Lanka, southern India, Burma or southern China. Longan trees are evergreen and produce best in subtropical environments with cool, dry winters and warm, wet and humid summers (Nakasone and Paull, 1998). Criteria used in the selection of cultivars include the production of large fruit, high percent of aril recovery, good flavor and aroma, crisp flesh, high sugar content and regular and heavy bearing (Subhadrabandhu, 1990). 'Kohala', a selection that was previously released in Hawaii, exhibits good vegetative growth in Hawaii but is very erratic in its bearing.

'Egami' is the newest longan selected by University of Hawaii horticulturists from an open-pollinated seedling established at the University of Hawaii Kona Research Station (Ito et al., 2000). 'Egami', which was formerly known as 'Kona No. 1', 'Mauka' and 'Kainaliu', produces more regularly than 'Kohala' and bears fruit from August to October. Trees usually produce within 4 years after propagation. A comparison of fruit quality of 'Egami' with the 'Biew Kiew', Champoo' and 'Kohala' cultivars over a two year period showed that 'Egami was very comparable to these varieties in terms of fruit size and weight, soluble solids content and percent flesh (Table 1).

Table 1. Two year comparison of 'Egami' fruit quality from trees at two locations in Hawaii (Hilo and Kona).

Cultivar[z]	Year	Fruit Weight (g)	Fruit Diameter (mm)	Total Flesh Weight (g)	Seed Weight (g)	Edible Pulp (%)	Soluble Solids (%)
Egami (Hilo)	1999	12.2±1.4	28.6±1.0	8.6±0.8	1.8±0.3	70.1±1.8	22.0±0.9
Biew Kiew	1999	11.7±1.6	28.0±1.5	7.9±1.1	1.5±0.2	68.1±1.4	23.1±1.1
Champoo	1999	11.9±0.9	28.5±0.6	7.8±0.6	1.5±0.1	65.4±1.8	23.3±0.6
Egami (Hilo)	2000	12.9±1.4	29.6±1.2	8.8±1.0	1.9±0.4	67.9±1.8	23.8±1.8
Egami (Kona)	2000	13.2±0.9	28.9±1.3	8.8±0.7	1.9±0.2	66.1±2.4	22.4±0.7
Champoo	2000	11.2±1.7	28.0±1.5	7.6±1.3	1.1±0.2	67.5±3.2	24.1±1.3
Kohala	2000	11.8±1.3	28.8±1.2	7.7±0.8	1.8±0.3	65.4±1.5	19.8±0.7

[z] Values are means ± standard deviation. n=25.

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Quarantine Pest Research and Hawaii's Tropical Fruits

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INTRODUCTION

Hawaii now has accepted quarantine treatments (heat, cold, irradiation, or non-host status) for 13 different tropical fruits including abiu, atemoya, avocado, banana, carambola, citrus, durian, lychee, longan, papaya, pineapple, rambutan, and sapodilla. In all cases, quarantine treatments were developed against tephritid fruit flies (Mediterranean fruit fly, oriental fruit fly, melon fly). Although fruit flies are the most important quarantine pests, other insect and mite pests are found on or in Hawaii's fresh fruits and have equal status with fruit flies in interrupting export shipments. Non-fruit fly pests presently of regulatory concern on tropical fruits from Hawaii are: *Calacarus brionesae* (papaya leaf edgeroller mite) on papaya; *Ceroplastes rubens* (red wax scale) on abiu, atemoya, and rambutan; *Coccus viridis* (green scale) on abiu and rambutan; *Cryptophlebia illepida* (koa seedworm) on lychee; *Cryptophlebia ombrodelta* (litchi fruit moth) on lychee and longan; *Eriophyes litchi* (litchi rust mite) on lychee and longan; *Dysmicoccus neobrevipes* (gray pineapple mealybug) on atemoya, longan, rambutan and sapodilla; *Ephiphyas postvittana* (light brown apple moth) on lychee; *Frankliniella schultzei* (yellow flower thrips) on rambutan; *Sternochetus* (=*Cryptorhynchus*) *mangiferae* (mango seed weevil) on mango; and *Maconillicoccus hirsutus* (pink hibiscus mealybug) on atemoya, durian, longan, rambutan, and sapodilla.

Fruit pests can be categorized as either surface feeders or internal feeders. Surface feeders such as scales, mealybugs, thrips and mites, are usually visible with the naked eye or a hand lens, although some species or life stages may be difficult to see without a good dissecting microscope. Fruits infested with internal feeders such as *Cryptophlebia* and fruit flies may be difficult to identify from visual inspection because fresh larval entry holes or oviposition sites are nearly invisible. Surface feeders can be mechanically dislodged from fruit by high-pressure water sprays or brushes, or eliminated through culling, and so fruit infested only with these pests may not require the development of a quarantine treatment *per se*. Fruits attacked by internal feeders require a penetration treatment such as heat, cold, or irradiation. We are exploring various approaches to ensure quarantine security for tropical fruits considering the pest complex. A look at several non-fruit fly quarantine pests in Hawaii illustrates some of the problems we have encountered and the approaches we are taking to ensure quarantine security in future fruit exports.

CRYPTOPHLEBIA SPP.

Biology. *Cryptophlebia* spp. are internal feeders and multivoltine. Two species of *Cryptophlebia* (Lepidoptera: Tortricidae) attack fruits in Hawaii: *Cryptophlebia illepida*, a native Hawaiian species known as the koa seedworm, and *Cryptophlebia ombrodelta*, an Australian import called the litchi fruit moth. Both species are regulatory pests of lychee and longan, but recently they been found infesting rambutan, also. All three are poor hosts. Eggs are laid singly on the fruit surface and newborn larvae bore through the skin and feed at the skin/pulp interface. Actual damage from larval feeding is often minimal and larval survival to pupation when fruit are on the tree is rare. However, when a neonate enters the fruit at the calyx or stem end, it may bore through woody tissue to the seed and feed there, improving the chance for survival to pupation.

Quarantine treatments. The irradiation and hot water quarantine treatments for lychee require that fruits are inspected and found free of *Cryptophlebia* spp. and other plant pests. The goal of quarantine treatments is to prevent adult emergence. Our results with *Cryptophlebia* show a susceptibility hierarchy for irradiation and heat treatments of neonates>early instars>late instars>pupae. Our quarantine studies have focused on late instars, the most tolerant stage infesting the fruit. Hot water immersion at 49^{o}C for 20 min. is an approved treatment for disinfestation of fruit flies in lychee. The same hot water immersion treatment is in the final stages of approval for longan. This treatment appears to be effective against *Cryptophlebia* spp.; we have treated over 8,000 late instars with no survivors. Likewise, irradiation with a minimum absorbed dose of 250 Gy is an approved treatment for fruit flies in Hawaii. Irradiation treatment appears to kill late instar *Cryptophlebia*, also; over 11,000 late instars have been treated with no survivors.

MANGO SEED WEEVIL

Biology. The mango seed weevil (MSW), *Sternochetus* (=*Cryptorhynchus*) *mangiferae* (Coleoptera: Curculionidae), is a federally quarantined pest that prevents the shipment of mangos from Hawaii into the continental United States. MSW feeds only on mango. Adult females oviposit on the surface of young fruit and the first instars burrow through the pulp to the developing seed where they feed and pupate. Larval development takes 20-30 d. The long-lived adult leaves the seed when the fruit falls to the ground to find protected places to overseason. Infestation levels can vary from 0-100% at sites in the same general area, suggesting dispersal is limited. Pest control research over the years has looked at a number of options including field sanitation, chemical sprays (trunk and foliar), natural enemies (parasitoids, *Beauvaria bassiana*[a fungus]), host plant resistance, and x-ray fruit culling technology with little success.

Pest Status. MSW allegedly causes reduced seed germination, damage to the fruit pulp, and premature fruit drop in mangos but studies examining these potential sources of crop loss are scarce. We conducted studies to assess the effect of mango weevil infestation on seed viability and premature drop while making observations on the frequency of pulp

feeding.

Naturally infested seeds from mature fruit were planted in pots and scored for successful germination. Germination rates for infested seeds were equal to that of uninfested control seeds in a polyembryonic cultivar ('Common'), whereas germination was significantly reduced for infested seeds of a monoembryonic cultivar ('Haden') compared with uninfested control seeds but germination of infested seeds was still >70%. To assess seed tolerance of damage, seeds were artificially damaged by cutting away 25, 50, or 75% of the cotyledon before planting and scored for germination. None of the damage treatments was significantly different from the undamaged controls, indicating that mango seeds can withstand substantial damage and still germinate successfully.

To examine premature drop, small mango fruits (approx. 50 g) were collected from both the tree and the ground, and cut open to determine the presence or absence of MSW. If MSW-infested fruit were more prone to dropping than uninfested fruit, the prediction was that a higher infestation rate would be found in fruit on the ground compared with fruit on the tree. Over 800 fruits were collected from the Yamada orchard in Kalapana during two seasons. Mango fruits on the ground had a higher incidence (41%) of MSW than fruit on the tree (32%), but the difference was small. MSW-infested fruit may have a slightly higher tendency to drop prematurely than uninfested fruit.

Over the 2-yr period we conducted experiments, only 15 of 5,192 mango fruits (0.29%) showed evidence of direct feeding damage to the pulp. Results suggest that *C. mangiferae* is a less serious pest of mangos than previously thought.

Quarantine treatments. The high-risk quarantine pest status given to mango weevil is mainly in response to concerns from the mango industry in southern Florida that mango weevil infestation will reduce seed germination and limit seed production in nurseries and orchards. It is doubtful that mango weevil should be classified as a high-risk pest for this reason because infestation does not dramatically reduce the seed germination rate; therefore, it would not be a serious threat to the small mango industry in southern Florida if it became established there. Mango weevil is strictly monophagous and poses no threat to other agricultural crops or native flora. Nonetheless a treatment was required to overcome the quarantine barrier.

A typical quarantine treatment is developed by testing hundreds of thousands of lab-reared insects, which are artificially inoculated into fruit. The absence of an artificial diet for MSW and the fact that there is only one generation per year have slowed development of a quarantine treatment. In the past, Hawaii researchers have unsuccessfully attempted to kill the weevil in mangoes using heat, cold, and fumigants. Irradiation appears to be the best alternative. Irradiation studies were conducted in our lab. Treatment of mango seed weevil in naturally infested mangoes with irradiation doses of 100 and 300 Gy resulted in sterility, however, only a few thousand weevils were treated. This irradiation data was submitted to APHIS with the pest status information for approval of irradiation as a quarantine treatment. A Proposed rule was published in the Federal Register on May 26, 2000, recommending an irradiation dose of 100 Gy to control MSW in exported mangoes. Publication of the final rule will be the first time that irradiation has been approved for an insect other than a fruit fly. This will open U.S. mainland markets to mango exports from Hawaii.

WHITE PEACH SCALE

Pest status. White peach scale (WPS), *Pseudaulacaspis pentagona* (Homoptera: Diaspididae), has a cosmopolitan distribution. It is one of the most economically important scale insects in Florida and other southeastern states where it is a serious pest of peaches and other fruit and ornamental crops. Although WPS may be attacked by parasites and predators, chemical control is often required to prevent severe crop injury. WPS was collected for the first time in Hawaii in September 1997 on papaya. The scale initially attacks the trunk of the tree, usually starting at the base, but as the density of scales increases the infestation spreads up the trunk and can spill out onto fruits. Its distribution presently is limited to several farms on the windward (east) side of the island of Hawaii, but its distribution is expected to expand rapidly. WPS potentially is a threat to the Hawaiian papaya industry as a source of tree stress and fruit downgrading, and as a quarantine pest on fruit for export.

Quarantine Treatment. Currently, papayas for export from Hawaii receive a vapor heat treatment developed to disinfest fruit of tephritid fruit flies. This treatment requires that fruits be heated to a core temperature of >117^{o}F (47.2^{o}C) during a treatment of not less than 4 h duration. We initiated studies to determine the efficacy of the papaya vapor heat quarantine treatment against WPS. WPS naturally infesting papayas were subjected to vapor heat treatment at one of two commercial papaya treatment facilities. Scales of the different stages were scored as dead or alive based on their color (2nd instar and adult females, termed "hardshells"), leg movement (crawlers), or ability to develop to the next stage (eggs and 2nd instar and pupal males). Vapor heat treatment of papayas killed all 26,912 crawlers, 5657 hardshell stage scales, 19,025 eggs, 13,618 immature male scales, and 1049 male pupae, while untreated control survival for each life stage was generally high. Our results demonstrated that WPS on papayas subjected to the vapor heat quarantine treatment should pose no threat to quarantine security in export shipments of Hawaii-grown papayas.

UNWANTED NONREGULATORY PESTS

Occasional pests and hitchhikers. Non-regulatory arthropods appearing on fruits can be actionable depending on the destination of shipments. For example, in February 1997 an experimental shipment of rambutan from Hawaii that had been irradiated at 250 Gy was rejected in San Francisco, California, when *Pulvinaria psidii* (green shield scale), *Hemiberlesia lataniae* (latania scale), *Psuedococcus viburni* (obscure mealybug,), and *Cardiocondyla wroughtoni* (an ant) were found on fruit. Although the fruit had been irradiated, no information was available on the effect of the treatment on the insects in question, resulting in shipment rejection. Two of the species causing rejection were on the list of pests associated with rambutan in APHIS' pest risk assessment (green shield scale, latania scale), and the other two were not (obscure mealybug, *C. wroughtoni*). Therefore, the problem is twofold: information on the diversity of insects and mites found on Hawaii's tropical fruits is incomplete, and the effect of quarantine treatments on

non-fruit fly regulatory pests and other incidental arthropods is unknown. In addition, little information is available on the infestation biology (i.e., infestation rates, cultivar susceptibility, infestation phenology) of any of the nonfruit fly pests in Hawaii. My lab has been collaborating on pest surveys for rambutan, lychee and longan to identify additional problematic species. It is essential that USDA-ARS, APHIS, and the University of Hawaii exchange information on new pest arrivals and new occurrences on tropical fruits. Growers are often the first to notice new pests on the farm and their role in developing a science base for tropical fruits shouldn't be underestimated.

EFFECT OF QUARANTINE TREATMENTS ON FRUIT QUALITY

Fruit quality is an important element in developing and refining quarantine treatments. For several of Hawaii's tropical fruits (see Quarantine Updates), there are two or more quarantine treatments available. Fruit quality maintenance may be a key factor in choosing one treatment over another. A study was conducted to make a direct comparison of two treatments on rambutan quality. Irradiation with a minimum absorbed dose of 250 Gy is an approved quarantine treatment for exporting rambutans to the U.S. mainland. A hot forced-air treatment, consisting of heating fruit to a seed surface temperature of 117^{o}F (47.2^{o}C) in not less than 4 hours and holding for 20 min., has also been developed and is in the final stages of approval by APHIS. 'R167' and 'R134' fruit were treated and qualitative and quantitative measures of fruit quality were made. Fruit treated with hot forced-air had less acceptable external appearance ratings (fruit were darker or had more dark blotches) than did irradiated or untreated fruit at 4, 8 and 12 days posttreatment. For both cultivars, external appearance of fruit in all treatments was rated as unacceptable after 12 d of storage, whereas taste was rated as acceptable for all treatments on all days. Overall, under the experimental conditions tested, irradiation was superior to hot forced-air as a quarantine treatment on the basis of fruit quality maintenance. Similar studies with longan and lychee comparing the effects of hot water immersion and irradiation quarantine treatments are planned for the current season.

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