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THE SPICES AND ESSENTIAL OIL CROPS OF THAILAND*

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INTRODUCTION

This report is directed towards the preliminary survey of essential oil (spices) crops and some drug plants in Thailand. The main objective of this assignment is "to collect and collate all the information of growing areas, cultivation methods, production levels, plant material utilization, and management practices to find out the extent of crop and management improvements that have been brought about in the last decade on each specific crop of Thailand and objectively assess what measures could be adopted to further improve these crops".

Unlike Indonesia, Sri Lanka and India, where the essential oil products have long been firmly established, the data and information on the essential oil crops and drug plants in Thailand are very scarce since these crops are normally grown at a small scale only for domestic consumption. In Thailand natural flavouring materials are easily available in any market and locally used in their natural state not only for aroma but also for decorating dishes. This may be one of the main reasons why the concentrated essential oil extractions are not quite attractive to the local investment. The productions of essential oil on the commercial scale have been attempted during the past two decades, namely lemon grass oil, citronella oil and basil oil, each of which lasted only a few years before collapsing. The promising essential oil crop at present is an introduced Japanese mint which has attracted several factories to produce mint oil on the commercial scale.

The information and data on each specific essential oil crop and drug plant in Thailand, therefore, were made from the well-known and favourite plant crops which were commercially used for domestic consumption and

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exports. The crops involved in this report are mint, basil, pepper, cardamom, bastard cardamom, cinnamon, lemon/citronella grass, clove, nutmeg/mace and cinchona besides the brief additional notes on phlai, khing, turmeric, khaa, krachaai, coriander and makruut. The compilation of data and information on these essential oil (spices) crops and drug plants in Thailand was only possible due to the courtesy of the staff members of Agricultural Products Research Institute, Technological Research Institute and Economic Evaluation Group, Applied Scientific Research Corporation of Thailand (ASRCT), whose kind cooperations are gratefully acknowledged. The ASRCT, the leading research department in this field, has conducted research on the essential oil crops, medicinal plants and spices since 1965. For the lists of researchers see References.

MINT

INTRODUCTION

Mint is the common name of plants in the genus *Mentha* which is native to many temperate regions, mostly in the Northern Hemisphere. The most well-known and favourite introduced mint in Thailand as condiments is "Saranae" (*Mentha cordifolia Opiz*). Thai people consume fresh leaves of this kitchen mint which adds the flavour to many native dishes. This species yields very little oil, only about 0.10 percent of oil on the basis of fresh weight.(1) This confirms the impression that the oil content of Thai mint is relatively low and not of commercial interest.

The major and the most important industrial component of the crude mint oil is menthol. The amount of menthol contained in the oil varies with species and varieties of mint as well as the cultural condition, and the process of extraction. Among the species of *Mentha* cultivated commercially for menthol, Japanese mint, *M. arvensis* var. *piperascens Malinv.* contains the highest percentage of menthol in its oil (c. 70–90%).

COMMERCIAL MINT IN THAILAND

Thailand has imported peppermint oil and menthol prior to 1969 at a minimal amount (about 800,000 baht/year). The demand for peppermint oil and menthol was increasing rapidly since 1969 as shown in Table 1. Since there is a great demand of crude mint oil and menthol not only for domestic

consumption but also in the world trade, a programme for the crude mint oil production was launched in 1973 by the Applied Scientific Research Corporation of Thailand (ASRCT) under the agreement of the Thai Chemicals Company, a local menthol producer in Bangkok. As a result, the imports of peppermint oil and menthol were considerably reduced in 1975.

Table 1. Imports of peppermint oil and menthol during 1969–76.

Year	Peppermint Oil		Menthol	
	(Litre)	(Baht)	(Kg)	(Baht)
1969	11,085	1,134,535	125,381	9,012,950
70	28,385	3,167,789	47,043	7,403,412
71	25,451	3,270,134	52,603	11,220,680
72	65,283	7,485,331	94,521	19,790,166
73	61,854	7,504,859	151,546	27,682,062
74	85,882	18,726,335	33,532	12,477,444
75	22,439	6,509,258	9,549	3,958,324
76*	17,283	5,199,777	21,857	7,822,268

*January–June

Source : Foreign Trade Statistics of Thailand, Dept. of Customs.

Components Of Mintoil

During 1971-1973 several varieties of mint from Japan, India, People's Republic of China, Taiwan and Brasil were introduced into this country by ASRCT. After extensive agronomic investigations, a variety of Japanese mint was found which can thrive under the warmer conditions of the tropic, called "Ryokubi" (or So Wo 1 in Thai) yielding the highest yield and best quality of oil. Pichitakul & Sthapitanonda (2) studied the constituents of oil from three varieties of Japanese mint *(Mentha arvensis* var. *piperascens)* namely : So Wo 1 (Ryokubi), Indian, and Akamaru (from Taiwan) of which major constituents are shown in Table 2. Mint oil from So Wo 1 variety out-yielded the others in the amount of 1-menthol (81.95–82.80%) and the crystalizable menthol (68.5%).

With the support of ASRCT in technological and economic assistance, several factories have been established in many parts of the country, especially in the north with Nan as its strong foothold where more than two-thirds of the mint oil was produced (Tables 3 and 4).

Besides Nan, mint growing is sparsely and occasionally encountered in the provinces of Phrae, Udon Thani, Chanthaburi, Nakhon Pathom and Ratchaburi, the cultivation area of which, however, is rather fluctuating depending on the demand of other agricultural crops; since mint is grown as a vegetable-substitute crop.

Table 2. Composition of oil from three varieties of Japanese mint (*Mentha arvensis* var. *piperascens*).

Compound	Percentage Composition					
	So Wo 1		Indian		Akamaru	
	Oct. 73	Dec. 73	Oct. 73	Dec. 73	Oct. 73	Dec. 73
Alpha-pinene	0.59	0.38	0.62	0.57	0.63	0.85
Beta-pinene	1.40	0.90	1.53	1.51	1.51	1.83
Limonene	1.60	1.80	2.70	2.40	1.98	1.68
Octanol–3	0.87	0.62	0.82	0.79	0.20	0.20
Unidentified compound	0.10	0.13	0.48	0.45	0.02	0.02
Linalool	0.19	0.54	0.10	0.09	0.30	0.20
Menthone	5.32	5.12	7.37	6.09	19.26	10.52
Menthyl acetate	2.70	2.67	11.89	9.10	11.32	21.90
Neomenthol	2.60	2.03	4.00	2.62	3.08	4.12
Menthol	81.95	82.80	67.65	73.51	55.41	53.16
Isomenthol	0.75	0.70	0.58	0.66	0.46	0.27
Pulegone	1.03	1.46	1.01	1.07	0.50	0.44
Piperitone	0.90	0.85	1.25	1.14	4.32	3.73
Unidentified compound	–	–	–	–	1.10	1.08

The yield of mint oil is very variable subject to the growth and age of the plant, the season and time at harvest, the amount of water within the plant at the time of distillation and the efficiency of the distillation unit. The average yield of fresh material is 6,000 kg per hectare. After being half-dried, the weight is reduced by one third to 4,000 kg; hence, about 20–32 kg of oil are expected. At present, the price of mint oil in Thailand is abous US$ 15 per kg.

Table 3. The acreage of mint under cultivation in Nan Province in 1976.

District	Cultivated areas (rai)*	Number of growers	Average (rai/person)
Muang	616	1,014	0.61
Sa	358	334	1.07
Tha Wang Pha	1,231	825	1.49
Bua	679	1,126	0.60
Chiang Klang	998	1,630	0.61
Thung Chang	500	250	2.00
Total	4,382	5,179	0.85

*1 acre=2.5 rai

Source : ASRCT Res. Proj. No. 62/1 Rep. No: 4.

Table 4. The average yield of nint cultivation in the districts of Nan Province.

District	Quantity of herb harvested/rai*		
	1st Harvest	2nd Harvest	3rd Harvest
Muang	1,411 (33%)	2,391 (57%)	400 (9%)
Sa	1,891 (51%)	1,805 (49%)	–
Tha Wang Pha	1,567 (33%)	2,153 (45%)	1,086 (22%)
Chiang Klang	484 (19%)	1,587 (63%)	440 (18%)
Thung Chang	1,873 (43%)	1,513 (35%)	934 (22%)
Average	1,539 (36%)	2,016 (46%)	793 (18%)

*1 acre=2.5 rai

Source : ASRCT Res. Proj. No. 62/1 Rep. No. 4.

CULTIVATION OF MINT IN THAILAND (3, 4)

Mint can be vegetatively propagated from stems, twigs, and stolons. The best method of propagation is to lay down sections of the stem horizontally on raised beds of rich, organic soil in a moist, shady place. The shoots will sprout from the buds within a week and will be ready for transplanting in the field in a month's time.

Types of cultivation. In Thailand, several types of mint cultivation have been attempted as follows :

1. As the upland crop in the rainy season. The land should be well-drained upland soil on a gentle slope. Soil preparation is similar to other field crops. To obtain the best yield, a ridge or raised bed should be made either by manual labour or by a tractor. Generally, the bed is 1 m wide on which the mint is planted in two rows with 50 x 50 cm spacing. Fewer or more rows are also under practice, depending on the draining property of the soil. Three harvests are expected during the growing season.

2. As a summer crop in the paddy field. Mint may be grown on a raised bed in the paddy field after rice harvest as well, provided irrigation facility is available in the dry season, as in Nan Province. Since the growing season of mint is rather short, spacing should be narrowed down somewhat to about 30 x 30 cm. Two harvests are expected before the commencement of the rainy season.

3. As rice substituted crop in the paddy field in the rainy season. In some areas, where the paddy fields are located on the highland such that drainage of excess water during the rainy season is possible, mint is grown instead of rice since the return is higher, and the crop can be maintained throughout the dry season through irrigation. Methods of soil preparation and planting are similar to the second type. From four to five harvests may be expected, provided soil fertility is being restored after every harvest.

4. As vegetablesubstituted crop on raised ridges in the Central Plain. Since most areas in the Central Plain are lowland with a high water table, raised ridges of 5 m in width have to be prepared for growing vegetables and other crops such as cut flowers and fruit trees. The high cost of labour and other problems make mint non-competitive with other

crops in this area. Quite a few disadvantages have been encountered, namely, the type of soil (mostly clay), the high acidity of the soil (and sometimes of water as well) and the high water table (sometimes flooded).

5. Other less popular types.

5.1 On the steep slopes on the high hills. Attempts have been made to grow mint as opium-substituted crop for the hill tribe people on the highland of northern Thailand (5). After the act on the Prohibition of Opium Smoking was enacted in 1959, the hill tribe people have been struggling for their existence because their main income depended primarily on opium production. As no other crops prove to be more suitable, illegal cultivation of opium is under practice as a source of income. There is, however, some indication that mint may be an ideal crop to replace opium since it is one of a high income earning cash crop, employing minimum skill, technology and capital; besides the extraction of oil could be easily processed at the location. Still, many problems have arisen in such a planting, especially with respect to the difficulty of soil preparation due to the slope of the land and various other limiting factors, *viz.* temperature, rainfall, photoperiod, soil fertility, soil erosion, etc. Once established, mint may be able to propagate itself year after year if fertility can be restored.

5.2 As intercrop along with other types of plantations while the main crops are still young. Mint may be grown along with fruit trees (e.g. coconut, peach, orange and mango), forest trees (e.g. teak at Mae Chaem District, Chiang Mai Province), and para rubber trees with no ill effect to the main crop. Instead, several advantages can be recognized such as additional income while the main crops are still young and unproductive, keeping the growing area free from weed and conserving moisture.

5.3 Within the vicinity of homes in the villages. The following are the advantages of such a planting: (1) favourable edaphic conditions, (2) farm manure is plentiful in most villages in the rual areas, (3) labour is also available, (4) oil extraction is simple using small distilling units and (5) energy for oil extraction is abundant. This project is now being tried in some 20 villages throughout the country by ASRCT.

5.4 As an alternative crop in the school project. Several schools in the rural areas throughout the country are now including the vegetable growing lesson in addition to the regular classroom curriculum. The use of mint as an alternative crop for vegetables has been suggested since mint possesses many desirable characteristics to be used in the school project such as (a) being non-consumable – thus it is less subject to be stolen; (b) being easily processable at the school – thus it can be transformed into a high-valued product; (c) the fund for the project is respent efficiently. Moreover, students not only learn about agriculture, but also become familiar with agro-industry.

CULTURAL PRACTICES (3, 4)

Water. Mint requires considerable amounts of water during the entire period of growth, except at harvest time; it cannot withstand a long period of drought. It is, therefore, recommended that mint be grown in the rainy season unless some type of supplemental water is available. Rainy season has certain effects on the growth of the mint plants and the yield of oil. Luxuriant growth is expected, but the oil percentage of the fresh material is relatively low. On the contrary, mint grow in the dry season through irrigation yields low fresh material but high percentage of oil. Other than rain water, several systems of irrigation are practiced in mint cultivation in Thailand, *viz.* furrowing, flooding, watering through the use of special equipment, pump and sprinkler.

Fertilizer. Although mint requires a considerable amount of nutrients. chemical fertilizer is not commonly applied by mint farmers since it is costly and the response is not great. Moreover, the mint plants are normally grown in relativley rich soil, or after tobacco (in Nan Province) which is earlier planted with heavy amounts of fertilizers. Organic fertilizers are, however, most needed by the mint plants since they not only provide the plants with the nutrients but also improve water-holding capacity, drainage, and aeration of the soil and they help in the penetration of underground stems and root systems of the plants. Thus, only the areas where organic matter is abundant should be selected for mint cultivation. Several sources of organic fertilizers are available, namely compost, green manure, and farm manure. Among these, the latter is the most popular among mint growers in Thailand.

Mulching. Since mint requires considerable amounts of moisture in the soil, mulching is strongly recommended for its cultivation, especially during the dry season. Several kinds of mulching materials are used by the mint growers in Thailand, namely, peanut shell, rice husk and rice straw. Mulching not only conserves moisture for the plants, but also reduces the amount of weeds and provides nutrients after decomposition.

Pests And Diseases (3, 4)

Although mint has fewer enemies than other economic crops, in some areas and conditions some enemies are observed. Among the most important ones are wilt disease which occurs only in waterlogging acid soil, aphids, looper, termite and mite – none of which causes serious problems.

The most serious enemy is probably the weed, which should not become a problem at all if care is taken during the first month of its growth. Several herbicides have been tried in several areas; Terbacil was found to be the most effective both as pre- and post-emergent herbicides, although its cost is rather high and the method of application is too complicated for most farmers.

Harvesting And Drying (3, 4)

In spite of the fact that the highest percentage of mint oil is obtained when the plant is in blooming stage, which takes about three months after planting the seedling in the field, the maximum yield of fresh material and of oil is also obtained when the plant is at its maximum vegetative growth when all leaves are still attached to the plant. Normally, it will take two months to reach this stage; hence, it is suggested that the plant should be harvested at the age of two months. The appropriate time for harvesting is in the afternoon of a bright sunny day, at least three days after the rain or irrigation. Harvesting is practically done by the use of sickle or knife, cutting the stem at the lowest possible point so that no stump is left for sprouting; this will encourage sprouting to take place from the underground stem. The harvested material should be left in the sun for evaporation before collecting, which will reduce the damage caused by fermentation and molding. The material should then be dried in the shade for three to seven days before distillation.

After each harvest, the field should be covered with a layer, about an inch thick, of compost or manure to renew soil fertility and conserve moisture to induce sprouting of the next crop.

DISTILLATION (3, 4)

Principle of mint oil extraction. Mint oil is a kind of essential oil which is synthesized by the mint plant and is stored in the glands in various parts of the plant, especially the leaves. It can be extracted from the plants by various means but stem distillation is the most popular, since it is very convenient and most economical.

In distillation, the herbs are packed firmly in a tub or barrel. When the steam, which may come directly from the distillation unit or from a steam generator, passes through the packed mint leaves, the oil will be extracted and passed through the pipe along with the steam to the condenser, wherein both oil and water vapour condense and come out of the condenser to the oil separator. Since the oil is lighter than water, it will accumulate on the top layer while water, together with a very small amount of oil, passes through the chamber of the oil separator and finally out of the separator. The oil, therefore, remains in the oil separator automatically.

Types of still. Many types of mint distillation units were invented both for laboratory and field investigation and for commercial production. In principle, they are similar; modifications are observed in the size of the tub and condenser and the source of steam (either direct heat or from a boiler). The popular types are the oval-shaped tub with 500 kg capacity, and 200 l oil drum; both are the direct heat tvpe. Many companies are producing both types for sale to the mint oil factories.

Mint oil extraction factory. At present there are over 150 units of the oval-shaped tub type all over the country, together with about ten 200 l oil drum units. In a typical mint oil extraction factory, the following building facilities are present: (1) the main factory building which houses the distillation units, condensers, and other accessories, (2) mint drying

shed, (3) buying quarter, (4) an office, (5) water tank, (6) water pool, (7) water cooling pond, (8) firewood store, (9) an area for spent-hay depositon.

PROBLEM (3,4)

Mint is a relatively new crop in Thaiand, a crop easy to be grown and oil-extracted. Having relatively few enemies, it produces marketable products of high income per unit area within a short time. However, being a new industrial crop, it has several problems, as follows:

1. Lack of experience. Mint cultivation is entirely different from other field crops requiring intensive cultural practices, which are new to most Thai farmers. Consequently, only few farmers are successful at the beginning.

2. Lack of proper management. Most of the factory operators do not grow their own mint crop but encourage the farmers in the surrounding area of the factory to grow mint for them. In so doing, the farmers are subsidized with a certain capital (*ca* US$ 15 per rai) to encourage them to expand their acreage for more subsidiary funds. In practice, they are not able to cope with the management of the extensive cultivation, which becomes more complicated. The factory owners are always at a great risk. In cases where the factory owners run their own mint fields through the employment of labourers, several problems are encountered, i.e. high cost of labour, lack of efficient supervision, scarcity of labour at the time of need, etc.

3. Unsuitability of the environment. Mint requires organic in the air. soil rich in plant nutrients and high in moisture content both in the soil and in the air. The soil should not be too alkaline or acid, besides it should have high water-holding capacity and good drainage; such a soil is, of course, very difficult to find. Moreover, during the past few years when mint cultivation was expanded, serious environmental hazards occurred in the mint growing areas.

4. Competition with other crops. Although mint is a relatively high income-earning crop, in certain conditions when another item of produce becomes scarce and fetches a high price, mint will be discarded and the attention is then paid to another crop, thereby creating a great problem to the factory owners.

BASIL

INTRODUCTION

Basil is an annual herb found throughout the Old World tropics, belonging to the family Labiatae under the name *Ocimum basilicum* Linn. Basil is now cultivated in many parts of the world, being common in South-East Asia, India, North Africa, Southern Europe, Sri Lanka, Reunion, the Seychelles and the Indian Archipelagoes, as well as in China. *O. basilicum*, locally known as "Horaphaa" is one of the common aromatic herbs in kitchen gardens throughout Thailand. Basil oil produced by steam distillation of the leaves and inflorescences offers many uses such as flavouring confectionary, foods, condiments, dental creams and mouthwashes.

Two types of basil oil are commercially recognized. The European type of Sweet Basil oil, distilled in Europe and the United States of America contains linalol and methyl chavicol as the main constituents; the oil is devoid of camphor and exhibits laevorotation. This type of oil possesses a fine odour and is considered superior in quality to many others. The Reunion type of basil oil, produced in the islands of Comoros, Madagascar and the Seychelles, contains methyl chavicol and camphor but does not contain linalol; the oil exhibits dextrorotation. This type of oil is considered inferior to the European type of Sweet Basil oil (6). The oil distilled from the local Thai Basil plant is considered to be the Reunion (or Comoros) type of basil oil (7,8).

Research work on the various aspects of cultivation of the plant, chemical composition of the oil and the production of basil oil were carried out in Thailand by the ASRCT (9,10,11,12) in collaboration with the Tropical Products Institute (TPI), London, U.K. (13) and the Stange Canada Limited, Ontario, Canada (7) between 1967 and 1970.

AGRONOMIC INVESTIGATIONS

Besides basil, there are a few of its closely related species commonly grown in Thailand, namely *Ocimum sanctum* Linn. (Kaphrao), *O. canum* Sims (Maenglak) and *O. gratissimum* Linn. (Kaphrao chaang). These plants are obtainable from the local markets where they are sold for use as flavours in cooking. Initially there was some confusion in the identity of these *Ocimum*

plants because of the frequent occurrence of the phenotypic variation among each of them, such as the stem and leaf colouration and form of the inflorescence, particularly in "Horaphaa" (*O. basilicum*) and "Kaphrao" (*O. sanctum*). From the experimental cultivation (6), Horaphaa and Kaphrao display distinct variation within the species, in which six and five forms were distinguished in the former and the latter respectively; while Maenglak and Kaphrao chaang seem to show none at all. The comparative study on oil yield was done on four forms of Horaphaa (*O. basilicum*), namely:

Form 1 "White-flowered, long raceme";
Form 2 "Violet-flowered, long raceme";
Form 4 "Violet-flowered, panicle"; and
Form 5 "Violet-flowered, panicle";

It was found that Form 5 of basil out-yielded other forms and other *Ocimum* species in the fresh weight of plant material and percentage of oil as shown in Table 5.

Table 5. Yield of *Ocimum* spp.

	Fresh weight g/3 m^2/ cutting	Dry weight (% of fresh weight)	% oil based on dry weight	% oil based on fresh weight	Calculated yield/ rai/ cutting fresh weight (kg)	Oil (l)	Rank
O. gratissimum	749.8	14.78	1.43	0.21	399.89	0.84	7
O. sanctum form 2	643.3	14.96	1.66	0.25	343.09	0.86	5
,, ,, ,, 3 & 4	393.4	13.35	1.59	0.21	209.81	0.44	9
,, ,, ,, 5	468.5	13.94	1.36	0.19	249.87	0.48	8
O. basilicum form 1	611.8	13.59	2.66	0.36	326.29	1.18	3
,, ,, ,, 2	948.6	12.11	2.96	0.36	505.92	1.82	2
,, ,, ,, 4	838.0	12.00	2.14	0.26	446.93	1.16	4
,, ,, ,, 5	950.8	11.29	3.33	0.38	507.09	1.93	1
O. canum	722.8	12.81	1.69	0.22	385.49	0.85	6

Agronomic investigations (9) on yield-trial experiments of basil conducted at four locations in Thailand revealed that the production of fresh weight was 2,935 to 12,414 kg/rai/year (24 harvestings) and the average yield of oil was 0.33%.

COMPONENTS OF THAI BASIL OIL

The chemical composition of Thai Basil oil was identified and quantitatively estimated by LAWRENCE *et al.* (7, 8) who reported the compounds analyzed by gas-liquid chromatography as shown in Table 6.

As seen from the result in Table 6, Thai Basil is mostly of a methyl chavicol type. The oil is considered very similar to the commercial basil oils from the Reunion of the Comoros Islands. However, on the basis of its physiochemical properties, the Thai Basil oil is classified as standing between the Reunion type, and the European type of Sweet Basil oil (7, 8).

From the comparison of the chromatograms obtained from phenotypic variations Form 1, 2, 4 and 5 of the Thai *Ocimum basilicum* along with a commercial sample, it is interesting that all the forms of *O. basilicum* studied show no significant diflerences in chemical composition between the individual oils (7, 8).

CULTIVATION

Basil, like other *Ocimum* plants, is suitable to most tropical and subtropical conditions, preferring richer soils and adequate moisture. When a private enterprise, the Natural Flavours and Fragrances Co. (Thailand) Ltd. (NFF) was established in Kanchanaburi Province in 1969 and started to produce basil oil in 1970, the farmers in Ratchaburi and Kanchanaburi Provinces in the vicinity of the NFF factory were contracted to grow the plant material far the company. Although four varieties of native basil exist, only one, Form 5 (violet-flowered, panicle), is planted on the commercial scale since it produces the greatest yield of fresh weight and oil.

Table 6. Composition of a volatile oil of *Ocimum basilicum*

Compound	Percentage Composition
Alpha-pinene	0.2
Camphene	0.1
Beta-pinene	0.3
Sabinene	0.1
Myrcene	0.5
Limonene	0.1
1, 8 – Cineol	2.0
Gamma-terpinene	0.1
Trans-ocimene	2.6
3 – Octanone	trace
Terpinolene	0.1
Trans-ocimene oxide	0.1
Linalol	0.5
Camphor	0.3
Trans-alpha-bergamotene and bornyl acetate	1.5
Beta-elemene	0.5
Terpinen–4–01	0.1
Methyl chavicol and alpha-humulene	88.2
Alpha-terpineol, geranial and germacrene D	0.8
Gamma-cadinene	0.4
Caryophyllene oxide and methyl eugenol	0.3
T-cadinol	0.6

Two methods of basil propagation by seedlings and cuttings can be done, but the former is preferable. Seeds are sown in the nursery beds and transplanted at the age of 25–30 days in the field. Two methods of planting are practiced. In the intensive planting, basil seedlings are transplanted, 30×30–40 cm, on ridges of 6 m wide with 1.5 m ditches on both sides. This method is practically applied to the lowland clayey soil of Damnoen Saduak District of Ratchaburi Province. The extensive method of planting

is preferred in soils with favourable condition for furrow system of irrigation, such as in Tha Maka District in Kanchanaburai Province. Watering is necessary during the dry spell in the hot season. Weeding is a serious problem since only manual work is feasible. After the first harvest, it is advisable to apply fertilizer 25-10-0 formula, at the rate of 50 kg/rai.

HARVESTING

Harvesting is normally done at the age of two months after planting and once or twice more at every two months thereafter. Inflorescences, leaves and branches are harvested for oil extraction. Yield of 2,000 to 3,000 kg per rai per harvest equivalent to an income of 700 to 1,050 Baht is obtained.

DISTILLATION

Distillations of basil oil in Thailand on the commercial scale were carried out at the NFF factory during 1970 and 1971. Charges of approximately 500 kg of fresh plant material were distilled by steam injection for a period of three hours in the two stainless steel tubs of which maximum capacity for oil prodution is about 5,400 kg annually. Normally, four charges may be distilled daily, yielding 6 kg of oil, about 0.3 percent in average of the weight of fresh material; however, during September to December 1971 the yields of oil from 468 distillations varied from 0.15 to 0.53 percent. One cause of the lower yield of oil was that a quantity of woody material which does not contain oil was also used. In some distillations, packing of charged material was not done firmly to ensure a more even distribution of steam throughout the still; another reason was that the plant material was immature containing high moisture content.

MARKETING (12)

Statistics on the production and utilization of basil oil in various countries are not readily available. According to available information, basil oil is not used in large quantities at present. The estimation of the world demand in 1971 was approximately only 15,000 kg annually. Perhaps its high market price, ranging from US$ 15 per kg, is one of the reasons for such a low demand. Moreover, there are problems in marketing of flavour materials

and essential oils, which have not previously been produced commercially. In the case of Thai Basil oil there are some difficulties in marketing the oil because it is a product from new producing areas and there is a slight difference in the quality as compared to the commercial oil of Comoros Islands. In cosmetics or toiletries there is always a risk of difference in the finished products caused by a slight difference in the quality of an essential oil. If the manufacturers cannot keep the consistency of the products, they will eventually lose the market. Therefore, Thai Basil oil was sold as a substitute or as a dilutant to a commercial oil when there was a shortage.

Basil Oil Production In Thailand

The NFF factory was started in 1969 with a sound techno-economic feasibility to produce basil oil in Thailand. In 1970 and early 1971, 460 kg of oil was produced and sold to an essential oil broker in UK and USA at US$ 22.5–25 per kg FOB Bangkok because there was a shortage at that time. The production in late 1971 amounted to 1,500 kg but the oil could not be sold until March 1973 at the FOB Bangkok price of US$ 14–18.57 per kg. The NFF factory has ceased production since then due to the shortage of operating funds; and later on, the share-holders turned their interests to other more profitable business, especially sugar production. The production of basil oil in Thailand may revive if we could find a regular market with a reasonable price.

PEPPER

Introduction

Pepper, locally known in Thailadd as "Phrik Thai", is one of the oldest and most important of all spices. It is used for seasonings and medicinally to stimulate digestion. Several species of the genus *Piper* offer pepper and other similar spices. Pepper is the product of *Piper nigrum* Linn. which is native to the peninsula of India (Western Ghats). It occurs also in the hills of Assam and North Burma, perhaps only as an introduced plant. Pepper has been cultivated by the people of certain parts of Thailand for centuries. The growing areas of pepper in Thailand are now chiefly

confined to the Chanthaburi and Trat Provinces in the Southeast, Trang and Krabi Provinces in the Peninsula. These regions are under the influence of monsoonal climates. In Trang and Krabi, pepper was once grown on a fairly large scale, but due to the increasing demand of para rubber it was ultimately replaced by the latter. At present, only a few plantations of pepper are existing in these regions.

Commercial Pepper In Thailand

The production of pepper in Thailand is mainly for domestic consumption; only a small amount of pepper has been exported (Table 7). Persuant to the fact that pepper is in great demand while the growing areas are rather limited, the price of pepper, therefore, has increased considerably since 1970 (Table 8). Pepper oil is very rare in commerce; it is distilled from unripe berries, containing an alkaloid, piperine and piperidine. The pungent taste of pepper is due to a biting substance, the resin chavicine, which is most abundant in the mesocarp (14). In Thailand only the dried berries of pepper plant are exclusively used as spice.

Commercial Varieties Of Pepper

Among tropical agricultural crops, pepper is nearly unique in that only a small number of varieties have proved worthy of cultivation. A major criterion for the selection of a commercial variety is the uniformity of fruit ripening.

Table 7. Export of Black and White Pepper during 1972–76.

Year	Black and White pepper			
	Powdered		Not Powdered	
	(Kg)	(Baht)	(Kg)	(Baht)
1972	15,479	178,519	13,650	106,862
73	3,504	45,152	37,840	590,948
74	450	9,000	40,400	821,643
75	–	–	2,850	57,000
76*	131	8,802	50,720	662,352

* January–June

Source : Foreign Trade Statistics of Thailand, Dept. of Customs.

Table 8. Yearly wholesale price of Black and White Pepper in Bangkok market during 1965–74.

Year	Black Pepper (good) (kg/Baht)	Black Pepper (ordinary) (kg/Baht)	White Pepper (good) (kg/Baht)
1965	13.86	10.42	25.32
66	14.53	11.44	25.44
67	13.06	9.65	22.74
68	11.63	9.30	20.20
69	12.81	8.91	23.48
70	16.09	9.58	30.13
71	17.89	11.69	31.80
72	18.69	12.35	32.46
73	22.49	14.12	39.92
74	34.67	22.09	66.76

Source : Agricultural Statistics of Thailand No. 54. 1976.

Since the entire fruiting spikes must be harvested, only fully ripe berries produce top-quality pepper. Productiveness is affected by soil and climatic conditions as well as resistance to *Phytophthora* root rot.

At present, only five cultivated varieties of pepper are grown:

(1) "Chanthaburi", the local variety from Chanthaburi Province;
(2) "Krabi", the local variety from Krabi Province;
(3) "Palian" the local variety from Palian District in Trang Province;
(4) "Sarawak", an introduced variety from Sarawak; and
(5) "Malaysian", an introduced variety from Malaysia.

Among them, the Chanthaburi and Malaysian varieties produce the best yield because they bear spikes of berries profusely.

Climate And Soils

Pepper plant prefers a monsoon climate with regular annual rainfall of at least 1250-2000 mm. It requires hot wet tropical weather and is usually grown at low altitudes. It canot stand water-logging conditions and is usually planted on mounds. However, regular watering during the dry spell of hot season is necessary.

The most suitable type of soil on which pepper grows best is a red friable clay, deep and very well-drained. Such type of soils are found in some places in the vicinity of the basaltic hills of Tha Mai District in Chanthaburi Province. The red soil region at Tha Mai covering approximately an area of 45 sq. kilometres is most important from the point of view of pepper cultivation. Generally, pepper can be grown in the soil which is neither too sandy nor very stiff but rich in organic matter.

CULTIVATION

Preparing the land. After the land is cleared of shrubs and trees the soil is hoed at the depth of 60–80 cm to make mounds ready for planting before October, which means the land is prepared before the rainy season. The rhizomatous stocks of weeds must be removed entirely. If possible, hoeing should be practiced twice. The spacing for planting pepper plant is 2×2 m and 2.25×2.25 m for Chanthaburi and Malaysian varieties respectively. Formerly the planters applied the top soil and organic debris (burnt earth) of the forest for pepper cultivation. With the limited forested areas at present, some animal dung is applied to enrich the type of soil in the proportion of dung : soil at 1 : 3.

As pepper is a creeping vine, provision must be made for supports. Heart wood posts of any kind with $3'' \times 5''$ girth and about 4 m in length or $4'' \times 4''$ and 4 m in length are generally used as the permanent supports, which may be fixed to the ground before or after planting pepper.

Preparing the planting material. Pepper is propagated vegetatively by cuttings, which are obtained from the well-selected young vines. The plants on the supports are cut off very near the bases and carefully removed from the posts without disturbing the roots at the nodes. Each cutting, possessing about seven nodes, is then planted in the nursery.

Planting. Before transplanting, pits of $40 \times 40 \times 60$ cm must be dug on the planting mounds in the plantation. In order to keep the bases of vines open for the sun, the pits should be either in the north or south of the supports.

PREPARATION

Processing of black pepper. The processing of the ripe fruits into commercial black pepper consists of piling the collected fruiting spikes into heaps for fermentation under the zinc plates or canvas sheets for three to four nights. During the fermentation process, the berries turn black and can easily be separated from their spikes. The blackened berries are then spread out on mats in the sun until dry.

Processing of white pepper. The best and fully ripe berries are selected, bagged, and submerged entirely in running water for seven to ten days to allow them to soften. The softened berries are then scarified to remove their skins in a basket until seeds are cleaned. When completely dried in the sun the seeds will turn white.

PESTS AND DISEASES

The most serious disease of *Piper nigrum* is root rot caused by *Phytophthora palmivora*. The first diagnosis is the drooping of the vine for two to three days, followed by the yellowing of the leaves which soon after drop rapidly; rapid die-back then occurs and at the end, the vine dies. Waterlogging and overshading from the living supports can easily induce root rot. The control is done by monthly applications of 7.5 g Difolatan : 31 water or 1 g Dexon : 20 l water during the rainy seasons.

The frequent major pests found in pepper plantations are root-knot nematode, causing damage to the vine within three to five years; bugs and pepper weevil, damaging the berries; and termite destroying the root system of vines and the supporting posts.

CARDAMOM

INTRODUCTION

Cardamom trade in Thailand is derived from the plants belonging to the members of the genus *Amomum* (Zingiberaceae). About five species of *Amomum* are native to Thailand, two of which, *A. krervanh* Pierre and *A. zanthioides* Wall. are of commercial interest. The first one locally known as "Krawaan khaao" (Camphor Seed) is a source of commercial

cardamoms, exclusively grown in Chanthaburi Province, particularly on the chain of mountains of Khao Soi Dao in Pong Nam Ron District. The second one commonly known as "Reiw or Krawaan paa" (Bastard Cardamom) is found on the chain of mountains throughout the country, especially, in north-eastern Thailand.

International Trade

Both Thai cardamom species (Krawaan khaao and Reiw) have fetched much income in export trade (Tables 9 and 10) the chief countries of consumption being Hong Kong, Japan, South Korea and Taiwan. The export of cardamoms is in the forms of dried capsules containing seeds (not powdered), and decorticated capsules with seeds only (powdered).

Sources Of Cardamoms

The true cardamom of international commerce is, in fact, *Elettaria cardamomum* Maton, a member of the family Zingiberceae, whose seeds are used medicinally and as a spice. *E. cardamomum* is related to the genus *Amomum*, the former with inflorescences and fruit clusters in the form of panicles, while the latter is in short spikes. *E. cardamomum* is native to South-western India, and often cultivated through the tropics. However, it is reported by Gagnepain (15) as wild and also indigenous in upper Tonkin at Lao-kay. In Thailand this plant is occasionally cultivated at an experimental scale and is known as "Krawaan thet". The spice consists of the three-lobed globular capsules or rather the numerous small brown angular seeds, which possess a strongly aromatic odour and flavour. Commercial circles and pharmacists recognize the Indian species as up to standard, yielding high medicinal quality.

There are, however, several substitutes for the true cardamom, one of them being *Amomum krervanh*, the Cambodian and Thai Cardamom. The main production of Thai cardamom (Krawaan khaao) is obtained from the cultivation in Chanthaburi Province, towards the Cambodian border, particularly in the massive range of Khao Soi Dao Nua (North) and Khao Soi Dao Tai (South) in Pong Nom Ron District. The local name "Krawaan khaao" indicates the white flowers and pale straw colour of capsules of *A. krervanh* (Khaao = white).

Table 9. Export of Cardamoms, both powdered and not powdered, (including Bastard Cardamom) during 1962–75.

Year	Tons	Bath (1,000)
1962	149	1,969
63	86	907
64	225	3,139
65	142	1,976
66	114	2,251
67	127	1,883
68	157	2,058
69	84	1,270
70	121	2,413
71	324	7,459
72	357	6,301
73	260	5,050
74	499	9,682
75	357	6,851

Source : Agricultural Statistics of Thailand No. 54. 1976.

Table 10. Export of Cardamom (Krawaan khaao) and Bastard Cardamom (Reiw) during 1972–76.

	Cardamom				Bastard Cardamom			
	Powdered		Not powdered		Powdered		Not powdered	
	(Kg)	(Baht)	(Kg)	(Baht)	(Kg)	(Baht)	(Kg)	(Baht)
1972	35,109	817,615	52,748	1,296,586	92,888	1,511,624	175,925	2,675,189
73	6,620	159,511	30,453	737,317	54,606	1,342,744	168,154	2,810,413
74	300	6,939	49,056	1,223,937	16,400	232,353	433,724	8,218,465
75	–	–	68,815	1,661,081	1,000	54,945	286,880	5,135,135
76*	–	–	7,750	157,401	–	–	15,460	315,954

* January-June

Source : Foreign Trade Statistics of Thailand, Dept. of Customs.

COMPONENTS OF CARDAMOM OIL

In ASRCT's report (1), the yield of oil from local krawaan, *A. krervanh* (wrongly named as *A. cardamomum*) is investigated by using steam distillation and solvent extraction with the following results: (a) steam distillation gave 1.2 percent oil yield, (b) extraction with petroleum ether gave 1.3 percent oil yield, and (c) extraction with 95 percent ethanol gave 0.48 percent oil yield. The petroleum ether fraction has a smell similar to eucalyptus oil. According to BURKILL (16), the oil of *A. krervanh* possesses 5 percent of borneol and camphor in almost equal quantities. These chemical compounds give a distinctive odour to the Thai cardamoms so marked that they pass in London market under the name of "Camphor Seeds".

CULTIVATION

Krawaan khaao in its own habitat attains a height of at least 180 cm. It thrives best at the elevation between 300–800 m in moist humus soil of either basaltic or granitic origin, under light natural shade, on hill slopes in the tropical evergreen forest of which undergrowth has been cleared.

Propagation is mostly by division of the rhizomes, three to four of which are planted together with about 3–4 m spacing each way. This must be done under the shade of big trees in evergreen forests prearranged for the purpose just in time for rainy season; moisture thus obtained accelerates growth. In suitable habitat the first crop may be harvested in the third or fourth year from planting; but at about seven years of age the plant is considered to regularly produce a good yield. When it is too old the plant yields less crop. Replanting, therefore, is necessarily needed. There is no real statistical figure to show the acreage yield of this crop in Thailand. An average yield of krawaan khaao is rather fluctuating depending on the cultivation, nature of soil, the amount of rainfall, etc. Heavy rains, while the plants are in blossom, will reduce the crop by preventing flowers from setting. To produce flowers and fruits it requires about three to four years, flowering starts about March–April, and the maturity of fruits is about August–October.

HARVESTING

Harvesting of the cardamoms must be done at the right time when the capsules are just mature; if the capsules are left to ripen fully they are liable to oplit spen and disperse the seeds. The fruits are collected by

cutting the whole bunch before they are fully ripe, and then placed on mats laid on top of platforms. They are slowly dried by a fire and when properly dried they are packed for sale.

From an old belief and superstition, krawaan khaao is deemed as a highly-esteemed crop and thus women are forbidden to go to the cultivation area as they might render plants fruitless.

Problem

The prospect of Thai cardamom trade, especially krawaan khaao in Chanthaburi Province looks very dim. The cultivation areas of krawaan khaao are mostly confined to the massive range of Khao Soi Dao in Pong Nam Ron District, which has been decreed by law as a Wildlife Sanctuary since 1975. Hence, any kind of cultivations is this area have become illegal from the time the Act was promulgated. The harvesting of the existing plants, however, is still temporarily allowed until they come to the end of their age.

The extension of krawaan cultivation areas into other regions of similar suitable atmospheric conditions of Chanthaburi Province is beyond any question, since much of the tropical evergreen forest of the country centre has been drastically destroyed during the past 15 years. The virgin forests, left over from such destruction, have already been decreed by law either as a national park or wildlife sanctuary.

BASTARD CARDAMOM

A second Thai cardamom is scientifically known as *Amomum xanthioides* Wall. or "Bastard Cardamom" in commerce. In Thailand it is commonly called "Reiw" or "Krawaan paa", growing in the wild in tropical evergreen forests throughout the country, particularly in the north-east and south-east. Reiw (*A. xanthioides*) can be readily distinguished from krawaan khaao (*A. krervanh*) by its reddish flowers and soft spiny fruits. The harvest of the fruits is gathered only from the wild species. No traditional cultivation or propagation of reiw has been made like krawaan khaao plantation in Chanthaburi Province. Bastard cardamom can be also obtained in the form of dried capsules containing seeds (not powdered) and decorticated capsules with seeds only (powdered). It becomes an important item of exports (Table 10).

COMPONENTS OF BASTARD CARDAMOM OIL

By gas-liquid chromatography LAWRENCE *et al.* (17) identified and quantitatively estimated the chemical constituents of oil from freshly ground fruit (yield 2.5 percent based on dry weight) of "Reiw" or Bastard Cardamom (wrongly named as *Amomum globosum* Lour.) and found to have the compounds given in Table 11.

Table 11. Composition of the essential oil of *Amomum xanthioides*.

Compound	Percentage composition
Alpha-pinene	0.8
Camphene	4.2
Beta-pinene	0.1
Alpha-phellandrene	2.4
Limonene	4.1
1, 8–cineol	0.3
P-cymene	trace
Terpinolene	trace
Fenchyl acetate	0.3
Alpha-ylangene	0.1
Copaene	0.2
Camphor	38.9
Linalol	1.9
Bornyl acetate and trans-alpha-bergamotene	25.5
Borneol	0.4
Delta-selinene and alpha-amorphene	5.0
Neryl acetate ane geranial	1.0
Delta-cadinene	0.4
Geranyl acetate and ar. curcumene	0.7
Nerol	0.5
Geranyl acetone	0.1
Nerolidol	0.7
Farnesol	4.7
Unidentified constituents	6.9

CINNAMON

Introduction

Cinnamon is actually a trade name for the bark of *Cinnamomum zeylanicum* Linn. produced in Sri Lanka, commercially known as the true cinnamon or the standard cinnamon. Cassia or Chinese cinnamon is the bark of *C. tamala* Th. Vries (Syn. *C. cassia* Bl.), a native of Burma and cultivated in southern China. Chinese cinnamon bark (cassia) is only a little inferior to the true cinnamon. Chinese cinnamon also produces cassia buds, which are the dried, unripe fruits and are used as spice; cassia oil is obtained from the leaves.

Most of the species of *Cinnamomum*, a genus of trees of the family Lauraceae found in eastern and south-eastern Asia through Malaysia and into the Pacific, are aromatic. The aroma depends upon different substances, and their mixtures. Some species contain cinnamic aldehyde, characteristic of the true cinnamon; eugenol, smelling of cloves; safrol, smelling like sassafras; and camphor (16). *C. zeylanicum* and *C. tamala* contain cinnamic aldehyde as the chief aromatic substance.

Uses And Oil Of Thai Cinnamon

In any commercial cinnamon plantation in Thailand there is *C. zeylanicum*, an introduced species from Sri Lanka, and it is sometimes cultivated in the temple compounds and known as "Kaarabuun". The Chinese cinnamon, *C, tamala*, locally called "Kaeng", however, is found scattered only in the hilly evergreen forests on the mountainous areas of northen Thailand. The local trade in this kind of cinnamon is not known in this region, but it is locally esteemed as a spice and medicinal ingredient substituting for the true cinnamon, of which import data is shown in Table 12.

Table 12. Import of cinnamon during 1972–76.

Year	Cinnamon (powdered)		Cinnamon (not powdered)	
	(Kg)	(Baht	(Kg)	(Baht)
1972	77	13,553	25,441	483,394
73	231	24,056	29,959	756,408
74	412	29,350	15,411	338,824
75	226	18,464	32,924	638,386
76*	–	–	19,119	479,434

* January-June

Source : Foreign Trade Statistics of Thailand, Dept. of Customs.

Besides *C. tamala*, the Thai cinnamon is mostly derived from *C. bejolghota* (Ham.) Sweet, locally called "Opchoei" and *C. subavenium* Miq. (Syn. *C. burmanni* Bl.), locally known as "Suraamarit". Other species are Chiat or Mahaapraap (*C. iners* Bl.), Chuang hom [*C. porrectum* (Roxb.) Kostem.] and Takhrai ton (*C. illicioides* Chev.), barks of which are medicinally used. Neither real statistical production nor the cultivation methods of the Thai cinnamon is available because the exploitation is entirely harvested from the forest trees growing wild.

Obchoei (*C. bejolghota*) is a small to medium-sized tree commonly found in the tropical rain forests in south-eastern and peninsular Thailand. This domestic cinnamon bark when extracted with petroleum ether and ethanol yielded the following results: petroleum ether fraction 5.2 percent, ethanol fraction 17.4 percent. These materials have strong cinnamon odour and flavour and appear interesting for investigation of commercial possibilties (18). PODIMUANG & PIETIYA (1) obtained 0.70 percent of oil from the wood.

Suraamarit (*C. subavenium*) is a tree growing to a height of 25 m, scattered in evergreen forests in the mountainous areas throughout the country. Its bark contributes the supplies of cassia bark. Trunk-bark is considered the best. The chief constituent of the oils contained in the bark is cinnamic aldehyde, The bark is a well-known medicine for diarrhoea (cf. BURKILL, 16).

Chiat or Mahaapraap (*C. iners*) is a moderate-sized tree commonly found in the evergreen forests up to the elevation of about 900 m throughout the country. Its bark is usually devoid of aroma. The roots of *C. iners* are used medicinally for fever. The leaves are also used medicinally. Besides, the leaves serve as a poultice for rheumatism (16).

Chuang hom (*C. porrectum*, Syn. *C. parthenoxylon* Nees) is a moderate- to big-sized tree found scattered in the hilly evergreen forests throughout the country. The bark is aromatic, and is used for flavouring foods. The roots are used medicinally like those of other cinnamons. The ivory white wood, when dried, smells like fennel and aniseed and retains this smell for some years, or it is like sassafras.

The aromatic substance in the oil from wood is safrol, and not, as in cinnamon, cinnamic-aldehyde (16,25). This substance is a scent for soaps.

Takrai ton (*C. illicioides*) is a medium- to large-sized tree, commonly found by mountain streams of evergreen forests in Kanchanaburi, Phitsanulok, Chiang Mai and Saraburi (Khao Yai National Park) Provinces. The colourless oil from water distillation of the wood (0.84 percent) has a pleasant and very interesting odour. Also petroleum ether and ethanol extractions give good yields (2.69 percent and 5.33 percent respectively). The flavours are very interesting (1).

LEMON/CITRONELLA GRASS

Introduction

Lemongrass, locally called "Takhrai", *Cymbopogon citratus* (DC.) Stapf. is one of the most favourite aromatic plants for flavouring certain soups and curries. It is widely grown in kitchen and market gardens, and can be purchased daily in any local market. It resembles citronella grass or "Takhrai hom", *C. nardus* Rendle in general appearance, but is distinct from the odour of the leaves and less robust habit of growth. Takhrai hom, unlike takhrai, is recently cultivated in this country to a small extent because it is not much used locally.

Citronella grass was introduced from Ceylon and first cultivated for oil extraction in Chiang Mai Province about 1937, and a few years later in Si Racha District of Chonburi Province. Citronella oil was made on an

industrial scale for export at one time in 1964 by the Thai Esteric Oil Co., Ltd., Bangkok. The distillation units were established in Sukhothai and Nakhon Ratchasima Provinces. However, after a few years of operation, for some reason or another, one has not heard about this enterprise anymore. The world market situation of citronella oil is not encouraging for the establishment of the large-scale production, because citronella oil is one of the cheapest and most abundant essential oils in world trade. In Thailand the domestic consumption of citronella oil is very low, depending entirely from the import (Table 13). The essential oil obtained from citronella leaves by water distillation was 1.25 percent (1).

Table 13. Import of citronella oil during 1972–76.

Year	Litre	Baht
1972	–	–
73	–	–
74	220	9,428
75	483	36,089
76*	1,146	71,685

* January-June

Source : Foreign Trade Statistics of Thailand, Dept. of Customs.

COMPONENTS OF LEMONGRASS OIL

Lemongrass oil is one of the most important essential oils. The principal use of lemongrass oil is as a source of citral, its chief constituent. Citral is itself used in fragrance and flavovr compositions. It is also the basic material for the synthesis of the important ionones and, through B-ionone, of Vitamin A. Lemongrass oil is used in the scenting of soaps, detergents and many products. Lemongrass oil is yellow or amber in colour obtained by steam or water distillation of cultivated species of *Cymbopogon* grasses, of which two main types are recognized by the trade: the "East Indian" oil is obtained from *C. flexuosus* (DC.) Stapf., cultivated in Travancore near the Malabar coast; the "West Indian" lemongrass oil is obtained from *C. citratus*,, cultivated in the tropics, particularly in Guatemala, where oil production is on a large scale. Both types of lemongrass oil contain 75–85 percent of aldehyde (citral) (19).

The yield of lemongrass oil extracted from *C. citratus* cultivated in various localities in Thailand by water and steam distillation is shown in Table 14 and 15 (20).

Generally, the samples from the local markets tend to yield less oil than those from the plots at TAPI** and the experimental farm in Nakhon Pathom Province. This may be due to the material consisting of the stem, which is known to have a lower oil content than the blade portion of the grass. From the same investigation (20), on the basis of the physical and chemical constants of lemongrass oil (Table 16), the oil of lemongrass in Thailand corresponds to the range of the West Indian type of lemongrass oil, the distinguishing features from the East Indian type of oil being the lower density and insolubility in alcohol. A gas chromatogram of Thai lemongrass oil also indicates that the traces obtained are typical of West Indian lemongrass oil. It was concluded that lemongrass growing in Thailand offers a source of such oil for possible commercial production.

Table 14. Results of laboratory-scale water distillation.

Sample from	Weight of fresh material (g)	% of oil*
1. Local market	330	0.23
2. Local market	310	0.22
3. Local market	370	0.32
4. Local market	240	0.36
5. TAPI	195	0.31
6. TAPI	120	0.30
7. Nakhon Pathom	275	0.35
8. Nakhon Pathom	276	0.36
9. Nakhon Pathom	260	0.38

* Based on the fresh weight of material charged to the still.

** Tropical Agricultural Products Instiute, Bangkok.

Table 15. Results of laboratory-scale water distillation.

Sample from	Weight of fresh material (kg)	Yield of oil (ml)	Yield of oil % of oil
1. Local market	39.0	110	0.28
2. Local market	25.0	90	0.36
3. TAPI	19.4	60	0.31
4. TAPI	12.0	35	0.29
5. Nakhon Pathom	27.5	95	0.35
6. Nakhon Pathom	27.6	100	0.36
7. Nakhon Pathom	26.0	100	0.38

Table 16. Physical and chemical constants of lemongrass oil.

	Analyzed samples	East Indian	West Indian
Apparent density at 20°C	0.886–0.892	0.893–0.903	0.870–0.895
Optical rotation	–0.24–(0.29) at 2°C	–3–(+1)	–3–(+1)
Refractive index (26°)	1.4824.–1.4854	1.483–1.489	1.483–1.489
Carbonyl value	275–283	Not less than 276	Not less than 276
Citral, percent W/W	74–77	Not less than 75	Not less than 75
Solubility in 70 percent V/V alcohol at 56°C	Insoluble	1 vol. soluble in 3 vol.	Insoluble

Lemongrass Oil Extraction Factory

Because of its luxuriant growth, the oil production from the lemongrass was once attempted by a private company, The Pood Pol Kamphaeng Phet Co., Ltd., established in Kamphaeng Phet Province in 1960. Distillations were carried out in this factory during 1961–1964. Charges of approximately 100 kg of fresh grass were distilled by steam injection lasting about three hours. The average yield of oil from each charge was about 4–5 kg. The distillation units at that time could produce monthly an average of 1000 kg of oil, which was exported to USA through the East Asiatic Company in Bangkok. However, the oil production lasted only four to five years since the contracted growers suspended lemongrass cultivation in favour of rice, maize and other more valuable food praducts.

CLOVES

Introduction

The cloves or "Kaanphluu" in Thai (*Eugenia caryophyllus* Bull. & Harris) are dried flower buds, which are picked green and spread to dry in the sun for a few days or until they become dark brown. The clove tree was originally native on several small islands of the Malay Archipelago, mainly Ternate, Timore, Motir, Makyan and Bachan, and became widely distributed through-out the Far East where Indonesia is the main clove producer in this area. More than two-thirds of the world clove crop comes from Zanzibar, Pemba and Madagascar. It is also grown in Thailand but the quantity is not sufficient for mass consumption; therefore, the import of cloves is inevitable (Table 17).

Table 17. Import of cloves during 1972–76.

Year	Cloves (powdered)		Cloves (not powdered)	
	(Kg)	(Baht)	(Kg)	(Baht)
1972	566	54,036	19,076	1,065,258
73	607	49,976	33,333	2,251,474
74	22	2,428	23,435	1,879,427
75	21	6,279	31,376	2,946,000
76*	660	16,620	68,755	1,626,529

* January–June

Source: Foreign Trade Statistics of Thailand, Dept. of Customs

CLIMATE AND SOIL

Clove trees are occasionally found in Chanthaburi Province only. Being under the influence of a monsoonal climate with the mean temperature about 20° to 30°C, and the annual rainfall 1,500 to 2,000 mm, clove tree has reached its best development on deep, fertile, well-drained sandy loam of Chanthaburi region. The clove is propagated exclusively by seed. The first crop is obtained about eight to twelve years after the plants have been cultivated in the plantations. However, the large-scale planting of clove has long been suspended by planters in favour of other fruit trees, i.e. durian, rambutan, longan and oranges.

HARVESTING

The flower buds are collected just when the calyx becomes tinged with red or purple, and afterwards dried in the sun. The aromatic flavour dissipates quickly if the flower buds are allowed to grow too large or too dark in colour; so they must be picked at the right time.

USES AND OIL

Cloves are used as a table spice and in the preparation of curry powder. They are also used to flavour the betel quid, in which chopped betel nut (*Areca catechu* Linn.) mixed with lime is folded in a leaf of betel pepper (*Piper betle* Linn.) and fastened with a clove and chewed. Medicinally, cloves are used as stimulant, antispasmodic and carminative. When local clove oil was extracted with petroleum ether and with 95 percent ethanol, it gave the yields of 12.4 percent and 13.0 percent respectively. The petroleum ether fraction possessed a strong smell of eugenol (1). The distillation of clove oil on a commercial scale has never been practiced in Thailand due to the limited amount of raw material.

NUTMEG/MACE

INTRODUCTION

The only growing area of the nutmeg tree or "Chan thet", *Myristica fragrans* Houtt. in Thailand is found in Trang Province where the monsoonal climate in the peninsula offers the most suitable atmospheric conditions for the tree's growth. Originally native to the Moluccas, the nutmeg tree has been distributed to many other parts of the Malay Archipelago. The Thai nutmeg was probably introduced from Penang, once one of the major producing areas, but its yield has diminished greatly in recent decades. Two

spices are obtained from *M. fragrans*, nutmeg from the seed and mace from the aril. In the eastern Asian countries the use of these products is much less a condiment than a drug, and vice versa in europe. The domestic consumption of nutmeg and mace in Thailand depends mostly on imports (Table 18) since the quantity of production in the Trang area is relatively low, insufficient for mass consumption. Indonesia and the small West Indian island island of Grenada are now the largest producers of nutmeg and mace.

CULTIVATION

Nutmeg grows best in a humid tropical climate with rainfall well-prevailed over the year in deep loamy and well-drained soil, needing shade when young. It is usually propagated from seed which takes about two to three months to germinate. The trees normally come into production when they are at least eight to ten years old.

HARVESTING

The nuts are harvested when the fruits burst open on the tree during March–April. The nuts with aril (mace) must be removed from the fruits, then aril is peeled off, and both nuts and mace are dried thoroughly in the sun. In Trang Province the harvest of nutmeg and mace is collected from the old trees since the farmers prefer to grow para rubber instead of nutmeg. The complicated cultivation problems (i.e. the selection of female trees and the long-awaited crop) as well as the low demand of local consumers are the main reasons to discourage the nutmeg and mace production in Thailand.

Table 18. Import of nutmeg/mace during 1972–76.

Year	Nutmeg				Mace			
	Powdered		Not powdered		Powdered		Not powdered	
	(Kg)	(Baht)	(Kg)	(Baht)	(Kg)	(Baht)	(Kg)	(Baht)
1972	9,628	184,829	13,875	267,238	9,217	317,766	11,357	343,998
73	7,134	161,473	10,513	215,194	3,690	128,884	5,881	193,235
74	6,916	191,752	11,090	351,689	4,275	238,237	13,908	802,667
75	4,331	143,146	24,670	773,234	511	32,442	18,639	1,101,209
76*	–	–	13,847	401,150	–	–	6,770	382,976

*January June

Source : Foreign Trade Statistics of Thailand, Dept. of Customs.

CINCHONA

INTRODUCTION

Several species of Cinchona, notably *C. ledgeriana* Moens. ex Tremen., *C. succirubra* Pav. ex Klotzsch, *C. calisaya* Wedd., and *C. officinalis* Linn. are classed among the most important medicinal plants of the world, since their bark contains quinine and other closely related alkaloids. *Cinchona* spp. occur wild in the Andean rain forests, where they are found at elevations ranging from 800 to 3,000 m. Cinchona trees in south-eastern Asia grow best in areas having an average minimum temperature of 13.5°C and an average maximum of 21°C with a mean relative humidity of 83 percent. The annual rainfall should be a little less than 2,000 mm if it is spread equally over the year; if distinct dry seasons occur, a minimum of 3,500 mm is required. At low elevations and where soil moisture is limited, the yield of alkaloids is reduced (14).

THAI CINCHONA

Two species of the commercial Cinchona, *C. ledgeriana* and *C. succirubra* were introduced from Indonesia, and planted on an experimental scale in the mountainous areas of Doi Suthep, Chiang Mai Province and Doi Tung, Chiang Rai Province in 1949. Despite the availability of well-drained, virgin forest soils, rich in organic matter, the trees grow very slowly due to the limited soil moisture and relatively low annual rainfall (average 1.245 mm). It was found that *C. ledgeriana* gave a higher yield of alkaloids than those from *C. succirubra* (Table 19) (21). The domestic consumption of quinine and other medical and chemical products for the treatment of malaria is considerably high, depending entirely on the imports (Table 20).

Table 19. The alkaloid quinine content of *Cinchona ledgeriana* and *C. succirubra* cultivated at Doi Tung, Chiang Rai Province.

Age	Alkaloid quinine (%)	
	C. ledgeriana	*C. succirubra*
1	–	0.15
2	0.75	0.75
3	2.25	0.75
4	2.50	1.50

Table 20. Imports of quinine and other drugs and chemical products for the treatment of malaria during 1972–76.

Year	Quinine		Other drugs and chemical products for the treatment of malaria	
	(Kg)	(Baht)	(Kg)	(Baht)
1972	4.074	953,665	26,470	9,427,241
73	2,180	555,668	30,830	12,766,723
74	2,478	1,853,267	29,003	11,787,205
75	345	687,939	27,745	14,210,769
76*	30	24,273	18,372	9,897,958

* January-June

Source : Foreign Trade Statistics of Thailand, Dept. of Customs.

Additional essential oil crops (spices) and drug plants in Thailand under examination and assessment for their commercial potential are briefly noted as follows:

PHLAI

Phlai, *Zingiber cassumunar* Roxb., is a herbaceous plant with a stem 1–2 m high rising from a rhizome which is used for flavouring several Thai dishes. The fleshy rhizomes are about 2–5 cm diameter with a scaly, light-brown epidermis, the inside being a rich golden yellow. The odour is strong and reminiscent of a mixture of ginger, camphor and turmeric, the taste is hot and camphoraceous. It is also used medicinally. The 0.5 percent yield of volatile oil from water distillation had reportedly a good smell, making it interesting for further investigation (1).

The properties of the essential oil of Phlai were studied by MATTHEWS & NABNEY (22). It was found that the quality of the Phlai oil possesses the following values : apparent density 0.895, optical rotation–33.2°, refractive index 1.489; the oil was soluble in 4.6 volumes of 80 percent v/v alcohol. The ester value after acetylation (dimethyl-aniline acetyl chloride method for tertiary alcohols) corresponded to 36.5 percent by weight of total alcohols (calculated as $C_{10}H_{180}$) in the oil.

KHING

Khing or ginger, *Zingiber officinale* Roscoe, is one of the most well-known spices and its uses have been known from the earliest times in India and China. It is commonly grown and can be purchased in any local markets. The ginger grown in Thailand is used fresh to flavour food. Young tender parts of the rhizome are eaten raw; older ones are soaked, boiled or fried in several varieties of local dishes. The sun-dried ginger has long been highly esteemed for medicinal purposes. Preserved ginger, ginger ale, and soft drinks with ginger flavour are well-known throughout the world. The climatic monsoonal condition in the south-eastern and peninsular regions of Thailand is most suitable for growing ginger. The high yields, 11.0 percent and 6.0 percent from petroleum ether and ethonol extractions respectively were encouraging and their odours were good. This makes ginger another intereresting plant suitable for further experiments (1).

TURMERIC

Khamin or turmeric *Curcuma domestica* Valet. (Syn. *C. longa* Linn.), like Khing, has been known and used for a long time as a spice and as an ingredient in folk medicine as well as for dyeing. In the old Thai tradition turmeric water is rubbed over the body after a bath, or a powder daubed over children after bathing. Khamin is widely cultivated in central Thailand. The aromatic substance in turmeric or Khamin is a volatile oil, which is present to the extent of 1.3–5.5 percent on dry weight. From petroleum ether and ethanol extractions the yields of 5.0 and 11.0 percent were obtained respectively (1). This result thus makes Khamin oil interesting.

KHAA

Languas galanga Sw. [Syn. *Alpinia galanga* (Linn.) Sw.], locally known as "Khaa", is much-used as an ingredient in curry soups, as well as in medicine in south-eastern Asia. It is commonly cultivated in Thailand, and is easy to grow. Its rhizome is used fresh by the Thais to flavour food. Three to four months after planting, the rhizome can be dug up for consumption; otherwise it becomes too fibrous. The yields of essential oil

were 8.0 and 18.0 percent from petroleum ether and ethanol extractions respectively, making it very interesting (1). Such extracts from Kha could find a place in perfuming soap and in the food flavouring industry.

KRACHAAI

Krachaai or *Boesenbergia pandurata* (Roxb.) Holtt. (Syn. *Kaempferia pandurata* Roxb.) is a rhizomatous herb of the ginger family. The rhizome with lateral subclavate roots are used as a spice in food as well as in folk medicine. It grows wild in the northern region and has been cultivated throughout the country for a long time. The essential oil yields of 8.0 and 10.0 percent with pleasant odour from petroleum ether and ethanol extractions respectively make it interesting (1). The Krachai oil was found to have the following properties: specific gravity 0.867, refractive index 1.477, and specific rotation 14.90. The chemical composition of Krachai oil was also investigated by LAWRENCE *et al.* (23), and they reported the compounds analyzed by gas-liquid chromatography as shown in Table 21.

CORIANDER

Coriander or "Phak chi", *Coriandrum sativum* Linn., is an annual aromatic herb of the family Umbelliferae, commonly grown in kitchen gardens all over the country. The leaves and roots are used for flavouring soups and curries, and they can be eaten as a fresh vegetable. The fruits including seeds are also used in the East as a spice for seasoning food, and medicinal purposes. The fruits are used for the extraction of an essential oil which is commercially well-known. Water distillation of Phak chi leaves gave a product of good odour (0.11 percent), but the fruits gave a better yield (0.93 percent) which was higher than the average (0.7 percent). The volatile oil from fruits is pale yellow with a pleasant spicy odour (1).

MAKRUUT

Makruut, *Citrus hystrix* DC., is a small tree of the orange family, with a pear-shaped fruit, the skin intensely green, ultimately greenish-yellow, and wrinkled. The leaves and the peels of the fruit are used as a spice in soups and curries. Makruut is commonly grown in kitchen gardens throughout

the country. It is a source of essential oils which could be of some importance to the food and cosmetic industries. Both leaves and peels of makruut are of equal importance for oil production.

The peel oil obtained from a cold press of the peels of fresh makruut fruit and the leaf oil from a steam distillation of fresh makruut leaves were investigated by LAWRENCE *et al.* (24) with the results shown in Tables 22, 23 and 24.

Table 21. Composition of the volatile oil of *Boesenbergia pandurata Schltr.*

Compound	Percentage composition
Alpha-thujene	0.5
Alpha-pinene	1.8
Camphene	15.2
Myrcene	0.6
Limonene	5.0
1, 8–cineol	11.6
Trans-ocimene	0.5
P-cymene	0.7
Camphor	32.1
Linalol	3.6
Neral Alpha-terpineol and borneol	3.7
Geranial	1.8
Geraniol	11.2
Benzyl acetone	0.2
Methyl cinnamate	2.0
Unidentified constituents	9.5

Table 22. The properties of Thai peel and leaf oils of *Citrns hystrix*.

Constant at 20°c	Peel oil	Lea foil
Specific gravity	0.868	0.858
Refractive index	1.473	1.450
Specific rotation	+26°17′	−10°44′

Table 23. Composition of the volatile oil of *Citrus hystrix* peel.

Compound	Percentage composition
Alpha-pinene	2.5
Camphene	0.2
Beta-pinene	30.6
Sabinene	22.6
Myrcene	1.4
Limonene	29.2
1, 8–cineol	1.3
Gamma-teryinene	0.1
P-cymene	0.1
Terpinolene	0.1
Trans-sabinene hydrate	0.6
Citronellal	4.2
Copaene	0.6
Linalol	0.5
Beta-cubebene	0.5
Terpinen–4–01 and beta-elemene	0.2
Caryophyllene	0.3
Citronellyl acetate	0.2
Alpha-terpineol	0.7
Geranial	0.1
Geranyl acetate and citronellol	0.4
Delta-cadinene	0.3
Geraniol	0.1
Nerolidol	0.1
Elemol	0.3
Unidentified contistuents	2.8

Table 24. Composition of the volatile oil of *Citrus hystrix* leaf.

Compound	Percentage composition
Alpha-pinene	0.2
Camphene Beta-pinene	trace
Sabinene	4.9
Myrcene	0.6
Limonene	0.6
Trans-ocimene	0.3
Gamma-terpinene	0.2
P-cymene	0.1
Terpinolene	0.2
Citronellal	65.4
Copaene	0.1
Linalol	2.9
Beta-cubebene	0.1
Isopulegol	4.9
Caryophyllene	0.4
Citronellyl acetate	5.1
Citronellol Geranyl acetate and delta-cadinene	6.4
Unidentified constituents	7.6

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