

A Study on Production Management of Asam Gelugur (*Garcinia atroviridis*) in Sai Khao Sub-district, Khok Pho District, Pattani Province, Thailand

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Abstract

Production management of asam gelugur (*Garcinia atroviridis*) in Sai Khao sub-district, Khok Pho district, Pattani province, Thailand was studied. Thirty-five farmers were interviewed using questionnaires from August to September, 2019. The results showed that all of asam gelugur was *Garcinia atroviridis*. They were grown in low land (51.43%) which is a production land size of 1,600-3,200 square meters (65.71%). The growing density was 1-3 plants per farm. Mostly, the seeding method (97.14%) was used for *Garcinia atroviridis* planting. The plant grew in clay loam and sandy clay loam (34.29 and 34.29%, respectively) using rainwater (94.29%). The flowers bloomed from January to February (88.57%) and most fruits were produced in February. The harvest period was from July to September, with an average yield of 100-200 kg/rai/year. The postharvest management was in the form of sun-dried slices (82.86%), preserved slices (8.57%) and fresh fruit (8.57%) which net revenue were 12,600, 40,716 and 2,584.23 baht per year, respectively.

Keywords: *Garcinia atroviridis*, Production management

Introduction

Asam gelugur (*Garcinia atroviridis* Griffith ex T. Anderson., *G. atroviridis*) is a tropical plant belonging to the Guttiferae family. It is known as “asam gelugur or malabar tamarind”. The plant is native to Peninsular Malaysia, India, Myanmar and Thailand. It is widely cultivated in Myanmar and southern Thailand (Mackeen, M.M., et al., 2000; Lim, T.K., 2012). Fresh fruit and extract of various plant parts contain several organic acids such as citric acid, tartaric acid, malic acid, ascorbic acid and one of the most crucial an active Ingredient is hydroxycitric acid (HCA), which acts as a potent inhibitor of fatty acid and cholesterol synthesis by inhibiting lipogenesis. Furthermore, there are various benefits of the *G. atroviridis* such as, high potential in biological and pharmacological activities, including anti-HIV, antihepatotoxic, antioxidant, antimicrobial, anti-atherosclerotic and anti-inflammatory (Chuah, L.O., et al., 2013; Lewis, Y.S. & Neelakantan, S., 1965; Mackeen, M.M., et al., 2000). *Garcinia* is a large genus of polygamous trees or shrubs, distributed in tropical Asia, Africa and Polynesia. It consists of 180 species, of which 29 species are found in Thailand (Ritthiwigrom, T., et al., 2013) and 5 species (*G.*

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atroviridis *G. dulcis* *G. mangostana* *G. nigrolineata* and *G. scortechinii*) are found in southern Thailand (Phongpaichit, S., *et al.*, 2006; Lim, T.K., 2012; Kerddonfaek, J., 2010). There is a large number of *G. atroviridis* found in the upper southern Thailand i.e., Phuket, Phang Nga, Nakhon Si Thammarat and Krabi Provinces and in three southern border provinces i.e., Narathiwat, Yala and Pattani provinces (Thuengsuk, S., *et al.*, 2015). This *G. atroviridis* was found growing in abundance in Sai Khao sub-district in Khok Pho district, in lowlands. Sai Khao sub-district is surrounded by various mountains with adherent natural resources such as soil, water, and weather suitable for agricultural production. The aim of this study is to investigate production management of the *G. atroviridis* in Sai Khao sub-district, Khok Pho district, Pattani province in southern Thailand. The findings are expected to increase values of this plant leading to encouragement of this native source in this area. It has the potential to become a new economic plant and its products will have perfectly become well-known worldwide.

Literature reviews

Asam Gelugur (*Garcinia atroviridis*)

Garcinia atroviridis Griffith ex T. Anderson., *G. atroviridis* is a tropical species that occurs as individual trees in the humid, mixed lowland forest on the plains and up to 600 m in the highlands of high rainfall areas in Southeast Asia. Its ripe acid fruits which are bright orange-yellow are sliced, dried and used in curries, as a sour relish or stewed in plenty of sugar for consumption. The dried fruit slices are used to give acidity in cooked dishes replacing that of tamarind. The dried rind is also used in herbal health tea. In Thailand presently, the products of *G. atroviridis* are becoming popular as health food, and a lot of these products are sold in the markets in various different forms such as *G. atroviridis* tea, capsules and dried fruit slices. In Thailand, the demand for *G. atroviridis* as health food is dramatically increasing. Sun-dried slice of fruit is sold at 200–300 baht (5-7.5 US dollars) per one kilogram throughout the year. Additionally, young tender leafy shoots and leaves can be eaten fresh or cooked as a sour relish (Lim, T.K., 2012). *G. atroviridis* is highly acceptable and preferred for traditionally commercial Tom Yum mix. The *Garcinia* Tom-Yum mix could be used as a high acid seasoning to produce Tom-Yum soup, a popular hot and sour Thai soup. The scientists assert that it has unique taste and spiciness, and it is low in fat and calories which are features for an increase in its popularity worldwide (Siripongvutikorn, S., *et al.*, 2009). Moreover, some researchers reported there are various activities of production management of *G. atroviridis* is that, first, suitable environment for growing (temperate: 25-30°C and humidity: >80%), second, appropriate fertilizer management, third, diseases control and prevention, and finally, the post-harvest management such as sun-dry slice and preserved slices of fruit (Thuengsuk, S., *et al.*, 2015).

G. atroviridis (Figure 1) is a medium-sized fruit tree and can grow to a height of 6-12 meters and a long trunk. Crown is narrowly conical with numerous slender, terete drooping branches. Bole buttressed, the bark is smooth, pale grey to black with transparent yellow

latex. Leaves are coriaceous, oblong-lanceolate tapering to base and tip abruptly acuminate, 15×4 cm–25×7 cm, on 15–25 mm long petioles, pinkish-red when young and glossy dark green when mature. Flowers terminal at the end of twigs, pedicellate, with 4 yellow, spreading orbicular, concave sepals, 4 crimson, obovate and fleshy petals. Male flowers are in short few-flowered racemes with numerous stamens in whorls around the pistillode on a fleshy receptacle. Female flowers are solitary, large with an ovoid ribbed, 8–16 celled ovary and a deep red, pileate, sub-tetragonal, convex stigma and staminodes attached to an annulus. Green fruit turns to bright yellow when ripe, depressed globose, 6–10 cm diameter with broadly sunken concave apex, with 12–16 ribs and shallow grooves giving it a fluted form with persistent petals and sepals and a thick rind. The fruits often separate off into pegs or segments. Mature fruit can weigh up to 2 kg. The fruit contains several flattened seeds 1.5 cm long, which are surrounded by acidic, bright orange pulp (arillode) (Lim, T.K., 2012).

Physical and chemical properties

The physical and chemical properties of *G. atroviridis*, some researchers found that the average moisture and total soluble solid content of the fruit of *G. atroviridis* were 86.47 and 6.34 %, respectively. The total acidity as citric acid was very high at a 5.54 %w/w wet basis. Thus, total acidity was calculated to be a 40.95 % dry basis (Rittirut, W. and Siripatana, C., 2006). The chemical composition of *G. atroviridis* based on proximate analysis revealed that the mature fruit contained energy, moisture, crude protein, crude fat, crude fiber, carbohydrate, and ash of 230 (kcal), 30.39, 2.7, 1.3, 12.2, 51.9, 1.6 %, respectively. The amount of carotenoids, vitamin C and vitamin A were 155 mg, 3.6 mg, and 26 mgRE, respectively (Tee, E.S., *et al.*, 1997). Another researcher declared that the mature leaves contained energy, crude protein, carbohydrate, ash, and TPC value of 73.64 kcal, 2.16%, 15.98%, 0.72 % and 21.21 mg GAE/mg, respectively (Nursakinah, I., *et al.*, 2012).

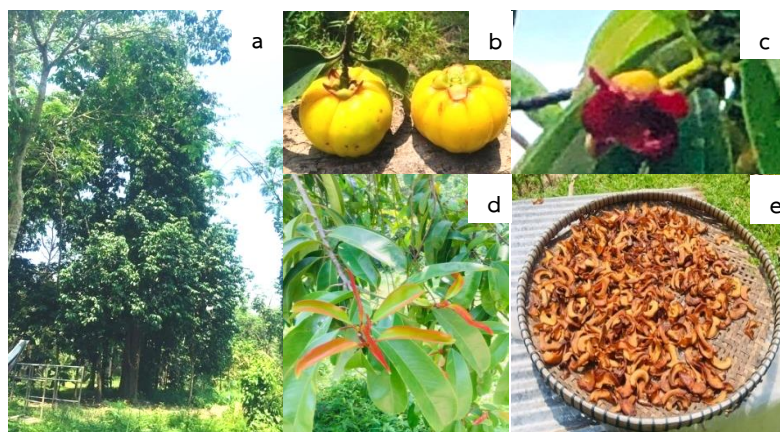


Figure 1 The various parts of *G. atroviridis*, (a) tree, (b) mature fruit, (c) male flower, (d) young and mature leaves, and (e) sun-dried slices of fruit

Active ingredients and benefits of *G. atroviridis*

G. atroviridis contains organic acids such as citric acid, tartaric acid, malic acid, and ascorbic acid. A major active ingredient is hydroxycitric acid (HCA) (Achmadi, S.S., 2001; Jena, B.S., *et al.*, 2002; Amran, A.A., *et al.*, 2009), the extract of fruit contains HCA 10–30% based on dry basis (Clouatre, D. and Rosenbaum, M.E., 1994; Roongpisuthipong, C., *et al.*, 2007) and 16–18% based on wet basis (Jayaprakasha, G.K. and Sakariah, K.K., 1998). Another researcher reported the fruit extract contained luteolin (flavonoid) (Miean, K.H. and Mohamed, S., 2001), various organic acids, for instance, dodecanoic acid, octadecanoic acid and pentadecanoic acid (Abdullah, N., 1994). The stem bark contained atroviridin (xanthone) (Kosin, J., Ruangrunsi, N., Ito, C. and Furukawa, H., 1998; Tisdale, E.J., Kochman, D.A. and Theodorakis, E.A., 2003) and garcinia flavanone A (Tan, W.N., Khairuddean, M., Wong, K.C., Khaw, K.Y. and Vikneswaran, M., 2014). Moreover, the etravirine, atroviridone (Permana, D., *et al.*, 2001) and fungicide (Permana, D., *et al.*, 2003) were found in the root. Besides, the fresh fruits and extracts of various parts of *G. atroviridis*, such as the leaves, fruits, roots, shoot and trunk showed high potential in biological and pharmacological activities including anti-atherosclerotic, antibacterial, antifungal, anti-inflammatory, antimicrobial, antioxidant, antitumor and cytotoxic activities. The root extract showed the strongest inhibition against the bacteria. There was a significant antifungal activity against *Cladosporium herbarum* exhibited by the fruit and the leaf extracts. The root, leaf, trunk and stem bark extracts (except for the fruits) showed strong antioxidant activity exceeding that of the standard antioxidant, alpha-tocopherol (vitamin E). The extract of this fruit had free-radical scavenging activity (Mackeen, M.M., *et al.*, 2000).

Materials and method

Data collection

This research is a quantitative research method for investigating an environment and production management of *G. atroviridis* in Sai Khao sub-district, Khok Pho district, Pattani province, Thailand. Thirty-five farmers (who grew *G. atroviridis* in Sai Khao sub-district) interviewed by using the questionnaires from August to September, 2019.

The data collection was divided into two sections: firstly, the primary data collected from the thirty-five farmers. Secondly, the secondary data were collected from the government sectors. The data collection techniques are as follow:

1. Data collection associated with the quantitative research

The survey on issues an environment and the production management of *G. atroviridis* in Sai Khao sub-district. This study used a specific sampling technique to interview thirty-five farmers (thirty-five lands which grew *G. atroviridis*). The samples were surveyed and the questionnaire was pre testing before data collection. The questionnaires consisted of three parts, 1) general information of farmers, 2) environmental data, and 3) production management of *G. atroviridis*.

2. Secondary data collection

The secondary data including geographic, soil characteristics, land used, rainfall, and weather were collected from government agencies such as the Meteorological Department and Land Development Department.

Research equipment

The equipment of this study was the specific structured questionnaire to cover information and details related to the general information of farmers, environment data and production management of *G. atroviridis* in Sai Khao sub-district. The questions contained close-ended and open-ended types. The questionnaires were divided into three parts: firstly, general information of farmers (gender, age, education and occupation), secondly, environmental data (location, coordinate, land size, land characteristic and soil texture) and thirdly, the production management (species of plant, planting characteristics, growing density, age of trees, seedling characteristic, water resources, plant diseases/pests, fertilization, flowering period, fruit production period, age for yield, harvest period, harvest characteristics, yield per annual, yield management, remaining products, production cost, postharvest management, income and investment return on investment).

Data analysis: Descriptive statistics such as percentage and mean were employed to explain the *G. atroviridis* farmer characteristic, environmental data on growing environment and production management.

Results and Discussion

1. General Information of Sai Khao sub-district

The geography of Sai Khao sub-district is surrounded by several mountains. The location of Sai Khao sub-district is in Khok Pho district, Pattani province, Thailand. The distance from Sai Khao sub-district to Pattani province is around 6 kilometers. This sub-district is divided into 6 villages. The neighboring sub-district of Sai Khao sub-district connected with Pa Bon sub-district in the north. In the south is connected with Nang Chan and Hin Chang. The west is connected with Chang Hai Tok sub-district, and in the east is connected with Na Pradu sub-district, Khok Pho district (Figure 2).

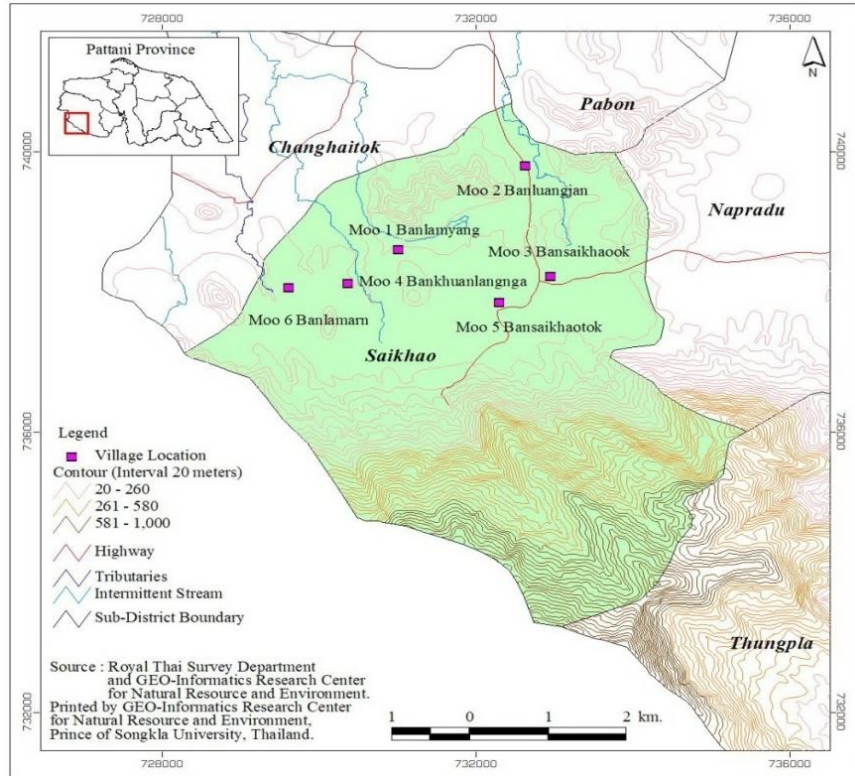


Figure 2 Location and neighboring sub-district of Sai Khao sub-district, Khok Pho district, Source: Adapted from Royal Thai Survey Department and GEO-Informatics Research Center of Natural Resource and Environment (2019)

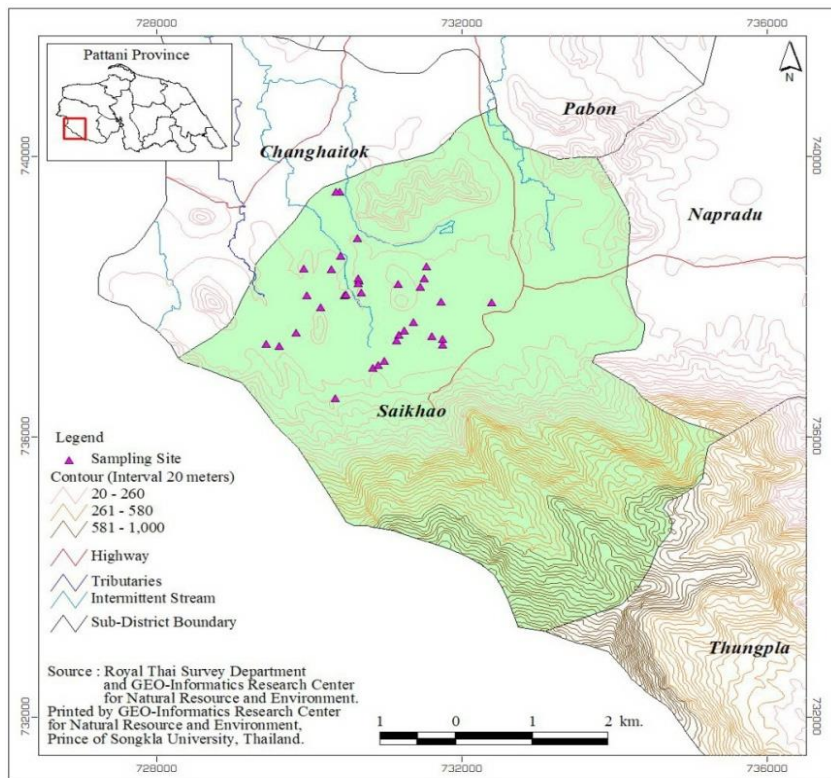


Figure 3 Coordinate map of *G. atroviridis* in Sai Khao sub-district, Khok Pho district

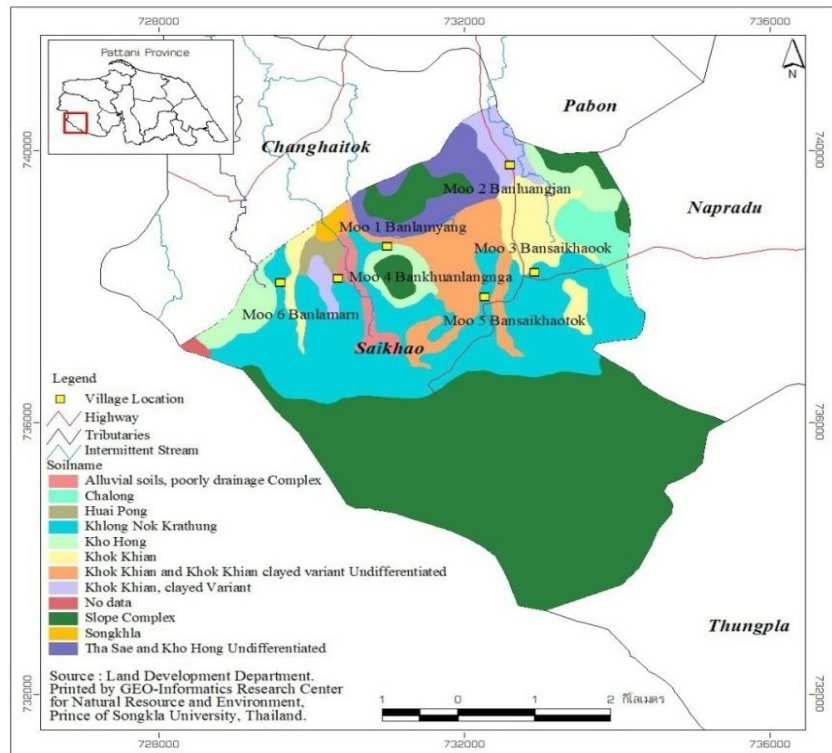


Figure 4 Soil resources map at Sai Khao sub-district, Khok Pho district

Source: Adapted from Royal Thai Survey Department and GEO-Informatics Research Center of Natural Resource and Environment (2019)

2. Environmental and production management in Sai Khao sub-district, Khok Pho district, Pattani province

2.1 General information of farmers

Almost 63% of the sampled farmers in Sai Khao sub-district were female and 37 % were male. Most of the farmer's age was higher than 60 years. Their education was mostly undergraduate level (71.43%), their main occupation was farming at 85.71 % (Table 1).

2.2 Environment of Sai Khao sub-district, Khok Pho district, Pattani province

G. atroviridis is grown at 35 coordinates (latitude and longitude) in Sai Khao sub-district as shown in Figure 3. From this study, it was found that the production land size to grow *G. atroviridis* was 1,600-3,200 square meters or 1-2 rai (65.71%), and the production land size of this plant was 4,800-6,400 square meters or 3-4 rai, and 8,000-9,600 square meters or 5-6 rai at 31.43 % and 2.86%, respectively. Most *G. atroviridis* was cultivated in low land (51.43%), slopes of the mountains and upland (25.71 and 22.86 %, respectively). Moreover, the results showed that *G. atroviridis* grew in clay loam, sandy clay loam, sand loam and loam at 34.29, 34.29, 22.85 and 8.57 per cent, respectively (Table 2). Previous research reported that the *G. atroviridis* cultivation in Phang Nga, Phuket and Nakhon Si Thammarat provinces were on foothills (84.44%) (Thuengsuk, S., et al., 2015). From this study, there are many soil names which found in Sai Khao sub-district, Khok Pho district, Pattani province including Khok Khian, clayed Variant, Songkhla, Kho Hong, Tha Sae and Kho Hong Undifferentiated, Slope

Complex, Khok Khian and Khok Khian clayed variant Undifferentiated, Khok Khian, Chalong, Alluvial soils, poorly drainage Complex and Huai Pong (Figure 4).

Table 1 General information of farmers (n=35)

Details		Number of farmers (person)	(%)
Gender	male	13	37.14
	female	22	62.86
Age (year)	< 21	0	0.00
	21-30	4	11.43
	31-40	7	20.00
	41-50	3	8.57
	51-60	9	25.71
	> 60	12	34.29
Education	Undergraduate level	25	71.43
	Bachelor degree level	9	25.71
	Master degree level	1	2.86
Occupation	Farming	30	85.71
	Government official/enterprise	1	2.86
	Self-employment	1	2.86
	Teacher (employee)	2	5.71
	General employee	1	2.86

Table 2 Production land size, land characteristic and soil texture (n=35)

Detail	Number of farmers (person)	(%)
Production land size		
1,600-3,200 square meters (1-2 rai)*	23	65.71
4,800-6,400 square meters (3-4 rai)*	11	31.43
8,000-9,600 square meters (5-6 rai)*	1	2.86
Land characteristic		
Upland	8	22.86
Lowland	18	51.43
On the slopes of the mountains	9	25.71
Soil texture		
Clay loam	12	34.29
Sandy clay loam	12	34.29
Loam	3	8.57
Sand loam	8	22.85

* 1 rai = 1,600 square meters or 0.16 hectare

2.3 Production management

This study found that most of the asam gelugur cultivated in Sai Khao sub-district, Khok Pho district, Pattani province was *Garcinia atroviridis* species. All sampled farmers used mixed cropping technique to grow *G. atroviridis* with other plants such as durian (*Durio*), longkong (*Lansium domesticum*), mangosteen (*Garcinia mangostana*), coconut (*Cocos nucifera*), rambutan (*Nephelium lappaceum*), banana (*Musa acuminata*), rubber (*Hevea brasiliensis*), santol (*Sandoricum koetjape*), chempedak (*Artocarpus integer*), pakria (*Parkia speciosa*), luk nieng (*Archidendron pauciflorum*), and rambai (*Baccaurea motleyana*). The planting distance of *G. atroviridis* was 10×10 meters. According to another researcher, *G. atroviridis* cultivation in Yala, Pattani, Narathiwat Satun and Songkhla provinces was primarily for household consumption by growing it mixed with rubber and fruit trees such as mangosteen. In some areas in Songkhla province, the farmers had converted rubber and fruit trees to make space for *G. atroviridis* (Thuengsuk, S., et al., 2015). Some farmers grew *G. atroviridis* with livestock such as cattle, and goats. Growing density of *G. atroviridis* was 1-3, 4-6 and 7-9 plants per farm (75.71, 28.57 and 5.71%, respectively). Plant age ranges from 26-30, 16-20, 11-15, 6-10, and 21-25 years (57.14, 20, 11.43, 8.57, and 2.86, respectively). Almost all farmers in Sai Khao sub-district grew *G. atroviridis* by seeding method (97.14%), and only 2.86% used grafting method. Most farmers used water resources from rainfall, and wells (94.29 and 5.71 per cent). Moreover, this study found that the growing of *G. atroviridis* in Sai Khao sub-district had no issues related to plant diseases and pests. All of the sampled farmers never used fertilizers for growth. The flowering period was during January to February. This available time was suitable for planting due to several factors such as water availability from rainfall and climate leading to right flowering and fruiting period. The results showed that the fruiting period of *G. atroviridis* was in February (88.57%) and January (11.43%). However, another study found that the flowering period of *G. atroviridis* in upper southern Thailand (Phuket, Phang Nga, Krabi and Nakhon Si Thammarat provinces) was in November to December (77.78%), fruiting period was in January (64.44%), with the harvest during March (66.67%). Most farmers also used water resources from rainfall. The growing density of these plants was no more than 10 trees per area (71.11%), and almost plant age was 80 years (20%) by using the grafting method (82.22%). Some farmers applied fertilizer (24.44%) (Thuengsuk, S., et al., 2015).

This study showed that *G. atroviridis* gave fruiting period, its first yield after eight years old (100%). The sampled farmers were specific to harvest ripe fruit. The yield produced in Sai Khao sub-district at 100, 200, 500, 300, 400, 600, 800, 900 and 1000 kilogram per year were 22.86%, 22.86%, 20.00%, 17.14%, 5.70%, 2.86%, 2.86%, 2.86%, and 2.86%, respectively. The peak production of *G. atroviridis* was in August, July and September at 88.57%, 8.57% and 2.86%, respectively. As Thuengsuk, S., et al., (2015) reported that the yield of *G. atroviridis* at Narathiwat province started at 7–8 years. The harvest period was from June to August, with the peak production of 56 fruits per tree, and the minimum yield was one fruit per tree. From

this study, the postharvest management of *G. atroviridis* yield showed that there were four main activities. Firstly, the yield was for household consumption; secondly, for processing; thirdly, for giving to other people; and finally, for sale of fresh fruit were 97.14%, 91.43%, 71.43%, and 60%, respectively. The average amounts of yield for processing, for sale of fresh fruit, for giving to other people and for households were 296.63, 293.33, 25.20 and 2.46 kilogram/year, respectively. There were two types of yield processing, sun-dried slices and preserved slices of fruits (82.86 and 8.57%) with the amounts of preserved slice and sun-dried slices of 233.33 and 63.30 kilogram/year, respectively. The price of both products was 200 baht/kilogram (Table 3). Thuengsuk, S., *et al.*, (2015) reported the harvest period of *G. atroviridis* in Narathiwat and Sai Khao sub-district, Khok Pho, Pattani province was from June to August, with 50–200 kilogram of fruit per tree and the price of fresh fruit selling was 10–15 baht per kilogram. The price of sun-dried slices of fruit was 80-160 baht per kilogram. About 33.33% of the farmers received an average income of 15,000 baht per person per year. The farmer's income and net revenue in Sai Khao sub-district show in Table 4. The farmers received an average income from *G. atroviridis* production from fresh fruit sale, sun-dried slice and preserved slice of 3,170.89, 12,600, and 46,666 (baht/year), and the net revenue of 2,584.23, 12,600 and 40,716 (baht/year), respectively. While, Thuengsuk, S., *et al.*, (2015) reported that the farmers in Phang Nga and Nakhon Si Thammarat provinces were received an average investment return of 2,340, and 3,312 baht per tree, with the return on investment rate of 3.4 and 3.3, respectively.

Table 3 Postharvest management of *G. atroviridis* in Sai Khao sub-district (n=35)

Yield management	Details	Number of farmers (person)	%	Mean
Household consumption	- Yes	34	97.14	
	- No	1	2.86	
	- Amount of yield that consumed in household (kilogram/year)			2.46
For giving other person	- Yes	25	71.43	
	- No	10	28.57	
	- Amount of yield for others (kilogram/year)			25.20
Sale of fresh fruit	- Yes	21	60	
	- No	14	40	
	- Amount of fresh fruit sold (kilogram/year)			293.33
	Price of fresh fruit (baht/kilogram)			10.81

Table 3 (Continue)

Yield management	Details	Number of farmers (person)	%	Mean
Sale of processed fruit	- Yes	32	91.43	
	- No	3	8.57	
	- Sun-dried slice of fruits	29	82.86	
	Preserved slices of fruits	3	8.57	
	Unprocessed	3	8.57	
	- Amount of sun-dried slices of fruits (kilogram/year)			63.30
	- Price of sun-dried slices of fruits (baht/kilogram)			200
	- Amount of preserved slice of fruits (kilogram/year)			233.33
	- Price of preserved slice of fruits (baht/kilogram)			200

Table 4 Income and net revenue (n=35)

Details	Income (baht/year)	Net revenue (baht/year)
Fresh fruit selling	3,170.89	2,584.23
Sun dried slice of fruits	12,600.00	12,600.00
Preserved slice of fruits	46,666.00	40,716.00

Conclusions and Implications

A study on *G. atroviridis* production management in Sai Khao sub-district, Khok Pho district, Pattani province was conducted on thirty-five farmers by using questionnaires from August to September, 2019. This research is a quantitative research method for investigating an environmental and production management of *G. atroviridis*. The results showed that *G. atroviridis* was grown in low land with production land size of 1,600–3,200 square meters. The growing density was 1–3 plants per farm by seeding method, the plants grew in both clay loam and sandy clay loam. Rainwater was the main source of water resource. The flowers bloomed from January to February and most fruits were produced in February. The harvest period was from July to September, with an average yield of 100–200 kg/rai/year. The

postharvest management was in the forms of sun-dried slices, preserved slices and fresh fruit with the net revenue were 12,600, 40,716 and 2,584.23 baht per rai per year respectively.

There are a large amount of *G. atroviridis* becoming waste products. Sixty per cent of the ripe fruits were changing to large wastes from agricultural farms. The result from this study may be useful as basic information for ecology and biodiversity conservation of native plants. It can be applied into the practical use for policy to help better balance between development and biodiversity. For further study, more rescaled to enhance the values of *G. atroviridis* to make several benefits for other activities is needed for an application of *G. atroviridis* as feed additive from natural livestock that can be to full utilization in a sustainable way.

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References

- Abdullah, N. (1994). *Pengasingan dan pencirian asid organic dalam Asam Gelugor (Garcinia atroviridis)*. (Bachelor of Science Dissertation). University Pertanian, Malaysia.
- Amran, A. A., Zaiton, Z., Faizah, O. and Morat, P. (2009). Effect of *Garcinia atroviridis* on oxidative stress and atherosclerotic changes in experimental guinea pigs. *Singapore Medical Journal*, 50(3), 295–299.
- Chuah, L.O., Ho, W.Y., Beh, B. K. and Yeap, S. K. (2013). Updates on Antiobesity Effect of *Garcinia* Origin (-) HCA. *Evidence-Based Complementary and Alternative Medicine*. 1–17.
- Clouatre, D. and Rosenbaum, M.E. (1994). *The diet and health benefits of HCA (hydroxycitric acid)*. New Canaan, CT: Keats Publishing.
- Jayaprakasha, G.K. and Sakariah, K.K. (1998). Determination of organic acids in *Garcinia cambogia* (Desr.) by high-performance liquid chromatography. *Journal of Chromatography A*, 806(2), 337–339.
- Jena, B.S., Jayaprakasha, G.K., Singh, R.P. and Sakariah, K.K. (2002). Chemistry and biochemistry of (-)-hydroxycitric acid from *Garcinia*. *Journal of Agricultural and Food Chemistry*, 50(1), 10–22.
- Kerddonfaek, J. (2010). 140 miracle plant species reduce cholesterol in blood (p. 176–177). Seven printing Bangkok.
- Kosin, J., Ruangrunsi, N., Ito, C. and Furukawa, H. (1998). A xanthone from *Garcinia atroviridis*. *Phytochemistry*, 47(6), 1167–1168.
- Lewis, Y.S. and Neelakantan, S. (1965). α -Hydroxycitric acid – the principle acid in the fruits of *Garcinia cambogia* Desr. *Phytochemistry*, 4(4), 619–625.
- Lim, T.K. (2012). Edible medicinal and non-medicinal plants volume 2: Fruits. 21–28.

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- Mackeen, M.M., Ali, A.M., Lajis, N.H., Kawazu, K., Hassan, Z., Amran, M., Habsah, M., Mooi, L.Y, ... Mohamed, S.M. (2000). Antimicrobial, antioxidant, antitumour-promoting and cytotoxic activities of different plant part extracts of *Garcinia atroviridis* Griff. ex T. Anders. *Journal of Ethnopharmacology*, 72(3), 395–402.
- Miean, K.H. and Mohamed, S. (2001). Flavonoid (myricetin, quercetin, kaempferol, luteolin, and apigenin) content of edible tropical plants. *Journal of Agricultural and Food Chemistry*, 49(6), 3106–3112.
- Nursakinah, I., Zulkhairi, H.A., Norhafizah, M., Hasnah, B., Zamree, M.S., Farrah, S.I., Razif, D., ... Hamzah, F.H. (2012). Nutritional content and *in vitro* antioxidant potential of *Garcinia atroviridis* (Asam gelugor) leaves and fruits. *Malaysian Journal of Nutrition*, 18(3), 363–371.
- Permana, D., Lajis, N.H., Mackeen, M.M., Ali, A.M., Aimi, N., Kitajima, M. and Takayama, H. (2001). Isolation and bioactivities of constituents of the roots of *Garcinia atroviridis*. *Journal of Natural Products*, 64(7), 976–979.
- Permana, D., Lajisa, N.H., Shaaria, K., Alib, A.M., Mackeenb, M.M., Kitajimac, M., Takayamac, H. and Aimic, N. (2003). A new prenylated hydroquinone from the roots of *Garcinia atroviridis* Griff ex T. Anders (Guttiferae). *Zeitschrift fur Naturforschung*, 58(4), 332–335.
- Phongpaichit, S., Rungjindama, N., Rukachaisirikul, V. and Saka-yaroj, J. (2006). Antimicrobial activity in cultures of endophytic fungi isolated from *Garcinia* species. *FEMS Immunology and Medical Microbiology*, 48(3), 367–372.
- Ritthiwigrom, T., Laphookhieo, S. and Pyne, S.P. (2013). Chemical constituents and biological activities of *Garcinia cowa* Roxb. Maejo Int. *Journal of Science and Technology*, 7, 212–231.
- Rittirut, W. and Siripatana, C. (2006). Drying characteristics of *Garcinia atroviridis*. *Walailak Journal of Science and Technology*, 3(1), 13–32.
- Roongpisuthipong, C., Kantawan, R. and Roongpisuthipong, W. (2007). Reduction of adipose tissue and body weight: Effect of water soluble calcium hydroxycitrate in *Garcinia atroviridis* on the short term treatment of obese women in Thailand. *Asia Pacific Journal of Clinical Nutrition*, 16(1), 25–29.
- Royal Thai Survey Department and GEO-Informatics Research Center of Natural Resource and Environment. (2019). Prince of Songkla University, Thailand. (in Thai).
- Siripongvutikorn, S., Thongraung, C., Usawakesmanee, W., Buatoom, T. and Thammarutwasik, P. (2009). Development of instant *Garcinia (Garcinia atroviridis)* tom-yum mix as a high acid seasoning. *Journal of Food Processing and Preservation*, 33(1), 74–86.
- Tan, W.N., Khairuddean, M., Wong, K.C., Khaw, K.Y. and Vikneswaran, M. (2014). New cholinesterase inhibitors from *Garcinia atroviridis*. *Fitoterapia*, 97, 261–267.
- Tee, E.S., Noor, M.I., Azudin, M.N. and Idris, K. (1997). *Nutrient composition of Malaysian foods*, 4th, Institute for Medical Research, Kuala Lumpur. p.299.

- Thuengsuk, S., Phomtasan, A., Phuekwivat, W., Phumchai, T., Raksa, N., Isama-ae, N., ... Dumampai, N. (2015). *Research and development on Malabar Tamarind production Technologies in the Upper Southern*. Department of agriculture. Thailand, 1–73. (in Thai).
- Tisdale, E.J., Kochman, D.A. and Theodorakis, E.A. (2003). Total synthesis of atroviridin. *Tetrahedron Letters* 44, 3281–3284.

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