

# Wax Apple Industry in Taiwan

## A Success Story



**Asia-Pacific Association of Agricultural Research Institutions**

c/o FAO Regional Office for Asia and the Pacific  
Bangkok, Thailand

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## Foreword

Wax apple (*Syzygium samarangense* Merrill & Perry), also known as java apple, rose apple, bell fruit and wax jambu, was introduced in Taiwan in 17<sup>th</sup> Century. In early days, its cultivation was on small scale limited to gardens and was grown mainly in summer season. With the development of improved varieties, and cultivation techniques, its cultivation spread to fairly large areas and has now become one of the most popular fruits in Taiwan. It is also now an important crop for export particularly to China, Hong Kong, Singapore and Canada. It is cultivated mainly in Southern Taiwan. The total area under wax apple cultivation in 2011 was around 5,416 hectares with total production of 78,109 tons. The largest planted area was in Pingtung County covering 4,232 hectares (79%) followed by Kaohsiung City with 445 hectares (8%). Its cultivation has also now extended to central Taiwan particularly in Yunlin County and Chiayi County.

Wax apple is a tropical evergreen tree and the fruits are highly nutritive, crispy, and juicy with deep red, pink, green or white colour and apple aroma. In Chinese medical science, wax apple fruits, leaves and seeds are antifebrile and the roots are diuretic. In the summer season, it protects from sunstroke or dehydration and also relieves from stomach discomfort. Wax apple is primarily used raw and in juice, jelly, salad and wine making. It is also used for decoration in the Chinese cuisine. With the development of high yielding and better quality varieties, improved agronomic practices, use of improved techniques for extending production period and application of efficient soil management techniques, wax apple is increasingly gaining more importance in Taiwan.

This publication entitled “Wax Apple Industry in Taiwan : A Success Story” embodies: i) importance, ii) general production scenario, iii) improved varieties, iv) cultivation practices, v) post-harvest handling, vi) processing and export, vii) production-market linkage, viii) factors for success of industry, and ix) future prospects and suggested strategy. This success story is a selective case study on wax apple, which has amply demonstrated the success of wax apple production and utilization in Taiwan, both for local consumption and export.

The Asia-Pacific Association of Agricultural Research Institutions (APAARI) has been publishing such success stories on various aspects of agricultural research and development that have large scale impact and have brought tangible benefits to both the farmers and consumers alike. So far, more than 50 success stories and status reports on diverse topics have been published by APAARI, details of which are available on APAARI website: [www.apaari.org](http://www.apaari.org). It is felt that dissemination of this success story will help in wider adoption of improved technologies benefiting largely the resource poor farmers in the developing countries.

I congratulate the authors for their sincere efforts in synthesizing quite valuable information on wax apple. Also, the efforts of Dr. Bhag Mal, Consultant APAARI in editing and bringing out this publication are very much appreciated. It is our expectation that the APAARI members, stakeholders and other readers will find this publication both informative and useful.



**(Raj Paroda)**

*Executive Secretary*  
APAARI

## Acronyms and Abbreviations

Ca	Calcium
COA	Council of Agriculture
Fe	Iron
IU	International Units
K	Potassium
Kcal	Kilo Calories
LCL	Less than a Container Load
Mg	Magnesium
NGOs	Non-Governmental Organizations
P	Phosphorus
RAE	Retinol Activity Equivalent
ROC	Republic of China
TSS	Total Soluble Solids
TWD	Taiwan Dollar
USA	United States of America
USDA	United States Department of Agriculture
Zn	Zinc





# 1 Introduction

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Wax apple (*Syzygium samarangense* Merrill & Perry) belongs to the family Myrtaceae and is an important economic tropical fruit in Taiwan. It has its origin in Malay Peninsula, Amman Islands and Andaman and Nicobar Islands. It is now widely cultivated in the tropics. This tropical fruit tree is known by various common names which include champoo (a transliteration of Thai name), lembu or lian-woo (native Taiwanese name), wax apple, love apple, Java apple, royal apple, bell fruit, Jamaican apple, water apple, mountain apple, cloud apple, wax jambu and rose apple. In the Philippines, it is commonly known as makopa.

According to the available records, wax apple was introduced in 17<sup>th</sup> century and planted in Taiwan over 300 years ago. Wax apple is a tropical fruit tree that generally grows to 12-15 m tall (Fig. 1). However, in well managed orchards, the tree height is at 4-5 m. It



**Fig. 1.** Wax apple tree

possesses 20-30 cm long and 6-12 cm broad evergreen leaves. The flowers are white with 2.5-3.0 cm diameter, four petals and numerous stamens. The characteristics of wax apple fruit include bell shaped fruit, edible berry; fresh fruit is glossy and waxy; fruit colour ranges from milky white, pale green or green to red, pink, purple, or crimson to deep purple or even black (Wang, 1991; Wang *et al.*, 1994). Fruits are 4-6 cm long in wild plants. The flowers and fruits are not limited to the axil of the leaves and can appear on nearly any point on the surface of the trunk and branches (Fig. 2). When mature, the tree is considered a heavy bearer yielding a crop upto 700 fruits. Small bushy type cultivars can also be grown in pots (Fig. 3).



**Fig. 2.** Wax apple branch laden with fruits

When ripe, the fruit will puff outwards, with a slight concavity in the middle of the underside of the 'bell'. Despite its name, a ripe wax apple only resembles an apple on the outside in colour. It does not taste like an apple, and it has neither the fragrance nor the density of an apple. Its flavour is similar to a snow pear, and the liquid-to-flesh



**Fig. 3.** Bushy wax apple plant growing in pot

(Source: [www.toptropicals.com](http://www.toptropicals.com))

ratio on the wax apple is comparable to watermelon. Unlike either apple or watermelon, the wax apple's flesh has a very loose weave. The very middle holds a seed situated in a sort of cotton-candy-like mesh. This mesh is edible, but flavourless. The colour of its juice depends on the cultivar; it may be purple to entirely colourless.

In early days, wax apple was cultivated on small scale, generally planted in gardens and produced in summer season. However, the fruit quality was not desirable due to small fruit size, poor flesh colour, and low total soluble solids (TSS), and, therefore, was not comparable with mango and litchi and was not considered fit to meet customers' need. In 1987, the production period adjustment technique (Shü, 1990; Wang, 1983; Wang, 1991; Wang *et al.*, 1994) was developed by agriculture

researchers and accordingly the farmers adjusted the cultivation of wax apple during summer (May - July) to winter (December - April) period. As a result of adoption of the production period adjustment technique, it became possible to produce wax apple ahead of the main season and with bigger size and crimson flesh colour of fruits, which enhanced the income of farmers. However, in the past decade, the area under wax apple cultivation had been gradually decreasing because of global warming, unstable forced flowering and higher production cost. In order to address these problems, there is a need to make appropriate modifications in the cultivation practices and revise the production strategy.

### Nutritional Value

Wax apple fruits are crispy, juicy and tasty with apple aroma. Fruit flesh contains spongy tissue and 92.87 per cent water content and therefore, wax apple is more popular in torrid summer. The nutritional composition of wax apple fruit is given in Table 1.

**Table 1.** Nutritional composition of wax apple fruit

Nutrient	Unit	Value (per 100 g)
<b>Proximates</b>		
Water	g	93.00
Energy	kcal	25.00
Protein	g	0.60
Total lipids (fat)	g	0.30
Carbohydrate	g	5.70
<b>Minerals</b>		
Calcium (Ca)	mg	29.00
Iron (Fe)	mg	0.07

*Contd...*

Table 1 contd...

Nutrient	Unit	Value (per 100 g)
Magnesium (Mg)	mg	5.00
Phosphorus (P)	mg	8.00
Potassium (K)	mg	123.00
Zinc (Zn)	mg	0.06
<b>Vitamins</b>		
Vitamin C, total ascorbic acid	mg	22.30
Thiamin	mg	0.02
Riboflavin	mg	0.03
Niacin	mg	0.80
Vitamin A, RAE	µg	17.00
Vitamin A, IU	IU	339.00

Source: USDA Nutrient Database for Standard Release 25

Health Benefits

Wax apple contains abundant water. In Chinese medical science, wax apple fruits, leaves and seeds are antifebrile; roots are diuretic. Use of wax apple fruit, especially in torrid summer, is beneficial in quenching thirst, releasing the sunstroke and removing harmful effects of dehydration. If used with some added salt, wax apple fruits are useful in releasing the discomfort in the intestines and stomach. The flowers of wax apple are astringent and used in Chinese medical science for the treatment of fever and diarrhea.

Common Usage

The major usage of wax apple is in the form of raw fruit but it is also used in the form of juice, jelly and for wine-making. It is also used for decorating Chinese cuisine and creative dishes. In the cuisine of Indian Ocean islands, the fruit is frequently used in salads

as well as in light dishes. The wax apple fruits are popular because of dark skin, crispy and juicy flesh and high sugar content. The fruit is often served uncut, but with the core removed, to maintain its bell shape.

The black pearl wax apples grown in coastal belt possessing glossy scarlet colour, small dry and slightly astringent fruits. The local residents offer cluster of wax apple fruit to worship gods or ancestors. Wax apples can also be cold brewed or distilled to produce a fruit liquor with a unique taste.

## 2

# Status of Cultivation and Production

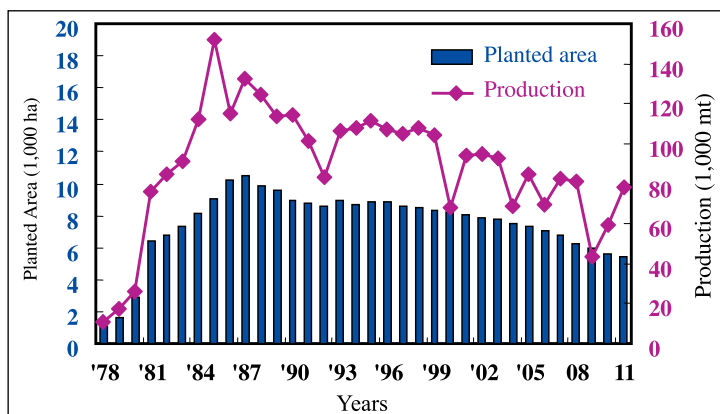
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## Area and Production

The wax apple area under cultivation is mainly confined to southern Taiwan. In the early days, wax apple was cultivated on a small scale but the area under cultivation increased gradually due to improved and stable production techniques (Wang, 1991; Wang *et al.*, 1994). The area under cultivation reached the maximum of 10,502 hectares in 1987, but subsequently declined year after year. The main reasons for reduction in the area under cultivation were the lack of techniques to induce flowering in the trees beyond the normal growing season and the competition from other crops as a result of which most of the farmers switched over to planting of other tropical fruit trees. After 1993, an advanced technique for inducing flowering by shading with black plastic nets could substantially increase the stability in production, enhanced the planting area, and consequently resulted in the enhanced farmers' income (Shü *et al.*, 2007). However, the frequent typhoon and heavy rains in summer and autumn affected the stability of harvest and hence, the cultivated area gradually started shrinking. According to the report of Council of Agriculture, Chinese Taipei (COA, 2012), the cultivated area in 2011 was 5,416 hectares and production reached to 78,109 tons in Taiwan (Fig. 4).

The area under cultivation was mainly confined to Southern Taiwan, of which Pingtung County and Kaohsiung County occupied 85 per cent. Of this, the largest planted area comprising 4,232 hectares is in Pingtung County which accounts for 79 per cent of the total





**Fig. 4.** Variation in planted area and production in wax apple

(Source: COA, 2012)

cultivated area in the country. This is followed by Kaohsiung City with 445 hectares, accounting for 8 per cent of the cultivated area. Currently, the cultivation area is gradually shifting to Northern region (Yilan County), Central region (Nangto, Zhanghua, Yunlin and Chiayi Counties), and Southern region (Kaohsiung County) in Taiwan (Fig. 5).



**Fig. 5.** Distribution of wax apple production area in Taiwan

Most production areas are located slightly below 1,000 m above sea level. Wax apple could be successfully grown year round in Taiwan by using the flower-forcing technique and selecting suitable varieties. How this trend develops further will depend on the stability of harvest yield expected in Pingtung County and Kaohsiung County. It is expected that the cultivated area will remain within 5,000 - 5,200 hectares.

### **Production Period Distribution**

Earlier the period of wax apple production was confined to May – July but after the development of a technique for adjusting the production period, it advanced to December – April. Also, the difference in weather conditions in the South and the North of Taiwan makes wax apple produce almost year round. About 70 - 80 per cent of annual production of wax apple occurs during the period December – April, 10 - 13 per cent in October – November, and 10 - 17 per cent in May – October. In the Central and Northern Taiwan, there is a very limited planted area and consequently the limited production. In the major production period (December - April), sometimes there are favourable weather conditions as a result of which there is good fruiting which results in huge production and improved fruit quality. However, this creates a situation where the supply exceeds the demand and thus would decrease selling price. If the production period is adjusted to avoid December – April period, typhoon, heavy rains and chilling injury become important factors affecting production (Kao, 1994; Lai, 2000). In conclusion, the risks and difficulties in wax apple production are higher than other tropical fruit trees; and if these factors are adequately addressed by overcoming the problems, the planters would be able to gain huge benefits.

### 3 Varieties in Cultivation

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Among the two wax apple varieties in Taiwan, namely 'Black Pearls' and 'Green Pearls' the 'Black Pearls' having purplish red fruits had been highly priced and sought after variety, while the variety 'Green Pearls' having small fruits with green colour was not so popular. In Southeast Asia, the black ones are nicknamed as 'Black Pearl' or 'Black Diamond', while the very pale greenish-white ones called 'Pearl' had been among the highest priced ones in the fruit markets. Nowadays, a number of improved cultivars with larger fruits are available.

The major wax apple cultivars grown in Taiwan are 'Pink' and 'Big Fruit', accounting for nearly 80 per cent production. The cultivation of newly introduced cultivars, namely, 'Thub Thim Chan' from Thailand and 'Indonesian Big Fruit' from Indonesia also increased and accounted for nearly 20 per cent production (Huang and Lin, 2009). The other recently introduced new variety 'Tainung No. 1' is grown only on small scale. The variety 'Pink' is highly adaptable and has long history of plantation and is mainly grown in the coastal areas. This variety is characterized with good flavour of fruit. 'Big Fruit' variety characterized with good appearance of fruit is distributed mainly in inland areas. Both 'Big Fruit' and 'Pink' varieties are still the main cultivars. The newly introduced varieties are scattered from Kaohsiung-Pingtung to Central Taiwan. The future trend indicates that the newly bred as well as introduced varieties are expected to be put into cultivation and production in the next few years.

The cultivated varieties of wax apple do not have their origin in Taiwan but were introduced from Southeast Asia about 300 years ago. According to the available records, the flesh colour included red, white and green; and the fruit shape included round, conical and long-

conical shape. Nowadays, 'Pink' variety (Fig. 6a) with red flesh colour, and conical fruit shape could meet the needs of Taiwanese customers (Lai *et al.*, 2012). Due to the booming market, customers prefer high quality fruit, especially with big size. In 1988, a branch variation of 'Pink' variety was found in wax apple orchard, and was denominated as 'Big Fruit' variety (Fig. 6b). Therefore, 'Pink' and 'Big Fruit' were the major varieties to fulfill the market's demand before 2000.

The main harvesting season of wax apple in Taiwan is summer time. However, high temperature, sunshine and heavy rain cause many problems, such as small fruit size, poor flesh colour or incidence of diseases. Efforts were made to develop the technique for adjusting the production period. By adopting this technique, summer production (May - July) was adjusted to winter or spring (November - April) in order to improve wax apple quality (Lai *et al.*, 2012). Due to the global warming, the trans-red flesh colour was not as effective as it used to be earlier and hence the dark flesh colour and stable expression were the most critical factors of concern at that time. In 2003 - 2004, the variety 'Thub Thim Chan' (Fig. 6c) was introduced from Thailand. After test-planting, it was observed that the variety 'Thub Thim Chan' was well adapted to the climate of Taiwan. This variety was preferred especially due to its dark and stable flesh colour, and long conical fruit shape which attracted customers' attention.

In 2005-2006, the variety 'Indonesia-Big-Fruit' (Fig. 6d) was introduced from Indonesia. Due to its special aroma and large fruit size, it was named as 'Indonesia-Big-Fruit' variety or 'Perfume-Wax Apple'.

In order to implement the new production strategy aimed at producing small quantities of better quality and diversified fruits, sincere efforts were made to introduce more varieties that can be produced in the off-season (after April) in order to increase varietal diversity and also the novelty. For example, some varieties such as 'Vietnam White'



**Fig. 6a.** Pink



**Fig. 6b.** Big Fruit



**Fig. 6c.** Thub Thim Chan



**Fig. 6d.** Indonesia Big Fruit



**Fig. 6e.** Vietnam White



**Fig. 6f.** Big Red

**Fig. 6.** Improved varieties of wax apple in Taiwan

(Fig. 6e), and 'Big Red' (Fig. 6f) which were introduced from Vietnam and Malaysia, though limited in cultivation, were capable of fetching truly high market price.

Nowadays, the 'Pink and Big Fruit' varieties occupy 75 - 80 per cent; the variety 'Thub Thim Chan' occupies 10 - 15 per cent; 'Indonesia Big Fruit' variety occupies 5 - 8 per cent, and other varieties occupy 1 - 2 per cent of the area under cultivation. All wax apple cultivars grown in Taiwan were introduced from exotic sources (Huang and Lin, 2009). 'Pink' variety is the most adaptable and widely planted variety with major production period from November to June. Its main disadvantage is that it has smaller fruit size. 'Big Fruit' variety is a branch variation of 'Pink' variety and its major production period is from December to April. In both 'Pink' and 'Big Fruit' varieties, the flesh colour after April becomes light pink. The variety 'Thub Thim Chan' is characterized with long conical fruit shape, crimson flesh colour, and longer production period (November - July) than 'Pink' and 'Big Fruit' varieties. 'Indonesia Big Fruit' is susceptible to chilling injury and has the production period from December to May. The range of variation in different characters of wax apple cultivars (Huang and Lin, 2009) is given in Table 2.

**Table 2.** Range of variation in different characters of wax apple cultivars

Characters	Cultivars			
	Pink	Big Fruit	Thub Thim Chan	Indonesia Big Fruit
Fruit weight (g)	90-150	150-250	130-250	180-480
Fruit length (cm)	6.70	6.90	10.14	12.00
Fruit width (cm)	6.40	7.60	6.16	8.60
Fruit length/width	1.04	0.90	1.64	1.33
Fruit skin colour	Deep red	Deep red	Dark red	Red - Deep red
Total soluble solids (TSS)	10-14	10-12	10-14	10-13
Major production season	Nov.-Jun.	Dec.-Apr.	Nov.-Jul.	Dec.-May.

Source: Huang and Lin, 2009

Traditionally, introduction from other countries had been the major and most quick method to bring into cultivation the new wax apple varieties in Taiwan. The Department of Agriculture, Council of Agriculture (COA) or non-governmental organizations (NGOs) introduce the material from abroad, and then proceed for planting and testing the material at different locations in Taiwan so as to assess the adaptability, production potential and analysis of the quality in order to fit well as per the market's need. However, the most introduced varieties possessed small fruit size, poor flesh colour, low total soluble solids (TSS) and low edible portion of the fruit. Nowadays, the researchers who work for the government department undertake intensive hybridization program, and then select high yielding and better quality lines from the segregating populations to suit to the needs of market (Lai *et al.*, 2013). Also, researchers undertake necessary awareness programs in order to popularize the improved varieties among the planters. They also develop and provide relatively better cultivation techniques and disseminate these to the wax apple growers.

### **Characteristics of Popular Varieties**

The characteristic features of popular and economically important varieties of wax apple (Fig. 6) grown in Taiwan (Huang and Lin, 2009) are given below :

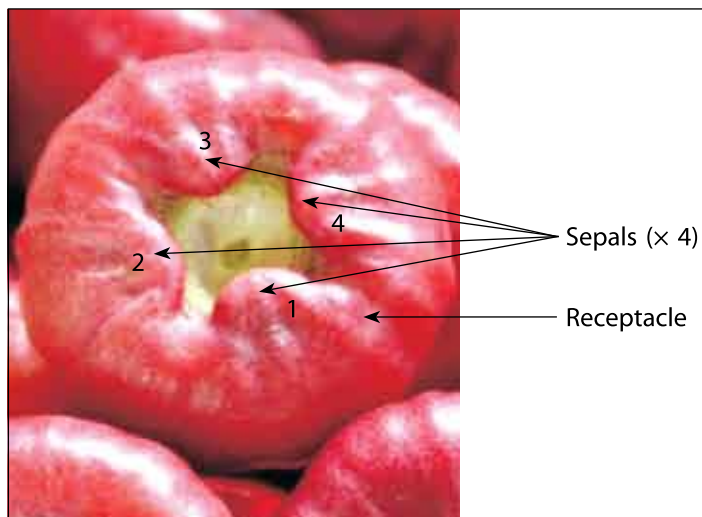
#### **Pink Variety**

The nickname of this variety is South Sea Wax Apple. It possesses pink to dark red fruit flesh, average fruit weight of 120 g, fruit length of 6.7 cm, fruit width of 6.4 cm, vertical and horizontal diameter nearly equal, and average total soluble solids (TSS) of 10 - 12° Brix which could reach upto 18° Brix. Nowadays, the 'Pink' variety is the most valuable and widely planted variety in Taiwan.

#### **Big Fruit Variety**

'Big Fruit' variety is a branch variation of 'Pink' variety. Its fruit size is larger than 'Pink' variety and contains average weight of 180 g,

fruit length of 6.9 cm, fruit width of 7.6 cm, fruit surface curved (cross section scallop shape), 4 fruit sepals, small and separated while maturing (Fig. 7), areola plain to tiny protruded, average TSS 12° Brix, fruit flesh dense, and both spongy tissue and fruit cavity are small,



**Fig. 7.** Wax apple fruit: Sepals and receptacle

fruit flesh is crimson to dark crimson. Due to larger fruit size and excellent flesh colour, 'Big Fruit' variety has the potential to replace 'Pink' variety gradually.

### **Thub Thim Chan Variety**

'Thub Thim Chan' variety was introduced from Thailand. This variety possesses average fruit weight of 150 g, and average TSS of 12.5° Brix. The characters such as long-conical fruit shape, deep red fruit colour, high TSS and low ratio of fruit cracking could be extremely useful in production period adjustment and consequently can successfully produce fruits during summer and winter seasons and thus the planted area can be increased gradually.



### **Indonesia Big Fruit Variety**

This variety, also called by nicknames 'Palm Wax Apple' or 'Perfume Wax Apple' was introduced from Indonesia and possesses average fruit weight of 230 g (fruit size as big as palm of human's hand), and special aroma. The fruit weight and quality could be substantially improved by flower or fruit thinning in order to control fruit yield.

### **Vietnam White Variety**

This variety was introduced from Vietnam. The variety possesses average weight of 60 g and average TSS of 10.2° Brix. It has round fruit shape and fine fruit flesh with the special characteristic feature of white fruit colour. The area planted under this variety is currently very limited.

### **Big Red Variety**

This variety was introduced from Malaysia. It possesses average fruit weight of 124 g, and average TSS of 11.4° Brix. It has large leaf size, fine fruit flesh, red fruit colour. Currently, the planted area under this variety is very limited.

It is quite well known that consumers' needs decide the market trend. Therefore, red flesh colour, large fruit size and low fruit cracking varieties of wax apple are in the main stream in Taiwan markets. The main production strategy is to use four major varieties, namely, 'Pink', 'Big Fruit', 'Thub Thim Chan', and 'Indonesia Big Fruit' in order to make adjustment in the production period in such a way that the wax apple fruits are available in the market for a longer duration. In this way, not only the production period is extended for over 6 months but also the fruit quality is improved. This certainly helps in enhancing the farmers' income.

## 4 Improved Cultivation Practices

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The wax apple is a tropical fruit tree species, and the optimum temperature for its proper growth is 25 - 30° C because cool temperature enhances TSS and skin anthocyanin accumulation in fruits. Abundant water supply is required for successful wax apple cultivation. The soil types ranging from mild acid to mild alkaline, and sandy to clayey are the most appropriate for higher production. Wax apple varieties that are grown in coastal area with mild alkaline and clayey soil usually get high quality fruits that contain dark red skin and higher total soluble solids (TSS).

The soil in coastal Pingtung County is highly saline. Due to the high external osmotic pressure, the roots of wax apples growing in saline soil have difficulty in absorbing sufficient moisture, and also tend to absorb large quantities of sodium, calcium, and magnesium salts. As a result, the fruit is small and not very juicy.

On the other hand, wax apples grown under these conditions have a very unique flavour. As a result, the COA's Pingtung Soil Fertility Laboratory paid much attention to improving the economic effectiveness of growing wax apples in saline soil by reducing salt uptake through the roots, in order to leave the wax apples with some of the flavour imparted by the salts, while also making the fruit larger and juicier.

After many years of experimentation, the COA made its research results available to local farmers, including instructions on how to flush salts from the soil, how to construct salt drains, how to perform irrigation management, and how to build salt-wicking dikes. Thanks to new techniques for growing wax apples in saline soil, many fruit

growers in Pingtung County are now able to produce large, juicy Black Pearl wax apples.

### **Seedling Propagation and Field Planting**

For establishing a wax apple orchard, the most appropriate distance is 7 - 8 m between rows and about 5.5 m between plants with plant density of 250 - 320 trees per hectare. Plant growth is expected to be slow in clay or saline soil and, therefore, the seedlings could be planted more densely. Major propagation is done through cutting and air layering, while grafting is used to renew varieties in resident orchards. Wax apple trees could attain fruit yield at economic production scale in about 3 - 5 years after planting or about two years after top grafting. In general, wax apple trees could be cultivated for fruit production for more than 30 years.

### **Pruning**

Wax apple is an evergreen tree, and plant height can normally reach to 12 - 15 m. However, in well managed orchards, the tree height is generally maintained at 4 - 5 m. Annual renewal pruning is done after harvesting or before production period adjustment to control plant height and induce the same maturity of fruits on new branches as that of the fruits on tree crown (Shu, 1999). The success of pruning is dependent on production period adjustment, season and soil type. Farmers in Southern Taiwan usually follow heavy pruning after harvesting in winter or spring time to enhance vegetative growth and to diminish natural flowering in spring. After the heavy pruning (Fig. 8), 1 - 3 new shoots will be allowed to grow before flower-forcing to adjust the production period.

### **Production Period Adjustment**

The development of flower-forcing technique is the most important milestone in the history of wax apple industry (Shu *et al.*, 2007). Traditionally, the flowering in wax apple trees used to occur



**Fig. 8.** *Pruning of wax apple trees*

during the period February - April and the fruit maturity period used to be May - July in Southern Taiwan (Wang, 1983; 1991; Wang *et al.*, 1994). However, the summer weather is usually hot, humid and rainy and, therefore, the fruit colour is generally pale and the fruits are infected by diseases easily. Summer wax apple fruits usually contain seeds, are thinner and have high percentage of spongy tissue. Since 1980, the growers started to use some techniques such as flooding, girdling root pruning and black net shading to induce flowering in autumn season to improve fruit quality. In 1990's, the production period adjustment technique (Wang, 1983, Shu *et al.*, 1990; Lai *et al.*, 2012) was developed and adopted on a large scale. The farmers induced flowering in the autumn season that has adequate sunlight and a few rainy days in Southern Taiwan to produce high quality wax apple fruit with dark red fruit colour, crispy texture, thick flesh, high total soluble solids (TSS) and good aroma, especially to meet the Chinese New Year market demand. As a result of large scale

adoption of flower inducing technique, wax apple turned out to be a high value and important economical fruit tree in Taiwan. In 2000s, the variety 'Thub Thim Chan' was introduced from Thailand, and widely planted in the hills of Central Taiwan. 'Thub Thim Chan' could produce dark red and high quality fruits in summer season and thus, quality wax apple is now produced successfully throughout the year in Taiwan.

The effective control of vegetative growth of fruit trees would be extremely helpful in inducing the reproductive growth. Before the development and use of flower-forcing technique, the farmers used to follow flooding, girdling and root pruning to control excessive vegetative growth of shoots. For instance, 95 per cent black net shading (Fig. 9) with flower forcing techniques could make flower bud initiation effectively. Black net shading is provided for about 20 - 40 days depending on the extent of plant growth and the growing season. After lifting the net, farmers proceed to undertake



**Fig. 9.** Wax apple trees covered with black shading net

moderate pruning, and application of fertilizer and irrigation to restart effectively the plant growth and flower bud initiation. Covering of whole canopy of wax apple trees with black shading net is an effective and efficient method to suppress shoot growth and contributes to uniform sprouting and flowering.

### **Fertilizer Application**

In general, wax apple trees of over 7 years age need 1,200 - 1,600 g of N,  $P_2O_5$  and  $K_2O$  each. Urea contains 46.4 per cent effective N and, therefore, about 2.6 - 3.4 kg urea should be used for one plant per year, and 10 - 20 tons organic matter per hectare should be applied. Basal dose of fertilizer could be applied by ditching or digging, and supplemental doses of fertilizers may be applied by soil drenching, spraying on leaves or broadcasting on soil surface before irrigation. In sandy soil orchards, lesser quantity of fertilizers should be applied more frequently and in the clayey soils, the use of chemical fertilizers should be reduced.

### **Sustainability of Orchard**

There is an increased emphasis on sustainable production of wax apple in the recent years, due to the fact that higher induction of flowering results in poor plant growth and consequently the decreased productivity and production. Most of the farmers started to improve their flower-forcing cultural practices, such as use of organic fertilizers, planting to protect soil, farmers' and customers' health and fruit safety. To prevent the fruits from insect bite and sun burn, bagging the fruits with paper bags (Fig. 10) has been practiced for more than 30 years. Also, the reduced use of pesticides helped in keeping fruits away from the effect of chemicals to ensure their better quality and safe consumption. Besides, the fierce wind and heavy rainfall resulting from typhoon in summer and autumn usually destroy the orchards almost every year and, therefore trunk



**Fig. 10.** *Use of paper bags for bagging of fruits in wax apple*

braces are used to support trees. Also, the water pumps are used to pump out the water and shorten flooding period in the low lying orchards.

## 5 Post-harvest Handling

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Post-harvest handling operations are extremely important for wax apple. Because of the characteristic feature of thin and dehydrated fruit skin, wax apple has to be graded and packed immediately after harvesting. The best production procedure is to harvest in the morning, transport in the afternoon, and sell to customers the next morning. Grading and storage affect shelf life to a great extent. However, to address the concern of controlling the cost, most local sellers do not store the produce in the refrigerators but store at the room temperature. Only high quality wax apple fruits of export value are stored and transported under low temperature in order to enhance the shelf life (Lai *et al.*, 2012). Nowadays, 'Pink', 'Big Fruit', 'Thub Thim Chan' and 'Indonesia Big Fruit' varieties are being exported. The export is encouraged not only to release the pressure of availability of excessive quantity of produce during the production period but also to fetch more money on account of higher price of the produce diverted to the export market.

### **Fruit Maturity for Harvest**

Taiwan market prefers larger size fruit, dark red flesh colour and high total soluble solids (TSS). Maintenance of good quality of fruits is highly related to the appropriate field management. Therefore, proper attention needs to be paid to the maturity level before harvesting. The wax apple fruit maturity level could be determined based on flesh colour and areola spread. For instance, for winter or spring wax apple, flesh colour appears to be crimson (Fig. 11), but the wax apple fruit in the summer season exhibit light pink to pink colour. The farmers should regulate the harvest timing, and focus on the relationship between harvesting season and maturity period in order to produce





**Fig. 11.** Wax apple fruits (a) mature fruits, (b) cut fruits

better and stable quality and consequently enhancing the income from the sale of the produce. The major varieties planted in Taiwan possess crimson flesh colour, and hence, the appropriate harvesting period is when the flesh colour turns red. The total soluble solids (TSS) of matured wax apple fruits could reach 10 - 12° Brix.

### **Harvesting and Collection**

After the harvesting, farmers should keep the fruits in cloth bags (Fig. 12) and store in a cool place and then they should exercise the grading of fruits based on size and flesh colour. Later, the graded fruits should be covered with styrofoam net to transport them to market. Due to the thin skin of fruit, farmers should pay more attention in handing the fruits during the process of grading, packing and storage. Because of thin skin, wax apples easily loose moisture and are difficult to be stored. They tend to become soft and wrinkled after too much time in storage.



**Fig. 12.** *Bagging of wax apple fruits after harvesting*

### **Pre-cooling**

Pre-cooling of fruits after harvesting would greatly help in bringing down the temperature of fruits and extend their shelf life. The recommended pre-cooling temperature is 10 - 12° C. For preparing the fruits for transport to export market, pre-cooling should be done at 0 - 5° C for one day, which should be followed by cooling at 10° C. This will enhance the shelf life of fruits considerably. However, pre-cooling at 0 - 5° C over 2 days would cause chilling injury to fruits and hence should be avoided (Lai *et al.*, 2012).

### **Fruit Grading**

Due to the problem of bruised fruit skin, grading of fruits is desirable. The wax apple fruits are graded on the basis of varieties and fruit size and shape (Fig. 13a). For sale in the local market, the grading standard is distinguished by single fruit weight, for example, the first grade is packed with 40 - 50 fruits per box (120 - 150 g/per



**Fig. 13a.** Wax apple grading

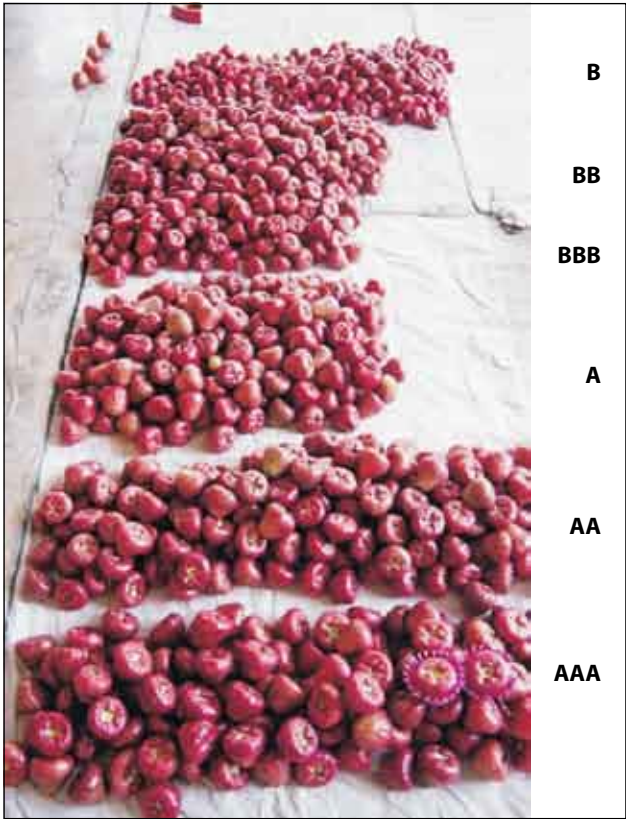
fruit); the second grade is packed with 50 - 60 fruits per box (100 - 120 g/per fruit); and the third grade is packed with 60 - 70 fruits per box (85 - 100 g/per fruit) (Fig. 13b). For export market, the first grade is 120-150 g per fruit; the second grade is 100 – 120 g per fruit; the third grade is 85 – 100 g per fruit; and the fourth grade is 75 – 85 g per fruit. The grading of fruits is also done on the basis of pericarp colour in different categories such as AAA, AA, A, BBB, BB and B depending on the intensity of red colour (Fig. 13c). After grading, styrofoam net is used to cover the fruits in order to reduce crash and crush (Lai *et al.*, 2012).

### **Fruit Packaging**

For sale in the local market, the general practice is to supply the produce in traditional 12 - 15 kg cardboard boxes that are separated into 2 - 3 layers (Fig. 14a), with stuff shredder paper to minimize the fruit crash. However, the packaging that is presently popular in Chinese New



**Fig. 13b.** Wax grading based on fruit weight



**Fig. 13c.** Wax apple grading based on fruit colour



Year is done in 3 - 6 kg cardboard boxes (Fig. 14b). For sale in the export market, general standard is to pack the fruits in 6 kg cardboard boxes. In order to reduce serious dehydrated situation, the usual pack box-in-box and cover the outer box with polyethylene plastic (PE) bag.



**Fig. 14a.** Packaging after grading



**Fig. 14b.** Packaging with Styrofoam net after grading

## Loading and Transportation

For sale in the local markets, the freight vehicle is used to transport the fruits at room temperature to the markets (Fig. 15a, b). In view of this, home-delivery service is prevailing so that the clients



**Fig. 15a.** Transportation of wax apple fruits



**Fig. 15b.** Shipment of packed wax apple fruits

could get cargo directly from the farm irrespective of the produce being at room temperature or under cool storage conditions. For transportation for export, the quantity of wax apple is usually less than a container load (LCL) and hence, transported alongwith other fruits. However, different storage temperatures often cause chilling injury to wax apple fruits and, therefore, it is suggested that the fruits should be transported by placing them in the middle of container to decrease chilling injury.

## 6 Marketing

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After planting, the farmers join farmers' association to receive professional training and related information, such as improved cultivars, cultivation and management techniques, use of fertilizers and herbicides, etc. The farmers' association will also provide information relating to the sale of produce including relative grading and packaging.

There are two critical selling channels: (i) through vegetables and fruits auction market, and (ii) home delivery directly from the individual farms. In the first channel, the wax apple fruits graded and packed by farmers are taken by professional fruit freight transport company to the vegetable and fruit auction market. Then, the dealers or auctioneers adopting the usual procedure would decide the auction price, buy the produce and will make payment to the farmers on a daily basis. The average wax apple selling price is \$50-83 TWD per kg, and high quality fruits could reach upto \$150 TWD per kg. In the second channel, the individual buyers place purchase order through phone or internet to buy wax apple directly from the farmers. After receiving the supply order and the payment, the farmers send the consignment to customer's place. Home delivery channel has become a very popular fruit selling channel in recent years. This is widely acceptable and also provides the fruit industry innovative methods of selling the produce.

### **Consumer Demand and Awareness**

Taiwan has four distinct seasons, viz., tropical, sub-tropical, sub-temperate and temperate and accordingly, different types of fruits and products are needed to suit to the requirements under different



seasons. Tropical fruits are the most representative, and wax apple is one of the representative and popular tropical fruits in Southern Taiwan because of its thirst-quenching and refreshing effect.

### **Importance of Quality**

In the recent years, the consumption habits of the people have changed drastically and the customers prefer only good quality products. Hence, the producers are required to improve the cultivation and management techniques; from extensive to refined (flower thinning and fruit thinning), and also focus on quality rather than quantity. Also, the farmers' profit is increased due to the increased sale of high quality fruits. Hence, better fruit quality needs to be paid greater attention.

### **Varietal Diversity**

Due to the change in consumption habits, the customers not only focus on the fruit quality but also on varietal diversity or speciality. Therefore, the wax apple variety initially under cultivation was 'Pink' but later the growers switched over to the cultivation of the variety 'Big Fruit'. In recent years, the varieties 'Thub Thim Chan' and 'Indonesia Big Fruit' have also become more popular amongst the consumers.

### **Production Area and Period Adjustment**

Southern Taiwan (Kaohsiung and Pingtung) is the major production area of wax apple, and accounts for about 80 - 85 per cent of production. The production period is distributed from December - May. In the Central and Northern Taiwan, the production area is distributed from June - August. In view of this, it is extremely important to adjust the production area and the period in order to stabilize the production and consequently the market price as well as the last supply period for which a long-term strategy need to be developed.

## **Harvesting, Grading, Packaging and Branding**

The current consumption habit tends towards high and stable quality, and, therefore, quality control is very critical. Nowadays, wax apple production control method includes management of cultivation techniques, grading by single fruit weight and TSS which contribute towards increasing the percentage of quality standardization. Brand name increases the reputation, for example, Black-Diamond and Black-Pearl wax apple mean high quality wax apple, and the customers are highly willing to purchase these branded wax apples. Hence, urgent attention needs to be given to fruit quality control and selling the produce under a specific brand name.

## **Farmer Associations**

Most individual farmers are smallholders having less than two hectares land and are not in a position to sell their produce at reasonable price. Therefore, after grading and packaging, the farmer associations help the individual farmers by pooling and transporting their wax apple produce to fruit and vegetable markets all over Taiwan. This is highly beneficial to smallholder farmers to channelize the marketing through farmer associations and through this mechanism, they earn more profits with relatively less efforts.

## **Auction Market**

The major fruit markets are distributed in Taichung and Taipei. After harvesting, wax apples are shipped directly to auction market or wholesalers who notify the selling price and buy the produce with agreement of farmers. In this process, the farmers receive payment on the same day. Although the farmers have the option to hold back their produce if they are not satisfied with the selling price, fresh fruits are not easy to be preserved for long and hence, the farmers are compelled to dispose-off their produce once it is taken to the market. Except for a few high quality and reputed brands, the selling

price of most of the varieties are decided by buyers' market and hence, is governed by the quantity, quality and weather.

### **Retailers and Home Delivery**

Auction market or wholesalers sell the produce to retailers from whom the customers could buy wax apple in departmental stores, supermarkets, traditional markets and fruit stores. Therefore, some farmers develop their own websites to introduce their orchard and products which helps the customers to place supply order directly through phone or internet. Then, the farmers arrange delivery of produce to the customers' place after receiving payment. The advantage of home-delivery is that not only farmers could control the selling price and the quality, but also the buyers could choose the reputed sellers and reliable source which ensures good quality fruits at reasonable price.

## **7** Processing and Export

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The major production of wax apple fruits goes for supply to the local market, and the production is year round and hence, there is no import record so far. Recently, with the adjustment of the production period, there is maximum production of wax apple during December - May, and thus the supply of fruits exceeds the demand causing thereby lowering of price. Export of surplus produce could help in overcoming this problem. Earlier, it was difficult to increase the quantum of export of wax apple because the export was restricted due to some adverse characteristics such as highly hydrous fruit flesh, flimsy fruit skin, and susceptibility to chilling injury. Moreover, the export countries were limited to China, Hong Kong, Singapore and Canada and there was also a great problem due to fruit fly damage. Therefore, developing effective quarantine procedures would prove to be extremely useful to expand the export to the market in Japan, USA and Korea.

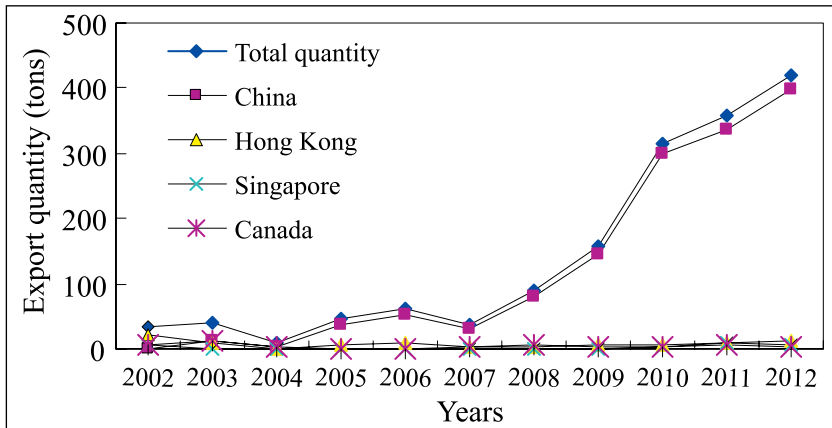
### **Current Status of Export**

Since 2007, the quantum of export of wax apple has steadily increased. In 2012, yearly export quantity reached to the maximum of 418.87 tons (Table 3; Fig. 16) which was a record in wax apple export history. The major countries for export included China, Hong Kong, Singapore and Canada. Although the transportation of fruits to China takes longer time involving 3 days in ocean shipping after harvesting the fruits, the export increased steadily year after year and the export to China in 2012 reached to 398.68 tons with 95.2 per cent of total quantity of export. The major varieties of wax apple being exported are 'Pink' and 'Big Fruit' followed by 'Thub Thim Chan' and 'Indonesia Big Fruit'. In the winter and spring seasons, the major export varieties are 'Pink' and 'Big Fruit', while in summer, 'Thub Thim Chan' and 'Indonesia Big Fruit' are the major export varieties.

**Table 3.** Taiwan wax apple exported to different countries during 2012.

Country	Quantity (tons)	Value (000 \$)
China	398.68	686.0
Hong Kong	11.16	90.0
Singapore	5.38	33.0
Canada	1.62	13.0
<b>Total</b>	<b>416.83</b>	<b>822.0</b>

Source: Database of Customs Administration, Ministry of Finance, Executive Yuan, R.O.C., 2012

**Fig. 16.** Status of export of Taiwan wax apple to different countries during 2002-2012

(Source: Database of Customs Administration, Ministry of Finance, Executive Yuan, R.O.C., 2012)

## Wax Apple Export Process

There are two major supply systems: (i) supply mainly for export, and (ii) supply mainly for local market. For export only category, the suppliers develop the farms for professional export to ensure stable production source of wax apple, good fruit quality and regulate the

price. For non-export local supply category, the suppliers mainly supply to the local market, but still have the capability to supply to the export market when export price is stable or more profitable. The export process (Lai *et al.*, 2012) involves the following three important steps:

#### **a) Indent by the importer**

This involves the placement of order by the importer to supply particular quantity of fruits of specific varieties of wax apple. This is based on the scheduled delivery, time of export to consumer markets, and specific orchards under contract to follow flower-forcing technique and better orchard management.

#### **b) Collection of material by the distributor**

In Taiwan, the wax apple production area is distributed from South (Kaohsiung and Pingtung), Central (Chiayi) to North (Yilan). Due to different flower-forcing periods, the distributors have to manage the collection of wax apple produce from different production areas and transfer to the suitable place in order to supply the material to the indenter.

#### **c) Harvesting, grading and packaging by farmers**

The quality standard of wax apple for export purpose is very high and is taken more seriously as compared to the produce being sold in the local market. The important characteristics include good fruit appearance, perfect and clear grading and good packaging. The export grading standard is 120 g per fruit, total soluble solids (TSS) 10 - 12° Brix, dark flesh colour and no fruit-cracking. After the grading of fruits as per these characteristics, each fruit is covered with styrofoam net and then packaging is done.

### **Export Problems/Issues**

#### **i) Lack of export-only orchards**

Currently, the number of orchards only for export are inadequate and can not meet the existing demands and hence, the produce from non-

export category orchards is also used for export. However, the quality of fruits obtained from non-export category orchards is highly inconsistent and is not preferred for export purpose. Therefore, there is a great need to expand the area under export-only orchards to have regular supply with high quality and stable amounts of wax apple fruits.

### **ii) Quality control**

Low temperature, typhoon and chilling injury affect wax apple quality adversely and unstable and poor fruit quality affects the export seriously which is a matter of great concern. Therefore, there is a need for rigorous grading and good packaging which will improve significantly the consistency and quality of fruits for export. This will help in promoting the exports to a great extent.

### **iii) Shipping**

Wax apple is often shipped along with guava or carambole due to its quantity being less than a container load in low temperature (under 10°C), which causes chilling injury. Hence, the transportation methods have to be improved urgently. In order to avoid chilling injury to wax apple fruits, it should be transported using full container load and at low temperature suitable for wax apple, or be transported by air to shorten the shipping time.

### **iv) Fruit fly quarantine**

Taiwan wax apple suffers with fruit fly epidemic which seriously limits the development of export market. Under this situation, wax apple could be exported only to China and nearby countries. There is a need to undertake studies on priority to improve the efficiency of low and high temperature, or radiation quarantine. If appropriate quarantine methods are developed successfully, the existing wax apple export market could be expanded considerably and even the new avenues for export could be located and used to further promote the export.

## 8

# Factors for the Success of Wax Apple Industry

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Wax apple production in Taiwan has been highly successful and is now developed into an economic scale industry as a result of production period adjustment and other improved cultivation techniques. However, production period sometimes suffers from typhoon, heavy rain and chilling injury, and therefore, wax apple production management is more difficult than other tropical fruits. Production period concentrating in December - April is an important factor to increase farmers' income considerably. Increased use of high yielding and better quality varieties and improved cultivation techniques contributed significantly towards consistent production and stable benefits to the farmers and also enhancing their reputation.

Cultivated area in Taiwan is small and hence small-scale planting method for wax apple was adopted. Average wax apple orchard has an area of 0.3 - 0.5 hectares, 1 - 2 hectares amounts to large scale cultivation, and an orchard of over 10 hectares is rarely seen in Taiwan. High labour cost, and delicate cultivation practices, such as pruning, flower and/or fruit thinning, flower-forcing and bagging are important factors that create hinderance in large scale cultivation.

Nowadays, wax apple industry has the capability to produce quality fruits almost year round. The production and cultivation experience that researchers and farmers learnt through hard work for several years and the factors responsible for the success of wax apple industry are enumerated below:



## **Proper Management of Orchards**

Wax apple trees start fruiting with mass production after 3 years of planting. Farmers could make good use of this period to improve skills for cultivation and orchard management, such as pruning, flower-forcing, flower and/or fruit thinning, bagging, harvesting, grading and packing. They also formed farmers' associations and got linked with agriculture organization in order to increase relative knowledge and information and set the stage for mass production at a commercial scale in order to harness greater returns.

## **Planting in Appropriate Soil**

Wax apple is a high water requiring plant and, therefore, planting in clay loam soil is highly desirable as it could retain water and fertilizer for a longer time and will thus improve the production and fruit quality. Therefore, the planters have paid greater attention to growth vigour, and also to avoid flooding by digging deep ditches.

## **Use of Improved Varieties**

Identification and use of different improved varieties of wax apple is extremely important to fit well the customers' and market's needs. For example, in Taiwan in Chinese New Year (January or February), wax apple is a popular gift because Chinese think that red colour would bring good luck to them. Hence, 'Big Fruit' variety is a good choice because of big fruit size and deep flesh colour.

## **Improved Cultivation and Management Techniques**

Use of improved cultivation and management techniques is very important. The production period adjustment technique includes covering with black net, girdling and dipping. The farmers should be familiar with these techniques and apply these at the correct time. Flower-thinning, fruit-thinning and bagging are also very important but involve heavy labour cost. In order to solve high

incidence of fruit disease, the farmers have to pay greater attention to environmental hygiene, such as appropriate ventilation and reasonable use of fungicides and insecticides. The most serious problem is fruit-cracking and how to decrease fruit-cracking is a critical issue which needs to be addressed by the researchers to find out an effective solution.

### **Grading and Branding**

Proper grading and branding of the produce are very important for enhancing the income of farmers. Clear and appropriate grading, includes single fruit weight, flesh colour, and the amount of total soluble solids (TSS). These parameters would help in brand building and improving brand reputation which will increase auction price and consequently the farmers' income.

### **Expanding Selling Channels**

Farmers should consider how to make more profits and build reputation of their produce and brand so as to promote the sale through different channels. For example, taking supply order through phone or internet or ship wax apple to different auction markets so to increase the selling price, will greatly benefit the farmers in raising their income.

Wax apple used to be mainly eaten raw initially, but later on, its use was extended to cooked form or as wine and vinegar made from it to widen its general usage and also to take care of over-production. Originally, Taiwan wax apple used to be produced in the summer season. After the development of production period adjustment technique, it could be possible to produce high quality fruits of wax apple in winter or spring seasons also. Therefore, the new cultivars that were introduced and test planted successfully, or improved by breeding could increase the fruit diversity and competition so as to fit well the local market's needs.

The normal climate in Taiwan, which is hot in summer and cool in winter, is advanced for wax apple production. However, global warming, extreme weather conditions, and typhoon cause unstable production and also adversely affect fruit quality, and consequently increase the cost of production. The current strategy is to improve production techniques, and breed cold-resistant cultivars in order to adapt to changing climate and result in enhanced production on a sustainable basis.

Nowadays, large-scale and economical production is being done in countries such as China, Indonesia, Malaysia, Taiwan, Thailand and Vietnam, and the major production countries are Taiwan, Thailand, China, and Malaysia (Shu *et al.*, 2006). In Taiwan, because of the large scale adoption of production period adjustment technique and the customers' preference, wax apple has become a highly valued fruit and has come into the main stream of fruit production in the country. In China, the major production county is Hainan. The fruit quality is not steady and as advanced as that in Taiwan because production period

adjustment technique has not been developed perfectly and not in use prevalently. In Malaysia and Thailand, there is high diversity of tropical fruits available, and the customers have more options and hence, the wax apple is not in the main stream of tropical fruits. Recently, Malaysia and Thailand farmers made efforts to make use of Taiwan's production period adjustment technique and tried to improve quality and quantity of wax apple production and commercialization through the industry.

Thin skin and dehydrated fruit are the main limiting factors in the export of wax apple and China is the main export country. The maximum period recommended for transportation is 5 - 7 days, and the temperature of 12 - 15° C (Lai *et al.*, 2012). However, the fruit skin shrinks or disease spots appear on the fruit skin if stored under low temperature for a longer duration. Therefore, there is a need for improving storage and transportation techniques as well as breeding improved cultivars that can sustain well longer storage duration and transportation. This will extend the shelf life considerably and consequently expand the export market and will reduce the risk of over production in a limited period.

The essential elements of the revised production strategy are: i) new varieties should be bred/developed and appropriate cultivation techniques be standardized to suit to the needs of these new varieties in order to produce better quality wax apple on a sustainable basis, ii) the area of production and the period of production should be staggered in such a way that huge amounts of wax apple are not produced at the same time as a result of which, there will not be surplus produce in the market at any point of time and consequently, this will help to increase the selling price and expanded export market, iii) the export market in countries such as China, Hong Kong and Singapore may be expanded which will help in reducing the concentration of produce at a specific point of time and thus maintaining the level of sale price.

The following important points/recommendations need consideration for greater thrust and developing appropriate strategies for enhanced production and utilization of wax apple:

### **Breeding New Varieties**

The major varieties in cultivation in Taiwan include 'Pink', 'Big Fruit', 'Thub Thim Chan', and 'Indonesia Big Fruit', and all these varieties are important for supply to export and local markets. The variety 'Thub Thim Chan' has dark red flesh colour and hence, it is very popular in the summer season. However, most of the varieties suffer with chilling injury during storage and transportation. Therefore, there is a great need to develop varieties with low temperature resistance and dark red flesh colour for which greater thrust needs to be given to concerted breeding programs.

### **Developing Improved Cultivation Practices**

The global warming and changing climates adversely affect wax apple production. The important factors include low temperature in winter and spring (Kao, 1994; Lai, 2000), heavy rains in spring, and typhoon in summer. To solve the problem of light colouration of fruits in the summer season, there is a need to adjust fruit-setting position in the lower layers of trees so as to promote deepening of fruit colour.

### **Extending Production Period**

Although the quality of wax apple fruits has been increased to a considerable degree, wax apple still has the disadvantage of too short a production period. The current challenge is, therefore, to use improved cultivation technology to prevent pests and diseases, while lengthening the production period and achieving higher yield and quality during the summer.

### **Improving Fruit Quality**

Wax apple production methods could be considered in terms of both quality and quantity. The strategy for higher production could

save the labour cost, but is unfavourable for better fruit quality due to small fruit size and low TSS. However, although quality production would require much more labour in pruning, flower thinning, fruit thinning, bagging and fertilizer application but the fruit quality will be improved considerably and hence, will fetch higher monetary returns due to increased market price.

### **Standardized Grading**

Uniformity in the quality of the product is extremely important and is a measure of standard advanced farm product. For this, a clear strategy for standardized grading of wax apple fruits needs to be developed and followed. This will obviously enhance the sale of the product and will also generate more income to the farmers.

### **Improving Storage and Transportation Techniques**

The thin skin of wax apple fruit is easily crashed and thus has a short shelf life which is a serious problem and needs to be addressed urgently. For this, new wax apple storage and transportation techniques need to be developed. There is also a great need to devise new and efficient transportation methods. The use of full container load to avoid chilling injury, and transportation through air cargo is extremely important and necessary to shorten the shipping time.

### **Widening the Usage**

The major usage of wax apple is in the form of raw fruits, and also in the form of wine, preserved fruits and salad. Some studies have shown that the essential oil extracted from flower buds is used to make cosmetics. In the future, there is a need to also focus on whole plant usage (leaves, flowers, branches) in order to widen the scope of utilization of wax apple and make it a widely accepted and largely grown tropical fruit species.

## **Improving Quarantine Measures**

Taiwan wax apple usually suffers with fruit fly epidemic which limits the development of export market for this important fruit and thus the export is restricted only to China and nearby countries. There is an urgent need to enhance the efficiency of quarantine measures through low and high temperature, or radiation quarantine. In view of the need for expanding the export market, new and improved quarantine methods for fruit fly need to be developed urgently.

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## **Asia-Pacific Association of Agricultural Research Institutions**

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- Regional Dialogue on Conservation Agriculture in South Asia: Proceedings and Recommendations (2012)
- Expert Consultation on Agricultural Biotechnology, Biosafety and Biosecurity: Proceedings and Recommendations (2012)
- Workshop on Moving Beyond Strategy to Improve Information and Knowledge Management for Agricultural Development in the Pacific Islands Countries and Territories: Proceedings (2012)
- Stakeholders' Interface on GM Food Crops : Proceedings and Recommendations (2011)

- Expert Consultation Meeting on Postharvest and Value Addition of Horticultural Produce – Strengthening Technologies for Linking Farmers to Market : Proceedings and Recommendations (2011)
- International Symposium on Sustainable Agricultural Development and Use of Agrobiodiversity in the Asia-Pacific Region (2010)
- APAARI-ADB Asia-Pacific Consultation on Agricultural Research for Development (AR4D) in Asia and the Pacific-The Way Ahead (2009)
- Expert Consultation on Biopesticides and Biofertilizers for Sustainable Agriculture (2009)
- Symposium on Global Climate Change : Imperatives for Agricultural Research in Asia-Pacific (2008)
- Expert Consultation on Agricultural Biotechnology for Promoting Food Security in Developing Countries (2008)
- Workshop on Development and Management of ARD Information Resources (2008)
- Asia-Pacific Regional Workshop on Agricultural Research for Development (2008) (for establishment of NGO Consortium-NAARAP)
- Expert Consultation to Review Progress of Agricultural Research Networks and Consortia in Asia-Pacific (2007)
- ICT/ICM Sensitization and Awareness Building Workshop for NARS Leaders and Senior Managers (2007)

### Success Stories

- Agricultural Information and Knowledge for All : Success Stories on ICT/ICM in AR4D in Asia and the Pacific Region (2013)
- Linking Farmers to Market: A Success Story of Lettuce Export from Chinese Taipei (2012), Min-Chi Hsu *et al.*
- Biofuel Growers Market Network (2012), K. Narayan Gowda
- Success Stories on ICT/ICM in AR4D in Asia and the Pacific Region, Malcolm Hazelman and S. Attaluri
- Short Duration Mungbean: A New Success in South Asia (2010), M.L. Chadha
- Taro Improvement and Development in Papua New Guinea (2009), Abner Yalu *et al.*
- Cotton-Wheat Production Systems in South Asia: A Success Story (2008), C.D. Mayee *et al.*
- Linking Farmers to Market: Some Success Stories from Asia-Pacific Region (2008), Rosendo S. Rapusas *et al.*

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

### **Status Reports**

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

### **Other Publications**

- Benchmarking Agricultural Research Indicators Across Asia-Pacific : ASTI Regional Synthesis Report
- Training Workshop on Open Access Publishing Using Open Journal Systems
- APAARI on CD
- Priorities for Agricultural Research for Development in South-Asia
- Improving Wheat Productivity in Asia
- Fifteen Years of APAARI - A Retrospective
- APAARI Vision - 2025
- APAARI Newsletter (half yearly)

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