Improving Pitaya Production and Marketing

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PREFACE

Pitaya or dragon fruit (*Hylocereus* spp. and *Selenicereus* spp.) is a climbing-vine cactus species native to the tropical forest regions of Mexico and Central and South America. In the past two decades, it has gained popularity among producers, exporters and consumers alike in Indonesia, Malaysia, Myanmar, the Philippines, Taiwan, Thailand, and Vietnam where agro-environmental conditions are conducive for growing this fruit plant. In Vietnam alone, its cultivation area is reaching near 30,000 hectares with 640,000 ton of fruit products in 2013. And several factors are accountable for the popularity of this crop: 1) high net returns; 2) functional properties because of its high level of antioxidants; and 3) emerging export potential to high-value markets in developed countries due to its uniqueness and health benefits. Pitaya also shows certain agronomic features that improve its potential as a replacement crop with high commercial value. These characteristics include: 1) the relative ease of propagation by cuttings; 2) its relatively low crop maintenance; 3) the short turnaround time between planting and harvesting compared to other tropical fruit trees; 4) its high yield rate; and 5) as a perennial crop, with proper care, it can provide a steady income.

However, on the negative side, many factors limit pitaya potential productivity and downgrade fruit quality. Among them, heavy rainfall events or poor crop management practices such as over-watering can cause flowers to drop, and fruit to split or rot. Apart from limiting the pitaya crop to reach its yield potential, prevailing poor production technologies also lead to serious occurrences of diseases and pests. Currently, anthracnose, stem canker, brown stem spots, and fruit rot are prevalent in major pitaya growing areas in the Asian-Pacific region. And the emerging infectious stem canker has recently caused collapses of many pitaya orchards in Southeast Asia. Protection measures to control these diseases with chemical pesticides are not only costly to small-scale farmers, they also can disrupt natural biological control, and are damaging to human health and the environment. On the other hand, to access higher-value markets of local, regional or international importance, pitaya fruit products need to be free from diseases, pests, blemishes and pesticide residues, along with desirable size, shape, color and taste. Addressing these issues, the implementation of integrated crop management systems including the use of healthy planting materials can improve yield and quality, forcing culture techniques extend the harvest season, and Good Agricultural Practices (GAP), which involve a systematic, stepwise on-farm operation, assure fruit product safety and quality that will benefit both farmers and consumers.

Therefore, the Food and Fertilizer Technology Center (FFTC) for the Asian and Pacific Region, Taiwan Agricultural Research Institute (TARI), and the Southern Horticultural Research Institute (SOFRI) in Vietnam join hands to organize the workshop to share the latest advances in understanding the constraints limiting pitaya production and marketing as well as newly-developed doable technologies such as optimal spacing, trellising, disease diagnosis, integrated pest management, pruning, phenology manipulation, and GAP that increase pitaya productivity, safety and marketability.

Yu-Tsai Huang
Director
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THIRTY-ONE YEARS OF RESEARCH AND DEVELOPMENT IN THE VINE CACTI
PITAYA IN ISRAEL

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ABSTRACT

**Taxonomy:** The vine cacti have three genera and many species in each one of them. The genera are: *Hylocereus*, *Selenicereus* and *Epiphyllum*. Only *Selenicereus megalanthus* combine characteristics of the first two genera.

**Genetics and breeding:** *Selenicereus megalanthus* is tetraploid (4n) while all others are diploids (2n). We obtained inter-clonal, interspecies, and intergeneric hybrids with much improved characteristics, to the point that today we have new excellent hybrids which can provide fruits from July to May.

**Physiology:** All plants are of the CAM (crassulacean acid metabolism) photosynthetic pathway; hence use 10% of water other plants are using in the same environment. CO₂ enrichment increases both the vegetative and reproductive productions. Nitrogen fertilization should accompany the CO₂ enrichment to get maximum efficiency. Stomata were found on the fruit surface functioning through the CAM pathway. Stomatal density is much higher on the fruit scale than on the fruit surface. Cytokinins induces and gibberelllic acid (GA₃) delays flowering. Scale shrinking is the major reason to shorten the shelf life. Root system is very shallow maximum depth, 40cm.

**Uses:** There are more uses to the plants parts other than the fruit, such as fruit pigments as coloring agents, edible flowers and more.

**Keywords:** cacti, pitaya, dragon fruit, taxonomy, genetics, breeding, physiology, cytokinins, GA₃, flowering, post-harvest

INTRODUCTION

The vine-cacti pitaya of the Cactaceae, subfamily Cactoideae, tribe Hylocereeae is known to have been used for thousands of years by the indigenous people of the Americas (Ortiz-Hernández and Carrillo-Salazar 2012). In the mid nineteenth century it was introduced by French priests to "Indochina", at that time the name for Vietnam, Laos and Cambodia. It acclimatized so well there, that the local people believed that this plant was native to their region (Mizrahi et al., 1997). In 1995 Vietnam was the first country to sell pitayas in world markets, under the name Dragon Pearl Fruit (Thang Loy in their language); however, nowadays this crop is grown and marketed in over 20 countries as a new horticultural fruit crop. Vietnam is the leading producer and exporter of this fruit, far ahead of all other countries combined; hundreds of thousands of tons are shipped and sold from Vietnam around the world annually. However, the taste of the Vietnamese fruit is quite bland, which is an obstacle for converting it into a major
world fruit crop. Moreover, many countries obtained their clones from Vietnam, and unfortunately these clones currently govern the world pitaya markets. Consumers who have tasted these fruits are reluctant to try new better tasting varieties which exist today. This marketing obstacle should be resolved for the pitaya to become a mainstream fruit crop.

Until 1994, only scarce research existed on these plants; however the worldwide interest in this novel fruit crop is evident, as numbers of pitaya-related publications have grown rapidly, especially during the past decade (Figure 1). However, there is a big confusion about both botanical and commercial names and there is a need to clear this point. Herein, we attempt to review existing knowledge on the taxonomy, breeding and other horticultural characteristics of this unique crop.

Figure 1. Number of published scientific papers on vine-cacti pitaya (Hylocereus spp) which appeared in the scientific databases.

TAXONOMY

The vine-cacti belong to three separate genera. The three-ribbed shoots belong to Hylocereus, the two-ribbed shoots belong to Epiphyllum, while four and more ribbed shoots belong to Selenicereus genus (Hunt 2006; Tel-Zur et al. 2011a). Over the years, our research team has collected many genotypes of this group of plants, and produced a large genetic database. This database includes over one hundred genotypes of various genera, species and clones differing in morphological, physiological and many other horticultural characteristics (Figure 2 and http://www.bgu.ac.il/life/Faculty/Mizrahi/index.html).
Improving Pitaya Production and Marketing

Figure 2. Appearance of various clones of pitaya genotypes (all *Hylocereus* spp), included in our Vine-Cacti genes bank.

All tested genotypes were found to be diploids, with the exception of the real yellow pitaya *Selenicereus megalanthus* (synonym *H. megalanthus*) and *S. vagans* which are tetraploid genotypes (Lichtenzveig et al. 2000; Tel-Zur et al. 2011a&b). In the scientific literature this plant appears under three names, the above two and *Mediocactus coccineuss* (Infante 1992; Tel-Zur et al. 2004). Recent taxonomic and molecular data suggest that this species belongs to the *Hylocereus* genus, hence the new recent name *Hylocereus megalanthus* (Hunt 2006; Tel-Zur et al. 2004; Plume et al. 2013). Personally, I prefer to use the name *Selenicereus megalanthus* and not *Hylocereus megalanthus* since this pitaya has common morphological characteristics with species of the *Selenicereus* genus, especially the spiny fruit (Figure 3). It also differs in 17 characteristics from all other *Hylocereus* genotypes (Table 1).

Figure 3. Appearance of yellow fruits of *S. megalanthus*, the real yellow pitaya and the yellow clone of *H. undatus* which we named Golden. Both fruits are named by the local people of their country of origin Pitaya Amarallia which means yellow pitaya.
Table 1. Differences between *Selenicereus megalanthus* (real yellow pitaya) and all other *Hylocereus* clones (red pitayas).

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<th>Yellow pitaya clones</th>
<th><em>Hylocereus</em> spp clones</th>
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<tr>
<td>Spiny fruit</td>
<td>No spines on fruit</td>
</tr>
<tr>
<td>Tiny fruit scales</td>
<td>Big fruit scales</td>
</tr>
<tr>
<td>Three years to production</td>
<td>One year to production</td>
</tr>
<tr>
<td>Weak vegetative growth</td>
<td>Vigorous vegetative growth</td>
</tr>
<tr>
<td>Small weak root system</td>
<td>Well-developed root system</td>
</tr>
<tr>
<td>Most sensitive to low temperature</td>
<td>Relative resistance to low temperature</td>
</tr>
<tr>
<td>Superior taste</td>
<td>Taste from bland to good</td>
</tr>
<tr>
<td>Long shelf-life</td>
<td>Short shelf-life</td>
</tr>
<tr>
<td>Long fruit development time</td>
<td>Short fruit development time</td>
</tr>
<tr>
<td>Flowering in autumn</td>
<td>Flowering in summer</td>
</tr>
<tr>
<td>Tetraploid, self-compatible</td>
<td>Diploid only 10% self-compatible</td>
</tr>
<tr>
<td>Fruit size is small-medium</td>
<td>Fruit size is medium-large</td>
</tr>
<tr>
<td>Seed number in fruits is low</td>
<td>Seed number in fruits is high</td>
</tr>
<tr>
<td>Stomata are big</td>
<td>Stomata are small</td>
</tr>
<tr>
<td>Many aborted seeds</td>
<td>All seeds are viable</td>
</tr>
<tr>
<td>Parenchyma &amp; chlorenchyma are mixed, as one layer</td>
<td>Parenchyma &amp; chlorenchyma are separate layers.</td>
</tr>
<tr>
<td>All clones sensitive to nematodes</td>
<td>Many genotypes are resistant to nematodes</td>
</tr>
<tr>
<td>Seeds are big</td>
<td>Seeds are small</td>
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It is very important to distinguish between the yellow clones of the *Hylocereus undatus*, which we named "Golden" pitayas, and the real yellow pitaya *S. megalanthus* (Figure 3). After visiting Nicaragua I found that they also have yellow clones of *Hylocereus costaricensis*, which they name Pitaya amarilla (yellow pitaya in Spanish).

**BREEDING**

When we started to conduct research, these species almost nothing was known in scientific literature (Figure 1). The first thing we did was to collect genotypes from cacti collectors, botanical gardens, private gardens, wild types from countries of origins, etc. The variation in appearance among these groups of vine-cacti is obvious (Figure 2). However there are also huge differences in many other aspects including taste, pigment profiles, both of peel and flesh, and many other characteristics. The first genotypes we released to farmers were beautiful but their taste was very bland, similar to the Vietnamese clones. We started to perform crosses between clones of the same species [inter-clonal hybrids], between different species [interspecific hybrids] and between different genera [inter-generic hybrids] (Tel-Zur et al. 2004). Luckily enough, many crosses were successful, and some yielded our first generation of hybrid clones which are grown today as commercial pitayas both in Israel and abroad. The *Hylocereus* sp. hybrids, either inter-clonal or interspecific ripen in summer; while the inter-generic hybrids ripen from the autumn to the end of winter; and the real yellow pitaya (*S. megalanthus*) ripen from the end of winter to the late spring. The only month we cannot obtain ripe fresh fruits is June. The crosses between the tetraploid *S. megalanthus* and various *Hylocereus* genotypes yielded diploids, triploids, tetraploids, pentaploids, hexaploids and octaploids hybrids (Tel-Zur et al. 2004 and 2005; 2011a;&b; Cisneros et al. 2013). Among all these polyploids the triploids yielded two commercial hybrids which exhibit good taste, long shelf-life and ripening in late autumn to end -winter, differing from all other *Hylocereus* genotypes. The fruits are spiny, but to a much lesser
extent than the S. megalanthus. All these crosses enable us to find dominant, co-dominant and recessive characteristics which will help us in future breeding (Tel-Zur 2004). Tel-Zur and her co-workers also developed an embryo-rescue technology which enables to produce a viable hybrid when normal crossing fails (Cisneros and Tel-Zur, 2010; Cisneros et al. 2013).

One of the problems with growing these genotypes is self-incompatibility (Nerd and Mizrahi 1997). Among our Hylocereus collection, we found around 10% of self-compatible genotypes, while all others need cross pollination. This means that the grower has to grow at least two clones, which flower at the same time and are compatible. We developed a technology to preserve viable pollen for long periods of time (over 18 months) by desiccating fresh pollen under vacuum to 5-10% humidity and storing at -20°C (Metz et al. 2000). Doubling the chromosomes also solved this problem by breaking incompatibility (Cohen and Tel-Zur 2012). Chromosome doubling was achieved by several means; by applying colchicine and/or oryzalin, both to germinating seeds and to areoles (Te-Zur et al. 2011b), by crossing between genotypes of various ploidy where some offspring were found to be of different ploidy from the parents (Tel-Zur et al. 2004), or alternatively by gynogenesis (Benega-Garcia et al. 2009b). Today, we work on F2 offspring of self and cross pollination of the existing hybrids (F1) with their parents as well as with other Hylocereus species. On the basis of some seedlings, some hybrids seem to have a much better appearance than the original F1, lack of spines, good taste and long shelf-life; some of them are tetraploids and self-compatible (Figure 4). Of course one cannot rely on good performance of one seedling; hence, several cuttings were given to good growers around the country to test their performance in comparison with the existing commercial hybrids. We hope that within a few years we will have much better clones than the existing ones. The crosses of Hylocereus genotypes with Epiphyllum may be of special interest, since some of the Epiphyllum fruits are very tasty and aromatic, reminiscent of passion fruits. Crosses between Hylocereus and/or Selenicereus genra with Epiphyllum species failed. However, when we crossed F1 between Hylocereus and Selenicereus genotype which produced viable pollen, with Epiphyllum, we obtained several offspring which show characteristics of the three original genera. We wait to see the final results when they will enter into their reproductive stage. On the other hand, crosses between Hylocereus spp. and Selenicereus spp. other than S. megalanthus have so-far yielded un-tasty fruits. A very powerful breeding tool was developed by Tel-Zur and coworkers. They were able to produce haploids from both pollen mother cells and ovaries (Benegra-Garcia et al. 2009a&b). By doubling the chromosomes of these haploids one can obtain homozygous clones which are easy to work with as parents, for further future breeding.
Figure 4. Appearance of one of the new F₂ hybrids under consideration of being a new commercial clone. This genotype has much less spines, better appearance, good taste, is self-compatible and has a long shelf-life.

It is important to note that our success in breeding new hybrids is the result of our pioneering efforts to improve this new crop through known genetic techniques used with other crops. Most likely, with time, further improvement will become harder to achieve, as is the situation today with well-established old fruit trees crops that have already undergone many years of breeding.

**PHYSIOLOGICAL AND HORTICULTURAL CHARACTERISTICS**

After establishing plants mainly from seedlings and cuttings of several genotypes, we planted them in various ecozones around Israel. We soon realized that the plants have to be protected from the intense Israeli solar radiation, which caused severe photo inhibition and death. The stems turned yellow then bleached and die. In summer our radiation as PPFD (photosynthetic photon flux density) may reach 2,200 µmol photons/m²/second, hence, all pitayas in Israel are currently grown under nets. The provided shade is from 20% along the Mediterranean coast to 60% in inland desert areas (Raveh et al. 1998). The needed degree of shade may vary among clones; those having layers of wax on stems might need less shade than those without the wax.

Since these genotypes utilize the Crassulacean Acid Metabolism (CAM) pathway, it is expected that their water use efficiency will be much higher than that of other fruit crops. Indeed, according to Mizrahi et al. (2007), the vine-cacti pitaya, the columnar pitaya *Cereus peruvianus* and the famous cactus-pear *Opuntia ficus-indica*, use around 10% of the water used by various C₃ fruit crops such as citrus fruits, peach, avocado and pear. The data were taken from farmers who grow both C₃ and CAM cacti fruit trees.
in the Israeli Negev desert. With the yields and prices which these farmers obtain for these exotic fruits, they claim that it is a negligible expense to pay for the water, even if they need to pay for desalinated water at 1 USD per cubic meter. We found that the root system of these hemi-epiphytic plants is very shallow; the depth is no more than 40 cm (Mizrahi et al. 2007). Irrigation is required only during summer (the dry season). In mid-summer we irrigate every day with a small amount of water; otherwise the water will slip below the root system. Farmers apply between 60-250 mm of water annually, and those who irrigate with 250 mm/year cannot believe that our recommendation of 120 mm/year is enough (Mizrahi et al. 2007).

Pitaya does require mineral fertilization, especially when annual yields are high, between 20 to 45 tons/hectare. However, data on mineral fertilization needs are lacking, thus the exact demand for the various mineral nutrients is unknown. Evidence for the need for fertilization came from the works of Nobel and De la Barrera (2002), and Weiss et al. (2009), which tested the effect of mineral application and CO₂ enrichment on these vine-cacti. The common belief that CAM plants do not respond positively to CO₂ enrichment, was proven several times to be a misconception (Nobel and De la Barrera 2004; Raveh et al. 1995; Weiss et al. 2010). CO₂ enrichment enhanced growth and production of both vegetative and reproductive organs (Weiss et al. 2010). Preliminary unpublished results (M. Dudai) obtained by measuring influx and efflux of fertigated pitayas grown in soilless culture demonstrated that: Total annual N/P/K requirements for 1 hectare are 110/25/280 kilograms. Their fluctuations in needs during the various periods of the plants phenology are as follows: During flowering and fruit production N should be doubled, P should be multiplied by 5 while K should be multiplied by 2.5 in comparison to their vegetative periods.

The optimal temperature for growth of this cactus was found to be between 20 to 30°C while the range of 30-40 °C was found to be damaging (Pelah et al. 2003, Nobel and De la Barrera 2004; Ben-Asher et al. 2006). In these experimentations it was also found that CO₂ enrichment might alleviate water stress damage. We have recently noticed several hybrids which can be productive even in the Israeli Arava valley where the average temperature in summer is around 40°C. After a spell of subfreezing temperatures in January 2008 and December 2013, we also found big differences in cold tolerance of various clones grown in different ecozones around the country.

The hemi-epiphytic vine-cacti require a trellis system for support. Many countries adapted the Vietnamese system where they plant 3-4 cuttings around a support pole which allows the shoots to bend down (Figure 5). It is not very efficient system to harvest. Also there is no need to plant 3-4 cuttings around the main pole where one can produce 20-45 tons/hecate/year. In Mexico they use live trees for trellising (Ortiz-Hernández and Carrillo-Salazar 2012). In Israel we use a different support system, where we hang the shoots on wires at a height of no more than 160 cm. This allows two "walls" of fruit production on both sides of the system and also provides easy access to growers, to pollinate flowers and harvest fruits (Figure 6).
Today several Israeli farmers grow the pitayas in soilless systems, in 20 liter buckets (Figure 7). This system may solve many soil-borne problems and enable to more precisely regulate both irrigation and fertilization, by monitoring water efflux collected from the bottom of sampled buckets. It also enables to measure the uptake of minerals delivered by the irrigation system (Figure 8).
Figure 7. Soilless pitaya, trellised and grown in 20 liter buckets, in 30% shade net-house.

Figure 8. Pitaya bucket in the orchard with a tray to collect and measure efflux of water and minerals.
One major problem with the pitaya plants is that they tend to flower in waves (Weiss et al. 1994). Some clones will flower twice per season which will result in two waves of ripe fruits. Each wave takes about one week from the first flower to the last one, and fruit ripening will occur after around 30 days. One way to solve this problem and provide the market with a steady supply of fruits throughout the season is to use clones with many waves (up to ten throughout the season). Another possible solution is to use different clones which flower and ripe at different times (http://www.bgu.ac.il/life/Faculty/Mizrahi/index.html). If these solutions are adopted, fruit quality will fluctuate throughout the marketing period, since fruits from different clones reach the market. We have also tried several other solutions such as thinning fruit buds and hormone applications (Khaimov and Mizrahi 2006). We tested the *Hylocereus undatus* and *Selenicereus megalanthus* and found that removal of young flower buds delayed the wave of flowering and produced late cropping. In both species, CPPU (a synthetic phenylurea cytokinin) promoted precocious and early flowering and led to early ripening, whereas gibberellic acid (GA$_3$) delayed both flowering and ripening. Hence, CPPU can be used to obtain early fruit production, and GA$_3$ or flower thinning to delay cropping (Khaimov and Mizrahi 2006). Khaimov and Mizrahi (2006) reported that application of long days was not effective in induction of early flowering as was reported by other papers (Yen and Chang 1997, Jiang et al. 2012). Recently, we found that the positive response to long days in the pitaya is temperature dependent. Temperatures ranging between 20 to 30°C are the optimal, while either lower and/or higher will decrease or even inhibit induction of flower bud production (Khaimov-Armoza et al. 2012). It is important to note that this temperature regime is also optimal for growth and development, as mentioned above.

Analyses of endogenous cytokinins throughout the year supported the assumption that active cytokinins are important inducers of flower bud production in *Hylocereus undatus* (Khaimov–Armoza et al. 2012). The active cytokinins peak just before flower buds appear. Pruning shoots at the proper times can regulate the flowering in both *S. megalanthus* and its triploid hybrids. When pruning the shoots every week between the beginnings of August to the beginning of September, these genotypes will burst in flower bud production. Consecutive pruning will result in consecutive flowering and ripening. The periods which elapse between the waves of flowering and ripening become longer with time, due to shorter days and lower temperatures (Figure 9). Hence, ripening will occur from November to April, namely providing winter crop. The first fruits of the season are 50% of the size of the later fruits, probably due to more appropriate temperatures for fruit development and ripening in the late season.
Figure 9. Appearance of the triploid commercial clones at various stages of flowering, resulting from pruning at different times. The three pictures were taken on the same day of October 10th 2011. The difference in stages of flowering is the result of weekly consecutive pruning from August 3rd (a) to September 3rd (c).

Another approach to stretch the season is by pollinating the flowers with two different sources of pollen. If pollinated with *Hylocereus* spp, the time which elapses from pollination to ripening is shorter by 5 to 30 days than if pollinated with pollen of *Selenicereus* spp. clones. This is a classical metaxenia phenomenon to be used for elongating the ripening season (Mizrahi et al. 2004).

**POSTHARVEST**

Pitaya fruits are very attractive in appearance when fresh. However, in most end-markets which sell these fruit, the appearance becomes very poor, mainly due to the shriveling of the fruit scales (Figure 10). We found that the pitaya fruit-peels contain active stomata. These stomata follow the CAM photosynthetic pathway like those of the shoots (Figure 11). The fruit stomata density varies throughout the fruit surface. They are more concentrated in the scales than in the other parts of the fruit peel (Figure 12), and are most concentrated on *Hylocereus undatus* fruit peel (Figure 12). Indeed we found that that shriveling occurs more rapidly in *H. undatus* fruit than in the other two tested species (Kaplan-Levy 1999). Covering fruit with plastic sheets can extend the shelf-life by a few days and the most effective film is IP9 (StePac, Tefen Israel). The main reason that pitaya fruits lose their taste after harvest is a sharp decline in acidity such as malic acid concentration (Nerd et al. 1999). This problem could probably be solved by crossing with parents which have high acid content or in clones in which the decline in acid is inhibited, or both. We have not materialized this option yet.
Figure 10. Poor appearance of pitaya fruits in Sweden and Paris. Similar appearance can be seen all over the world.

Kinetics of fruit stomata opening of *H. polyrhizus* and *H. undatus* at 4 stages of fruit ripening

![Stomata opening graphs](image)

Figure 11. Daily stomata opening in *Hylocereus undatus* and *Hylocereus polyrhizus* (synonym *H. monacanthus*) at four stages of fruit ripening. Stomata opening is presented both as % of open stomata and average area of open stoma in mm².
Improving Pitaya Production and Marketing

Figure 12. Stomata distribution and density throughout the pitaya fruit surface.
A. Areas from where stomata print were taken and counted per mm².
B. Density of stomata (number/mm²) in three species of pitayas.

We found that the minimum temperature to store pitayas is 10°C since they are sensitive to chilling injury (Figure 13). Chilling injury is manifested by early shriveling of scales, watery pulp, decline in taste and development of off-flavor (Nerd et al. 1999). We found that the best way to achieve long shelf-life fruit is by breeding. We bred several clones which can tolerate sea-freight to Europe, having a 26 day shelf-life, 21 days at 10°C followed by 5 days at 20°C.
Other than fruits, pitaya plants can also serve other important human needs. The most important of all is to use the beautiful pigments of the red flesh pitayas as food coloring agents (Naderi et al. 2010). We found a new glowing-magenta-pigment in *Hylocereus polyrhizus* (*H. monacanthus*). Since it was first found in this genus we named it *Hylocerenin* (Wybrabiec et al. 2001; Wybraniec and Mizrahi 2002). Afterwards a tsunami of new papers was published mainly by German researchers Stintzing, Carle, Herbach, and Moßhammer, and some others. Some of their work was reviewed by Stintzing and Carle (2007) emphasizing the importance of this group of pigments to the food industry. The Betalain pigments, especially those from the vine-cacti are excellent pigments due to their beautiful color, their stability in various ranges of pH and heat treatments and their high nutritional value. They contain antioxidants among other compounds, all summarized in the excellent review by Azeredo (2009).

Flowers of *Hylocereus undatus* are used as a vegetable named “Bawanghua” in Chinese cooking (Chinese Academy of Sciences 1999). Recently, “Bawanghua” has been commercialized as a healthy beverage in China, on top of many other uses as a health food (Yin et al. 2012). Ortiz-Hernández and Carrillo-Salazar (2012) also mentioned in their review many other medicinal uses of the pitaya species such as hypoglycemic, diuretic, for treatment of heart disease, dysentery, anti-proliferation properties, antimicrobial activity and more. Also the pitaya shoots and seeds are an important source of nutraceuticals.
DISEASES AND PESTS

In tropical countries pitayas are infested with many fungi, bacteria, viruses, insects and nematodes. In Israel which is a semi-arid zone, this crop was free from any pests for many years. Only recently we found that two nematode species are causing damage mainly to the *Selenicereus megalanthus* and few other *Hylocereus* genotypes. The nematodes belong to the *Meloidogyne* genus; they are *M. incognita* and *M. javanica*, and cause problems only in sandy soils. Resistant clones of pitayas are available to be used as rootstocks. It is very easy to graft these plants and they become productive one year after grafting.

Recently several fungi were discovered, which might become a problem in pitaya fruits. One is *Bipolaris cactivora* which appears as black patches on the fruits, sometimes penetrating into the fruit flesh; however, damaged fruits are discarded. The other fungus is *Scytalidium lignicola*, which penetrates into the fruit via the flower style but has not reached a stage of causing real commercial damage.

GRAFTING EFFECTS

We found recently an effect of *Hylocereus* spp rootstocks for the yellow pitaya *Selenicereus megalanthus* on fruit taste. The yellow pitaya fruits grown on their own roots were much better in taste than the fruits from the grafted plants (Table 2).

Table 2. Effect of *Hylocereus* spp. rootstocks on taste and other fruit parameters of yellow pitaya. Twenty randomly-selected tasters participated in taste test. Each taster was required to grad the samples from 1 to 5, where 1 is the lower and 5 are the highest taste. In all other parameters n=5. Different letters are significantly different (Duncan multiple range test <5%).

<table>
<thead>
<tr>
<th>Plant</th>
<th>Fruit wt. (g)</th>
<th>Pulp (%)</th>
<th>TSS (%)</th>
<th>Taste (1-5)</th>
<th>Black seeds / gram pulp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rooted</td>
<td>203 ± 65 a</td>
<td>62.7 ± 1.1 a</td>
<td>17.8 ± 0.5 a</td>
<td>4.60 ± 0.16 a</td>
<td>1.91 ± 0.30 a</td>
</tr>
<tr>
<td>Rootstock 1</td>
<td>171 ± 7 b</td>
<td>53.2 ± 2.3 b</td>
<td>13.6 ± 0.4 c</td>
<td>2.80 ± 0.29 b</td>
<td>0.36 ± 0.20 b</td>
</tr>
<tr>
<td>Rootstock 2</td>
<td>131 ± 4 b</td>
<td>55.7 ± 0.9 b</td>
<td>15.2 ± 0.4 b</td>
<td>3.20 ± 0.36 b</td>
<td>0.70 ± 0.15 b</td>
</tr>
</tbody>
</table>

CONCLUSIONS

To sum up almost three decades of worldwide research and development on this unique vine-cacti plant; it seems that the pitaya has a bright future due to the following reasons: It is an extremely visually attractive fruit; which also nowadays has a good taste thanks to the new hybrids. The water use efficiency is the highest among all fruit trees. It contains many nutraceuticals which today are highly appreciated by consumers; yields are high; fruits can be produced almost year around which is huge market advantage; and finally - plants have uses other than for fresh market fruits. One obstacle to the success of this fruit is the marketing of the old bland clones, which should be avoided in the emerging new markets. We have already experienced consumers who were reluctant to taste the new hybrids since they experienced the old un-tasty clones.
Many essential areas of research are in need for R&D activities, among them fertilization, irrigation and many other manipulations used in other fruit trees.

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COUNTRY REPORTS
STATUS OF DRAGON FRUIT CULTIVATION AND MARKETING IN INDONESIA

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ABSTRACT

Dragon fruit (*Hylocereus* spp.) has been intensively cultivated in Indonesia since 15 years ago. This crop is found in almost all parts of Indonesia with the production centers located in the provinces of Riau, Kepulauan Riau, West Sumatra, East Kalimantan and Java Island. Red flesh dragon fruit (*H. polyrhizus*) is the most common cultivar. Statistics information for dragon fruit cultivation, production and marketing in Indonesia is very limited. Based on altitude and climate conditions, the regions below 800 meters above sea level is suitable for dragon fruit cultivation. Preliminary survey of ITFRI and farmers’ experiences reveal that dragon fruit productivity in Indonesia was about 24 to 30 t/ha/year. There are two flowering and fruiting patterns of dragon fruit in Indonesia. The first pattern of flowering and fruiting throughout the year occurred in the regions near the equator. The second pattern is flowering and fruiting for 6 to 7 months, from October to April, which occurred in Java Island. The main problem in cultivation is diseases. In the last few years, disease outbreaks destroyed many dragon fruit orchards in production centers, especially outside of Java Island. Major diseases are white/yellow spot (scab), yellow and black stem rots, stem and fruit scabs, anthracnose and stem canker (*Neoscytalidium dimidiatum*), which attacked simultaneously. Other diseases include stem rots caused by *Fusarium* sp., *Schlerotium* sp. and bacteria, and anthracnose by *Colletotrichum gloeosporioides*, and stem and fruit scabs by *Pestalotiopsis* sp. and *Alternaria* sp. The major problem in marketing is low price due to over supply of fruits due to similar harvest seasons at almost all production centers. In addition, the long distance between production centers and markets led to the high cost of transportation. Indonesian dragon fruit productions mainly supply to local markets, but a small portion of which is exported to Singapore. Indonesia also imported dragon fruit from Vietnam, China and Thailand. Research on dragon fruit in Indonesia is still limited. Research activities in ITFRI started in 2013. The activities focus on the identification and control of the diseases, and the application of chemical and organic fertilizers. Research on the extension of flowering period with the use of artificial lights is conducted in the Java region.

Keywords: dragon fruit, cultivation, marketing, Indonesia

INTRODUCTION

Dragon fruit (*Hylocereus* spp.) is a veining epiphytic cactus, native to the tropical forest regions of Mexico and Central and South America (Mizrahi et al. 1997). *Hylocereus* has been introduced for production to Bahamas, Bermuda, the United States (Florida and California), Australia, Thailand, India, China, Taiwan, Philippines, Malaysia, Vietnam, Indonesia, Cambodia, Israel and others (Nerd et al. 2002; Lim et al. 2012). *Hylocereus undatus* has become an important crop in Southeast Asia, ever since it was introduced via the Philippines, in the XVI century (Casas and Barbera 2002; Marten 2003).
Dragon fruit can be cultivated in wet and dry temperate zone with irrigation facilities. Dragon fruit adapt well in various environmental conditions, such as poor soil and various temperature. The tropical climate is very favorable for cultivation of dragon fruit. The optimum temperature ranges from 20 to 30°C, and annual rainfall of about 500-1500 mm.

Production areas of dragon fruits have continuously increased in Indonesia since 2000s. The popularity might be due to its unique appearance, exotic, fresh sweet taste, and many health benefits. Unfortunaley, there is no official data about dragon fruit production in Indonesia. But it has been cultivated commercially in West Sumatra, Riau, Central Java, East Java, East Kalimantan and Nusa Tenggara Barat. Between 2005 and 2011, the islands of Bintan and Batam, province of Kepulauan Riau have a number of dragon fruit orchards for Singaporean markets. But most of dragon fruit production is used to fill local market demand.

CURRENT STATUS OF DRAGON FRUIT CULTIVATION AND MARKETING

Cultivated Area
Dragon fruit was introduced to Indonesia around 1997 and developed in the islands of Sumatera, Java, and Kalimantan. Main cultivated areas are East Java, Central Java, West Java, Bali, Riau, Kepulauan Riau, West Sumatra, North Sumatra, East Kalimantan and South Sulawesi (Figure 1). Widely cultivated varieties are red-skin and red-flesh, and red-skin and white-flesh. Cultivation of yellow–skin and white-flesh is still limited. Specific locations of dragon fruit orchard are presented in Table 1.

Figure 1. Locations of dragon fruit orchards in Indonesia.
Table 1. Locations of dragon fruit orchard in Indonesia

<table>
<thead>
<tr>
<th>Province</th>
<th>District</th>
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</thead>
<tbody>
<tr>
<td>North Sumatera</td>
<td>Deli Serdang</td>
</tr>
<tr>
<td>Riau</td>
<td>Pekanbaru, Siak</td>
</tr>
<tr>
<td>Kepulauan Riau</td>
<td>Batam, Bintan, Karimun, Tanjung Pinang</td>
</tr>
<tr>
<td>West Sumatera</td>
<td>Padang Pariaman, Solok, Pasaman</td>
</tr>
<tr>
<td>Lampung</td>
<td>Lampung Timur, Tulang Bawang, Lampung Selatan</td>
</tr>
<tr>
<td>West Java</td>
<td>Bogor, Bekasi, Sumedang, Indramayu</td>
</tr>
<tr>
<td>Centre of Java/</td>
<td>Boyolali, Karanganyar, Kendal, Semarang, Pati, Wonosobo, Purbalingga,</td>
</tr>
<tr>
<td>Yogyakarta</td>
<td>Pemalang, Banjarnegara, Sragen, Sukoharjo, Sleman, Bantul, Kulonprogo.</td>
</tr>
<tr>
<td>East Java</td>
<td>Jember, Pasuruan, Malang, Lumajang, Banyuwangi</td>
</tr>
<tr>
<td>East Kalimantan</td>
<td>Kutai Kartanegara</td>
</tr>
</tbody>
</table>

At first, many Indonesians assumed that dragon fruit can be grown and produced well in both coastal areas and fertile land. Related to those assumptions, the dragon fruit developed in coastal areas were located in Yogyakarta, West Sumatra and Riau. Since the last few years, dragon fruit has been cultivated in the areas from the low land to 800 m above sea level. In addition, a lot of farmers have cultivated the dragon fruit on marginal lands which is known as low fertility area. In the marginal land at the district of Kutai Kartanegara, East Kalimantan province, dragon fruits grow rapidly and show good productivity. At the end of 2014, the dragon fruit cultivation area in East Kalimantan reach about 1,500 ha (Source: Dragon Fruit Farmer Group, East Kalimantan). This information indicates that at marginal lands supported with good farming technology, dragon fruit can grow and produce well.

**Cultivation**

The propagation technique known as stem cuttings propagation is the most commonly used form of propagation by dragon fruit growers. This technique ensures the quick growth of plants and fruiting will occur quickly, at 10 to 12 months after planting. Cuttings can be obtained throughout the year. However, it is preferable to collect the cuttings after fruiting period of the mother plants. Plant materials for cuttings are chosen from the healthy and dark green branches, about 20-30 cm long. Dragon fruit plants need some type of trellis to support the plants when grown in orchards. Many trellises designs have been used, such as live tutors, solid wood and concrete pillars used in many production areas. The trellis used must be strong, well-built and durable to support dragon fruit plants, with about 2-2.5 m height.

In general, the planting system of dragon fruit in Indonesia is carried out by a spacing or distance between the trellises of about 2 to 3 m x 2.5 to 4 m. Each trellis consists of four seedlings or cuttings. To obtain better growth and productivity, good management of planting, fertilizing, watering, pruning, pest and disease control is needed. Well managed plant will bear fruits in one year.
Dragon fruits are night blooming and the hermaphroditic blooms remain open for one night only. Dragon fruit generally has a very short period of blooming and the maturation of male and female gametes do not happen together. This condition caused the low percentage of successful fruiting which is only 50% (Kriswiyanti et al. 2009). *Hylocereus polyrhizus* and *H. costaricensis* have been reported as self-incompatible, requiring cross-pollination to set fruit. *H. undatus* cannot produce fruits by automatic self-pollination and produce a reduced number of seeds by hand self-pollination (50-79.6% fruit set) compared to outcrossed fruits (100% fruit set). *Selenicereus megalanthus* is self-compatible, producing fruits both by automatic self-pollination (60-73% fruit set) and by hand self-pollination (100% fruit set) (Weiss et al. 1994). Apparently, differences between the pollination systems of the two species are due to morphological differences in the position of anthers and stigma that prevent automatic self-pollination (Weiss et al. 1994). The anthers and stigma were separated by at least 2 cm. Most of the dragon fruit plants grown in Indonesia possess self-incompatibilities. Several of the autogamous *Hylocereus* clones produce about 350 grams of fruit at the average, when the flower is not hand-pollinated.

The application of fertilizer rates vary widely in orchard areas. The use of inorganic fertilizers on crops highly influenced the growth and productivity of plants. Organic manures and composts have been used in Indonesia with much success. About 300 - 500 g N, 500-700 g P₂O₅, 300-500 g K₂O, and 20 kg organic manure per pillar per year were used.

Based on the preliminary survey of ITFRI and from farmers’ experiences dragon fruit productivity in Indonesia was about 24 to 30 t/ha/year. The productivity varies among locations and cultivation technique. The Standard Operating Procedure (SOP) for dragon fruit cultivation has not been developed yet.

In Indonesia, there are some morphological variations in phenotypes of dragon fruit, both in group *H. polyrhizus* and *H. costaricensis* (Figure 2). The variations can be seen on stem and fruit which can be observed, i.e.; stem shape (triangle, quadrangle), stem color (whitish green, light green, dark green), flower color (pure white, white), calyx color (light green, reddish green), fruit color (vermilion, red, dark red), color of fruit flesh (white, red, dark red, blackish red), and fruit shape (round, oval), etc. (Rahmawati and Mahajoeno 2009).
Figure 2. The variation of fruit shape of *H. polyrhizus* (above) and *H. costaricensis* (below).

**Flowering and Fruiting Season**

There are two flowering and fruiting patterns of dragon fruit in Indonesia (Table 2). The first pattern is flowering and fruiting throughout the year, which occurs in the regions near the equator such as Sumatra, Kalimantan and Sulawesi islands. The second pattern is flowering and fruiting for six to seven months from October to April, which occurred in part of Sumatra (Lampung province), Java Island, Madura, Bali, West Nusa Tenggara and East Nusa Tenggara. These areas are located near the Southern Hemisphere, more than $50$ S. Previous observations reported that the different circumstances, occurred in the Northern Hemisphere, several dragon fruit bear flowers from May to October (Nerd and Mizrahi 1997). The flowering season in California is from May through November (Thomson 2002).

<table>
<thead>
<tr>
<th>Region</th>
<th>Month</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>J</td>
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<tr>
<td>Near of the equator</td>
<td>V</td>
</tr>
<tr>
<td>Southern Hemisphere (more than $50$ S)</td>
<td>V</td>
</tr>
</tbody>
</table>

Under optimal conditions, floral buds appear at intervals of about two weeks, especially at the location near the equator. From emerging floral buds to opened flower, it takes about one month, and from opened flower to harvest time, it takes about a month. The average from the floral buds to harvest takes about two months (Figure 3) and the harvest can be done at intervals of about two weeks. The harvested fruit cannot be stored longer than 7 days, unless it is stored in a cold storage. Therefore it should be marketed soon after harvesting.
Marketing

Prior to year 2000, Indonesia imported 100% of its dragon fruit from overseas. After 2000, dragon fruit started to be cultivated commercially, and area and production increased rapidly. In a short time the fruit orchard spread to many regions. Many farmers show great interest to cultivate the dragon fruit because this commodity has several advantages: period from planting to fruiting is short (about 10 months), long period of productivity, high prices, and many good health benefits.

Dragon fruit has a great potential in Indonesia with 250 million people. About 10 years ago, most consumers of dragon fruit are limited to high-income groups. Now the fruit can be found even in traditional markets and roadside with the consumers consisting of practically all levels of society. Dragon fruit is considered as the fruit of the future which are commonly consumed directly as fresh fruit or processed into juice, jam, syrup, and other valuable products.

Marketing of dragon fruit is very simple. After harvesting, the dragon fruits are collected by merchants and sold to the fresh fruit stores, supermarkets or directly marketed to consumers. For farmers who are just starting the business, they usually market the fruits to vendors who in turn offer the fruit to shops, supermarkets, merchants in traditional markets. Some farmers join the dragon fruit growers association.

The demand for dragon fruit in Indonesia is all-year round but the highest demand is usually during the celebration of the Lunar New Year (January or February). During this time, the demand can increase of up to 25% compared to other times of the year. Currently Indonesia still imports the dragon fruit from Vietnam, China and Thailand. The proportion of dragon fruit import is estimated to be about 50% of the total requirement.

MAJOR PRODUCTION CONSTRAINTS AND MARKETING CHALLENGES

Pests and Diseases

The main constraint in dragon fruit cultivation is pest and diseases that have destroyed dragon fruit cultivation. Rarely, cactus scale (Pseudococcus sp.), ants and aphids will cover a bloom or fruit, but they are easily controlled and not usually a serious problem. In Bintan and Batam, the district of Kepulauan Riau provinces, this case have been reduced by 80 to 100% in 2011. Diseases problem also occurred at central production in West Sumatera province since 2012. In these locations, hundreds of hectares planted to dragon fruit were destroyed.
Sumatera and Kepulauan Riau provinces. The diseases were white/yellow spot (scab) that attack stem and fruit (*Alternaria* sp. and *Pestalotiopsis* sp. as causal agents?), yellow stem rot (*Fusarium* sp., *Schlerotium* sp., *Phythtophthora* sp., and bacteria), antrachnose (*Colletotrichum* sp.) and disease like stem canker in Malaysia and Vietnam that caused by *Neoscytalidium dimidiatum*. The symptoms of yellow stem rot, white/yellow spot, antrachnose, black/brown spot, and black rot disease were presented in Figures 4, 5, 6, 7 and 8.

Figure 4. Symptoms of yellow stem rot disease of dragon fruit plants.

Figure 5. Symptoms of white/yellow spot (Scab) of dragon fruit: A=early symptoms, B, C=further symptoms, D=died shoot due to disease, E, F, G= symptom on fruits
Marketing Constraints

The harvesting period of dragon fruit is unique and different from other commodities. Under similar agroecological conditions, dragon fruit harvesting occur simultaneously. In this case, there are many production stocks in these areas. The harvested fruit must be marketed as soon as possible, since it cannot be stored longer. These fruit are non-climactic and the quality of which can last for at least two weeks when stored at 14°C (Nerd et al. 1999). Cold storage facilities are needed to extended storage period of the dragon fruit.

In some production centers, such as East Java and East Kalimantan, the prices of dragon fruit often drop when over supply occurs. Furthermore, high transportation costs from production centers to other regions in an archipelagic country is another constraint. In addition, there are inadequate refrigeration, storage and transport facilities. These problems become obstacles in marketing of dragon fruit in Indonesia. Compounding the marketing problem is the fact that currently, there is no existing farmer association of dragon fruit producers in Indonesia.
PROTECTION OF DRAGON FRUIT PRODUCTION AND MARKETING

Efforts to Increase Production
Development of dragon fruit area was carried out by considering agronomy, potential region, agro-climate, human resources, facilities and infrastructure, as well as economical aspects. The development program was conducted through two approaches. First approach is through strengthening the existing area through optimization of cultivated management such as fertilization, irrigation, and control of pest and diseases. The second approach is using good quality of seedlings followed by application of Good Agricultural Practices (GAPs) based on Standard Operating Procedure (SOP). Good Handling Practices (GHPs) are also needed to maintain good quality of dragon fruit. The orchards that have implemented GAP were then registered. The registration number reflected that the dragon fruit produced from the orchard is safe for consumption.

Efforts to Increase Marketing
Institutional farmers, such as those belonging to farmers’ groups or associations play an important role in promoting their production. The existence of farmers’ associations can provide the assistance, financing and marketing process to become easier. The strong association will enhance farmers’ bargaining position and they will not easily be manipulated by middlemen. The association can also facilitate the network and partnership in marketing the product.

Application of cultivated technology, postharvest handling, the provision of facilities and infrastructure are the important components in the dragon fruit business. The selection and use of suitable facilities and infrastructure will maintain good quality of dragon fruit and give good price and high competitiveness.

FOCUS IN RESPONSE TO FUTURE TREND AND MARKET DEMAND

Dragon fruit has the potential to be further developed in Indonesia in order to meet the demand of domestic and export markets. Domestic market demand is increasing every year along with population growth and increasing of public awareness on healthy living. But Indonesia has not been able to fill in those markets. Development focus of dragon fruits in Indonesia is to meet domestic demand, reduce import and increase farmers’ income. Therefore it is necessary to increase the production which is focused on expansion of planting areas and improvement of production management. Extending planting areas is possible as Indonesia has wide areas which are suitable for the development of dragon fruit. Extending the area around the equator is better than the area far from equator since the plants could be flowering and fruiting throughout the year. Formation of areas for dragon fruit production is important to achieve economies of scale which can lead to efficient cultivation, marketing, and facilitate the empowerment of farmers. Improvement of cultivation techniques can be performed through optimal fertilization, irrigation, and pest and disease control. Drip irrigation technique is important to overcome the difficulties in water supply on the dry land.

Postharvest activities and the development of dragon fruit processed products like jelly, jam, syrup and cake are needed to overcome the problem of over-production when harvest time occurs simultaneously in various locations. In addition, the development of processed products can support the agriculture bioindustry, which is one of the
programs of the Department of Agriculture. In East Kalimantan province the dragon fruit has been processed into flour and on Batam Island processed into various types of food that are unique to these areas.

RESEARCH AND DEVELOPMENT PROGRAM

Research on dragon fruit in Indonesia is still limited. Research activities of dragon fruit in ITFRI have started in 2013. The activities focus on identification and control of the diseases, and the application of chemical and organic fertilizers. Other research on the extension of flowering period with the use of artificial lights is carried out especially in the Java region. Field observation on several dragon fruit orchards in Indonesia found various varieties of dragon fruit. Selection and evaluation of superior varieties based on morphology, horticultural traits and molecular markers need to be done, especially for self-compatible and autogamous red-fleshed varieties.

CONCLUSION

There are many aspects that must be considered to improve productivity and quality of dragon fruit in Indonesia. Superior varieties, planting system, fertilization, irrigation, pruning, proper harvest time and post-harvest storage are some of the things that determine the success of the dragon fruit business. And the farmers need to be well informed with these techniques before they embark on this kind of business.

White/yellow spot (scab) disease is one of the serious disease attacks on dragon fruit plants in some areas. The disease destroyed a great number of dragon fruit orchards. The clones that are resistant to this disease, along with its effective management measures, have yet to be developed. Moreover, issues and challenges such as problems in peak harvesting of dragon fruit, preparation for marketing, postharvest handling and reducing transportation costs, which impact upon horticultural chain management and marketing need to be overcome.

REFERENCES

Rahmawati, B and E. Mahajoeno. 2009. Variation of morphology, isozymic and vitamin C content of dragon fruit varieties. Bioscience 1:131-137
STATUS OF DRAGON FRUIT PRODUCTION IN MALAYSIA

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ABSTRACT

Dragon fruit is one of most popular fruits grown in Malaysia even though it was not originally considered native of this country. Dragon fruit planting has become one of the potential export fruits beside existing local fruits. It has fast return on investment which could raise farmers income for small and large cultivation. Between the years of 2006 until 2009, many growers in Malaysia produce dragon fruit due to high demand and good price. Dragon fruit production area reached its highest peak in 2008 with 2,200 hectares compared with only 920 hectares in 2006. Its production reached highest in 2009 with 15,700 metric tons compared with 2,500 metric tons in 2006 with average 12.5 t/ha of yield. However the production of this fruit decrease steadily starting in 2011 (1,525 ha) and till 2013 only 452 ha actively produce this fruit. This is because of outbreak of soft rot caused by Xanthomonas compestri. High rainfall and humidity caused disease outbreak in Malaysia. However, some dragon fruit farms managed to escape from the catastrophe. This is due to the patience and relentless efforts to combat disease problems. Farmers had managed to move forward from their past experiences to uphold this lucrative industry. Several steps have been taken to enhance this industry such as disease and resistant planting materials, improved crop management practices, post-harvest handling and storage management, as well as efficient transfer of technology.

Keywords: dragon fruit, production, diseases

INTRODUCTION

Dragon fruit (Hylocereus polyrhizus) or ‘buah naga’ and ‘buah mata naga’ in the local language is one of the most recent newcomers in the Malaysian fruit industry. The dragon fruit originated from the South America, and was brought by the US Army to Vietnam during the Vietnam War. Since then, it has been cultivated in Vietnam and slowly became a commercial product. Dragon fruit has been grown in large scale in Vietnam since 1990 to provide fruits to the local and export markets in South East Asia. It also became an attractive product for foreign consumers. Dragon fruits have been introduced to Malaysia when Malaysians imported the product from Vietnam 15 years ago.

Dragon fruit has oval shape, red in color and its fruit between 10-15 cm; weighs between 300 to 500 grams. It has sweet to light sour taste and has many tiny black seeds which can be eaten. Yellow dragon fruits are small size and with average weight of about 100 grams and are very sweet. Dragon fruit has been reported to be a long day plant. It belongs to the Crassulacean Acid Metabolism (CAM) species which means that
it only opens their stomata at night for carbon dioxide intake. A dragon fruit plant is an epiphytic where it needs pillars to support its soft stems and branches.

Dragon fruits are rich in vitamins and minerals that can help improve body metabolism. It is good for digestion and blood circulation. Reports have shown that dragon fruits have positive response to reduce high blood pressure and neutralize toxins in the body. Red flesh dragon fruit has high antioxidants content which has high medical value. Besides consumed fresh, the red dragon fruit can also be processed into cordial, jam, wine and other products. There are reports that the content and the skin of dragon fruit can be used as natural food coloring for lipsticks. This natural food coloring is safe to be used because it does not have any side effects and no known harm to our health.

**VARIETY**

Nowadays, the dragon fruit has been cultivated on a large scale in Malaysia as well as in other countries. The dragon fruit growing areas are in the states of Johor, Perak, Negeri Sembilan, Pahang, Pulau Pinang and Sabah (Table 1). They are three varieties of dragon fruits grown in Malaysia namely; white flesh dragon fruits (*Hylocereus undatus*), red flesh dragon fruit (*Hylocereus polyrhizus*) and yellow skin dragon fruit (*Selenicereus megalenthus*). However, there were two varieties that suitable planted in Malaysia i.e. red and white flesh varieties (Figure 1).

Table 1. Dragon fruit production in by state in Malaysia

<table>
<thead>
<tr>
<th>States</th>
<th>2008 Hectarage (Ha)</th>
<th>2008 Production (Mt)</th>
<th>2009 Hectarage (Ha)</th>
<th>2009 Production (Mt)</th>
<th>2010 Hectarage (Ha)</th>
<th>2010 Production (Mt)</th>
<th>2011 Hectarage (Ha)</th>
<th>2011 Production (Mt)</th>
<th>2012 Hectarage (Ha)</th>
<th>2012 Production (Mt)</th>
<th>2013 Hectarage (Ha)</th>
<th>2013 Production (Mt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Johor</td>
<td>591.0</td>
<td>3,842.3</td>
<td>571.0</td>
<td>11,175.0</td>
<td>510.3</td>
<td>2,876.2</td>
<td>366.6</td>
<td>2,497.1</td>
<td>190.5</td>
<td>1,515.7</td>
<td>91.9</td>
<td>4143.1</td>
</tr>
<tr>
<td>Kedah</td>
<td>69.3</td>
<td>145.2</td>
<td>46.9</td>
<td>211.1</td>
<td>46.4</td>
<td>71.6</td>
<td>18.2</td>
<td>38.0</td>
<td>12.1</td>
<td>48.6</td>
<td>12.2</td>
<td>128.3</td>
</tr>
<tr>
<td>Kelantan</td>
<td>170.0</td>
<td>462.1</td>
<td>76.2</td>
<td>105.0</td>
<td>28.3</td>
<td>69.6</td>
<td>12.1</td>
<td>100.9</td>
<td>4.2</td>
<td>46.2</td>
<td>1.9</td>
<td>10.7</td>
</tr>
<tr>
<td>Melaka</td>
<td>138.0</td>
<td>771.5</td>
<td>166.0</td>
<td>1,005.0</td>
<td>169.0</td>
<td>977.5</td>
<td>159.0</td>
<td>1,168.0</td>
<td>151.0</td>
<td>1,208.0</td>
<td>105.5</td>
<td>1034.8</td>
</tr>
<tr>
<td>Negeri Sembilan</td>
<td>506.4</td>
<td>687.7</td>
<td>78.4</td>
<td>280.1</td>
<td>76.3</td>
<td>238.8</td>
<td>31.4</td>
<td>365.4</td>
<td>29.4</td>
<td>484.6</td>
<td>50.8</td>
<td>885.9</td>
</tr>
<tr>
<td>Pahang</td>
<td>364.9</td>
<td>1,293.8</td>
<td>307.0</td>
<td>593.8</td>
<td>128.1</td>
<td>478.4</td>
<td>23.1</td>
<td>219.5</td>
<td>19.7</td>
<td>97.5</td>
<td>10.9</td>
<td>60.0</td>
</tr>
<tr>
<td>Perak</td>
<td>57.7</td>
<td>197.7</td>
<td>60.9</td>
<td>104.2</td>
<td>58.6</td>
<td>137.6</td>
<td>18.2</td>
<td>60.8</td>
<td>40.7</td>
<td>75.0</td>
<td>11.9</td>
<td>99.7</td>
</tr>
<tr>
<td>Perlis</td>
<td>2.1</td>
<td>4.7</td>
<td>2.1</td>
<td>4.5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Pulau Pinang</td>
<td>53.5</td>
<td>165.6</td>
<td>52.1</td>
<td>383.9</td>
<td>39.5</td>
<td>397.4</td>
<td>36.3</td>
<td>402.5</td>
<td>6.0</td>
<td>210.7</td>
<td>13.8</td>
<td>1003.0</td>
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<td>Selangor</td>
<td>220.2</td>
<td>759.4</td>
<td>211.0</td>
<td>1,129.2</td>
<td>248.5</td>
<td>4,332.5</td>
<td>215.5</td>
<td>2,887.8</td>
<td>279.8</td>
<td>2,127.5</td>
<td>87.3</td>
<td>913.6</td>
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<td>Terengganu</td>
<td>16.1</td>
<td>59.6</td>
<td>34.5</td>
<td>30.2</td>
<td>59.3</td>
<td>32.8</td>
<td>31.7</td>
<td>32.6</td>
<td>11.8</td>
<td>42.4</td>
<td>5.6</td>
<td>9.2</td>
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<tr>
<td>Peninsular M’sia</td>
<td>2,189.2</td>
<td>8,389.6</td>
<td>1,606.2</td>
<td>15,022.0</td>
<td>1,364.2</td>
<td>9,612.3</td>
<td>912.1</td>
<td>7,772.5</td>
<td>745.3</td>
<td>5,856.3</td>
<td>391.8</td>
<td>8288.3</td>
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<tr>
<td>Sabah</td>
<td>75.7</td>
<td>622.6</td>
<td>78.7</td>
<td>637.9</td>
<td>89.1</td>
<td>532.4</td>
<td>41.3</td>
<td>130.3</td>
<td>59.5</td>
<td>358.0</td>
<td>52.0</td>
<td>258.8</td>
</tr>
<tr>
<td>Sarawak</td>
<td>-</td>
<td>-</td>
<td>75.5</td>
<td>36.60</td>
<td>69.9</td>
<td>43.7</td>
<td>7.1</td>
<td>36.6</td>
<td>7.1</td>
<td>36.6</td>
<td>8.0</td>
<td>29.9</td>
</tr>
<tr>
<td>WP Labuan</td>
<td>2.5</td>
<td>4.0</td>
<td>2.0</td>
<td>4.00</td>
<td>2.5</td>
<td>3.5</td>
<td>2.3</td>
<td>3.5</td>
<td>0.6</td>
<td>0.6</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>2,267.4</td>
<td>9,016.2</td>
<td>1,762.4</td>
<td>15,700.5</td>
<td>1,525.7</td>
<td>10,191.9</td>
<td>962.8</td>
<td>7942.9</td>
<td>812.5</td>
<td>6251.5</td>
<td>451.8</td>
<td>8577.0</td>
</tr>
</tbody>
</table>

Source: Department of Agriculture
Improving Pitaya Production and Marketing

White flesh variety  Red flesh variety  Yellow skin variety

Figure 1. Three varieties of dragon fruits that could be grown in Malaysia

PRODUCTION

Malaysia has hot humid climate which permits the cultivation of many different types of fruit. Some of the fruits grown here are native to this part of the world. These includes indigenous fruits like mangosteen, durian, rambutan and a number of species of bananas. Dragon fruit production in Malaysia started with the public sector and was not included in Malaysian government’s development plan. After many trials and errors, dragon fruit cultivation has finally made its way in the Malaysian fruit industry. Unlike Vietnam and Thailand which had long history of dragon fruit growing, Malaysia is keeping good pace to lead its niche market due to high local demand.

The years 2006 until 2009 showed many growers in Malaysia producing dragon fruit because it has high demand and commanded good price. This crop also has good return on investment because it is yields fast and starts to produce fruit as early as one year after planting. Besides fruits, growers also make profit in supplying planting materials for new growers and hobbyists that offer high prices. Its production reaches highest in 2009 with 15,700 metric tons compared 2500 metric tons in 2006 with an average of 12.5 met/ha of yield. However the production of this fruit decreased steadily starting in 2011 (1,525 ha) and till 2013 only 452 ha actively produced this fruit (Figure 2). This is because of the outbreak of soft rot disease caused by Xanthomonas compestri.

Figure 2. Dragon fruit hectarage and production in Malaysia 2006-2013. Source: Department of Agriculture
Dragon fruit can be harvested all-year round and it bears fruits after one year of planting. The peak seasons are around April and September but in some places the harvesting time might vary. The average production in one hectare for second year of planting ranges between 2 to 8 tons and later increases to more than 10 t/ha once the crops mature.

The size of fruits depends on several factors such as good pollination, sufficient water and farm management practices. Bigger fruit size will command higher prices compared with the small ones. Dragon fruits are graded into ‘AA’ for 500-800g, grade ‘A’ for 350-450g, grade ‘B’ for 250-350 g and grade ‘C’ below 250 g.

MAJOR CONSTRAINTS

Bacterial and fungal diseases are considered the major constraints for dragon fruit production. The major enemy is stem and collar rots which is caused by *Xanthomonas campestris*. This disease was the reason why many dragon fruit farms did not survive and production decreased dramatically. Once infected, the disease will spread all over the farm if they are not controlled with bactericides. Good agricultural practices must be implemented to avoid this disease. It is to be noted that pruned branches that are infected with disease should not be left freely in the field due to buildup of more diseases instead they should be burnt or thrown far away. Another disease is fungal infection by *Phomopsis* and *Dothirella*, which is caused by black spots on the fruits. Regular control using fungicides could reduce disease infestations.

Despite disease outbreak in Malaysia, some dragon fruit farms managed to survive from the catastrophe. This is due to the patience and relentless efforts to combat the disease. Farmers had managed to move forward from their past experiences to uphold this lucrative industry. While researchers at their utmost doing research to support the industry be it in farm production or by products. Research must be geared up in order to find new innovations and technological advancements to cater to future problems like climate change and organic farming.

MARKETING: LOCAL, NATIONAL AND INTERNATIONAL

The marketing of dragon fruits are mainly local. As far as international market is concerned, countries like Singapore, Hong Kong and Middle East countries as well as UK are keen on buying the fruit. The red flesh variety is the most popular due to its high price at RM 8.00 (USD 2.00) per kg compared to white at RM 5.00 per kg (USD1.50).

Lately in 2013, the production of dragon fruit in Malaysia was reduced to 8,577 metric tons due to diseases.

ORGANIZATION OF PRODUCTION AND MARKETING

The Malaysian authorities had taken positive measures to enhance the growing of dragon fruits in the country. For instance, the Malaysian Standards (SIRIM) has produced standard operating procedures (SOP) and specifications on planting materials.
Improving Pitaya Production and Marketing

(Figure 3). The Department of Agriculture had also come out with farming practices with Good Agriculture Practices through MyGAP or SALM (Figure 4).

![Figure 3. Malaysian Standard on dragon fruits planting materials specification](image3.jpg)

**SKIM AKREDITASI LADANG MALAYSIA (SALM)**
**FARM ACCREDITATION SCHEME OF MALAYSIA**

![Figure 4. Logo MyGAP or SALM, Farm accreditation scheme of Malaysia](image4.jpg)
RESEARCH AND DEVELOPMENT

Early research on dragon fruits was carried out on yield performances and varietal evaluation. Zainudin (2005) found that dragon fruits yielded from 5 to 8 t/ha. after second year of planting and increased by 10-15% as the crop matures. Red flesh cultivar (H. polyrhizus) was found to better accepted compared to white flesh (H. undatus) by farmers basically due its high consumer preferences. Other research aspects on flower biology, flower initiation and development by Realiza et al. (2007) revealed that poor fruit set of 10-20% in pitaya is the main constraint in producing high yield.

Hamidah et al. (2008) studied the diseases of dragon fruits which were heavily infested by Dothirella and Phomopsis which caused black spots on the fruits, and X. campestris, which caused soft rot. Pests like Xylopetrus and Dacus dorsalis are common. This was mainly due to non-accredited planting materials and crop husbandry problems. However, the Malaysian Standards (SIRIM 2010) has come out with dragon fruits planting specifications guidelines for growers to overcome such problems.

Marini et al. (2008) studied the growth, yield and fruit quality of red dragon (H. polyrhizus) fruit as affected by plant support system and intercropping with long bean (Vigna sinensis). They found that dragon fruit plants grown using the pole system showed 17-38% more flower buds, 15-36% more fruits and 24% heavier total fruit weight compared to those of the T bar trellis and V shape systems, respectively. There were also significant effects of plant support systems on soluble solid concentration (% Brix) where T bar trellis and pole systems showed 7% higher soluble solid concentration than that of the V shape system. Intercropping had no influence on all the parameters measured. Support systems did not have any significant effect on the stem diameter, chlorophyll concentration of stem, and days to attain fruit maturity in red dragon fruit and in the yield of long bean. Similarly, fruit quality including fruit pH, fruit diameter, fruit length, peel and pulp color and titratable acidity were not affected by different support systems or intercropping.

Nazarudin et al. (2011) found that extraction from dragon fruit peels (H. polyrhizus), a by-product of processing contained an alternative source of pectin. They found that the extracted pectin from dragon fruit peels was 20.1% (dry weight basis) by ammonium oxalate/oxalic acid extraction with 11.2% moisture and 6.9% ash. Extraction by deionised water yielded 15.4% pectin, 11.3% moisture and 11.6% ash. Whereas, the acid extraction gave the lowest yield (15%), 11.1% moisture and 12% ash. The amount of pectin from all extraction conditions were comparable to pectin obtained from commercial apple (12%) or citrus (25%).

Metabolites studies in dragon fruits carried out by Sew et al. (2010) on red pitayas were with different ripening index. Total RNA of red pitaya fruits with 35 days after anthesis (DAA) were extracted and purified to get high quality total RNA. The purified total RNA was then subjected to Solexa sequencing using paired-end mRNA-seq method. The mRNA-seq sequencing results showed that total number of red pitaya paired-end reads obtained was 18,530,028 sequences and total number nucleotides obtained was 1,389,752,100nt. Sequence assembly using Velvet software revealed a total of 106,867 nodes. After the sequence filtering process (set value as >80bp/node), we obtained 62,333 nodes. The homology search on the filtered sequences against non-redundant nucleic acid database (NR) showed that 31,423 nodes with significant E-
value $\leq 10^{-5}$. It was found that there were at least 97 nodes mapped to secondary metabolic pathways via Blast2Go analysis, particularly the biosynthesis pathways of phenylproparoid, betalain, flavonoid, carotenoid and monoterpenoid. They concluded that identification of genes involved in secondary metabolism and their corresponding biochemical pathways would enable harnessing the potential of red pitaya as functional food with optimal level of beneficial phyto-chemicals and also to control the production of those phyto-nutrients through genetic manipulation.

Post-harvest of dragon fruit maturity indices were done by Abdullah (2006) and it was found that red pitaya fruits were harvested eight stages of fruit development. They found that farmers would normally fruit index at stage 6 for local markets and at stage 5 for distant markets (Figure 5).

![Figure 5. Fruit index 1 to 8 in dragon fruits with TSS and PH.](image)

**CONCLUSION**

There is no doubt that dragon fruit planting has become one of the potential export fruits beside existing local fruits in Malaysia. It has fast return on investment which could raise farmers income for small and large cultivation. Besides, the fruit’s future is bright due to untapped downstream activities of its by products which could be developed by the agriculture sector. Several steps should be taken to enhance this industry such as disease and resistant planting materials, improved crop management practices, post-harvest handling and storage management, as well as efficient transfer of technology.
REFERENCES

Abdullah, H. 2006. Development of effective storage and handling techniques for selected highly perishable fruits (dokong, salak, wax apple and dragon fruit) with good market potential. 05-03-08-SF0026. (unpublished).


PITAYA PRODUCTION AND MARKETING SCENARIO IN MYANMAR: CURRENT STATUS AND CHALLENGES

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ABSTRACT

Pitaya cultivation in Myanmar is at its infancy stage but the domestic producers are trying to meet all local demand and the surplus to export. Unfortunately, there are some limitations to improve its yield potential. The major production constraints includes pre-harvest and post-harvest practices such as pest/disease problems, appropriate technologies that would improve yield, quality, and marketability of dragon fruit. Moreover, there is a need to develop strategies to promote dragon fruit in the international markets. Value chain of pitaya production should be started from the farm for export marketing. Myanmar's Ministry of Agriculture and Irrigation has been trying to increase pitaya production by conducting research and development activities to develop appropriate production technologies and establishing large demonstration farms for disseminating developed technologies to local producers. With market oriented policy and foreign investment law in Myanmar, contract farming for pitaya production should be encouraged for further development of pitaya production and marketing.

INTRODUCTION

Myanmar is geographically located between 9°58´ to 28°31´north and 9° 29´ to 10°10´ East. Myanmar’s population is increasing steadily at an annual growth rate of 1.8% with approximately 50 million in 2014. Seventy-five percent of its total population is living in rural areas. Agriculture sector is the backbone of the country’s economy. It contributes 23% of the GDP and 20% of total export earnings, and employs 61.2% of the labor force. The main functions of the Department of Agriculture under the Ministry of Agriculture and Irrigation (MAI) are: 1) provision and production of high-quality seeds; 2) training and education; and 3) research and development.

Presently, there are about 11.87 million hectares of net sown area in Myanmar (Table 1). A variety of crops is grown in the sown area (Table 2). For the expansion of new agricultural land, the remaining 0.46 million hectares of fallow land and 5.28 million hectares of cultivable waste land can still be developed.
Table 1. Land utilization in Myanmar in 2013-2014

<table>
<thead>
<tr>
<th>Particulars</th>
<th>Million hectares</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net area sown</td>
<td>11.87</td>
</tr>
<tr>
<td>Fallow land</td>
<td>0.46</td>
</tr>
<tr>
<td>Cultivable waste land</td>
<td>5.28</td>
</tr>
<tr>
<td>Reserved forests</td>
<td>18.60</td>
</tr>
<tr>
<td>Other forest area</td>
<td>14.84</td>
</tr>
<tr>
<td>Other land</td>
<td>16.61</td>
</tr>
<tr>
<td>Total</td>
<td>67.66</td>
</tr>
</tbody>
</table>

Source: Department of Agricultural Planning, MAI

Table 2. Main crops cultivated in Myanmar

<table>
<thead>
<tr>
<th>Group</th>
<th>Crops</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cereals</td>
<td>paddy, wheat, maize, sorghum</td>
</tr>
<tr>
<td>Oilseeds</td>
<td>groundnut, sesame, sunflower, niger, mustard</td>
</tr>
<tr>
<td>Pulses</td>
<td>17 kinds of pulses including black gram, pigeon pea, soybean, pelun, kidney bean, butter bean, chick pea, garden pea, sultapya</td>
</tr>
<tr>
<td>Industrial crops</td>
<td>cotton, sugarcane, jute, rubber, coffee, mulberry, oil-palm</td>
</tr>
<tr>
<td>Kitchen crops</td>
<td>chili, onion, garlic, ginger, turmeric, potato</td>
</tr>
<tr>
<td>Fruit &amp; vegetables</td>
<td>mango, banana, citrus, pears, durian, mangos teen, pineapple, rambutan, pitaya and others tropical and temperate vegetable</td>
</tr>
</tbody>
</table>

Source: Department of Agricultural Planning, Ministry of Agriculture and Irrigation

The tropical and temperate climate in Myanmar favors the year-round fruit production. Table 3 shows the fruit cultivation area in Myanmar. Although pitaya or dragon fruit (*Hylocereus* spp.) is a new crop in Myanmar, it has gained popularity among local growers and consumers in the past decade. Commercial cultivation is expanding because of its high market potential. And domestic producers are trying to meet all local demand and the surplus to export. However, there are still no reliable official data available on the nation-wide production of this crop (Table 3).
Table 3. Fruit cultivation area in Myanmar (hectare)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Mango</td>
<td>78009</td>
<td>79909</td>
<td>82958</td>
<td>93890</td>
<td>95993</td>
</tr>
<tr>
<td>Lime</td>
<td>17059</td>
<td>17660</td>
<td>18106</td>
<td>19892</td>
<td>19808</td>
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<tr>
<td>Orange</td>
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<td>14289</td>
<td>14192</td>
<td>14463</td>
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<td>6696</td>
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<td>Durian</td>
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<td>8443</td>
<td>8614</td>
<td>9457</td>
<td>9479</td>
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<tr>
<td>Grape</td>
<td>1298</td>
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<td>884</td>
<td>1232</td>
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<td>87416</td>
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<tr>
<td>Tamarind</td>
<td>18249</td>
<td>18573</td>
<td>18703</td>
<td>18882</td>
<td>18897</td>
</tr>
<tr>
<td>Pitaya</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>101</td>
</tr>
</tbody>
</table>

Source: Department of Agricultural Planning, MAI

DRAGON FRUIT CULTIVATION AND CONSUMPTION

Growing area
According to the feasible study of dragon fruit production in selected area, there are 46 hectares in Naung Cho Thibaw in Shan state; 28 ha in Pyin Oo Lwin, Kyaukse, Meiktila; 12 ha in Oattwin, Yedashe, Bago, Pyay in Bago division; 4 ha in Aunglan, Pakokku; 4 ha in Naypyitaw; 6 ha in Taikyi and Hlegu. A total of 100 hectares have been cultivated with pitaya crop ranging from small to commercial scale.

Varieties
Growers are using several species and hybrids with varying skin and pulp colors. But *Hylocereus undatus* (pitaya blanca or white-fleshed pitaya) and *H. costaricensis* (pitaya roja or red-fleshed pitaya or *H. polyrhizus*) are imported and widely grown in Myanmar.

Cultivation system
In the dragon fruit growing area, various lengths of cuttings are taken from one year old mother plant. The cuttings are transplanted to the field after one month in the seed bed. Different spacing are used (9’x9’), (9’x12’), (8’x8’), (8’x10’), (8’x12’), (10’x12’) in different growing regions. Strong poles are used so that they can withstand the stem weight. A trellis for individual plants is also constructed consisting of a pole of rocks or blocks and a structure at the top of the pole to support the plant.

Pitaya market
The ripening season generally occurs from May-June to the end of October. Six to seven waves of fruit picking could be done in a year. All fruit harvests could be sold out in the local markets. During the off-season period, some dragon fruits are imported from abroad. Dragon fruit consumption is low in comparison with other fruits in Myanmar. This is due to some consumers do not like the taste, and higher prices comparing with other fruits. However, there is a high potential of increased consumption in view of the increasing trend of commercial production.
**Pests and diseases**

Rats and ants are main pests causing damage to fruit and plants. Several important diseases have also been observed in the growing areas including severe stem rot, stem canker, soft rot and anthracnose damage to plants and fruits.

**Uses**

In terms of fruit consumption, dragon fruits are not only eaten fresh but are also used to make jams, salads, ice-cream, juice and beverages. Moreover, introduction of dried fruit process is being planned by using non-marketable fruits. Most consumers in Myanmar believe dragon fruits have some health benefits that includes control of blood glucose level in diabetes, hypertension and others. They use different consumption styles such as tops in soups, dried flowers in tea, and vegetables in traditional meals.

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**PITAYA RESEARCH AND DEVELOPMENT**

Research results from the Vegetables and Fruits Division of MAI’s Department of Agricultural Research show that 6-cm top cutting promoted flower initiation, and increased flower number, fruit number, and fruit weight. Moreover, fertilizer rate of 50 gm (once in 6 week) increased in fruit yield (number and weight) and gave the highest profit (Annual Reports 2009 and 2010).

Po (2011) found that more number of roots, shoots, and longer shoot produced using longer cutting (23 cm and 31 cm) than the shorter ones (15 cm) in both dry and wet seasons. And a growing substrate with a mixture of sand, organic manure and burnt rice husk resulted in maximum number of roots, shoots and longer shoot. Moreover, application of indole 3-butyric acid at 1000, 2000 and 3000 ppm on 15-cm cuttings grown in sand significantly produced more roots.

Apart from the above, R&D activities on dragon fruit are still in its infancy stage and have not been widely developed in Myanmar. As a profitable potential new crop, more efforts on area expansion and R&D activities will be performed.

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**RECORDS ON GROWTH CONDITION**

**Shan State**

It is located in the hilly region and has favorable environment conditions for pitaya production which, according to experts are marketable since it has pH 5.7, annual rainfall of 1,300-1,500 mm, and 90-100 raining days in a year and minimum temperature 0°C. Cultivation system consists of two types; trellis or pile type and row planting. Plant and row spacing for row planting is 1’x10’, 4300 plants per acre and plant and row spacing for pile planting is 7’x10’, 622 plants per acre. All are well within the parameters of good growth condition and average yield was recorded at 8,000-10,000 kg per acre. Still, this is still considered as home gardening state because of the limited technology and skilled workers. There is yet no export market available and all produce are sold out in the local market. Price is different depending on fruit size and color. Red-fleshed pitaya is higher price of 2500 Kyats-3000 Kyats (USD2.5-3) per kg than 2500 Kyats-3000 Kyats (USD2.5-3) per kg for white-fleshed pitaya. Pitaya cultivation and market are shown in Figures 1 and 2.
**Bago Division**

It is located in the lower part of Myanmar and has 1,800-1,900 mm of annual rainfall, 120-135 raining days in a year and maximum temperature of 42°C. Wine making by using non-marketable fruits are introduced as value-added products. Traditional medicine product by using fruit paste from wine making is still in its experimental stage. Ripe dragon fruits are marketed to locals and in the Mandalay area. The selling price is 2000-2500 Kyats (USD 2.0-2.5) per kg depending on fruit size.
Mandalay Division

It is located in central dry zone and has 1,400 mm of annual rainfall, 55 raining days in a year, minimum and maximum temperature of 19°C and 38°C. Dragon fruit cultivation in Popa region started in 2000. Cultivation system consists of two types; trellis or pile type and row planting. Plant and row spacing is 9'x9' or 9'x6', and 2-3 plants per pile and grown 540-880 plants per acre. Dragon fruits are marketed to Mandalay, Magwe and Naypyitaw regions.

CHALLENGES IN PITAYA PRODUCTION AND MARKETING

In Myanmar, there are several constraints limit achieving yield potential of dragon fruit. Poor production technologies lead to serious occurrences of pests and diseases. Disease-free and high yielding varieties are not available to the farmers. Therefore, some varieties have been attacked by pests and diseases after 2-3 years of planting and the plants are in deep need of replacement, especially with new varieties. Systematic quarantine procedure is urgently needed to check the imported varieties from abroad. Ripe fruits are accumulated in markets within 2-3 days although fruit production period is long. Absence of cold storage facilities could not control the market price. Value-added byproducts could not be produced. If the farmers know and use the off-season production technologies, they will earn year-round income and be more profitable. Cold storage facilities are needed to avoid the product accumulation at the market. During the off-season period, only rich people could buy the imported dragon fruits which are sold at high prices. With the current state of cultivation and production, which is often described to be in its gardening stage, government departments should cooperate in technology transfer and financial support and policy concern for import and export market availability.

CONCLUSION

In the past decade, pitaya crop has gained popularity among local growers and consumers in Myanmar. Commercial cultivation of dragon fruit has been extended except for very cool regions because the authorities are very much aware of the fruit’s high market potential. However, there is a need to develop strategies to promote dragon fruit in the international markets. Value chain of pitaya production should start from the farm for export marketing. Myanmar’s Ministry of Agriculture and Irrigation has been trying to increase pitaya production by developing appropriate production technologies and establishing large demonstration farms, for example, in area near new capital Naypyitaw, and disseminating the technologies to local producers. With the Government’s new market-oriented policy and foreign investments law, contracted farming for pitaya production is possible. Detailed information on this is available in MAI’s Department of Agriculture.
REFERENCES

DRAGON FRUIT PRODUCTION AND MARKETING IN THE PHILIPPINES: ITS STATUS, CONSTRAINTS AND PROSPECTS

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Email: leopascua59@yahoo.com

ABSTRACT

Dragon cactus, *Hylocereus* spp., is an introduced crop in the country. Its cultivation in the Philippines started in small scale in the early 90’s. Through the years, it had evolved wherein areas expanded and production increased tremendously. This is because of the implementation of several strategies in technology promotion through the sustained efforts of various agencies and individuals reaching the grassroots in most parts of the archipelago. State universities such as the Mariano Marcos State University in the City of Batac and Cavite State University in Indang, Cavite carried out basic and applied researches for the improvement of the package of technology on dragon fruit production, its utilization and marketing. Whereas, the Kailokoan Saniata Producers Cooperative (KASACOOP) has become a very potent partner which assumes the lead role in the dragon fruit production and marketing that had transformed into a private led industry. Likewise, its fruits are marketed locally in supermarkets, fruit stands in the cities and municipalities, along the highways, on-line selling, peddling and special distribution or delivery lines and are also brought to big cities by the producers or by middle men.

Major constraints were identified such as low yield, prevalence of insect pests and diseases, short shelf life of fruits, no standardization of fruit quality, no continuous supply of fruits, problems on marketing among others. Thus, the development of Quality Assurance Protocol (QAP), Good Agricultural Practices (GAP), technology on organic dragon fruit production and high yielding varieties that posses good fruit quality and resistance to pests; the improvement of Integrated Crop Management (ICM), Integrated Pest Management (IPM) and Post-Harvest Quality Management (PQM); and the conduct of supply and value chain analysis as well as marketing studies will be undertaken. In addition, value adding on food, pharmaceutical and beauty products can also be harnessed. Thus, efforts have to be exerted in research and development to facilitate the further expansion of the industry as an alternative crop for the changing environment. This is in support to the growing demand among local consumers and possibly for export in the near future. This will further generate employment and livelihood opportunities, and give benefits to other industries such as trade, tourism, transport among others which ultimately contributes in addressing community development and economic growth.
INTRODUCTION

Dragon cactus (Hylocereus spp.), locally known as “saniata” (a lovely maiden derived from its beautiful flowers), is an introduced crop in the country. It gained popularity, hence, poses a great demand among local consumers. Despite its relative high price, it is still a favorite fruit among many Filipinos because of its known therapeutic properties (Mahattanatawee et al. 2006; Khalili et. al. 2006; Thulaja 1999; Zee et al. 2004; Jaafar et al. 2009) and is being considered as a “Healthy Food for the Table.” This fruit has eventually posed great demand among local consumers and has encouraged many farmers to get involved in dragon fruit production.

Dragon fruit is adaptable in the Philippines because of the favorable climatic conditions. This can be grown even in marginal areas which abound the country. This has become an emerging champion in the local fruit industry because of its high profitability and the great demand thereby giving a lucrative income to growers.

Dragon fruit was probably introduced during the Manila-Acapulco galleon trade in the Spanish era from New Spain, Mexico to Manila or Cebu in 1565. A proof is the presence of a variety in many homes grown for many years as ornamental plant before the introduction of the commercial cultivars.

The first commercial variety grown in the Philippines was traced back in the farm of a Taiwanese businessman named Mr. Alex Liton in Tambong Balagbag in Indang, Cavite. According to Mr. Nicolas Silan, who was employed as caretaker in his six hectare-farm, Mr. Liton introduced a white-fleshed variety from Taiwan in 1992 and planted in his six-hectare farm.

Out of interest, he got dragon fruit cuttings for 16 posts and planted in his farm, just besides Mr. Liton’s. During his stint as caretaker, he had obtained ample knowledge and skills in dragon fruit production. His first harvest was sold in Binondo, Manila and realized a lucrative. At first, there was difficulty of selling the produce because dragon fruit was not known yet to the populace. However, as the fruit was introduced, the demand started to increase tremendously because of its good taste. He was satisfied with the first income so he added 2,000 posts and left his job as caretaker of Mr. Liton’s farm and concentrated in his own farm. To date, these are considered as the oldest dragon fruit in the country. The older dragon cactus plants of Mr. Liton were already replaced with sugar apple after Cavite was saturated with dragon fruit.

After two years, he gave planting materials to his relatives and unselfishly taught them how to grow. His relatives and neighbors had started growing dragon fruit which led the expansion of dragon fruit in Cavite, in Luzon, in Visayas and in Mindanao. One of his nephews, Mr. Eddie Silan, was the recipient of the dispersal. He also believed that the initial planting materials in Remulla’s Farm came either from him or Mr. Liton’s.

After few years, Mr. Eddie Silan encountered some abnormalities in his dragon fruit. He consulted experts of the Cavite State University in Indang Cavite. This gave an avenue on the conduct of researches on dragon fruit pest management and cultural management practices led by Dr. Teddy F. Tepora and Dr. Evelyn Singson. With their passion and commitment on this commodity, the Cavite State University Research Team started making innovations on dragon fruit processing wherein they successfully acquired patents for the various products developed.
In view of the Techno Gabay Program, Mr. Eddie Silan was appointed as Farmer Scientist for dragon fruit in the Southern Tagalog Region. The Techno Gabay Program is a technology promotion modality in agriculture and natural resources which was spearheaded by the Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development (PCAARRD) in coordination with various research and development (R&D) consortia in the country.

In Ilocos Norte, the crop found its niche way back in the early 90’s when Dr. Xuan Yhoi Troung brought home cuttings of white fleshed dragon cactus from Vietnam. He and his wife, Mrs. Luzviminda Troung planted these cuttings at the back of their apartment at the National Tobacco Administration (NTA) Housing located in Tabug, Batac, Ilocos Norte. Because this fruit was not popular in the country at that time and was considered as ordinary, they kept this plant to themselves and none bothered asking them for planting materials.

In Cagayan, Engr. Bejamin Bayani, a former assistant director of the National Irrigation Administration of Region 2, recalled that a Taiwanese friend, a certain Mr. Amigo Chan introduced the dragon fruit by inviting him to his farm in Baler, Aurora in the late 90’s. With a very persuasive explanation of Mr. Chan focusing on the medicinal values and lucrative income, he acquired about 500 stem cuttings and planted in his farm in Lucban, Abulog, Cagayan. After the first harvest, he gained a lucrative income which propelled him to expand into wider scale up to four hectares. The market of his produce was not a problem because fruits heavier than 250 grams were traded to Mr. Chan for export and domestic market.

Engr. Bayani remembered that dragon fruit was not initially saleable in their locality. But his wife patiently marketed them in the various offices and schools in their own town by giving the buyers free taste. The delicious taste and people’s awareness on the medicinal benefits of the fruits, consumers gradually accepted it that led into higher demand not only of the fruits but also of the planting materials. Several farm owners in Abulog and nearby towns and provinces followed the steps of Engr. Bayani. Many households also planted in their backyards. Engr. Bayani believed that the source of planting materials of dragon fruit farms in Ilocos Norte such as REFMAD Farm of Mrs. Edita A. Dacuycuy in Burgos, Ilocos Norte, Benemerito Farm in Pagudpud among others was from him.

In 2004, Mr. Florendo Raneses of Nagebcan, Badoc, Ilocos Norte planted another variety of the red-fleshed variety brought home by a relative from Taiwan. He just planted it in his backyard as an ornamental plant, not knowing the economic and health importance. With no knowledge on it, children in the locality gathered the fruits and used them as ball in their playing activities. It was only when a close friend visited their home that he was informed that the fruits commanded a high price.

Because of the mother’s love for her child who was suffering from cerebral palsy, Mrs. Edita A. Dacuycuy ventured into dragon fruit production. Hoping to ease her child’s constipation problem, she started planting the plant on their backyard in Barangay 2, Pasuquin, Ilocos Norte in 2005 and later expanded in their REFMAD Farm in Paayas, Burgos, Ilocos Norte for family consumption. Because of the fruit’s great potential, however, this expanded into a plantation and became the first dragon cactus plantation in Region 1.
Lacking knowledge in agriculture, Mrs. Dacuycuy sent her child, Mimi to Thailand to learn the cultural management. At the same time she sought the assistance of Mrs. Lolita Raposas and her Research Team of the Provincial Agriculture Office (PAO) of Ilocos Norte and then Ilocos Agriculture and Resources Research and Development Consortium (ILARRDEC) through Mr. Leonardo T. Pascua with the Mariano Marcos State University (MMSU) Extension Directorate headed then by Dr. Marivic Alimbuyuguen. As part of the implementation, a technology promotion dubbed as Project Saniata, was executed and was spearheaded by ILARRDEC together with MMSU, PAO of Ilocos Norte, Department of Agriculture (DA), PCARRD, Philippine Rice Research Institute (PhilRice), National Tobacco Administration (NTA), Cotton Development Administration (CODA), Saniata Growers Association and local government units. Mrs. Dacuycuy was also appointed as Farmer Scientist of ILARRDEC in 2008 after which a science and technology based farm (STBF) on dragon fruit was established in her farm. With the increasing number of growers, the Saniata Growers Association was organized in 2009 and this was transformed into Kailokuan Saniata Growers Cooperative (KASACOOP) in 2011.

**CURRENT STATUS OF DRAGON FRUIT PRODUCTION, PRODUCTIVITY, USES, BENEFITS AND MARKETING**

Dragon fruit cultivation in the Philippines started in small scale in the early 90’s and through the years had evolved and the areas expanded into 267 hectares with the production of 1,573 metric tons (Tables 1 and 2). The implementation of several strategies in technology promotion had increased the area planted through the sustained efforts of various agencies and individuals reaching the grassroots in most parts of the archipelago. At first, many people were reluctant in adopting the technology, however, with the testimonies of successful growers, many joined the bandwagon which is now becoming a trend.

![Table 1. Area planted (ha) of dragon fruit in the Philippines (2008-2014)](image.png)
Table 2. Volume (MT) of production of dragon fruit in the Philippines (2008-2014)

<table>
<thead>
<tr>
<th>Province</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ilocos Norte</td>
<td>15.00</td>
<td>46.56</td>
<td>338.41</td>
<td>514.42</td>
<td>441.21</td>
<td>893.84</td>
<td>1,053.52</td>
</tr>
<tr>
<td>Cavite</td>
<td>172.89</td>
<td>151.20</td>
<td>175.00</td>
<td>202.40</td>
<td>222.50</td>
<td>281.85</td>
<td>281.58</td>
</tr>
<tr>
<td>Other provinces</td>
<td>20.80</td>
<td>24.49</td>
<td>44.23</td>
<td>58.75</td>
<td>153.43</td>
<td>238.86</td>
<td>238.86</td>
</tr>
<tr>
<td>Total</td>
<td>208.69</td>
<td>222.25</td>
<td>557.64</td>
<td>775.57</td>
<td>817.14</td>
<td>1,414.55</td>
<td>1,573.96</td>
</tr>
</tbody>
</table>

1 Provincial Agriculture Office of Ilocos Norte
2 Provincial Agriculture Office of Cavite
3 Bureau of Agricultural Statistics
4 Data on 2013 because no other available data

Harvest, yields, and production times

Dragon fruiting season usually start in late part of April but the peak of production is on June and July. Harvest season commences on November but some fruits can extend up to December. The cactus plants flower at the same time with a frequency of 8 to 10 in a year thus, harvest has also an interval of 8 to 10. The yield ranges from 10 to 50 tons and varies according to age of the crop and location. Since most of the areas planted are marginal areas most especially in the Ilocos, the production yield is low compared to other countries.

Post-harvest management and/or processing

After harvest, the fresh fruits are sorted and those pass the quality standard are packed in paper boxes for market. Fruits with low quality are utilized for the processing. Because of the limited supply of fruits, processing of the fruits is still in small scale and most of the products are limited for local consumption.

Uses and benefits

Uses. The fruits can be eaten as raw or processed for ice cream, cookies, candies, jam, wines, shake, for special beverages or as flavour for all kinds of drinks and ingredients of various recipes. The flowers can be cooked as soups, lumpia and as ingredient of Filipino viands. The skin pulps can be processed as embotido, pickles, jam and be boiled as cleansing drinks. The stems and skin pulps can be processed as beauty soap.

Benefits. Many lands in the rural areas in the country especially in the Ilocos Region are characterized as marginal environments: with high pH soil, low fertility, limited water supply, high temperatures and hilly areas. These factors are constraints to intensive agriculture. Many crops, especially those that require very favorable environments are not suited to these areas such as sandy, red or rocky soils where few or no crop is grown. Many of these areas were turned into opportunities. Converting them into dragon fruit farms made these areas into huge productivity gains. In addition, this will also help greening the gray areas which could help climate change mitigation.

Most areas have already been experiencing climate variability. The current weather conditions do not fit with the present farming system. This probably is attributed to climate change which is the result of the many practices that contributed to the deterioration of our environment. Farmers are now experiencing rainfall and temperature patterns outside the regular variability ranges which give very strong impact on the cropping patterns and the daily implementation of farming practices and
ultimately the crop yields and quality. Dragon fruit is a resilient crop that can adapt to very adverse conditions brought about by climate change.

Dragon fruit production helps in poverty alleviation efforts by providing good source of income for the rural families from their home gardens and vacant lots. If a household can harvest a few kilograms of fruits, this can be immediately sold in the market. Similarly, the dragon cactus flowers, fruit peelings and even the fruits can be processed and become an additional income for the family. The sale can provide the basic needs of the family. It can also answer the problems of high prices of fruits and malnutrition of household members. Through planting dragon cactus in home gardens, availability of a delicious and medicinal fruit is possible even to the low-income families. Previously, only few families eat this fruit because the price is exorbitant. Prioritizing the basic needs for survival, eating dragon fruit seemed impossible for those at the lower end of economic scale.

In schools, dragon fruit provides an excellent income for the improvement of the school for more conducive setting of learning. Planting dragon fruit is self-sustaining and lessens the burden of parents, teachers and the government on school operating expenses. Dragon fruit in schools and in home gardens enhance the aesthetic value of the community. This can also increase gross domestic happiness of all growers. Dragon fruit also benefits the tourism industry. Dragon fruit farms are favorite destinations of local and foreign tourists and profited other business.

**Organization of production and marketing**

Dragon fruits are marketed locally in supermarkets, fruit stands in the cities and municipalities, along the highways, on-line selling, peddling and special distribution or delivery lines. The fruits are also brought to big cities such as Metro Manila, Baguio, Cebu, Davao among others by the producers or by middle men. In addition, these are brought to auction markets and sold as wholesale and these are passed to retailers or peddlers. It is also believed that dragon fruits are also exported to Taiwan by a Taiwanese businessman who has a farm in Pampanga.

For possible export of dragon fruit in the future, Ilocos Norte Gov. Imee R. Marcos had initiated a trade mission in Shandong, China. Dragon fruit was also promoted and exhibited in food expositions in China, Germany, United States of America among others.

The Kailokoan Saniata Producers Cooperative (KASACOOP) is a very potent partner in the promotion and commercialization of dragon fruit. It helps provide planting materials for new growers, market products, create and add value and give feedbacks about the applicability of the package of technology. It assumes the lead role in the production and marketing in support to the transformation of dragon fruit as a private led industry. Originally known as Saniata Growers Association, its conversion into a cooperative has boosted the enthusiasm of the growers to expand their production and give more investments in this industry. The cooperative has started selling dragon fruits produced by its members to La Tondena Industries.

Likewise, The Philippine Dragon Fruit Growers and Processors National Council was organized composed of more than 40 big time players in the industry headed by Mrs. Edita A. Dacucuy. The council aims to further boost the dragon fruit industry for local and export markets (Adriano 1014).
CURRENT PRACTICES AND EFFORTS TO PROMOTE PRODUCTION AND MARKETING

Current Practices
A package of technology was developed based on literature, research results and experiences of growers.

Area Selection. Dragon cactus can be grown in well-drained soil with pH value from 5.3 to 6.7. It prefers sandy soil with high organic matter. The crop also needs full sunlight.

Planting Requirements. Planting during the rainy season is encouraged to save irrigation cost in the plant establishment and to ensure that the crop coincide with the flowering season when the plants reach eight month old or more.

Nursery Management. Prepare the planting materials either from the entire stem segment or 15 to 20 cm long. Make a slanted cut on the stem end to improve rooting. Treat stem cuttings with rooting hormones and place in a cool, dry area for five to seven days before planting. Plant the stem cuttings individually in plastic pots or in plots using a well-drained potting medium.

Plant Establishment. Clear the area. Use kakawate wooden posts (40 to 50 cm diameter and 2 m long) or cement posts (15 x 15 cm x 2 m). Bury 45 cm length of the posts and arrange at the distance of 2 m to 2.5 between posts. Place old motorcycle tires as crown at the top of the post supported by three to four L-shaped 10 mm steel bars. Plant four stem cuttings or propagules around the post. Tie the stems in the post. In sandy areas, replacing the soil with high in organic matter is advisable.

Nutrient Management. The fertilizer recommendation at different stages of dragon fruit is as follows:

<table>
<thead>
<tr>
<th>Plant age /Month</th>
<th>Approximate fertilizer requirement/post</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Organic (shv*)</td>
</tr>
<tr>
<td>From planting to one year</td>
<td></td>
</tr>
<tr>
<td>At planting</td>
<td>1</td>
</tr>
<tr>
<td>3 months</td>
<td>-</td>
</tr>
<tr>
<td>6 months</td>
<td>1</td>
</tr>
<tr>
<td>9 months</td>
<td>-</td>
</tr>
<tr>
<td>One year and up</td>
<td></td>
</tr>
<tr>
<td>November</td>
<td>2</td>
</tr>
<tr>
<td>January</td>
<td>2</td>
</tr>
<tr>
<td>April</td>
<td>2</td>
</tr>
<tr>
<td>June/July</td>
<td>-</td>
</tr>
</tbody>
</table>

*shovelful (approx. 2 kg)
**tablespoonful (approx. 18 g)

Method of application. Saniata is a shallow rooted plant and most of the roots are concentrated at the top 15 to 30 cm soil depth. It is then appropriate to split the application of fertilizer to prevent fertilizer leaching. Apply the organic fertilizer liberally
Improving Pitaya Production and Marketing

at the base of the post and incorporate in the soil. Dibble the inorganic fertilizer 5-8 cm away from the base of the plant to prevent direct contact of the fertilizer to the plants.

**Foliar Fertilization.** Apply foliar fertilizer late in the afternoon every two weeks. Follow the manufacturer’s recommendation.

**Tying, training and topping the shoots.** Train the stem canopies leaning towards the posts and tie them using stripped cloth. Top the shoots when the plants reach about one meter. Before the shoots reached the crown, top the shoots to allow the production of numerous shoot. Train the shoots to spread out producing umbrella-like structure.

**Irrigation.** Irrigate the newly planted dragon cactus and twice a week thereafter and just after applying fertilizers except during rainy days. Wet the posts to enhance the growth of aerial roots from the underside of the stems that could provide anchorage for the plants in climbing.

**Pruning.** Prune the stems to obtain an open, manageable and productive umbrella canopy. Remove the shoots developing at the base of the plants; these can be used for planting materials.

**Weeding.** Hand weed within the inner 30 cm diameter of each post and cut the weeds using brass cutter in between posts.

**Pest Management.** Ants attack the shoots and fruits of the dragon cactus. Scale insects attack the stems which cause rotting. Spray soap solution or insecticide only on those affected plant parts. Fruit fly larvae attack the fruits causing them to rot. Use methyl eugenol as pheromone traps to control this pest. Bag the fruits with plastic, cloth or paper bags. Use color on bags as codes for knowing the time of harvesting. Remove disease-infected plant parts or spray fungicide for those attacked by diseases caused by fungus.

**Harvesting and Storage.** The fruit is harvested 28-32 days after flowering. The indices are full red coloration and swelling of the navel. Store at 5 ºC with 90 % RH up to 40 days but they last less than 10 days at room temperature.

**Intercropping.** Plant vegetables, ginger, mungo, pigeon pea, and other short statured crops and vine plants that creep on the ground.

**Research Studies Conducted**
State universities such as the Mariano Marcos State University in the City of Batac and Cavite State University in Indang, Cavite carried out basic and applied researches for the improvement of the package of technology on dragon fruit production, its utilization and marketing.

Basic researches were carried out such as germplasm collection and evaluation (Dancel 2011; Pascua and Bilgera 2013; Gacutan 2012), generation of hybrids, nursery management (Calacal 2012); plant establishment (Pascua 2010); fertilizer management (Gacutan 2012; Gabriel and Pascua 2013; Pascua et al. 2013a; Pacariem, 2014; Joaquin 2013); pest management (Tepora et al. 2009; Aribuabo 2014); topping, supplemental lighting (Pascua et al. 2013a), bagging the fruits (Aribuabo 2014); post-harvest practices (Demdem; 2013; Barroga, 2014); chemical
characterization and pharmaceuticals (Ines 2012; Abellon et al. 2014; Castillo et al. 2014; Bondoc et al. 2014).

The Cavite State University (CavSU) came up with the following products and now registered as patented products:
- Severino Dragon fruit juice (clear) Registration No. 2-2010-000283
- Severino Dragon fruit puree, Registration No. 2-2010-000284
- Severino Dragon fruit juice (pulpy), Registration No. 2-2010-000285
- Severino Dragon fruit jam, Registration No. 2-2010-000286
- Severino Dragon fruit jelly, Registration No. 2-2010-000287
- Severino Dragon fruit wine, Registration No. 2-2013-000152
- Severino Dragon fruit flower cider, Registration No. 2-2013-00053
- Severino Dragon fruit cider vinegar, Registration No. 2-2013-000154

MMSU published a brochure and two volumes of monograph on dragon fruit-based recipes using the various plant parts (Table 2). In addition, the recipes were the product of cookfests held during the dragon fruit festivals. Likewise, Prof. Maura Luisa Gabriel Prof. Maura Luisa S. Gabriel formulated a dragon fruit herbal soap while Dr. Arnold Dumaoal of MMSU developed a dragon fruit soap mixer-blender and soap maker machine.

Table 2. Dragon fruit-based recipes

<table>
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<tr>
<th>Plant part</th>
<th>Recipe</th>
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<td>dragon tuna in rubix with vinaigrette dressing⁵</td>
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<td>saniatsum (steamed saniata sum dimsum)⁵</td>
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<td>fintaya (sweet and sour fish fillet pitahaya stalks in tropical sauce)⁵</td>
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1 MMSU IEC Material
2 MMSU Saniata Dragon Fruit-based Recipes Monograph Vol. 1
3 Garcia (2013)
4 MMSU Saniata Dragon Fruit-based Recipes Monograph Vol. 1
5 First Dragon Fruit Festival Cookfest
6 Third Dragon Fruit Festival Cookfest

Applied and adaptive research played a vital role in ensuring that the benefits of investments in R&D would reach the farmers. The conduct of demonstration trials in farmers’ fields and the science and technology based farms of Farmer-Scientists has greatly increased the areas planted to dragon fruit.

**Technology Promotion**

The Project SANIATA which has been the spring board of the technology promotion, has gained notable accomplishments and insights on research management, research activities, research utilization and public-private partnerships. Its success has brought dragon fruit in the national scene. Also, this has also earned recognitions from stakeholders, strengthened the public partnership with the cooperatives and the local government units, and contributed to the enhancement of industries such as agriculture, trade, tourism, transport among others (Pascua et al. 2012).

The various initiatives were:

1. The conduct of trainings, fora or caravans, lectures and hands-on trainings to disseminate information and technologies to growers, housewives, youth,
entrepreneurs and food processors, agricultural technologist, secondary and elementary school teachers and prospective growers various parts of the country;

2. Technology services for walk-in clients such as farmers, technicians, students, former overseas Filipino workers, processors, and housewives in the Farmers Information and Technology Service (FITS) centers strategically located in different municipalities and cities agricultural offices in the country;

3. Services for Short Messaging System (SMS) and internet clients;

4. Publications of technology guides on dragon fruit production and recipes in print and video as well success stories of dragon fruit growers featured in magazines, national dailies and TV programs;

5. Holding dragon fruit festivals;

6. Cross-visits and field days;

7. Technical assistance, monitoring and on-field;

8. Nurturing the youth as the next generation growers by involving elementary and secondary schools and rural youth organizations;

9. Plant-Now-Pay-Later Scheme and planting material dispersal;

10. Stem cuttings dispersal to resource poor households;

11. Strengthening public and private partnership.

Major constraints in production and main challenges in marketing

With the increase of areas planted to dragon fruit, several problems have been identified. Dragon fruit can be grown in the country because of the climatic and soil conditions. However, the national average yield is quite low compared with other dragon fruit growing countries and this can be attributed to the local variety, cultural management, insect pest and diseases. The varieties available in the country were introduced from Vietnam and Thailand which are probably inferior to the commercial varieties grown in other countries. The cultural management used in the country were patterned from Thailand and Vietnam with only few revisions and localized package of technology has yet to be developed. The insect pest and diseases have contributed to the decrease in yield. Tepora et al (2009) in their survey of insect pests and diseases in Cavite found out the following: oriental fruit fly (Bactrocera dorsalis Hentel), coconut scale insect (Coccus viridis), aphids (Toxoptera sp.), mealy bug (Ferrisia virgate Cockerell), dinidorid bug, orange dog butterfly (Papilio demoleus libanos), tussock moth (Orgia australis), bagworm (Eumeta fuscescens Snellen) small red ants, fruit spotting bug, katydid, flea beetle, orange beetle, coffee bean weevil, black pentatomid bug, pachyrrynchid beetle. They also identified the following diseases associated with bacteria: fruit rot, leaf spot and flower rot; associated with fungus: rust, leaf blight, yellow spot, anthracnose and flower rot; a certain disease suspected to be caused by virus and scab with unknown causal organism. In the Ilocos, the prevalent insect pests are the oriental fruit fly and the red ants while the prevalence of diseases is alarming.

One of the problems that beset the dragon fruit production these days is the intensive cultivation by applying inorganic fertilizers and pesticides to the crop. This may be economically profitable in the short run but may not be sustainable in the long run. The massive use of these farm inputs contributes to the environmental degradation and adversely affects the health of farmers and the consumers as well.

Many available areas for dragon fruit expansion, however the bottle necks are high cost of initial investment and problems on credit. The unavailability of post harvest facilities and technologies had affected the shelf life and continuous supply of fruits. The
development of Quality Assurance Protocol (QAP) and Good Agricultural Practices (GAP) have to be developed to have globally competitive products.

With the increasing but unstable supply of fruits, the price and market demands were affected. The supply and value chain analyses were not yet studied. Creating niche markets locally or globally will be a great challenge on marketing.

**Development focus in response to future trends and marketing demands**

In the Philippines, the development of dragon fruit as an industry has a great prospect considering the country’s climatic conditions, availability of area for expansion and other resources as well as the fruit’s demand on local and export. Thus, efforts have to be exerted in research and development to facilitate the further expansion of the industry as an alternative crop for the changing environment. The development of Quality Assurance Protocol (QAP), Good Agricultural Practices (GAP), technology on organic dragon fruit production and high yielding varieties that posses good fruit quality and resistance to pests; the improvement of Integrated Crop Management (ICM), Integrated Pest Management (IPM) and Post-Harvest Quality Management (PQM); and the conduct of supply and value chain analysis as well as marketing studies will be undertaken. In addition, value adding on food, pharmaceutical and beauty products can also be done.

The industry goal is to increase yield by 50% and quality of fruits, the production area by 5,000 hectares and the reduction of production cost by 15 to 20%.

These can be achieved with the following strategies:

**A. Strategic R&D**

1. Crop improvement (varietal introduction, selection of improved varieties, hybridization, and use of genetic markers for variety identification)
2. Enhancement of production and post production technologies (improvement of ICM such as crop establishment, soil and nutrient management, water management, pest management; post-harvest quality management and establishment of good agricultural practices)
3. Reduction of production cost such as plant establishment and ICM without sacrificing the yield
4. Development of off-season production technology
5. Sustainability maps using GIS; area validation and evaluation
6. Supply and value chain analyses and marketing studies
7. Development of food, pharmaceutical and beauty products
8. Development of package of technology on organic dragon fruit production

**B. Techno Transfer**

1. Promotion and techno transfer of improved practices (QAP, ICM, PQM and GAP) through IEC, ICT, FIESTA and media networks
2. IP protection
3. Community S&T based farm
4. Mass production of certified varieties in nurseries
5. Techno mart
6. Nurturing the youth as next generation growers in partnership with schools and youth clubs
7. Profiling of dragon fruit growers and documentation of best practices
C. Policy Formulation
1. Development of Quality Assurance Protocol
2. Export policy
3. Analysis and development of models to address marketing, product grade and standards
4. Compliance to quality and safety standard protocols of domestic and international markets (Producers certified/accredited)
5. Policy on pricing (Stability and uniformity in prices according to size and variety)
6. Strengthening the chain from the producers to the consumers achieving a private-led industry

D. Capability Building
1. Training and establishment of facility for genetic marker development on dragon fruit variety identification
2. Training of trainers on QAP, ICM, PQM and GAP for dragon fruit production
3. Establishment of post harvest facilities for dragon fruit production

Processing
A Science and Technology Park-Technology Business Incubator (TBI) was established at MMSU in cooperation with the Department of Science and Technology (DOST) to help entrepreneurs and processors such as those who venture on dragon fruit. The S & T Park is a shared facility and can also extend business development and management services.

Future trend
The sufficiency of food supply is not only the concern but also the quality of farm products, environmental management, human resource management, health issues, and decreased cost of production. The presence of growers in the chain contributes to the success in achieving the production goals. Hence, the welfare and interests of growers should be taken into utmost consideration such that maximization of their profits and elimination of health hazards should be well addressed. Similarly, this should also focus on environment-friendly technologies preventing environmental degradation. In addition, the welfare of consumers is supposed to be a prime concern. Consumer interests are protected such as appropriate standard and quality, safe and healthy food and availability in adequate quantities at reasonable prices. Thus, the socially responsible role is expected to equal opportunities, environmental protection to all sectors of the society, food production and climate change mitigation.

The potential of organic dragon fruit production can be fully harnessed for local and foreign markets. Branding dragon fruit products into "organically grown dragon fruit" will become locally and globally competitive considering the preference of consumers on these products. This will create a niche in the local and foreign markets and help small farmers and investors in the production, processing, export and other business opportunities.

CONCLUDING REMARKS
Dragon cactus is adaptable in the Philippines because of the climatic and soil conditions of the country. It can grow even in marginal areas which abound in the country. Most likely, this can help in greening the gray-and-dry areas or those left
uncultivated. This crop can adapt to vulnerable conditions because of its resilience to
drought, erratic rainfall and typhoons brought by climate change which the country is
now experiencing.

Aside from utilizing these lands, dragon fruit production helps in poverty alleviation by
providing a lucrative means of livelihood to people in marginal and depressed areas.
This provides an opportunity for the underutilized and idle areas to be converted into
productive lands.

Dragon fruit is an emerging champion in the local fruit industry considering the lucrative
income to farmers and its export potential. This fruit has likewise generated a great
demand among local consumers and a possibility for export in the near future. Thus,
efforts have been exerted in research and development and technology promotions in
expanding the industry that will benefit various industries in the future.

In summary, dragon fruit in the Philippines has been changing the lives of the Filipinos
such that it:

- Provides good sources of income and nutrition to households;
- Provides available alternative crop for farmers affected by the changing
  environment;
- Brings/strengthens partnerships among GOs, NGOs, and private sectors together
  for development;
- Creates employment and livelihood opportunities; and
- Contributes in addressing community development and economic growth

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BREEDING, PHYSIOLOGY
AND CROP MANAGEMENT
PITAYA BREEDING STRATEGIES FOR IMPROVING COMMERCIAL POTENTIAL IN TAIWAN

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ABSTRACT

Pitaya or dragon fruit (Hylocereus spp.) is a new fruit crop with rapid development in Taiwan. It was first introduced 300 years ago and was brought from Vietnam again in 1983 with area of production increasing to 1,200 ha in 2013 (Agricultural Annual Report, Council of Agriculture). Collections of germplasm and breeding among genus or species were well conducted by several growers in its 30 years. The diversity of fruit characteristics in pitaya is plentiful and interesting in Taiwan. Through the cooperation of Dr. Yi-Lu Jiang, variety test guideline and characteristic ID method of pitaya was established by Fengshan Tropical Horticulture Experiment Branch (FTHEB), Taiwan Agricultural Research Institute for the requirement of variety right and identification of variety characteristics. By 2015, ‘Xi-Yun#1-Mi-Bao’ (certified in 2012), ‘Xi-Xiang-Hong’ (under certification) and ‘Sun-Xe-Long’ (under certification) have been applied for the variety right.

Currently, both red and white flesh varieties are grown in Taiwan. The bearing and fruit quality are more stable in white flesh variety. However, their being not true-to-type, the pollination requirement, variable fruit size and fruit crack are still the main problems for red flesh pitaya variety. Breeding for variable fruit and flesh color, large size, spineless, good flavor and fragrance, and storage are conducted by FTHEB since 2009. ‘Vietnam White’, ‘Da-Hong’, ‘Mi-Long’ and yellow pitaya were used as parents. Clone 98-3, 3-4-5, 3-10-7 and 4-12-5 were selected from more than 200 hybrids in 2012-2014. Clone 3-4-5 (Xiao-Tien-Tien) will be promoted and will be applied as the right variety in 2015. Besides the breeding goals mentioned before, the next breeding program will focus on variable color, better quality and texture to attract new consumers. Meanwhile, selection for lower threshold of flower initiation for season regulation is also considered in the future.

Keywords: pitaya, breeding, characteristic test

INTRODUCTION

Hylocereus spp. known as pitaya, dragon fruit, sesame fruit or prickly pear fruit, is a perennial climbing succulent plant which belongs to Cactaceae. The cactus family comprises of 122 genus and more than 1,600 species. Cactus’ most significant features are their succulent stems and thorns. According to the growth habit of Cactus fruit plant, it can be divided into: climbing cacti, prickly cacti and columnar cacti.
Dragon fruit has very strong ability to adapt to soil and climate, so it is often selected under marginal environments. In cultivation, the old dragon fruit branches were used for propagation and can spread quickly. Additionally, flowering takes place after a short growth (about 10 months after planting), with an annual output of up to 15,000 kg/ha with long yield and scatter time. Dragon fruit trees have excellent traits such as easy to store and transport, drought resistant with few pests and diseases, which make it good for food processing, as fresh fruit and as ornamentals. As a result, in recent years, it sets off a planting boom both at home and abroad.

At present, cultivated cactus fruit are mainly climbing class in Taiwan, which needs support frame for branches to cling and grow and droop their branches for flowering and fruit production. The cultivated *Hylocereus* in Taiwan is divided into white flesh (*H. undatus*) and red flesh (*H. polyrhizus* and *H. costaricensis*). There are also a small number of *Selenicereus megalanthus* Brit & Rose, which is known as golden pitaya, yellow pitaya or yellow dragon fruit. Although its quality is better than that of *Hylocereus* spp., its fruit, covered with thin spines, is small (generally less than 300g). Thus, these undesirable traits deter farmers to grow it for commercial purpose.

Dragon fruit cultivation area in Taiwan is 1,191 hectares as recorded in Statistical Yearbook of Agriculture in 2013. Production mainly concentrated in the central and southern plains area of Taiwan. Among them, Erhlin Township of Changhua County (118 ha), Chichi Township of Nantou County (45 ha) and Waipu district of Taichung (33 ha) and other neighboring regions are more concentrated and accounted for total production area of nearly 40% in Taiwan. The remaining counties and cities in Taiwan, including Kinmen and Penghu islands (Chimei) are also planted with dragon fruit. The total output is 27,654 tons in 2013. In addition to domestic demand dragon fruit has also been exported in small quantities with total foreign sales of nearly 45 tons, of which most were exported to China (39,058kg), while the others were exported to Japan, Singapore, Hong Kong and Canada. The average export price per kilogram was NTD72 (USD2.5).

Taiwan dragon fruit commercial production began in 1983. The original varieties were introduced from Vietnam and Central/South America. In the beginning, cross-breeding works were carried out by farmers resulting in improved varieties with various peel and flesh color, and other desirable traits. Some well-known released varieties are ‘Jan-Long’, 'Chou-Zou Large', 'Xi-Long' and 'Xiang-Long'. However, high prices of pitaya plants have prevented nurserymen to sell not true-to-type seedlings to growers, which led to unstable quality and yield, fruit cracks and pollination-requirement after planting. Nevertheless, the situation improved when true-to-type varieties are regulated a decade later.

GUIDELINES FOR VARIETY CERTIFICATION AND RIGHT

According to "Plant Variety and Nursery Act", there are several requirements for variety rights of pitaya in Taiwan. One prior requirement is the difference as compared with control or check variety. This variety should perform stable and maintain plant characteristics after propagation. The check or control variety may be determined by 1) similar among plant characters, 2) one of the parents, 3) popular variety in the market, or 4) by the variety ID committee.
Dragon fruit traits can be divided into quantity (weight, peel thickness etc.) and quality (prickly form, degree of suberization). The quantitative traits are easily affected by sampling and cultivation management so differences in performance were not objective; on the other hand, qualitative traits in theory should be fixed, with more valuable and distinguishable traits. The important traits test of dragon fruit include: stem, flower, and fruit. Applicants need to provide the main traits difference with color photos when submitting traits test so as to facilitate the review process.

According to Article 7 from Committee of New Plant Species Reexamination Board Organization, new species verification facility are specified by the Council of Agriculture, may, base on actual needs, increase the number of facility if necessary. For example, when verifying the new species of dragon fruit, refer directly to the applicant experimental field to complete at least two experimental verifications. If necessary, this may be extended based on the actual needs. When carrying out traits verification of the plant management, it should be based on the cultivation and management instructions provided in order to maintain normal growth of plants. Otherwise the planting will just be in accordance with customary pattern. In particular the test method is based on a single-column planting, but the actual cultivation patterns could vary as long as the control and verification species are consistent. Test species seedlings branches are grafted or cut as long as the breeding methods are consistent. Verification number of each species is 15 or more, with at least 10 survey data was collected. The control species were usually planted in rows or interlaced with compartments next to test species to facilitate observation of each trait. For fruit weight, soluble solids, cracking etc. and other verification test results should be analyzed based on their significant differences.

**CURRENT SPECIES WITH PLANT VARIETY RIGHTS**

Cutting or grafting method was used to expand production of dragon fruit, due to their short sizes and ease of transport of seedlings. Furthermore, large amount of available shoots source (seed) also makes it easy for cultivation. However, it is advised to choose pure breed and healthy branches carefully. In order to ensure the quality and purity of future shoots and fruit, field observations of fruit quality and management is also recommended. In theory, traits using cutting and other vegetative propagation methods can be fixed as same as the original mother plant, but inconsistencies still appear in the field and should be eliminated immediately.

Currently the dragon fruit cultivation area of white and red flesh in Taiwan varies with consumer behavior and market prices. To consumers, their acceptance and reaction for flavor of red and white flesh were polarized, sugar and betalain contents are generally higher in red flesh, but the flesh is soft and less crispy. The high content of betalains made it more difficult to digest and absorb completely, resulting in fecal remains with the pigment; sugar content of white flesh are generally lower than red flesh species, but are sweet and has crispy taste. However, due to the more dazzling appearance of white flesh species, demand will be higher than red flesh during ritual season and in restaurants. Therefore market price varies more than red flesh. Currently the cultivation proportion of red/white/other species are roughly 30:65:0.5 respectively.
1. *Hylocereus undatus* Britt. & Rose

White flesh species with short distance between stigma and stamen is self-compatible, and does not require cross-pollination. Fruit bearing will not be affected by rain during flowering period, and the fine short thorns on the branches makes farm management easier. Fruits are elongated and oval shaped with long scales; remain in green color when ripe. The peel color is bright with a glossy appearance which is better than the red flesh species. The taste is crispy and sweet, juice will not stain clothes. Its soluble solids in core are averaged 16-20 Brix. In general, it has grassy smell.

The flowering of white flesh species in the southern region occurs two weeks later compared with the red flesh species (late April to early May), flowering period (flowering period end in mid-September) also end earlier than red flesh species, the production period is 1-1.5 months shorter than red flesh species, but the amount of fruit each phase is more stable, and fruit size is more consistent, therefore the average annual production is at par with red flesh species. White flesh species use of Kraft paper or non-woven bagging and peel color would be more beautiful, if using gauze bagged the peel color is uneven and hard to sell.

2. *Hylocereus polyrhizus* Britt. & Rose; *Hylocereus costaricensis* Britt.& Rose

Flowering period of red flesh species are earlier than white flesh species, flowers bloom in the southern region as the night temperature begins to rise in early April. Flowering period can be extended until December using artificial light. The number of flowers each year is estimated to be more than 12 batches. In order to distinguish red flesh and white flesh species by flesh color, the strips of the edge branches could be identified, and the leading edge of the petals is red, the length of thorn branches, length of scales as well as other traits are notable marks that determine the species. The branch edge strips of red flesh species are mostly discontinuous, petal front edge is red, long thorns on the branches, and the stigma is longer than stamens, they are also not prone to self-pollination and are self-incompatible. However, the fruit rate increases up to 100% if they are pollinated by different species, thus they have to mix with other kinds pollen of red flesh or white flesh species with artificial pollination. The sizes of each batch of fruit vary significantly. They are also hard to plant and costs higher.

The varieties with plant variety rights are four varieties including 'Xin-Yun 1 - Mi-Bao', 'Da-Hong', 'Xi-Xiang-Hong' and 'Tricolor dragon' (according to the application time sequence) the rest are mostly original breeding from production area, the most well-known species are listed below.

**Xin-Yun 1 - Mi-Bao**
Registered in 2012, its traits are: oval or spherical fruit-shaped, scales are shorter than the white flesh species, easy to pack. They are also not easy to crack compared to red flesh species—and even the calyx depth is shallow. The fruit has a core soluble solid of 80%, has ripped fruit average of 18 degrees Brix and has been found to be tastier and crispier. The fruits are easy to store (scale not easy to browning), normally five days at room temperature, at low temperature (5°C) shelf life can be up to 2 weeks or more through refrigeration. Long fruiting period, fruits are not easy to crack even one week after peel turns red. Areole is slightly longer than white flesh species, but shorter than the red flesh species, so the cultivation, management, fruit picking and other job actions are less susceptible species in red flesh species. The species are positioned for export to foreign markets.
**Da-Hong**
Fruit is large and dark red flesh. The most prominent feature of this species is a self-compatible and short distance between stigma and pollen. Thus it does not require cross-pollination and the fruit size are above average, fruit bearing does not affect in case of rain during flowering period (but fruit-size still too small). The average weight is up to 400g or more (less heat tolerant in southern summer season, smaller fruit). The shape is partial circular, scale is wide, short and thin, and peel will not scratch due to friction with scales in transport. The core soluble solid of 80% ripped fruit average of up to 20 degrees Brix or higher. The calyx is short with moderate cracking rate. The sagging succulent stem also has the advantage of not being easily broken by strong winds. The disadvantage is less crispness flesh, thin peel, thus shorter shelves lifetimes. At present the cultivated area of this species accounts for about 60% in red flesh species.

**Hi Xianghong**
The strong aroma is its most prominent feature, with long oval fruit shaped, longer rewinding scales, does not crack easily (after color change still fruiting for two weeks), self-compatible, an average core soluble solids of 18 degrees Brix or higher, well distributed amount of fructose, crispy, succulent and has excellent flavor. Currently this species undergoes traits test.

**Tricolor dragon**
It is a hybrid variety of Xiang-Long from Central and South America and white flesh species Registered in early 2015, its flesh is bicolor that varies with temperature. The flesh color is white between May and July, turns pink near peel and white in the center between July and September; and achieves a red color near peel between October and November, showing clear red and white color. After November, the color becomes pink flesh. Fruit does not have grassy smell and tastes very sweet. Currently the variety is undergoing traits test.

**PITAYA BREEDING METHODS AND PROCEDURES**

**Breeding objectives**
In recent years, pitaya is widely cultivated. In addition to the early introduction, several research stations are working on the breeding improvement programs to develop superior varieties. The breeding goals of research stations are described as follows:

1.1 **Self-compatibility**: Flower shape of red flesh species (pistil often protruding 1 cm longer than stamens) is unfavorable for pollination via wind or insect-borne, which causes self-incompatibility. The fruit size is often too small due to poor pollination. Although artificial pollination can eliminate this shortcoming, but it requires a lot of manpower and time as well as the cost of production. Therefore, we can ensure production of red flesh species and earnings if a self-compatible varieties are developed.

1.2 **Storage and transportation**: Dragon fruits are supplied both to domestic and foreign markets, the fruit are abundant between July and August. Thus it is necessary to relieve pressure through export. But there is a lack of cultivars that are prone to commercial storage and transportation. We can only select from the current cultivars that are easy to transport and store. There is also a strong demand of red flesh species from foreign markets in recent years, but domestic red flesh cultivars have not been gathered well and each farm planted with various varieties. Thus the quality
is uneven and not conducive to the subsequent export business and fruit quality control.

1.3. **Low crack**: Red flesh species have shallow calyx end. The calyx cracks or thin peel develops when the fruit matures. Fruit crack when they enlarge. This greatly affects the value of goods.

1.4. **Excellent fruit flavor**: Dragon fruit from early days were not selected properly and smells grassy, affecting the consumers’ willingness to purchase. The requirements of non-grassy smell are more pronounced now and the requirement is that the fruit should have a more pleasing aroma.

2. **Germplasm collections**
It is necessary to select parent species in order to improve traits of species, so the priority of hybridization is gathering more special varieties. Varieties with strong growth potential were selected and combined with parent variety after clarifying properties of variety source.

3. **Parents selection**
The initial hybridization combination was carried out according to the breeding objectives mentioned above. Better parent traits are as follows: 1 Vietnam white flesh species: self-compatible, medium-large fruit, long scales, white flesh, crispy taste; 2 Mi-Bao: Red flesh, large fruit, short scales, easy to transport; 3 Mi-Long: good flavor, red flesh, small-medium fruit, long production period; 4 Huang-Long: yellow fruit, small fruits, high Brix, long soft thorn, long fruit bearing period, slightly weaker growth potential.

4. **Hybridization**
Dragon fruit species improvement program currently applies hybridization method, and promotes variety diversity by inter-generic hybridization. Procedures and methods of implementation are as follows:

1. Different hybrid pollinations: With Vietnamese white flesh species and Mi-Long as female parents, Mi-Bao and Huang-Long as male parents, four types of crossing pollination were conducted. More than 10 flowers for each parent pollination combination. Collect and plant their hybrid offspring after harvest hybrid seeds.
2. Cultivate hybrids of above combinations, young stems can be grafted to adult succulent stem at when seedlings are about 5 cm high, to shorten flowering and fruiting period from juvenility.
3. Hybrids seedlings management allows the branches grow well and evaluate the results by early flowering and fruiting.
4. Investigate flowering habit, flowering traits were primaries: the closer lines of pistil and stamen were selected with higher probability of self-compatibility.
5. Fruit quality analysis: fruit breeding goals are excellent flavor, high sugar content (core 18 degrees Brix or above), large fruit (450g or more), thornless, short branch thorns, easy regulation of yield.

**CONCLUSION**

Variety is the base of good fruit yield, in addition to nursery management techniques; selection of appropriate variety is also a critical factor to successful fruit production. The conduct of assigned and non-assigned plant rights and licensing in recent years, have
improved and maintained the right of good variety in Taiwan. The rise and fall of dragon fruit are like a sauna, the industry promotes the nursery industries which rose rapidly in 1997. By 2003, the area planted to dragon fruit together with the status of the industry dropped less than half due to unhealthy seedlings and unstable fruit quality. The dragon fruit planting boomed again due to selection of high-quality variety and purification in 2008. Market expanded in recent years due to healthy and safe dragon fruit and consumer demand for high-quality fruit from variety selection and planting. FTHEB was assigned in 2008 to develop "dragon fruit test methods and traits questionnaire", and the dragon fruit was covered in applicable items of plant protection, coupled with encouragement of subsequent application for plant rights. Farmers widely planted dragon fruit and updated variety in recent years. Although there are self-compatible species nowadays, the pollination-required variety are still maintained. This makes the quality unstable as compared with new variety. This will beat consumers’ confidence and willingness to purchase fruit.

Variety improvement (for various color, spineless, large fruit size and self-compatibility), good management and season regulation should be the top priorities for the continuous success of the pitaya industry in Taiwan.

REFERENCES

DEVELOPMENT OF INTEGRATED CROP MANAGEMENT SYSTEMS
FOR PITAYA IN TAIWAN

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ABSTRACT

The harvested area for dragon fruit or pitaya in Taiwan reached 1,587 hectares, according to agricultural statistics yearbook of 2014. Of this figure, 53.6% and 35.6% of the harvested fruits were located in the middle and southern plain area of west Taiwan. The production industry for pitaya belongs to Taiwan’s intensive agriculture, which emphasizes more on stable production of high quality fruits and demands high cultivation technique. Thirty percent of the common grown clones/varieties belongs to Hylocereus undatus, while 70% of them belongs to red flesh H. sp. ‘Da Hong’ and ‘Fu Gui Hong.’ Those are the two most popular H. sp. cultivars with 60% and 25% market occupancy. In an orchard, shoot management affects productivity regardless of ordinary or off-season production. Pruning before previous December along with heading cut before April would increase early yield. On the other hand, continuous thinning of floral buds may delay large harvest peak at the end of the ordinary schedule. By applying night breaking treatment, off-season production can be achieved both in autumn and winter in H. sp. The fruit’s appearance is already an assurance that pitaya can already be bagged.

Keywords: floral thinning, heading cut, night-break, off-season, pitaya,

INTRODUCTION

Dragon fruit has been introduced in Taiwan since the 1980s and have since increased in terms of popularity (Hsu 2004; Jiang 2005; Jiang et al, 2011; Yen and Chang 1997). The productivity was approximately 25 metric tons/ha in recent years (Figure 1) and the price ranged from $US2 to $US6/Kg. According to Taiwan’s 2014 Agricultural Statistics Yearbook, the harvested area for dragon fruit or pitaya reached 1,587 hectares, with 53.6% and 35.6% located in the middle and southern plain area of west Taiwan (Figure 2A). Majority of the fruits are for domestic demand, and a small quantity is for exports.

Of the total foreign sales of nearly 158 metric tons of pitaya in 2014, 85% of those were exported to China. Other exporting countries are Japan, Singapore, Hong Kong, Canada etc. The average exporting price was $US2.69/Kg. We also imported 202 metric tons of dragon fruits at a price of US$1.63 Kg from Malaysia.
Improving Pitaya Production and Marketing


PITAYA PRODUCTION IN TAIWAN

Pitaya’s commercial production began in 1983. The production activities were fueled by farmers including Tu-Sha Chen from Dali, Huo-Quan Shi and Pei-Ran Wu from Chichi, Lian-Fang Wu from Mingjian, and Qun-GuangWang. The original species was directly introduced to Taiwan and came from Vietnam and Central/South America. Through years of intra- and interspecies breeding, varieties of pitaya with various peel and flesh color were developed in Taiwan, some well-known clones/varieties such as 'Jan Long', 'Chouzou Large', 'Xi Long' and 'Xiang Long' were eventually released. Thirty percent of the common grown clones/varieties belong to *H. undatus*, while 70% of them belong to *H. sp.* (Figure 2B). ‘Da Hong’ and ‘Fu Gui Hong’ are the two most popular *H. sp.* cultivars with 60% and 25% of market occupancy, respectively.

Figure 2. (A) The partition of production area in Taiwan; (B) The major species/cultivars grown in Taiwan.
In the early years, the production system was complicated because the nursery system was not yet established. Some of the nurserymen used to sell seedlings to the growers. As a result, the fruit quality and some other fruit characteristics could not be predicted such as color, shape, cracking, self-compatibility, etc. Thus, the development of dragon fruit production was restricted until 1999 when the true-to-type clones/varieties were released. The first rapid expansion was between 1999 and 2004 (Figure 1), the cultivation area and average yield per hectare increased rapidly, and the major varieties belonged to *H. undatus*. In the period between 2005 and 2009, the development of the industry was much lower and was halted mainly because the growers were not familiar with *H. sp*. The second rapid expansion started from 2012 with the introduction of the self-compatible *H. sp.* clones and a stabilizing of off-season production techniques.

### INTEGRATED CROP MANAGEMENT SYSTEM

#### General practice

Red pitaya (*H. sp.*) is a long-day plant whose flowering and major sprouting processes switched at the equinoxes in subtropical Taiwan. The time between Spring and Autumn equinoxes is called the inductive period. The areoles on the newly matured shoots that sprouted in the previous year are induced to enter reproductive growth after the Spring equinox and the appearance of the first flower at the end of May.

Meanwhile, the old shoots resume their evocation and flowers a little bit earlier than the newly matured shoots. The shoots will flower naturally in two to three waves in an inductive period. In Taiwan, pitaya production system belongs to intensive agriculture, which focuses on fruit quality rather than yield. The general practice of the system could be explained in three categories, shoot, flower, and fruit management (Figure 3). Training and pruning are the most important practices to assure productivity at all times, particularly in early spring for ordinary production. Flower management is meant to control pollinated flower number for fruit size which includes floral thinning, pollination, and floral corolla removal after pollination. Finally, fruit management is able to guarantee the fruit appearance (Figure 4A). In tropical and subtropical regions, preventing insect bite is a very important issue (Figure 4B); therefore, the two types of bags, light transmittable and un-transmittable, are developed for pitaya fruits. The coloring of pitaya fruit is independent of light and if exposed to too much light will hinder coloring in the exposed side (Figure 4C). However, perfect coloring may have a trade off with fruit bracts shelf life if light is not transmitted. Figure 4 represents the effect of bag materials on fruit appearance (Huang 2015).
Figure 3. The general practice schedule for ordinary production in southern Taiwan.

Figure 4. Fruit appearance (A) perfect fruits, (B) fruit with insect bites, (Photos by Huang, S. H.) and (C) uneven coloring fruit. (☀) represented sunshine.

Figure 4. Effect of bag materials on fruit coloring. (Photos by Huang, S. H.)
Off-season production

Through market analysis, an integrated off-season production has been proposed (Figure 5). Within the inductive season, a minor adjustment can be achieved by heading cut and floral thinning to increase early and late yield, respectively. For heading cut, 10% of the length was suggested to cut off in newly matured shoots before April (Jiang and Yang 2015), and pruning between November and December was suggested for the number of the competent shoots. For put off large harvest peak, it was suggested that there should be continuous floral buds thinning before mid-August. Off-season production means producing fruits in non-inductive season by night breaking treatment. *H. sp.* is more responsive to NB treatment, the production can be achieved both in autumn and winter (Jiang et al. 2012). Autumn trial can be initiated any time before mid-November in southern Taiwan and mid-October in central Taiwan, and the winter trial is suggested to halt until mid-February. The sensitivity of *H. undatus* towards night breaking treatment is different from *H. sp.*, whose autumn trials were suggested to start from mid-September and the harvest time towards the end of December.

**Figure 5. Strategies of integrated off-season production in Taiwan.**

**CONCLUSION**

The pitaya production industry belongs to intensive agriculture in Taiwan, which emphasizes more on stable production of high quality fruits and demands high cultivation technique. In an orchard, shoot management affects productivity regardless of ordinary or off-season production. Pruning before previous December along with heading cut before April would increase early yield, while continuous thinning of floral buds may delay large harvest peak at the end of an ordinary schedule. By applying night breaking treatment, off-season production can be achieved both in autumn and winter in *H. sp.* The fruit appearance can be assured through bagging.
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PITAYA REPRODUCTIVE PHENOLOGY IN RELATION TO PRODUCTION SYSTEM

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ABSTRACT

The cultivation of vine pitayas has spread to tropical and subtropical regions throughout the world. In Taiwan, red pitaya fruits are produced both during the flowering inductive and non-inductive seasons. In scheduling a promising year-round production system, a better understanding of the relationship between flowering and environmental factors is very important. Red pitaya is a long-day plant with critical day length of 12 hours. The day length at 3° North and South latitude ranges from 11.95 h to 12.3 h reveals that 3° latitude is the fringe from equator for year-round flowering nature of red pitaya. In subtropical Taiwan, the reproductive growth both switch on and off at the equinoxes. The matured shoots, sprouted in previous autumn and winter, are both competent in response to long-day length after spring equinox. In an experiment, through 5 weeks of induction and 4 weeks of evocation, the first flush of floral buds emerged on 27 May. Off-season production can thus be achieved by night breaking treatment. Night temperature was suggested to keep it higher than 15°C. For obtaining 50% of the shoots flowering, one hour of lighting at midnight was sufficient in autumn and winter and 0.5 h in spring.

Keywords: long-day plant, critical day length, induction, evocation, off-season production, night breaking treatment

INTRODUCTION

Vine pitayas belonging to the genus Hylocereus are native to tropical habitats in North and South America (Barbeau 1990; Briton and Rose 1963). The cultivation has spread to tropical and subtropical regions throughout the world (Nerd et al. 2002). Red pitaya (Hylocereus sp.) was introduced to Taiwan in 1980s, and the most commonly grown red pitaya varieties are selected from crosses between H. undatus and Hylocereus sp. (Jiang et al. 2012). Because the flowering period is between May and October in the northern hemisphere, pitaya is classified as a long-day plant (Barbeau 1990; Nerd and Mizrahi 1997; Ortiz 1999).

In Taiwan, red pitaya fruits are produced both during the flowering inductive and non-inductive seasons (Jiang et al. 2012). The areoles on the matured shoots may be induced to flower after the March equinox naturally and produce fruits in summer and autumn in several flushes. Off-season flowering can be achieved using night-breaking (NB) treatment after autumn equinox. In scheduling a promising year-round production system, a better understanding of the relationship between flowering and environmental factors should be pursued.
REPRODUCTION PHYSIOLOGY

The long-day plant nature
To understand the flowering physiology of red pitaya (*Hylocereus* sp.) under natural conditions, a forcing experiment was recently conducted by heading cut 10% of the length of the newly matured plant continuously for 4 months between February and May of 2006 (Figure 1). This resulted in the sprouting of four types of buds including normal shoot buds (S), partial evocation shoot buds (PS), partial evocation flower buds (PF), and normal flower buds (F) according to the phenotype and the arrangement of areole and bracts (Figure 2A). The chronicle record of the bud types revealed that the period between March and April was critical to bud types. Besides, the appearance of PF decreased sharply after 27 May while F increased steadily, indicating that the critical timing to fulfill flower evocation closed at the end of May. The observation was further confirmed in the reproductive phenology of 2009 (Figure 2A). The natural day length shortened from 12.25 h to 11.95 h between 17 September to October 1 was sufficient to cease floral bud formation (Figure 2B) suggested that the critical day length was approximately 12 h, and which also implied that its reproductive growth switched on/off at the equinoxes in subtropical Taiwan. The day length at 3° North and South latitude ranges from 11.95 h to 12.3 h reveals that 3° latitude is the fringe from equator for year round flowering nature of red pitaya (Figure 3).
Figure 1. (A) The four types of pitaya buds emerged in the spring; (B) Normal shoot and Partial evocation shoot, (C) Normal flower and Partial evocation flower. S: normal shoot, PS: partial evocation shoot, PF: partial evocation flower, F: normal flower. (Abstracted from J. Taiwan Soc. Hort. Sci. 61:45-54.)
Figure 2. The photoperiodic response of floral bud formation in red pitaya: (A) shortening day length (SD/S) and continuous floral bud thinning (FT/S) treatments in summer; (B) four hours of night-breaking treatment (NB/W) in winter. The summer and winter treatments were applied from 2 June to 2 Sep. 2009 and 17 Sep. to 21 Dec. 2009, respectively. The control plants (CK) did not receive any treatment. (Abstracted from HortScience 47:1063-1067.)
The floral induction and evocation

The duration of long day length required for *Hylocereus* sp. to fulfill floral induction and evocation was approximately nine weeks from spring equinox in southern Taiwan. The duration for *H. undatus* in Israel was about 14 weeks (in July) (Khaimov and Mizrahi 2006). The effect of CPPU [N-(2-chloro-4-pyridinyl)-N-phenylurea], a kind of cytokines, on accelerating flowering is effective under certain period of time (Khaimov and Mizrahi 2006). In Israel, CPPU accelerate flowering by 1.5-2.5 months in *H. undatus* if sprayed in mid-May, while spraying in mid-April produced vegetative shoots and produced null response if sprayed earlier. The response of CPPU was much faster but the accelerating flowering effect was not observed in southern Taiwan (Figure 4). The stimulation of CPPU resulted in sprouting or flowering after 2 or 1 weeks, respectively. Those areoles produced shoots including normal shoots and partial evocation shoots when CPPU was sprayed before 13 April 2012 and partial floral buds when applied on 22 April 2012. Applying CPPU on 29 April 2012 produced normal floral buds after 1 week, it was revealed that the status of the areoles (meristematic regions) were determined. Once areoles are determined, they have to go through evocation, differentiation, and development before the real flower forms. At the early stage of cactus bud transformation, several bracts are differentiated before the floral bud (Almeida et al. 2010). The emergence of floral buds marked the completion of evocation, and the duration for evocation in southern Taiwan takes around four weeks. In the process of evocation, we observed that the buds swelled progressively (Figure 5). Another week is required for floral organ differentiation to take place and two weeks are all it needs for development to happen before anthesis. In the induced but rested buds, we observed bud swelling (bracts differentiation) is independent of long day length or night breaking treatment while floral bud emergence is the opposite of that.

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Figure 3. The day length variation within a year. The pink rectangle represents the daylength varies between 11.95 h to 12.3 h within the region between 3° North latitude and equator.
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Figure 4. Chronicle record of effect of 50 mg·l⁻¹ CPPU on bud transformation in spring of 2012. S and PS sprouted 2 weeks after spraying and PF and F emerged 1 week after. The recording of CK was 6 May 2012. S: normal shoot, PS: partial evocation shoot, PF: partial evocation flower, F: normal flower.

Figure 5. The of floral initiation model in southern Taiwan

PRODUCTION SYSTEM

Year-round production
Red pitaya is a long day plant, and the reproductive gap in the non-inductive period can be sealed by night-breaking treatment (Jiang et al. 2012). Off-season flowering in red pitaya is similar to natural flowering in yellow pitaya (Selenicereus megalanthus) in the winter of Southern Taiwan (Jiang et al. 2011). The shoots sprouting in spring can be used for flowering in winter, whereas shoots sprouting in winter flower in the

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subsequent autumn (Jiang 2005). In terms of productivity, summer flowering could inhibit or suppress the pitaya plant by shortening day length and heavy shading in the off-season production system (Jiang et al. 2012; Jiang and Yang 2015).

The night-breaking treatment
The duration of NB treatment for flower emergence was considerably longer in the cooler season compared to its warmer counterpart (Jiang et al., 2012), i.e. 3 months in winter (January–March) and 1 month in autumn. One hour of lighting in the midnight was sufficient to obtain 50% of the shoots flowering in autumn and winter. Heating up night temperature to higher than 15°C in winter could shorten the duration from three to one month. In spring, the lighting duration can be shortened to 0.5 h.

CONCLUSION
Red pitaya is a long-day plant whose reproductive growth continuously switches at the equinoxes in subtropical Taiwan. Matured shoots, sprouted in previous autumn and winter, are competent to respond to long-day length after spring equinox. In an experiment, through five weeks of induction and four weeks of evocation, the first flush of floral buds emerged on 27 May in southern Taiwan. Off-season production can be achieved by night breaking treatment and night temperature was suggested to be kept higher than 15°C. To obtain 50% of the shoots’ flowering, one hour of lighting during midnight was sufficient in autumn and winter and 0.5 h in spring.

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AND INSECT PESTS
AN OVERVIEW OF FUNGAL DISEASES OF PITAYA IN MALAYSIA

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ABSTRACT

Dragon fruit (Hylocereus species) is a group of tropical epiphytic cacti and is also known as pitaya or pitahaya. Practically unknown 15 years ago, today pitaya occupies almost all exotic fruit markets worldwide including Malaysia. Pitaya is considered as a promising fruit species and cultivated on different scales in different parts of the world which attributed by the fruit qualities and characteristics (attractive colours and shape), nutritional values and health benefits. The suitability of tropical climate, rainfall requirements, light intensity and soil types may contribute to the successful cultivation of this exotic fruit in Malaysia. However, like many other fruit crops, pitaya in Malaysia was seriously infected with several complex diseases caused by fungi. The diseases were anthracnose caused by Colletotrichum gloeosporioides and C. truncatum, stem necrosis by Curvularia lunata, stem canker by Neoscytalidium dimidiatum and stem rot by Fusarium proliferatum. Until to date, there is no comprehensive review is available on the fungal diseases of pitaya in Malaysia. Therefore, the present review gives inclusive information regarding various aspects on symptomology, pathogenicity and morphological and molecular identification of the causal pathogens. This review, thereby providing some information for promoting further studies on plant protection of the pitaya species.

Keywords: Hylocereus, fungal diseases, etiological studies

INTRODUCTION

Pitaya (Hylocereus species) originated from North, Central and South America (Britton and Rose 1963; Barbeau 1990); today, this crop is cultivated all over the world, including in the tropical and subtropical regions. This fruit has drawn much attention worldwide, not only because of its attractive red colour and economic value as food products, but also for its antioxidative activity (Wybraniec and Mizrahi 2002). Pitaya, rich in micronutrients, has generated a great deal of consumer interest and being popularized as a healthy fruit (Wu et al. 2005). In Malaysia, pitaya had been initially planted on large scale at the end of 1990s by Golden Hope Company at Sungai Wangi Estate, Perak. Until 2011, Malaysia has around 1200 ha growing areas of pitaya (Zainudin 2011). Pitaya is now being cultivated almost in all states of Malaysia including Sabah and Sarawak.

With an increase on areas planted with pitaya, the disease incidence has also increased. Pitaya in Malaysia was reported to be seriously infected with several economically important diseases caused by fungi including anthracnose (Masratul Hawa et al. 2008; Masyahit et al. 2009; Suzianti et al. 2014), stem necrosis (Masratul Hawa et al. 2009), stem canker (Masratul Hawa et al. 2013b), and stem rot (Masratul Hawa et al. 2013a).

In this paper, a review on the fungal diseases of pitaya in Malaysia is described with
reference to disease symptoms, pathogenicity and morphological and molecular identification of the causal pathogens.

**ANTHRACNOSE**

Anthracnose has been considered as the most common disease of pitaya in Malaysia and causes huge losses in quality of the fruits, thus rendering large quantity of pitaya fruits unfit for consumption. It has been found that at least two species of *Colletotrichum* were involved namely *C. gloeosporioides* and *C. truncatum* (Masratul Hawa et al. 2008; Masyahit et al. 2009; Suzianti et al. 2014). However, both species produced similar symptom, which was reddish-brown lesions with chlorotic haloes symptoms (Figure 1A, 1B and 1F). Masyahit et al. (2009) reported that the inoculated fruit became completely decaying on seventh day after inoculation, while the stem got severely rotting on tenth day after inoculation. Reports from other crop have shown that conidia from infected plants and plant residues can become sources of inoculum of *Colletotrichum* species infection once favourable conditions for infection occur (Buchwaldt et al. 1996).

Morphological characteristics of *C. gloeosporioides* were characterized as whitish and grayish with blackish or orange masses of conidia in concentric rings, the conidia were straight, cylindrical to slightly curve and hyaline (Figure 1C-1E) (Masratul Hawa et al. 2008). *Colletotrichum truncatum* produced white to greenish grey colony with white to dark grey pigmentation, salmon-coloured conidial masses; the conidia were falcate with acute apex and narrow truncate base, setae were abundant with swollen base and tapered apex and appressoria were dark brown, spherical to ovate 8–11 µm x 6–8 µm (Figure 1G-1J) (Suzianti et al. 2014).

![Figure 1. Symptom of anthracnose and morphological characteristics of C. gloeosporioides and C. truncatum: A) Brown lesion on pitaya stem caused by C. gloeosporioides; B) Brown lesion on pitaya fruit caused by C. gloeosporioides (Masyahit et al. 2009); C, D) Colony appearance and pigmentation of C. gloeosporioides; E) Straight, cylindrical to slightly curve and hyaline conidia of C. gloeosporioides; F) Brown lesion on pitaya stem caused by C. truncatum; G, H) Colony appearance and pigmentation of C. truncatum; and J) Falcate with acute apex and narrow truncate base conidia of C. truncatum (Suzianti et al. 2014).](image-url)
Besides using morphological characteristics, Suzianti et al. (2014) reported that species identity of *C. truncatum* were further confirmed using several genes such as internal transcribed spacer regions (ITS), β-tubulin, actin (ACT) and glyceraldehyde 3-phosphate dehydrogenase (GAPDH). Based on BLAST results of ITS regions, β-tubulin, ACT and GAPDH sequences, the percentage of similarity ranging from 98 to 100% with *C. truncatum* epitype strain sequence and therefore confirmed the species identity of *C. truncatum* as the causal pathogen of anthracnose on pitaya.

**STEM NECROSIS**

In 2009, Masratul Hawa et al. (2009) reported the occurrence of stem necrosis in most of pitaya plantations in Malaysia (in the states of Kelantan, Melaka, Negeri Sembilan, Penang, and Perak) with 41% disease incidence and 25% disease severity. The disease symptom was observed as spots or small, circular, faint pink-to-beige necrotic lesions that generally coalesced as symptoms progressed (Figure 2A-2C).

A fungus was consistently isolated from the stems of symptomatic *Hylocereus polyrhizus* and identified as *C. lunata*. *Curvularia lunata* showed grey colony and black on the backside (Figure 2D and 2E), produced pale brown multicelled conidia (phragmoconidia; three to five celled) that formed apically through a pore (poroconidia) in sympodially, elongating, geniculated conidiophores. The conidia were relatively fusiform, cylindrical or slightly curved, with one of the central cells being larger and darker (26.15 ± 0.05 μm) (Figure 2F and 2G) (Masratul Hawa et al. 2009). *Curvularia lunata* was identified based on morphological description by (Ellis 1971).

![Figure 2. Symptom of stem necrosis and morphological characteristics of *C. lunata*: A, B, C) Beige and pink necrotic lesions; D, E) Colony appearance and pigmentation and F, G) Fusiform, cylindrical or slightly curved conidia of *C. lunata* with one of the central cells being larger and darker.](image)

Based on pathogenicity test using injecting conidial suspension (1 x 10^6 conidia/ml) and pricking of colonized toothpicks showed that all tested isolates of *C. lunata* were pathogenic towards *H. polyrhizus* while the control plants were remained healthy.
Curvularia lunata was reisolated from 88% of the inoculated stems, thus completing the Koch's postulates (Masratul Hawa et al. 2009).

**STEM CANKER**

Stem canker was considered as the most destructive disease on pitaya in Malaysia and has been first reported by Masratul Hawa et al. (2013b). It was found that the causal agent of stem canker was *N. dimidiatum*. The initial symptoms of stem canker were brown sunken lesion and the lesion became dark brown with age. Orange spot and black pycnidia were formed on the surface of the canker. As the disease progressed, the infected stem subsequently rotted (Figure 3A-3C) (Masratul Hawa et al. 2013b).

The causal pathogen of stem canker was described as effuse, hairy or woolly colony and olive green to greyish colony with dark-grey to black pigmentation on PDA (Figure 3D and 3E). Meanwhile, on MEA, this fungus showed white to olive green colony with pigmentation of olive green to ochraceous yellow. *Neoscytalidium dimidiatum* grows rapidly and colonized the plate within 3 days. The growth rate was 3.00 cm/day on both PDA and MEA. Conidiogenous cells (pycnidal anamorph) were characterized as hyaline and intermingled with paraphyses. Conidia were ellipsoid to ovoid, rod shaped or round shaped, hyaline with an acutely rounded apex, truncate base, initially aseptate, becoming brown and 2-septate at maturity, 10.99 ± 0.35 x 5.02 ± 0.44 µm, with the central cell darker than the end cells. For mycelium anamorph, the hyphae were branched, septate, brown and disarticulated into 0- to 1-septate arthrospores (Figure 3F and 3G) (Masratul Hawa et al. 2013b). The morphological characteristics shown by the *N. dimidiatum* fit with the descriptions of Crous et al. (2006).

![Figure 3. Symptom of stem canker and morphological characteristics of *N. dimidiatum*: A, B, C) Sunken lesion with black pycnidia and rotted stem; D, E) Colony appearance and pigmentation; F, G) Straight, cylindrical to slightly curve and hyaline conidia; F) Conidia were ellipsoid to ovoid, rod shaped or round shaped and G) Contiguous arthroconidia.](image-url)
Based on DNA sequences of ITS regions, all isolates showed 99% similarity with *Neoscytalidium dimidiatum* (FJ648577) and further confirmed the species identity of the causal pathogen of pitaya stem canker in Malaysia. Besides pitaya, *N. dimidiatum* has been reported to cause canker disease on *Citrus sinensis* (Polizzi et al. 2009), *Mangifera indica* (Sakalidis et al. 2011) and *Hylocereus undatus* and *H. polyrhizus* in Taiwan (Chuang et al. 2012). It has a wide geographical locations and host range.

**STEM ROT**

Stem rot disease was detected in *H. polyrhizus* plantations in Malaysia, with symptom appeared as circular, brown sunken lesion with orange sporodochia and white mycelium formation on the lesion surface (Figure 4A-4C). Isolation from infected stem lesion showed that a total of 83 isolates of *Fusarium* were isolated from 20 plantations and were morphologically identified as *F. proliferatum* based on the variability of colony appearance, pigmentation, growth rate, length of chains, production of bluish sclerotia, concentric ring aerial mycelium and sporodochia (Masratul Hawa et al. 2013a).

The causal pathogen of stem rot produced dense-cottony, whitish aerial mycelium and purplish pigments (Figure 4D and 4E). Macroconidia produced by *F. proliferatum* were characterized as rare to abundant, slender, almost straight, curved apical cell, foot-shaped basal cell, 19.5–50.5 x 2.5–4.5 μm and 3–5 septa (Figure 4F). The microconidia were club-shaped with a flattened base, 3.5–15.5 x 1.55–6.2 μm, no septa (Figure 4G), formed in short chain (1–5 conidia/chain) or moderate chain (6–10 conidia/chain), in false head or abundant in the aerial mycelium. The conidiogenous cells were monophialide and polyphialide. Some isolates produced orange sporodochia on carnation leaves and chlamydospore was not formed. On the basis of the descriptions in the *Fusarium* Laboratory Manual (Leslie and Summerell 2006), all isolates from stem rot of *H. polyrhizus* were identified as *F. proliferatum*.

![Figure 4. Symptom of stem rot and morphological characteristics of *F. proliferatum*: A, B, C) Brown sunken lesions and rotted stem; D, E) Colony appearance and pigmentation; F) Slender, almost straight, curved apical cell, foot-shaped basal cell, and 3–5 septa macroconidia and G) Club-shaped with a flattened base and no septa microconidia.](image-url)
Besides morphological characteristics, determination of causing agent was performed under the basis of comparisons of translation elongation factor 1-alpha (TEF1-α) sequences (O’Donnell et al. 1998). Three species-specific primers, namely ITS1/proITS-R (White et al. 1990; Visentin et al., 2009), PR01/2 (Mule et al. 2004) and Fp3-F/4-R (Jurado et al. 2006) successfully produced PCR products and confirmed that the isolates from stem rot of *H. polyrhizus* were *F. proliferatum* isolates.

**CONCLUSION**

As a conclusion, pitaya in Malaysia was seriously infected with several economically important diseases namely anthracnose, stem necrosis, stem canker and stem rot that caused by different plant pathogenic fungi such as *C. gloeosporioides*, *C. truncatum*, *C. lunata*, *N. dimidiatum* and *F. proliferatum*. This review may help the future researchers especially in Malaysia as well as worldwide to devise an effective strategy for evaluating different pathological aspects of pitaya. Besides, information in this review can be used for quarantine purposes and to formulate an effective disease control management of pitaya. Further study is needed to reveal all the other recent diseases that infect pitaya by using integration of morphological and molecular tools such as ribosome and nuclear gene sequencing and RT-PCR to ensure the quality and continuous production of pitaya.

**REFERENCES**


DRAGON FRUIT (PITAYA) DISEASES IN THAILAND: INCIDENCE AND MANAGEMENT STRATEGIES

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ABSTRACT

An important aspect of dragon fruit production is the outbreak of diseases, especially in the tropical and subtropical regions. This study was conducted to investigate the distribution and identification of dragon fruit diseases in various locations in Thailand. Diseased plants were collected during October 2012 to September 2014 to observe the prevalence of dragon fruit diseases in Chanthaburi, Rayong, Ratchaburi and Nakon Ratchasima. Through the survey, three diseases (anthracnose, fruit rot and stem canker) with their respective incidences were identified and recorded. The highest disease incidence in anthracnose on stem, anthracnose on fruit, fruit rot and stem canker were recorded 23.4%, 22.5%, 13.5% and 58.2%, respectively. Identification was based on morphology and molecular characteristics and pathogenicity test. The different symptoms of diseases were isolated on potato dextrose agar (PDA) and the causal agents were identified as Bipolaris cactivora which causes fruit rot, Colletotrichum gloeosporioides and C. truncatum causes anthracnose on stem and fruit as well as Neoscytalidium dimidiatum causes stem canker. The stem canker disease, which is considered a new disease, was found in dragon fruit plantations. This is the first report of dragon fruit diseases caused by C. truncatum and N. dimidiatum in Thailand.

Keywords: dragon fruit disease, pest incidence, plant management

INTRODUCTION

Dragon fruit (Hylocereus undatus) is known by many names: pitaya, pitahaya and strawberry pear. This plant is native to South and Central America. Dragon fruit is now cultivated in the tropical and sub-tropical regions around the world. Currently most dragon fruits are commercially grown in Vietnam, Thailand, and south China. In 1981, Dr. Surapong Kosiyajinda, a fruit and vegetable scientist, conducted a study on dragon fruit and suggested that Thai people be acquainted with this fruit that is widely cultivated in Thailand particularly in the provinces of Chantaburi, Chumphon, Chiang Mai, Chiang Rai, Nakhon Pathom, Nakhon Ratchasima, Pathum Thani, Rayong, Samut Sakhon, Samut Songkhram. However, an important problem in producing dragon fruit in Thailand are diseases. They are often the most important hindrance in the production of dragon fruit. In Thailand, a few fungal diseases have been reported to infect the stems and fruit of dragon fruits such as anthracnose which has been reported to infect the stems and fruit caused by Colletotrichum gloeosporioides and C. truncatum (Athipunyakom and Likhitekaraj 2010; Athipunyakom et al. 2012), fruit rot caused by Bipolaris cactivora (Athipunyakom et al. 2009). Anthracnose disease is one of the important diseases in dragon fruit production. The fungi can damage the stems, flowers and fruits of dragon fruit in various locations in Thailand such as Kanchanaburi, Bangkok, Chumphon, Chiang Mai, Chiang Rai,
Chanthaburi, Nakhon Pathom, Pathum Thani, Ratchaburi, Rayong, Samut Sakhon, Samut Songkhram provinces. The pathogens were identified as *Colletotrichum gloeosporioides* and *C. truncatum*. Fruit rot of dragon fruit caused by *Bipolaris cactivora* was found in Pathum Thani, Samut Sakhon, Samut Prakarn, Ratchaburi, Nakorn Pathom, Ratchaburi, Rayong, Chanthaburi, Chiang Mai and Chiang Rai. The symptom included depressed water-soaks lesions with olive to black powdery spot coalescing into soft rot (Athipunyakom et al. 2009).

The aim of this research was to determine the occurrence and distribution of dragon fruit diseases in Thailand and to identify the pathogens using morphological and molecular characteristics.

**MATERIALS AND METHODS**

**Field surveys**
The survey was conducted in the dragon fruit plantations of Chanthaburi, Rayong, Ratchaburi and Nakhon Ratchasima during October 2012 to September 2014. The incidences of different diseases were recorded. Evaluations were conducted on 20 orchards in each province. Data were expressed as percentage.

**Isolation and identification of the pathogens**
Between October 2012 and September 2014, samples were collected from dragon fruit plantations showing symptoms of anthracnose, fruit rot and stem canker in Chanthaburi, Rayong, Ratchaburi and Nakhon Ratchasima. The specimens were aseptically excised from the edges of infected tissue, dissected into 2x2 mm 50 pieces per disease, immersed in 1% sodium hypochlorite for 1 minute, rinsed in sterile water three times and air-dried on a clean bench. Surface-sterilized lesion tissues were then placed on Potato Dextrose Agar (PDA). The plates were incubated at room temperature (28-30°C) and examined daily. Mycelia that grew from the tissue were transferred to PDA plates for further growth and sporulation (Tuite 1972). Identification was based on morphological characteristics as observed under a light microscope. Pure cultures were maintained on PDA slant and liquid paraffin at the Culture Collection, Department of Agriculture, Thailand.

**Molecular identification**
**Culture selection**
Fungal cultures were grown on PDA for 4-16 weeks at 25°C. Actively growing mycelium was scraped off the surface of a culture and transferred to 2 ml of microcentrifuge tubes and the biomass lyophilized at -80°C for 24 hours.

**DNA extraction**
Extraction buffer (1% CTAB, 0.7 M NaCl, 50 mM Tris-HCl, 10 mM EDTA, pH8) was added to fungal samples. The samples were ground in a 2 ml microcentrifugetube and the volume adjusted by adding 700 μl extraction buffer and mixed by inverting the tubes and incubated at 65°C for 1 hour. Samples were centrifuged at 12,000xg for 10 min at 25°C. The aqueous supernatant was transferred into a new microcentrifuge tube with phenol-chloroform-isooamyl alcohol by mixing gently and by centrifugation at 12,000xg for 10 min at 25°C. The upper liquid phase was transferred to a new microcentrifuge tube containing 7.5 M of ammonium acetate. The DNA was precipitated by ethanol (–20°C overnight) by centrifugation at 12,000xg for 10 min at 15°C. The DNA-pellet was
washed with ice-cold 70% ethanol and dried at 25°C. The pellet was redissolved in 50 μl of TE buffer (10 mM Tris-HCl, pH 8.0; 1 mM EDTA pH 8.0).

**PCR amplification**

Primers used for PCR amplification and for sequencing of the internal transcribed spacer region (ITS) were ITS4 and ITS5 (White et al. 1990; Bunyard et al. 1994; Landvik 1996). Amplification was performed in a 50 μl reaction mix: 10 mM of each dNTP (1 μl), 10 μM of each primer (1 μl), 10% of dilution buffer (5 μl), 25 mM of Mg (5 μl), 4 M of enhancer (5 μl) and 60-62% of sterile distilled water (30.8 μl), 0.2 μl of Taq DNA polymerase kit from FERMENTAS and 10-50 ng of genomic DNA template (1 μl) carried out using a PCR Model MJ Research DYAD ALD in 200 μl reaction tubes. (95°C, 0.5 min; 52°C, 1 min; 72°C, 1.5 min; 35 cycles). PCR products (7 μl aliquots) were checked by electrophoresis in 1% agarose gels with 0.003% ethidium bromide in 0.5×TBE buffer (0.044 M boric acid, 1.1 mM EDTA, 0.045 M Tris, pH 8) for purity.

**DNA purification and sequencing**

PCR products were purified using NucleoSpin® Extract Kit (Macherey-Nagel, Germany). The PCR products were sequenced by Macrogen Inc. in Korea with the same primers as those in the PCR amplification.

**Phylogenetic analyses**

Each sequence was checked for ambiguous bases. They were refined visually and assembled using BioEdit 7.0.9.1 (Hall 1999). The consensus sequences for each DNA region were multiple aligned by Clustal W 1.6 (Thompson et al. 1994) and checked manually with all sequences derived from the GenBank database and the accession numbers that are included in the phylogenetic trees. The alignment included the most similar sequence identified through BLAST search.

**Pathogenicity test**

The pathogenicity of each isolates was tested using Koch’s postulate. A 9 mm-diameter young mycelia PDA agar disc was used as inoculum placed on the surface of asymptomatic fruits and stems, either unwound and wound with a sterile needle. The inoculate stems and fruits were kept at room temperature (28-30°C) in dark.

**RESULTS AND DISCUSSION**

**Field surveys**

Survey was carried out in October 2012–September 2014 in the dragon fruit plantations of Chanthaburi, Rayong, Ratchaburi, Nakhon Ratchasima. Three diseases were found in dragon fruit orchard in Thailand such as anthracnose on stem and fruit (Figure 1A, B), fruit rot (Figure 1C) and stem canker (Figure 1D). The highest disease incidence in anthracnose on stem, anthracnose on fruit, fruit rot, and stem canker were recorded 23.4%, 22.5%, 13.5% and 58.2%, respectively (Table 1). The highest anthracnose disease incidence on stem (23.4%) was recorded in Chanthaburi province (Table 1). The highest anthracnose disease incidence on fruit (22.5%) was recorded in Rayong province (Table 1). The highest fruit rot disease incidence (13.5%) was recorded in Rayong province (Table 1). The highest stem canker disease incidence (58.2%) was recorded in Chanthaburi province (Table 1).
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Figure 1. Diseases of dragon fruit in Thailand: A) Anthracnose on stem; B) Anthracnose on fruits; C) Fruit rot; D) Stem canker

Table 1. Disease incidence of dragon fruit plantation surveyed in various locations.

<table>
<thead>
<tr>
<th>Locations</th>
<th>Anthracnose (C. gloeosporioides)</th>
<th>Anthracnose (C. truncatum)</th>
<th>Fruit rot (B. cacticvora)</th>
<th>Stem canker (N. dimidiatum)</th>
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<td>Incidence (%)</td>
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<td>stem</td>
<td>fruit</td>
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Identification of the pathogens and pathogenicity
Three diseases were found in dragon fruit orchard in the provinces of Chanthaburi, Rayong, Ratchaburi and Nakhon Ratchasima. These were anthracnose, fruit rot and stem canker.
Anthracnose

The different symptoms of anthracnose diseases were isolated on PDA and the causal agents were identified as *Colletotrichum gloeosporioides* and *C. truncatum*. The first symptoms of infected stems and fruits showed reddish brown lesions with yellow haloes. The center of a lesion showed brown and coalesced into the highest of anthracnose disease incidence on stem. It was also found that *C. gloeosporioides* and *C. truncatum* were detected in 23.4% and 8.9% at Chanthaburi and Rayong, respectively, whereas *C. truncatum* and *C. gloeosporioides* were detected in 22.5% and 9.6% of disease incidences on fruits at Rayong and Ratchaburi, respectively (Table 1). In this survey, we found the anthracnose disease on stem caused by *C. gloeosporioides* more than *C. truncatum* while the anthracnose disease on fruit caused by *C. truncatum* more than *C. gloeosporioides*.

The tissue transplanting method was used to isolate plant pathogenic fungi from infected stems (Figure 2A and 2B) and fruits (Figure 3A, B) on PDA and incubated at room temperature. Colonies on PDA at first white, became gray with concentric rings of salmon-colored spore mass. Identification was based on morphological characteristics. The pathogen was identified as *C. gloeosporioides* (Figure 2C, D). The second symptoms on stems and fruits are sunken circular lesions. The center of the lesions became tan in color and were dotted with many dark fruiting bodies of the fungus. Colonies grown on PDA changed from grayish to dark grey with an average colony diameter of 80.5 mm after 7 days, conidia mass honey. Conidia were falcate and 18.2 to 20.8 × 2.55 to 3.28 μm (Figure 3D). Sclerotia and setae are abundant (Figure 3D). Identification was based on morphological and cultural characteristics, the causal agent was identified as *C. truncatum* (Figure 3C, D).

![Figure 2. Anthracnose disease on stem caused by *Colletotrichum gloeosporioides*: A, B) Symptom on stem; C) conidia on conidiophores; D) conidid with oil-droplet-like body](image-url)
Figure 3. Anthracnose disease on fruit caused by *Colletotrichum truncatum*: A,B) Symptoms on fruits; C) Acervulus on fruit; D) Acervuli with setae and falcate conidia.

Morphological characters of this isolate, which was isolated from the symptom on dragon fruit, agreed with the original description of *C. truncatum* in that conidia were falcate, sclerotia and setae are abundant. In addition, the molecular data of this isolate based on the internal transcribed spacer (ITS) region was 100% identical to the ITS sequence of an epitype (Damm et al. 2009). Therefore, the fungus was identified as *C. truncatum*.

Pathogenicity tests were conducted on stems and fruits inoculated with mycelium and conidia of *C. gloeosporioides* and *C. truncatum* was used as inoculum. The fungus was reisolated with symptomatic stem and fruit tissues. The pathogenicity test showed that *C. gloeosporioides* and *C. truncatum* were the cause of anthracnose on dragon fruits.

In this study, the isolates of *C. truncatum* which isolated from dragon fruit were previously identified as *C. capsici*. These isolates are morphologically similar to *C. capsici* from anthracnose of chilli (Than et al. 2008). Molecular diagnostics are recommended to confirm the identity of these isolates which was identified as *C. truncatum*. It is similar to anthracnose of dragon fruit disease caused by *C. truncatum* in China (Guo et al. 2014) and in Malaysia (Vijaya et al. 2015).

**Fruit rot**
The symptom included depressed water-soaks lesion with olive to black powdery spot coalescing into soft rot on fruit (Figure 4A) and flower. In addition, the pathogens also destroyed flowers (Figure 4B). The pathogens form black colonies, and hair on fruit (Figure 4C). Conidiophores were pale to light brown, caespitose (Figure 4 D), straight or flexuous, and often swollen at the apex and at the base. Conidia with a basal hilum were straight, ellipsoidal, fusiform or obclavate, 2-4 pseudosepta, pale light brown to golden brown and were 20 - 54 x 6 -11 (ave. 34.75 x 7.28) μm (Figure 4 E, F). The causal fungus was identified as *Bipolaris caktivora* (Petrak) Alcorn. Pathogenicity tests were conducted on fruits inoculated with mycelium and conidia was used as inoculum.
The fungus was reisolated with symptomatic fruit tissues. It is similar to fruit rot of strawberry pear (pitaya) caused by *B. cactivora* in Okinawa Prefecture, Japan (Taba et al. 2007) and in Florida (Tarnowski et al. 2010). Tarnowski et al. (2010) indicated that *B. cactivora* causes flower and fruit rot on pitahaya, but does not seriously affect mature plant stems. The flower rot does not appear to significantly increase the incidence but may provide inoculum for the fruit rot. The high incidence of fruit rot affecting commercial operations in Miami-Dade County over the past two years requires an effective disease management strategy. Athipunyakom et al. (2009) reported that fruit rot of dragon fruit (*Hylocereus undatus* Haw.) caused by *B. cactivora* was found at Pathum Thani, Samut Sakhon, Samut Prakarn, Ratchaburi, Nakorn Pathom, Ratchaburi, Rayong, Chanthaburi, Chiang Mai and Chiang Rai.

Figure 4. Flower and fruit rot of Dragon fruit caused by *Bipolaris cactivora*: A) Early brown spot lesion on fruit; B) Flower rot; C) Black colonies, hairy on fruit; D) Cespitose conidiophores and irregularly at the apex; E, F) Conidia.
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**Stem Canker**
In 2012, a new dragon fruit disease called stem canker, was found in Chanthaburi, Rayong, Ratchaburi and Nakhon Ratchasima. It is characterized by many small, circular, reddish brown spot on the diseased stems (Figure 5A). The spots continuously expanded, and formed large areas of canker on stems (Figure 5B). Some lesions developed near the ribs of stem (Figure 5C, D). Yellowing of tissues was followed by softening and the rotten stench of tissues. Black pycnidia fruited on the stem which was subsequently rotten (Figure 5E, F and 6A, B). There was also the fungus conidia aseptate, hyaline substance, thick-walled, smooth, subcylindrical to oblong-elliptical, sometimes slightly curved, with rounded ends. There was hyaline after discharge from pycnidia (Figure 6 C, D).

![Figure 5](image)

Figure 5. Stem canker symptom caused by Neoscytalidium dimidiatum: A) Early brown spot lesion on stem; B) Sunken and brown lesion symptoms; C, D) Early infection from the rib; E, F) Black pycnidia on surface fruit.
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Figure 6. Stem canker symptoms caused by Neoscytalidium dimidiatum: A, B) Black pycnidia on surface fruit; C) Cross section through pycnidia; D) Conidia.

For identification, cultures were grown on PDA at room temperature. After three days, colonies were seen with with dark grey to black aerial mycelium form. The colonies produced abundant conidia that occurred in arthric chains in aerial mycelium. Mycelium were branched, septate, hyline to brown which constricted in to spore chains and disarticulated into arthroconidia. The arthroconidia were cylindrical truncate, orbicular to doliform, dark brown, 0-1 septate. The teleomorph was never observed in PDA culture. It is similar to stem canker of dragon fruit disease caused by Neoscytalidium dimidiatum in Taiwan (Chuang et al. 2012) and China (Yi et al. 2013; 2015).

Morphological characters of this isolate, which was isolated from the symptom on dragon fruit, agreed with the original description of Neoscytalidium dimidiatum in that the arthroconidia were cylindrical truncate, orbicular to doliform, dark brown. The DNA sequence containing 679 characters of the internal transcribed spacer (ITS) region was 100 % identical to N. dimidiatum, using BLASTN 2.2.32 (Zheng et al. 2000). The ITS sequence of this isolate also had similarity to the type sequence of N. novaehollandiae (NR 111260), but was only at 99 % of identity. Based on morphological characters as well as the similarity of the ITS sequence, the fungus was identified as N. dimidiatum.

In this study, the isolates of N. dimidiatum which were isolated from dragon fruit were previously identified as Dothiorella sp. These isolates are morphologically similar to
Botryospheria dothidea from stem spot on Hylocereus undatus in Mexico (Valencia-Biotin, et al. 2003). Molecular diagnostics are recommended to confirm the identity of these isolates, which were identified as N. dimidiatum. It is similar to stem canker of dragon fruit disease caused by Neoscytalidium dimidiatum in Taiwan (Chuang et al. 2012) and China (Yi et al. 2013; 2015).

Neoscytalidium dimidiatum has a wide geographical and host range such as Albizia lebbeck, Delonix regia, Ficus carica, Ficus spp., Peltophorum petrocarpum and Thespesia populena in Oman; on Arbutus, Castanea, Citrus, Ficus, Juglans, Musa, Populus, Prunus, Rhus, Sequoiaedendron in the USA; and on Mangifera indica in Niger (Ray et al. 2010). Stress factors such as water stress enhance the severity of disease caused by this fungus and symptoms include branch wilt dieback, canker, gummosis and tree death (Punithalingam and Waterson 1970). This pathogen can cause dragon fruit canker and spot on the stem or fruit ((Lan et al. 2012; Chuang et al. 2012; Yi et al. 2013; Mohd et al. 2013), internal black rot in fruit (Ezra et al. 2013), stem canker (Ni et al. 2013) fruit internal brown rot in Guangdong Province, China (Yi et al. 2015). This is the first reported causing stem canker on dragon fruit in Thailand.

Management strategies

Dragon fruit diseases can have significant constraints in production, especially when they occur in environments with high rainfall and uniform, warm temperatures. The successful management of plant disease utilizes several principles and practices, regardless of the host and environment in which it is grown. These include the avoidance, exclusion and eradication of the causal agents. The removal of infested debris and host materials is another common eradication strategy but it is the most important to control the diseases especially in dragon fruit production in Thailand.

REFERENCES


PATHOGEN IDENTIFICATION AND MANAGEMENT OF PITAYA CANKER AND SOFT ROT IN TAIWAN

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INTRODUCTION

Pitaya (Hylocereus spp.) is one of the important newly emerging fruit crops in Taiwan. However, the fruit production is limited by pitaya canker and wet rot, which were found in 2009 and 2012, respectively. The pathogen identification and management of these two diseases are introduced in this paper.

PITAYA CANKER

Pitaya canker is now considered to be the most severe disease of pitaya in Taiwan in recent years. The disease could be found in nearly 80% of the commercial planting areas. At the early stage of the disease, the symptoms on the stem are small, circular, orange sunken spots, and then develop into cankers. At the late disease stage, stems subsequently rot, and pycnidia could be observed on the surface of the cankers (Figure 1A-C). The similar symptoms were also visible on the infected fruits (Figure 1D-F). The pathogen could also infect the fruits after harvest. The infected fruits showed brown to black water-soaked rot symptom (Figure 1G), and eventually dried with numerous pycnidia erumpenting from the surface.
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Figure 1. *Neoscytalidium dimidiatum* caused canker symptoms on stems (A-C), fruits (D-F) and harvested fruit of pitaya (G).

**Identification of the pathogen of pitaya canker**

Tissues adjacent to cankers were placed on acidified potato dextrose agar (PDA) and incubated at room temperature. After culturing for 1 week, fungal colonies grew from the disease tissues with dark gray-to-black aerial mycelium. Under the light microscope, hyphae were branched, septate, and pale brown, and easily disarticulated into 0- to 1-septate arthrospores (Figure 2A). Conidia (12.79 ± 0.72 × 5.14 ± 0.30 μm) produced in pycnidia, were one-celled, ovate and hyaline (Figure 2B). Dark, septate and 3-celled conidia were not observed on agar media but in the diseased samples (Figure 2C). The extracted DNA of the cultured mycelium was amplified by PCR reaction with the primer pair ITS1 and ITS4 for the internal transcribed spacer (ITS) region. The ITS (ITS1-5.8S-ITS2) sequence (GenBank Accession No. HQ439174) showed 99% identity to *Neoscytalidium dimidiatum* (Penz.) Crous & Slippers (GenBank Accession No. GQ330903). On the basis of morphology and nucleotide-sequence identity, the isolates were identified as *N. dimidiatum*.

The taxonomic classification of *N. dimidiatum* is as follows.

Fungi

   Ascomycota
   Dothideomycetes
   Botryosphaerales
   Botryosphaeriaceae
   Neoscytalidium
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Figure 2. Arthroconidia (A) and young (B) and mature (C) pycnidial conidia of Neoscytalidium dimidiatum in vitro (A-B) and in diseased samples of field (C). Bar = 10 μm.

Pathogenicity and epidemic study of Neoscytalidium dimidiatum
Disease development was observed in detail by inoculating conidia of N. dimidiatum on pitaya stems with wound treatment in the field. After inoculation, small, circular, orange sunken, orange spots appeared and then developed into cankers 2 weeks later. Black pycnidia were observed on the surface of the diseased tissue 6 weeks after inoculation, and the lesion tissue fell off and form shot-hole symptom on the stem 12 weeks after inoculation. The infection could extend from the shot-hole edge to the healthy tissue and resulted in the collapse of a large area of stem tissue 18 weeks after inoculation.

So far, we have observed that the primary inoculum source of pitaya canker in the orchard are from the diseased seedlings and spreads through water and rain. It has also been observed that the pathogen can spread and infect the tissue by arthrospores and pycnidial conidia in the field only in the existence of free water under high humidity.

Besides, according to the experiments in vitro, the optimal temperatures for mycelial growth and pycnidial conidia germination of N. dimidiatum were 25–35°C (Figure 3) and 20–40°C in free water (Figure 4) respectively.

Figure 3. Effect of temperature on the mycelial growth of Neoscytalidium dimidiatum.
In summary, these evidences might be able to explain that the symptoms of canker of pitaya are observed nearly 1 to 2 months after raining and the disease spreads faster in the hot and raining seasons, which are spring and summer in Taiwan.

**Chemicals selection for the control of pitaya canker**

According to the plant protection manual in Taiwan, there are 9 synthetic chemicals could be used legally on pitaya. The tests of effects of these 9 chemicals on *Neoscytalidium dimidiatum* were conducted on agar media. Mycelial growth was effectively inhibited *in vitro* by cyprodinil + fludioxonil, azoxystrobin + difenoconazole and tebuconazole at 10 ppm a.i. Pycnidial conidia germination of *N. dimidiatum* *in vitro* was inhibited by metiram, trifloxystrobin, pyraclostrobin, azoxystrobin, azoxystrobin + difenoconazole and iminoctadine at 10 ppm a.i. These fungicides were therefore recommended to control canker of pitaya in the field in Taiwan. Further tests should be conducted in the field before these chemicals are recommended to control the disease (Figures 5-6).
Figure 5. Effect of synthetic chemicals on the mycelial growth of *Neoscytalidium dimidiatum* Nd-55.

Figure 6. Effect of synthetic chemicals on the pycnidial conidia germination of *Neoscytalidium dimidiatum* Nd-55.

Furthermore, for management of organic farming, the tests of effect of Bordeaux mixture (formulas: 2-2-1 and 4-4-1; copper sulfate (g) - lime (g) - water (L)) on pathogen was also conducted on agar media. The result showed that these materials effectively inhibit both mycelial growth and arthrospore germination of *N. dimidiatum* in vitro. What’s more, it was proved in greenhouse that disease severity was reduced with the application of Bordeaux mixture (Figure 7), and the field. So far, Bordeaux mixture has been recommended to control the disease in Taiwan.
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Figure 7. Effects of Bordeaux mixture on the disease severity caused by *Neoscytalidium dimidiatum* on the stem of pitaya. Formulas: copper sulfate (g)- lime (g)- water (L).

Management of pitaya canker in Taiwan

1. For preventive management, using disease-free seedlings is suggested since it had been found that the seedlings were the major primary inoculum in the orchard.
2. To reduce the inoculum, cankered stems and fruits should be pruned and removed out of the orchard.
3. Because of less rain and lower temperature in fall and winter, the development and propagation of *N. dimidiatum* is slow down. It’s a good time for managing the disease such as pruning and subsequently spraying the chemicals mentioned above.
4. As Bordeaux mixture can leave a blue-green discoloration on the surface of the tissue, the application of the material is not advised at fruiting season unless the fruits are bagged.

**PITAYA WET ROT**

Pitaya wet rot caused by *Gilbertella persicaria* (Eddy) Hesseltine severely affected flowering, fruiting and postharvest storage of pitaya in Taiwan. In the disease survey of pitaya orchards, the infection occurred mainly during rainy season. Diseased flower buds (Figure 8A), petals (Figure 8B) and young fruits (Figure 8C) showed brown and small water-soaked lesion. Most of the infected fruits in the orchard failed to develop normally and dropped prematurely. Internal black rot of fruits could also be observed when the infection occurred during fruiting (Figure 8D). Mature fruits were infected when harvested or during storage and appeared water-soaked and soft rot on the fruit appearance (Figure 8E). Wet rot of fruits usually initiated from the stem-ends, occasionally from the middle of fruits or scales, and could develop into completely fruit rot 2-4 days after infection. After harvest, fruits could be infected through the wounds and become rotted during storage or transportation. Brown to black sporangia of *G.*
persicaria could be observed producing on the surface of infected tissues, especially under humid conditions.

Figure 8. Gilbertella persicaria caused wet rot symptoms on flower bud (A), petals (B), young fruit (C, D) and harvested fruit of pitaya (E).
Identification and differences of *Gilbertella persicaria* var. *pitaya*

According to the description by Benny (1991), the taxonomic classification of *G. persicaria* is as follows:

**Fungi**

**Zygomycota**

**Zygomycetes**

**Mucorales**

**Gilbertellaceae**

The morphology of *G. persicaria* var. *pitaya* (Figure 9) was similar with the description of the holotype of *G. persicaria* (CBS 190.32, isolated from rot peach, *G. persicaria* var. *persicaria*) (Table 1). However, interestingly, in *G. persicaria* var. *pitaya*, the number of longitudinal sutures on the sporangial wall were found no less than 1 and splitting the sporangial wall into 2-7, usually 4, equal pieces, while there was only 1 suture in the holotype; the number of the appendages at the ends of the sporangiospores of the pitaya isolates were 0-3 while 2-7 in the holotype.

Figure 9. Morphology of asexual reproduction structures of *Gilbertella persicaria* var. *pitaya* produced on fruit tissues (A - B) and PDA (C - F). A: mature sporangia produced on curved (mostly) sporangiophores. B: persistent sporangial wall with longitudinal sutures. C: sporangial wall could separate into 2 - 5 pieces (in the case of this picture were 4 pieces). D: sporangial wall covered with crystalline spines. E: a columella with collar (arrow). F: a spore with two hyaline appendages (arrows), stained by rose bengal. G: an intercalary chlamydospore produced by *G. persicaria* var. *pitaya* on MEA. Bar = 10 μm.
Table 1. Morphological characteristics of *Gilbertella persicaria* var. *persicaria* and *G. persicaria* var. *pitaya*.

<table>
<thead>
<tr>
<th>Characters</th>
<th><em>Gilbertellapersicaria</em> var. <em>persicaria</em></th>
<th><em>Gilbertellapersicaria</em> var. <em>pitaya</em></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sporangiophore</strong></td>
<td>19-33 μm in diam</td>
<td>18-50 μm in diam</td>
</tr>
<tr>
<td>(branched or rarely branched; bent when young, upright at maturity)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Sporangia</strong></td>
<td>45-170 μm in diam.; 60-115 μm in diam</td>
<td></td>
</tr>
<tr>
<td>(yellow to dark brown, more or less globose; covered with calcium oxalate crystals)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Columella</strong></td>
<td>36-81 μm in diam. at the widest</td>
<td>25-60 μm in diam. at the widest</td>
</tr>
<tr>
<td>(with basal collar; obpyriform, oboboid to cylindrical)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>No. of longitudinal suture</strong></td>
<td>1</td>
<td>1.5</td>
</tr>
<tr>
<td>(on the surface of sporangia wall)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>No. of separated sporangial wall</strong></td>
<td>2</td>
<td>2-7 (avg. 4)</td>
</tr>
<tr>
<td><strong>Sporanigospores</strong></td>
<td>5.1-17.8 × 3.8-12.7 μm</td>
<td>5.5-11.8 × 4.5-8.8 μm</td>
</tr>
<tr>
<td>(globose, ellipsoid to ovoid)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>No. of hyaline appendages</strong></td>
<td>2</td>
<td>0.3</td>
</tr>
<tr>
<td>(up to 24 μm, at the ends of sporanigospores)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Chlamydospores</strong></td>
<td>15-29 × 10-16 μm</td>
<td>18.9-25. × 14.9-23.8 μm</td>
</tr>
<tr>
<td>(globose to irregular; light brown, smooth-walled)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Occasionally, field survey also showed that *Rhizopus stolonifer* could be found in the petal of withered flowers and might be confused with *G. persicaria* var. *pitaya*. These fungi can be distinguished by morphology and maximum temperature. The differences are listed in the Table 2.
Table 2. Differences of diagnostic characters between \textit{Rhizopus stolonifer} and \textit{Gilbertella persicaria}.

<table>
<thead>
<tr>
<th>Characters</th>
<th>\textit{Rhizopus stolonifer}</th>
<th>\textit{Gilbertella persicaria}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sporangiospore with appendages</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Max. growth temp.</td>
<td>33 °C</td>
<td>38 °C</td>
</tr>
<tr>
<td>Rhizoid</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Sporangioptores</td>
<td>Branchless; erect</td>
<td>Branched or rarely branched; bent or upright</td>
</tr>
<tr>
<td>Sporangia</td>
<td>Up to 200-300 μm</td>
<td>Less than 180 μm.</td>
</tr>
<tr>
<td>Sporangial wall</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

In addition to morphological characteristics, identity of \textit{G. persicaria} var. \textit{pitaya} was also confirmed by ITS (ITS1-5.8S-ITS2) sequence analysis. The identity between \textit{G. persicaria} var. \textit{pitaya} and the holotype of \textit{G. persicaria} was 98.4\%, which with 5 additional and 6 different nucleotides in the \textit{G. persicaria} var. \textit{pitaya}.

We also inoculated fruits of pitaya with the \textit{G. persicaria} var. \textit{persicaria} (CBS190.32, the holotype, and F209130). The water-soak lesions caused by these isolates were smaller and browner than those of \textit{G. persicaria} var. \textit{pitaya}.

In summary, these data suggested the \textit{G. persicaria} var. \textit{pitaya} was different from the holotype of \textit{G. persicaria} in regards of the sporangial wall, ITS sequence and virulence to fruits of pitaya.

**Pathogenicity of \textit{Gilbertella persicaria} var. \textit{pitaya}**

Our data showed the optimal temperatures for \textit{G. persicaria} hypha growth were 24-36°C (Figure 10), maximum at 38°C. In order to understand the effect of temperature on the disease development of pitaya wet rot, healthy mature fruits were collected from the field for artificial inoculation with sporangiospores of the pathogen. The tests results showed that wounding and higher temperatures (24-36°C) resulted in severe infection, indicating that wounding and temperature were important factors affecting the disease severity.
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Figure 10. Effect of temperature on mycelial growth of *Gibertella persicaria* var. *pitaya* isolates. Cultures were grown on PDA in petri dishes (diam. 9 cm) for 2 days. Linear growth rates were shown as average of 3 replicates of each isolates in a single experiment. This experiment was repeated for 3 times with similar results.

Results of artificial inoculations also showed that *G. persicaria* var. *pitaya* were pathogenic on fruits of peach and wounded fruits of apple, mango, persimmon, plum and tomato, but they were non-pathogenic on banana and kiwifruits. These results suggested that *G. persicaria* var. *pitaya* might be a potential pathogen for these sensitive fruits in the field or upon marketing and affect the storage periods in the market.

Chemicals selection for the control of wet rot

Synthetic chemicals with different inhibition mechanism were selected to test the inhibition to *G. persicaria* var. *pitaya* on agar media, although some chemicals, like fluazinam, difenoconazole, tridemorph and prochloraz-Mn have not been yet authorized to be used on pitaya. The data showed that the mycelial growth was completely inhibited by cyprodinil + fludioxonilat 1 ppm a.i., and pyraclostrobin, prochloraz-Mn, tridemorph, difenoconazole and tebuconazole at 10 ppm a.i. The sporangiospore germination was completely inhibited by fluazinam at 1 ppm a.i., and cyprodinil + fludioxonil, difenoconazole, metiram, tebuconazole, tridemorph, prochloraz-Mn and pyraclostrobin at higher a.i.

The tests of effect of some control agents for organic farming on pathogen were also conducted on agar media. The data showed that neutralized phosphorous acid could inhibit sporangiospores germination, and Bordeaux mixture or Hey-Show-Lo (a kind of plant extract) could inhibit both mycelial growth and sporangiospores germination. The
efficiency of these agents for controlling wet rot for organic management in the field would be further tested.

Management suggestions of wet rot
The disease severity of pitaya wet rot is closely related with the occurrence and frequency of the raining based on the epidemic investigation. In addition, the sporangia would emerge from the diseased tissue quickly under high humidity, and the sporangiospores could spread out by rain drops and wind.

Based on the epidemic and pathogenic studies so far, advices are given as follows.
1. To reduce the inoculum, flowers and fruits with wet rot symptoms should be excised, and then packed and removed out of the orchards immediately.
2. For crop protection in the flowering period in the field, sporangiospores germination inhibiting chemicals and mycelia growth inhibiting chemicals are recommended to be used before and after raining, respectively.
3. In order to reduce fruit infection, harvesting the fruits on the raining day should be avoided, and the wounds and the surface of the fruits should be dried before packaging.
VIRAL DISEASES OF PITAYA AND OTHER CACTACEAE PLANTS

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ABSTRACT

Pitaya (Hylocereus spp.), also called dragon fruit, pitahaya or pitajaya, native to the forests of Latin America, and the West Indies, belongs to the family of Cactaceae. Among the cactus fruit crops, pitaya is classified as the climbing epiphytic species and produces edible fruits which have sweet pulps with numerous small black seeds on the trailing cladode stems. Due to the progress in breeding and cultivation techniques in Taiwan, pitaya is becoming an important fruit crop in the domestic and foreign markets. During a disease survey of pitaya in Taiwan, some plants were found with systemic mild mottling on the stems, and these were found to be infected by a potexvirus, Cactus virus X (CVX). In addition, another two potexviruses Zygocactus virus X (ZyVX) and Pitaya virus X (PiVX), were identified later in Taiwan. Because of the similar features of Cactaceae plants, there is high possibility that cactus-infecting viruses will infect pitaya just like CVX and ZyVX did. The objective of this article is to provide information of viral diseases of pitaya and other Cactaceae plants so as to help further study of pitaya-infecting viruses and propose the control strategy.

Keywords: pitaya, Hylocereus, Cactaceae, viral diseases

INTRODUCTION

Pitaya, also called dragon fruit, pitahaya or pitajaya, native to the forests of northern South America, Central America, Mexico, and the West Indies, belongs to the genus Hylocereus in the family of Cactaceae (Mizrahi et al. 1997; Le Bellec et al. 2006). Among the cactus fruit crops, pitaya is classified as the climbing epiphytic species (Mizrahi et al. 1997) and produces edible fruits which have sweet pulps with numerous small black seeds on the trailing cladode stems. According to the Britton and Rose classification (Britton and Rose 1963), the genus of Hylocereus contains 16 species of plants, five of these are planted as fruit trees including H. purpusii, H. polyrhizus, H. costaricensis, H. undatus, and H. trigonus (Le Bellec 2006). The pitaya industry is distributed mainly in Latin America, such as Mexico, Colombia, Costa Rica and Nicaragua, in Asia, such as Vietnam and Israel, and also in Australia (Le Bellec et al. 2006). In Taiwan, pitaya had been firstly introduced by Dutch colonists in 1600s, and pitaya cultivars with higher yield have been further introduced from South America and Vietnam in recent decades (Hsu 2004). Due to the progress in breeding and cultivation techniques in Taiwan, pitaya is becoming an important fruit crop in the domestic and foreign markets. Among the three major species cultivated in Taiwan, H. undatus plant produces oblong rosy-red fruit with white pulps, whereas the ovoid fruit of H. costaricensis and the oblong fruit of H. polyrhizus plants contain purple-red and purple-red pulps, respectively. The first two Hylocereus species are also the most widely cultivated pitaya species in the world (Le Bellec et al. 2006). Pitaya fruit is noticed with
high nutrients and antioxidants, for example, betalains including betanin, phyllocactin, and hylocerenin which only present in few families of plants (Stafford 1994; Stintzing et al. 2002; Wybraniec and Mizrahi 2002; Stintzing et al. 2005). Therefore, pitaya is the best source of betalains among the fruits in Taiwan.

Based on the record by Taiwan's Agriculture and Food Agency in 2012, the planting area and yield of pitaya in Taiwan were about 979 hectares and 23,550 tons, respectively. Compared to other fruit crops, there are not many pests and pathogens causing serious problems on pitaya, so the application of chemicals is only infrequent during the growth season. However, since the cultivation of pitaya in commercial plantations started in earnest, symptoms of soft rot, lesions and spots in stems and fruits which were caused by bacteria and fungi were observed (Valencia-Botin et al. 2013). During a disease survey of pitaya in Taiwan, some plants were observed with systemic mild mottling on the stems, and these were found to be infected by a potexvirus, Cactus virus X (CVX) (Liou et al. 2001; Liou et al. 2004a, 2004b). In addition, another two potexviruses Zygocactus virus X (ZyVX) and Pitaya virus X (PiVX), were identified later in Taiwan (Mao 2008). Consequently, for a promising and important fruit crop as pitaya, study in diseases of pitaya is essential. Because of the similar features of Cactaceae plants, there is high possibility that cactus-infecting viruses will infect pitaya just like CVX and ZyVX did. For this reason, we collected the literatures of plant viruses which have been reported to infect cactus plants. The objective of this article is to provide information of viral diseases of pitaya and other Cactaceae plants so as to help further study of pitaya-infecting viruses and propose the control strategy.

**PLANT VIRUSES FOUND IN THE CACTACEAE PLANTS**

**The reported cactus-infecting viruses**

The family Cactaceae comprises between 122 and 200 genera consisting of 1600 to 2000 species, and nearly all members have spiny and succulent stems, found especially in the semi-arid regions of Latin America (Mizrahi et al. 1997; Le Bellec et al. 2006). Since the study of Amelunxen on cactus virus, several viruses with elongated particles similar to Potato virus X (PVX) have been found in wild and cultivated cactus plants (Giri and Chessin 1975a). More than 40 species in the family Cactaceae have been reported to be infected by these elongated viruses (Koenig et al. 2004). Up to now, at least five different genera of plant viruses, including Carlavirus, Carmovirus, Potexvirus, Tobamovirus and Tospovirus, have been identified in Cactaceae plants.

In the late 1950s, several reports about cactus-infecting elongated viruses were published in German (Amelunxen 1955a, 1955b, 1958). Brandes and Bercks (1962) isolated a virus (B1 isolate) from Zygocactus sp. which was morphologically and serologically similar to Amelunxen’s cactus virus, and they proposed the name Cactus virus X (CVX) for all elongated cactus viruses similar to PVX (Brandes and Bercks 1962). Plese and Milicic (1966) compared the host reactions of B1 isolate from Zygocactus sp. to a K11 isolate from Schlumbergera bridgesii and four isolates from Opuntia spp. in Yugoslavia, and all these so-called CVX isolates displayed different virulence in the tested plants (Plese and Milicic 1966). Milicic et al. (1966) found all CVX isolates were morphologically similar but serologically different, and described that the Zygocactus isolate B1 and the four isolates from Opuntia spp. were serologically closely related, whereas the Schlumbergera isolate K11 and another isolate CC10 from an Opuntia plant in the U.S.A. were found to be only distantly related serologically to other five CVX...
isolates. Therefore, Milicic et al. raised a question whether these three CVX isolates, B1, K11 and CC10, should be considered as separate viruses (Milicic et al. 1966). This question has not been answered until the article of Koenig et al. who published the sequence information of B1, K11 and CC10 isolates in 2004. According to the results of sequence comparison, the B1 isolate from Zygocactus sp., the K11 isolate from S. bridgesii, and the CC10 isolate from Opuntia sp. should be regarded as distinct virus species of the genus Potexvirus for which the names Zygocactus virus X (ZyVX), Schlumbergera virus X (SchVX) and Opuntia virus X (OpVX) are proposed (Koenig et al. 2004). In the same year, the complete nucleotide sequence of CVX of a Hu strain was published by Liou et al. at National Taiwan University isolated from pitaya plants (H. undatus) with systemic mild mottling symptoms (Liou et al. 2004a).

In addition to the above mentioned potexviruses which possess a single-stranded positive-sense RNA genome encapsidated into flexuous filamentous particles, Casper and Brandes identified a virus from a symptomless Christmas cactus (Zygocactus X Schlumbergera hybrid) and named it Zygocactus virus (ZyV) which had different properties from CVX (Casper and Brandes 1969). Giri and Chessin reported another potexvirus isolated from Christmas cactus (Giri and Chessin 1972) and designated the virus as Zygocactus virus X (ZyVX) which differed from the B1 isolate and Casper’s Zygocactus virus (ZyV) in host range test (Giri and Chessin, 1975a). This virus was found distantly related serologically to PVX and CVX but not related to ZyV (Giri and Chessin, 1975a). However, there is no further information or sequence about Giri’s ZyVX or Casper’s ZyV; the species status of these two potexviruses has not yet been determined. Therefore, there are four formal species of the genus Potexvirus, Cactus virus X (CVX), Opuntia virus X (OpVX), Schlumbergera virus X (SchVX) and Zygocactus virus X (ZyVX), reported to be cactus-infecting viruses so far.

Some workers pointed out that one difficulty in working with the cactus viruses has been the lack of external symptoms in the virus-infected cactus plants (Bercks 1971). However, a strain of CVX was identified to infect California barrel cactus plants (Ferrocactus acanthodes) in a cactus forest in San Bernardino County, California in 1974. The virus-infected plants showed distorted areoles, malformed spines, necrosis and systemic mottle (Attathom et al. 1978). In Taiwan, a strain of CVX infected Indian fig opuntia (Opuntia ficus-indica) and resulted in poor growth and inconspicuous chlorotic mottling (Chen and Tzeng, 1996). Recently, single and mixed infection of CVX, OpVX, SchVX and ZyVX in three different cactus plants, Opuntia tuna, Hylocereus undatus and Schlumbergera truncate, showing chlorotic spots and mosaic symptoms were reported in Brazil (Duarte et al. 2008). Consequently, the outcome of virus-infected cactus plant depends on the combination of plant and virus as well as the environment.

Until now, there are four cactus-infecting tobamoviruses described which have rod-shaped particles containing a single-stranded positive-sense RNA genome (Sammons and Chessin 1961; Giri and Chessin 1975b; Min et al. 2006; Kim et al. 2012). Sammon’s Opuntia virus (SOV) was the first reported tobamovirus isolated from Opuntia engelmannii in Arizona in the United States (Sammons and Chessin 1961). Although the amino acid composition of the capsid protein (CP) of SOV has been reported (Gibbs 1977), no nucleotide sequence of this virus is available so far. A severe strain of Tobacco mosaic virus (TMV) was found and isolated from the Beavertail cactus (Opuntia basilaris) grown in the wild of Arizona (Giri and Chessin 1975b). The antiserum prepared against the purified virus showed a positive reaction with TMV common strain.
However, the result of indicator plant assay indicated this virus is a new strain of TMV, and is tentatively named the Beavertail Cactus strain of TMV (Giri and Chessin 1975b). In 2001, Cactus mild mottle virus (CMMoV), a cactus-infecting tobamovirus, was isolated from diseased moon cactus (Gymnocalycium mihanovichii) which was grafted onto Hylocereus trigonus in Korea (Min et al. 2006). The CMMoV-infected cactus showed very mild mosaic and its rootstock revealed ring-type mottling along the stem. Western blot analysis showed that the virus was unrelated to SOV (Min et al. 2006). The complete genome sequence of CMMoV was determined and phylogenetic analysis of the viral replicases and MP indicated that CMMoV is closely related to cucurbit-infecting tobamoviruses, while the CMMoV CP is more closely related to brassica- and solanaceous infecting tobamoviruses (Min et al. 2009). Recently another new tobamovirus, Rattail cactus necrosis-associated virus (RCNaV), was identified in rattail cactus (Aporocactus flagelliformis) plants showing necrosis symptoms and the complete genome sequenced was determined (Kim et al. 2012). Phylogenetic analysis suggests that RCNaV could be clustered in a new subgroup, cactaceae-infecting tobamoviruses, with CMMoV (Kim et al. 2012).

Another cactus-infecting virus with flexuous filamentous particles is Cactus virus 2 (CV-2) which was first reported by Brandes and Wetter (1959), belongs to the genus Carlavirus and is grouped into aphid-borne carlaviruses (Adams et al. 2004). However, no further information or sequence about CV-2 has been reported.

The first and only isometric virus isolated from the family Cactaceae is Saguaro cactus virus (SgCV) which belongs to the genus Carmovirus and is the first virus to be found in saguaro cactus (Carnegiea gigantea) in Arizona (Milbrath and Nelson 1972). According to a cactus virus survey, 52 (40%) out of 131 sampled saguaros were infected with SgCV. It was suggested that the cactus is a latent carrier of SgCV therefore the widespread virus has not been noticed for a long time (Milbrath and Nelson 1972).

Besides positive-sense RNA viruses, two species of the genus Tospovirus with negative-sense RNA genomes, Impatiens necrotic spot virus (INSV) and Tomato spotted wilt virus (TSWV), have been reported in cactus plants (Hausbeck and Gildow 1991; Blockley and Mumford 2001). During a survey of greenhouse ornamentals in Pennsylvania, TSWV was detected in samples of the Thanksgiving cactus (Schlumbergera truncata) which were symptomless or showed mild symptoms of sunken chlorotic lesions, dark green spots, chlorosis, necrosis, and distortion (Hausbeck and Gildow 1991). The possible role of S. truncata as a reservoir for TSWV should be considered when developing the disease management strategies. In the United Kingdom, prickly pear cactus (Opuntia microdasys var. albata) with necrotic spots or lesions was proved to be infected by INSV (Blockley and Mumford 2001).

According to the above literatures, there are four potexviruses (CVX, OpVX, SchVX and ZyVX), four tobamoviruses (SOV, TMV, CMMoV and RCNaV), one carlavirus (SV-2), one carmovirus (SgCV), and two tospoviruses (TSWV and INSV) have been reported to infect cactus plants. Both potexviruses and tobamoviruses had much more information than the other three virus groups. Interestingly, most of the cactus-infecting viruses are only sap transmitted without vector except for thrips-transmitted TSWV and INSV, and potentially aphid-transmitted SV-2. Among these cactus-infecting viruses, CVX is the most frequently reported and widely spread. However, the importance of other viruses may be observed when more virus surveys of the cactus plants are conducted as in Brazil (Duarte et al. 2008).
Viruses identified in pitaya (Hylocereus spp.)

Pitaya (Hylocereus spp.) is a popular fruit crop in Taiwan, and is becoming an important exporting agricultural product. *H. undatus* is the first pitaya species commercially cultivated in Taiwan, but the planting areas of other species such as *H. costaricensis* and *H. polyrhizus* as well as the new hybrid cultivars increase rapidly. Pitaya is mainly propagated by cutting, so if mother plant is infected with viruses, disease can be spread easily. Therefore, viral diseases of pitaya are becoming important issues. The genus *Potexvirus* is the only viral genus reported to infect pitaya (*H. undatus*) so far, including four virus species of *Cactus virus X* (CVX) (Liou et al. 2001; Liao et al. 2003; Liou et al. 2004a, 2004b; Lu, 2007), *Zygocactus virus X* (ZyVX) (Mao, 2008), Pitaya virus X (PiVX) (Mao, 2008) and *Schlumbergera virus X* (SchVX) (Duarte et al. 2008). SchVX was only detected in pitaya plants which was mix infected with ZyVX according to a field survey in Brazil (Duarte et al. 2008). The rest of pitaya-infecting viruses were studied by the researchers in Taiwan. The first published pitaya-infecting virus is CVX by Liou et al. in 2001. The three pitaya isolates of CVX reported in Taiwan are CVX-Hu, first isolated in the Kawnshi area (Liou et al. 2001; Liou et al. 2004b), CVX-EL1 from Ilan (Liao et al. 2003), and CVX-NTU from the experimental farm at Nation Taiwan University (Lu 2007). The antisera against CVX-EL1 and CVX-Hu had been produced (Liao et al. 2003; Liou et al. 2004b), and used in virus survey which revealed high frequency of CVX infection on pitaya (Liao et al. 2003; Lu 2007). The complete nucleotide sequence of CVX-Hu strain was first published by Liou et al. derived from pitaya with systemic mild mottling symptoms (Liou et al. 2004a) and the complete sequence of CVX-NTU was also determined (Lu 2007).

During a survey of CVX in pitaya, a sample reacted positively to CVX antiserum, and produced a 150-bp nonspecific fragment without the expected CVX cDNA fragments (Lu 2007). Based on our studies, this fragment was derived from *Zygocactus virus X* (ZyVX), and a virus isolate was obtained, characterized, and named as ZyVX-P39 (Mao et al. 2007; Mao 2008). The complete sequence of ZyVX-P39 was determined and compared to other potexviruses (Mao 2008). This is the first report of ZyVX in pitaya and also the first record of ZyVX in Taiwan (Mao et al. 2007).

Another pitaya sample which was also collected from the same CVX survey produced a 300-bp unexpected RT-PCR product besides the CVX cDNA fragment (Lu 2007). The sequencing results indicated that this cDNA fragment was not derived from CVX or ZyVX, but it had high sequence identity with many potexviruses (Lu, 2007). Subsequently, the unknown potexvirus was isolated, characterized, and the complete sequence of the P37 isolate was determined and analyzed (Mao 2008; Li 2010). According to the species demarcating criteria of the genus *Potexvirus*, P37 isolate should be a new pitaya-infecting potexvirus and thus designated as Pitaya virus X (PiVX) (Mao 2008). The results of phylogenetic analyses on full-length genome of ZyVX-P39, PiVX-P37 and other published potexviruses demonstrated that all Cactaceae-infecting potexviruses belong to the same cluster (Mao 2008; Li 2010).

In addition, a multiplex RT-PCR method was developed for field survey of CVX, PiVX and ZyVX in pitaya plants in Taiwan (Mao 2008). However, the total RNA extraction from mucilaginous pitaya plants is difficult and time-consuming. To solve this problem, a rapid detection method, named magnetic nanoparticle-capture RT-PCR (MNC RT-PCR), was developed recently (Kuo 2015). Moreover, the antiserum against the CP of PiVX was generated for subsequent studies and field survey (Li 2010). To further study the properties of PiVX-P37, the full-length cDNA clone with a 35S promoter was constructed.

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and its biological activity was proved by inoculating plasmid DNA to *Chenopodium amaranticolor* and *C. quinoa* plants (Li 2010).

Although symptoms of pitaya caused by potexviruses have been described (Liou et al. 2001; Lioa et al. 2003; Li 2010), it is impossible to differentiate the virus species only by external symptoms; especially mixed infection appears very frequently (Figure 1). Moreover, the influence of virus infection on the growth of pitaya plants as well as the yield and quality of pitaya fruits is still unknown. This is question the most frequently asked by growers and need to be answered in the future.

![Figure 1. Symptoms of pitaya (*Hylocereus undatus*) plants caused by potexviruses under natural field conditions. Pitaya infected by *Cactus virus X* (CVX) alone (left); pitaya mix-infected by CVX and *Zygocactus virus X* (ZyVX) (middle); pitaya mix-infected by CVX and *Pitaya virus X* (PiVX) (right).](image)

**CONCLUSION**

Pitaya is mainly propagated by cutting, so if mother plant is infected with viruses, disease can be spread easily. Therefore, viral diseases of pitaya are becoming main issues. Even though pitaya is an important tropical fruit crop in many countries and the high virus incidence on pitaya plants, there are few studies on pitaya-infecting viruses. Because plants in the family Cactaceae have similar features, it is very likely that cactus-infecting viruses will infect pitaya. Most of the cactus-infecting viruses are only sap and grafting transmitted, so virus-free propagation materials are essential for controlling viral diseases. Since pitaya is becoming an important fruit crop in Taiwan,
the establishment of virus indexing system is strongly recommended. Both multiplex RT-PCR and MNC RT-PCR developed by our research team are convenient and rapid methods to detect individual potexviruses in pitaya and other cactus plants. These rapid and accurate detection methods can be used for field survey as well as the certification program of virus-free seedlings to control the viral diseases of pitaya.

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Improving Pitaya Production and Marketing


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MANAGEMENT STRATEGIES OF MAJOR PITAYA DISEASES IN VIETNAM

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ABSTRACT

Among the principal commercial fruit crops grown in Vietnam, pitaya (Hylocereus undatus) occupies a prominent place with approximately 36,000 ha of area and 140,000 tons of production. It plays an important role in the economy of the country because of their value in export as compared to others. Pitaya has been exported to more than 40 countries as commodity. The domain varieties are white and red flesh. The crop is damaged by a number of pests and diseases, of which canker, bacterial fruit soft rot, Bipolaris black spot, sooty mold and anthracnose are more serious than pests. These diseases have recently assumed serious proportions in Binh Thuan, Long An, Tien Giang and some newly established regions. In the last decade, many new approaches to control the diseases have been thoroughly developed in the country, whereas emerging pests and diseases, together with their control management are still not well developed. Important diseases listed in this paper, along with review of studies on causal agents, symptoms, epidemiology and management strategies are also mentioned as recommended by pitaya growers in Vietnam.

Keywords: pitaya, Hylocereus undatus, management strategy, disease, canker, bacterial fruit soft rot, Bipolaris black spot, sooty mold, anthracnose.

INTRODUCTION

Pitaya (Hylocereus undatus) is considered one of the most important tropical fruits in Vietnam. Recently, area for growing pitaya is approximately 36,000 ha with production of about 140,000 tons and average yield of 30-40 tons/ha (MARD 2014). It is being mainly cultivated in Binh Thuan, Tien Giang, Long An and some other provinces in the North and South East regions. The majority of varieties are white flesh (Binh Thuan and Cho Gao vars.) and red flesh (Long Dinh 1), which are popularly grown in the country and exported to more than 40 countries. However, due to rapidly expansion of planting area and production and climate changes as well, the fruit industry is also facing many pests and diseases in the last few years (Hoa et al. 2011; Hieu et al. 2014a). Since many emerging diseases caused the reduction of fruit productivity as well as other issues like high pesticides residues on fruit products due to intensive chemical and inappropriate applications. Moreover, there is high demand of importing markets on good quality, food safety and quarantine regulations which continue to challenge growers and exporters (Hoa and Hieu 2014). In this paper, the authors would like to share their knowledge in management strategies of importance diseases which have contributed to the fruit industry in Vietnam.
MANAGEMENT STRATEGIES OF MAJOR PITAYA DISEASES IN VIETNAM

In Vietnam, the diseases recognized belonging to *Hylocereus* are canker (*Neoscytalidium dimidiatum*) (Hieu et al. 2014a; Hien and Oanh 2014), bacterial fruit soft rot (*Erwinia chrysanthemi*) (Hieu et al. 2011), Bipolaris black spot (*Bipolaris* sp.) (Hieu et al. 2008), sooty moth (*Capnodium* sp.), anthracnose (*Collectotrichum gloeosporioides*) (Hoa et al. 2011), root rot (*Fusarium solani, F. oxysporium, Pythium aphanidermatum*) (Hieu et al. 2012) and sun burn. Nematodes (*Meloidogyne* sp., *Helicotylenchus* sp., *Hemicyclyphora* sp., *Tylenchorhynchus* sp., *Xiphinema* sp.) also attack this crop (Linh et al. 2015, data unpublished).

Assessment of crop losses due to diseases have been a difficult and often controversial subject. By investigation of pests and diseases in the past few year, data of economic losses of importance diseases are recorded as describe in Table 1.

Table 1. Importance diseases of pitaya in Vietnam

<table>
<thead>
<tr>
<th>Disease</th>
<th>Causal organism</th>
<th>Attacked parts</th>
<th>Estimated loss in yield (%)</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canker</td>
<td><em>Neoscytalidium dimidiatum</em></td>
<td>Stem, flower, fruit</td>
<td>55.0</td>
<td>Hieu et al. 2011 &amp; 2014</td>
</tr>
<tr>
<td>Anthracnose</td>
<td><em>Collectotrichum gloeosporioides</em></td>
<td>Flower, fruit ripening</td>
<td>17.0</td>
<td>Hoa et al. 2011</td>
</tr>
<tr>
<td>Bacteria soft rot</td>
<td><em>Erwinia chrysanthemi</em></td>
<td>Flower, fruit</td>
<td>25.0</td>
<td>Hieu et al. 2011</td>
</tr>
<tr>
<td>Black spot</td>
<td><em>Bipolaris</em> sp.</td>
<td>Flower</td>
<td>20.0</td>
<td>Hieu et al. 2008</td>
</tr>
<tr>
<td>Sunburn</td>
<td><em>Temperature Bipolaris crustacea, Fusarium equiseti</em></td>
<td>Cladode</td>
<td>15.0</td>
<td>Hieu et al. 2013 &amp; 2014</td>
</tr>
<tr>
<td>Sooty moth</td>
<td><em>Capnodium</em> sp.</td>
<td>Cladode, flower, fruit</td>
<td>20.0</td>
<td>Thu et al. 2013</td>
</tr>
</tbody>
</table>

CANKER DISEASE (*Neoscytalidium dimidiatum*)

Canker disease is known as internal black rot in Israel (Ezra et al. 2009), stem canker in Taiwan (Chuang et al. 2012), and brown spot in China (Lan et al. 2012). In Malaysia, Mohd et al. (2013) reported that the disease has attacked 10 states during 2008-2009.

Binh Thuan is the first province of Vietnam to have recorded the disease in 2009 and later it became a devastating disease with an infested area of approximately more than 10,000 ha, with losses ranging from 30-70% in individual fields; especially growers could not harvest fruits during continuous rainy days or tropical low pressures. Heavily infected fruits could not be sold even in the domestic market.

**Symptoms:**
Symptoms may occur on young shoots, immature and ripping fruits. Initial symptoms appear as many small circular of pin prick on surface of cladodes or fruits. Later they turn to white spots, yellowish/reddish brown canker. Finally, the spots may coalesce to cover large areas of cladode and infection may cause rot under favorable conditions.
Causal agent:
The fungus *Neoscytalidium dimidiatum* has been known as the causal agent by many workers (Ezra et al. 2009; Chuang et al. 2012; Lan et al. 2012; Mohd et al. 2013). Hieu et al (2011, 2014a) reported that 80 isolates from Binh Thuan, Long An and Tien Giang were morphological characteristics identified and Koch’s postulate as *Neoscytalidium* sp. Lately, it was confirmed by molecular DNA sequences of 233bp that 100% homologized to *Neoscytalidium dimidiatum* from NCBI. Similarly, later researches of Hien and Oanh (2014) also showed similar results.

Mycelium of *N. dimidiatum* is fast growing on potato dextrose agar medium plate (PDA) after 3 days of incubation at 30°C. From macroscopic characteristics, the fungus produced round shape, effuse, hairy or woolly colony and white to greyish colony with dark-grey to black pigmentation on PDA. Fragment spores are characterized as brown color and develop arthrospores 0-2 septa up to 2 days after incubation. The conidia are ellipse, egg, round and cylindrical-truncate shapes. Dimension of conidia are $6.33 \pm 1.91 \mu m$, $7.85 \pm 1.68 \times 5.06 \pm 0.91 \mu m$, $10.12 \pm 2.99 \mu m \times 4.33 \mu m \pm 1.11 \mu m$, respectively with round shape, egg shape and cylindrical-truncate conidia (Hieu et al. 2014a).

Optimum temperature of this fungus was identified from 30-40°C with growth rate from 0.4-0.5mm/h. However, mycelium growth was slowed when temperatures are lowered than 15°C and above 40°C (Hieu et al. 2014a). PDA, MEA medium were found as the best media that support the mycelium growth of fungus at 30°C, 12/12hrs light/dark condition in control incubator. On the other hand, agar medium added with extract of fruit skin was found to have better rapid growth as compared to media which were added with extract of flower and cladode (Hieu et al. 2015, data unpublished).

Epidemiology:
The pathogen colonizes dead, infected plant materials and have been found to be significant sources of inoculum. Conidia are dispersal by wind and rain water, and optimum temperatures of germination between 30-40°C.

Disease management:
Field hygiene:
In 2013, the thinning of practical model were carried out at Long An and Tien Giang by SOFRI to show farmers that frequency thinning and opening up of the canopy allows better air movement which will significantly assist control every year. Treatment of thinning up to 30-40% of canopy was reduced by 40-50% of disease incidence and didn’t give any evidence on the term of yield losses (Hieu et al. 2014; data not showed). To avert infection, affected plant organs retained in the canopy should be removed to reduce spore numbers.

Initial research showed that fragment spore can be spread by air and pycnidia spore could survive in soil as well. So that after pruning and removing of infested cladodes, fruits should be buried into the soil or chopping machine should be used to chop cladode into small piece and used for compost. Temperature of composting heap could be kill the spores (Hieu et al. 2015, data unpublished).
Culture practices:
In case of heavily infected orchards, there should be a limited number of selected young shoots during the rainy season. The price of fruits is often reduced during the main harvest season so farmers often neglect to take care of their plant and high inoculum, environment support create the favorable conditions for the disease to develop.

Use fertilizer in balance; avoid applying too much nitrogen at the young shoot stage. However, increase the organic matter content in soil by using manure plus *Trichoderma*.

Maintain grass growth and drain out excess water in the orchard during wet season.

Biological control:
Out of 8 plant extracts testing, the extracts of *Allium sativum* (clove) was highly toxic and showed no fungal growth thereby indicating 100% inhibition of up to 60 hours after incubation at 50% concentration. *Bougainvillea spectabilis, Allium cepa* (clove) were determined as the next best extracts which suppressed mycelium growth of *N. dimidiatum* (Hieu et al. 2015, data unpublished). However, Uyen et al. (2014) reported that *Impatiens balsamina* extract was also determined as other plant extract which could be inhibited mycelium growth (64.25%) at 7.5% concentration.

Among 21 bacteria and fungus collected and isolated from Plant Protection Division (SOFRI), isolated bacteria strain VK2 and VK3 (not yet identification) was strongest inhibited mycelium growth of *N. dimidiatum* up to 48 hours after incubated (Hieu and My, 2013, data unpublished).

Chemical control:
Hieu et al. (2014b) reported that out of 22 agro-chemicals checking, there were 9 chemicals which were highly toxic and showed no fungal growth thereby indicating 100 per cent inhibition by Food Poined Technique in petri plates. According to their toxicity, authors were classified in 4 groups of chemicals which checking mycelium growth in plates (Table 2). There were:

1) **Group 1- completely inhibition (8 chemicals):** Cyat (Trifloxystrobin), Viroval (Iprodione), Dithane (Mancozeb), Tilt super, Sagorain and Map super (Propiconazole + Difenoconazole), Map Unique (Tebuconazole + Tricyclazole), và Ridomyl gold (Metalaxyl-M và mancozeb);

2) **Group 2- Good inhibition (7 chemicals):** Folicur (Tebuconazole), Bonazale (Cyproconazole), Funomyl (Benomyl), Saipora (Carbendazim và Hexaconazole), Aliette (Fosetyl-Aluminium), Vicarben (Carbendazim) và Norshiled (Cuprous Oxide);

3) **Group 3- Moderate inhibition (3 chemicals):** Gomy (Tricyclazone + thiophanatemethyl), Score (Difenoconazole), Map Hero (Azoxystrobin +Dimethomorph + Fosetyl-aluminium);

4) **Group 4 – No inhibition (3 chemicals)** (Anvil, Coc 85 and Isacop).
## Table 2. Effect of fungicides against *N. dimidiatum* mycelium growth in *in vitro* condition

<table>
<thead>
<tr>
<th>Sr.No</th>
<th>Treatments</th>
<th>Mycelium growth (mm)</th>
<th>24 HAI</th>
<th>36 HAI</th>
<th>48 HAI</th>
<th>60 HAI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Tricyclazone + Thiophanatemethyl</td>
<td>0.00 f</td>
<td>7.80 ef</td>
<td>15.30 d</td>
<td>15.60 f</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Trifloxystrobin</td>
<td>0.00 f</td>
<td>0.00 h</td>
<td>0.00 i</td>
<td>0.00 j</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Triadimefon</td>
<td>0.00 f</td>
<td>1.60 gh</td>
<td>3.80 gh</td>
<td>4.00 hi</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Propiconazole + Difenoconazole</td>
<td>0.00 f</td>
<td>0.00 h</td>
<td>0.00 i</td>
<td>0.00 j</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Difenoconazole + Propiconazole</td>
<td>0.00 f</td>
<td>0.00 h</td>
<td>0.00 i</td>
<td>0.00 j</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Difenoconazole</td>
<td>8.00 c</td>
<td>11.80 cd</td>
<td>15.00 d</td>
<td>19.50 e</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Fosetyl-Aluminum</td>
<td>7.00 cd</td>
<td>8.40 ef</td>
<td>10.60 e</td>
<td>10.60 g</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Azoxytrobio + Dimethomorph + Fosetyl-aluminium</td>
<td>0.00 f</td>
<td>9.70 de</td>
<td>11.10e</td>
<td>19.60 e</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Tebuconazole</td>
<td>0.00 f</td>
<td>0.40 h</td>
<td>0.40 e</td>
<td>0.40 j</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Tebuconazole + Tricyclazole</td>
<td>0.00 f</td>
<td>0.00 h</td>
<td>0.00 i</td>
<td>0.00 j</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Difenoconazole + Propiconazole</td>
<td>0.00 f</td>
<td>0.00 h</td>
<td>0.00 i</td>
<td>0.00 j</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Iprodione</td>
<td>0.00 f</td>
<td>0.00 h</td>
<td>0.00 i</td>
<td>0.00 j</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Carbendazim</td>
<td>4.00 e</td>
<td>6.60 f</td>
<td>9.40 ef</td>
<td>10.80 g</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Hexaconazole</td>
<td>0.00 f</td>
<td>13.80 c</td>
<td>21.80 c</td>
<td>29.40 d</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Metalaxyl-M + Mancozeb</td>
<td>0.00 f</td>
<td>0.00 h</td>
<td>0.00 i</td>
<td>0.00 j</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Mancozeb</td>
<td>0.00 f</td>
<td>0.00 h</td>
<td>0.00 i</td>
<td>0.00 j</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Carbendazim +Hexaconazole</td>
<td>5.40 de</td>
<td>3.70 g</td>
<td>7.70 f</td>
<td>9.70 g</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Benomyl</td>
<td>0.80 f</td>
<td>1.20 gh</td>
<td>4.40 g</td>
<td>4.40 h</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Cyproconazole</td>
<td>0.00 f</td>
<td>1.20 gh</td>
<td>1.20 hi</td>
<td>1.20 ij</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Copper Oxychloride (1)</td>
<td>12.40 b</td>
<td>22.60 b</td>
<td>35.00 b</td>
<td>45.00 c</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>Cuprous Oxide</td>
<td>7.60 c</td>
<td>10.00 de</td>
<td>11.80e</td>
<td>11.80 g</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>Copper Oxychloride (2)</td>
<td>13.80 b</td>
<td>23.40 b</td>
<td>34.60 b</td>
<td>49.00 b</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>Control</td>
<td>26.60 a</td>
<td>41.80 a</td>
<td>57.60 a</td>
<td>73.40 a</td>
<td></td>
</tr>
</tbody>
</table>

Significant: **: significant at 1%.

CV (%)  
25.48 23.80 16.54 13.13

H.A.I.: Hour after inoculated. Values in the same column followed by the same letter were not statistically significant. **: significant at 1%.

All chemicals above were tested in the field conditions to show that Saipora (Carbendazim + Hexaconazole), Ridomil gold (Metalaxyl-M + Mancozeb), Dithane (Mancozeb) and Vicarben (Carbendazim) were the best treatments reduced disease incidence on cladode as compared with control and others (Table 3). While Dithane (Mancozeb), Ridomyl gold (Metalaxyl-M + Mancozeb), Saipora (Carbendazim + Hexaconazole) were recorded significantly better in reducing the disease intensity on fruit as compared to control (Table 4). However, Than Ho (Siloxane Alkoxylate) is a best spreader could be mixing with chemical for completely cover cladodes.
## Table 3. Disease severity and disease intensity on cladode under field conditions

<table>
<thead>
<tr>
<th>Treatment</th>
<th>7DAS (1st spray)</th>
<th>7DAS (2nd spray)</th>
<th>7DAS (3rd spray)</th>
<th>7DAS (6th spray)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>D.S</td>
<td>D.I</td>
<td>D.S</td>
<td>D.S</td>
</tr>
<tr>
<td>Tri + thi</td>
<td>47.98ab</td>
<td>10.43a</td>
<td>75.63a</td>
<td>19.77 ab</td>
</tr>
<tr>
<td>Trifloxystrobin</td>
<td>17.78abcd</td>
<td>5.78abc</td>
<td>41.67abcd</td>
<td>10.00 abc</td>
</tr>
<tr>
<td>Triadimefon</td>
<td>38.10abc</td>
<td>7.62ab</td>
<td>68.89a</td>
<td>17.11 ab</td>
</tr>
<tr>
<td>Pro + Di</td>
<td>0.00d</td>
<td>0.00c</td>
<td>66.67a</td>
<td>13.33 ab</td>
</tr>
<tr>
<td>Di + Pro</td>
<td>13.33bcd</td>
<td>2.67bc</td>
<td>71.67a</td>
<td>15.67 ab</td>
</tr>
<tr>
<td>Difenoconazole</td>
<td>51.59a</td>
<td>10.32a</td>
<td>75.79a</td>
<td>18.73 ab</td>
</tr>
<tr>
<td>F-Aluminum</td>
<td>11.11cd</td>
<td>2.22bc</td>
<td>43.17abcd</td>
<td>8.63 bc</td>
</tr>
<tr>
<td>Azo + Di + F</td>
<td>0.00d</td>
<td>0.00c</td>
<td>13.89 cde</td>
<td>2.78 cde</td>
</tr>
<tr>
<td>Tebuconazole</td>
<td>9.52cd</td>
<td>1.90bc</td>
<td>57.14 ab</td>
<td>13.21 ab</td>
</tr>
<tr>
<td>Di + Pro</td>
<td>24.54abcd</td>
<td>4.91abc</td>
<td>52.38 abc</td>
<td>12.38abc</td>
</tr>
<tr>
<td>Iprodione</td>
<td>33.33abcd</td>
<td>12.00abc</td>
<td>63.10 a</td>
<td>27.29 a</td>
</tr>
<tr>
<td>Carbendazim</td>
<td>11.11 cd</td>
<td>2.22bc</td>
<td>37.22abcd</td>
<td>7.44 bcd</td>
</tr>
<tr>
<td>Hexaconazole</td>
<td>17.04cd</td>
<td>3.41abc</td>
<td>49.07 ab</td>
<td>12.04 abc</td>
</tr>
<tr>
<td>Me + man</td>
<td>0.00d</td>
<td>0.00c</td>
<td>0.00 e</td>
<td>0.00 e</td>
</tr>
<tr>
<td>Mancozeb</td>
<td>0.00d</td>
<td>0.00c</td>
<td>0.00 e</td>
<td>0.00 e</td>
</tr>
<tr>
<td>Car+Hex</td>
<td>0.00d</td>
<td>0.00c</td>
<td>4.76 de</td>
<td>0.95 de</td>
</tr>
<tr>
<td>Benomyl</td>
<td>0.00d</td>
<td>0.00c</td>
<td>26.67bcd</td>
<td>5.33 cde</td>
</tr>
<tr>
<td>Cyproconazole</td>
<td>0.00d</td>
<td>0.00c</td>
<td>66.67a</td>
<td>13.33 ab</td>
</tr>
<tr>
<td>Control</td>
<td>46.18ab</td>
<td>9.24ab</td>
<td>68.25a</td>
<td>13.65 ab</td>
</tr>
</tbody>
</table>

**Significant**

CV (%) 106.24 95.18 51.55 45.88 35.00 35.46 11.17 21.37

**DAS:** Day after sprayed, **DS:** disease severity, **DI:** disease intensity, **Tri+ Thi:** Tricyclazole + thiophanatemethyl, **Pro+ Di:** Propiconazole + Difenoconazole, **F-Aluminum:** Fosetyl-Aluminium, **Azo+ Di+F:** Azoxystrobin + Dimethomorph + Fosetyl-aluminium, **Te+Tri:** Tebuconazole + Tricyclazole, **Di+Pro:** Difenoconazole + Propiconazole, **Me+ Man:** Metalaxyl-M + mancozeb, **Car+Hex:** Carbendazim và Hexaconazole. Values in the same column followed by the same letter were not statistically significant. Ogrinal data were converted to arcsine before analysis. **:** significant at 1%.

## Table 4. Disease severity and disease intensity on fruit under field conditions

<table>
<thead>
<tr>
<th>Treatments</th>
<th>1 DARP</th>
<th>8 DARP</th>
<th>15 DARP</th>
<th>22 DARP</th>
<th>29 DARP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>D.S</td>
<td>D.I</td>
<td>D.S</td>
<td>D.I</td>
<td>D.S</td>
</tr>
<tr>
<td>Control</td>
<td>36.67ab</td>
<td>7.33ab</td>
<td>76.67a</td>
<td>20.00a</td>
<td>80.00a</td>
</tr>
<tr>
<td>F-Aluminum</td>
<td>10.00bc</td>
<td>2.00bc</td>
<td>76.67a</td>
<td>16.67a</td>
<td>80.00a</td>
</tr>
<tr>
<td>Iprodione</td>
<td>43.33a</td>
<td>8.67a</td>
<td>80.00a</td>
<td>20.67a</td>
<td>100.00a</td>
</tr>
<tr>
<td>Carbendazim</td>
<td>13.33bc</td>
<td>2.67bc</td>
<td>13.33b</td>
<td>2.67b</td>
<td>43.33ab</td>
</tr>
<tr>
<td>Me+Man</td>
<td>0.00c</td>
<td>0.00c</td>
<td>3.33b</td>
<td>0.67b</td>
<td>33.33ab</td>
</tr>
<tr>
<td>Mancozeb</td>
<td>0.00c</td>
<td>0.00c</td>
<td>10.00b</td>
<td>2.00b</td>
<td>43.33ab</td>
</tr>
<tr>
<td>Car+Hex</td>
<td>0.00c</td>
<td>0.00c</td>
<td>3.33b</td>
<td>0.67b</td>
<td>30.00b</td>
</tr>
</tbody>
</table>

**Significant**

CV (%) 70 64.92 28.35 47.22 39.95 41.72 21.14 36.64 26.64 44.95

**DARP:** Day after removed petals, **DS:** disease severity, **DI:** disease intensity, **F-Aluminum:** Fosetyl-Aluminium, **Me+ Man:** Metalaxyl-M + Mancozeb, **Car+Hex:** Carbendazim + Hexaconazole. Values in the same column followed by the same letter were not statistically significant. Ogrinal data were converted to arcsine before analysis. **:** significant at 1%.
**BACTERIAL FRUIT SOFT ROT (Erwinia chrysanthemi)**

Fruit soft rot was addressed as a field problem in all pitaya growing areas in Vietnam. The disease is most severe during wet season at both orchard establishment period and commercial orchards. In spite of the control measures that were practiced in the Southern provinces, annual losses of 5-20% occurred. In severe case, 70-80% of fruit are discarded in Vietnam due to this disease. In case of red flesh cultivars, yield losses was ranged 30-50%, whereas losses of 10% occurred on white flesh cultivar. However, since 2011 up to now the disease is under controlled by growers due to applied advance technologies (Hieu et al. 2011; Hoa et al. 2011).

**Symptoms:**
Initial symptoms appear as blister water soak and tiny bubbles on young fruit skin. By visible inspection, there are many abundant black mycelium laying on the surface of lesion known as secondary infection (*Rhizopus* sp.). Infection bud or fruit shall be completely rotten after a few hours and produce a bad smell (bad odor) and attract to insects such as *Protaetia* sp. and *Hypomeces squamesus*.

**Causal agent:** *Erwinia chrysanthemi*

**Epidemiology:**
The pathogen colonizes dead, infected plant materials which are significant sources of inoculum. Bacterial spores are dispersed by wind, rain splash and insects wounding (*Protaetia* sp. and *Hypomeces squamesus*).

**Disease management:**

**Cultural practices:**
Pruning and removing infected cladode, bub and fruit and opening up the canopy allow better air movement can significantly assist control. To avert infection, affected organs retained in the canopy should be removed to reduce spore numbers. The bacterium can enter the vines via wounds, so disinfect secateurs using bleach or household spirits between diseased and healthy trees when pruning, to avoid spreading the disease. Pruning should be followed with an application of a protective fungicide. Some other measures include:

1) Petals should be removed in proper time (2-3 days after flowering depend on season).
2) Avoid over irrigation of canopy in infected trees and should not be done in late afternoon.
3) Wind break should be involved when growers are in new orchard.
4) To support the trees suppress infection, balance nutrient should be considered as best practice in the orchard.

**Biological control:**
The application of high organic matter content plus antagonist fungi such as *Trichoderma* are strongly recommended.

**Chemical control**
Regular bactericide applications when infection conditions are favorable during rainy months are recommended such as Kasugamycin, Streptomycin sulfate, Oxolinic acid. However, controlling wounding insects should be done in appropriate ways (Hieu et al. 2011) (Table 5).
Table 5. Disease incidence of bacterial soft rot at Long An and Tien Giang

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>Treatments</th>
<th>Long An</th>
<th>Tien Giang</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>After 3&lt;sup&gt;rd&lt;/sup&gt; spray application (%)</td>
<td>After 4&lt;sup&gt;th&lt;/sup&gt; spray application (%)</td>
<td>After 3&lt;sup&gt;rd&lt;/sup&gt; spray application (%)</td>
</tr>
<tr>
<td>1</td>
<td>Oxolinic acid 20%</td>
<td>0.00 c</td>
<td>3.04 e</td>
</tr>
<tr>
<td>2</td>
<td>Ningnamycin 8%</td>
<td>0.00 c</td>
<td>6.68 cd</td>
</tr>
<tr>
<td>3</td>
<td>Saikuzuo 20%</td>
<td>0.00 c</td>
<td>6.48 cd</td>
</tr>
<tr>
<td>4</td>
<td>Oligo-Chitosan</td>
<td>0.00 c</td>
<td>4.76 de</td>
</tr>
<tr>
<td>5</td>
<td>Streptomycin sulfate 50gr/kg</td>
<td>0.00 c</td>
<td>0.00 f</td>
</tr>
<tr>
<td>6</td>
<td>Kasumycin 2%</td>
<td>7.45 a</td>
<td>10.82 b</td>
</tr>
<tr>
<td>7</td>
<td>Cuprous oxide 82.6%</td>
<td>4.17 b</td>
<td>25.00 a</td>
</tr>
<tr>
<td>8</td>
<td>NaHCO&lt;sub&gt;3&lt;/sub&gt;</td>
<td>0.00 c</td>
<td>5.67 cd</td>
</tr>
<tr>
<td>9</td>
<td>Control</td>
<td>5.08 ab</td>
<td>8.34 bc</td>
</tr>
</tbody>
</table>

Significant CV (%) = 13.02 21.49 46.57 63.75

Values in the same column followed by the same letter were not statistically significant. Original data were converted to arcsine before analysis. *: significant at 5%.

SUN BURN

Sun burn is known as yellow cladode-brown spot which attacked on a widespread basis in most fruit growing region in the southern of Vietnam (Hieu et al. 2013). Binh Thuan is one of the most area which suffered serious problem as compared to others. Few reports from the United State and Israel indicated that light factor is relative to yellow cladode phenomenon (Mizrahi and Nerd 1999; Merten 2003; Thomson 2002; Crane and Balerdi 2005).

Symptoms:
Sun burn usually occurs in the dry season (Feb.-June, Oct.–Dec.) and mostly appears at the top of plants. Initial symptoms appear as yellow patches cover on upper cladode surface which receive full strong sun light. Pinpoint are reddish-brown color *Bipolaris crutacea*. However scabs are usually surrounded by yellow halo and spots expand will cause large yellow areas as well as the attack of secondary infection (special stem rot) during the rainy season (Hieu et al. 2013).

Causal agent:
High ambient temperature was found to be the main abiotic factor which causes cell damage and induces yellow cladode in both laboratory and field studies. However, *Bipolaris crutacea* and *Fusarium equiseti* proved as biotic agents which stimulate brown spot appearance as secondary infection (Hieu et al. 2014c). Microscopic examination conidia of *Bipolaris crutacea* are 19.56±4.97 x 9.3±1.46 μm, elliptical, straight or curved, yellow to yellow brown, 1-4 septates (commonly 2-3 septate). While *Fusarium equiseti* conidia are 17.5±6.06 x 4.58±2.68μm, oval to comma-shaped, white colony on PDA medium, tan to brown, 1-4 septates (commonly 2-4 septates).

Epidemiology:
In field conditions, sun burn attacks plants during dry season and gives bad look to the plant and reduces fruit quality as well. Severe symptoms will be viewed in case of imbalance of using fertilizer by growers during the shooting period.
**Disease management:**

**Cultural practices:**

Shading nest: Findings from Hieu et al. (2014c) revealed that in the case of hot conditions shading nest (type of 40-60% light reducing) could help pitaya to avoid damage by sun burn (Tables 6 and 7). Observation of temperature inside tissue of cladode showed that approximately higher (1-2°C) than ambient temperature at hottest day time due to light has captured accumulation of heat. However, field practice with the application of sprinkler irrigation also reduces heat injury to canopy.

Table 6. Effective of differ shading degree of nest to sun burn

<table>
<thead>
<tr>
<th>Sr.No</th>
<th>Treatment</th>
<th>Sun burn severity (on cladode) (%)</th>
<th>Sun burn length on cladode (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>18 NSC</td>
<td>56 NSC</td>
</tr>
<tr>
<td>1</td>
<td>50% of light reduced</td>
<td>0.64 b</td>
<td>0.64 c</td>
</tr>
<tr>
<td>2</td>
<td>43% of light reduced</td>
<td>0.64 b</td>
<td>0.64 c</td>
</tr>
<tr>
<td>3</td>
<td>40% of light reduced</td>
<td>0.64 b</td>
<td>0.64 c</td>
</tr>
<tr>
<td>4</td>
<td>30% of light reduced</td>
<td>39.89 a</td>
<td>30.47 b</td>
</tr>
<tr>
<td>5</td>
<td>25% of light reduced</td>
<td>40.74 a</td>
<td>26.12 b</td>
</tr>
<tr>
<td>6</td>
<td>20% of light reduced</td>
<td>50.77 a</td>
<td>43.64 a</td>
</tr>
<tr>
<td>7</td>
<td>Control</td>
<td>59.47 a</td>
<td>54.45 a</td>
</tr>
</tbody>
</table>

**Significant**

**CV (%)** 28.92 22.82 33.80 40.52

*Values in the same column followed by the same letter were not statistically significant. Original data were converted to arcsine before analysis.**: significant at 1%.

Table 7. Effective of differ shading degree of nest to electrolyte leakage, chlorenchyma tissue damage/injury, and chlorophyll

*Values in the same column followed by the same letter were not statistically significant.*

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Electrolyte leakage (%)</th>
<th>Chlorenchyma tissue damage/injury (%)</th>
<th>Chlorophyll (µg/100g)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>a</td>
<td>b</td>
<td>Tông</td>
</tr>
<tr>
<td>50% of light reduced</td>
<td>31.44 b</td>
<td>26.35 e</td>
<td>0.011 0.003 0.014</td>
</tr>
<tr>
<td>43% of light reduced</td>
<td>40.44 ab</td>
<td>30.40 d</td>
<td>0.013 0.003 0.017</td>
</tr>
<tr>
<td>40% of light reduced</td>
<td>34.57 ab</td>
<td>25.68 e</td>
<td>0.012 0.003 0.016</td>
</tr>
<tr>
<td>30% of light reduced</td>
<td>37.30 ab</td>
<td>43.92 c</td>
<td>0.013 0.003 0.017</td>
</tr>
<tr>
<td>25% of light reduced</td>
<td>38.14 ab</td>
<td>46.12 bc</td>
<td>0.008 0.002 0.010</td>
</tr>
<tr>
<td>20% of light reduced</td>
<td>46.10 a</td>
<td>47.40 b</td>
<td>0.006 0.002 0.008</td>
</tr>
<tr>
<td>Control</td>
<td>45.28 a</td>
<td>54.14 a</td>
<td>0.013 0.003 0.017</td>
</tr>
</tbody>
</table>

**CV (%)** 16.55 4.88 46.59 47.79 46.55

Foliar spray: since time of new shoots start up to layering (which will take approximately 2 months), foliar spray of phosphoric, potassium and acid humic should be applied during this time to encourage and support healthy shoots and avoid affection of light as well. Number of sprays at 2-3 times is still best recommendation from growers (Hoa et al. 2011).

**Biological control**

The efficacy of these antagonistic disease was evaluated using an *in vitro* assay, the obtained results revealed that all the test treatment of *Bacillus subtilis*, *B. megaterium*, *Pseudomonas* sp. and SOFRI- Trichoderma could reduce mycelium growth (40-80% of
mycelium growth inhibition) of both *B. crustacea* and *F. equiseti* at seven days after inoculated (Tables 8 and 9).

### Table 8. Effective of antagonists against *B. crustacea*

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Percent inhibition (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2 D.A.I</td>
</tr>
<tr>
<td><em>B. subtilis</em></td>
<td>6.19c</td>
</tr>
<tr>
<td><em>B. megaterium</em></td>
<td>3.09d</td>
</tr>
<tr>
<td><em>P. florescent</em></td>
<td>15.47b</td>
</tr>
<tr>
<td>SOFRI-Trichoderma</td>
<td>24.75a</td>
</tr>
<tr>
<td>CV (%)</td>
<td>1.13</td>
</tr>
<tr>
<td>LSD (0.01)</td>
<td>0.45</td>
</tr>
</tbody>
</table>

D.A.I: Day after inoculated. Values in the same column followed by the same letter were not statistically significant. Ogrinal data were converted to arcsin before analysis.

### Table 9. Effective of antagonist against *F. equiseti*

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Percent inhibition (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 D.A.I</td>
</tr>
<tr>
<td><em>B. subtilis</em></td>
<td>15.16a</td>
</tr>
<tr>
<td><em>B. megaterium</em></td>
<td>18.24a</td>
</tr>
<tr>
<td><em>P. florescent</em></td>
<td>15.16a</td>
</tr>
<tr>
<td>SOFRI-Trichoderma</td>
<td>7.58b</td>
</tr>
<tr>
<td>CV (%)</td>
<td>8.42</td>
</tr>
<tr>
<td>LSD (0.01)</td>
<td>2.66</td>
</tr>
</tbody>
</table>

D.A.I: Day after inoculated. Values in the same column followed by the same letter were not statistically significant. Ogrinal data were converted to arcsin before analysis.

### Chemical control

Under laboratory conditions, several agro-chemicals evaluated for disease checking showed that Mancozeb (Man 80WP) and Iprodione (Viroval 50WP) were the best treatments to completely inhibited mycelium growth of *B. crustacea* as compared to control. Meanwhile, Mancozeb + Metalaxyl (Ridomil 68WP), Fosetyl Aluminium (Aliette 80WP) and Tebuconazole + Trifloxystrobin (Nativo 750WG) showed no fungal growth thereby indicating 100 per cent inhibition of *F. equiseti* (Tables 10 and 11).

### Table 10. Effect of some fungicides against *B. crustacea*

<table>
<thead>
<tr>
<th>Sr. no</th>
<th>Treatments</th>
<th>Percent inhibition (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 D.A.I</td>
<td>2 D.A.I</td>
</tr>
<tr>
<td>1 Mancozeb Copper Oxyloride</td>
<td>100.0a</td>
<td>100.0a</td>
</tr>
<tr>
<td>2 Iprodione</td>
<td>100.0a</td>
<td>100.0a</td>
</tr>
<tr>
<td>3 Cuprous oxide</td>
<td>89.74b</td>
<td>93.04b</td>
</tr>
<tr>
<td>4 Chlorothalonil</td>
<td>100.0a</td>
<td>87.44c</td>
</tr>
<tr>
<td>5 Oligo-chitosan</td>
<td>0.0c</td>
<td>0.0d</td>
</tr>
<tr>
<td>CV (%)</td>
<td>3.68</td>
<td>3.89</td>
</tr>
<tr>
<td>LSD (0.01)</td>
<td>5.24</td>
<td>5.29</td>
</tr>
</tbody>
</table>

D.A.I: Day after inoculated, Te+ Tri: Tebuconazole + Trifloxystrobin, Azot+Di: Azoxystrobin + Difenoconazole, F-Aluminium: Fosetyl Aluminium, Man + Me: Mancozeb + Metalaxyl. Values in the same column followed by the same letter were not statistically significant. Ogrinal data were converted to arcsin before analysis.
Table 11. Effect of some fungicides against F. equiseti

<table>
<thead>
<tr>
<th>Sr.no</th>
<th>Treatments</th>
<th>1D.A.I</th>
<th>2D.A.I</th>
<th>3D.A.I</th>
<th>4D.A.I</th>
<th>5 D.A.I</th>
<th>6D.A.I</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Te + Tri</td>
<td>100.0a</td>
<td>100.0a</td>
<td>100.0a</td>
<td>100.0a</td>
<td>100.0a</td>
<td>100.0a</td>
</tr>
<tr>
<td>2</td>
<td>Dimethomorph</td>
<td>45.80c</td>
<td>51.99e</td>
<td>61.90e</td>
<td>73.82d</td>
<td>73.83e</td>
<td>70.44d</td>
</tr>
<tr>
<td>3</td>
<td>Azo + Di</td>
<td>95.59a</td>
<td>84.87c</td>
<td>89.25c</td>
<td>90.49c</td>
<td>87.76c</td>
<td>87.63c</td>
</tr>
<tr>
<td>4</td>
<td>F-Aluminium</td>
<td>100.0a</td>
<td>100.0a</td>
<td>100.0a</td>
<td>100.0a</td>
<td>100.0a</td>
<td>100.0a</td>
</tr>
<tr>
<td>5</td>
<td>Azoxystrobin</td>
<td>71.08b</td>
<td>47.20e</td>
<td>62.54e</td>
<td>61.62e</td>
<td>63.04f</td>
<td>64.96e</td>
</tr>
<tr>
<td>6</td>
<td>Man + Me</td>
<td>100.0a</td>
<td>100.0a</td>
<td>100.0a</td>
<td>100.0a</td>
<td>100.0a</td>
<td>100.0a</td>
</tr>
<tr>
<td>7</td>
<td>Difenoconazole</td>
<td>100.0a</td>
<td>87.55b</td>
<td>92.10b</td>
<td>92.05b</td>
<td>93.37b</td>
<td>94.74b</td>
</tr>
<tr>
<td>8</td>
<td>Benomyl</td>
<td>94.61a</td>
<td>62.40d</td>
<td>71.25d</td>
<td>76.12d</td>
<td>77.19d</td>
<td>70.30d</td>
</tr>
</tbody>
</table>

CV (%)  
10.67  
5.21  
2.46  
2.10  
1.63  
1.28  
1.20

LSD$_{0.01}$  
9.14  
3.92  
1.93  
1.67  
1.29  
1.20

D.A.I: Day after inoculated, Te+ Tri: Tebuconazole + trifloxystrobin, Azo+Di: Azoxystrobin + Difenoconazole, F-Aluminium: Fosetyl Aluminium, Man + Me: Mancozeb + Metalaxyl. Values in the same column followed by the same letter were not statistically significant. Original data were converted to arcsin before analysis.

Nicotinic acid is SAR chemicals could be reduced more than 50% of sun burn damage area on cladode (Hieu et al. 2014d).

**BIPOLARIS BLACK SPOT (Bipolaris sp.)**

Bipolaris black spot is a minor disease that occurs in the flowering stage during wet season and storage (Hieu et al. 2008; Tuong et al. 2014). However, many researches also revealed that Bipolaris cactiobra causes fruit rot, fruit blotch and stem rot of pitaya in Israel, China, South Florida (Jeong-Ho et al. 2004; Taba 2007; Tarnowskia 2010; Israel 2011; He 2012).

**Symptoms:**
In general, symptoms appear in the flower bud and flower as small, brown to black spot lesions on the skin. As infection advances, ellipse sunken lesions with light brown margin form, brown to black conidia masses cover the central portion of the lesions. A second type of symptom appear as black, felty fungal growth cover flower top and inhibited flower opening. Symptoms are most common at petals and may occupy true leaf (bract closing to petals) under high humidity and inoculum.

**Causal agent: Bipolaris sp.**
Fungus produced round shape colony, olive to brownish, grey and black color on PDA medium. Conidia are single-cell, straight, brownish, 1-4 septa, smooth apex, 29.48 ± 1.68 x 3.31± 0.22 with wavy margins (Tuong et al. 2014).

Among of these mediums of Potato Carrot Agar (PCA), Water Agar (WA), Dragon Agar (DRA), Potato Dextrose Agar (PDA), there were two mediums DRA and PDA which were considered to be the best medium to support mycelium growth under in vitro condition. Mycelium growth of Bipolaris strains were constantly inhibited by ranges of under 20°C and above 40°C, while the range of 25-30°C was quite suitable for their growth. Similarly, under different pH condition, the growth of test fungi were mostly developed at pH level from pH6 to 8 (Tuong et al. 2014).
**Epidemiology:**
In the southern part of Vietnam, symptoms begin to show during rainy season, moist climates appear to favor Bipolaris black spot development. Conidia are dispersed by rain splash, wind and can also be spread by insects.

**Disease management:**

**Cultural practices:**
Remove and destroy infected flowers to reduce inoculum in orchard. Pinch off petals should be applied after 2-4 days depend on variety and weather conditions. Proper time of pinch off petals can be recover about 50% of saving flower from disease (Hieu et al. 2008).

**Biological control:**
Ensure that organic fertilizer management is adequate and maintained throughout the year. However, *Trichoderma* is considered as the best antagonist agent which could quickly decompose organic matters and kill the living spore in soil habitat. Before flowering stage, several bio-fungicides (based on Chitosan) are currently being evaluated for control of Bipolaris black spot (Hieu et al. 2008).

**Chemical control:**
In preliminary trials, Iprodione, Difenoconazole, Diniconazole, Cuprous oxide and Copper oxychloride significantly reduced disease severity in alternative using. Since time of bubble formation to flowering stage, 2-3 times of spray is recommended to control the disease (Hieu et al. 2008).

**CONCLUSION**

In the Southern part of Vietnam, tropical climate is very suitable for many fruit crops to grow and contribute huge amounts of fruit productions into the domestic and export markets. Of them, pitaya is considered as a potential crop that could bring a lot of farmers to have better lives. However, there are many challenges that affect the industry such as many dangerous and economic pests and diseases which recently emerged and widely spread over the last decade. Moreover, pesticide residues and food safety measures are identified as subsequent issues which revolve around quality and quantity especially in the export market. Although many advanced technologies have been tried and tested and were found to be effective to growers, some emerging pests and diseases are not yet well understood especially its management aspect. Knowledge sharing and science cooperation are surely sound means to effectively adopt management strategies of pests and diseases in the future.

**REFERENCES**


caused by *Neoscytalidium dimidiatum* on *Hylocereus undatus* (Pitahaya) fruit in Israel. Plant Dis. 97:1513.


Improving Pitaya Production and Marketing


Tuong Le Thi, Nguyen Huy Cuong, Nguyen Thanh Hieu, Nguyen Van Hoa. 2014. Identification and biological characteristics of Bipolaris black spot on pitaya flower. SOFRI annual reported (in Vietnamese).

STUDY OF INSECT PESTS AND DEVELOPMENT OF THEIR CONTROL MEASURES ON DRAGON FRUIT

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ABSTRACT
The study was conducted between 2003 to 2012 to: 1) identify the damage caused by insect pests; and 2) set up IPM model for ants and fruit flies in the dragon fruit fields in three provinces (Tien Giang, Long An and Binh Thuan) in southern Vietnam. Results showed dragon fruit were most affected by ants and fruit flies. Evenly distributed on all surveyed areas, 7 species of ant and 3 species of fruit fly infested dragon fruit were identified. SOFRI trukien® and SOFRI protein® applications, field sanitary practices, traps reduced fruit fly population but no single method was able to guarantee sustainable control of ants and fruit flies. SOFRI protein® (hydrolysed protein yeast waste mixed with fipronil 5SC 3ml) was effective to control fruit flies when spot-sprayed onto the branch. On IPM dragon fruit orchards, the number fruit flies trapped by methyl eugenol was very low, and the fruit yields of these orchards were clearly higher compared to untreated orchards.

Keywords: ants, fruit flies, insect pests, dragon fruit, pitaya, methyl eugenol, SOFRI TruKien®, protein bait.

INTRODUCTION
Ants and fruit flies are of significant economic concern in the fruit tree industry in tropical countries (White and Elson-Harris, 1992; Nguyen Thi Thu Cuc 2000). Some of them attack a wide range of fruits (Vargas et al. 1984; White and Elson-Harris 1992; Nguyen van Nam, 2005). They display high reproductive rates, and great dispersal capacity (Peterson and Denno 1998; Nguyen Thi Thu Cuc 2000), thus making the problem more difficult to tackle. Currently, their control management heavily depends on insecticides (Roessler 1989; Stonehouse et al. 1998; Jessup et al. 2007; Nguyen Huu Huan 2005). The most common insecticides against ants and fruit flies are those belonging to the groups of organophosphates, pyrethroids and carbamates (Besser and Gutmann 1994; Van Mele et al. 2001; Raga and Sato 2005; Jessup et al. 2007; Nguyen Huu Huan 2005). They normally provide a high and consistent level of protection (Allwood 1997), but it is necessary to develop alternative control strategies which are equally effective and friendly to the agro-ecosystems.

Dragon fruit (Hylocerus undatus) is the most important fruit in South Vietnam in terms of value and amount of production, representing a major source of income in many farming households. However, the presence of ants and fruit flies and other serious pests has caused severe damage to the local production and created a barrier to Vietnam’s access to world markets. In the southern provinces of Vietnam, 30 fruit fly and 7 ant species have been recorded and they infest numerous kinds of fruit and
agricultural produce such citrus, longan, lychee, mango, plum, apple, dragon fruit and cucurbit vegetables (Drew et al. 2001; Le Quoc Dien et al. 2009). Among the six fruit fly species of economic importance that are present in Vietnam, two species, namely the oriental fruit fly *Bactrocera dorsalis* and the guava fruit fly *Bactrocera correcta*, are considered to be associated with dragon fruit as their fruit host (Drew et al. 2001). Up to now, there has been no complete effective control measure and farmers usually have to harvest fruits at an early date to minimize the yield and quality loss (Drew et al. 2001). For many years, fruit growers in Vietnam have depended heavily on a broad-spectrum of insecticides (Dien and Cuc 2007).

Integrated Pest Management (IPM) combines the use of healthy and resistant plant varieties, beneficial organisms, cultural practices and biological pesticides in order to reduce chemical sprays for cost saving and being environmentally safe (Schulten 1997). Through a participatory approach, IPM improves farmers’ understanding of local ecosystems, enabling farmers to make decisions on pest management that are safe and cost effective (Alston 2011; FAO undated). In ants and fruit fly control, the main focus has been on the development of management practices that are in line with the concepts of IPM (Allwood 1997; Vo Huu Thoai et al. 2012). This report will address the following specific topics:

1. The current composition of insect pests communities in dragon orchards of Tien Giang, Long An and BinhThuan Provinces;
2. The differences in ant and fruit fly abundances and infestation percentages between dragon orchards sprayed with fipronil protein bait and those with conventional management and no protein bait use;
3. The impact of ants and fruit flies abundance and diversity; and
4. SOFRI Trukien® and SOFRI Protein® on ants and fruit flies.

**MATERIALS AND METHODS**

**Experimental Sites**

The research was undertaken in fruit growing regions of Tien Giang Province’s Cho Gao, Long An’s Long Tri District, and BinhThuan’s Ham Thuan Nam. The mean annual rainfall of the province is around 1,500 mm with the rainy season from December until May (Hien et al. 2006). The main dragon fruit cultivars planted are white, red, pink color with 3 to 10 year old plants. Most of the dragon orchards are less than 3,000 m² in size and managed by small-scale farming households. Dragon fruit is planted at a density of 1000 poles/ha. A total of seven sites were selected on the basis of the ease of access and similarity in dragon fruit varieties, and soil types.

**Composition of Protein Bait and Ant Bait:**

**SOFRI Protein®:** Protein, 21.52%; NH₄⁺ 0.11%; Brix, 13% (Chemical Insitute 2013).

**SOFRI Trukien®:** Fructose: 50% (Chemical Insitute 2014)

**Applications of Protein Bait and Ant Bait**

An area of approximately 1 to 500 ha of dragon fruit orchards was sprayed with insecticidal protein bait sprays (SOFRI Protein® 10 DD) to control fruit flies; area of approximately 1 to 20 ha of dragon fruit orchards was paint with borax (3%) plus SOFRI Trukien® to control ants. Hereinafter, I refer to SOFRI Protein® as the commercial product of toxic hydrolysed protein bait developed by the Southern Fruit Research Institute of Viet Nam (SOFRI). It includes a 100 ml bottle of hydrolysed protein bait and
a 4 ml sachet of fipronil 5% supplied by Can Tho Pesticide Co. SOFRI Protein® 10 DD bait and fipronil 5% were diluted into 900 ml of water to prepare one litre of solution. The spot applications were sprayed on lower canopy foliage along the tree rows with each dragon fruit tree receiving approximately 50 ml of the solution. SOFRI Protein® was applied between 8 to 10 AM for four times on a weekly schedule in January, March, and October. A team of four members of the commune agricultural cooperative was responsible for spraying across 500 ha of dragon fruit orchards so that the area-wide treatment with SOFRI Protein® was attained within one day; SOFRI Trukien ® was applied between 8 AM and 4 PM for three times on a weekly schedule.

**Trap Construction and Deployment**

Traps were made on the basis of the Steiner trap principle (IAEA 2003) using plastic bottles. A trap was a vertical, clear plastic container about 20 cm high and 15 cm in diameter with three opening flaps (10 cm × 3 cm) cut equidistantly around the side of the bottle that allowed fruit flies to enter and feed on the lure. A metal wire was punctured through the centre of the bottle lid with a hanger on one end used to hang the trap from tree branches. The other end of this wire was hooked through the lid with a cotton ball suspended at the centre of the inside of the trap. The cotton ball was soaked with 3 ml of the mixture of an attractant (methyl eugenol, Cure lure) and insecticide (20% Pyrinex 20EC) to kill the target flies.

At each site, three traps were placed in the centre of the dragon orchard at a height of approximately 2 m above the ground and with a trap-to-trap distance of about 20 m. Male flies were attracted by the lure and promptly killed by the insecticide. Traps were set once a month for one week. Dragon orchards were monitored for 12 months, giving a total of 5 trapping periods.

**Collection of Host Fruit**

In addition, samples of ripe and unripe fruit of dragon fruit were collected to further investigate the fruit fly community. One plant collected randomly 4 fruit at 4 site of plant (north, south, east and west) in Cho Gao district, Long Tri district and Ham Thuan Nam district. Fruit were then taken to the laboratory and placed in separate plastic containers for each type. Fruit were incubated for two weeks at the room temperature of 27°C to check for any fruit fly emergence.

**Species Identification**

Fruit flies captured in the traps were dried at the temperature of 50°C for 24 hours before being sorted and counted. Identification of fruit flies is based on the illustration guide of R.A.I. Drew (1987). Some specimens of fruit flies were sent to R.A.I. Drew for confirmation.

**Data Analysis**

Differences in the numbers of fruit flies captured between treatment and non-treatment sites were measured. Traps were considered as individual samples for analysis, in which the data were square root transformed to prevent overweighting the most abundant species (Clark and Warwick 2001). An analysis of similarities was conducted to test whether the fruit fly communities between sites, months and treatments were statistically different from each other. Student t-tests were performed to assess the differences in fruit fly abundances between treatments for fruit fly. Comparisons were based on the mean number of fruit flies captured in treated and untreated sites for each moth of the trapping period. Trap catches for each species were square root transformed \(\sqrt{(x + 0.5)}\) and log \((x+1)\) to achieve data homogeneity before analysis.
RESULTS AND DISCUSSION

Pest Abundances and Composition
A total of 1,325 specimens of pests were collected by vacuum machine in 12 months, comprising Diptera, Thysanoptera, Coleoptera, Homoptera, Lepidoptera, and Hymenoptera. The pest populations of dragon orchards in Tien Giang were dominated by Diptera; about 83% in bud stage; 76% in flowering stage; 86% in fruit set stage; and 90% in fruit ripen stage. Hymenoptera had the second highest abundance, about 17% in bud stage; 6% in flowering stage; 2% in fruit set stage; and 6% in fruit ripen stage. Other families shared about 6% of the total collections (Table 1).

Table 1. Insects collected on different stages of dragon fruit

<table>
<thead>
<tr>
<th>No.</th>
<th>Family collected</th>
<th>% in each stage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Bud</td>
</tr>
<tr>
<td>1</td>
<td>Diptera</td>
<td>83.33</td>
</tr>
<tr>
<td>2</td>
<td>Thysanoptera</td>
<td>0.00</td>
</tr>
<tr>
<td>3</td>
<td>Coleoptera</td>
<td>0.00</td>
</tr>
<tr>
<td>4</td>
<td>Homoptera</td>
<td>0.00</td>
</tr>
<tr>
<td>5</td>
<td>Lepidoptera</td>
<td>0.00</td>
</tr>
<tr>
<td>6</td>
<td>Hymenoptera</td>
<td>16.66</td>
</tr>
</tbody>
</table>

There are many other pests (Table 2) in surveyed dragon orchards. Among them ants and fruit fly causeed highest damage to dragon orchards (Table 2).

Table 2. Pests associated with dragon fruit in Vietnam

<table>
<thead>
<tr>
<th>Family</th>
<th>Name of insects</th>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
<th>Level 4</th>
<th>Popularity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scarabaeidae</td>
<td>Protaetia sp.</td>
<td>30.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>Minor</td>
</tr>
<tr>
<td>Formicidae</td>
<td>Ants</td>
<td>49.17</td>
<td>57.50</td>
<td>15.00</td>
<td>0.00</td>
<td>Major</td>
</tr>
<tr>
<td>Coreidae</td>
<td>Stinkbug</td>
<td>9.17</td>
<td>9.17</td>
<td>0.00</td>
<td>0.00</td>
<td>Minor</td>
</tr>
<tr>
<td>Aphididae</td>
<td>Aphis</td>
<td>10.83</td>
<td>7.50</td>
<td>4.17</td>
<td>0.00</td>
<td>Minor</td>
</tr>
<tr>
<td>Pyralidae</td>
<td>Worms</td>
<td>59.17</td>
<td>5.01</td>
<td>4.17</td>
<td>0.00</td>
<td>Minor</td>
</tr>
<tr>
<td>-</td>
<td>Snail</td>
<td>15.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>Minor</td>
</tr>
<tr>
<td>Tephritidae</td>
<td>Fruit fly</td>
<td>42.50</td>
<td>15.83</td>
<td>11.67</td>
<td>0.00</td>
<td>Major</td>
</tr>
<tr>
<td>Thripidae</td>
<td>Thrips</td>
<td>33.30</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>Minor</td>
</tr>
<tr>
<td>Pseudococcidae</td>
<td>Mealy bug</td>
<td>13.32</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>Minor</td>
</tr>
<tr>
<td>Tarsonemidae</td>
<td>Mite</td>
<td>6.67</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>Minor</td>
</tr>
</tbody>
</table>

Ants on Dragon Fruit
There were different species of ant on dragon fruit at 8 AM (Table 3). Collected ants were also infected with bacteria and fungi (Table 4), which may afflict on dragon fruit. About 26% of ant specimen infected with unidentified bacteria, 24% with *Fusarium* sp., 24% with unknown microorganisms, 14% with unidentified fungi, 5% with fungus *Curvularia* sp., 5% with *Trichoderma* sp., and 2% with *Aspegillus* sp.
Table 3. List of ant species on different stages in dragon fruit orchard

<table>
<thead>
<tr>
<th>Ant species</th>
<th>Stem</th>
<th>Flower</th>
<th>Fruit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Camponotus sp. 1</td>
<td>0.54</td>
<td>0.42</td>
<td>0.05</td>
</tr>
<tr>
<td>*Paratrechina longicornis</td>
<td>6.23</td>
<td>62.79</td>
<td>22.17</td>
</tr>
<tr>
<td>Camponotus sp. 2</td>
<td>0.19</td>
<td>0.38</td>
<td>0.27</td>
</tr>
<tr>
<td>Tapinoma melanocephala</td>
<td>0.60</td>
<td>0.59</td>
<td>0.39</td>
</tr>
<tr>
<td>Paratrechina sp.</td>
<td>18.16</td>
<td>20.51</td>
<td>13.03</td>
</tr>
<tr>
<td>Cardiocondyla wroughtonii</td>
<td>73.19</td>
<td>14.90</td>
<td>63.77</td>
</tr>
<tr>
<td>Monomolium sp.</td>
<td>1.08</td>
<td>0.42</td>
<td>0.32</td>
</tr>
</tbody>
</table>

Table 4. Bacteria and fungi attached on ant body.

<table>
<thead>
<tr>
<th>Species</th>
<th>Relationship fungy and bacteria on ant body</th>
</tr>
</thead>
<tbody>
<tr>
<td>Camponotus sp. 1</td>
<td>Bacteria*, fungi*</td>
</tr>
<tr>
<td>*Paratrechina longicornis</td>
<td>Fusarium sp; bacteria*</td>
</tr>
<tr>
<td>Camponotus sp. 2</td>
<td>Bacteria*, fungi*</td>
</tr>
<tr>
<td>Tapinoma melanocephala</td>
<td>Aspegillus sp.; Trichoderma sp.; Fusarium sp; bacteria*</td>
</tr>
<tr>
<td>Paratrechina sp.</td>
<td>Fusarium sp; bacteria*</td>
</tr>
<tr>
<td>Cardiocondyla wroughtonii</td>
<td>Bacteria*</td>
</tr>
<tr>
<td>Monomolium sp.</td>
<td>Curvularia sp.; Trichoderma sp.; Fusarium sp; bacteria*</td>
</tr>
</tbody>
</table>

*Not yet identified

Odorous ants will readily seek out honeydew (Smith 1928). Honeydew is collected by ant workers from honey dew-excreting insects such as aphids, scale insects, mealy bugs and membracidae (Smith 1965). Ant workers have also been observed visiting floral and extract floral nectaries of plants (Smith 1965). Figure 1 shows that ants were most active on dragon fruit from April to June.

Figure 1. Number of ants on young shoot, bud, flower, young fruit and ripe fruit.
**SOFRI trukien® baits for controlling ants:** Ant baits consist of an attractive fructose and a toxicant. The most effective ant baits have a slow acting toxicant that allows the ants to pick up the bait and bring it back to the nest where they can share it with other members of the colony. This method of control provides several advantages. One of them is that colonies do not have to be located for control to be effective. Results show that ants were attracted to the bait one minute right after placing it. After 120 minutes, number of ants attracted with 50% fructose was similar to higher concentrations of fructose (Table 5). In addition to baiting, an effective ant management program should also include good SOFRI Trukien® trap practices to prevent ants from orchard (Hedges 1998; Silverman and Roulston 2001).

**Table 5. Attraction of ants with different concentrations of fructose in SOFRI Trukien**

<table>
<thead>
<tr>
<th>Treatments</th>
<th>1 min</th>
<th>30 min</th>
<th>120 min</th>
<th>150 min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fructose (14%)</td>
<td>0.24 b</td>
<td>0.61 b</td>
<td>0.77 b</td>
<td>0.89</td>
</tr>
<tr>
<td>Fructose (50%)</td>
<td>0.55 a</td>
<td>1.02 a</td>
<td>1.09 a</td>
<td>0.97</td>
</tr>
<tr>
<td>Fructose (80%)</td>
<td>0.36 ab</td>
<td>1.09 a</td>
<td>1.11 a</td>
<td>0.90</td>
</tr>
<tr>
<td>Fructose (90%)</td>
<td>0.33 ab</td>
<td>0.93 a</td>
<td>0.99 ab</td>
<td>0.73</td>
</tr>
<tr>
<td>Fructose (100%)</td>
<td>0.41 ab</td>
<td>0.64 b</td>
<td>0.76 b</td>
<td>0.79</td>
</tr>
</tbody>
</table>

F** **: Means in a column followed by a common letter are significantly different at P 0.05 by Duncan. Data number of ants were transformed log(x+1) with x trap catches for each ant.

| CV (%) | 53.53 | 21.32 | 18.03 |

Legend: **: Means in a column followed by a common letter are significantly different at P 0.05 by Duncan. Data number of ants were transformed log(x+1) with x trap catches for each ant.

**Fruit Fly on Dragon Fruit**

**Fruit fly in different ecological areas:** The fruit fly was collected from methyl eugenol (ME) and CuE traps. Three fruit flies (*Bactrocera*) species were identified. The CuE traps collected 2 fruit flies species and the ME traps 3 species. The results showed that methyl eugenol is a powerful sex attractant to *B. dorsalis* (Table 6). The result is in line with reports of Allwood (1997) and Vayssieres et al. (2007), and similar to those of previous research conducted in South Vietnam (Drew et al. 2001b) and in Thailand (Orankanok et al. 2007) where *B. cucurbitae* and *B. tau* were confirmed to be major fruit flies on dragon fruit orchards. Therefore ME traps are useful to measure the populations of *Bactrocera* species (Vayssieres et al. 2007, 2009a). ME trap collected the number of *Bactrocera dorsalis* in Tien Giang, Long An and Binh Thuan areas are more than *B. correcta* and *B.carambolae*. As a result of a national survey of fruit fly communities in dragon fruit growing regions, CuE trap collected the number of *B. cucurbitae* in the Tien Giang and Long An areas are more abundant than *B. tau* (Table 7).

**Table 6. Species and number fruit fly in dragon fruit zone by methyl eugenol trap (ME)**

<table>
<thead>
<tr>
<th>Species</th>
<th>Content</th>
<th>Tien Giang</th>
<th>Long An</th>
<th>Binh Thuan</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>B. carambolae</em></td>
<td>Number fruit fly</td>
<td>192</td>
<td>205</td>
<td>252</td>
<td>216.33</td>
</tr>
<tr>
<td></td>
<td>Sample (%)</td>
<td>2.01</td>
<td>2.88</td>
<td>7.28</td>
<td>4.056</td>
</tr>
<tr>
<td><em>B. correcta</em></td>
<td>Number fruit fly</td>
<td>463</td>
<td>998</td>
<td>893</td>
<td>784.66</td>
</tr>
<tr>
<td></td>
<td>Sample (%)</td>
<td>4.85</td>
<td>14.06</td>
<td>25.8</td>
<td>14.903</td>
</tr>
<tr>
<td><em>B. dorsalis</em></td>
<td>Number fruit fly</td>
<td>8884</td>
<td>5893</td>
<td>2316</td>
<td>5697.67</td>
</tr>
<tr>
<td></td>
<td>Sample (%)</td>
<td>93.13</td>
<td>83.04</td>
<td>66.9</td>
<td>81.02</td>
</tr>
</tbody>
</table>

*: Mean number fruit fly/trap per day.
Improving Pitaya Production and Marketing

Table 7. Species and number fruit fly in dragon fruit zone by Cure lure trap (CuE)

<table>
<thead>
<tr>
<th>No.</th>
<th>Species</th>
<th>Tien Giang</th>
<th>Long An</th>
<th>Mean (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Number fruit fly (*)</td>
<td>Sample (%)</td>
<td>Number fruit fly (*)</td>
</tr>
<tr>
<td>1</td>
<td>B. cucurbitae</td>
<td>1224</td>
<td>99.63</td>
<td>2265</td>
</tr>
<tr>
<td>2</td>
<td>B. tau</td>
<td>45</td>
<td>0.37</td>
<td>87</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>1231</td>
<td>100</td>
<td>2403</td>
</tr>
</tbody>
</table>

Host of fruit flies: Among 5,190 samples (fruits) collected, there were 392 infected plants, and various levels of infection with different stages of fruit development (Table 8). And five Bactrocera species were detected, but only B. dorsalis, B. correcta and B. cucurbitae dominated (Table 9).

Table 8. Fruit flies collected on dragon fruit in the south of VietNam (2003-2012)

<table>
<thead>
<tr>
<th>Host</th>
<th>Number of dragon fruit collected</th>
<th>Number of sample infected plant</th>
<th>Fruit collected</th>
<th>Infected plant</th>
<th>Sample (fruit collected)</th>
<th>Stage fruit infected ratio (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dragon fruit (White)</td>
<td>4500</td>
<td>300</td>
<td>1500</td>
<td>1500</td>
<td>1500</td>
<td>0.00</td>
</tr>
<tr>
<td>Dragon fruit (red)</td>
<td>450</td>
<td>57</td>
<td>150</td>
<td>150</td>
<td>150</td>
<td>0.00</td>
</tr>
<tr>
<td>Dragon fruit (pink)</td>
<td>240</td>
<td>35</td>
<td>80</td>
<td>80</td>
<td>80</td>
<td>0.00</td>
</tr>
<tr>
<td>Total</td>
<td>5190</td>
<td>392</td>
<td>1730</td>
<td>1730</td>
<td>1730</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Table 9. Fruit fly species in host fruit in Viet Nam from 2003-2012.

<table>
<thead>
<tr>
<th>Dragon fruit (color flesh)</th>
<th>% of species fruit fly on fruit infested</th>
<th>Number species</th>
</tr>
</thead>
<tbody>
<tr>
<td>BDO</td>
<td>BCO</td>
<td>BCU</td>
</tr>
<tr>
<td>Dragon fruit (White)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Dragon fruit (red)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Dragon fruit (pink)</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

(*) Note: BDO: B. dorsalis; BCO: B. correcta; BCU: B. cucurbitae; BCR: B. carambolae; BTA: B. tau;

Fruit fly infestation: During the off season (January and March) harvested dragon fruit had low infestation (Table 10) with B. dorsalis, B. correcta and B. carambolae, which are among seven fruit flies species occurring in Viet Nam and regarded as of economic significance (Drew et al. 2001; Clarke et al. 2005; Dat 2007).

Table 10. The fruit fly infestation on dragon fruit in South Viet Nam (2005-2008)

<table>
<thead>
<tr>
<th>Harvesting time</th>
<th>2005 % fruit infested</th>
<th>2008 % fruit infested</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>2.20 c</td>
<td>4.20 c</td>
<td>3.20 c</td>
</tr>
<tr>
<td>Mar</td>
<td>8.60 b</td>
<td>9.40 b</td>
<td>9.00 b</td>
</tr>
<tr>
<td>Oct</td>
<td>13.80 a</td>
<td>15.00 a</td>
<td>14.40 a</td>
</tr>
<tr>
<td>CV (%)</td>
<td>10.88</td>
<td>10.92</td>
<td>7.87</td>
</tr>
</tbody>
</table>

Legend: **: Means in a column followed by a common letter are significantly different at P0.05 by Duncan. Data number of ants were transformed (X + 0.5)^(1/2) with x trap catches for each fruit fly.
**Impact of SOFRI Protein® on fruit fly:** The use of protein bait was tested in Tien Giang, Long An, and Binh Thuan 2003-2012. Each orchard is 10,000 m² to 50,000 m². The fruit fly populations sprayed with SOFRI Protein® were significantly different from those at the Tien Giang province where no protein baits were applied (Table 11). The overall mean fruit infested (2%) in the treated site were lower by nearly four and two times, respectively, than those recorded in the non-treatments (14.49%). In June 2004, the fruit fly populations at the site sprayed with SOFRI Protein® were not significantly from those in the Long An province.

**Table 11. The result control fruit fly using protein bait in some local (2003-2012)**

<table>
<thead>
<tr>
<th>Time</th>
<th>Local</th>
<th>During timespray</th>
<th>Fruit infected (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003</td>
<td>Tien Giang</td>
<td>Jan</td>
<td>2.00</td>
</tr>
<tr>
<td>2004</td>
<td>Long An</td>
<td>June</td>
<td>15.12</td>
</tr>
<tr>
<td>2006</td>
<td>Binh Thuan</td>
<td>March</td>
<td>3.00</td>
</tr>
</tbody>
</table>

**Relation between fruit fly population and infection:** Results indicate that population and infection of fruit fly in dragon orchards in Tien Giang was related (Figure 2), and fruit fly populations and fruit fly infection in dragon orchards were low Jan to March and July to Nov. Previously, Dien et al. (2007) had reported an clear relationship between population and SOFRI Protein spray in barbados cherries.

**Impact of SOFRI Protein® on fruit fly:** The fruit fly populations at the site sprayed with SOFRI Protein® were significantly different from those at the other province where no protein baits were applied. The overall mean number of fruit flies per trap in the treated site at 6 to 15 insects per trap per day was lower by nearly four and two times than those in the non-treatment (24.48 insects). These findings supported that the strong control effect of SOFRI Protein® on fruit fly. The protein baits laced with spinosad,
another type of insecticidal toxin, are also highly attractive to both the females and males of \textit{B. dorsalis} (Barry et al. 2006; Pinero et al. 2009). Stark et al. (2009) reported that \textit{B. dorsalis} was more susceptible to fipronil than \textit{B. cucurbitae} after exposure to spot sprays. Since spinosad is known to be safer to humans and the environment than fipronil, fipronil based protein baits have been highly recommended for the control of \textit{Bactrocera} fruit flies in general and \textit{B. dorsalis} in particular (Stark et al. 2009).

The results for \textit{B. dorsalis} in this study, however, are different from those of Vayssierres et al. (2009b) who observed that there were no significant differences in the abundances of \textit{B. invadens} between dragon orchards treated with protein baits and untreated orchards in Benin, West Africa. \textit{B. invadens} was recently described and categorised in the \textit{B. dorsalis} complex (Drew et al. 2005).

Numbers of \textit{B. dorsalis} and \textit{B. correcta} were captured in all traps fluctuated throughout the investigation period. However, numbers in the treated site were always lower than those in the untreated site in all pairwise data for both species (Table 12). The mean number of \textit{B. dorsalis} captured per trap was highest in September 2010 and decreased toward the end of the harvest time in both treatment and non-treatment orchards (Table 12). There were significant differences in the mean trap catches of \textit{B. dorsalis} between the two treatments across the six-month period ($t$-test, $p < 0.05$) (Table 12). Overall, the mean captures of \textit{B. dorsalis} across six month in non-treated sites were nearly four times higher than those in the treated site (Table 12).

Table 12. Comparison of mean (± SE) numbers of fruit fly captured monthly per methyl eugenol trap in 4 sites in Tien Giang, Long An and BinhThuan Province from 2008 to 2012.

<table>
<thead>
<tr>
<th>Location</th>
<th>Area (ha)</th>
<th>Duration time spray</th>
<th>Number of fruit flies (mean ± SE) captured per trap per 7 day</th>
<th>Infected fruits ratio (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>SOFRI Protein</td>
<td>Control</td>
</tr>
<tr>
<td>BinhThuan</td>
<td>500</td>
<td>Jan 2008</td>
<td>14,50±2.65</td>
<td>62.25±10.59</td>
</tr>
<tr>
<td>BinhThuan</td>
<td>500</td>
<td>Mar 2009</td>
<td>12,50±2.08</td>
<td>73.25±19.97</td>
</tr>
<tr>
<td>Long An</td>
<td>50</td>
<td>July 2010</td>
<td>10,50±1.91</td>
<td>77.50±15.37</td>
</tr>
<tr>
<td>Tien Giang</td>
<td>100</td>
<td>Jan 2012</td>
<td>10,50±1.91</td>
<td>86.00±15.85</td>
</tr>
</tbody>
</table>

Legend: Control: Farmer control; Data number of fruit files were transformed log(x+1) with $x$ trap catches for each fruit fly; ** significantly different $p0.01$.

In all locations, control of fruit fly in large areas produces good results. The infected fruit was only 1.00 to 3.00%, while for untreated fruit this figure was 17.18 to 22.10%.

Adoption of New Management Tools Against Ants and Fruit Flies
The ultimate objective of applying any management method in crop production is to improve product quality and productivity. However, the cost of implementing new management approaches should be justified by economic benefits. In this regard, there might be a concern about whether SOFRI Protein® baiting could reduce infestation rates on dragon fruit to such a low level that the harvested fruit is still marketable. Currently, Japan markets require unblemished dragon fruit, and Australia and New
Zeland have strict quarantine barriers. To ge access to these ‘hard’ markets, unfortunately, SOFRI Protein® applications still not adequate. Additional measures such as fruit bagging and quarantine treatments may be undertaken to achieve the zero tolerance for fruit fly infestation.

Table 14. Yield of model applied IPM and traditional on dragon fruit in Tien Giang province

<table>
<thead>
<tr>
<th>Plot</th>
<th>Mean yield (kg/ha)</th>
<th>Mean loss yield (fruit fly) (kg/ha)</th>
<th>Fruit quality (kg/ha) (+)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IPM</td>
<td>26.000</td>
<td>260.00</td>
<td>25.740.00</td>
</tr>
<tr>
<td>Control</td>
<td>23.000</td>
<td>3.291.30</td>
<td>19.708.70</td>
</tr>
</tbody>
</table>

(*) note: data recorded 20 orchard, 10 orchard for IPM and 10 orchard for control; (+): fruit not infested fruit fly and ants

CONCLUSION

There are seven species of ants occurred in dragon fruit orchards in Tien Giang, Long An and Binh Thuan provinces in southern Vietnam. And three species of fruit flies caused high levels of damage on dragon fruit. And both SOFRI TruKien® and SOFRI Protein® bait were effective for the control of the aforesaid pests.

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VALUE CHAIN INITIATIVES
DEVELOPMENT AND IMPLEMENTATION OF GAP ON PITAYA IN VIETNAM: STATUS AND CHALLENGES

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2 Plant and Food Research Institute (PFR), Motueka, New Zealand
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ABSTRACT

In Vietnam, dragon fruit or pitaya is widely grown in seven ecological zones of the country. The total area of pitaya in the year 2014 was 36,686 ha, a 2.3-fold from 2010. There are about 26,890 ha bearing fruit with a total production of 602,680 tonnes. There are three main production areas for pitaya in the Provinces of Binhthuan of about 24,191 ha with 430,120 tonnes, Tiengiang of 4,052 ha with 75,109 tonnes and Longan of 5,568 ha with 78,500 tonnes. The average yield is about 22.4 to 25 t/ha and flowering can be manipulated for the plants to produce fruit the whole year round. Vietnamese dragon fruit has been exported to over 40 countries and territories in the world. By the year 2014, 8,284 ha had been certified for GlobalGAP/VietGAP, occupying 24.5% of the total production area, making good contribution to the exportation in terms of quantity, quality uniformity and enhanced GAP benefits awareness by producers, exporters and customers. The Australian projects and New Zealand experts have successful helped to put the first important foundation on the development of GAP in pitaya and fruit tree industry of Vietnam. All the GlobalGAP standards have been successfully transferred through development of manuals, capacity building for both SOFRI and project partners and has expanded to many agricultural players in Vietnam. Even though there are many challenges ahead, the GAP initiative will continue to spread to the rest of the Pitaya industry and many other fruit crops.

Keywords: GlobalGAP, VietGAP, SOFRI, PFR, dragon fruit, pitaya, manual, capacity building, challenge

INTRODUCTION

Dragon fruit or pitaya (*Hylocereus undatus*) is considered to be one of the most important fruit crop in terms of income for producers, packers, exporters in the Provinces of Binh Thuan, Tien Giang and Long An in Vietnam. The total area of pitaya in Vietnam increases annually: in the year 2000 total area was 5,512 ha, in 2005 it was 8,607, 2010 was 16,302 ha and in the year 2014 it was 36,686 ha. The total production in 2005 was 134,465 tonnes, in 2010 it was 361,780 ton and in the year 2014 it was about 602,680 tonnes. In Vietnam, pitaya is produced mostly for export, 80-86% compared to domestic consumption of only about 15-20%. Vietnamese pitaya has been exported to over 40 countries and territories in the world. The main markets are China, Thailand, Indonesia, Malaysia, Singapore and then the Netherlands, Spain, Germany, UK, Canada, USA, etc. Under tropical conditions, fruit can be harvested from April to September during the main season, while flower initiation can force fruiting to be harvested from October to March. There are two main varieties are cultivated such as white flesh and red flesh with red peel. Since 2005, the Good Agricultural Practice
has been applied to the pitaya industry with the first EUREPGAP certification awarded to the Vietnamese fruit industry for pitaya at the HamMinh cooperative, BinhThuan Province, with 11 ha in 2006. Subsequently, many farms, groups of growers, cooperatives, clusters of farmers have been certified for GlobalGAP and VietGAP standards. By the year 2014, 8,284 ha had been certified for GlobalGAP/VietGAP, occupying 24.5% the total production area. In this paper, the development and implementation of GAP on pitaya in Vietnam will be presented and discussed.

PITAYA PRODUCTION IN VIETNAM

In Vietnam, pitaya is widely grown in seven ecological zones of the country. In the year 2000 the total area in production was 5,512 ha; in 2005 it was 8,607 ha (1.6-fold increase from 2010); in 2010 it was 16,302 ha; and in the year 2014 it was 36,686 ha (2.3-fold increase from 2010) with about 26,890 ha bearing fruit. The total production had increased from 134,465 tonnes in 2005 to 361,780 tonnes in 2010 (2.69-fold increase) and again increased to 602,680 tonnes for the year 2014 (1.7-fold increase from 2010). There are three main areas for pitaya such as Binhthuan (Hamthuanbac, Hamthuannam, Bacbinh, Hamtan, Tuypophong districts, Lagi town and Phanthiet city) with about 24,191 ha and a production of 430,120 tonnes, Tiengiang (Chogao, Goongtay, Tanphuoc) of 4,052 ha with 75,109 tonnes and Longan (Chauthanh, Tantru) of 5,568 ha with 78,500 tonnes. In addition, in the South, in many other provinces e.g. Vinhlong, Travin, Cantho, Angiang, Camau, Dongnal, Taynin, Baria-Vungtau, etc. and in the North, Vinhphuc, Quangninh, Haiduong, Hanoi, Thanhoa, Nghean, etc provinces, pitaya have also been planted but with smaller areas. (Table 1).

Table 1. Area, yield and production of dragon fruit in major production zones

<table>
<thead>
<tr>
<th>No</th>
<th>Items</th>
<th>Unit</th>
<th>2005</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Binhthuan</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total area</td>
<td>Ha</td>
<td>5,799</td>
<td>13,404</td>
<td>18,616</td>
<td>19,419</td>
<td>20,551</td>
<td>24,191</td>
</tr>
<tr>
<td></td>
<td>Harvesting area</td>
<td>Ha</td>
<td>4,880</td>
<td>10,825</td>
<td>15,287</td>
<td>15,807</td>
<td>18,184</td>
<td>19,927</td>
</tr>
<tr>
<td></td>
<td>Yield</td>
<td>Ton/ha</td>
<td>19.8</td>
<td>27.6</td>
<td>26.0</td>
<td>24.8</td>
<td>22.0</td>
<td>21.6</td>
</tr>
<tr>
<td></td>
<td>Production</td>
<td>Ton</td>
<td>96,806</td>
<td>299,302</td>
<td>397,584</td>
<td>392,373</td>
<td>400,800</td>
<td>430,120</td>
</tr>
<tr>
<td>2.</td>
<td>Longan</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total area</td>
<td>Ha</td>
<td>1,155</td>
<td>918</td>
<td>1,247</td>
<td>1,718</td>
<td>2,838</td>
<td>5,568</td>
</tr>
<tr>
<td></td>
<td>Harvesting area</td>
<td>Ha</td>
<td>1,152</td>
<td>809</td>
<td>972</td>
<td>1,387</td>
<td>1,685</td>
<td>2,154</td>
</tr>
<tr>
<td></td>
<td>Yield</td>
<td>Ton/ha</td>
<td>13.0</td>
<td>31.4</td>
<td>31.0</td>
<td>30.5</td>
<td>36.6</td>
<td>36.4</td>
</tr>
<tr>
<td></td>
<td>Production</td>
<td>Ton</td>
<td>15,004</td>
<td>225,380</td>
<td>30,154</td>
<td>42,303</td>
<td>61,622</td>
<td>78,500</td>
</tr>
<tr>
<td>3.</td>
<td>Tiengiang</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total area</td>
<td>Ha</td>
<td>1,653</td>
<td>1,885</td>
<td>2,158</td>
<td>2,449</td>
<td>3,139</td>
<td>4,052</td>
</tr>
<tr>
<td></td>
<td>Harvesting area</td>
<td>Ha</td>
<td>1,466</td>
<td>1,810</td>
<td>1,969</td>
<td>2,132</td>
<td>2,364</td>
<td>3,014</td>
</tr>
<tr>
<td></td>
<td>Yield</td>
<td>Ton/ha</td>
<td>15.5</td>
<td>18.1</td>
<td>17.9</td>
<td>20.2</td>
<td>24.0</td>
<td>24.9</td>
</tr>
<tr>
<td></td>
<td>Production</td>
<td>Ton</td>
<td>22,655</td>
<td>32,798</td>
<td>35,302</td>
<td>43,108</td>
<td>56,823</td>
<td>75,109</td>
</tr>
</tbody>
</table>
The average yield of pitaya in the country is about 22.4 t/ha. Pitaya in Longan has the highest yield of 35.4 t/ha, followed by Tiengiang 25 t/ha, Binhthuan is about 21.6 t/ha. In other provinces the yield of pitaya is from 15 to 17 t/ha (Crop Production Department, 2014).

Vietnamese pitaya have been exported to over 40 countries and territories in the world. The main markets being China, Thailand, Indonesia, Malaysia, Singapore and then Holland, Spain, Germany, UK, Canada, USA, etc. (Lap et al. 2013).

Under tropical conditions, fruit can be harvested from April to September for main season production; light induced flowering can forcing production of fruit for harvesting from October to March of the following year. In the offseason, light has been used to induce pitaya flowering. Originally the industry used 65 watt incandescent bulbs but subsequently changed to 20 watt compact power saving bulbs and now there is a shift to 7 watt LED lights.

There are two main pitaya varieties cultivated in Vietnam for commercial production: the white flesh with red peel and red flesh with red peel. The white flesh variety is from a natural selection and the red flesh red peel variety a result of the SOFRI breeding program, and released in 2005. Production of this variety is currently around 4,500 to 5,000 hectare (Crop Production Department, 2014).

DEVELOPMENT AND IMPLEMENTATION OF GAP ON PITAYA IN VIETNAM

EUREPGAP/GLOBALGAP STANDARDS

The supply chain for pitaya in Vietnam (Sanh et al. 2010) is complicated and processes through many steps (Figure 1) that lead to share of the benefit to many players but to the main player (farmer) gaining the least. To understand that situation, the establishment of the group of growers to cooperate with the packinghouse to produce pitaya under certain standards plays very important role to set up the millstone for the industry later on.

Since 2005, the Good Agricultural Practice has been applied to pitaya industry zone with the first EUREPGAP certification awarded to Vietnamese fruit industry for pitaya was the HamMinh Cooperative, with 11 ha in 2006, following another 7 ha farm received certification in 2007. In late 2007 one other group of farmers of 80 ha received EUREPGAP certification. Since 2008 to the present, 230 ha have been certified and recertified. The above achievements were due to the AusAID project fund to Vietnamese institution and pitaya industry along with a USA project to help farmers to implement GAP. And SOFRI and PFR played a major role in implementing these projects. The AusAID project established a private sector working pilot of exporter/packer and supplying pitaya growers in which the European high value market driven standards of BRC at the packer and EUREPGAP/GlobalGAP at the farmer level were implemented. Project implementation delivery included:
Benchmarking survey of pitaya production
The benchmarking survey of pitaya production was conducted by end of July 2005. There were 125 farmers in Binh Thuan and 30 farmers in Long An and Tien Giang Provinces interviewed to collect data on cultivation practices and other related techniques. They were relevant to practical production of pitaya as compare to EUREPGAP standards for improvement to satisfy the requirements, and the result delivered as a Power Point presentation to SOFRI personnel, packers, farmers, MARD and DARD personnel of Binh Thuan in 2007.

Development of quality manual
The manual was first written in English and then translated into Vietnamese. The manual was based on the specific background which meet the requirements of quality systems for the project pilot model for the farmer section complying to EUREPGAP and section for packer to BRC (British Retailers Consortium, Global standard: Food). The manual is subject to revision whenever the standard or condition changed. By late of 2007 and early 2008, SOFRI's project staff had revised the manual as Version 2.0 upgrading the EUREPGAP to GlobalGAP standards, and the quality management system for packer compliance with BRC standards – Issue 5 (Hoa et al. 2011).

ESTABLISHMENT OF PROGRAMME FOR IMPLEMENTING GAP PILOT MODELS
Chosen standards of quality management systems

EUREPGAP standard has been chosen for production farm to link people together for carrying out the same standards, later when the revised version for GlobalGAP has been released, the new version for pitaya also updated and at packing house, BRC standard was selected for implementation. The both standards were supplementing to each other to ensure pitaya being produced and packed in a quality, legality and meeting the requirements of high value markets, “satisfaction of customers' demands” on traceability.

At packer level

In Vietnam, Hoang Hau Dragon fruit Ltd. Co. is the biggest exporter, therefore Hoang Hau Company’s dragon fruit packing house was selected as packaging pilot model. The project team had negotiated with Mr. Tran Ngoc Hiep (director) about level of implementation and the collaboration in development of the packing house to comply with BRC standard. The quality manual (in English and Vietnamese) was provided to Mr. Hiep. While, in the meantime, SOFRI’s project team had conducted a number of trainings/consultancies for the personnel working in the packing house and farm management. The contents of trainings and consultants included: customers and customers’ demands; quality systems and objectives; packinghouse management; indicators of “progress” from farm through packing house to exporters; linkage between farmers and packers, and their responsibilities; purpose and implication of the pitaya quality manual; identification for areas of improvement at farm and in packinghouse; staff responsibilities as related to their positions; role and responsibility of internal auditor; and process of improvement and promotion for sustainable production.

At farm level

The farmer group was set up and trainings were conducted for farmers on quality systems which fetch back more benefits if compliance to GAP. The project had also focused and instructed farmers specifically to help them to approach and comply with the standards before the auditing of certify body. The selected farmers’ groups, however, could not meet the requirements due to lack of investment and too much depend on middlemen – collectors and these issues were not expected by project. The project, therefore, came back with selected the contracted farmers’ group supplying for packing house of Hoang Hau Dragon Fruit Co. and then to process the project as above said including the training on GAP, safe production, cultivation techniques, plant protection and all other criteria for GAP implementation, establishment of the farm, practicing to apply the GAP standards to their own farms, continue improvement for compliance to the standards.

CERTIFICATION AND EXPANSION OF THE PITATY PILOT MODELS

Project team had negotiated with SGS Vietnam (Société Générale de Surveillance), an international certify body responsible for Vietnam, Indonesia and New Zealand, to provide information on auditing, evaluation, and the potential of certifying of project. General information on progress of implementation of the pilot model based on internal audit checklist of BRC/EUREPGAP to evaluate the model, certification and lastly, 80 ha of pitaya was certified for EUREPGAP in 2007.

Based on the certified project pilot model, Hoang Hau Dragon Fruit Co. and its contracted supplying farmers’ group, got re-certificated by October 2008, with increase
in area up to 230 ha. And it was repeated in 2009 with their own source of fund. In the process, SOFRI staff continued providing technical support. The achievement came from the enhancement of capability of local project facilitators in techniques, organization and implementation.

Later, the project team has worked to expand the GlobalGAP pitaya model in Long An province. In early of 2013 the Duongxuan Cooperative with 37 member farmers and one packinghouse, Hoang Phat Co., received GlobalGAP certification. In Binhthuan, ten other organizations/farms have been certified on 222.7 ha for GlobalGAP standards (Dung 2014).

In addition, with the knowledge gained from the project, SOFRI staff had developed GlobalGAP standards for mango (11.7ha on Cat Hoa Loc mango in 2008 at Can Tho), Cat Hoa Loc and Cat Chu in Dong Thap province in 2011, rambutan (24ha in 2011 in Vinh Long), sweet potato in Vinh Long province in 2012 and many other fruit and vegetable crops (Thoai et al. 2012).

**Building capacity**

While delivering the project, one SOFRI staff had visited fruit GlobalGAP farms and BRC packinghouses in New Zealand and also participated in 2-day training course for internal auditing at Hasting NZ, in July 2006. After that, through the agreement from New Zealand Organization of Quality (NZOQ), a training course for internal auditing had been delivered to 8 staff of SOFRI by John Campbell, using parts of training materials of the same course provided by NZOQ. In addition, in the year 2009, SGS-Vietnam had organized a training course for Lead Auditor (LAC) in which two SOFRI’s staff were invited and qualified to be the GlobalGAP lead auditor.

As above said, Vietnam project team had also learnt through the project in the documentation of the materials, management, operation procedures, etc. SOFRI’s project team, therefore, had up-graded successfully the pitaya quality manual version 2.0 and even for other crops such as mango, rambutan, sweet potato and citrus crops.

SOFRI’s staff and other facilitators from established model of GlobalGAP of 30 people had also trained by SGS-Vietnam for GlobalGAP, HACCP, Internal Audit and Inspection in 2008, these personnel provided their efforts to bring GlobalGAP standards to provincial agricultural staff and farmers and in return many other crop production obtained GlobalGAP certificates.

One very important input of the project personnel to fruit industry in Vietnam was the contribution to the building up and releasing of VietGAP standards in the year 2008 by Ministry of Agriculture and Rural Development (MARD). During that time, SOFRI staff had played key role in developing the general regulations of VietGAP standards; this standard was issued on 28th December 2008.

**Publications**

During delivering project and onwards, a number of publications had been published, in which some major publishes listed below:

- Handbook for trainer for GAP fruit and vegetables (Training guidelines for trainer who are playing role as extension workers, technicians, members of Farming
Improving Pitaya Production and Marketing

- The Pitaya GlobalGAP quality manual both in English and Vietnamese languages have been updated in 2010.
- The Citrus GlobalGAP quality manual both in English and Vietnamese languages have been developed in 2009.
- The Rambutan GlobalGAP quality manual in Vietnamese languages has been developed in 2012.
- The Sweet Potatoes GlobalGAP quality manual in Vietnamese languages has been developed in 2013.
- The Water Melon GlobalGAP quality manual in Vietnamese languages has been developed in 2013.

VietGAP STANDARDS

VietGAP standard was issued and validated on 28th December 2008 through the Decision 99/2008/QD-BNN on October 10th, 2008 signed by the Minister of MARD (Crop Production Department MARD, 2008). After this issuing, SOFRI was also the first organization who guided pineapple farmers to run successful VietGAP production model in the year 2009 for 30 ha of 22 farmers. Up to now, there were 32 VietGAP models have been successfully consulted by SOFRI and certified by the certification body, including one for pitaya.

According to the Crop Production Department, MARD is building a route to upgrade the good agricultural practice standard (VietGAP) for vegetables, fruits, tea towards integration with the international GAP (GlobalGAP) after 2015. MARD will promote the application to obtain VietGAP certification if all conditions are met, including focusing production scale or coordination between farmers. In addition, MARD is continuously revising the VietGAP regulations for some crops to better match the conditions of Vietnam and in harmony with international standards.

MARD also asked Crop Production Department to accelerate developing the guidance documents of implementing the Decision No. 01/2012/QD-TTg dated 01.09.2012 of the Prime Minister on a number of policies to support VietGAP application in agriculture, forestry and fisheries; and technical regulations on food safety conditions for vegetables, fruits, tea leaves during production and preliminary processes.

According to MARD, there was a significant number of successful VietGAP models so far, but it occupied only 1% in the total production area for fruit crops. MARD and the
local authorities will continue to guide the production facilities, especially in the field of producing fruit and vegetable to organize the production and implement technical standards under VietGAP in order to ensure product safety.

For pitaya, Binhthuan leaders have provided strongly supports to develop and certify GAP for pitaya product in their areas. For VietGAP, the certified area has been increasing year by year from 6,529 ha (2012), 7,395 ha (2013) and 7,500 ha in the year 2014 (Dung, 2014). While in Tiengiang province, four groups with 67 ha have been certified for VietGAP standards. Of them, one first model has been developed by SOFRI staff and the manual and protocol for VietGAP on pitaya have been developed. In this province, they are conducting project to develop and apply high technologies for 100 ha better yield, quality and get VietGAP certificate in 2015 and 2016. While in Longan, they had program to train 400 farmers about the awareness of GlobalGAP or VietGAP and the farmers themselves apply VietGAP standards on their own farms.

The survey conducted by Sanh et al. (2010) on the perception of farmers to VietGAP, the results shown that more farmers keen to apply VietGAP on their farms. They indicated the advantages of VietGAP for: (i) better knowledge on production and supplying safe product to customers; (ii) better health care for farmers, society and eco-friendly environment; (iii) better management in production, reducing the use of chemicals; (iv) higher income through higher prices for their products; and (v) good opportunity to cooperated with packers and exporters for selling their product in proper chain.

CHALLENGES IN APPLYING GAP STANDARDS

Unfortunately, there were some farmers and others to hesitate to apply VietGAP standards. Results of the survey by Sanh et al. 2010 indicated that major reasons for their hesitance are: (i) not yet clear about the standards (44.2%); (ii) hard for them to apply (32.6%); (iii) they know about the standards but they do not like; (iv) no one to guide them to apply (2.3%); (vi) no source of fund to operate (9.3%); and (vii) other reasons (7.0%). Furthermore, many of them know clear about the standards its advantages and benefits, but they still hesitate to apply on their farms since the price of certified pitaya product is not higher than that of the normal product.

According to Crop Production Department (2012), there were many challenges in implementation of GAP in pitaya products: (i) the general planning of pitaya production and the plan for GAP production have not completed and comprehensive for different planted regions, market fluctuation, the infrastructure system is still poor, the land per household is small, the cost for implementation is high, therefore most for the GAP models are still at the demonstration site, which cannot be up-scaling; (ii) the policy for GAP is there but not strong enough to support the groups and farmers to apply GAP standards; (iii) awareness of people on safety products is still limited, the customer is not ready to pay more for safe products; (iv) VietGAP has not yet had the logo so the people cannot recognize which product produced by VietGAP standards; and (v) the use of certificate is sometime not proper.

Hoa (2012) also cited some of the challenges in GAP implementation under Vietnam conditions. They are: (i) the certified models are mostly small leading to small amount of production, which is not suitable to subsequently supply to the contracted supplier,
therefore, some groups of farmers, local agricultural officers turned their back to GAP production; (ii) the central government has not had the general planning for pitaya, while each province it has its own planning, but not link to each other for large production and cannot control the unprompted development; (iii) the Prime Minister issued policies to support GAP development, but at the Ministry level, they have not detailed for the industry to utilize them; (iv) the cooperative or cluster of growers are still limited in numbers and weak in functioning; (v) the linkage amongst growers themselves and between growers to packers, collectors and exporters are weak and too formality and complicated, and the roles of local government, scientists are not clear within the linkages; (vi) it takes time for farmers to change their habits from traditional production; and (vii) the cost for auditing and certify is high, which retards the farmers to bear the cost for recertification.

On 18-19th March 2014, the Vietnam Academic of Agricultural Science (VAAS) and Syngenta Foundation for Sustainable Agriculture (SFSA) have jointly organized the workshop on “Good Agricultural Practice – VietGAP: Current Status, Orientation and Development for Safe Vegetable Production in Vietnam” at the VAAS headquarters in Hanoi. In that workshop, Dr. Bo’s presentation showed that there are seven reasons causing obstacles in VietGAP implementation in Vietnam: (1) Not clear communication between different stakeholders; (2) No strong enforcement & punishment applied to violators; (3) Complex assignment between different ministries related to food safety (MARD is responsible in the field; Ministry of Trade in the market; Ministry of Health in the daily meals; (4) Growers do not know who is consumer. What are standards for their produces; (5) Consumers do not trust on growers especially on pesticide use; (6) Consumer’s perception and knowledge on food safety are low; and (7) Weakness in collaboration between different associations.

**SUGGESTIONS AND SOLUTIONS**

Thuy (2014) suggested that the GAP system should be combined with the application of new and modern technologies for large and uniform product with high quality. It should be done in three steps: (i) the business man, packers, exporters must link to the GAP production zone; (ii) the packer/exporters must build up and properly run the quality control system both at their factory and the large GAP production area; and (iii) the use of the quality control system to manage the production zone toward applying new technologies for safety product.

The experiences in Taiwan in gathering farmers to the cooperative for production and marketing are much in advance, which should be shared to Vietnamese growers, agricultural officers and scientists. Since the cooperative is the key tool for future collaboration for GAP implementation, especially under Vietnam conditions of small holder of 0.4 to 0.5 ha/household. In additions, the extension system must be strong to train more local technical staff as the TOT for farmers training both technical aspects, experiences in organizing cooperative activities and GAP knowledge, etc. The good policies from the government are key elements to supports farmers, packers, exporters to apply GAP and other advanced standards to their activities. The infrastructure and the logistic must be invested and properly focused will also bring better results.
CONCLUSION

In Vietnam, all the GlobalGAP standards have been successfully transferred through development of manuals, capacity building for both SOFRI and project partners, and has expanded to many agricultural players in Vietnam. But there are many challenges ahead for the GAP initiative to spread to the rest of the pitaya industry and many other fruit crops.

ACKNOWLEDGEMENT

We, the SOFRI personnel wish to thank CARD programme for funding to the projects, the FFTC and other organizers of this Workshop to give us the opportunities to share our experiences to people.

REFERENCES

VALUE CHAIN INITIATIVES FOR DRAGON FRUIT (PITAYA) MARKET DEVELOPMENT

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ABSTRACT

During the period 2003 to 2005 high value export markets for Vietnamese dragon fruit in the United Kingdom and Europe were closing down because of global food safety issues. In 2005 Plant and Food Research undertook to implement an AusAID project, “Collaboration for Agriculture and Rural Development (CARD)” for the introduction of Good Agricultural Practices (GAP) at “Global Standards”. This project aimed to assist Vietnamese dragon fruit farmers to comply with, and gain certification for the then EUREPGAP Standard to enable the Viet Nam dragon fruit industry to re-enter the high value export markets. The success of the first project led to a second AusAID funded project for the extension of the original initiative. This paper covers, not only the AusAID initiatives, but also a subsequent NZ Aid programme initiative which aims to build on the original successes and to ensure the Vietnamese dragon fruit industry can resolve “value chain” constraints and continue to meet GAP Standard requirements for Safe, Legal and Quality product and remain a global leader in dragon fruit production technology and marketing.

Keywords: GAP, Good Agriculture Practice, EUREPGAP, Global GAP; Viet GAP, compliance, pitaya, dragon fruit, CARD; PFR, SOFRI

INTRODUCTION

This paper reports the implementation of several initiatives aimed at assisting the Viet Nam dragon fruit industry to develop GAP quality systems at global standards to re-open, and sustain access to high value export markets.

Prior to the 2005 the Viet Nam dragon fruit industry was facing increasing areas of dragon fruit production but contracting high value export markets, resulting in oversupply on the domestic market and a consequent drop in domestic market prices.

To date there have been several projects which have been specifically designed to assist the Viet Nam horticulture industry by implementing value chain initiatives aimed to re-open, expand and sustain high value export markets for Vietnamese dragon fruit:

2. The AusAID CARD Project (029/07VIE - 2008 to 2009): “Extending export opportunities to small-plot dragon fruit growers through Good Agricultural Practices”

The projects have been implemented by the New Zealand Institute of Plant and Food Research Limited (Plant and Food Research, PFR) through the Southern Horticulture Research Institute (SOFRI), My Tho, Viet Nam. This paper outlines the processes involved in two projects for the introduction and implementation of Good Agriculture Practices and the Viet Nam value chain initiatives undertaken for high value dragon fruit export market access by the PFR and SOFRI partnership with resourcing from Australian and New Zealand aid programmes.

VALUE CHAIN INITIATIVES FOR DRAGON FRUIT MARKET DEVELOPMENT

1. Project 1. Developing Good Agricultural Practices (GAP) Systems for dragon fruit producers and exporters in Binh Thuan and Tien Giang Provinces

At the commencement of the AusAID CARD project there had been many previous initiatives to introduce GAP systems into the Viet Nam horticulture industry, mostly in the public sector. Although considerable knowledge and capability had been introduced to various institutions very little had been done to implement GAP in the commercial sector. Indeed there appeared a reluctance by public sector “trained specialists” to engage with the private sector.

The AusAID GAP project became the catalyst for change from public sector theory to private sector commercial GAP implementation. National capability development, both in the public and the private sectors, was led and mentored by the senior author and was based on experience gained in the New Zealand commercial pipfruit and kiwifruit industries, which were operating GAP quality systems, at the appropriate level required by the Viet Nam dragon fruit industry.

It was a pre-requisite for donor support that the project would improve the livelihoods of Viet Nam small-holder dragon fruit growers. Most dragon fruit growers in Viet Nam are small-holder and have between 0.2 and 5 hectares in production (Figure 1). The target for the project included securing access to high value export markets particularly in the European Union by achieving compliance with and certification at the EUREPGAP standard. However it was acknowledged that the complexity and cost of implementing and maintaining certification to EUREPGAP standard was beyond the capacity of small-holder growers.
The project overcame the complex documentation requirements and high compliance costs issues for small-holder growers to access to GAP demanded by the high value export markets. Rather than trying to convince a lot of small growers of the value of certification, a strategy was adopted to establish a “pilot model” in association with a large producer to demonstrate the financial advantages of producing fruit to the new export standards and to allow benefits to flow on to his contracted growers. The commercial “Pilot Model” was established in the Binh Thuan Province.

The pilot model was developed in cooperation with a dragon fruit grower, postharvest operator and exporter of significant size and, who met the following criteria:

- Had a strong desire to implement the EUREPGAP Standard quality systems to regain lost access in high value export markets and to access other new markets
- Had significant volumes of production (market required critical mass), packing capacity and export volume and was already operating at a relatively high standard of management
- Had contracted medium and small-holder growers as suppliers
- Could manage the quality system to avoid / minimise the constraints of trying to implement the quality system directly among multiple small-holder growers who lacked the resources / capability to do so
- Had a scale of operation that meant that the compliance and certification costs would not be prohibitive (Table 1).
Improving Pitaya Production and Marketing

Compliance costs are significant and the project has encouraged each outreach unit being developed to generate as much production area as possible to ensure the cost per tonne of fruit remains manageable. The following table provides a comparison of compliance costs per tonne for different grower number; production area; and yield.

<table>
<thead>
<tr>
<th>Certification Unit - Individual or Group</th>
<th>Number to be audited</th>
<th>CB cost - US$</th>
<th>Grower No.'s</th>
<th>Hectare</th>
<th>Crop volume - tonnes</th>
<th>Compliance cost US$ per tonne</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual grower</td>
<td>1</td>
<td>2000</td>
<td>1</td>
<td>30</td>
<td>450</td>
<td>4.17</td>
</tr>
<tr>
<td>Small group of growers</td>
<td>4</td>
<td>2500</td>
<td>10</td>
<td>12</td>
<td>192</td>
<td>11.98</td>
</tr>
<tr>
<td>Large group of small volume growers</td>
<td>10</td>
<td>3000</td>
<td>100</td>
<td>75</td>
<td>1200</td>
<td>2.08</td>
</tr>
<tr>
<td>Large group of large volume growers</td>
<td>2</td>
<td>3000</td>
<td>4</td>
<td>400</td>
<td>9600</td>
<td>0.31</td>
</tr>
</tbody>
</table>

**Comments:**
- Square root of the total number of growers covered by the Certificate and externally audited
- Approximate cost for the Certifying body to undertake verification and certification
- Based on: 49 tonnes per hectare; 40% packing for small holders; ≤ 16 tonnes per ha; 60% packing for large producers = 24 tonnes per ha

Table 1. Example of “Cost of compliance”

The pilot model was subsequently expanded during the first and second projects and replicated by SOFRI specialists and national capability to other similar grower / packer / exporter operations, cooperatives and farmer groups.

**Project delivery pathway to high value export market access:**

The project commenced with a benchmarking survey of dragon fruit growers in the Binh Thuan and Tien Giang Provinces by the SOFRI project team. The survey questionnaire was based on 140 questions, mostly from the then current EUREPGAP Check List with some 150 dragon fruit growers interviewed. On completion of the survey, data was analysed and presented by the project leader to SOFRI and to the industry as an out-put of the project.

Selection of the project “Pilot Model” operation was made and a programme of developing quality systems to meet the EUREPGAP standards for certification commenced.

Implementation of the pilot included:

- Using the information gathered in the benchmarking survey to formulate the approach and strategy needed for GAP implementation especially at the small-holder dragon fruit grower level
- Identification and documentation of each and every step of the dragon fruit value chain from the grower, through harvest and postharvest operations, including transport to export
- Training and mentoring of counterparts and subsequent delivery of training to other interested and appropriate groups in the Binh Thuan, Tien Giang, Long An and Can Tho provinces

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• Introduction of a “market driven” process throughout the value chain
• Development of a documented quality system and its uptake by the project pilot model
• Development of a "Dragon Fruit Quality Manual" (Figure 2) for the project pilot which described the steps for the entire value chain and how they would need to operate to be in compliance with the EUREPGAP Standard. The manual was developed in English and subsequently translated into Vietnamese by the SOFRI specialist project team.

Figure 2. Draft Fruit Quality Manual

• Implementation of the GAP quality systems in the pilot model by embedding the EUREPGAP Standard Operations Manual in the packhouse management system and to ensure the contracted small-holder growers were assisted towards compliance and to minimise complexity
• Conducting internal audits of progress towards compliance with the standards
• External auditing by an internationally approved “certifying body” for compliance with the for EUREPGAP standard and certification awarded
• Advertising of the success of the certification and the availability of EUREPGAP certificated product to current and potentially new export market customers.

Growing the volume of certified produce:
  o Increasing production and export sales of the pilot model to establish sustainability and reduce the cost of compliance per unit sold
  o Replication of the model in other dragon fruit export facilities and extension to other Viet Nam crops of importance
• Transition from EUREPGAP to Global GAP standards for recertification of the pilot model. This required:
  o Revision of the operations manual to bring it into line with the new Global GAP Standards. This was achieved largely by local staff that were now competent in the development of quality standards
  o Auditing by an internationally approved certifying body and certification to Global GAP Standard.
The project met or exceeded all project expectations in implementing a pilot programme for EUREPGAP and subsequently Global GAP certification of a pilot model.

2 Project 2. “Extending export opportunities to small-plot dragon fruit growers through Good Agricultural Practices”

This project was a continuation of the original AusAID project and was designed to utilize and enhance the national capability developed in the first project and to expand the pilot model operations to the wider dragon fruit industry and potentially to other crops of importance to Viet Nam.

The standout features of this project included:

- Continuation of the GAP programme at the project pilot model supported by the SOFRI GAP specialists and mentored by the project for continued compliance
- Implementation of the British Retail Consortium Global Standard - Food (BRC) in a “special” packhouse within the Pilot Model as an alternative option for “direct” access to elite high value export markets. The BRC standard was implemented but not certificated by the pilot owner at the time as a packhouse upgrade / replacement was in progress
- Collaboration between SOFRI GAP specialists and Department of Agriculture and Rural Development (DARD) / Ministry of Agriculture and Rural Development (MARD) for the development of the new standard, the Viet Nam GAP (VietGAP) standard for Vietnamese horticulture
- Establishment of infrastructure in support for the VietGAP initiative in the areas of leadership, training, certification, industry support. Many of the GAP quality systems documentation templates currently in use in Viet Nam horticulture have been developed by the SOFRI GAP specialists
- Steady progress in delivering GAP quality systems training to the Viet Nam dragon fruit industry and to other crops (pineapple, mango, longan) in Binh Thuan, Tien Giang, Long An and other provinces with GAP certification successes at the Global GAP and VietGAP levels.

The timing of the development of the Viet GAP Standard and its implementation amongst Viet Nam dragon fruit growers, especially in the Binh Thuan Province, was timely and was able to mitigate the effects of the closure of dragon fruit exports by China until specified conditions were met e.g. the registration of dragon fruit growers, product traceability, etc. All the China requirements had been covered in the VietGAP Standard.

The ability for Viet Nam to export dragon fruit to high value export markets began a rapid increase from 2008 onwards reflected in the increasing areas of dragon fruit planted. The trend in volumes of product exported and the value of those exports are shown in Figures 3 and 4. Exports of Vietnamese dragon fruit to the USA and Japan commenced during the second project. Each of these markets required quality systems and conditions over and above the GAP quality systems implemented by the project mostly in relation to biosecurity requirements e.g. some packhouse handling and packaging requirements: dragon fruit for the USA market is required to be irradiated; dragon fruit for the Japan market requires hot moist air disinfection, etc.
Improving Pitaya Production and Marketing

Figure 3. Area and production of dragon fruit in Viet Nam from 2000- to 2013. (No data available about 70-75% of dragon fruit produced are exported).

Figure 4. Value of dragon fruit exported from Viet Nam from 2005 to 2014

Figure 4. Value of dragon fruit exported from Viet Nam from 2005 to 2014
3. **New dragon fruit Industry Improvement Initiative**

The expansion of the dragon fruit industry, both on the domestic and export markets, and its increasing importance to the Viet Nam economy led to a new initiative, based on targeted research for the long term-support of the commercial dragon fruit industry of Viet Nam. The new initiative is in the form of a five-year NZ Aid project (2013 to 2017). The project is enhancing the capabilities of research institutes of SOFRI and the Sub-Institute of Agricultural Engineering and Post-Harvest Technology (SIAEP) to enable the dragon fruit industry to meet global standards, be market driven, sustainable and competitive. The aim of the aid initiative is to support the Viet Nam dragon fruit industry through world class research and development to ensure improved benefits are achieved and passed on to small-holder dragon fruit growers.

This project involves a team of experienced PFR specialists contributing across SOFRI research capabilities; including the implementation of a modern dragon fruit breeding programme; crop protection capability enhancement; agronomy and value chain improvement; harvest and postharvest systems; and improvements. It has a strong emphasis on cross-discipline cooperation and the focusing of research programmes on industry needs. The programme also includes the upgrading of SOFRI research facilities and equipment as required.

The programme covers the following key activities

**Plant breeding:**
- Enhancing SOFRI's plant breeding capability to develop new superior dragon fruit varieties for release to industry
- Introduce modern plant breeding techniques and practices
- Implement a “Plant Variety Rights” programme to protect varieties developed by SOFRI.

**Crop protection:**
- Specialist plant pathology support for up-skilling and capability development in the control of dragon fruit diseases particularly dragon fruit canker (*Neoscytalidium dimidiatum*)
- Specialist support for the diagnosis of causes of post-harvest rots and their control as part of the programme to increase the storage and shelf life of dragon fruit
- Guidance and support as required for SOFRI research and control of pests affecting dragon fruit.

**SOFRI research farm development:**
- Implement the Global GAP Standard quality system in the SOFRI research farms
- Enhance the quality of management of the SOFRI research farms based on the New Zealand PFR research orchard model which allows the farms to function both as secure facilities for research while at the same time engaging in commercial production to generate revenue to support research
- Utilise the research farms as models for best practice for all aspects of dragon fruit production for demonstration to growers.
Improving Pitaya Production and Marketing

**Pomology:**
- Develop novel dragon fruit management systems to enhance production and fruit quality
- Coordinate training systems, plant spacing and canopy management research trials with plant pathology and the dragon fruit canker control programme for:
  - Value of orchard hygiene especially for canker infected cladode removal and disposal
  - Canopy management in relation to canker control spray programmes
  - Equipment type for the most effective and safe systems for delivering agrichemical spray programmes
  - Determining effect of fungicide programmes for canker control on the incidence of postharvest rots many of which infect the fruit in the field prior to harvest.
- Develop plant training systems, nutrient management, irrigation and orchard floor management to allow for mechanisation to mitigate a growing shortage of labour.

**Postharvest:**
- Develop postharvest handling systems
- Conduct research trials which lead to protocols for industry for dragon fruit handling, postharvest treatments and cool-chain management.

**Industry support:**
- Education and training for dragon fruit growers, postharvest operators and exporters as a delivery of the project products.

**Challenges:**
- To ensure dragon fruit research is accurate and appropriate and delivered to growers and industry in a form that is easy to understand and implement.

**CONCLUSION**

The Viet Nam dragon fruit industry has developed rapidly since the introduction of appropriate GAP quality system standards. The industry now needs to refine its operations through quality and targeted research to enable the industry to move forward in a sustainable, organised, safe, and legal way. This will ensure that Viet Nam retains a position of global leader in dragon fruit production and, with premium quality product, enable it to remain competitive in the face of increasing competition from neighbouring and other countries.

**REFERENCES**

Luong Ngoc Trung Lap. Viet Nam dragon fruit production data (Unpublished).
OFF-SEASON FLOWERING TREATMENT BY LIGHTING RED PULP DRAGON FRUIT IN GIA LAM DISTRICT, HANOI, VIETNAM

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ABSTRACT

In Northern Vietnam, red pulp dragon fruit is widely planted in the provinces of Vinh Phuc, Quang Ninh, Ha Noi, Hai Duong, and Son La, with the whole cultivation area reaching more than 800 ha and producing some 16,000 tons of fruit. Following the annual ecological conditions in the Northern provinces, harvesting time of red pulp dragon fruit happens anytime between 15 July and 30 October. Our study on the red pulp dragon fruit variety TL5 was conducted in Gia Lam district, Ha Noi between 2013 and 2014. Our primary aim was to study the off-season flowering treatment by lighting and draw conclusions regarding the prolongation of harvesting time of the said variety.

The lamps that were used for the study were of the incandescent type with 75 watts of power. Quantity of lamps was equivalent to the planting density of the dragon fruit. They were hung in between rows of dragon fruit plants with height of 70 to 100 cm from the ground to the lamps. The lighting experiment started on 20 February which is considered the first season while the second season started on 20 October. Lighting was done at 10 hours/night and continued for 20 days.

The initial results showed that the red pulp dragon fruit variety TL5 gave good flowering ability and good quality fruit at both off season of flowering treatment times of the year. At the first flowering treatment time, plants had flower buds appearing at 3-4 days after lighting was switched off. The duration from budding to flowering was about 27-30 days and the blossoming duration was three days. Meanwhile, the duration from flowering to harvesting occurred in 45-48 days, while the duration from budding to harvesting happened in 75-78 days. At the second flowering treatment time, plants flower buds appeared at 3-4 days after the lights were switched off. The duration from budding to flowering was about 20-22 days and the blossoming duration was three days. Likewise, the duration from flowering to harvesting occurred in 30-35 days while the duration from budding to harvesting happened in 57-62 days.

The mean fruit weight of the red pulp dragon fruit variety TL5 at both off season flowering treatment times reached 420-450 grams with yield of 5.0 – 5.2 kg fruit/polar/lighting time. This was equivalent to 5.0–5.2 t/ha. Fruit harvested in the off-season flowering treatment condition has the similar quality compared to the harvested fruit in the main season with Brix of 17- 18%. Off season flowering treatment contributed to improve the economic efficiency of dragon fruit farmers in the Northern provinces of Vietnam.
PRODUCTION POTENTIAL OF PITAYA IN THE U.S. VIRGIN ISLANDS

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ABSTRACT

Pitaya or Dragon Fruit is a cactus, closely related to the native night blooming cereus, with a large succulent fruit. Twenty-six Pitaya varieties were established in a former grape trellis wire system. Plants were set in a replicated trial at either 2 ft (61 cm) or 4 ft (122 cm) intervals. Pitaya were established and proved able to grow to the top of a six foot trellis wire and flower within a year. Plant growth and flowering were monitored monthly and data recorded. Ripe fruit were harvested and data collected on weight, length, width, fruit flesh color and soluble sugar content. After a year of field establishment, 63% flowered and set fruit and all fruited by the second year. All flowers were naturally pollinated at night by bats and moths so no hand pollination was required. Six pitaya are recommended based on first year production, fruit size and sweetness. These varieties are ‘Dark Star’, ‘Delight’, ‘Halley’s Comet’, ‘Makisupa’, ‘Physical Graffiti’ and ‘Purple Haze’. Pitaya has potential for production in the Virgin Islands. This research was supported by USDA-Regional Hatch and USDA-SCBG administered through VIDoA.

Keywords: dragon fruit, cactus, Hylocereus, cereus
Improving Pitaya Production and Marketing

DRAGON FRUIT: THE NEW MONEY CROP IN THE COASTAL AREAS OF NORTHWESTERN CAGAYAN

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ABSTRACT

The Philippines’ Department of Agriculture, Regional Field Office 02 (DA-RFO 02) recognizes dragon fruit as a commercial fruit crop grown in the coastal municipalities of Cagayan. There are 12 coastal municipalities that are located in Northern Cagayan. Various Techno Demo on Dragon Fruit Production were established in 2011 under the supervision of Northern Cagayan Experiment Station. The objective is to promote dragon fruit as new money crop for favorable upland areas and marginal adverse ecosystem.

Among the stakeholders who are now profiting from the business are Engineer Mauro Daquigan and his cousin, Baltazar Daquigan, a retired DENR employee. The owner of Bang-R farm is now a millionaire. Engr. Daquigan turned his six-hectare idle land into dragon fruit farm, almost one kilometer away from the seashore of Culao, Claveria, Cagayan because after tagging dragon fruit as a new money crop, he also added his Manong R beach house/resort which is a popular tourist destination in Cagayan. Bang-R Dragon Fruit farm was named after his cousin Baltazar (Bang). Bang, is his full time industrial partner while Engr. Mauro is in Manila who runs a construction firm. Their farm is in its 3-year operation earning a gross income of PhP320,000.00-500,000.00 (about US$7,000-11,000) per hectare per year. The yield ranges from 3,200 to 5,000 kg/ha. at Php100/kg; hence, it generated an income of PhP2-3 million (US$44,000-65,000) from 6 hectares of dragon fruit plantation. However, the capital invested was only realized after 2 years.

Among the cultural management developed were the fabrication of concrete post (200cm long x 13cm width), choice of variety, distance of planting, fertilization, pest and disease management, harvesting and packaging. The red (Hylocereus polyrhizus) and the white (Hylocereus undatus) flesh dragon fruit are the most popular varieties known for their health values. The spacing of 2m x 2.5m gives an appropriate population density with a higher income. Application of extensive organic fertilizer was employed to ameliorate the sandy soil in the seashore. Application of 0.5 kg of inorganic fertilizer (14-14-14) and 16 kg of organic fertilizer per post was done. Pests were controlled by insecticide and weed by one cattle per hectare. Water was critical during dry months; however, flood prone site is avoided. Over ripeness will cause fruit cracking leading to a lower price. Packaging in crates labeled with Bang R signature can reach as far as Manila and still remain fresh. The Bang R dragon fruit farm had increased the agri-entrepreneurs in Cagayan because of its good market potential and relatively short growing period. All of these led to profitability coupled with the widely available production technologies that have been developed, and dragon fruit has been experiencing wide promotions.
SUSTAINING AND IMPROVING WHITE PITAYA PRODUCTION UNDER ABIOTIC STRESS ENVIRONMENTS: A CASE STUDY IN PENGHU, TAIWAN

Yu-Chun Chu¹, Wen-Hao Lee², and Jer-Chia Chang³
¹Kaohsiung District Agricultural Research and Extension Station, Pingtung, Taiwan
²Fengshan Tropical Horticultural Experiment Branch, Taiwan Agricultural Research Institute, Kaohsiung, Taiwan
³National Chung Hsing University, Taichung, Taiwan

ABSTRACT

Pitaya (Hylocereus sp.) is generally regarded as a crop with high tolerance to environmental stresses. To meet the self-sufficiency market in Penghu County, an archipelago in the Taiwan Strait with dry and high-irradiance climate, pitaya has recently been grown in the area. However, a suitable cultivation model for sustaining and improving its production still needs to be established. The phenology and effects of flowers and fruits thinning, fruit bagging and shading of the plants quality and maintaining shoot growth have been evaluated in nine-year-old white pitaya (H. undatus) field grown plants in Magong, Penghu from 2008 to 2010. The harvest season in Penghu is from late July to November. Yield reaches its peak from September to October, the period which is approximately 1-2 months later compared to the peak season in southern Taiwan. The fruit weight is smaller compared to those produced in Taiwan Island and has an average weight of 345 g. The largest fruits are produced in October but these have the lowest total soluble solid content. Thinning flower buds and fruits did not significantly improve both the whole plant yield and the fruit quality, possibly due to the dry climate and saline soil which limit the development of the fruit. A non-woven fabric bag that was covered in a gray plastic film produced the best red color in both the exposed and shaded side of the fruit, leading to its uniform coloration. In addition, the bags did not affect the remaining characteristics and increased the incidence of the fruits’ sooty molds disease. To protect the plants from damage caused by extremely high solar radiation in summer, a 50% shading of net covered above the plant canopy from June to September was found to effectively reduce sun burn and necrosis, and kept the shoots green. Although shading slightly reduce the yield, it did not affect the fruit quality.
TAIWAN'S NEW GROWERS GROUP EXPANDS AND PROMOTES PITAYA

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ABSTRACT

“Pitaya Jhong Hen Da” is a Facebook Group consisting of pitaya growers and researchers in Taiwan which has been in existence since 2013. Unlike other traditional agricultural groups, Pitaya Jhong Hen Da is a virtual and borderless organization, where members communicate like close pals. The members are widely distributed geographically, most of whom have never met each other, but communicate constantly with one another, sharing stories and anecdotes about the science, art and business of growing and marketing pitaya. Thanks to the social network, such a loose organization spreads massive pitaya management techniques and knowledge, and provides a channel by which members can share and exchange information, tell stories, and give advice regarding what everyone considers to be a very promising tropical fruit.

Keywords: pitaya, growers group, social network
WORKSHOP PROGRAM
Background and Rationale:

Pitaya or dragon fruit (*Hylocereus* spp. and *Selenicereus* spp.) is a climbing-vine cactus species native to the tropical forest regions of Mexico and Central and South America. In the past two decades, it has gained popularity among producers, exporters and consumers alike in Indonesia, Malaysia, Myanmar, the Philippines, Taiwan, Thailand, and Vietnam where agro-environmental conditions are conducive for growing this fruit plant. In Vietnam alone, its cultivation area is reaching near 30,000 hectares with 640,000 ton of fruit products in 2013. And several factors are accountable for the popularity of this crop: 1) high net returns; 2) functional properties because of its high level of antioxidants; and 3) emerging export potential to high-value markets in developed countries due to its uniqueness and health benefits. Pitaya also shows certain agronomic features that improve its potential as a replacement crop with high commercial value. These characteristics include: 1) the relative ease of propagation by cuttings; 2) its relatively low crop maintenance; 3) the short turnaround time between planting and harvesting compared to other tropical fruit trees; 4) its high yield rate; and 5) as a perennial crop, with proper care, it can provide a steady income.

However, on the negative side, many factors limit pitaya potential productivity and downgrade fruit quality. Among them, heavy rainfall events or poor crop management practices such as over-watering can cause flowers to drop, and fruit to split or rot. Apart from limiting the pitaya crop to reach its yield potential, prevailing poor production technologies also lead to serious occurrences of diseases and pests. Currently, anthracnose, stem canker, brown stem spots, and fruit rot are prevalent in major pitaya growing areas in the Asian-Pacific region. And the emerging infectious stem canker has recently caused collapses of many pitaya orchards in Southeast Asia. Protection measures to control these diseases with chemical pesticides are not only costly to small-scale farmers, they also can disrupt natural biological control, and are damaging to human health and the environment. On the other hand, to access higher-value markets of local, regional or international importance, pitaya fruit products need to be free from diseases, pests, blemishes and pesticide residues, along with desirable size, shape, color and taste. Addressing these issues, the implementation of integrated crop management systems including the use of healthy planting materials can improve yield and quality, forcing culture techniques extend the harvest season, and Good Agricultural Practices (GAP), which involve a systematic, stepwise on-farm operation, assure fruit product safety and quality that will benefit both farmers and consumers.
Therefore, the Food and Fertilizer Technology Center (FFTC) for the Asian and Pacific Region, Taiwan Agricultural Research Institute (TARI), and the Southern Horticultural Research Institute (SOFRI) in Vietnam join hands to organize the workshop to share the latest advances in understanding the constraints limiting pitaya production and marketing as well as newly-developed doable technologies such as optimal spacing, trellising, disease diagnosis, integrated pest management, pruning, phenology manipulation, and GAP that increase pitaya productivity, safety and marketability.

**Workshop Objectives:**
1) To contribute to the improvement in pitaya productivity, safety and marketability 
2) To share the current state of pitaya research 
3) To identify areas for collaboration in research and exchange of plant materials

**Venue:**
Fengshan Tropical Horticultural Experiment Branch (FTHEB), which is a branch of Taiwan Agricultural Research Institute, was established in 1940 for the improvement of fruit and vegetables adaptable to tropical and sub-tropical environments. Its 64-hectare site is located in Kaohsiung City (22°33' N and 120°22'E) where average temperature during summer is around 33 degrees Celsius and average rainfall in the wet season could reach 2,000 mm. FTHEB with 70-plus research and technical staffs under four research departments has been successful at breeding and selecting tropical fruit and vegetables, improving diagnostic and research techniques, and developing innovative pre-harvest and post-harvest management systems to enhance productivity and quality.
PROGRAM

SEPTEMBER 7, 2015 (MONDAY)

09:00-09:40 Opening Session

   Emcee: Mr. Ronald G. Mangubat
   Information Officer, FFTC

   Welcome Remarks
   Dr. Yu-Tsai Huang
   Director, Food and Fertilizer Technology Center

   Opening Remarks
   Dr. Nguyen Van Hoa
   Director General, Southern Horticultural Research Institute, Vietnam

   Dr. Junne-Jih Chen
   Director General, Taiwan Agricultural Research Institute

   Introduction of the Speakers
   Mr. Ronald G. Mangubat

   Group Photo

09:40-10:00 Coffee Break and Networking

Keynote Session

   Moderator: Dr. George Kuo, FFTC

10:00-10:45 Thirty One Years of Research and Development in the Vine Cacti Pitaya Cultivation in Israel (Part I)
   Dr. Yosef Mizrahi, Department of Life Sciences, Ben-Gurion University of the Negev, Israel

10:45-11:00 Break

11:00-11:45 Thirty One Years of Research and Development in the Vine Cacti Pitaya Cultivation in Israel (Part II)
   Dr. Yosef Mizrahi, Department of Life Sciences, Ben-Gurion University of the Negev, Israel

11:45-12:00 Q&A

12:00-13:20 Lunch Break
Session I

Moderator: Dr. Kan-Shu Chen, Fengshan Tropical Horticultural Experiment Branch, TARI

Mr. Shang-Han Tsai, Department of Plant Industry, National Pingtung University of Science and Technology, Taiwan

13:50-14:20 Development of Integrated Crop Management Systems for Pitaya in Taiwan
Dr. Yi-Lu Jiang, Department of Horticulture, National Chiayi University, Taiwan

14:20-14:50 Pitaya Reproductive Phenology in Relation to Production System
Dr. Wendy Wen-Ju Yang, Department of Horticulture and Landscape Architecture, National Taiwan University

14:50-15:10 Off-Season Flowering Treatment by Lighting Red Pulp Dragon Fruit in Gia Lam District, Hanoi, Vietnam
Dr. Nguyen Quoc Hung, Fruit and Vegetable Research Institute, Vietnam

15:10-15:30 Coffee Break

Session II

Moderator: Dr. Masratul Hawa Mohd

15:30-15:50 Production Potential of Pitaya in the U.S. Virgin Islands
Dr. Thomas W. Zimmerman, University of the Virgin Island Agricultural Experiment Station, Kingshill, VI 00850, U.S.A.

15:50-16:10 Status of Dragon Fruit Cultivation and Marketing in Indonesia
Mr. Irwan Muas, Indonesian Tropical Fruit Research Institute

16:10-16:30 Status of Dragon Fruit Production in Malaysia
Dr. Ahmad Hafiz Bin Baharom, Horticulture Research Centre, Malaysian Agricultural Research and Development Institute

16:30-16:50 Pitaya Production and Marketing Scenario in Myanmar: Current Status and Challenges
Mr. Zaw Htun Myint, Department of Agriculture, Ministry of Agriculture and Irrigation, Myanmar

16:50-17:10 Dragon Fruit Production and Marketing in the Philippines: Its Status, Constraints and Prospects
Dr. Maura Luisa S. Gabriel, College of Agriculture, Food and Sustainable Development, Mariano Marcos State University, Philippines
17:10-1730  **Dragon Fruit: The New Money Crop in the Coastal Areas of Northwestern Cagayan**  
Ms. Marilou B. Agaid, Department of Agriculture, Regional Field Office 02, Northern Cagayan Experiment Station, Philippines

**SEPTEMBER 8, 2015 (TUESDAY)**

08:25  Shuttle buses leave separately from Garden Villa, and Rainbow Bazaar (彩虹市集) near Exit 2 of Taiwan High Speed Rail Zuoying Station

**Session III**

Moderator: Dr. Ya-Chun Chang

09:00-09:30  **Fungal Diseases of Pitaya in Malaysia**  
Dr. Masratul Hawa Mohd, Department of Plant Pathology, Universiti Sains Malaysia

09:30-10:00  **Diseases of Dragon Fruit in Thailand: Incidence and Management Strategies**  
Dr. Pornpimon Athipunyakom, Plant Protection Research and Development Office, Department of Agriculture, Thailand

10:00-10:30  **Pathogen Identification and Management of Pitaya Canker and Soft Rot in Taiwan**  
Ms. Chu-Ping Lin, Taiwan Agricultural Research Institute

10:30-10:50  Coffee Break

**Session IV**

Moderator: Dr. Pornpimon Athipunyakom

10:50-11:20  **Viral Diseases of Pitaya and Other Cactaceae Plants**  
Dr. Ya-Chun Chang, Department of Plant Pathology and Microbiology, National Taiwan University

11:20-11:50  **Management Strategies of Major Pitaya Diseases in Vietnam**  
Dr. Nguyen Thanh Hieu, Southern Horticultural Research Institute, Vietnam

11:50-12:20  **Study of Insect Pests and Development of Their Control Measures on Dragon Fruit**  
Dr. Le Quoc Dien, Southern Horticultural Research Institute, Vietnam

12:20-13:30  Lunch Break
Session V

Moderator: Dr. Maura Luisa S. Gabriel

13:30-13:50 Sustaining and Improving Pitaya Production in Abiotic Stress Environments: A Case Study in Penghu, Taiwan
Dr. Yu-Chun Chu, Kaohsiung District Agricultural Research and Extension Station, Taiwan

Dr. Nguyen Van Hoa, Southern Horticultural Research Institute, Vietnam

14:25-15:00 Value Chain Initiatives for Dragon Fruit (Pitaya) Market Development
Dr. John M. Campbell, New Zealand Institute of Plant and Food Research Limited

15:00-15:20 Coffee Break

15:20-16:20 Wrap-up Discussion
(Q&A, and recommendations on research focus and potential collaboration)

Dr. Yosef Mizrahi
Dr. John Campbell
Dr. Nguyen Van Hoa
Dr. Yi-Lu Jiang
Dr. Maura Luisa S. Gabriel

16:20-16:30 Closing Remarks

Dr. Yu-Tsai Huang
FIELD TRIP PROGRAM

09:00 (Departure)
Depart from Garden Villa for Pingtung County, which is the focus of the day.

Pingtung County is located in the very southern tip of Taiwan. It is renowned for its marvelous scenery, majestic mountains and beautiful beaches. With a land area of over 2,775 km² (1,072 mi²) and a population of about 900,000, its economy is being dominated by agriculture and fishery industries, as well as tourism related to the largest national park in the country, Kenting National Park. The Maanshan Nuclear Power Plant located nearby South Bay in the county is Taiwan's third nuclear power plant and second largest in terms of generation capacity. About tropical and subtropical fruits; wax apple, pineapple, jujube, mango, lemon, star fruit, banana, and litchi are produced in the county. And pitaya is an emerging fruit that attracts young farmers, most of them with a virtual connection.

09:30-10:30 (Visit)
Ru-Yuan Fresh Fruit Orchard
1. Location: Wandan Township (22°37'14.5"N, 120°27'40.7"E)
2. Owner: Mr. Chao-Ju Hong, the first prize winner of the 2015 National Pitaya Contest for the red flesh category.
3. Main features: The very orchard produces red-flesh pitaya (*Hylocereus costaricensis*) for online ordering and home delivery. Thus, quality rather than quantity is all that matters. Two distant fields of the same orchard employ sod mulch (*Portulaca quadrifida*) for weed control, and wide spacing at 3 m between rows and 0.6 m between plants for easy field management. Both A-shaped and U-shaped steel frames are used to support plants. Much of the plants in the first field are derived from disease-free seedling stocks. And long scions (30-40 cm) are grafted on long stocks (100-120 cm) in the second field to induce early fruiting.

10:30-12:00 (Travel)
View FFTC, SOFRI and TARI video stories on board, and enjoy scenic views en route to Hengchun Township

12:00-13:30 (Lunch)
Nanbei Diving Restaurant at Hengchun Township

13:30-14:00 (Travel)
Enjoy scenic views en route to Checheng Township

14:00-15:30 (Visits)
Nan-Dao Pitaya Farm
1. Location: Checheng Township (22°03'23.9"N, 120°43'50.0"E)
2. Owner: Mr. Chun-Chin Fu
3. Main features: The farm grows red-flesh pitaya, mainly for export market. The farm employs temporary farm labors for pruning, bagging, harvesting and packing. When there is overproduction and the price of the produce is low, the harvested fruit is sliced, dehydrated and packed for valued-added products. The first field of the farm is established one year ago, and spaced at 120 cm x 270 cm. But the field is suffering from stem canker, likely because the source of planting materials was already afflicted with the disease. The second field is located near where mountain breezes are common, and...
its spacing is smaller. Black mesh bags are used to wrap around growing fruits to prevent fruit flies, and Tyvek (DuPont protective material) sheet inserted inside to block sunlight. However, Tyvek sheet also has the drawback of preventing washout of nectar at the base of scale, thus offering environments favorable for the occurrence of sooty mold. Pitaya plants in the second field are also often damaged by gusting winds from the mountain during the northeast monsoon in the winter season.

Lai's Farm
1. Location: Checheng Township (22°03'23.9"N, 120°43'50.0"E)
2. Owner: Mr. Ming-Te Lai, a septuagenarian leader for the area with a total of 25 hectares of pitaya
3. Main features: The farm is distinct for its close spacing, intensive management and high unit land yield for white flesh pitaya (*Hylocereus undatus*). Artificial lighting fixtures are installed for forcing culture, and natural windbreaks planted to prevent gusting winds from the mountain during the northeast monsoon.

15:30-16:30 (Travel)
Enjoy scenic views en route to Eluanbi Lighthouse

16:30-17:00 (Visit)
Eluanbi Lighthouse is located on the southernmost point of Taiwan. It is built between the Pacific Ocean and the Taiwan (Formosa) Strait, facing toward the Luzon Strait. Thus, the lighthouse has a splendid panorama.

17:00-19:30 (Travel)
Enjoy scenic views, sandwich box and snooze en route to Garden Villa
## List of Participants

<table>
<thead>
<tr>
<th>Name</th>
<th>Position and Affiliated Organization</th>
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<tbody>
<tr>
<td><strong>Indonesia</strong></td>
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<tr>
<td>Irwan Muas</td>
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<td><strong>Israel</strong></td>
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<tr>
<td>Yosef Mizrahi</td>
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<tr>
<td><strong>Malaysia</strong></td>
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