PITAYA BREEDING STRATEGIES FOR IMPROVING COMMERCIAL POTENTIAL IN TAIWAN

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ABSTRACT

Pitaya or dragon fruit (Hylocereusspp.) 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.
Improving Pitaya Production and Marketing

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 crisper. The fruits are easy to store (scale not easy to browning), normally five days at room temperature, at low temperature (5℃) 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