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Shuttle Breeding: A Strategy for Improving Commercially Grown Pitaya

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ABSTRACT

Pitaya or dragon fruit (Hylocereus spp.) is a popular fruit with rapid development in Taiwan growing from 900 to 2,800 ha over the last decade. New varieties created from species and genus were well conducted by growers and breeders in past decades. The quality of white flesh pitaya is more stable compared with the red one but the red pitaya is the most popular in Taiwan because of its sweet taste and high antioxidation property. Meanwhile, the unstable fruit size, hand pollination requirement, and fruit cracks are the major problems for red pitaya. For breeding new pitaya variety in Taiwan, pleasant flavor, spineless, special flesh color, large fruit size, and long shelf life have been conducted. More than 200 hybrids of pitayas were selected, some of them became popular in Taiwan in recent years, such as 'Vietnam White', 'Mi-Long', 'Da-Hong' and Xiao-Tien-Tien. The goals of those breeding program will focus on variable color, quality and texture for consumers and has lower flower initiation, spineless for farmers. However, those goals of different country breeders are not quite the same and breeding work are costing money and time. Shuttle breeding is an effective way for created new varieties and reduced time and money. In this article we will give an idea for international cooperation and work together for those interested breeders to accelerate the release of newly bred pitaya.

Keywords: Pitaya, shuttle breeding, characteristic test

PITAYA INDUSTRY IN TAIWAN

Since 1983, pitaya or dragon fruits have been grown by farmers for commercial purpose in Taiwan (Jiang and Yang, 2016). Few years later, some famous varieties with different flesh color such as 'Jan-Long', 'Chou-Zou Large', 'Xi-Long' and 'Xiang-Long' were released (Liu *et. al.* 2016). In recent years, Pitaya (*Hylocereus* spp.) has been rapidly grown and developed in Taiwan with a production area from 900 ha to 2,800 ha and with annual export volume reaching to 110 tons. Meanwhile, the red pitaya is the most popular one in Taiwan, although hand pollination, unstable fruit size, cracking and serious diseases are the major weaknesses of the fruit since those new varieties were released and was found to be sweeter compared to the white variety. Until now, 20% of the common varieties belong to *H. undatus*, and 75 % of them belong to *H. sp.* Especially, 'Da Hong' and 'Fu Gui Hong' are the two most popular varieties in Taiwan which with 60 % and 25 % of market occupancy of red pitaya, respectively. In 2019, the production of pitaya in Taiwan is 2,775 hectares. Major production areas are in central and southern parts of Taiwan. Among them, Changhua County (18%), Nantou County (16%), Pingtung County (15%), Tainan City (12%) and others. The total production is 69,127 tons in 2018. In addition to the domestic demand, dragon fruit has also been exported in small quantities with total foreign sales of about 180 tons, of which most were exported to Hong Kong (37%), China (33%), Canada (26%), and others (4%) (COA, 2019).

CHALLENGES OF PITAYA PRODUCTION IN TAIWAN

When the pitaya industry was beginning in Taiwan, the fruit characteristics and quality could not be stable such as its flesh color, fruit shape, cracking, self-compatibility, etc. because nurserymen used to sell seedlings from seeds to growers. Since 1999, those true-to-type clones were released to keep better yields and quality of pitaya. In recent years, some plants were observed with systemic mottling and these were infected by a *potexvirus*, *potexviruses* *Zygocactus virus X (ZVX)*, *Pitaya virus X (PiVX)* and *Cactus virus X (CVX)*, in Taiwan (Li *et al.* 2016). Although pitaya has been found to have few pests and pathogens but they still had some inappropriate pesticide use cases in Taiwan. Meanwhile, planted area increased too fast; small scale production system; higher production cost: short of labor are also became problems in the future (Yu, 2015). Also, climate change and extreme weather, depleting environmental resources, increasing competition in the international trade market and diversification of consumers are the major challenges faced by of dragon fruit producers in Taiwan. In the past decade, a system of breeding new variety, shoot management, pest control techniques, bagging and off-season production was established (Jiang and Yang, 2016). Currently, the Taiwan government encourages growers to establishment net houses for cutting down bagging labor cost and avoid bird and oriental fruit fly damage; Also, the government also encourages the construction of productive information databases of pitaya provision of real-time dynamic information for farmers, establishment of integrated productive information network and increase in multiple pathways for both domestic and foreign markets for pitaya. Through the help of the new agricultural policy, Taiwan's pitaya industry has indeed taken a giant step forward. The goal is to have happy farmers, safe agriculture and rich rural area in Taiwan (Lee, 2018).

CURRENT DRAGON FRUIT VARIETIES IN TAIWAN

There are several requirements for variety rights of pitaya in Taiwan according to the "Plant Variety and Nursery Act." First requirement is there must be significant difference when the fruits are compared with control or check variety. The new variety should be stable of characteristics after propagation and checked by control variety which may have, 1) similar plant characteristics, 2) one of the parents, 3) popular variety in the market, or 4) by the variety ID committee. Applicants need to provide the main different traits with matching color photos when submitting to traits test so as to facilitate the review process, new species verification facility are specified by the Council of Agriculture. 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 of 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 and other verification test results should be analyzed based on their significant differences (Liu *et al.*, 2016).

For consumers, acceptance of red and white pitaya were different, total soluble solid (TSS) and betalain contents are generally higher in red one, but the texture of flesh is soft and less crispy. Meanwhile, higher betalains content can't absorb the pigment completely resulting in fecal remains with pigment; normally white pitaya are lower than red flesh species but sweet and crispy taste. Currently the cultivation proportion of red, white, and others pitaya are roughly 75%, 20% and 5% respectively, caused by prices and consumer behavior.

***Hylocereus undatus* Britt. & Rose**

This variety is white flesh, self-compatible and not required to be hand pollinated because have short distance between stigma and stamen. Fruit setting will not be affected by rainfall and short thorns makes management easier (Liu, 2015). Fruits of white pitaya are elongated oval shaped with green longer scales, bright glossy peel color which is better than the red flesh species. Crispy and sweet taste, juice will not stain lips and clothes, total soluble solids in core are averaged 16-20 Brix are all popular for consumers. The flowering period of white pitaya starts in late April to early May and ends in mid-September but two weeks late compared with the red one in southern Taiwan. Normally, the fruit size of white pitaya is more consistent but production period is shorter 30 to 45days than red pitaya, however, the average annual yield production is at par with red pitaya.

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

The flowering time of red pitaya starts in early April when night temperature rises and can be extended until December if there is ample supply of artificial light in southern Taiwan (Jiang, 2005). Mostly, the branch edge strips of red pitaya are discontinuous, front edge of petal is red color, longer thorns, not easy to self-pollinate and are self-incompatible (Hsu, 2004). However, pollinated by different varieties will increase fruit setting of up to nearly 100%. Normally, farmer mix different pollens from red or white pitaya when they need to do hand pollination. Recently, variety names Xin-Yun 1 - Mi-Bao, Da-Hong and Hi Xianghong are popular in Taiwan. Among them, Mi-Bao has oval or spherical fruit-shaped, scales are shorter than white pitaya, easy packing, few of crack; Da-Hong is dark red flesh color and large fruit size. This variety is self-compatible, short distance between stigma and pollen characters that made it do not require hand pollination and bigger fruit size. The shape of Da-Hong is partial circular, scale is wide, short and thin, peel will not scratch due to friction with scales in transport; Hi Xianghong has strong aroma with long oval fruit shaped, longer rewinding scales, not easy crack, self-compatible, excellent flavor. Those three varieties occupy more than 90% of red pitaya in Taiwan.

SHUTTLE BREEDING AND INTERNATIONAL COOPERATION

In recent years, pitaya is widely cultivated and popular in Taiwan. In addition to THE improvement of quality of fruits and superior varieties both of consumers and farmers, the breeding goals of research institutes are described as follows: 1. Self-compatibility: Red pitaya is self-incompatible and is not favorable for insect or wind pollination because pistil often protrudes 1 cm longer than stamens, which causes fruit size to be smaller due to poor pollination. Although, Hand pollination can solve this problem but it needs more labor cost and time consumption. Therefore, we can ensure yield and reduce production cost of red pitaya if self-compatible varieties are developed (Yen *et. al.*, 2013); 2. Long storage life and transportation: Pitayas are abundant between July and August in Taiwan, but there is a lack of cultivars suitable for long term storage and transportation. If we can select a variety which is suitable for long term storage that will be more easy for marketing and quality control; 3. Low crack: Red pitaya have shallow calyx end and can easily enlarge cracks when the fruit matures. This greatly affects the value of red pitaya fruits (Lin *et. al.*, 2016); 4. Excellent fruit flavor: Some pitaya smells grassy affecting consumption, consumers requires of non-grassy smelling and more pleasing aroma for pitaya (Liu *et. al.*, 2015). For purposes of consumer needs, shuttle breeding is a better way to get those goals. Basically, if we change the growth environment of pitaya during selection process it is the way to increase the adaptability of varieties. only ff we test the breeding pitaya at two or more very different environment locations such as testing the plant growth in different countries. For example, the first selection of progeny can be tested under damp weather country, the next generation is selected in a dry weather country and the third generation will then be selected again under drought stress, and so on. Besides promoting adaptation to abiotic factors such as heat, drought, waterlogging, salinization, acidification, shuttle breeding is also used to improve resistance against various pests and diseases (Moore & Janick, 1983). Generally, shuttle breeding is used in early generations when the more of selection locations resemble late production sites, the greater the selection success. When testing at several sites with very different soil and climate conditions and varied disease and pest pressures, varieties are bred so that the plants can adapt to other environmental conditions (Weidmann, 2015).

CONCLUSION

The pitaya industry is facing big challenges especially when issues such as rapid expansion, over productivity and competition of lower priced and poor quality come into the picture. This holds true especially, for major import countries like China, which has boosted their pitaya plantation. To solve these issues, the international pitaya industry should join together to enhance the fruit quality, safety and acquire balance for output capacity. Establishment of facilities or selected good adaptation of new variety are needed to reduce unstable weather conditions. The government has to make sure that the income of pitaya growers is competitive, and there should be improvement in the equipment of supply chain or release of those long shift life pitaya varieties as it could enhance competitiveness in the international market. The growers must understand that only those high-quality production clusters, which have fine varieties, with technical service supporting and are assured of premium quality crops, and those who follow QR-code implementation, GAP (Good Agriculture Practices) proper labeling, do organic farming, and have good traceability systems can most likely succeed. Hopefully, all countries which are interested in the pitaya industry can join together, work together, and share those breeding

programs and selected different pitaya varieties for their country needs, to make the global pitaya industry achieve more progress.

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