Pitaya: a new exotic fruit for Mauritius

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Réduit

1. Introduction

Pitaya (sometimes spelled pitahaya) is the Spanish name for the edible fruit of several cacti in the genera *Hylocereus*, *Selenicereus*, *Stenocereus* and sometimes even, *Cereus*. The same name is used in French and English, except in the Far East, where the fruit is called 'dragon fruit'. In Mauritius, most people know it under the vernaculars: '*cactus tortue'*, '*raquette tortue'* or '*raquette de France'*.

Pitaya originates from Central and South America in a zone extending from Mexico in the North through Costa Rica and Guatemala in the Centre to Guyana and Colombia in the South. It may have been introduced from there to Mauritius at the time of the French colonization, perhaps to feed giant land tortoises as the vernacular names suggest. It has become naturalized in the dry zone of Mauritius, where it can be seen on stone walls, rock heaps in sugar cane fields and on trees. It is also present in Rodrigues.

Figure 1. Pitaya plant growing on rock wall

I first noticed the fruit a very long time ago at Balfour Gardens in Beau Bassin in the 1950s. Pitaya grew up the steep banks of the Grand River North West. These plants may have originated from rubbish dumped from the gardens for, in those days, there was a tortoise park in the gardens and pitaya was the favourite fodder fed to them.

I came across the fruit much later, in 1988, during a trip to Malaysia. They were large, 500 g at least, and rather pricy. Since then I have wondered why it seldom produced fruits in Mauritius.

The first reference to pitaya as one possible crop for marginal lands in Mauritius was made at the end of year 2000 in a presentation at MSIRI in connection with the revision of our Research and Development Programme in preparation of the Sugar Sector Strategic Plan.

The crop was not mentioned by name in the Sugar Sector Strategic Plan of 2001 or in the Non-Sugar Sector Strategic Plan of 2003. There is, however, a specific reference to it now in MSIRI's R & D programme 2005-2009. We have proposed to examine its prospects for Mauritius.

At the end of 2001, a few cuttings were planted in order to observe the growth of the plant.

This paper presents results of the observations to date and explain the prospects.

2. The species and some of its relatives

Several plants in the Sahara, Kalahari, Gobi and other deserts in the Old World resemble cacti but, in fact, they are not cacti because, with one exception, all members of the family Cactaceae are from the New World. All cacti are succulent, that is, they conserve water in their tissues, but all succulent plants are not necessarily cacti. For instance, one of the succulent plants sometimes called *raquette*, commonly grown here as a hedge plant and which produces abundant white and poisonous latex, is not a cactus, but a euphorbe, *Euphorbia lactea*. But, another succulent also known as *raquette*, *Opuntia vulgaris*, is a cactus. It produces round and flat leaf-like organs covered with spines. It was an invasive plant in pastures until it was controlled biologically in the first quarter of the 20th century. The fruit known as prickly pear in English and *figue de barbarie* in French is edible, but not relished because of the numerous, large and very hard seeds; it is mainly used for juice.

The name pitaya is given to several cactus genera. One is a tree-like columnar cactus (fr = *cactus cierge*) in the genus *Cereus*. The common species present here as a decorative plant is *Cereus dayamii*. The small red fruits are edible and some people make juice from them. The species grown in some countries for the fruit known as apple cactus is *Cereus peruvianus*. It is being developed as an export crop in the Negev desert of Israel. This fruit may be too small for our purpose. Likewise, the fruits of several species of *Selenicereus megalanthus* are small. Because of their colour, they are known as yellow pitayas. They are not grown commercially, except in Colombia. Their prospects here do not look bright from what we have seen so far.

The fruits of *Hylocereus* spp are preferred. The plant which is widespread in Mauritius is a *H undatus* clone. There seems to be a single clone, and we shall refer to it as *Local White 1* because it gives red fruits with white pulp. A few other *Hylocereus* species give yellow fruits, and some species such as *H polyrhizus, H purpusii* and *H costaricensis* give red fruits with red pulp. They are popular in some countries.

Hylocereus undatus is produced commercially in the Far East (Vietnam, Thailand, Malaysia and China) and marketed under the name 'dragon fruit'. The local press reported that former Prime Minister Bérenger was impressed by the 'dragon fruits' which he discovered on his visit to the Chinese island of Hainan in January 2005. At the time we had produced the first fruits here. *H undatus* and other species are also produced commercially for export in Guatemala, Ecuador and Nicaragua.

3. Description and floral biology

H undatus is a climbing plant capable of living as an epiphyte on trees. Like other cacti, it does not have leaves. The triangular-shaped, segmented and green succulent stems take on the role of leaves. The segments have one row of small depressions along each of their three edges. These depressions are known as areoles and they occur only on cacti. They bear spines, branches, flowers and fruits. In *H undatus* the segments are 15 to 60 cm long, the areoles are spaced at 3 to 4 cm, and in each areole, there are 2 to 3 small spines. In other *Hylocereus* species the segments may be shorter or longer, the areoles closer or further apart, shallower or deeper, the spines fewer or more numerous and smaller or larger. *H undatus* strikes roots readily when the stem meets anything solid such as the soil, a rock, or a branch and, hence, the plant climbs. The roots normally grow down the support and develop in the soil, such that the aerial parts maintain contact with the ground. But the plant can also survive as an epiphyte without contact with the ground.

Figure 2. Pitaya plant growing on trees

H undatus is long-day plant. It flowers when daylength exceeds a threshold, which must be more than 12 hours. In Mauritius, this means from November to April. The flowers develop in waves or flushes. They are very large, white and trumpet-like. They open at night and stay open for one single night.

Figure 3. Large, white trumpet-like flowers

The fruits are variable in size, red in colour and are covered with soft leaf-like scales. The edible pulp is white and contains numerous tiny, black and edible seeds. The pulp is juicy and sweet with a touch of acidity. It does not have vitamin A and has only a modest amount of vitamin C. It is quite rich in certain minerals such as potassium, phosphorus and magnesium. Species with red pulp are rich in anti-oxidants of the type found in beetroot. The fruit has a shelf-life of 1-2 weeks at ambient temperature. It can be kept for 3 weeks or more in a refrigerator. It is mainly consumed fresh, but it can also be processed into juice, jam, ice cream, sherbet, and added to cooked dishes in the place of pineapples.

Figure 4. Fruit with white pulp and numerous black seeds

4. First observations on pitaya in 2004

Fifty cuttings were procured at the end of 2001 and placed in pots for sprouting. In January 2002, the sprouted plants were transplanted to holes at Réduit and staked to 5 ft-tall wooden posts. There were 2 plants per hill. They were watered occasionally. During 2002, as they developed, they were trained up the posts. Branches were removed to keep one or two main stems per plant. By the end of 2002, a few stems had reached the top of the posts where they were allowed to branch. None bloomed in the first year, in January to April 2003. They developed further in 2003 and all branches below the top of the posts were removed.

By the end of 2003, some of the top branches had started to hang down. Water was withheld as from October 2003, and most of the plants bloomed in the period late December 2003 to April 2004, that is, two years after planting. In all, about 50 flowers were produced or an average of 3 per hill. There were only three waves or flushes of flowers. The smallest and least developed plants did not flower. Contrary to what had been reported, the flowers started to open late in the evening and they stayed open until about ten in the following morning.

Some flowers were selfed, some were crossed with flowers from the same plant or from neighbouring plants. In the end, five fruits were formed (10%), all but one quite small (< 100 g) and unmarketable. It was time to take stock.

The first hypothesis to explain why the local clone seldom produces fruits here was the absence of pollination. Some reports had mentioned that in their native habitat, in Central and South

America, the main pollinating agents of pitaya are small night-flying bats and large moths, neither of which exists in Mauritius. This hypothesis was abandoned in February 2004 because artificial pollination had not resulted in fruit set and also because many bees had been observed to visit the flowers early in the morning.

More recent reports had mentioned the existence of self-incompatibility in many clones. Self-incompatibility is a genetic mechanism whereby pollen from flowers in a clone either does not develop on the stigma, or does not fertilize the ovules of flowers of the same clone. It is a well-known phenomenon in plants such as apples, pears and apricots, and is supposed to have evolved in order to prevent self-fertilization and to promote out-crossing. Our results are consistent with the existence of self-incompatibility in the local clone. The conclusion was that a compatible clone is essential to get fruits.

5. The search for germplasm

In 2003, requests were made to Israel and Queensland for cuttings, but without success. CIRAD – Réunion, where reports had indicated good preliminary results, was contacted, but it, too, declined to send cuttings.

Joseph Guého, the former Curator of the Mauritius Herbarium, had imported pitaya several years ago to enrich his collection of cacti. His plants had produced fruits and he had given cuttings to several persons interested in cacti. Two such persons still had plants, one of whom had harvested fruits. This is how some time late in 2003, cuttings of what might be a compatible clone were obtained. We will refer to this clone as "*Guého*".

In January 2005, a newspaper published the interview of a person in which reference was made to the 'marriage' of vanilla, passion fruit and dragon fruit. On enquiry about the latter, it was learnt that, indeed, he had plants and, indeed too, had crossed them and obtained fruits. During a visit to his farm, two groups of plants aged more than 3 years were seen and on one group, there was a flush of flower buds. Morphologically, the two were different from each other and from the local clone. They are definitely not *H undatus*. Cuttings were planted at Réduit and labeled *Tamarin A* and *Tamarin B*.

Later, another *Hylocereus* species was found in a backyard at Moka which resembles the clone labeled *Tamarin B.* The same clone has been found at Grand Baie and in at least four locations in Rodrigues. Consequently, this clone is not so rare in Mauritius, where it is grown as a decorative plant. It has now been relabeled *Local Red 1*.

6. Observations in 2005 and in 2006

Figure 5. Branches hanging down from wooden frame

During 2004 the plants developed further. In most of them the aerial roots attached to the posts grew down to reach the soil and develop there. More branches were produced, many of them hanging down on the sides of the small wooden frame which had been fitted to the top of the posts.

The first flower in the local clone opened on 1 January 2005 and the last on 12 April. There were 5 major and 4 minor flower flushes. On average, in a major flush there were 6 flowers per hill and in a minor one, 1 per hill. In all, during the 2005 flowering season, 734 flowers, or 33 per hill were obtained. This is an excellent result for 3-year old plants. Mature plants could have more than 50. Since some flushes may be spoilt by heavy rain and since some may not be quite synchronized with a possible pollinator, ultimately the aim should be to get 60 flowers and 30 fruits per hill.

Many more flowers were selfed or crossed with others on the same or other plants. And, as shown in table 1, very few fruits indeed were obtained, which confirmed the hypothesis put forward in 2004, that the local clone is self-incompatible. The few fruits which were formed were small and unmarketable.

Pollen was collected from the other *Hylocereus* clone (*Guého*) or species, *Local Red 1* and *Local Red 2* and used to pollinate flowers of the clone *Local White 1* whenever flowering was synchronized and the owners accepted to donate the pollen. As shown in table 1, *Local Red 1* and *Local Red 2* are fully compatible with *Local White 1*, most crosses resulting in fruit formation. Moreover, the fruits were large.

Figure 6. Large fruit of clone Local White 1

Fruits formed with clone *Local Red 2* as male weighed 375 g on average, and those formed with clone *Local Red 1*, 545 g (Table 1). In a grading system proposed for Vietnamese export, such fruits would have been considered regular and large, respectively. However, in both crosses, there were a few small unmarketable fruits. The presence of these small fruits lowered the average fruit size.

Clone *Guého*, however, was not compatible. It may be a variant of the local clone. Another clone which resembles *Local Red 1* was later obtained from Joseph Guého's collection.

Table 1. Compatibility of pitaya clone, *Local White 1*

Pollinator	No. of crosses	No. of fruits	% compatibility	Average fruit size (g)
Open-pollinated	491	0	0	-
Selfed	47	1	2	-
Crossed with *Local White 1*	123	4	3	-
Crossed with *Guého*	18	2	11	-
Crossed with *Local Red 1*	23	22	96	375
Crossed with *Local Red 2*	35	35	100	545

Other pertinent observations are:

- Up to 2005, pitaya plants had not been observed to flower at one year except for two plants of clone *Guého 1*. These plants had in fact been in pots for a while; so they were older than one year. Since then, many plants have flowered at one year or even at 10 to 11 months at several sites.
- Most flower flushes were synchronized. That is, several plants produced flower buds at the same time. No causal factor has been proposed in the literature for this synchrony. The observations do not support the involvement of day length or temperature as direct causal factors. Perhaps rain is implicated since many flushes occur four to five days after heavy showers.
- The flowers start opening late in the afternoon. Pollen is shed right away whereas the stigma is not receptive until late at night. The flowers stay open and the stigmas remain receptive until late morning. By mid-day, the pollen may not be viable. By the next morning, it is definitely not viable, even when dried and cold-stored.
- The fruit has one of the fastest development rates of all fruits. From pollination to maturity, there are a mere 34±2 days. In contrast, such tropical fruits as mangoes need 4-5 months, litchi 4 months and most citrus fruits 8 months.
- As has been reported in the literature, fruit size is a direct function of the number of developing seeds and, hence, of the amount of pollen transferred. Largest fruits (> 500 g, extra large) were obtained when pollen from one compatible flower was used to pollinate less than ten flowers. When it was used to pollinate fifteen flowers or so, then

fruit size decreased to 300-400 g (regular grade). Fruits weighing less than 200 g are not marketable as the fresh fruit but can still be used for juice or jam.

- The two clones *Local Red 1* and *Local Red 2* are themselves self-incompatible, which explains why so many persons who have *Local Red 1* plants had never seen the fruit. The clone *Local White 1* can be used to cross both, and the resulting fruits may reach 500 g in size. The pulp in these two clones is red, not white as in the other widespread local clone.

Figure 7. Fruit of clone Local Red 1 with red pulp

7. Observations in 2007

An attempt was made at the end of 2006 to get the clones to flower in late November so as to harvest ripe fruits for Christmas. Water was withheld as from August and the plants were irrigated in mid-October. This was only partially successful since very few fruits were obtained. The site at Réduit may receive too much rain after July for this method to work.

Very many flowers opened in the period January to March 2007 in 4 major and 3 minor flushes and numerous crosses were made. Several new clones flowered. Two of these, one with red and one with white pulp have been found to be self-compatible. But they may not be so interesting because, although pollination is not necessary to produce fruits, yet the fruits are too small to be commercially acceptable. Fruit size only increases when the flowers are self- or cross-pollinated.

Other observations made in 2006 have been confirmed. The fruits of the two red clones, *Local Red 1* and *Local Red 2* are approximately of the same size, and rarely more than 500 g. Thus, both gave distinctly smaller fruits than *Local White 1*.

8. Development of the crop's prospects

Observations made during the past four years show that pitaya can be grown and commercially-acceptable fruits can be produced in Mauritius. For this, it suffices to train the clone *Local White 1* on individual posts or a trellis system and to cross it with a compatible clone. By late 2005, two such compatible clones had been identified.

The results were presented to the agricultural community in a talk in February 2006 and it generated much interest. The slides of this talk can be viewed at this site (Govinden, 2006a). Plants of the compatible clone *Local Red 1* were produced and sold to growers as from the end of 2006. A recommendation sheet (Anon, 2006) has been issued on how to grow pitaya. The cheapest support system seems to be a two-wire trellis. Visits were organized to the experimental plot at Réduit for several producer groups during 2006 and 2007. Sale of plants was pursued until mid 2007. Now, three large plantations and small ones have been made in different areas. One grower has in fact harvested a few fruits in early 2007, after only one year.

On three occasions during the 2007 season fruits of *Local White 1* were put on sale at Rs 75/kg in four supermarkets. They were sold out within hours. The feedback is very positive.

More clones have been introduced and their growth, flowering behaviour, compatibility, synchrony and fruit characteristics are being observed on MSIRI's stations in three agro-ecological zones. Fruits have been obtained at Pamplemousses in the sub-humid zone and at Belle Rive in the superhumid zone.

9. Conclusion

For several years all stakeholders of the sugar industry have known that land will be released from sugar cane in many areas and that, consequently, it is of strategic importance that the agricultural alternatives be examined. In 2003, after a 5-year project the pejibaye palm was proposed and is now being developed in the humid and superhumid regions. Now, information at hand indicates that pitaya offers good prospects for the dry zone (Govinden, 2006b).

The crop is new in the world and still practically unknown in Mauritius. This first paper is meant to provide information to those who are interested in alternative crops. In a year or so when all those who have purchased pitaya plants in 2006 and 2007 start producing fruits, it will be necessary to review the prospects, especially the financial aspects, and to establish priorities for research and development.

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11. References

Anon. 2006. Growing Pitaya: 1. Guidelines for plant establishment. Recomm. Sheet 157 (May 2006): 2 pp. Réduit, Mauritius Sugar Industry Research Institute.

Govinden, N. 2006a. **La pitaya ou fruit du dragon: un atout pour le développement fruitier à Maurice**. Presented at MSIRI, march 3, 2006. Mimeo (unpublished): 26 pp, Réduit, Mauritius Sugar Industry Research Institute.

Govinden, N. 2006b. Alternative crops for small-scale cane growers: two case studies. Occ. Paper 39: 9 pp. Réduit, Mauritius Sugar Industry Research Institute.