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Purple-fruited Pitanga (*Eugenia uniflora* L.): Crop Development and Commercialization

John L. Griffis, Jr.[1]*, Malcolm M. Manners[2], Carl E. Sams[3], Ty G. McDonald[4], and Theodore J. Radovich[4]

[1]*Marine and Ecological Sciences Department, 10501 FGCU Boulevard S., Florida Gulf Coast University, Fort Myers, FL 33965*

[2]*Horticultural Science Department, 111 Lake Hollingsworth Drive, Florida Southern College, Lakeland, FL 33801*

[3]*Department of Plant Sciences, 252 Ellington Plant Sciences Building, 2431 Joe Johnson Drive, University of Tennessee, Knoxville, TN 37996*

[4]*Tropical Plant and Soil Sciences Department, University of Hawai'i–Manoa, Honolulu, HI 96822*

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Many species of plants produce some edible or medicinal component, yet fewer than 100 species provide almost all of the food products available commercially worldwide. Hundreds of other edible crops remain non-commercialized; why? Examination of the ongoing commercialization project of purple-fruited pitanga yields some explanations to this question. Pitanga is certainly not a new crop. The wild red-fruited type was spread throughout the tropics many years ago by European explorers. Although the plant grows in many places and is commonly used as an ornamental hedge in Florida, it has seen only limited commercialization of the fruits in its native Brazil. Many factors may have limited further development of the crop although considerable variation among seedlings and their fruits (e.g., many of the fruits have an unpleasant, resinous aftertaste) may be the largest single factor. The dark purple fruits that are the focus of our project tend to taste much better than most of the red or orange fruits. The purple fruits also contain significant levels of antioxidants that are not found in the red-fruited ones. Factors that may have limited further development of pitanga include difficulty in clonal propagation, lack of recognizably superior cultivars, limited production information, lack of pest and disease control recommendations, difficulty in determining when to harvest the fruits, lack of postharvest handling information, lack of nutritional content information, lack of marketing, limited development of commercial uses for the processed fruits and a lack of research funding. Our research addresses many of these factors as the development and commercialization of the crop progresses.

Although there are many edible crop plants produced around the world, a relatively small number of species provides almost all of the food products that are available worldwide (Azam-Ali et al., 2001; Janick, 1999; Padulosi et al., 1999). Why other crops, often grown and consumed in restricted geographic areas, have not become more widely grown and consumed is not entirely clear, although there are many reasons spread across the hundreds of underutilized and neglected crops. Most likely the absence of clear field production and postharvest handling information for any crop is a leading reason the crop has not been successfully commercialized. Another significant problem for commercialization is a lack of breeding work and cultivar development such that the plant products are predictably similar each time they are made available to the consumer. Certainly a lack of research funding to support field production research that aims to clarify a wide range of production issues severely limits grower interests in producing commercial quantities of any crop, so commercialization is further restricted. Pitanga (*Eugenia uniflora* L.), distributed throughout the tropics worldwide for many years (Morton, 1987; Popenoe, 1920), seems to have been limited by all these factors. Only in Brazil, where research funding and research field space have been available for several decades, has the crop had any modest commercial success (Bicas et al., 2011; Silva, 2006). Our research is aimed at increasing the amount of information available to prospective growers in areas such as Florida, Puerto Rico, and Hawai'i where the crop can be grown.

Pitanga, a shrub or small tree of the family Myrtaceae, is one of the most widely distributed edible-fruited *Eugenia* species (Morton, 1987). The plant has a spreading growth habit, with aromatic foliage that is often bronze-colored when young, but darker green and glossy when mature, and with fruits that resemble small pumpkins, changing in color from green to orange to red and in some cases, on to dark purple as the fruit matures (Griffis et al., 2009; Lima et al., 2002; Morton, 1987; Santos et al., 2001). The plants are rather widely distributed throughout eastern South America from Surinam south to Uruguay (Morton, 1987) although they are often cultivated in other areas around the world such as Florida, California, Hawai'i (Glass, 1997), the Philippines (Morton, 1987), and Israel (Lahav and Slor, 1997). The foliage can be harvested for a variety of possible industrial (Gallucci et al., 2010) and medicinal purposes (Agbedahunzi and Aladesanmi, 1993; Auricchio and Bacchia, 2003; Consolini and Sarubbio, 2002; Santos et al., 2010). It is only to a limited extent, and in

*Corresponding author; phone: (239) 590-1396; email: jgriffis@fgcu.edu

just a few places, that the fruit is commonly found at market. It can be found in some markets seasonally in production areas of Brazil (although most of the fruit seems destined for processing) and it can also be found at farmers' markets in Hawai'i, Puerto Rico, California, and sometimes even Florida. There has recently been considerable interest in the purple-colored pitanga fruits for culinary uses in Hawai'i (Adams, 2007; Love et al., 2007). However, it is the red-colored fruits that appear to have a modest place in the Brazilian market and there has been some interest in the selection and commercial production of improved varieties for a range of cosmetics, fresh fruit, juices, frozen pulp and for various culinary purposes (Bezerra et al., 1995, 1997, 2004; Donadio, 1997; Melo et al., 2000). Because of the worldwide interest in fruits such as blueberries or açai that contain valuable antioxidants, Brazilian researchers have also begun to investigate the various antioxidants found in all colors of pitanga (Azevedo-Meleiro and Rodriguez-Amaya, 2004; Lima et al., 2002) and to develop varieties and grower recommendations for purple-fruited pitanga (Lira Jr. et al., 2010).

There could be many reasons why this crop has not become more widely grown and consumed in Florida and California. Local guides for field production and postharvest handling information do not seem to exist outside of Brazil. Lack of breeding work and cultivar development such that the plant products are predictably similar each time they come to the consumer is probably another reason (Griffis et al., 2013). One possible way to determine just how far along the development of this underutilized crop, the purple-fruited pitanga, has progressed would be to discover an existing, recently commercialized fruit crop that could serve as a production and sales model. The first logical screen for a model would appear to be for a tropical, perennial fruit crop that has achieved obvious commercial success. Possible model crops might include avocado (*Persea americana* Mill.), mango (*Mangifera indica* L.), guava (*Psidium guajava* L.), lychee (*Litchi chinensis* Sonn.), rambutan (*Nephelium lappaceum* L.), jackfruit (*Artocarpus heterophyllus* Lam.), carambola (*Averrhoa carambola* L.), mangosteen (*Garcinia mangostana* L.), cacao (*Theobroma cacao* L.), kiwifruit [*Actinidia deliciosa* (A. Chevalier) C.F. Liang et A.R. Ferguson var. *deliciosa*] or maybe even a citrus crop such as the clementine (*Citrus clementina* hort. ex Tanaka). Of course, there are a great many other tropical tree fruits, but most, like the pitanga, are not well developed commercially beyond local markets. To narrow the model search, a close evaluation of the fruit to be harvested was performed for each possible model crop, since harvest and postharvest handling are such important factors in commercial success. The pitanga is a nonclimacteric fruit (Akamine and Goo, 1979) that must be harvested fully ripe to obtain the best flavor and appearance; immature fruits are generally unpalatable. The mature fruit requires rather delicate handling along the lines of a raspberry or a strawberry; the harvester should place the fruit carefully in the final package and it should not be touched again. Additionally, the crop fruiting cycle is asynchronous, with open flowers and immature and mature fruits present on the same plant at the same time so that harvesting is performed frequently over an extended period of time. Fruits that are fully ripe abscise from the plants after a few days. These important harvest factors would eliminate many of the possible model crops previously listed if they were the only matching factors.

Propagation, production and pest management, marketing and possible processing into less perishable food items are also important components for a production system. The pitanga will grow readily from seed, but as with most perennial fruit crops, there is considerable seedling variation, so superior clones are needed to ensure some commercial acceptability. Pitanga cuttings will not root; the plant is very difficult to air layer, fairly difficult to graft (Bezerra et al., 2002; Franzon et al., 2010; Griffis et al, 2009; Manners et al., 2011), and mature, adult selections have never been successfully micropropagated (Griffis, 2006; Lattuada, 2010). There have not been large numbers of plants available to interested growers. We have begun testing a range of factors that might have significant effects on the success of pitanga grafts. We have determined at least one graft method (veneer) that appears to be sufficiently successful for commercial production (Manners et al., 2011), although more trials need to be done. We have installed a row of veneer-grafted 'Zill Dark' plants in the field at the Kona Experiment Station and they are undergoing further evaluation. An additional planting of grafted, superior selections of purple-fruited pitanga will soon be installed at Lakeland, FL.

When using a successful commercial crop as a model for commercial production of an underutilized crop, it appears to be most valuable to look for the various production problems that seem to constrain the underutilized crop, and then determine how producers of the model crop were able to overcome similar sorts of problems. It is also important for us to be able to "spot" when the model crop moved from a seasonal offering at farmers' markets to a place in the produce aisle at the local grocery store. For example, carambola or starfruit might be selected as the model crop since it shares many of the commercially important characteristics previously mentioned. The tropical carambola trees bear both flowers and fruits at different stages of maturity at the same time and there can be multiple crops a year, the mature fruits are hand harvested and will not tolerate rough handling and clonal propagation is essential since seedling trees produce fruits of highly variable quality and flavor. Also like pitanga, the flavors of the mature carambola fruits are somewhat unusual and difficult to compare to other better-known crops.

To expand the comparison, it might be useful to look backwards to the time when *A. carambola* was first grown outside of its native Southeast Asia. Fortunately, a history of the commercialization of carambola in South Florida (Crane, 1993) and carambola grower recommendations for South Florida and Hawai'i (Crane, 1994) are available. The carambola was introduced into both Florida and Hawai'i over 100 years ago. The pitanga, better known locally by the name Surinam cherry, was also introduced into both states at about the same time. The carambola was grown as a curiosity until the 1960s, with only a few South Florida and Hawai'ian local markets and stores selling the fruit. Many starfruits produced by the early seedling introductions were quite sour and some were entirely unpalatable. The introduction by nurserymen of improved, better-tasting selections of carambola to South Florida in the 1970s (Crane, 1993) and by researchers to Hawai'i in the 1980s (Hamilton and Ito, 1992) created considerable grower interest and the commercial production of a grafted crop in both states took off. In fact, it appears that selection and distribution of superior cultivars of many underutilized crops, coupled with the availability of production and postharvest recommendations for growers is frequently the point where actual commercialization of the crops may begin.

The story for the pitanga follows a similar path, at least up to a point. The plants are widely used in Florida as ornamental hedges, but little effort has been made to select among the plants for taste or yield. In fact, most red fruits are not harvested at all. Hawaiians seem to appreciate the fruits to a greater extent than Floridians and seedling plants are found on most of the islands.

Fruits of pitanga seedlings are highly variable in size, color and flavor, and many are also nearly unpalatable if eaten fresh. Additionally, the first seedling plants distributed in both Florida and Hawai'i were the red-fruited types that tend to have smaller, sour, resinous fruits when compared to the much less common purple-fruited types. Eventually, interested nurserymen in Florida and Hawai'i introduced superior, grafted, purple-fruited cultivars of the pitanga ('Zill Dark' and 'Black Star' in Florida, 'Kawahara' in Hawai'i): but grafting has proven difficult (Manners et al., 2011) and they have never been widely distributed. Seedling production of purple-fruited pitanga is not desirable because the plants do not come true-to-type and some of the seedlings may produce inferior, unpalatable red fruits (Campbell, 1977) while others may not yield well or may have maroon fruits that are also not particularly tasty. So, there are improved varieties of purple-fruited pitanga, but they have not caught on with the growers or they have not been widely trialed so that there are neither reliable yield data nor a published production program. To address these concerns, our project has performed self-pollinations on a grafted plant of 'Zill Dark' several times. One hundred and twenty seedlings from the first self-pollinations were grown out in Florida and 75% of the seedlings were purple-fruited (Griffis and Manners, 2005). These plants were installed as a hedge at Florida Southern College, Lakeland, FL in 2003 and they have been observed and evaluated for about 10 years. Two hundred seeds from additional self-pollinations of 'Zill Dark' were germinated and the seedlings were grown for a year in the greenhouses of the University of Hawaii–Manoa. One hundred and thirty-five of the seedlings were transferred to a field plot at the Kona Experiment Station in Kealakekua in Dec. 2006. They were separated into nine different fertilizer treatments, four of them organic. We have been collecting production data including date of first bloom, seasonality of bloom, days to maturity for fruit, crop yield, fruit size, fruit color, taste, and other various data from these plants for several years. The objective of these trials in Hawai'i is to determine general production recommendations for the crop and to select several superior seedlings that will be named and propagated further and made available to growers (Smith et al., 2009). We have determined that more than 90% of the seedlings are purple-fruited and that yield, fruit size and fruit taste vary among these seedlings. Preliminary data and observations taken at the current field project at the Kona Experiment Station will allow us to provide some basic recommendations for growers. Initial fertilizer recommendations can now be made for the crop when it is grown in the Kona area. General pruning recommendations can also be made and a survey of pests and/or diseases found in the seedling field will alert growers to possible threats to their crops. Additional field research needs to be conducted in new fields planted with specific grafted cultivars, not seedlings. Harvest methods, postharvest handling methods, and shipping information still need to be properly developed for the purple-fruited pitanga. The crop needs to be harvested by hand in a timely manner. It is important that the fruits be fully ripe before they are removed from the plants; immature fruits often have an unpleasant, resinous flavor. Harvest can be tricky, as mature fruits will drop to the ground soon after ripening. No better method for harvesting the crop has been discovered and so some ripe fruits are lost and some fruits that are not entirely mature are sometimes harvested.

Processing of purple-fruited pitanga into other products is still not well developed. A small business for producing jams and jellies already exists in Hawai'i and the producers would like to be able to produce more product. Additionally, chefs at several resorts in Hawai'i are interested in using the fruits for various recipes. The purple-fruited pitanga got a big publicity boost when the winning chef of a national cooking competition used the fruits to prepare a sorbet (Adams, 2007). In our current trials, we are also investigating how long the fresh fruit may be held in cold storage and how well the fruit dries. Additionally, the purple-fruited pitanga is filled with quite a range of antioxidants (Oliveira et al., 2006; Reynertson et al., 2008), several of them in considerable demand. This places the fruit into the group of antioxidant-rich "superfruits" along with blueberries, acai, blackberries, and pomegranates. We are currently investigating the antioxidants and other phytonutrients contained in the fruits of various seedling pitangas to see how they compare to each other and to other crops (Griffis et al., 2012; Wheeler, 2013; Wheeler et al., 2011). An increased interest by several Brazilian researchers in the nutritional qualities of the purple-fruited pitanga (Jacques et al., 2009; Santos et al., 2010) could give a considerable boost to the crop. The potential for using the fruit juice (Nzeagwu and Onimawo, 2010) and/or antioxidants in other products certainly needs to be investigated further. Some preliminary results from our evaluations of antioxidants found in fruits harvested from individual purple-fruited pitanga, using methods previously reported (Griffis et al., 2012) show considerable variation among individual plants (Table 1.)

So, what barriers continue to block the purple-fruited pitanga from successful commercialization? There appear to be a combination of things, but most likely the factors are a lack of superior, grafted cultivars being made available to growers combined with a lack of published production procedures that would tell farmers how to plant, grow, harvest, and deliver their purple-fruited pitangas to market—there just has not been enough research completed and published that would provide production information to interested parties. Additional field research could provide the required production recommendations. Additional laboratory research into the usefulness of the antioxidants contained within the ripe purple fruits may also produce other uses for the crop that increase commercial interests. After fields of superior, purple-fruited cultivars are planted and begin production, we may see fresh purple-fruited pitangas and processed pitanga products appearing on store shelves.

Table 1. Myricetin, quercetin, and lutein content of mature fruits from 12 randomly selected sister seedlings of purple-fruited pitanga compared to 'Zill Dark' fruits.

Sample	Myricetin	Quercetin	Lutein
I	0.171	93.439	0.030
II	0.294	80.593	0.149
III	0.283	180.255	0.065
IV	0.419	239.520	0.097
V	0.488	192.872	0.120
VI	0.427	238.061	0.106
VII	0.413	187.393	0.090
VIII	0.417	320.871	0.053
IX	0.264	303.405	0.021
X	0.275	145.981	0.050
XI	0.319	116.441	0.021
XII	0.225	144.293	0.095
Zill Dark	0.250	172.745	0.012

Concentrations ($\mu mol \cdot g^{-1}$ DW), each value is the average of three subsamples.

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