America (C. W. Campbell and R. J. Campbell, personal observations) indicates a desire to explore such possibilities.

In conclusion, 'Ruby' has some outstanding characteristics which make it suitable as a commercial mango cultivar; namely, consistent production, outstanding color, good internal quality, and anthracnose resistance. The small size of its fruit, and production of nubbins have limited its use in Florida, but if environmental conditions are suitable and the fruit can be marketed successfully, it may have a future as a commercial mango for both domestic and export markets in Tropical America.

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CHARACTERS NEEDED FOR COMMERCIALLY SUCCESSFUL PASSION FRUIT

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Abstract. **Efforts to grow passion fruit in southern Florida have uncovered problems that necessitate specific genetic modifications of the clonal material in order to make crop production economically feasible. Field observations show that the carpenter bees that normally pollinate *Passiflora edulis* elsewhere are absent from the fields in Dade County, and that essentially all pollination here is done by the honey bee, not a normal pollinator of *P. edulis*. This bee's small body size necessitates the selection of *P. edulis* genotypes with a high degree of self-compatibility (or pseudo-self-compatibility) and a flower having stigmas and anthers borne close together, making self-pollination relatively easy. The North American market appears to prefer red or purple-colored fruit over yellow, but the yellow-fruited form of the species (*P. edulis* f. *flavicarpa*) survives field conditions in south Florida whereas pure purple (*P. edulis* f. *edulis*) does not, thus red-fruited hybrids of purple × yellow breeding, or seedlings derived from such hybrids, are often grown. Fungus diseases of root, leaf, and fruit are serious problems. Sources of genetic resistance to fungus disease are being sought for use in breeding improved lines with enhanced commercial potential.**

Florida's passion fruit industry is small, but was growing until the recent setback imposed by Hurricane Andrew. The area planted in mid-1992 was 65 acres (26 ha), with an annual production of about 200,000 pounds of packed fruit (C. A. Campbell, pers. comm.). Because much fruit (50% of some lots) is discarded at the packinghouse because of disease or blemishes, this figure does not represent the total state production. The estimated yield of approximately 3,200 pounds of packed fruit per acre does not approach normal yields in Hawaii, for example, where yellow passion fruit is the form normally cultivated. Returns from recent production in Florida, however, have been adequate to encourage expansion of plantings. The objective of this work is to examine current needs and chart a course of action aimed at developing improved cultivars that can be expected to produce reliably here.

Problems and Needs

The passion fruit cultivar commonly grown in south Florida, 'Possum Purple', in spite of its name is not a pure clone of *Passiflora edulis* f. *edulis*, the purple passion fruit, but is of mixed purple and yellow (*P. edulis* f. *flavicarpa*) background. This has been demonstrated by the fact that seedlings of 'Possum Purple', self-pollinated, segregate for yellow and purple fruit color. This cultivar bears an attractive maroon-colored fruit weighing between 50 and 65 grams that is well accepted in the market but has several serious problems. The most serious is its susceptibility to fungal diseases that attack the root, stem, leaf, and fruit. Anthracnose (*Colletotrichum gloeosporioides* Penz.) is probably the most widely distributed fruit disease in southern Florida. On passion fruit it causes severe fruit and leaf spotting and defoliation that weakens the vine, particularly in early summer after the normal rainy season begins, when fruit of the early crop is ripening. This fungus was reported to cause a severe fruit canker on purple and yellow passion fruit in India (10). Some years ago, a *Phytophthora* species was isolated from diseased stems of *P. edulis* growing near Miami (6). More recently Ploetz (9) found *Nectria haematococca* Berk & Broome causing a sudden wilt syndrome from which *Passiflora* plants did not recover. He also found that this fungus can grow from the soil upward along the vine, making a resistant rootstock ineffectual, should such a stock be found. No plants of *P. edulis* examined in the field in Dade County have yet shown immunity to sudden wilt or to anthracnose, but we have observed resistance in a minority of the vines, and are keeping these under observation. We are using those observed to have the greatest field resistance as parents to breed progenies that we hope will have sufficient field resistance to disease to enable them to survive and fruit well here. Another problem shown by 'Possum Purple' is the production of "light" fruit that is incompletely filled with seeds and the surrounding juice sacs that make a marketable passion fruit (C. W. Campbell, pers. comm.). This problem relates to pollination in that each fertile seed in the fruit is the result of the fertilization of one embryo sac by one pollen grain, and the greater number of viable seed a fruit contains, the larger the fruit is and the greater is its juice content. Most vines of *P. edulis* are self-incompatible, and need cross-pollination to set fruit (1, 8, 4), although the purple-fruited form shows some degree of self-compatibility (2, 3). The vine subsequently named 'Possum Purple'

attracted the attention of the nurseryman who selected and named it by virtue of the plant's tendency to set large numbers of fruit from open-pollination, unlike most passion vines on his farm (R. Barnum, pers. comm.). When we tested 'Possum Purple' by self-pollination, we found it is not completely self-compatible but does set fruit from self-pollinations about 60% of the time. The occasional failure to set and also the occasional light or partially-filled fruits probably result from incomplete self-compatibility, as was reported some years ago for the 'Golden Star' carambola (7). Confirmatory evidence comes from the fact that fully compatible hand-pollinations of 'Possum Purple' resulted in well-filled fruit.

A reliably productive clone that could be expected to make well-filled fruits from self-pollination would be a stimulus to passion fruit production in south Florida. The carpenter bees (*Xylocopa* spp., Hymenoptera : Anthophoridae) that naturally pollinate this crop are almost totally absent here. Examination of vines in the field in Dade County in spring 1991, showed all pollinations made by honey bees, which are not well equipped to pollinate this crop, and do so inefficiently (11). Their small bodies enable them to fly in below the anthers on large flowers, collect the pollen they seek, and leave without touching the stigmatic surface which remains unpollinated. This indicates that in addition to self-fruitfulness, to be successful in this area a clone needs a short-coupled flower in which anthers and stigmatic surfaces are sufficiently close together to permit bees visiting the anthers to brush against a stigmatic surface as well.

A small progeny (20 plants) grown from seeds of 'Possum Purple' self-pollinated included individuals that were totally self-incompatible as well as a few which, like 'Possum Purple' itself, set fruit from a majority (but not all) of the flowers pollinated. Another small population (40 vines) of seedlings originating from self-pollination of a large yellow-fruited selection (M-32025) contained only a small minority of functionally self-compatible plants. This suggests that the apparent self-compatibility of the parent plants of each population was in fact not due to loss of self-incompatibility but instead was a form of pseudo-self-compatibility in a plant that remained genetically self-incompatible. A couple of plants in this yellow-fruited population set appreciable numbers of fruit from open pollination, and also set fair numbers from self-pollination. A few individuals in this progeny also showed greater resistance to fungus disease than did any of the seedlings of 'Possum Purple' inbred. Therefore, cross-breeding between the two S-1 populations (inbred for one generation) has been done in the hope of achieving F-1 hybrids that combine disease resistance, functional self-compatibility promoting dependable productivity, and high fruit quality.

Germplasm Resources: Dwarfness, Delayed Drop, Extra Locules

Other potentially useful traits have appeared in passion fruit germplasm under evaluation. One was a gene for dwarfness that appeared in a line derived from P.I. 424814 grown by USDA horticulturists at Isabela, Puerto Rico. One expense in passion fruit culture to date has resulted from the need to supply trellising of one sort or another to support the vigorous vines. The first dwarf plant observed was approximately one meter tall and bore a full crop of maroon-colored fruit. The implications of this trait are obvious: if the right characters can be combined with dwarfness—in particular fruit quality, disease resistance and high productivity—tomorrow's grower will be able to produce passion fruit more or less as stake tomatoes are grown, without making a heavy investment in trellising. Seedlings from a test cross to determine the mode of inheritance of dwarfness are still young, but this trait appears to be a simple Mendelian recessive that may be affected to some degree by accompanying modifier genes.

Passion fruit normally drop from the vine when they mature, and the usual mode of harvest is to collect them from the ground. A gene for retention of fruit on the vine for a month or more after maturity (as indicated by color break) appeared in the same line (P.I. 424814) that exhibited dwarfness. The trait of delayed dropping will be of value in many areas where soil-borne disease is common, because it will enable pickers to determine which fruit is mature while it is still on the vine and relatively clean. With plants of P.I. 424814, ripe fruit continued to hang on the vine for a month or more after color break. If the delayed-drop character is incorporated into commercial lines, this will make it possible to collect fruit less frequently than at present, and to expect considerably less spoilage, with a reduced rate of cullage in the packinghouse. Delayed dropping appears to be inherited as a simple Mendelian dominant, having appeared in numerous seedlings derived from P.I. 424814.

A trait that appeared in a line of yellow passion fruit coming to Florida from Colombia but probably originally from Hawaii, is for fruit with supernumerary locules. Fruit of *P. edulis* normally is 3-locular, but many fruit on these vines have four or five locules. The value of this trait, although it makes for large, fully-packed fruits, is yet to be determined. However, the fact that 'Possum Purple' often tends to make a light fruit with low pulp content suggests that the character for extra locules may be important to growers if incorporated into commercial lines. The trait appears to be under genetic control since it is common in one line of yellow passion fruit (M-32025 inbred), but the mode of inheritance is yet to be determined.

Season of Ripening and the Environment

The natural range of *P. edulis* includes much of Brazil and parts of Argentina and Uruguay, and as might be expected with such an enormous habitat, the species shows a wide range of genetic variation (5). The purple-fruited form is best adapted to subtropical climates and to higher elevations within the tropics proper. It shows little resistance to soil-borne disease at sea level in warm climates and does not flower well during hot weather. The yellow passion fruit is well adapted to lowland tropical conditions, shows more resistance to soil-borne disease than does the purple, and flowers and sets fruit well through the summer's heat. Purple and yellow-fruited forms of *P. edulis* have no sterility barriers, producing vigorous hybrids that are fully fertile and more or less intermediate between the parents for climatic adaptation and other attributes (6). The 'Possum Purple' cultivar is of mixed purple and yellow background, as has been demonstrated by its breeding behavior. One drawback, probably related to genes from the purple-fruited form in its background, is the fact that 'Possum Purple' bears a heavy crop in late spring and early

summer, then ceases flowering and bears no fruit in midsummer, and subsequently yields a light crop in autumn. A lengthened fruiting season is essential to build an economically healthy passion fruit industry in Florida and similar subtropical areas. Yellow passion fruit vines as a rule crop well through summer and into the autumn here, but their fruit is not preferred for the fresh market in North America and Europe. One objective of our current breeding effort of crossing inbred yellow and purple-fruited lines is to obtain F-1 plants that ripen fruit of good quality over a longer season than that currently filled by 'Possum Purple'.

Discussion and Conclusion

In summary, it is easy to state what is needed in lines or cultivars of passion fruit for commercial production: enhanced resistance to fungal disease in all parts of the plant, including the growing and mature fruit, plus dependable, heavy production of fruit of high market acceptability. Preference to date has been for maroon or dark red-colored fruit, but yellow fruit is also marketed to some extent. Fruit of good quality needs to be available throughout the season, from first ripening in spring until the last harvest in late autumn. Less obviously necessary, but of interest for their potential effects in lowering production costs and the rate of fruit spoilage between time of picking and marketing, are characters for dwarfness and for retention of ripe fruit on the vine. The tendency to have one or more extra locules in the fruit also may prove valuable if it assures well-filled fruit, eliminating the threat of "light", partially-filled fruit.

From the information presented here it is evident that the *Passiflora* germplasm assembled to date offers breeders a number of presently unexploited opportunities that can help alleviate the numerous problems that confront passion fruit production at the present time. Furthermore, the number of useful characters found already as a result of relatively limited plant exploration suggests the desirability of a well-coordinated effort to find new sources of disease resistance and enhanced environmental adaptation for this crop among wild populations that grow within the natural area of distribution of the species.

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REJUVENATION OF A MATURE, NON-PRODUCTIVE 'LULA' AND 'BOOTH 8' AVOCADO GROVE BY TOPPING AND TREE REMOVAL

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Abstract. **The effect of topping height and tree removal on yield of over-crowded, non-productive, 34-year-old 'Lula' and 'Booth 8' avocados (*Persea americana* Miller) was studied. Trees were periodically topped at 9 (subsequently 12), 16, or 22 ft with or without eventual removal of every other tree on a diagonal within the grove. 'Lula' produced no fruit during the first three seasons after topping. During the fourth season, 'Lula' topped at 16 and 22 ft with trees removed had more fruit per tree (1.6 and 2.2 bu/tree, respectively) than other topping treatments. 'Lula' trees topped to 22 ft with and without trees removed produced more fruit per acre (119 and 108 bu, respectively) than trees topped at 9 ft (43 bu/acre) and 16 ft with trees removed (86 bu/acre). 'Booth 8' topped at 22 ft with no trees removed and 16 and 22 ft with trees removed produced fruit during the second season after topping. More fruit was produced in 'Booth 8' plots topped to 16 and 22 ft with trees removed (469 and 464 bu/acre, respectively for two years combined) than those topped to 9 ft with trees removed and 22 ft with no trees removed (130 and 249 bu/acre, respectively for two years combined). Topping at 16 and 22 ft with tree removal increased the percentage of fruit in the lower third of 'Lula' and 'Booth 8' canopies, whereas more fruit was produced in the middle of the canopy for trees topped at 22 ft without tree removal. Profitability estimates suggest that topping 'Booth 8' at 16 and 22 ft with tree removal and topping 'Lula' at 22 ft without tree removal were the most cost effective treatments to date.**

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