Planning for a Successful Commercial Subtropical/ Tropical Fruit Grove[1]

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Planning is the key to successful grove establishment, maintenance, and production. Developing a detailed infrastructure description and plan, cultural program, and financial and marketing plan for a new or existing grove with a new fruit crop will save you time and money and help minimize mistakes (Evans 2017). More information on developing a farm business plan may be found at UF/IFAS EDIS (Electronic Digital Information Service) at https://edis.ifas.ufl.edu (keyword search "business plan").

Prospective growers should compile and analyze information needed to select a grove site, establish the needed infrastructure (e.g., irrigation system and drainage), and develop maintenance plans for the plants and how the production will be marketed. Below is an outline of the type of information growers need when establishing a tropical fruit grove or contemplating management or modification of an existing tropical fruit grove.

Economic Considerations

Markets

Before embarking on a new venture, several important aspects should be considered. Acquiring or establishing a tropical fruit crop operation involves significant capital expenditures; therefore, a thoughtful research and planning process is needed. While it may sound trivial, the decision on what to produce/grow has important ramifications. If you plan to grow/produce a new crop, then on top of the production activities, you may need to assess the potential market for the product to decide if it meets your financial expectations. On the other hand, if you plan to grow a crop that has an established market, then the research process simplifies considerably. Under the former scenario, the first step is to conduct market research: a prospective grower should investigate the current market conditions for both conventional and organically produced fruit. It is a good idea to contact packing houses, retail stores, supermarket chains, restaurants, and the local cooperative Extension service to collect information about trends and prices for different fruit crops.

Information on economic returns for some tropical fruit crops may be found on EDIS (keyword search "marketing") and on the UF/IFAS Tropical Research and Education Center (TREC) Agricultural Economics Extension website (http://agecon.centers.ufl.edu/) (Evans and Ballen 2018). Once you have selected/identified a particular crop, the next step is to develop your marketing plan. To determine your target market, at this stage you should define your customer. Demographic data is available for this purpose (e.g., US Census data at https://www.census.gov/) and can be of tremendous help in targeting various ethnic groups and geographic areas with specific fruit crops. Additionally,

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it is important to consider competition, seasonality in production, windows of opportunity for better prices, and the different marketing channels/options available. Given the widespread consumer engagement in e-commerce, web-based marketing and sales should also be considered.

While the demand for organic fruit is growing, it deserves extra consideration. There is a cost (time and money) associated with obtaining the organic certification. A prospective grower should watch closely how premium prices for the crop of interest are evolving. It is important to analyze the price trends for both domestic and foreign competitors. This information may help to decide if the extra risk associated with organic production is properly compensated. Additional information on the regulations and transitioning to organic production and certification can be found through the USDA National Organic Program (https://www.ams.usda.gov/rules-regulations/organic/handbook) and state organic certification entities (e.g., Florida Organic Growers at https://foginfo.org/). Once all the relevant information has been compiled, the prospective grower should conduct a feasibility analysis, including a sensitivity analysis, to evaluate the profitability of the crop under consideration.

Land Values and Taxes

There is a multitude of financial factors to consider when selecting a new grove site. These include knowledge of land values and tax appraisal characteristics. Land values may be a limiting factor, and careful consideration should be made of the potential cost of grove establishment, time to full production and target markets, and time to profitability. Land values can vary greatly depending upon location (nearness to urban development), elevation, and land improvements such as land and water conservation structures and buildings. Marginal grove sites generally cost less than better sites. Land values may be found through local realtors and tax assessor agencies.

Cost of land preparation or grove modification must be calculated and considered when deciding whether to buy a particular grove site. Land that has an established grove and/or irrigation system infrastructure may cost more to buy than vacant land, depending upon the type of fruit crop and condition of the irrigation system, but it may be more economical over time.

Land value and taxes should also be considered when selecting grove sites. Because of its location, some land is simply too valuable to grow tropical fruit. Land purchased at a high price may also carry high property taxes, depending upon its location and zoning characteristics. Agricultural property taxes may vary from area to area and should be investigated. Special exemptions for agriculture may not always be in effect.

Site Selection

Grove Site Selection

There are many factors to consider when selecting a new grove site. These include climate (e.g., temperature extremes of the intended site); access and availability of good-quality irrigation water; soil type, fertility, and drainage characteristics; and type of land preparation needed (e.g., rock plowing) (Vincent et al. 2019).

Climate and Cold-Weather Considerations

Climate is a key factor in the suitability and success of any fruit crop, but it is especially critical for tropical fruit crops. As average annual and monthly temperatures rise and weather patterns become more erratic, careful attention to current weather patterns and trends becomes important in choosing the proper grove site and fruit crop species to produce. Of primary importance is the potential of the region (locality and grove site) to experience cold or freezing temperatures. Many subtropical and tropical fruit crops are sensitive to temperatures above freezing but below 50°F (Paull and Duarte 2011, 2012). For example, mango trees during bloom exposed to temperatures 40°F–49°F or below often have reduced fruit set and crop yields, and papaya and banana plants exposed to prolonged periods at or below 50°F often result in reduced flowering, production, and fruit quality (Litz 2009). In contrast, one of the requirements for reliable lychee flowering and production is exposure of dormant trees to prolonged (2–4 months) temperatures below 59°F but above 32°F (Menzel and Waite 2005).

Freezing temperatures are the most limiting factor for most subtropical and tropical fruit crops (Table 1) (Menzel and Waite 2005; Litz 2009; Paull and Duarte 2011, 2012; Schaffer et al. 2013). The ability of various subtropical and tropical fruit crops to withstand exposure to freezing or subfreezing temperatures depends upon their inherent genetics, the depth and hours of freezing temperatures, and the number of freezing events that occur. In addition, tree size (age), stage of plant growth (e.g., trees with or without fruit, dormant versus actively growing), and recent plant stresses (e.g., drought or flooding) influence tree tolerance and recovery from freezing temperatures. Recent cultural practices (e.g., fertilization and pruning) also greatly influence tree reaction to freezing temperatures. Mature loquat trees, for example, can withstand freezing temperatures to 10°F, and lychee to ~24°F, but banana and papaya are damaged or killed below ~31°F. Dormant (quiescent, not actively growing) fruit trees are more freeze tolerant than actively growing fruit trees. For historical precipitation and temperature data in your area, visit the Southeast Regional Climate Center's database at https://sercc.com/. Additional data may be found on National Weather Service and commercial weather websites (look for historic data).

Avoid planting in low-lying areas, especially low areas surrounded by obstructions (e.g., tall trees, hedges, buildings, etc.), which may prevent the movement of cold air off the land. Elevation of a few feet may make the difference between plant survival and damage or death due to cold weather. In Miami-Dade County, areas with marl soils (gray) and muck soils (black organic soil) in Palm Beach County are at lower elevation than Krome (very gravelly loamy soil, reddish rockland soil) areas. In other counties, greater differences in topography, elevations, and soil types within an area occur. Sandy soils predominate outside Miami-Dade County, and their elevations and drainage characteristics should be known prior to purchase and grove establishment. Determine the drainage characteristics (i.e., elevation, slope, and proximity to windbreaks, etc.) of a potential planting site before purchasing and establishing a new grove.

Edaphic (Soil) Considerations

Elevation above sea level, soil type, and depth are important factors that influence the microclimate, the potential for flooding, and necessary land preparation for a grove site. For soil type data and characteristics, visit the website of the USDA Natural Resource Conservation Service (NRCS) at https://www.nrcs.usda.gov/, the local UF/IFAS Extension office at https://sfyl.ifas.ufl.edu/find-your-local-office/, and UF/IFAS EDIS at https://edis.ifas.ufl.edu (keyword search "soils"). For elevation and flood potential information, visit the Miami-Dade government website at https://www.miamidade.gov/environment/flood-maps.asp and FEMA Flood Map Service Center at https://msc.fema.gov/portal/home. The USDA Soil Survey (WSS) provides soils data and information produced by the National Cooperative Soil Survey. It is operated by the USDA Natural Resources Conservation Service (NRCS). Information regarding your soil type can be found on the NRCS website at http://websoilsurvey.nrcs.usda.gov/app/.

The possibility of flooding is the most important consideration for the site selection in south Florida because many subtropical and tropical fruit crops do not tolerate flooded or saturated soil conditions (Table 2; Crane et al. 2019). Most soils in Miami-Dade County are well drained because of the extensive canal network in the county, which is used for flood control. However, poor drainage of some fields often is due to the high-water level in adjacent canals managed by the South Florida Water Management District (SFWMD). In the eastern and western coastal counties, land elevations above sea level may be low, and the existing canal and drainage systems may provide little flood protection for agricultural areas. Sandy soils in some areas have hard pans (spodic horizon) that may impede water drainage anywhere from one to four feet below the soil surface, adding to the flooding potential. Before purchasing a grove site, one should: a) contact the USDA Natural Resources Conservation Service for topography data; b) talk with neighbors near the site about whether the site has flooded in the past; c) look up the site on a topography map to determine its general elevation and drainage characteristics; and d) observe the site after heavy rainfall to see if flooding occurs. Fruit crops require well-drained soil conditions. Establishing beds of two to five feet in height and four to twenty feet in width may allow some fruit crops to be successfully grown in low-elevation sites. However, the probability of "rare" or periodic severe flooding events should be considered before establishing a grove.

Drought stress tolerance varies among tropical and subtropical fruit crops (Table 3). Symptoms of drought stress include wilting, leaf necrosis and abscission (drop), fruit drop, stem and limb dieback, and tree death. Just as important, mild to moderate stress may reduce flowering, fruit set, ultimate fruit size, and fruit quality (Menzel and Waite 2005; Litz 2009; Paull and Duarte 2011, 2012; Schaffer et al. 2013). Oolitic limestone soils in Miami-Dade County and sandy soils in south-central Florida possess a low water-holding capacity and therefore require good irrigation management to avoid plant drought stress.

Soil drainage characteristics (e.g., texture, hardpan) and fertility, including organic matter and salinity, can vary markedly even within a given area. The importance of a careful survey prior to planting cannot be overemphasized, because surveying may help to prevent mistakes (e.g., purchase of flood-prone land, land with a saline water source) that the grower will have to contend with for the life of the grove. The very gravelly loamy Krome soils and marl soils of south Florida are predominately found in parts of Miami-Dade, Broward, and Monroe counties (Wang et al. 2005; Li 2018). Both types of soils are calcareous with high pH (7.4–8.4) and low nutrient- and water-holding capacities. Water-holding capacity of the Krome soils is low (0.12

inch water per inch soil depth) but much higher in the marl soils (0.25 inch water per inch soil depth). Rapid removal of excess surface water by adequate soil drainage infrastructure (e.g., tile drains and beds) from heavy rainfall is critical because many tropical fruits do not tolerate flooded soil conditions for extended periods.

Availability of Water and Irrigation Systems

Most fruit crops produce much better when irrigated during dry periods (Paull and Duarte 2011, 2012). Select a grove site that has access to good-quality water or that has the legal and physical ability to access good-quality water. Check with the water management district (https://floridadep.gov/water-policy) about permits needed for well drilling, water use permits, and access to water at the proposed grove site.

Most subtropical and tropical fruit crops do not tolerate saline soils or saline water (Schaffer and Andersen 1994; Maas and Grattan 1999) (Table 4). Saline irrigation or saltwater intrusion typically results in tree decline or death. Mitigating a saline source of irrigation water or saltwater intrusion is very difficult and costly (Boman and Stover 2018). In most cases, the cost of mitigating salinity may be cost prohibitive.

The cost of irrigation installation, maintenance, and energy use of the proposed irrigation system should be investigated prior to establishment. Pumping capacity and fuel costs (e.g., diesel, gas, and electric) should be considered carefully.

Which irrigation system will best serve your needs depends on what the system is designed to do and how much installation, maintenance, and running the system costs (Crane et al. 2020). Contact your local county UF/IFAS Extension office for recommendations and search the EDIS website for publications on different types of irrigation systems. Contact several irrigation companies about designs and costs per acre for different systems and their views on the pros and cons of different systems. In order to draw up cost estimates and plans, the company will need to know how many trees per acre, the plant spacing, and whether the system is for irrigation only, irrigation plus fertilizer injections, and/or freeze protection (Parsons and Boman, 2019).

We recommend microsprinkler systems for irrigation and fertigation (injecting fertilizer through the irrigation system) (Clark et al. 2017; Migliaccio and Li 2018) and high-volume irrigation systems for cold/freeze protection of tropical fruit crops throughout Florida. Microsprinkler systems have underground PVC main and sublines and aboveground plastic tubing in-line along the tree-rows. Microsprinkler irrigation may be designed as low-volume (usually 5–25 gal/hr or less) or high-volume (25–50 gal/hr) systems (Kadyampakeni et al., 2023; Oswalt and Vashisth, 2023). Drip irrigation is appropriate for herbaceous fruit crops grown on beds covered with plastic, such as papaya. In general, drip systems do not provide sufficient water for fruit crops grown on sandy and rockland-type soils. These soils have a low water-holding capacity and limited lateral spread of drip-applied water; thus, irrigate only a small area of the tree root system.

A low volume microsprinkler and drip system will not protect tropical fruit trees from freezing temperatures. High-volume irrigation systems are designed to distribute 0.2 inches/acre/hour or more water over an entire grove area. Generally, they are powered by diesel or gas engines, so they are not susceptible to being turned off by electric companies during freeze events. These systems have been successfully used to protect subtropical/tropical fruit crops for over 50 years. There are three types of high-volume irrigation: overhead, under-tree, and in-tree. The systems are designed to distribute water over the entire grove land area. Overhead systems generally consist of tall metal pipes distributed 40 to 60 ft apart, topped with either metal or hard plastic impact sprinklers that make one 360° rotation per minute. High-volume under-tree systems consist of three-to-four-foot-tall metal or PVC pipes along every other row and every two to three trees in the rows. These too are topped with impact sprinklers that rotate completely every minute. The in-tree high-volume irrigation system consists of one PVC-topped pipe with one impact or spinner-type sprinkler per tree placed within the tree dripline (usually 3–4 feet from the trunk) adjacent to the tree trunk. In-tree high-volume systems require larger pumping capacity than the overhead and under-tree high-volume systems.

A high-volume microsprinkler system also consists of plastic tubing on top of the soil with one or more individual microsprinklers adjacent to each tree with the ability to distribute 25–50 gallons or more of water per hour per sprinkler (Jackson et al., 2023; Oswalt and Vashisth, 2023; Parsons and Boman, 2019). In general, the distribution of water from high-volume microsprinkler systems is limited to the in-row tree canopy area. We have limited experience with using high-volume microsprinkler systems to protect subtropical/tropical fruit trees during freezing temperatures. Please contact your local county Extension agent for more information.

For those sites with high-volume or nonfunctional irrigation systems already installed, the USDA Natural Resources Conservation Service (NRCS) offers cost-share programs that may help with improvements. For more information, visit http://www.nrcs.usda.gov/. The USDA Farm Service Agency (FSA) administers and manages farm commodity, credit, conservation, disaster, and loan programs as laid out by Congress through a network of federal, state, and county offices. For more information, visit the FSA website at http://www.fsa.usda.gov, and meet with the local FSA staff in your location.

Irrigation management consists of installation, maintenance, and optimum use of the established irrigation system in a grove. Best management practices involve applying the amount of water to meet crop needs and avoid or minimize loss of nutrients past the root zone (rhizosphere). Irrigation scheduling may be based on experience with the crop and environmental conditions, soil moisture monitoring, and historical or recent evapotranspiration data and crop coefficients (amount of crop water use compared to standard evapotranspiration losses). For more information, visit the EDIS website (keyword search "irrigation scheduling").

Wind Protection

Protection from constant winds is very important in the establishment and production of many subtropical/tropical fruit crops, such as carambola, papaya, banana, guanabana, and caimito. Exposure to constant winds may result in young tree loss due to desiccation, dieback, and mechanical damage; or to poor tree establishment and growth, reduced fruit set and production, and reduced fruit quality due to tree desiccation and fruit damage (sometimes called windscar). Planting sites surrounded on one or more sides by natural windbreaks, such as pineland or natural hammocks, or a perimeter of old-established fruit trees can protect adjacent sensitive fruit crops. If no natural windbreaks exist, select a noninvasive fast-growing tree species that will begin to provide wind protection over the next four or more years. For more information on windbreaks, see Ask IFAS at https://edis.ifas.ufl.edu, and USDA-SARE at https://projects.sare.org/project-reports/gs08-075/. Artificial windbreaks are an option but are very expensive to establish and to maintain.

Crop Insurance

To mitigate the risk from adverse weather events, such as droughts, floods, excessive winds, and hurricanes, as well as damage from plant pests and diseases (with some policies), prospective growers may also consider crop insurance. There are some crop insurance programs targeted to fruit crops in south Florida. For more information, please visit http://agecon.centers.ufl.edu/Workshops.html, where you can find detailed information about several crop insurance policies available, including an Excel tool to simulate different insurance and losses scenarios. If the crop you want to grow is not covered by a specific policy, you may still insure your crop by participating in the Noninsured Crop Disaster Assistance Program (NAP); for more details, go to https://www.fsa.usda.gov/programs-and-services/disaster-assistance-program/noninsured-crop-disaster-assistance/index.

Fruit Crop Selection

Choosing a Fruit Crop

One of the most important factors to successful fruit production is producing a fruit crop with a proven market or that thorough analysis shows has good market potential. Establishment costs for avocado (De Oleo et al. 2017), longan (Ballen et al. 2019), Thai guava (Garcia et al. 2019), pink guava (Evans et al. 2018), mamey sapote (Ballen et al. 2018), and sapodilla (Ballen et al. 2017) are available on the EDIS website. As part of the market research process, any prospective grower may access price and volume information using the USDA Agricultural Marketing Service (USDA/AMS) website, which offers a wide diversity of reports such as the terminal (wholesale) market report (https://www.marketnews.usda.gov/mnp/fv-report-config-step1?type=termPrice), the shipping point market report (https://www.marketnews.usda.gov/mnp/fv-report-config-step1?type=shipPrice), the movement report (https://www.marketnews.usda.gov/mnp/fv-report-config-step1?type=movement), and the retail report (https://www.marketnews.usda.gov/mnp/fv-report-retail-loading?category=retail&portal=fv&startIndex=1&class=ALL&region=NATIONAL &organic=ALL&commodity=ALL&reportConfig=true&dr=1&repType=wiz&step2=true&run=Run&type=retail &locChoose=locState&commodityClass=allcommodity) among others. However, it is important to clarify that information for some crops may not be available because there is a minimum quantity requirement for the volume traded in order to be included in the report.

From a biological standpoint, it is critical that the fruit crop or crops chosen to produce are adapted climatically to the area. Plants grown out of or near the edge of their adaptable area will experience more problems (e.g., poor growth, fruit set, and yields) than fruit crops suited to the climate. For example, some fruit crops such as lychee require exposure to a cold or cool (59°F or below) period of weather in order to properly flower and fruit (Menzel and Waite 2005). Therefore, this species is generally more adapted to locations north of Miami-Dade County with more reliable annual cool weather. In contrast, other fruit crops are susceptible to cool or cold weather (e.g., guanabana, caimito, banana, and papaya). These crops generally slow growth below 60°F and stop growth below 50°F; prolonged exposure may result in chilling injury. Most subtropical and tropical fruit are injured or killed by freezing temperatures (Table 1). Check with the local county agricultural Extension agent about fruit crops adapted to your region and local area in Florida.

The invasive potential of the fruit crop should also be considered when deciding which fruit crop to grow (Lieurance and Flory 2020). The invasive potential of tropical and subtropical fruit crops may be found online through the UF/IFAS Assessment of Non-native Plants in Florida's Natural Areas at https://assessment.ifas.ufl.edu. Many fruit species are recommended (i.e., not a problem species); however, some have been deemed low risk and others high invasive risk and should only be grown if well-defined practices and uses are identified to prevent escape (Table 2). Many others can be grown with caution if practices are implemented to prevent their escape.

Choosing a Variety

Selecting the right cultivar (cultivated variety) of a fruit crop is also a key factor in the profitability of a fruit grove. This may greatly impact the number of fruits harvested (yield) and the price you receive for the fruit. For many subtropical/tropical fruit crops, yields may be high, but if the price for that fruit or cultivar is low due to market conditions (competition from imports, overproduction, etc.), your return may not cover the costs to manage the grove. However, if you have a moderate yield of a variety that typically commands a high price in the market, your return on your investment may be higher for the lower-yielding cultivar. Producers (or potential producers) should investigate the market for their intended fruit crop and cultivar. For a list of tropical-fruit packinghouses in your area, contact your local county Extension agent or search online. For a list of nurseries in south Florida, contact your local UF/IFAS Extension office (https://sfyl.ifas.ufl.edu/find-your-local-office/).

Grove Establishment

Land Preparation

Land preparation costs for new and already established groves may include clearing land, fencing, rock plowing, trenching, auguring, drilling wells, bed establishment, drainage infrastructure, planting a new fruit crop, top-working existing trees to new varieties, and installation of an irrigation system.

Grove Design

Tree planting patterns should be selected to provide spacing between trees for maximum sunlight exposure and interception, allow for air circulation, reduce potential for wind-storm damage, and facilitate cultural practices such as mowing, spraying, pruning, and harvesting operations (Table 5).

The planting arrangement and/or tree density should be selected based on several considerations: land slope, maximum use of the land area, inherent tree vigor, final managed tree size, required spacing between rows for equipment movement, and type of fruit grown.

Typically, groves are planted in a rectangular arrangement with the in-row spacing closer than between-row spacing (Table 5). In general, the closer the in-row spacing, the more rapidly the tree space among trees in-row becomes filled with canopy, and the sooner trees begin to compete for water, nutrients, and light in-row. Between-row spacing should be wide enough to accommodate equipment movement for mowing, spraying, harvesting, and so on.

There are advantages and disadvantages to close and wide in-row spacing with respect to time to full production and overall long-term per-acre productivity. In general, per-acre production increases rapidly in closely spaced in-row plantings; however, pruning to keep in-row space between adjacent trees becomes difficult as trees mature. In contrast, production per acre increases more slowly in widely spaced groves, but maintaining space between individual trees in-row is easier. One strategy is to plant at a relatively close in-row spacing to increase production early in the grove's lifetime and then later systematically remove trees when crowding begins. However, many producers are reluctant to remove productive trees, and as in-row tree canopies merge, a hedgerow is formed. Hedge-row plantings can be productive if a pruning program (i.e., topping and hedging) is instituted that maintains the productive along-the-row canopy and production.

To maximize the number of trees per unit land area and long-term production of high-quality fruit, trees should be under an annual or biannual pruning program to limit tree height and spread (Table 7). Trees allowed to become taller than two-thirds the distance between rows may result in loss of the lower fruit canopy. For example, if tree rows are spaced 25 ft apart, ultimate tree height should be ~16 ft or less. This will allow the duration of sunlight to be sufficient to maintain fruit production in the lower tree canopy.

Generally, row orientation should be north-south to maximize canopy exposure to sunlight. However, north-south orientation is more important for groves that are closely spaced within the rows and for hedgerow plantings. When closely spaced trees are aligned in east-west rows, typically one side of the tree receives significantly more sunlight than the other.

Costs

Availability of Labor

Labor costs need to be considered. Most high-value fruit crops are labor intensive to manage and harvest. Investigate the labor situation and cost in your area. Government regulations may make finding, hiring, and retaining labor more difficult.

Time Investment

Establishing and maintaining a grove takes time, even for a small grove, and harvesting can be very time consuming, depending upon the fruit crop grown. For example, the time spent on cultural requirements for sugar apple is most intense from April through about October, whereas the time spent on banana and papaya cultural requirements is year-round. Diversifying the number of fruit crops grown is a wise strategy for distributing the risk of crop failure (or poor sales). However, growing multiple fruit crop species may increase the time required on cultural practices and the harvesting period. Overlapping harvest periods may pose a time and labor challenge. However, local grove service companies are available, and most may be contracted to do specific grove maintenance practices.

Capital Costs

Material costs may include machinery, fencing, plant material, fertilizers, and pesticides. Plant material costs will vary with availability, quality, and size and number of the plants purchased. Estimates for machinery needed for grove maintenance must be included in the analysis for cost of grove establishment and maintenance.

Equipment Costs

Possible equipment needs include tractors, mowers, sprayers, and harvesting and picking equipment. Some equipment can be leased or rented, and you may opt to pay a grove maintenance company to conduct some grove operations. For help developing an agricultural enterprise budget, visit the UF/IFAS Agricultural Economics Extension website at http://agecon.centers.ufl.edu/ and contact your local county agricultural agent.

Financial and Insurance Costs

Using money has its own additional costs that should be considered. Either using your own capital or securing a loan has cost implications—opportunity cost if using your own funds, or interest cost if securing a loan. Therefore, cost of capital should be included as it provides a more realistic view about the total costs incurred. A prospective grower should assess the financial cost and return of the new fruit crop enterprise(s) considered and compare it with alternative uses of the capital.

Frequently overlooked, insurance in the form of property and crop insurance policies helps to mitigate and manage risk. A property insurance policy helps to protect your buildings and other structures from fire or adverse weather, and depending on the structure of the policy, it may also offer liability protection. Crop insurance may be the difference between staying afloat or exiting the industry.

Fertilizer Costs

Whether opting to implement organic or conventional practices, you should use information from commercial fertilizer suppliers, soil-testing nutrition laboratories that offer soil and leaf analysis, and university and county Extension personnel to determine approximately how much fertilizer will be required per year. Fruit crops need both macronutrients (nitrogen, phosphorus, potassium), secondary elements (magnesium and sulfur), and micronutrients (iron, manganese, zinc, boron, and nickel) to be healthy and productive. On limestone soils with low plant-nutrient holding capacity, frequent but light applications of fertilizer are recommended. On sandy, low-pH soils, application of liming materials to raise the pH may be necessary to increase the availability of micronutrients. Some sandy soils, however, are underlain by a limestone (calcareous) layer. Search EDIS for information on soils and contact your local UF/IFAS Extension office for local soil type information.

Contact your local UF/IFAS Extension office for fertilizer recommendations, contact fertilizer companies about the types and costs of locally available fertilizer materials, and then calculate fertilizer costs per year. Trees on calcareous, very gravelly loamy soils and sandy soils are conventionally fertilized anywhere from 3–10 times per year depending upon the tree type, tree size, and tree health. Organic soil health development and fertilizer recommendations may be found through various organizations (Florida Organic Growers, https://foginfo.org/), agencies (e.g., USDA National Organic Program, https://www.ams.usda.gov/rules-regulations/organic/handbook), and the EDIS website (keyword search "organic production"). For more information on supplying fertilizer to tropical fruit groves via chemigation or fertigation, search the EDIS website.

Regulatory Factors

Pesticide Use and Worker Protection

Weed, insect, and plant pathogen control is an important component of successful tropical/subtropical fruit production. Strategies for mitigating pests include planting pest-resistant cultivars, spacing plants appropriately to reduce long periods of dew (leaf and fruit wetness), installing an irrigation system that minimizes canopy exposure to prolonged periods of water (e.g., microsprinkler), periodic pruning to increase canopy light penetration and maintain optimum durations of canopy light exposure, installing soil drainage systems (e.g., tiles and ditches) or beds to avoid excessively wet or flooded soil conditions, using organic or plastic mulch (e.g., papaya) to reduce weed growth, and using natural (e.g., leaving a perimeter of mature fruit trees or bamboo) or artificial windbreaks to reduce windblown debris damage to fruits.

Implementation of an integrated pest management (IPM) system is paramount to successful pest control and begins with the mitigation strategies mentioned above, scouting, and pest identification. Strategies to control insect pests include exclusion (e.g., bagging fruit), enhancement or introduction of predators and/or parasites of pests (e.g., Swirski mite for control of two-spotted mite in papaya), trapping (e.g., sticky-traps), modification of environmental conditions (e.g., pruning to increase light levels and durations), and use of biological and conventional pesticides. Likewise, strategies to control disease pests include mitigation strategies mentioned above, such as growing resistant cultivars, grove infrastructure that reduces prolonged periods of soil saturation or flooding, and use of biological and conventional pesticides.

In the United States, producers who want to use restricted-use pesticides (RUPs) are required to have a pesticide license. However, most producers obtain their license even if not applying RUPs because of the training in safe pesticide use. Search the EDIS website for content (keyword "pesticide license"). Free classes and testing are available through local UF/IFAS Extension county offices (https://sfyl.ifas.ufl.edu/find-your-local-office/).

In the United States, to use conventional and some organic pesticides, the crop name *must* appear on the label of the product. Furthermore, it is illegal to use a pesticide differently than directed on the label. In addition, there are recordkeeping requirements for pesticide use, and those records are open to inspection by local, state, and federal regulatory agencies.

The federal regulation entitled the Worker Protection Standard for agricultural workers (WPS) is primarily intended to reduce the risks of illness and injury to workers and handlers resulting from occupational exposure to pesticides on agricultural establishments (Kraus and Bultemeier, 2022; Ferrell and Fishel, 2023). There is annual mandatory training to inform workers and handlers about the required WPS protections and how to respond to pesticide exposure. Search the EDIS website (keyword "worker protection") for more information.

Food Safety

Foodborne illness (microbial contamination) caused by consumption of fresh produce has historically been a national issue with lethal consequences. Historically, local, state, and federal authorities' only option was to respond to foodborne illness outbreaks after the fact, that is, while the outbreaks were in progress. In 2011, the federal government enacted the Food Safety Modernization Act to be administered by the Food and Drug Administration (Lepper et al. 2018). This law and the regulations from it are designed to eliminate or minimize the number of foodborne illness outbreaks caused by microbial contamination of the US food supply. All producers who earn more than $25,000 per year on a rolling three-year average must take and pass food safety training and implement a food safety plan at their farms. Training classes and testing are available through local UF/IFAS Extension county offices (https://sfyl.ifas.ufl.edu/find-your-local-office/). Search the EDIS website for relevant articles (keyword "food safety").

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Table 1. Estimated temperatures for freeze damage or death of non-cold-protected tropical fruit trees in south Florida[1].

Common name	Temperature (°F)[2]	Rating[3]
Atemoya	<32	L
Avocado	West Indian 25–30, Guatemalan 25–28, Mexican 18–26; hybrids vary	L, M, M
Banana	28–31 injury, <28 death	L
Barbados cherry	Mature 28, young 30	L
Black sapote	Mature 28, young 30	L
Canistel	Mature 23, young 29	M
Carambola	Mature 26–28, young 27–32	M
Coconut	<32	L
Guava	Mature 25–26, young 27–28	M
Jaboticaba	Mature 27–29, young <30	L
Jackfruit	<32	L
Jujube (Chinese/Indian)	-28 to 10	L
Key lime	<32	L
Kumquat	<18	H
'Tahiti' lime	Mature 22–30, fruit 28, young 25–30	M
Longan	Mature 24–28, young 28–30	M
Loquat	Dormant 10, fruit <27–28	H
Lychee	Mature 24–25, young 28–32	M
Macadamia	Mature 25–26, young <32	M
Mamey sapote	Mature 28, young <32	L
Mango	Mature 25, young 29–30, fruit <40	M
Monstera	Leaves 30–32, stems 26–28	L
Papaya	<30	L
Passion fruit	<32	L
Pineapple	<28, <40 heart rot	L
Pitaya	~31	L
Plantain	<28	L
Pummelo	<32	L
Sapodilla	Mature 26, young 30–32	M
Spanish lime	<32	L
Spondia spp.	<30	L
Star apple	Mature 26–29, young 31	L
Sugar apple	Mature 28–29, young 30	L
Tamarind	Mature 28, young 32	L
Wampee	<32	L
Wax jambu	<32	L
White sapote	Mature 24, young 26	M

[1] Estimated temperature based on: Campbell, C. W. 1977. "Freeze damage to tropical fruits in southern Florida in 1977." *Proc. Fla. State Hort. Soc.* 90:254–257; Campbell, C. W. 1974. "Research on the caimito (*Chrysophyllum cainito* L.) in Florida." *Proc. Tropical Region of the Amer. Soc. for Hort. Sci.* 18:123–127.
[2] Estimated temperatures at which tree damage or death may occur. The actual tree damage or death temperature will depend upon current and previous tree condition, tree growth stage, and depth, duration, and frequency of freezing temperatures.
[3] L, low freeze tolerance; M, moderate freeze tolerance; H, high freeze tolerance; Mature, Mature/large tree; Young, young/small tree.

Table 2. Flood tolerance of tropical and subtropical fruit crops based on the literature and field observations. *Tolerant*—flood-tolerant fruit crops will survive excessively wet (high water table) and flooded conditions for several days to a few weeks. However, the stress of wet conditions may reduce tree growth and fruit production. In addition, root diseases may develop and result in tree damage or death. *Moderately tolerant*—moderately flood-tolerant trees will survive several days of excessively wet or flooded soil conditions. However, the stress of wet conditions may reduce tree growth and fruit production. In addition, root disease may develop and result in tree damage or death. *Not tolerant*—trees not tolerant of wet or flooded soil conditions. Trees may sustain heavy damage or be killed by one to a few days of wet soil conditions.

Tolerant	Moderately tolerant	Not tolerant
Caimito	Banana	Atemoya
Coconut	Canistel	Avocado
Citrus (grafted)	Carambola	Jackfruit
Guava	'Tahiti' lime	Papaya
Sapodilla	Mamey sapote	Passionfruit
	Mango	Sugar apple
	Longan	
	Lychee	
	Pitaya (dragonfruit)	

Table 3. Drought tolerance of tropical and subtropical fruit crops based on the literature and field observations. *Tolerant*—trees tolerate lack of water for a few days to several weeks. However, drought stress may reduce tree growth and yields. *Moderately tolerant*—trees may withstand several days of drought. However, drought stress may reduce tree growth and yields. *Not tolerant*—trees may survive a few days of drought. However, this may result in severe leaf drop, poor vegetative growth, and a large reduction in yield.[1]

Tolerant	Moderately tolerant	Not tolerant
Canistel	Atemoya	Air-layered citrus
Citrus (grafted)	Avocado	Banana
Mango	Caimito	Papaya
Sapodilla	Carambola	
	Coconut	
	Guava	
	Jackfruit	
	Longan	
	Lychee	
	Mamey sapote	
	Passionfruit	
	Pitaya (dragonfruit)	
	Sugar apple	

[1] Paull and Duarte (2011, 2012); see Literature Cited for more.

Table 4. Salinity tolerance of selected tropical fruit crops.[1]

Reported tolerant	Reported not tolerant
Coconut	Avocado
Date palm	Banana
Fig	Carambola
Guava	Lychee
Jujube	Mango
Pitaya (dragonfruit)	Papaya
Pineapple	Passionfruit

[1] Schaffer and Andersen (1994); Maas and Grattan (1999).

Table 5. Examples of tree spacing and plant density. As plant spacing decreases, intensity of grove maintenance practices increases.

Category	In-row × between-row spacing (ft)	Plant density (trees per acre)
Low	40 × 40	27
	30 × 30	48
	28 × 28	55
	25 × 25	69
	25 × 28	62
	25 × 26	67
Moderate	24 × 24	75
	20 × 25	87
	22 × 22	90
	20 × 24	90
	20 × 22	99
	20 × 20	108
	18 × 20	121
High	18 × 18	134
	15 × 18	161
	15 × 15	193
	10 × 20	217
	12 × 15	242
	10 × 15	290
	8 × 10	544
	8 × 8	680
	6 × 6	1,210

Table 6. UF/IFAS assessment of the invasive status of selected tropical and subtropical fruit crops.

Common name	Assessment status[2]	Comments
Atemoya	1	
Avocado	1	
Banana	1	
Barbados cherry	1	
Black sapote	1	
Canistel	1	
Carambola	1	
Coconut	2-3	Caution in central Florida, invasive in south Florida
Guava	2	Caution in central and south Florida
Jaboticaba	1	
Jackfruit	1	
Jujube (Chinese/Indian)	1	
Key lime	1	
Kumquat	1	
'Tahiti' lime	1	
Longan	1	
Loquat	1	
Lychee	1	
Macadamia	1	
Mamey sapote	1	
Mango	2	Caution in central and south Florida
Monstera	1-3	Invasive; grow under commercial conditions
Papaya	1	
Passion fruit	1	
Pineapple	1	
Pitaya	3	Invasive; grow under commercial conditions
Plantain	1	
Pummelo	1	
Sapodilla	3	Invasive in central and south Florida; grow under commercial conditions
Spanish lime	1	
Spondia spp.	1	
Star apple	1	
Sugar apple	1	
Tamarind	1	
Wampee	1	
Wax jambu	1	
White sapote	1	

1. Not considered a problem species at this time; may be recommended.
2. Caution; may be recommended but managed to prevent escape.
3. Invasive and not recommended except for "specified and limited" use.
4. Invasive and not recommended.

Table 7. Recommended maintenance tree height for subtropical and tropical fruit trees in Florida. Maintenance tree height depends upon tree row spacing; the closer the row spacing, the lower the tree maintenance height.

Common Name	Scientific Name	Range in height (ft)
Atemoya	*Annona cherimola* × *A. squamosa*	8–12
Avocado	*Persea americana*	10–15
Black sapote	*Diospyros digyna*	12–15
Caimito (star apple)	*Chrysophyllum cainito*	8–12
Canistel (egg fruit)	*Pouteria campechiana*	10–12
Carambola	*Averrhoa carambola*	6–12
Citrus	*Citrus* species	10–14
Custard apple	*Annona reticulata*	8–12
Guanabana	*Annona muricata*	8–12
Guava	*Psidium guajava*	3–10
Jackfruit	*Artocarpus heterophyllus*	8–14
Longan	*Dimocarpus longan*	10–15
Lychee	*Litchi chinensis*	10–15
Mamey sapote	*Pouteria sapota*	12–15
Mamoncillo	*Melicoccus bijugatus*	12–15
Mango	*Mangifera indica*	6–15
Sapodilla	*Manilkara zapota*	12–15
Soursop	*Annona muricata*	8–12
Spondia	*Spondias* species	8–12
Sugar apple	*Annona squamosa*	6–12
White sapote	*Casimiroa edulis* and *C. tetrameria*	10–15