Deciduous and Tropical/Subtropical Fruits

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Situation - Temperate Fruits

Temperate fruit crops grown commercially in Florida include blueberry, stone fruit (peaches, nectarines and plums), muscadine grape, brambles (primarily blackberry) and persimmon. Of these, blueberry has demonstrated the most growth and expansion during the last decade. Harvested blueberry acreage has more than doubled from 1,200 acres in 2000 to 2600 acres in 2007 (USDA, National Agricultural Statistic Service). Total production and yield per acre have also increased significantly. The total production for the state was estimated at 7.8 million pounds in 2007 compared to 3.3 million pounds for 2000. In 2007, the industry's value was estimated at about $39 million for 2007, an increase of over $6 million from the previous year (USDA, National Agricultural Statistic Service). With the continued development of new plantings, all indications are for more growth and expansion of blueberry acreage for the foreseeable future. Blueberry farm sizes range from less than 5 acres to over 100 acres. Full-time blueberry growers usually have 20+ acres in production. Farms are scatter throughout peninsular Florida. Leading counties for blueberry production are Alachua and Polk, but significant acreage is located in Hillsborough, Hernando, Hardee, and throughout central and north central Florida (Williamson, et al, 2000). Most blueberry growers use deep wells (Florida Aquifer) for irrigation. Irrigation for freeze protection is needed for reliable production in most areas of Florida. Groundwater contamination from blueberry production has not been documented. However, some preliminary work on nutrient leaching in southern highbush blueberry grown in pine bark beds has been done by Haman and Williamson but results are not yet final.

Commercial acreage of stone fruit in Florida is limited to a few hundred acres, but the potential for growth of this alternative, high-value, crop is high (Andersen, et al., 2000). The area with the most potential for growth of stone fruit is central and north-central Florida where some winter chilling occurs, yet very early season production is possible. Peaches are also susceptible to freeze injury and require irrigation for cold protect. Muscadine grape and persimmon are each limited to a few hundred acres in north-central and central Florida (Andersen et. al, 2000).

Increased acreage (especially blueberry) in recent years along with rapid urbanization has resulted in greater competition for water with the urban sector. Many growers are using dual systems; low-volume for routine irrigation and overhead irrigation for freeze protection. However, freeze protection of flowers and young fruit is absolutely essential for reliable production and often requires large amounts of water for the duration of the freeze(s) (Lyrene and Williamson, 2006).

The major issues and challenges with sustainable cultural practices for temperate fruit crops include: a) managing irrigation to meet plant water needs while avoiding fertilizer leaching and runoff; b) reducing fertilizer usage as irrigation management becomes more efficient and precise in wetting the rhizosphere; c) developing soil management systems that facilitate deeper, more efficient, root systems, and; d) continue to improve the pest management systems and decrease the need for pest control substances with issues of environmental safety.

Nutrient and Irrigation Management – Temperate Fruits

Blueberry: Southern highbush (SHB) blueberries comprise the majority (approximately 3000 acres) of commercial blueberry acreage in Florida. The following discussion is for SHB blueberry as opposed to rabbiteye blueberry which has different management requirements but is only grown in small non-commercial plantings through north and north-central Florida. SHB blueberries are grown commercially throughout Florida with the exception of the western panhandle area and the southern most part of the peninsula. SHB blueberries are typically grown in Florida using one of the following soil management systems: 1) soil culture – plants are planted directly in a non-amended soil that is naturally suited for blueberries (rare in Florida); 2) amended soil culture – plants are planted in soil that is highly amended with pine bark or other organic soil amendment (30 to 50% by volume) to increase soil organic matter, increase porosity, and help lower soil pH. Usually an additional 7 to 10 cm of pine bark is added as mulch after planting; and 3) pine bark bed culture – plants are planted directly in 15 to 20 cm of pine bark on top of native soil. The bark is arranged in solid beds approximately 1 meter wide down the row (very common in Florida).

The most popular production system for SHB blueberry is the pine bark bed method which results in shallow root systems that are restricted to the pine bark layer. This medium has marginal water and nutrient holding capacities, especially when new or fresh bark is used. Together, the shallow root system and the physical and chemical properties of pine bark create a need for frequent irrigation and frequent light fertilizations if conventional fertilizers are used. Without careful management, more water than is required to wet the bark profile might be applied during irrigation events. In the case of micro or drip irrigation, where application rates per unit of surface area is greater than with overhead, much of the water may move below the pine bark layer before it is absorbed by plants (personal observation). In summary, pine bark beds should be managed very differently from soil or amended soil and the physical properties of pine bark change as the bark ages and decomposes, with fresh bark being the most difficult to manage.

Fertilizer requirements for SHB will depend on the soil management systems used. Since the most common production method in Florida is pine bark bed production, in most cases, the blueberry root system is limited to the top 6 to 8 inches (depth of the bark layer) of growing substrate. With current management systems, higher N rates are needed in pine bark culture than in soil culture for several reasons: 1) fresh pine bark has a relatively high C/N ratio and some N is temporarily unavailable for plant uptake; 2) Pine bark (especially fresh bark) does not retain water or bind anions or cations as well as many soils do and nutrient leaching may occur; 3) Roots of blueberries grown in pine bark beds tend to stay in the pine bark layer and do not colonize the soil below the bark. The result is shallow rooting which in turn results in the need for frequent irrigations which can move the nutrients below the shallow root system. Although no formal survey has been conducted, the majority of growers probably apply N within the suggested range (150 – 225 lbs N/a/year). Current research is underway at UF to further define N requirements in pine bark bed production and determine if there are advantages to pine bark amended soils over pine bark beds with regards to rooting depth. Many growers routinely use leaf nutrient analyses to monitor their fertilizer programs. Experienced growers use plant vigor and overall appearance along with leaf and soil analyses to fine tune their fertilization programs. Soil samples are used to monitor soil pH, P, K, Ca, and Mg content.

In blueberry culture, fertilizer is often applied as dry, granular fertilizer. This is especially true for plantings with only overhead irrigation. Growers tend to use blended fertilizers, and they use leaf analysis as a guide to make adjustments to their blends or to make supplemental applications of a particular element(s). Blueberries prefer ammonium to nitrate, so most blueberry fertilizers have relatively small amounts of nitrate (Williamson, et al., 2006). The N component is often from ammonium salts or urea, a portion of which may be coated with sulfur (slow release) or with polymers (controlled release). The two most common sources of N are probably urea and ammonium sulfate, however, nitrate is sometimes used in combination with other N forms if the substrate pH is low and if nitrate is only a small part of the total N applied (Krewer and Nesmith, 2004; Williamson, et al., 2006). Until recently, almost all fertilizer has been applied as dry, granular, blended formulations. Analyses vary but a common analysis for the industry is 12N – $4P_2O_5$ – 8 K_2O (Krewer and Ruter, 2006). With the introduction of micro-irrigation in some new plantings, fertigation is becoming more common. Application rates and timing vary from farm to farm, and with whether plants are grown in soil or in pine bark beds. Annual nitrogen recommendations for mature blueberry plants grown in soil in Florida are 90 to 120 pounds of N/acre in at least 5 equal applications beginning in April and ending in September (Lyrene and Crocker, 1991; Williamson and Lyrene, 1995). Exact beginning and ending dates will vary with location in Florida and length of growing season. For pine bark bed culture the N recommendation is considerably higher than for soil, 150 to 225 pounds of N/acre divided into 8 to 10 applications beginning in late February and ending in early October (Williamson, et al., 2006). A recent study (Williamson and Miller, unpublished) indicated that fertilizer rates recommended for soil systems were inadequate for pine bark bed culture. The same observation has been made by numerous blueberry growers throughout the state.

Blueberries are shallow-rooted and susceptible to drought. Depending on rainfall patterns, irrigation may be needed at any time during the year, the most critical periods usually are during fruit development and through summer and early fall during the major vegetative growth flush and when transpiration is high. Generally, it is believed that blueberries require about 1 to 1.5 inches of water per week during the growing season (Braswell, et al., 2004; Himelrick and Curtis, 1999; Williamson, et al., 2006). In Australia, Bell (1982) estimated water requirements of about 25 mm to 38 mm depending on the stage of growth. Brightwell and Austin (1980) suggested a range from 25 to 44.5 mm per week. Water requirements generally increase as leaf canopies develop and fruit growth and development occurs. Williamson and Lyrene (1995) suggest 8 to 30 mm of water per week depending on time of year and stage of crop development. In Chile, Holzapfel et al. (2004) found that 100% ET replacement with micro-sprinklers or drip yielded greater than 33 or 66 % ET replacement. However, there was no apparent advantage to 130 % over 100 % ET replacement. Overall, micro-sprinkler treatments yielded higher than drip treatments with the same amount of water applied, suggesting that micro-sprinkler was more efficient than drip.

Many blueberry growers subscribe to weather services or have weather stations and monitor temperature, wind speed, dew point, and ET. However, grower decisions on when to irrigate, and how much to irrigate, may be largely subjective. Unfortunately, soil moisture monitoring devices have not been reliable in pine bark medium. A recent study by Dourte (2007) suggests that growers may over irrigate on pine bark bed systems. In that study, plants that were irrigated daily for a short duration (in the absence of rain) were compared to a nearby grower field where plants were irrigated for longer durations but at less frequent intervals, usually every two or three days. During the course of the study, less water was applied to the daily, short-duration, plants with no apparent reduction in growth or yield when compared to the grower field. It is likely that there is a tendency for blueberry growers using the pine bark bed system to apply more water than is needed to wet the bark profile during a given irrigation event. Research is underway to develop a crop coefficient for blueberry in Florida.

Most SHB blueberries are currently grown on pine bark beds. Their root systems are limited to the depth of the pine bark bed (a few inches). Therefore irrigations should be scheduled frequently and for short durations, applying only enough water to wet the root profile. Williamson and Lyrene (1995) suggest irrigating two to three times per week during periods of no rain and high evaporative demand. Recent research suggests that even more frequent, short duration, irrigations may be more efficient on pine bark bed production systems (Dourte, 2007).

Irrigation systems for blueberry must be equipped to protect against late winter and early spring freezes. Typically this requires high output systems capable of supplying up to 3/10 in. of water per hour for several hours (duration of the freeze), possibly for 2 or 3 consecutive nights. The number of freeze events at any given location varies from year to year but can be numerous.

Irrigation practices vary with type of production system used (see above), plant age, soil profile characteristics, and management philosophy of the blueberry grower. However, blueberries tend to be shallow-rooted and susceptible to drought (Williamson, et al, 2006). Therefore irrigation is used by essentially all SHB blueberry growers in Florida. Almost all growers have overhead irrigation systems because of the additional benefit of freeze protection which is required for successful production in Florida's climate (Lyrene and Williamson, 2006; Lyrene and Williamson, 2004). Many older fields are equipped only with overhead systems that provide both routine irrigation needs and freeze protection capabilities. Many new plantings are being established with micro-irrigation systems for routine irrigation needs while also having overhead irrigation for freeze protection. Some new plantings are using various forms of drip irrigation. Whether or not these systems will provide adequate root zone coverage in pine bark substrate as plantings mature is not known. Micro-sprinklers are also being used in new plantings and may be better suited for pine bark and sands amended with pine bark because of better root zone coverage.

Blueberry growers use little irrigation during the winter, especially after leaf drop. Overhead irrigation is usually avoided during flowering (except for cold protection) to reduced the incidence of botrytis flower blight. The most critical period for irrigation of blueberry is during the fruit development period (February through May in Florida) which often corresponds with the driest period of the year in Florida (Williamson and Lyrene, 1995). Fruit harvesting in a particular field may extend for several weeks with individual pickings at 3 to 4-day intervals. During harvest, irrigation is usually timed immediately after a picking to minimize the possible negative effects on fruit quality and maximized the effects on berry size (Williamson, et al., 2006). A second critical period for irrigation is following summer pruning (June through October) when new growth is occurring which will determine next year's crop. During this time, long days and high temperatures put high water demands on the crop. Beginning in October, many growers apply lower rates of irrigation in an attempt to slow growth and prepare plants for dormancy. In southern growing areas, some growers are using a non-dormant production system

(Darnell and Williamson, 1997; Obreza, et al., 1998). In these cases higher rates of irrigation would be needed during late fall and winter than for the traditional dormant production system.

Most SHB blueberry production in Florida is currently on pine bark beds. This system is inherently difficult to manage from an irrigation and fertilization efficiency standpoint. Growers need to be more aware of the water holding capacities of the growing substrate (pine bark or soil) realizing that the physical and chemical properties of pine bark change as it ages and decomposes. Growers should know the depth of the plant root zones and approximately how much water is needed to wet the soil profile. In many cases, especially in pine bark bed production, frequent but shorter duration irrigation events may be needed to maximize water use and minimize nutrient loss. However, if bark becomes dry, it is difficult to rewet. Ideally, bark beds should not become excessively dry between irrigations.

We recommend that use of low-volume irrigation systems on new plantings although overhead irrigation which is needed for freeze protection and possibly to supplement low-volume systems until more research is available in this area. Where low-volume systems are used, fertigation should be employed to apply at least a portion of the fertilizer.

We also recommend the use slow-release, or controlled-release, fertilizers as a component of the nutritional program to reduce leaching of nutrients below the root zone. Even when irrigation is carefully managed, heavy summer rains can leach nutrients below the root zone, especially in pine bark culture. When dry fertilizer is applied, at least a portion of the N source could be from slow or controlled-release fertilizer. An exception would be in late fall when slowly released N would not be desirable as plants enter dormancy.

SHB blueberry plants have very specific soil requirements that complicate management practices such as irrigation and fertilization. *Vaccinium arborium* (sparkleberry) is a blueberry relative that is native to Florida and has a much broader adaptation to different soil conditions. It has deeper roots than SHB blueberry and is better adapted to mineral soils low in organic matter. Current research at UF is attempting to develop hybrids between SHB and *V. arborium*. Through continued breeding and selection, these crosses may result in blueberry plants with deeper root systems that are more efficient at water and nutrient uptake and adapted to a broader range of soil conditions.

Another (shorter-term) approach is to graft existing SHB blueberry cultivars onto *V. arborium*, using sparkleberry as a rootstock. If successful, this would allow existing SHB blueberry cultivars to be grown on a wider variety of soil types and conditions and could potentially reduce inputs such as irrigation and fertilization. Preliminary work in this area is currently underway at UF.

The feasibility and technology for blueberry zero discharge systems is untested and unknown. However, blueberries have been grown in containerized systems on small scale production operations of approximately 1 to 4 acres. It is possible that zero discharge systems could be designed for container-grown blueberries.

Stone fruit. Little is known about peach nutrition under Florida conditions. Most growers use soil and leaf tissue analyses, and plant vigor and appearance to evaluate their fertilizer programs. General annual nitrogen fertilizer guidelines for Florida peaches call for approximately 100 pounds of N per acre for mature trees with 1/3 applied shortly before bloom and the remainder applied in late May, shortly after harvest (Ferguson, et al., 2007). If trees appear N deficient, or growth is weak, a small amount of N (15 to 20 lbs/a) is recommended in early August. However, preliminary data suggests that current annual nitrogen recommendations of approximately 100 pounds N/a/year may not be adequate (Wert, 2006) when only 2 or 3 annual applications of dry, granular, fertilizer are made on sandy soils. Research is ongoing at UF to determine if peaches respond positively to higher rates of N, or to more frequent applications.

Due to Florida's typically sandy soils with poor water holding capacities, essentially all commercial stone fruit orchards in Florida are irrigated. Irrigation has been clearly shown to benefit peach production in the SE United States by increasing fruit size and uniformity and by increasing total yield. Water stress can be particularly devastating to peach during the last stage of fruit development known as "final swell" where the fruit attains about 60% of its final size (Frecon, 2002). During this period environmental conditions are such that ET is usually high and the tree's demand for water is great. Plums have a similar fruit development pattern. Drip irrigation systems are commonly used throughout the SE United States but in Florida, where sandy soils predominate, micro-sprinklers are probably more effective than drip systems because of greater root zone coverage. A mature peach tree can use from 36 to 45 gallons of water in one day (Frecon, 2002; Taylor and Rieger, 2007). During one week, a mature orchard can use up to 1.7 inches of water (assuming 300 trees/acre). Young trees without well established root systems are prone to drought injury and weak growth in Florida without irrigation. In Florida, most peach orchards are irrigated with overhead or micro-sprinkler irrigation. Overhead irrigation has the advantage of protecting flowers and young fruit from late winter and early spring freezes which are common throughout the peach growing areas of Florida.

Some stone fruit growers subscribe to weather services to monitor environmental conditions such as temperature, wind speed, dew point, and ET. Most growers do not use devices that directly monitor soil moisture content. Decisions on irrigation appear to be based on crop phenology, rainfall and other weather factors, and appearance of the soil and plants.

Stone fruit growers could consider dual systems, low-volume for normal irrigation needs, and overhead for freeze protection. Use of controlled or slow-release fertilizers should reduce nutrient loss. If low-volume systems are available, fertigation could be considered as a delivery method for at least a portion of the fertilizer.

Muscadine grape. Muscadine fertilizer recommendations for established vineyards in the southeastern US are generally about 80 to 140 pounds of N/a/yr (Andersen, et al., 2007; Braswell, et al; Krewer, et al. 2002.). Little research is available on irrigation of muscadine. Using drip irrigation, Nesmith (2004) reported that daily rates of 6 to 8 gallons per plant were sufficient for vigorous growth in Georgia. With a plant density of 181 plants/a, this would equal about 1500 gal./a/day. In Florida, Andersen et al. (2007) recommends one dripper per plant during the establishment year, and 2 additional emitters per plant thereafter. They recommend that 2 gallons per day per plant is sufficient during the first year and 12 gallons per day per plant should be satisfactory in subsequent years.

Little information on specific effects of fertilization or irrigation practices is available for muscadine. It is widely held that muscadine grapes respond well to irrigation and irrigation is essential for good vineyard establishment. Andersen et al. (2007) suggests that the dry spring period is usually the most critical time for irrigation in Florida. Nesmith (2004) reported that 6 to 8 gallons per plant per day were sufficient for good vigor in Georgia. Andersen et al. (2007) suggests that 12 gallons per plant per day should be sufficient in Florida under most conditions. Excess vine vigor from over fertilization is believed to reduce berry quality (Braswell, et al.).

Vision for the temperate fruit industry

Blueberry plantings are adopting micro-sprinkler and drip irrigation technology in highly amended soils, and in pine bark bed production. The performance of these systems in pine bark culture needs further study and evaluation. Currently it is not known whether or not drip irrigation will provide sufficient root zone coverage in pine bark or in sandy soils amended with pine bark. Similarly, various micro-sprinkler designs need to be evaluated and tested in current blueberry soil management systems.

Management systems other than pine bark bed production need to be evaluated. Systems that would facilitate deeper rooting and require fewer inputs (such as organic matter, fertilizer and water) would be desirable. Some of this work is ongoing at UF and needs to continue. Fertilizer (particularly N) requirements need to be more clearly defined in pine bark culture systems. This work is also ongoing at UF and needs to continue. Various slow and controlled-release fertilizers need to be evaluated as a major component of an overall nutritional program.

Blueberry water use and irrigation requirements under current management systems need to be determined. Research evaluating effects of irrigation frequency and the total amount of water applied for increased water use efficiency, and the development of a crop coefficient for mature SHB blueberry is underway and needs to continue.

Work with low-volume irrigation technology for stone fruit needs to be continued in terms of research and practical application. This would also allow use of fertigation technology which also needs further research on stone fruit in Florida. Controlled or slow-release fertilizers need to be evaluated and incorporated into overall fertilizer programs.

Critical issues facing the temperate fruit industry include limited land availability, availability of sufficient water, especially during critical periods of high use such as during freeze events, and interfacing with the urban sector.

Situation - Tropical/Subtropical Fruits

Tropical and subtropical fruit production in Florida covers about 13,000 acres and is located primarily in Miami-Dade County (~85% of the acreage) with small acreages in Lee, Palm Beach, Broward, Collier, Indian River, St. Lucie, Martin, Charlotte, Pasco, and Sarasota counties. Gross crop value in Miami-Dade County alone is estimated at $73+ million annually with an economic impact exceeding $137 million (Degner et al., 2002). The average size farm is 50 acres but the most common size grove (57%) is between 1 to 9 acres (Degner et al., 2002; Migliaccio et al., 2006). Demographically about 67% of the commercial tropical fruit growers are part-time producers and have limited agricultural background (Migliaccio et al., 2006; TREC Strategic Plan, 2005). The other 40% are full-time producers with educational and/or experiential backgrounds in agriculture (TREC, 2005).

The sustainability of tropical/subtropical fruit production in Florida is influenced by economic/market, technological, environmental, and social factors (Evans, 2005a, 2005b, 2008; Edwards et al., 2008a, 2008b; Migliaccio, 2007). The surficial Biscayne aquifer is the main source of water used by agriculture, urban, and the environmental/natural areas (e.g., Everglades National Park, Biscayne Bay National Park) (Migliaccio, 2007). This limestone/sand based aquifer is highly permeable and therefore potentially subject to pollutants from agricultural and urban activities. The demand for water from this aquifer has intensified in response to climate variability, rapid urbanization, and natural system protection requirements. The main sources of water for recharging the aquifer are rainfall and a number of springs at the northern end of the surficial aquifer system above Lake Okeechobee. Annual rainfall in the marine subtropical environment in south Florida averages about 1600 mm.

In a relatively recent ground water quality survey of 6 public supply wells in the agricultural area of the Miami-Dade County found only a few samples with elevated nitrate levels but detected 15 different pesticides at levels below drinking-water standards (Bradner et al., 2004). In a more detailed study, the magnitude and frequency of nitrate and phosphorus leaching in several avocado, 'Tahiti' lime and carambola groves were investigated in south Miami-Dade County (Schaffer and O'Hair, 2001). Groundwater monitoring of all groves after fertilizer applications found total Kejdhal nitrogen (TKN), NH_4-N, and NO_3-N concentrations below 1.9, 0.2, and 22.4 ppm. The 6 occasions when NO_3-N levels exceeded 10 ppm were after periods of heavy rainfall. Groundwater total phosphorus (TP) concentrations within all orchards were generally below 60 ppb, however inflow wells on 4 occasions went as high as 140 ppb. TP concentrations within avocado, lime, and carambola orchards were below inflow well (I-TP) concentrations about 50%, 38%, and 45% of the time, respectively. Orthophosphate (OP) concentrations within all orchards were below 19 ppb and below inflow well I-OP concentrations 38% to 60% of the time. However, there was usually not a significant amount of leaching of fertilizers into the groundwater in the experimental fields compared to nitrate-N values obtained from inflow (upstream) wells. This was confirmed by the fact that fertilizer treatments used in this investigation (increasing N-P-K application rates) did not affect leaching of nitrate-N into the groundwater. There was no significant leaching of NH_4-N or P into the groundwater.

The major issues and challenges with sustainable cultural practices for tropical fruit crops include: a) managing irrigation to meet plant water needs and avoid leaching of fertilizers into the aquifer; b) reducing fertilizer usage as irrigation management becomes more precise in mainly wetting the rhizosphere and; c) continue to improve the pest management systems to decrease the need for pest control substances with issues of environmental safety. Interestingly, 78% of the commercial fruit growers recently surveyed indicated they would implement BMPs under the Florida Department of Environmental Protection presumption of compliance incentive (Migliaccio et al., 2006). However, 66% reported they would not spend more than $500 to implement BMPs suggesting cost sharing will be an essential component for some producers to implement BMPs.

Nutrient and Irrigation Management – Tropical/Subtropical Fruits

The nutrient and irrigation management for tropical and subtropical fruit crops varies by species and sometimes by cultivar. In general, major nutrients such as nitrogen (N), phosphorus (P), and potassium (K) are applied in granular form or applied through a low volume irrigation system (fertigation). Secondary elements such as magnesium and sulfur are applied along with N-P-K or foliarly to the leaves. Minor elements including zinc (Zn), manganese (Mn), molybdenum (Mo), and boron (B) are commonly applied foliarly. Iron is applied in chelated form appropriate for high pH, calcareous soils either as a soil drench or through fertigation.

Nutrient management may be based on: previous research for some crops (e.g., avocado, mango, and carambola) but not others (e.g., sapodilla, guava, and papaya), recommendations from other production areas, and extension/research faculty, fertilizer sales people, consultants, and grower experience (Table 1). The range in the rates of N, P, and K applied among and within a particular fruit farming operation varies widely (Li et al., 1999). For example, the range in nitrogen, phosphate, and potash applied for per acre to mature avocado groves ranged from 36-288, 4-72, and 36-288, respectively (Table 2). The frequency of N-P-K applications ranged from 2-6 times per year.

Leaf and/or soil sampling is recommended as a basis for nutrient management but only about 19% of those responding to a recent survey utilized soil nutrient samples and 29-50% utilized leaf analysis (Li et al., 1999; Migliaccio et al., 2006). Fertilizer application methods vary from grove to grove with dry granular applications of N, P, and K the most common method followed by N and K applied through fertigation (Li et al., 1999). Magnesium, Zn, Mg, and B are applied foliarly whereas chelated iron materials are either soil drenched or fertigated. Organic (including sludge) materials are applied by an estimated 60% of the growers and this is increasing as the cost of chemical fertilizers has increased. Nutrient conservation practices reported by commercial fruit growers include monitoring weather conditions to avoid nutrient applications immediately preceding a rainfall event and using a calibrated low volume irrigation chemical injector (Migliaccio et al., 2006).

Widespread adoption of leaf sampling and phenological crop management would improve plant nutrient management of tropical and subtropical fruit crops and potentially reduce fertilizer rates and or frequencies. Optimum leaf nutrient levels in Florida are known for avocado, 'Tahiti' lime and mango and preliminary data is available for others. Plant phenology is somewhat documented for many crops. Nutrient uptake efficiency varies by fruit species and in some cases by cultivar. In the future, long-term breeding or selection programs for rootstocks and/or cultivars that integrate crop yields, quality and pest resistance along with nutrient uptake efficiency could potentially reduce the need for nutrient inputs.

Irrigation management varies widely among and within tropical/subtropical fruit groves (Li et al., 2000). The surficial Biscayne Aquifer is the main fresh water source and is commonly accessed through wells. A recent survey reported over 50% of these wells was capped and cased (Muñoz-Carpena et al., 2003a). Nearly 67% of the growers report having some type of high volume irrigation system (application rates of ≥0.20 inches/acre/hour) which may be utilized for freeze protection and/or irrigation. In contrast, over 75% of the growers reported using a low volume irrigation system (most commonly microsprinkler) with the capability of applying fertilizer materials (fertigation). The reported method of irrigation management varied by producer with about 48% of the growers reporting they utilized some type of soil moisture monitoring, 64 to 73% measured or monitored rainfall (e.g., FAWN), 60% monitored weather data for scheduling irrigation, and 44% took crop phenology and appearance into account (Li et al., 2000; Muñoz-Carpena et al., 2003a; Muñoz-Carpena et al., 2003b). The frequency and rate of irrigation

Water conservation practices vary by grower (Migliaccio et al., 2006; Muñoz-Carpena et al., 2003b). In recent surveys growers reported: 16-21% utilized drought tolerant fruit crops (e.g., sapodilla, mango), 75% or more used a low volume irrigation system (mostly microsprinkler), 10% used water meters to monitor water usage, 26-50% use some type of soil moisture monitoring, 60-69% reported monitoring weather data including rainfall, 20% had on-farm rain gages, 40-43% monitor plant phenology, 53% mulched their trees, 24% kept irrigation records, 72% irrigating mainly in the early morning or late evening, and 30% have used the South Dade Soil and Water Conservation District to assess the efficiency of their irrigation system.

The 3 most common reasons cited by growers for practicing water conservation included water, financial and time savings (Muñoz-Carpena et al., 2003b). Of these water and financial savings were ranked equally. Development and implementation of ET/crop factor based irrigation scheduling could potentially reduce irrigation rates and frequency and potential leaching of plant nutrients. In conjunction, discovery and/or development of practical and economic soil moisture monitoring probes, a better understanding of crop phenology cycles – what they mean and how to use them, and integration with better weather data could further improve irrigation management.

Vision for the tropical/subtropical fruit industry

Improvements in nutrient and irrigation management greatly reduce the potential for leaching of nutrients into the groundwater. Improvements in pest management continue to reduce potential negative environmental impacts. Research should be focused on developing and/or refining leaf nutrient standards (especially for N-P-K) for selected tropical/subtropical fruit crops (e.g., carambola, papaya, banana, mamey sapote, sapodilla, and guava). Irrigation research should focus on refining and or developing ET/crop factors for use in scheduling irrigation and identifying practical/economic soil moisture monitoring equipment. Critical pest management issues, i.e., crop limiting pests, need to be addressed through development of resistant cultivars; however, this is generally a long-term prospect.

Critical issues include reducing production costs, development and utilization of sustainable cultural practices. Development of value added products (e.g., sliced carambola, organically produced bananas), alternative markets (e.g., ethnic, local/organic), and marketing is critical to the economic sustainability of the industry. Although land availability and cost is an issue, tropical fruit acreage has been increasing not decreasing as the popularity of "estate" farming increases and conversion of vegetable fields to nurseries or groves continues.

Literature cited

Andersen, P.C., J.G. Williamson and T.E. Crocker. 2000. Sustainability assessment of fruit crops for north and north central Florida. Pub. HS765. Fla. Coop. Ext Serv., University of Florida, Gainesville, Fla.

Andersen, P.C., T.E. Crocker and J. Breman. 2007. The muscadine grape. Pub. HS763. Fla. Coop. Ext Serv., Univ. of Florida, Gainesville, Fla.

Bell, R. 1982. The blueberry. Dept. of Agriculture NSW, Sydney, Australia.

Bradner, A., B.F. McPherson, R.L. Miller, G. Kish, and B. Bernard. 2004. Quality of ground water in the Biscayne aquifer in Miami-Dade, Broward, and Palm Beach Counties, Florida, 1996-1998, with emphasis on contaminants. US Geological Survey Open-File Report 2004-1438. p. 1-20.

Braswell, J., J.M. Spiers and C.P. Hegwood. 2004. Establishment and maintenance of blueberries. Pub. 1778. Miss. Coop. Ext. Serv. Mississippi State University.

Braswell, J., J.S. Stringer, B. Sampson and D. Ingram. Establishment and production of muscadine grapes. Pub. 2290. Miss. Coop. Ext. Serv. Mississippi State University.

Brightwell, W.T. and M.E. Austin. 1980. Rabbiteye blueberries. Research Bulletin 259. Ag. Res. Station, University of Georgia, Athens, Ga.

Crocker, T.E. and P.M. Lyeren. 1991. Commercial blueberry production in Florida. Fl. Coop. Ext. Serv. University of Florida, Gainesville, Fla.

Darnell, R. L. and J. G. Williamson. 1997. Feasibility of blueberry production in warm climates. Acta Horticulturae. No. 446:265-269.

Dourte, D.R. 2007. Crop water requirements and irrigation management. Master of Science Thesis. Dept. of Agricultural and Biological Engineering. University of Florida, Gainesville, Fla.

Degner, R.L., T.J. Stevens, and K.L. Morgan. 2002. Miami-Dade County agricultural land retention study, Appendix B, Vol. 3. Fla. Agric. Market Res. Center, IFAS, Univ. of Fla., p. 16.

Edwards, E. 2008. Commodity analysis, fruits. Agricultural Economics – Fruit Crops. [http://agecon-trec.ifas.ufl.edu/CommoditiesFruit.htm]

Edwards, E. 2005a. Marginal analysis: an economic procedure for selecting alternative technologies/practices, FE565. Food and Resource Econ. Dept., Fla. Coop. Ext. Service, IFAS, Univ. of Fla., Gainesville, Fla. p. 1-6.

Edwards, E. 2005b. Florida avocado production and profitability analysis, FE575. Food and Resource Econ. Dept., Fla. Coop. Ext. Service, IFAS, Univ. of Fla., Gainesville, Fla. p. 1-5.

Edwards, E., R. Degner, and K. Morgan. 2008. Six ways to improve the profitability of lychee in south Florida, FE497. Food and Resource Econ. Dept., Fla. Coop. Ext. Service, IFAS, Univ. of Fla., Gainesville, Fla. p. 1-4.

Edwards, E., R. Degner, J. Crane, R. Rafie, and C. Balerdi. 2008. Is it still profitable to grow lychee in Florida, FE496. Food and Resource Econ. Dept., Fla. Coop. Ext. Service, IFAS, Univ. of Fla., Gainesville, Fla. p. 1-5.

Ferguson, J.J., J. Chaparro, J.G. Williamson, R. E. Rouse and R.M. Mizell. 2007. Florida subtropical peaches: Production practices. Fla. Coop. Ext Serv., University of Florida, Gainesville, Fla.

Frecon, J.L. 2002. Best management practices for irrigation peach trees. Rutgers Coop. Ext. Service. Rutgers, The State University of New Jersey, New Brunswick, N.J.

Himelrick, D. and L.M. Curtis. 1999. Commercial blueberries. Ala. Coop. Ext. Serv. Auburn University, Auburn, Ala.

Holzapfel, E.A., R.F. Hepp and M.A. Marino. 2004. Effect of irrigation on fruit production in blueberry. Agricultural Water Management. 67:173-184.

Krewer, G., M. Hall, D.S. Nesmith, D. Horton, H. Sherm, P. Summer, T. Tyson and G. Wesberry. 2002. Georgia muscadine production guide. Georgia Coop. Ext. Serv., University of Georgia, Athens, Ga.

Krewer, G, and D.S. NeSmith. 2004. Blueberry fertilization in soil. Fruit Publication 01-1. Georgia Coop. Ext. Serv., Univ. of Georgia, Athens, Ga.

Krewer, G. and J. Ruter. 2005. Fertilizing highbush blueberries in pine bark beds. Bulletin 1291. Georgia Coop. Ext. Serv. University of Georgia, Athens, Ga.

Li, Y., J. Crane, B. Boman, and C. Balerdi. 1999. Fertilizer management survey for tropical fruit crops in south Florida. Proc. Fla. State Hort. Soc. 112:172-176.

Li, Y., J. Crane, B. Boman, and C. Balerdi. 2000. Irrigation management survey for tropical fruit crops in south Florida. Proc. Fla. State Hort. Soc. 113:40-42.

Lyrene, P.M. and J.G. Williamson. 2006. Protecting blueberries from freezes in Florida. In N.F. Childers and P.M. Lyrene (Eds). *Blueberries, For Growers, Gardeners and Promoters.* N.F. Childers Horticultural Publications, Gainesville, Fla. pp. 21-25.

Migliaccio, K.W. 2007. Sustainability of agriculture in Miami-Dade County: considering water supply, AE429. Agri. and Biol. Engineering Dept., Fla. Coop. Ext. Service, IFAS, Univ. of Fla., Gainesville, Fla. p. 1-7.

Migliaccio, K.W., J.H. Crane, E. Evans, B. Schaffer, Y. Li and R. Muñoz-Carpena. 2006. South Florida tropical fruit grower perspectives: water conservation management practices, ABE368. Agri. and Biol. Engineering Dept., Fla. Coop. Ext. Service, IFAS, Univ. of Fla., Gainesville, Fla. p. 1-5.

Muñoz-Carpena, R., J.H. Crane, G.D. Israel, and C. Yurgalevitch. 2003a. Water conservation survey of Miami-Dade County agricultural and golf course commercial water users. Proc. Fla. State Hort. Soc. 116:15-21.

Muñoz-Carpena, R., J.H. Crane, G.D. Israel, and C.F. Balerdi. 2003b. Tropical fruit growers' water use and conservation practice in Miami-Dade County, ABE345. Agri. and Biol. Engineering Dept., Fla. Coop. Ext. Service, IFAS, Univ. of Fla., Gainesville, Fla. p. 1-5.

NeSmith, D.S. 2004. Drip irrigation, muscadines. Small Fruit News. The Southern Region Small fruit Consortium. [www.smallfruits.org].

Obreza, T.A., J.G. Williamson, R.L. Darnell and P.M. Lyrene. 1998. Performance of a young southwest Florida non-dormant blueberry planting. Proc. Fla. State Hort. Soc. 110: 175 - 177.

Taylor, K.C. and M. Rieger. 2007. Irrigation scheduling. Southeastern Peach Growers Handbook. Georgia Coop. Ext. Serv. University of Georgia, Athens, Ga.

TREC. 2005. TREC strategic plan 2005: providing excellence in tropical horticulture and natural resources research, extension, and teaching. [http://trec.ifas.ufl.edu/about_us.shtml] (Accessed 6 May 2008).

Wert. T. W. 2006. Evaluation of four low-chill peach cultivars in three climatic zones in Florida. Thesis. Master of Science. Horticultural Sciences Dept. University of Florida, Gainesville, Fla.

Williamson, J.G. G. Krewer, G. Pavlis and C. M. Mainland. 2006. Blueberry soil management, nutrition and irrigation. In N.F. Childers and P.M. Lyrene (Eds). *Blueberries, For Growers, Gardeners and Promoters.* N.F. Childers Hort. Pub., Gainesville, Fla. pp. 60-74.

Williamson, J.G. and P.M. Lyrene. 1995. Commercial blueberry production in Florida. Fl. Coop. Ext. Serv. Univ. of Florida, Gainesville, Fla.

Williamson, J.G., P.M. Lyrene and E.P. Miller. 2000. A survey of blueberry acreage in Florida. Proc. Fla. State Hort. Soc. 113: 24-25.

Table 1. Source of fertilizer recommendations, general fertilizer application rates and methods for the major tropical/subtropical fruit crops in Florida.

Crop	Recommendation source of information	Recommended N-P-K-Mg rates (lbs N/acre/year)[z]	Method of application	Comments
Avocado	Fla. research. Tissue sampling.	100-250	Granular	Previous research used highly soluble materials. Current rec. is for lower rates 70-140 lbs N/acre/year.
Banana	Literature and experience.	100-300	Granular, fertigation.	No formal R&D from Fla. High rates of sludge, manures, compost, and mulch utilized. High K fertilizer recommended.
Carambola	Fla. research and experience. Tissue sampling.	80-240	Granular, fertigation.	R&D during past 15 years. Iron is a major fertilizer input.
Guava	Literature, tissue sampling, and experience.	100-300	Granular, fertigation.	No formal R&D from Fla.
Longan	Literature, tissue sampling, and experience.	80-250	Granular, fertigation.	No formal R&D from Fla. Low N and moderate to high K is recommended.
Lychee	Fla. research, literature, tissue sampling, and experience.	40-100	Granular, fertigation.	Previous R&D from Fla. Low N and moderate to high K is recommended.
Mamey sapote	Literature, tissue sampling, and experience.	100-200	Granular, fertigation.	No formal R&D from Fla. Rate dependent on crop load.
Mango	Fla. research and experience. Tissue sampling.	100-250	Granular, fertigation.	Previous research used highly soluble materials. Current rec. is for lower rates 40-100 lbs N/acre/year.
Papaya	Literature and experience.	250-400	Fertigation, granular.	No formal R&D from Fla. Frequent small amounts applied throughout the year.
Passion fruit	Literature and experience.	100-250	Fertigation, granular.	No formal R&D from Fla. Frequent small amounts applied most of the year. Moderate N and higher K is recommended.
Pitaya	Literature and experience.	50-125	Fertigation, granular.	No formal R&D from Fla. Frequent small amounts applied. Moderate N and higher K is recommended.
Sapodilla	Literature and experience. Tissue sampling.	100-200	Granular, fertigation.	No formal R&D from Fla. Frequent small amounts applied. Low N and higher K is recommended.

[z] Common granular formulations are 8-3-9-3 and 6-3-16-3, and soluble sources of N-K for fertigation.

Table 2. Reported nitrogen, phosphate, and potash fertilizer application rates and frequencies for selected bearing tropical fruit crops.[z]

Crop	Annual pounds per acre			
	Nitrogen	Phosphate	Potash	Appl. per year
Avocado	36-288	4-72	36-288	2-6
Mango	54-288	0-72	192-288	2-3
Carambola	8-445	0-167	0-501	1-6
Lychee	24-320	12-360	24-360	1-8
Longan	5-242	14-91	41-273	1-6

[z] Li, Y., J. Crane, B. Boman, and C. Balerdi. 1999. Fertilizer management survey for tropical fruit crops in south Florida. Proc. Fla. State Hort. Soc. 112:172-176.