UF IFAS Extension UNIVERSITY of FLORIDA

HS765

Sustainability Assessment of Fruit and Nut Crops in North Florida and North Central Florida[1]

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Introduction

This article summarizes the degree of adaptation of deciduous fruit and nut species in Florida and identifies cultivars that are recommended for trial in various locations in Florida.

Agricultural sustainability can be defined by models incorporating agricultural inputs and outputs. Agricultural inputs encompass pesticides, irrigation, fertilizer, tree training and pruning, fruit thinning, and farm equipment and machinery. Agricultural outputs include yield, fruit quality, and gross and net profit. Any assessment of sustainability will also take into consideration the amount of labor required for the successful culture of a given commodity and the positive or negative impacts on the natural environment.

Deciduous fruit industries in Florida have changed during the last several decades. The prominence of a given commodity is determined by a multitude of climatic, edaphic, cultural, and economic factors. The subtropical climate of Florida is suitable for the culture of numerous fruit and nut trees. However, some species can only be grown in Florida with the application of numerous agricultural inputs (i.e., fertilizer, pesticides, water, etc.). Certain species/cultivars can be grown successfully in Florida only with the investment of substantial inputs (marginally adapted), while other species/cultivars can be grown with a minimum of inputs (adapted). Some species or cultivars require such an extensive quantity of inputs so as to preclude successful culture (nonadapted) in Florida. There is not always a good correlation between profitability and sustainability. Some of the more demanding crops grown in Florida (southern highbush blueberries, for example) can be very profitable under the right circumstances. By contrast, muscadine grapes are sustainable but offer relatively low profitability and market potential.

Before discussing the adaptability of species and cultivars, one point must be emphasized—the need for proper site selection. Almost without exception, the performance of fruit and nut crops is best in full sunlight and in well-drained soils. In addition, because many species sustain frost injury in the late winter or early spring, avoid planting fruit crops in low-lying locations.

The adaptability of a given species or cultivar is region-specific. A brief assessment of the suitability of adapted and marginally adapted fruit and nut species will follow (Table 1). Table 2 summarizes impediments to the successful

1. This document is HS765, one of a series of the Horticultural Sciences Department, UF/IFAS Extension. Original publication date November 2000. Revised January 2016 and February 2020. Visit the EDIS website at https://edis.ifas.ufl.edu for the currently supported version of this publication.

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culture of some deciduous crop species that are not adapted to north Florida.

In this publication, north Florida is defined as the region of the state north of Perry, which is near the Gulf Coast, north of Lake City, and north of Jacksonville, which is near the Atlantic Coast. North central Florida is defined as the region south of north Florida, but north of Cedar Key, which is on the Gulf Coast, north of Ocala, which is in central Florida, and north of St Augustine, which is on the Atlantic Coast. Central Florida is a region south of the north central zone and north of Interstate 4, which runs through Orlando. Lastly, south central Florida is the area of the state around Sebring and extending northward to Interstate 4.

Chilling Temperatures for Deciduous Crops in Florida

Figure 1 describes the average January temperatures of different regions in Florida. Relatively few deciduous crops are well adapted in the region of Florida that is roughly south of Tarpon Springs on the Gulf Coast and south of Daytona Beach on the Atlantic Coast. In the region of the state south of these cities, annual chilling temperatures are usually inadequate for deciduous crops. As a result, these crops may not have normal leaf and fruit development in the spring.

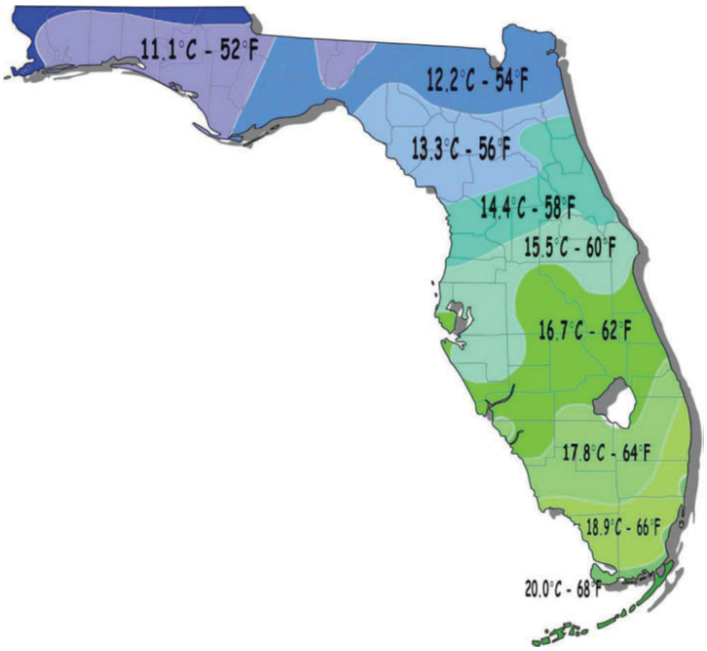

Figure 1. Average January temperatures in Florida.

Most of this publication is, therefore, devoted to the regions of the state that in Figure 1 are colored blue or purple. In these areas of Florida, deciduous fruit trees are likely to have at least 300 chilling units (Figure 2). Chilling units are estimated as the accumulation of hours at an air temperature of 45°F or lower during the dormant season (November through March). The farther north one proceeds in Florida, the greater the available selection of deciduous fruit species/cultivars. For a real-time summary of chill units for various locations in Florida, consult http://agroclimate.org/tools/chill-hours-calculator/. Chilling units are cultivar specific. Insufficient chilling units can result in delayed and prolonged bud break and abnormal growth, which cause uneven shoot development, flowering, and fruit maturity. In extreme cases, the number of flowers can be substantially reduced (Figure 3).

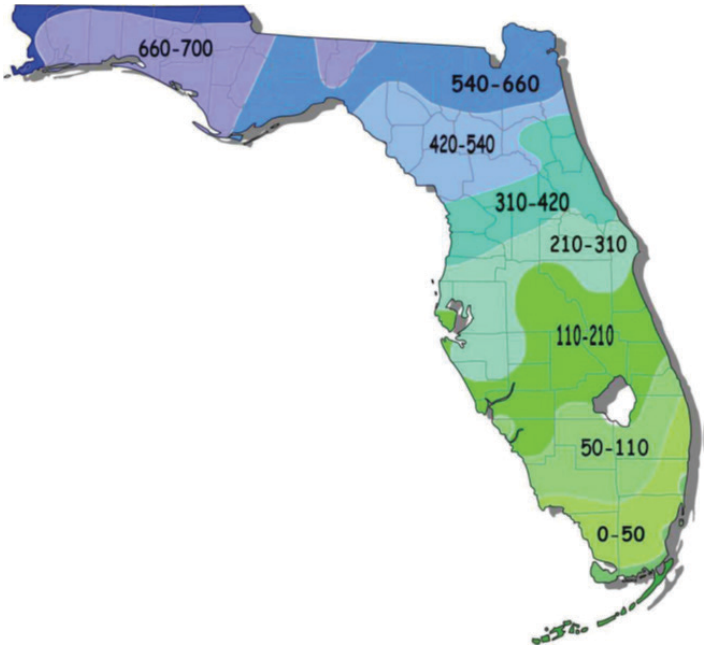

Figure 2. Estimated chill unit accumulation for Florida.

Figure 3. Budbreak in peach cv. 'Tropicbeauty' when (left) chilling requirements have been met, and (right) when they have not. Credits: Ali Sarkhosh, UF/IFAS

Pecan

Pecan trees (*Carya illinoensis* [Wangenh] C. Koch) can be grown without a great deal of care, but consistently high yields are not likely without a rigorous pesticide spray

program, irrigation, and fertilization (Andersen 1992b, 1992c, 1995b, 1996, 1999, 2014).

Limitations to successful pecan culture in the Southeast include:

- A lack of new cultivars of high quality with resistance to pecan scab (*Cladosporium caryigenum,* [Ellis and Langl.] Gottwald) and other leaf diseases;
- A long period before a return on investment can be realized (i.e., the first crop is produced at 4 to 10 years of age depending on the cultivar, culture, and management);
- A retraction of an Internal Revenue Service provision allowing for depreciation of orchards during nonbearing years (which can last 5–10 years);
- Importation of high quantities of pecans from Mexico;
- A lack of a suitable method of tree-size control;
- High and low yields in alternate years (i.e., alternate bearing); and
- Tariffs imposed on pecans exported from the United States.

The acreage of pecan orchards in Florida (12,238 acres) exceeds that of all other deciduous fruit in Florida combined. Recently, there has been some economic incentive for the expansion of pecan-orchard acreage in the southeastern United States and Florida. Since 2008, the worldwide demand for pecans has increased dramatically, mainly because of the emergence of China and other countries as major consumers. Unfortunately, in 2018–2019, China (the largest foreign market for pecans) instituted a high tariff on pecans imported from the United States.

Great advances have occurred in the biological control of insect pests by the use of exotic ladybug beetles to control aphids, the use of leguminous cover crops for maintaining populations of natural enemies, and the Tedder's Trap for monitoring pecan weevils. For more information consult Mizell (2015a). The application of pesticides usually precludes the opportunity for cattle or sheep to graze in pecan orchards because most of these materials are not approved or registered for land used for grazing.

Pecans are assigned a moderate sustainability rating of 5 because a spray program for insect and disease pests is required for most cultivars during most years (Table 1).

The best pecan cultivars for homeowners and commercial pecan growers in north Florida are the following: 'Elliott' (Conner and Sparks 2007); 'Excel' and 'Lakota' (Goff 2015, Wells and Conner 2015); and 'Sumner' (Leidner 1982). 'Amling', 'Eclipse', 'McMillian', and 'Zinner' have excellent scab resistance but are recommended on a trial basis because they have not been adequately tested in Florida. 'Caddo', 'Cape Fear', 'Desirable', 'Forkert', 'Kiowa', 'Moreland', and 'Pawnee' are conditionally recommended because they produce high-quality nuts but require an intensive fungicide program (Goff 2015, Wells and Conner 2015). 'Stuart' is conditionally recommended because many older trees are fairly productive, but newly planted trees can take 10 years to produce a substantial crop. Details concerning pecan cultivars are presented elsewhere (Andersen 1992a, 1995b, 1996, 1999, 2019b, Goff 2015, Sparks 1992a, 1992b, Wells and Conner 2015). A new pecan cultivar trial consisting of 'Amling', 'Caddo', 'Lakota', 'Gafford', 'Apalachee', 'Creek', 'Excel', 'Cape Fear', 'Desirable', 'Curtis', 'Forkert', 'Gloria Grande', 'Elliot', 'Pawnee', 'Moreland', 'Melrose', 'Oconee', 'Sumner', 'Stuart', 'Kanza', and 'Kiowa' has been initiated at the UF/IFAS North Florida Research and Education Center (NFREC)–Quincy. Several different cultivars should be planted together to ensure cross-pollination (Andersen 2017a, Goff 2015, Wells and Conner 2015).

In Florida, pecan production is associated with a January minimum temperature no higher than 58°F or at least 300 chilling units. There is very little information on the performance of pecan cultivars south of Ocala (Arnold 1971).

Peach and Nectarine

The successful culture of peach (*Prunus persica* [L.] Batsch) and nectarine (a glabrous peach) trees requires attention to detail.

Peaches and nectarines can be categorized based on melting- and non-melting-flesh fruit types. Because melting-flesh-type peaches and nectarines tend to incur bruising during handling, those destined for commercial markets are often picked before the optimum time and soften during placement on the grocery shelf. Nonmelting peaches may be picked and shipped at physiological maturity because the flesh is firm and resists bruising. Peaches with nonmelting flesh are somewhat apricot-like in texture.

Many low-chill peaches and nectarines have been developed by the UF/IFAS breeding program, which targets a market window from 1 April to 1 June (Sarkhosh et al. 2018). The optimum chilling requirement for cultivars adapted to north Florida is ca. 350–550 units, and ca. 225–375 units for cultivars adapted to north central Florida.

Some peach cultivars that can be grown in south central Florida require only 75–150 chilling units.

The increase in peach acreage occurs mainly south of Ocala and targets the March/April market window when peaches are not available from the remainder of the United States or from the Southern Hemisphere. The decline in peach/nectarine acreage over the last 30 years in north Florida was due to a high incidence of late winter/early spring frosts. The decreased per capita consumption of peaches in the United States, in general, has also reduced demand, and competition from California growers has increased supply, particularly for mid-to-late-ripening cultivars. However, new low-chill peach and nectarine cultivars released by the University of Florida breeding program offer great potential (Andersen and Sherman 1990, 1994a, 1994b; Sherman et al. 1988, 1995a, 1995b; Williamson et al. 1995a, 1995b; Ferguson et al. 2008; Sarkhosh et al. 2018).

Currently, the best available melting-flesh peaches for north Florida, in the order of ripening, are the following: 'Flordadawn' (Andersen and Sherman 1990); 'Flordaking' (Andrews et al. 1979); 'Flordacrest' (Sherman and Lyrene 1989a, b); and 'Junegold' (Ferguson et al. 2008, Sarkhosh et al. 2018). The best available nectarine for north is 'Suncoast' (Andersen and Sherman 1995a, Ferguson et al. 2008, Sarkhosh et al. 2018).

For north central Florida, the best available non-melting-flesh peach cultivars are 'Flordaprince' (Sherman et al. 1982), 'Flordaglo' (Sherman and Lyrene 1989b), 'TropicBeauty' (Rouse and Sherman 1989b), 'TropicSnow' (Rouse and Sherman 1989a, Williamson et al. 1995a, 1995b, Sarkhosh et al. 2018), and 'Flordabest' (UF patented, Ferguson et al. 2008). 'Sunmist' (Sherman et al. 1995b; UF patented), 'Sunbest' (UF patented, Sherman and Lyrene 2002), and 'Sunraycer' (Sherman et al. 1995a) are the best available nectarines for north central Florida (Ferguson et al. 2008, Sherman et al. 1988, 1995a, 1995b, 1988, Sarkhosh et al. 2018). For the central Florida and south central Florida region, 'Flordaprince' and 'TropicSnow' can be tried in dooryard situations (Ferguson et al. 2008, Williamson et al. 1995a, 1995b, Sarkhosh et al. 2018). 'Tropic Beauty' has performed well in commercial situations and is a standard low-chill cultivar worldwide (Rouse and Sherman 1986b).

Since 1997, non-melting-flesh cultivars have been released from the University of Florida. These cultivars are patented and should be purchased from licensed nurseries. Non-melting-flesh peaches recommended for trial in north Florida are 'Gulfking' (Beckman et al. 2005), 'Gulfcrest' (Krewer et al. 2005), 'Gulfcrimson' (Krewer et al. 2008), and 'Gulfprince' (Sarkhosh et al. 2018, Sherman et al. 2000). These four cultivars are joint releases from the United States Department of Agriculture–Byron, Georgia, the University of Florida, and the University of Georgia. Of the four Gulf series peaches, 'Gulfking' and 'Gulfcrimson' appear to have the greatest potential (Ferguson et al. 2008, Sarkhosh et al. 2018).

The non-melting-flesh peaches and nectarines with a UF prefix are also patented by the University of Florida. 'UFGold' (Sherman and Lyrene 1997), 'UF2000' (Sherman and Lyrene 2000), 'UFBeauty' (Sherman and Lyrene 2003), 'UFBlaze' (Sherman and Lyrene 2003), 'UFGlo' (Sarkhosh et al. 2018), 'UFO' (Sherman and Lyrene 2001b), and 'UFSharp' (Chaparro et al. 2006) are non-melting-flesh peach cultivars. 'UFQueen' (Sherman and Lyrene 1999) and 'UFRoyal' (Ferguson et al. 2008) are non-melting-flesh nectarines, suitable for trial in north central Florida. 'UFSun' (Rouse et al. 2004) and 'UFBest' (Sarkhosh et al. 2018) require 100–150 chilling units and are adapted to south central Florida. Establishment costs can exceed $6,000/acre. For more information about establishment and production costs, consult Singerman et al. (2017).

The agricultural sustainability of peaches and nectarines in Florida is rated as 4 (marginally adapted) due to the high frequency of insecticide and fungicide applications required for successful culture and due to the need to prune and to perform fruit thinning (in the absence of late-winter frosts). Rootstocks that are resistant to the peach root-knot nematode, *Meloidogyne floridensis* (Handoo et al. 2004), such as 'Nemaguard', 'Nemared', and 'Flordaguard', are required to ensure orchard productivity. Currently, 'Flordaguard' is the only commercially recommended rootstock for the sandy soils of south central Florida, although other new rootstocks, such as 'Sharpe' (Beckman et al. 2008) and 'MP-29' (Beckman et al. 2012) are available for trials.

Some common insect pests of these trees in Florida are white peach scale (*Pseudaulacaspis pentagona* Targioni-Tozzetti), San Jose scale (*Quadraspidiotus perniciosus* Comstock), greater peach tree borer (*Synanthedon exitiosa* Say), lesser peach tree borer (*Synanthedon pictipes* Grote & Robinson), plum curculio (*Conotrachelus nenuphar* Herbst), two-spotted spider mite (*Tetranychus urticae* Koch), and several species of stinkbugs (*Nezara viridula* L. and *Leptoglossus* spp.) (Mizell 2015b). The brown marmorated stinkbug (*Halyomorpha halys*) has also been found in Florida.

Some common diseases of these trees in Florida include mushroom root rot (*Armillaria tabescens* [Scop.] Dennis, Orton & Hara), *Botryosphaeria dothidea* (Moug.:Fr) (Ces. & de Not), peach scab (*Cladosporium carpophilium* Thuem.), and brown rot (*Monilinia fructicola,* G. Wint) (Horton et al. 2013). Most peaches and nectarines released from the UF/IFAS breeding program are resistant to bacterial spot (*Xanthomonas campestris* pv. *pruni*). Peaches are not adapted to south of Lake Okeechobee due to inadequate winter chilling in this region and a high probability of fruit fly damage prior to fruit harvest.

Blueberries

Southern Highbush Blueberry

Southern highbush blueberry (*Vaccinim corymbosum* L. × *V. darrowi* Camp) production in central Florida and north central Florida can be profitable because berry ripening in late March and early May coincides with a period of high demand and low supply. This open market window extends to distant markets in the United States as well as to markets in Europe and the rest of the world. However, over the last few years, the market window has been influenced by the importation of blueberries from Mexico.

The genesis of the low-chill southern highbush industry is the UF/IFAS blueberry breeding program. The increase in southern highbush acreage in Florida over the last 30 years, as well as future expansion of this acreage, is influenced heavily by the development of new cultivars.

During the 1980s and early 1990s, 'Sharpblue', 'Misty', and 'Gulf Coast' comprised most of the highbush blueberry acreage in central Florida and north central Florida (Andersen et al. 1991, Williamson and Lyrene 1995). Over the last 20 years, many southern highbush cultivars have been released from the UF/IFAS blueberry breeding program, which has provided growers with many options, but has complicated the overall cultivar selection process. In the mid to late 1990s, 'Star', 'Emerald', and 'Jewel' were released and became the predominant cultivars grown commercially in peninsular Florida (Andersen et al. 2008, Williamson et al. 2019). Since that time, 'Emerald' and 'Jewel' have remained important, but 'Star' acreage has declined due to susceptibility to blueberry leaf scorch (*Xylella fastidiosa*) and other factors. However, there are other new cultivar choices available to growers to address specific needs and concerns (Williamson et al. 2018, 2019). Some cultivars that fulfill a particular "niche" are often included in the cultivar mix on commercial farms. For example, 'Snowchaser', 'Springhigh', and 'Primadonna' are early blueberry cultivars that ripen in a market window (15 March to 15 April) and are potentially very profitable. 'Meadowlark' and 'Farthing' have some potential for mechanical harvest, but 'Meadowlark' has been shown to be susceptible to blueberry leaf scorch. 'Sweetcrisp' has exceptionally high-quality, firm fruit, but yields of 'Sweetcrisp' have been disappointingly low in Florida. 'Flicker' was initially thought to have potential as an early-season cultivar with good flavor and firmness, but it has been very susceptible to anthracnose stem canker. Currently, 'Kestrel' and 'Chickadee' are popular in low-chill areas of central Florida where evergreen production is possible. The UF/IFAS breeding program continues to release new cultivars that may be trialed by growers on a limited basis to evaluate their commercial potential (Williamson et al. 2018, 2019). Williamson et al. (2019) suggested a cautious approach to planting new southern highbush cultivars. Olmstead provided the following assessment on UF cultivars released since 2014: 'Abundance' (rarely planted), 'Springhigh' (stable cultivar for very early season), 'Springwide' (rarely planted), 'Primadonna' (early season but low yield), 'Snowchaser' (very early but fair fruit quality), 'Sweetcrisp' (north Florida/south Georgia potential, but low yield), 'Farthing' (widely planted north of Ocala), 'Scintella' (low plant vigor), 'Bobolink' (minor importance thus far), 'Chickadee' (some potential for low chill areas of central Florida), 'Flicker' (for central Florida, but no longer recommended), 'Kestrel' (potential for very low-chill areas of Florida), 'Meadowlark' (grown primarily in southern Georgia, susceptible to blueberry leaf scorch), 'Raven' (not widely planted), and 'Indigocrisp' (commercial interest, but a very new cultivar).

'Bluecrisp', 'Emerald', 'Jewel', 'Millennia', 'Misty', 'O'Neal', 'Sharpblue', and 'Star' have been evaluated in north Florida (Andersen et al. 2008). At the UF/IFAS NFREC–Quincy, a new trial has been established consisting of 'Emerald', 'Farthing', 'Indigocrisp', 'Legacy', 'Meadowlark', 'Rebel', 'Suziblue', and 'Ventura'. Blueberry cultivars named since 1995 by the UF/IFAS breeding program are all patented, as are recent cultivar releases from the University of Georgia and elsewhere. For north Florida, 'Camellia', 'Georgiagem', 'Legacy', 'O'Neal', 'Palmetto', 'Rebel', 'Southern Belle', 'Suziblue', and 'Ventura' may also be trialed (Krewer and NeSmith 2006).

The cultivation of southern highbush blueberries requires attention to detail from proper site selection (and soil amelioration) to pest control. The single greatest impediment to successful production of this berry in Florida is the probability of late-winter/early-spring frost during bloom and early fruit development. Consequently, it is necessary for

growers to use overhead irrigation to reduce the probability of frost/freeze injury. The likelihood of frost injury and later berry ripening in north Florida has reduced profitability for this fruit in north Florida (Andersen 1995a).

Other limitations for cultivation of southern highbush blueberry in Florida include a requirement for soils with a low pH and high organic-matter content. Pine bark is a virtual necessity. Establishment costs can exceed $25,000/acre. There may be many pest control issues (insects, disease, and birds). High labor requirements are involved in hand harvesting, and the development of cultivars that are efficiently and mechanically harvested is a selection criterion by blueberry breeders. For more information about establishment and production costs, consult Singerman et al. (2016).

The limitations are consistent with the placement of southern highbush blueberries in the moderately adapted category. As such, this berry has been assessed as 5 in terms of agricultural sustainability in Florida.

Rabbiteye Blueberry

Acreage of rabbiteye blueberries (*Vaccinium virgatum* Aiton) in Florida has not expanded substantially during the last few decades, largely as a result of competition with North Carolina's highbush industry. Although the UF/IFAS breeding program has emphasized development of early-ripening rabbiteye, such cultivars have a lower chilling requirement and often sustain frost injury in late winter.

The rabbiteye blueberry, native to north Florida, is resistant to most insect and disease pests in this region. Rabbiteye blueberries are, therefore, classified as a highly sustainable crop for north Florida (i.e., sustainability of 9). In Gainesville and further south, however, the culture of rabbiteye blueberries can be more difficult due to inadequate chilling in certain years and perhaps due to enhanced insect and disease pressures farther south in Florida.

Rabbiteye blueberries are more vigorous than highbush blueberries and have less-exacting soil requirements. Rabbiteye blueberries are labor intensive mainly due to the time required for hand harvesting. For U-pick operations, recommended rabbiteye blueberry cultivars include the following: 'Austin', 'Climax', 'Chaucer', 'Woodward', 'Bluebelle', 'Bluegem', 'Brightwell', 'Powderblue', and 'Premier' (Williamson and Lyrene 1995, 2004). For the northernmost portions of the north Florida region, Andersen (1995a) recommended 'Woodard', 'Premier', 'Powderblue', 'Tifblue', and 'Brightwell'. Chilling-induced problems with fruit seldom occur in those northernmost portions of the state, although late-spring frosts have reduced yield of cultivars with a low-chilling requirements (Andersen 1995a, Andersen et al. 1991). 'Arapaho', 'Austin', 'Brightwell', 'Climax', 'Ira', 'Ochlocknee', 'Powderblue', 'Premier', 'Savory', and 'Yadkin' were evaluated in north Florida and have all performed well (Andersen et al. 2009). 'Brightwell' produced the highest yield; 'Savory' produced the largest berry size but is no longer recommended due to bush dieback. 'Climax' produced berries with the highest sugar content. For Gainesville and northward in Florida, alternating rows of 'Climax', 'Bluegem', 'Brightwell', and 'Powderblue' have been recommended for the fresh market, utilizing machine harvesting (Williamson and Lyrene 1995, 2004). However, mechanical harvesting of rabbiteye blueberries is best suited for processed fruit. In addition, 'Meadowlark' and 'Farthing' (and other southern highbush blueberry cultivars in the development stage) are better suited for mechanical harvest.

Grapes

Muscadine Grapes

Muscadine grapes (*Vitis rotundifolia* Michx.) are native to north Florida and are a sustainable crop in the southeastern United States because a minimum of agricultural inputs (beyond vineyard establishment) are required for successful production (Andersen and Mortensen 1989, Andersen 1992a, Andersen et al. 2017). Successful crops of muscadine grapes can be grown in north Florida without any insecticide or fungicide applications.

The profitable segment of the muscadine grape industry is based on the large-fruited cultivars that are sold in U-Pick or direct market. These grapes are also shipped to moderate-distance markets as far as Miami. Although muscadine juice or wine grapes such as 'Noble' and 'Carlos' usually produce over 10 tons per acre, they are often not profitable due to low prices offered by wineries or juice processing facilities.

Muscadine cultivars that are rated highly for the fresh market include the following: 'Farrer', 'Fry', 'Granny Val', 'Jumbo', 'Ison', 'Summit', 'Nesbitt', 'Polyanna', 'Triumph', 'Supreme', 'Black Fry', 'Early Fry', 'Pam', 'Black Beauty', 'Pineapple', and 'Sweet Jenny'. All of the above cultivars except 'Fry', 'Jumbo', 'Summit', 'Nesbitt', and 'Polyanna' are patented by Ison's Nursery.

The fresh-market grapes 'Late Fry', 'Ison', 'Nesbitt', 'Florida Fry', 'Granny Val', 'Ison', 'Pineapple', and 'Polyanna' are self-fertile and do not require a pollinizer cultivar. 'Farrer', 'Fry', 'Jumbo', 'Summit', 'Supreme', 'Black Fry', 'Early Fry', 'Pam',

'Black Beauty', and 'Sweet Jenny' are pistillate cultivars and require a pollinizer. 'Noble', 'Welder', and 'Carlos' are self-fertile and are the best muscadine juice and wine grapes (Andersen et al. 1985, 1989, 2017; Olien 1990). Quantitative data on the performance of new muscadine grape cultivars are now available (Andersen et al. 2017).

Bunch Grape

Southern bunch grapes (*Vitis* hybrids) developed by the UF/IFAS breeding programs were promoted during the 1980s as a substitute for high-quality European (*Vitis vinifera* L.) or American (*Vitis labrusca* L.) grapes (Andersen 2017c). These latter two species cannot be grown in the southeastern United States due to susceptibility to a disease caused by a gram-negative bacterium (*Xylella fastidiosa* Wells et al.) and vectored by leafhoppers (Mizell et al. 2015). Poor yield and quality, as well as a lack of disease resistance, are major reasons for the drastic decline in acreage of bunch grapes in Florida. Bunch grapes are attacked by numerous fungal diseases, the most serious of which is anthracnose (*Elisone ampolina* Shear) (Andersen 2017c). Bunch grapes are among the least-sustainable crops that can be grown in Florida. Bunch grapes require numerous pesticide applications (Andersen 2017c). Moreover, no other crop has more worldwide competition.

'Stover', 'Suwannee', 'Blanc du Bois', 'Black Spanish', and 'Conquistador' are mainly planted for wine production (Andersen 2017c). 'Daytona' and 'Orlando Seedless' are fresh-market bunch grapes grown in Florida.

Oriental Persimmon

Interest in oriental persimmons (*Diospyros kaki* L.) has increased greatly in north Florida and north central Florida with the introduction of nonastringent cultivars from Japan (Miller and Crocker 1994). Consumer demand is sufficiently high, such that virtually all persimmons that are grown in Florida are marketed locally. Both local and distant markets have created an opportunity for an expansion in persimmon acreage in Florida.

The major impediment to successful persimmon culture in Florida is fungal gummosis caused by *Botryosphaeria* spp. (Miller and Crocker 1994). Leaf spot fungi, *Cephalosporium diospyri* Crandell and *Cercospora* spp., can also induce premature defoliation and stress the tree (Miller and Crocker 1994). Insect pests include wood borers, psylla, and soft scale and armored scale pests (Mizell and Brinen 2015). As a result, oriental persimmons are marginally adapted to north Florida and north central Florida and have a sustainability rating of 5.

Miller and Crocker (1994) recommended 'Izu', 'Mastsumoto Wayse Fuyu', and 'Fuyu' for trial in north Florida and north central Florida. Andersen (1993b) reported that 'Fuyu' was the best persimmon cultivar for north Florida.

Blackberry

Blackberries (*Rubus* spp.) have been grown in small-acreage plots throughout the northern part of Florida for many years. Consumer demand is extremely high; however, the culture and management of blackberries is labor intensive. Perhaps the most serious disease of blackberries is double blossom (*Cercosporella rubii* [Win., Plak]), followed by anthracnose (*Ellisone veneta* [Burkh.] Jenk.) and rust (*Gymnoconia* spp., *Kuehneola* spp., and *Kunkelia* spp.) (Andersen et al. 1995, Andersen 2017b). Insect pests include cane borers, thrips, mites, aphids, flea beetles, and stinkbugs (Mizell 2007d, Liburd et al. 2017). Blackberries are rated a 6 in terms of agricultural sustainability.

At the UF/IFAS NFREC in Monticello, Florida, thornless blackberry cultivars have been grown successfully without the application of pesticides (Andersen et al. 1995, Andersen 2017).

Prior to 1985, blackberries grown in Florida were cultivars released from the University of Florida such as 'Oklawaha', 'Flordagrand', and also 'Brazos' from Texas (Andersen 2017b). However, recent introductions in north Florida of blackberry cultivars from the University of Arkansas have become increasingly popular. Most of the University of Arkansas cultivars are resistant to double blossom. The thorny cultivars include 'Shawnee' (Moore et al. 1985) and 'Kiowa' (Moore and Clark 1996). Thornless blackberry cultivars include 'Arapaho' (Moore and Clark 1993), 'Navaho' (Moore and Clark 1993), 'Apache' (Clark and Moore 1999a), 'Ouachita' (Clark and Moore 2005), 'Natchez' (Clark and Moore 2008), and 'Osage' (Clark 2013). The primocane-fruiting cultivars 'Prime-Ark', 'Prim-Jan' and 'Prim-Jim' are not adapted to Florida. Based on the available information 'Ouachita', 'Natchez', and 'Osage' may be the best cultivars for north Florida. All of the recent blackberries from the University of Arkansas are patented. The southern limit of adaptation for these cultivars appears to be north or north central Florida.

Plum

Although there is no significant plum industry in Florida, the culture of plums offers some potential for homeowners (Sarkhosh et al. 2018). The University of Florida has released and patented 'Gulfbeauty' (Sherman and Lyrene

1998), 'Gulfblaze' (Sherman and Lyrene 1998), and 'Gulfrose' (Sherman and Lyrene 2001a). These plum cultivars are adapted to north Florida and to north central Florida and are recommended for grower trial. Fruit size of the Florida plums is 1¾–2 inches in diameter. The Gulf series of plums begin to ripen in early May, about two weeks before plums from California arrive in the marketplace. These cultivars are resistant to plum leaf scald (*Xylella fastidiosa* (Mizell et al. 2015) and bacterial spot (*Xanthomonas campestris* pv. *pruni*) (Sarkhosh et al. 2018). 'Gulfgold' and 'Gulfruby' are sometimes found in the nursery trade but are not recommended because of susceptibility to plum leaf scald and bacterial spot, respectively (Sarkhosh et al. 2018).

There are many other plums from the Alabama breeding program and elsewhere (e.g., 'Au-Cherry', 'Au-Roadside', 'Au-Rosa', 'Au-Rubrum', 'Byrongold', 'Excelsior', 'Methley', 'Ozark Premier', 'Rubusto', 'Santa Rosa', and 'Segundo'). However, most of those cultivars have not been adequately evaluated in north Florida. Those cultivars also have a high chilling requirement, and some are susceptible to plum leaf scald.

Low-chill plums should be propagated on nematode-resistant rootstocks, such as 'Flordaguard' peach or 'Sharpe' plum. The difficulty in growing plums in Florida is somewhat similar to the challenge of growing peaches and nectarines in Florida. For example, plum curculio, peach tree borers, and stinkbugs are common insect pests (Mizell 2015c), and brown rot is a common disease (Horton et al. 2007). Plums in Florida have a sustainability rating of 4. For more information on plums, consult Sarkhosh et al. (2018).

Mayhaw

Mayhaws (*Crataegus aestivalis* [Walter] Torr. & A. Gray, *Crataegus rufula Sarg.* or *Crataegus opaca* Hoak. & Arn.) produce small apple-like fruit that ripen in late April or early May in Florida (Krewer and Crocker 1997, Krewer et al. 1993). This specialty fruit is mainly used for making jelly. Mayhaws can grow in well-drained soils or in swampy areas and will grow as far south as Lake County, FL, just north of Orlando. There is low potential for expansion of commercial mayhaw acreage in Florida, although there is potential for expansion in direct-to-consumer outlets.

Mayhaw cultivars for the southeastern United States include the following: 'Lori', 'Lindsey', 'Big Red', 'Red and Yellow', 'Heavy', 'Mason's Super Berry', 'T. O. Super Berry', 'Highway Super Berry', and 'Super Spur' (Krewer et al. 1993). Mayhaw is native to the southeastern United States and has relatively few pest problems in this region. Perhaps the two greatest pests of mayhaw are plum curculio and deer. Mayhaw is rated as a sustainable crop for Florida.

Chestnut

Chinese chestnuts (*Castanea mollisima* Blume) and Chinese chestnut × American chestnut crosses (i.e., Dunstan chestnut hybrids) can be grown in Florida (Hochmuth et al. 2012). Many small plantings of the chestnut are in the Gainesville area.

The chestnuts must be harvested every other day and stored under refrigeration because fungi and bacteria will attack the nuts on the ground. The nuts should be stored under high-humidity refrigeration to prevent the nuts from drying and becoming too hard to eat. Gloves should be used when harvesting because of the spines on the nut burr.

Demand for chestnuts is high and some expansion in chestnut acreage in Florida is likely. Chestnuts have relatively few pest problems and are a fairly sustainable crop for north Florida and north central Florida. 'Carolina', 'Carpenter', 'Revival', 'Williamette', and 'Heritage' are some cultivars available for trial (Brinen 2007, Hochmuth et al. 2012). Due to a problem with graft incompatibility, seedlings are now often being sold in the nursery trade (Bob Wallace, personal communication).

Apple

Apples (*Malus domestica* Borkh.) are not significant crops in Florida due to the year-round availability of high-quality apples and pears from the Pacific Northwest. They are also susceptible to a multitude of insect and disease pests. However, low-chill cultivars of apples are often grown by homeowners in Florida (Andersen 1990, 2019a). 'Anna' is a cultivar from Israel and 'Dorsett Golden' originated in the Bahamas (Andersen 2015). A patented low-chill apple, 'TropicSweet', has also been released from the Florida breeding program (Andersen 2019a, Sherman and Lyrene 1996). Most apple cultivars require cross-pollination. The most serious diseases of apple include white rot (*B. dothidea*), black rot (*Botryosphaeria quercuum* [Schwein] Sacc), pear leaf spot (*Fabraea maculata*), and Cercospora leaf spot (*Pseudocercospora mali* Ellis & Everh.). Apples are rated as a marginally adapted species for Florida and have a sustainability rating of 3.

Pear

The European pear (*Pyrus communis* L.) is not adapted to Florida. Pear (*Pyrus serotina* L.) cultivars adapted to north Florida and north central Florida include 'Flordahome',

'Hood', 'Tenn', 'Baldwin', 'Kieffer', 'Orient', and 'Pineapple' (Andersen 1991). 'Baldwin', 'Kieffer', 'Orient', and 'Hood' are self-fruitful. However, 'Flordahome' and 'Pineapple' require cross-pollination. Some cultivars of pears are susceptible to many of the fungal diseases listed for apple. Pear have a moderate sustainability assessment of 5.

Fig

The fig (*Ficus carica* L.) is not a commercially important crop in north Florida, nor is it likely to be commercially important in Florida in the future. Virtually the entire fig acreage in Florida is in homeowner settings. The greatest limitation to fig production in Florida is due to winter freezes or late winter frosts, which generally prevent figs from growing into a tree form. This effect of cold weather on fig trees is why they are commonly thought of as a bush, rather than as a tree (Andersen and Crocker 2016). Fig rust (*Cerotelium fici*) is the most common disease of fig. They are also susceptible to nematodes, particularly in sandy soils. As a result, figs were rated a 7 in terms of agricultural sustainability in Florida.

The most common fig cultivars include 'Brown Turkey' and 'Celeste'. 'Alma', 'Black Spanish', 'Conadria', 'Celeste', 'Jelly', 'Osborne Prolific', 'Pasquala', 'Tena', and 'Ventura' have also been grown with success at the NFREC in Monticello. (Andersen 1993a).

Satsuma

From both a homeowner and a commercial perspective, there has been a resurgence of interest in growing cold-hardy citrus in north Florida and north central Florida. Prior to the 1980s, mature specimens of satsuma (*Citrus unshiu* Marcovitch) were not uncommon in north Florida. Since then, however, three major freezes virtually eliminated citrus in this region. Since 1990, new plantings of satsuma have been established in north Florida. Several cultivars of satsuma include 'Owari' (most popular), 'Brown Select', 'Kimbrough', 'Silverhill', and 'Xie Shan' (Andersen and Ferguson, 2015). Average yields of 20 tons per acre have occurred at the NFREC–Quincy for 'Brown Select' over a five-year period (Andersen and Brodbeck 2015, Andersen and Ferguson 2015).

Satsuma cultivars north of Ocala should be grafted on *Poncirus trifoliata* rootstocks. When properly conditioned to the cold, satsumas are hardy down to 12°F–14°F. Fruit are usually harvested in late November, thereby avoiding freeze damage to the fruit. For homeowner citrus plantings, trees should be planted on the south side of a house or other structure to minimize exposure to cold north or northwest winds. Microirrigation can be employed to reduce the probability of freeze injury. Soil can be mounded in a pyramid around the trunk of a tree during extremely cold conditions. Alternatively, for small trees, one can place a large garbage can or a portable structure over the top and place a 60-watt lightbulb on the ground under the shelter to warm the tree in cold weather. This practice will protect a young tree under any conditions that may occur in north Florida.

In north Florida and north central Florida, satsuma is a sustainable crop compared to apple and peach and requires relatively few pesticides (Andersen and Ferguson 2015). Satsuma is assigned a sustainability rating of 8. Citrus leaf miner (*Phyllocnistis citrella* Stainton) and citrus scab (*Elsinoe fawcetti* Bitancourt and Jenkins) may be the most common pests of citrus in north Florida. For more information on pests of citrus, consult Rouse and Zekri (2015).

Kumquat

Kumquat (*Fortunella* × *crassifolia*) is another type of citrus adapted to north Florida. Kumquat is at least as cold-hardy as satsuma. 'Meiwa', 'Nagami', 'Murumi', and 'Hongkong' are some of the available kumquat cultivars. The culture and management of kumquat is similar to that described for satsuma. Kumquat is relatively pest-free and has a sustainability rating of 8.

Olives

Olives have been successfully grown in north Florida (Thetford et al. 2017, Mulvaney et al. 2019). Most olives are pressed for olive oil. Approximately 25 pounds of olives yield about 1 quart of olive oil. 'Arbequina', 'Arbosana', 'Koroneki', 'Manzanillo', and 'Mission' are being grown in north Florida/south Georgia. 'Koroneki' have performed the best thus far. Olives appear to be a sustainable crop (rating of 8). Potential profitability has not yet been established.

Pomegranate

The statewide acreage of pomegranate is estimated to be around 150 acres. There is renewed interest and increased demand for fresh fruit, juices, and other products. We need more information to accurately assess sustainability or profitability (Sarkhosh and Williamson 2018).

Conclusion

Few cultivars of deciduous fruit and nut trees available for sale locally are sufficiently adapted to Florida's humid, subtropical climate to be grown in a sustainable manner. Limitations to successful culture may occur in the form of adverse climate (high humidity, high temperature, lack of winter chilling, risk of late winter/early spring frosts), soil conditions, or intense insect and disease pressures.

For a marginally adapted species, many of these barriers can be overcome with a substantial investment of resources and labor. Nonadapted species will experience severe limitations, such as to preclude successful culture. The more similar the climate and soils of a given species' native range to those of Florida, the more successful the species will likely be in Florida.

Native species such as muscadine grapes (*Vitis rotundifolia* Michx.) or rabbiteye blueberries (*Vaccinium virgatum* Aiton) have more potential for sustainable production in Florida whereas apples (*Malus domestica* Borkh), peaches (*Prunus persica* [L.] Batsch), or European bunch grapes (*Vitis vinifera* L.), all not native to Florida, require substantial agricultural inputs to be grown successfully in Florida.

Certain commodities that offer the highest growth potential and net profitability require substantial agricultural inputs. Peaches, nectarines, and southern highbush blueberries that ripen during an early market window (15 March to 15 May) are examples of crops with high profit potential. However, these crops rank rather low in terms of sustainability in Florida.

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Table 1. Adapted and marginally adapted species for North Florida and North Central Florida.

Fruit Crop	Approximate Acreage[y]		Reasons for Increase/Decrease in Acreage	Commercial Potential	Direct-to-Consumer Potential	Assessment of Agricultural Sustainability
	2017	2002				
Pecan (*Carya illinoensis* [Wangenh.] C. Koch)	8,079	10,656	Some new cultivars have potential. Many old cultivars are susceptible to scab and other leaf diseases. Long period required for return on the investment. Much acreage is not well-managed.	Low	Moderate	5
Peach/Nectarine (*Prunus persica* [L.] Batsch)	1,025	455	Choices of cultivars has recently improved. Susceptible to late winter frost. Insect and disease pressure are high. Competition from California increases after mid-May.	High	High	4
Plum (*Prunus salicina* L.)	94	35	New plum leaf-scald-resistant cultivars are available. Susceptibility to late winter frost. High insect and disease pressure.	High	High	4
Southern highbush blueberry (*Vaccinium* hybrid)	16,054	1,146	Excellent market niche for fresh-market shipment nationally and worldwide in March and April. Much of the highbush blueberry industry has moved to south central Florida.	High	Moderate	5
Rabbiteye blueberry (*Vaccinium virgatum* Aiton)	1,000*	500*	Acreage has not increased as much as southern highbush industry due to competition from highbush blueberry production in North Carolina.	Moderate	High	9
Muscadine grape (*Vitis rotundifolia* Michx.)	1,595*	688*	Large-fruited cultivars for fresh market are potentially profitable. Low prices offered for wine or juice grapes. Good insect and disease resistance. Limited consumer acceptance.	Low	Moderate	8
Bunch grape (*Vitis* hybrid)	50*	100*	Low yield per hectare. Poor disease resistance. High competition from grapes that are produced worldwide.	Very Low	Very Low	2
Apple (*Malus domestica* L.)	160	54	Poor quality. High insect and disease pressure. High- quality fruit are available year-round from the Pacific Northwest.	Low	Low	3
Pear (*Pyrus serotina* L.)	?	48	Poor quality. High disease pressure. High-quality fruit are available year-round from the Pacific Northwest. Some homeowner potential.	Low	Low	5
Oriental persimmon (*Diospyros kaki* L.)	58	537	High consumer demand for fresh-market nonastringent persimmon. Demand for astringent types is not high. The major limitation is *Botryosphaeria* spp.	Moderate	High	5
Blackberry (*Rubus* spp.)	200*	85	New thornless cultivars from Arkansas breeding program offer potential for north Florida growers.	Moderate	High	6
Dunstan hybrid Chestnut (*Castanea dentata* L. × *C. mollisima* Blume)	323	651	There is a need for frequent harvest (i.e., high labor and perishability may limit expansion). Resistant to most insects and diseases.	Moderate to High	Moderate to High	7
Mayhaw (*Crataegus* spp.)	?	?	Specialty crop with high consumer demand for jelly.	Low	Moderate	7
Fig (*Ficus carica* L.)	50	2	High incidence of freeze and frost damage to vegetative	Low	Low	7
Satsuma (*Citrus unshiu* Marcovitch)	350	50	Cold-hardy citrus that is relatively pest-free. Fruit are mostly seedless with ripening in Nov./Dec.	High	High	8

Kumquat (*Fortunella* × *crassifolia*)	59	73	Kumquats are at about as cold hardy as satsuma. Relatively pest free.	Moderate	High	8
Olives (*Olea europaea* L.)	80*	3	Relatively easy to grow with apparently few pests. Profitability has not been established.	Not known	Moderate	8
Pomegranate (*Punica granatum* L.)	146	?	Recent interest due to health benefits. The sustainability/profitability are not known.	Moderate	Moderate to high	?

[y] Assessment of agricultural sustainability by USDA Agricultural Census 2002 and 2012. ? =No updated USDA Agricultural Census available for the individual crop by State. *P. C. Andersen estimates where USDA data are lacking. Agricultural sustainability incorporates all necessary inputs (water, pesticide, fertilizer, trellises, mulches, etc.) for successful production based on a scale of 1–10 with 1 = least sustainable and 10 = most sustainable.

Table 2. Nonadapted species for Florida and limitations to these species' successful culture in Florida

Species	Limitations
Almond (*Prunus amygdalus* Batsch)	High-humidity-induced fungal disease; almond leaf scorch.
Apricot (*Prunus armeniaca* L.)	Unreliable cropping due to inadequate chilling and fluctuating temperatures during winter.
Cherry Sweet (*Prunus avium* L.), Sour (*Prunus cerasus* L.)	Inadequate chilling; foliar diseases.
Cranberry (*Vaccinium macrocarpon* Ait.)	Lack of winter chilling. Requires low temperatures during the growing season and low pH soils with high organic matter.
Filbert (*Corylus avellana* L.)	High incidence of frost damage to flowers that bloom during the winter; high induced foliar diseases.
Grapes (*Vitis vinifera* or *V. labrusca*)	Pierce's disease; many diseases associated with high summer temperatures, humidity, and rainfall.
Kiwi (*Actinidia deliciosa* A. Chev.)	Unreliable cropping due to inadequate winter chilling and spring frosts. Nematodes.
Pistachio (*Pistacia vera* L.)	High-humidity-induced foliar diseases. Inadequate winter chilling.
Raspberry (*Rubus* spp.)	Only one cultivar ('Dorman Red') can tolerate hot humid conditions of the southeastern United States and its quality is poor.
English Walnut (*Juglans regia* L.)	High-humidity-induced foliar diseases. Inadequate winter chilling.
Black Walnut (*Juglans nigia* L.)	Can be grown successfully in good soils located in extreme north Florida. Quantitative data are needed.