SL 193

Common Soils Used for Citrus Production in Florida[1]

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According to the 2000 commercial citrus inventory conducted by the Florida Agricultural Statistics Service, Florida citrus groves occupied 832,250 acres in four major production regions (Figure 1). Depending on geographical region, most citrus has been planted on soils belonging to one of three *soil orders*: Entisols, Spodosols, or Alfisols (Figure 2). Entisols are found mostly on the Central Florida ridge, while the majority of Spodosols are on the flatwoods and marshes of southwest Florida. Florida's Indian River citrus-growing area near the east coast contains a mixture of Alfisols and Spodosols.

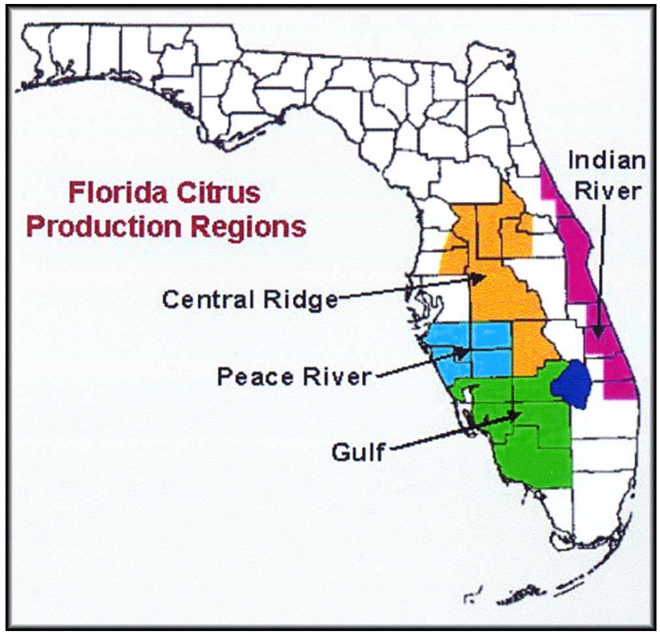

Figure 1. Florida citrus production regions.

General Characteristics of Soil Orders Important to Florida Citrus Production

A soil order is the most basic category of soil classification. Twelve soil orders exist in the USDA Soil Taxonomy classification scheme. The order gives a general idea about some of the physical and chemical characteristics of a soil. For Florida citrus soil orders, characteristics important to production are described below.

Entisols are sandy mineral soils low in organic matter, natural fertility, and water-holding capacity. These soils have weak or no diagnostic subsurface layers and are generally well drained. The establishment of Floridas citrus industry as a major commercial enterprise occurred as a result of plantings on these soils.

Spodosols are sandy mineral soils low in organic matter and natural fertility in the surface layer. These soils contain an acidic subsurface hardpan composed

1. This document is SL 193, one of a series of the Soil and Water Science Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. Published March 2002. Reviewed October 2008. Visit the EDIS Web Site at http://edis.ifas.ufl.edu.
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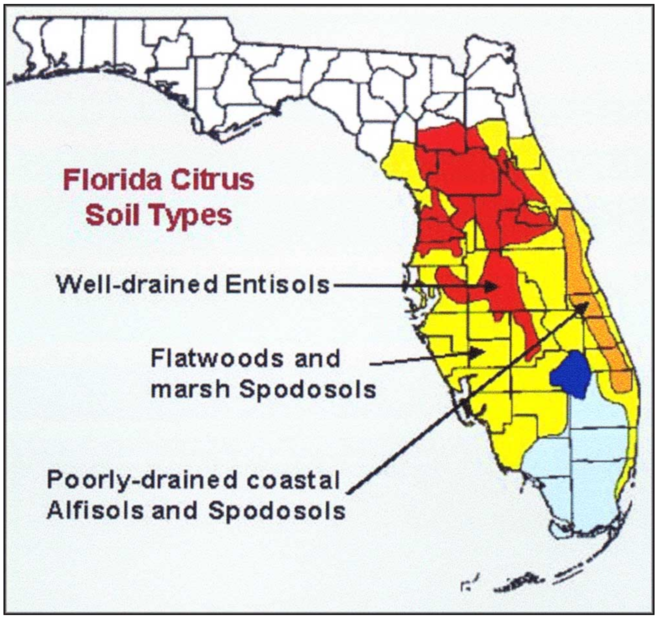

Figure 2. Soil orders on which citrus is planted in Florida.

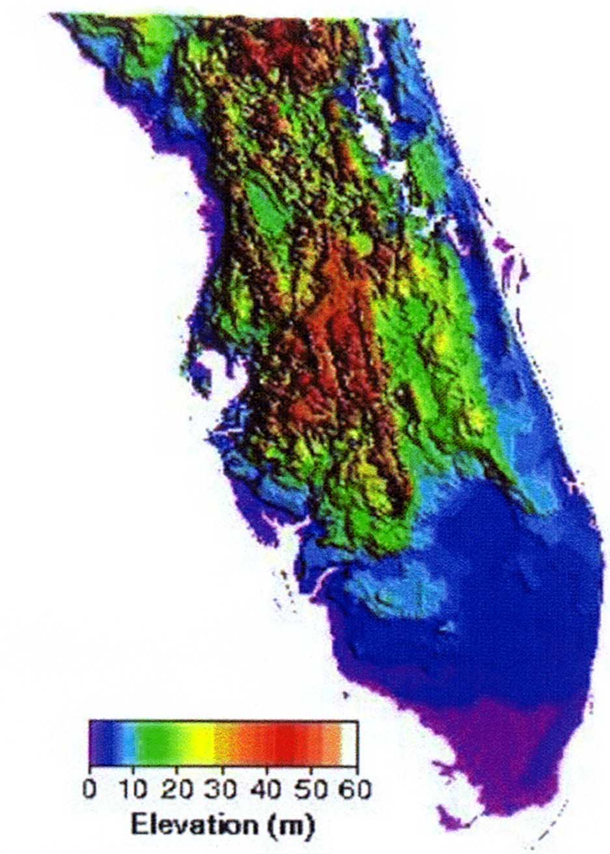

Figure 3. Topography of the Florida peninsula. Multiply meters by 3.28 to calculate ft above mean sea level.

of aluminum and iron “cemented” together with organic matter. The hardpan imparts poor drainage to most south Florida Spodosols, thus they cannot support healthy citrus production without an artificial drainage system. The southern movement of Florida's citrus industry following freezes in the early 1980s resulted in many new plantings on these soils.

Alfisols are sandy mineral soils low in organic matter in the surface layer but higher in relative natural fertility compared with Spodosols. These soils contain a subsurface layer of loamy material (a mixture of mostly clay and sand with little silt) that has a relatively high water-holding capacity. The loamy layer can cause these soils to be poorly drained, so artificial drainage is needed for citrus production as it is with Spodosols. Much of Floridas Indian River grapefruit, known for its high quality, comes from groves planted on these soils.

Specific Soils Typically Found in Citrus Groves

Although commercial citrus groves in Florida can be found almost anywhere from Lake County to the south, nine major citrus-producing counties contained more than three-fourths of the state's acreage in 2000 (Table 1). Fifteen *soil series* are most typical for citrus plantings, but not all of them are located in each county. A soil series is the most specific category of soil classification.

The general characteristics of these soil series can differ in landscape position, slope, natural drainage, and existence and type of subsurface restrictive layer (Table 2). Essentially all soil material on which Florida citrus is grown originated from marine sediments that were deposited as a result of the cyclical rise and fall of sea level through geologic time. The Entisols in Table 2 (other than Basinger) occur on high ridges and upland plains at an elevation greater than 100 ft above mean sea level (MSL) in the Central Ridge production area. Alfisols, Spodosols, and the Basinger soil series occur on broad, low flat areas or in sloughs at elevations from near MSL to about 35 ft in the Gulf and Indian River production areas, and 35 to 100 ft in the Peace River production area (Figure 3). Some of the Alfisols and Spodosols in Table 2 can also occur in depressional areas, even though they are normally located a little higher on the landscape.

Table 1. Land area planted to citrus and typical soil series found in nine counties accounting for 77% of Florida citrus acreage in 2000.

County	Production region	Citrus acres	Common soil series planted to citrus
Polk	Central Ridge	101,484	Candler, Tavares, Astatula
Hendry	Gulf	99,437	Oldsmar, Immokalee, Holopaw, Boca
St. Lucie	Indian River	98,899	Pineda, Riviera, Winder, Wabasso
Highlands	Central Ridge	78,132	Astatula, Basinger, Myakka
DeSoto	Peace River	71,781	Smyrna, Immokalee, Myakka
Indian River	Indian River	60,293	Riviera, Pineda, Wabasso, Winder
Hardee	Peace River	53,115	Pomona, Smyrna, Myakka
Martin	Indian River	44,746	Wabasso, Pineda, Riviera
Collier	Gulf	35,302	Immokalee, Pineda, Oldsmar, Boca

Central Ridge Entisols on which citrus has been planted are moderately to excessively well drained due to their sandy texture, relatively high elevation, and landscape positions that can have up to 8% slope. On the other hand, flatwoods Alfisols and Spodosols that support citrus are poorly to very poorly drained in their natural state because although the surface texture is sandy, the sub-surface *argillic* (clay) or *spodic* (organic hardpan) layer restricts downward water flow. These layers can be as shallow as 12 inches or as deep as 80 inches below the soil surface. The depth to the restrictive layer sometimes differentiates one soil series from another. An additional factor that contributes to poor drainage is a minimal horizontal gradient (slope). Most south Florida Alfisols and Spodosols exist on a flat landscape with relatively low elevation, so little driving force exists for surface water flow unless it is artificially provided by a network of furrows, ditches, canals, and drainage pumps.

A Word About Landscape Positions in the South Florida Flatwoods

The south Florida landscape positions *flatwoods*, *sloughs*, and *depressions* can look very similar, and can differ by as little as 6 inches in depth to the wet season water table:

Flatwoods occupy the highest positions on the landscape and are rarely under water.

Sloughs occupy transitional areas between flatwoods and depressions, and usually have overland sheet flow of slowly moving water during the wet season.

Depressions remain under ponded water for 6 to 12 months during the year.

Soil Physical and Chemical Characteristics Important to Citrus Production

The soil on which citrus is grown greatly influences how irrigation water, nutrients, and other agrichemicals should be managed to maximize production while minimizing resource use and effects on the environment. Soil properties that influence water management include soil texture, hydraulic conductivity, water-holding capacity, and natural drainage, while nutrient management is influenced by these factors plus organic matter content, soil pH, cation exchange capacity, and coatings on sand grains (Tables 2 and 3).

Soil texture is the relative proportion of sand, silt, and clay in a mineral soil. Texture influences how much water a soil can hold against drainage by gravity and how quickly water will drain away if it has an outlet. Florida citrus soils are dominated by the sand fraction (Table 3). Except for the Winder series, citrus soils contain 94% or more sand in the root zone, with about half of the series having 97% or more sand. These high sand concentrations make irrigation water management extremely difficult because sands are dominated by large pores that have little capacity to hold water through capillarity. Therefore, if too much water is applied during irrigation, the excess will be lost below the root zone and can induce nutrient leaching. On the other hand, large pores are beneficial for healthy growth of citrus since they allow a soil to drain rapidly following heavy rain.

Soil organic matter includes anything that was once alive, from freshly deposited plant residues to highly decomposed humus. In their native state, typical citrus soils may contain as much as 5% organic matter under grass vegetation, and somewhat less under pine and palmetto cover. Cultivated soils usually contain less organic matter than native soils due to decreased plant diversity and the use of herbicides. Native soils planted to citrus usually reach a lower state of organic matter equilibrium by the time the trees reach maturity (Table 3). In general, the more chronically wet a citrus soil is, the higher its organic matter content tends to be. For example, the Winder soil is usually the wettest of the Alfisols in Table 3, thus its organic matter content tends to be a little higher. Soil organic matter is rapidly lost by oxidation to carbon dioxide in Florida's warm and humid climate, and it is not replaced in large quantities by citrus trees. Use of herbicides beneath tree canopies also decreases organic matter accumulation. In a sandy soil, organic matter is an extremely valuable component because it provides both water and nutrient-holding capacity, and its decomposition provides recycled nutrients to plants.

Hydraulic conductivity indicates the maximum rate at which water can move through a soil when it is saturated. Hydraulic conductivity increases as soil pore diameters increase, thus water can move at a greater rate through sandy soils than loamy soils. The hydraulic conductivity of most Florida citrus root zone soils is high (Table 3), but that of intact argillic and spodic layers can be near zero (Table 4). Central Ridge Entisols drain quickly due to high hydraulic conductivity throughout the soil profile, but the drainage of Flatwoods soils is restricted because of low conductivity below the root zone.

Soil water-holding capacity is provided by the smaller pores that exist between and within the smallest fraction of soil and organic matter particles. Therefore, water-holding capacity is directly related to the amount of silt, clay and organic matter present. Since most Florida citrus soils contain only minimal amounts of these components, their water-holding capacities are rarely greater than 1 inch per foot of soil depth, and are often less than 0.75 inches per foot. During periods of dry weather and high atmospheric water demand, citrus trees may experience water stress within 1 to 2 days following irrigation. Low water-holding capacity soils require light and frequent irrigation to minimize water stress while simultaneously preventing nutrient leaching.

Soil pH affects the availability of plant nutrients including phosphorus, calcium, magnesium, and the micronutrients. Most soils used for citrus production are acidic in their native state, so they usually require liming prior to planting and may require additional liming as a grove ages. The optimum soil pH range for citrus is 6.0 to 6.5. The pH of Florida citrus soils can change rapidly as a result of chemical reactions caused by lime or fertilizer applications. An exception to this tenet is a *calcareous* soil. Some of the Alfisols in Table 3 can be calcareous due to a substratum of natural calcium carbonate rock or shell that dominates their chemistry. The pH of a calcareous soil remains relatively constant around 8.3.

Cation exchange capacity (CEC) is a measure of the ability of the soil to hold positively charged nutrients like calcium, magnesium, potassium, and ammonium against leaching. Generally speaking, as CEC increases, soil fertility increases. Soil CEC is supplied by clay and organic matter. Florida citrus soils are low in CEC, so nutrient management is difficult. The best fertilizer use efficiency can be obtained by applying nutrients (particularly nitrogen and potassium) frequently in small doses, similar to irrigation water. Entisols are the least fertile citrus soils, followed by Spodosols and Alfisols. The increased fertility of Spodosols reflects their slightly higher organic matter content, while Alfisols fertility is greatest because they contain some clay as well as organic matter.

Soil Leveling and Bedding in Flatwoods Citrus Groves

Citrus groves on Central Ridge Entisols are planted along the natural contour of the land because these soils are naturally well drained. No land preparation is required other than clearing. In contrast, Alfisols and Spodosols used for citrus production in the Florida flatwoods must be leveled, slightly sloped, and bedded before planting to provide artificial drainage. Precise leveling and shaping of a field directs drainage water to its designated outlet, and bedding allows excessive rainfall to drain quickly by means of surface flow rather than slowly by infiltration and subsurface drainage.

The topsoil layer of native Alfisols and Spodosols is usually no more than 6 to 8 inches thick. Below this layer is the first subsoil layer, which is usually white or light gray sand that is extremely low in fertility and water-holding capacity. Occasionally, land leveling removes all of the topsoil from a higher part of the field and transports it to a lower part, leaving the light-colored sandy subsoil as the new surface. Citrus tree growth and production in these areas (commonly referred to by flatwoods citrus growers as “scraped” areas or “sand ponds”) is usually poor.

After leveling has been completed, soil beds are constructed by cutting parallel wide and shallow v-shaped furrows about 50 ft apart. The soil removed from these furrows is shaped into a convex bed between them where the citrus trees are planted. The vertical distance from the bottom of the furrow to the top of the bed is usually about 2 to 3 feet. When constructing beds, the original soil surface is covered by subsoil that may have significantly different physical or chemical characteristics than the surface soil. The overburden soil can be either coarser or finer-textured than the surface soil, but it is almost always lower in organic matter. If the particular soil series has a limestone substratum (Table 2), the overburden may be calcareous. Therefore, the upper root zone soils in bedded groves are often less fertile and lower in water-holding capacity compared with the buried original surface layer.

Effect of Subsurface Argillic and Spodic Layers

The argillic and spodic layers in flatwoods soils can affect citrus production in two ways. If they are relatively deep as with Holopaw, Pineda, Immokalee, and Oldsmar soils, they remain intact following the bedding process and will impede downward water percolation because their permeability is often 0.2 inch/hr or less. Citrus rooting can be affected by these layers due to their influence on the depth and duration of high water tables during the wet season. Typically, the majority of flatwoods citrus roots reside in the top 18 inches of soil due to a recurring shallow water table that arises following heavy rains.

Some Alfisols and Spodosols like Riviera, Winder, Pomona, and Wabasso have relatively shallow argillic or spodic layers that can be excavated during the bedding process, so these subsurface materials are sometimes mixed into the root zone. The chemical and physical properties of argillic and spodic layers differ substantially from the sandy surface layers (Table 4). Compared with sandy surface soil, material from an argillic layer is higher in clay, while spodic layer material is higher in organic matter. Argillic layers can be either acidic or alkaline in pH, while spodic layers are always highly acidic. In addition, water-holding and cation exchange capacities are higher in argillic or spodic layers. The magnitude of influence that soil from these layers might have on root zone soil properties would be directly related to amount of material that was excavated and mixed in as a result of the bedding process.

A Word About Coated and Non-Coated Sand Grains

The movement of phosphorus (P) from agricultural fields to surface water bodies has become an environmental concern in Florida. Most soils nationwide have a moderate to high capacity to *adsorb* or hold soil P against leaching because they contain considerable quantities of silt and clay that provide a chemical mechanism to bind P. Florida soils dominated by quartz sand like those in Table 2 lack appreciable amounts of these silts and clays. However, in many cases the sand particles are coated with iron and/or aluminum compounds that also have some capacity to adsorb P. By definition, a soil contains coated sand if, within the 10 to 40 inch soil depth, the silt percentage plus two times the clay percentage is greater than 5.

One way to judge if coated sand grains are present is to observe the soil color. Yellow, orange, or brown colored sand is more likely to be coated, while bright white sand is not. Therefore, citrus groves on soils containing coated sands have the ability to build up a soil P reserve following P fertilizer applications. The presence of this P reserve can be determined with soil testing, and P fertilization may be curtailed if a high soil test P is found. Conversely, citrus groves on uncoated sandy soils may lack the ability to hold soil P. Excessive P fertilization in this case may induce P leaching, so P fertilizer should not be used indiscriminately due to the likelihood that it may be lost to the environment.

Summary

Florida has developed a major citrus industry mostly because of its climate, not because its soils are particularly favorable for management of water and agrichemicals. Florida citrus soils range from well-drained Entisols on relatively high, rolling landscapes to poorly-drained Alfisols and Spodosols on low-lying flatwoods. There are about 15 soil series that typify what is found in most citrus groves. With few exceptions, the root zones of these soils are dominated by sand and contain only minor quantities of silt, clay, and organic matter. They can vary widely in pH, but are low in water and nutrient-holding capacity, which makes the management of water and nutrients a challenging task for grove managers.

Figure 4. Astatula series (Entisol).

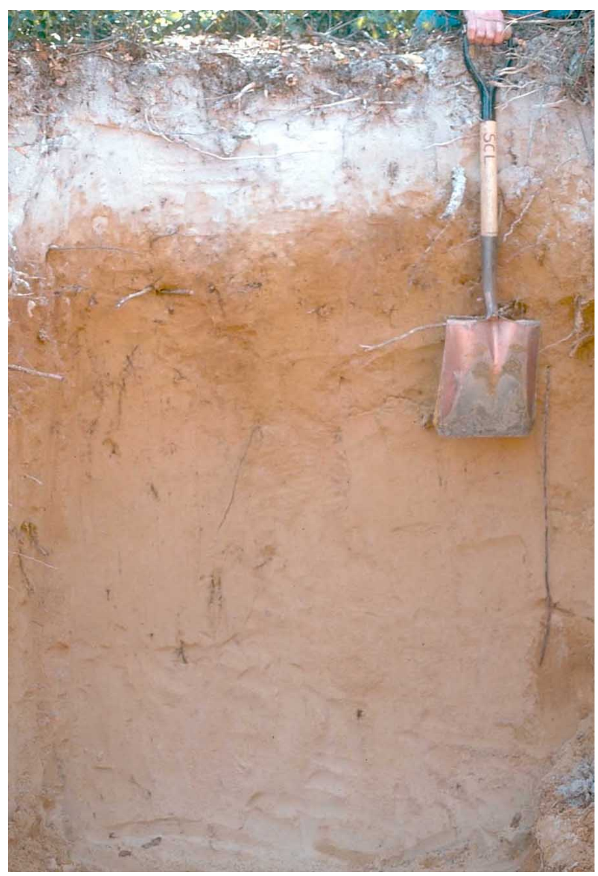

Figure 5. Basinger series (Entisol).

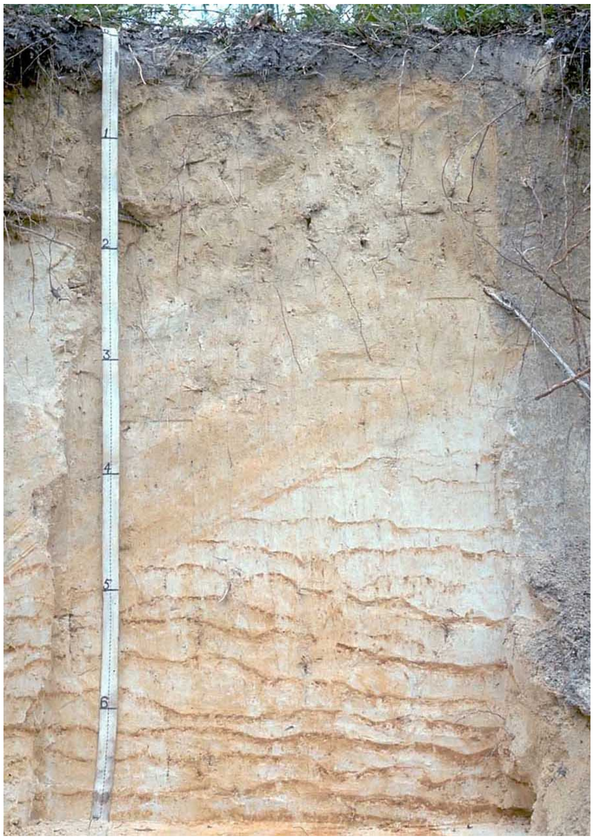

Figure 6. Candler series (Entisol).

Figure 7. Tavares series (Entisol).

Figure 8. Holopaw series (Alfisol).

Figure 9. Pineda series (Alfisol).

Figure 10. Riviera series (Alfisol).

Figure 11. Winder series (Alfisol).

Figure 12. Immokalee series (Spodosol).

Figure 13. Myakka series (Spodosol).

Figure 14. Oldsmar series (Spodosol).

Figure 15. Wabasso series (Spodosol).

Table 2. Typical characteristics of Entisols, Alfisols, and Spodosols planted to citrus in Florida.

Soil series	Parent material	Landscape position	Slope %	Natural drainage	Spodic layer depth (inches)	Argillic layer depth (inches)	Can find in a landscape depression?	Can have limestone substratum?
ENTISOLS								
Astatula	Uncoated sandy marine sediment	Sandy upland ridges	0-8	Excessively drained	---	---	No	No
Basinger	Sandy marine sediment	Slough	<2	Poorly drained	---	---	Yes	No
Candler	Uncoated sandy marine sediment	Broad undulating upland ridges	0-8	Excessively drained	---	---	No	No
Tavares	Uncoated sandy marine sediment	Broad uplands	0-5	Moderately well drained	---	---	No	No
ALFISOLS								
Boca	Sandy and loamy marine sediment over limestone	Flatwoods	<2	Poorly drained	---	28-33	Yes	Yes
Holopaw	Sandy and loamy marine sediment	Slough	<2	Poorly drained	---	48-65	Yes	Yes
Pineda	Sandy and loamy marine sediment	Slough	<2	Poorly drained	---	38-52	Yes	Yes
Riviera	Sandy and loamy marine sediment	Slough	<2	Poorly drained	---	23-54	Yes	Yes
Winder	Loamy marine sediment	Slough	<2	Poorly drained	---	12-49	Yes	Yes
SPODOSOLS								
Immokalee	Sandy marine sediment	Flatwoods	<2	Poorly drained	36-55	---	No	No
Myakka	Sandy marine sediment	Flatwoods	<2	Poorly drained	26-60	---	Yes	No
Oldsmar	Sandy and loamy marine sediment	Flatwoods	<2	Poorly drained	38-50	50-80	Yes	Yes
Pomona	Sandy and loamy marine sediment	Flatwoods	<2	Poorly drained	21-26	48-73	No	No
Smyrna	Sandy marine sediment	Flatwoods	<2	Poorly drained	12-15 (weak) 37-80	---	No	No
Wabasso	Sandy and loamy marine sediment	Flatwoods	<2	Poorly drained	25-34	34-58	No	Yes

Table 3. Typical root zone† soil physical and chemical properties for common soil series found in mature Florida citrus groves.

Soil series	Physical Properties							Chemical Properties	
	Soil texture ‡			Organic matter	Hydraulic conductivity	Water-holding capacity		pH	Cation exchange capacity
	Sand	Silt	Clay						
	-------------------------%----------------------				inches/hr	inches/foot	inches/root zone depth		meq/100 g
ENTISOLS									
Astatula	98.5	0.75	0.75	0.5-1.0	9-85	0.3-0.6	0.9-1.8	4.5-6.5	2-4
Basinger	98.5	0.5	1.0	0.5-1.0	8-17	0.4-0.8	0.6-1.2	3.6-7.3	2-4
Candler	97.5	1.25	1.25	0.5-1.0	6-50	0.3-0.7	0.9-2.1	4.5-6.0	2-4
Tavares	97.0	1.5	1.5	0.5-1.0	7-39	0.3-0.6	0.9-1.8	3.6-6.0	2-4
ALFISOLS									
Boca	94.0	3.0	3.0	1.0-2.5	3-20	0.4-0.9	0.6-1.4	5.1-8.4	6-10
Holopaw	94.0	3.5	2.5	1.0-2.5	1-10	0.7-1.2	1.1-1.8	5.1-7.3	3-7
Pineda	96.0	2.5	1.5	0.5-2.0	2-26	0.3-0.6	0.5-0.9	5.6-7.3	2-6
Riviera	96.5	2.0	1.5	0.5-2.0	3-18	0.6-1.0	0.9-1.5	4.5-6.5	2-6
Winder	85.0	6.0	9.0	1.0-3.0	1-24	0.7-1.2	1.1-1.8	5.6-7.8	14-18
SPODOSOLS									
Immokalee	98.5	1.0	0.5	1.0-2.0	6-20	0.4-0.8	0.6-1.2	3.6-6.0	2-6
Myakka	98.5	1.0	0.5	1.0-2.0	5-17	0.4-0.8	0.6-1.2	3.6-6.5	2-6
Oldsmar	98.0	1.5	0.5	1.0-2.0	5-28	0.3-0.6	0.5-0.9	3.6-7.3	2-6
Pomona	96.0	3.5	0.5	1.0-2.0	3-16	0.4-1.0	0.6-1.5	3.6-5.5	2-6
Smyrna	97.0	2.5	0.5	1.0-3.0	4-12	0.4-0.8	0.6-1.2	3.6-7.3	2-6
Wabasso	97.5	1.5	1.0	1.0-2.0	2-35	0.3-0.6	0.5-0.9	4.5-7.0	2-6

† Top 36 inches of soil for Central Ridge Entisols and top 18 inches of soil for flatwoods Alfisols, Spodosols, and Entisols.
‡ Particle diameters – sand: 2mm to 0.05 mm; silt: 0.05 to 0.002 mm; clay: <0.002 mm.

Table 4. Physical and chemical properties of the subsurface diagnostic layers of typical Alfisols and Spodosols found in Florida flatwoods citrus groves. These layers may reside in an undisturbed state beneath the root zone, or they may be partially excavated and mixed into the root zone soil during the bedding process.

Soil Series	Layer	Physical Properties						Chemical Properties	
		Soil texture‡			Organic matter	Hydraulic conductivity	Water-holding capacity	pH	Cation exchange capacity
		Sand	Silt	Clay					
		--------------------%-------------------				inches/hr	inches/foot		meq/100 g
ALFISOLS									
Boca	Argillic	81.0	4.0	15.0	0.3-1.2	0.3-1.0	1.2-1.8	5.1-8.4	16-24
Holopaw	Argillic	80.0	7.0	13.0	0.20-0.4	0.1-0.4	1.8-2.4	5.1-8.4	11-22
Pineda	Argillic	77.0	3.5	19.5	0.1-0.3	0.1-0.2	1.2-1.8	5.1-8.4	4-18
Riviera	Argillic	77.0	4.5	18.5	0.2-0.3	0.1-0.2	1.4-1.8	6.1-8.4	9-24
Winder	Argillic	80.0	4.0	16.0	0.1-0.3	0.0-1.1	1.2-1.8	6.6-8.4	12-26
SPODOSOLS									
Immokalee	Spodic	95.0	2.5	2.5	2.5-3.8	0.1-14	1.2-3.0	3.3-4.4	14-25
Myakka	Spodic	90.5	5.0	4.5	2.8-4.5	0.2-11	1.2-2.4	4.0-4.7	13-18
Oldsmar	Spodic	92.0	3.5	4.5	1.8-3.0	0.1-15	1.2-1.8	4.7-5.3	7-15
Pomona	Spodic	93.0	5.5	1.5	1.0-1.5	0.8-16	1.2-1.8	4.0-4.7	5-15
Smyrna	Spodic	90.5	5.0	4.5	3.3-3.9	0.6-14	1.2-1.8	4.3-4.7	19-21
Wabasso	Spodic	93.0	2.0	5.0	1.8-2.1	1.0-12	1.2-1.8	4.7-5.2	5-12

‡ Particle diameters--sand: 2mm to 0.05 mm; silt: 0.05 to 0.002 mm; clay: <0.002 mm.