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Sugarcane Production in Southwest Florida: Mineral Soils and Amendments[1]

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Introduction

This document integrates information that was presented at the Sand Land Workshop, held at the Dallas B. Townsend Hendry County Extension Center, LaBelle, Florida, 2003, dealing with the production of sugarcane on the mineral soils of southwest Florida. This document reviews challenges facing sugarcane growers dealing with soils, water management, and nutrients. Effective strategies, which are evolving to efficiently produce sugarcane in southwest Florida on mineral soils, are reviewed in this publication.

Soil Genesis and Soil Characteristics Affecting Sugarcane Production

The unique combination of climate, landscape, parent material, and living organisms in southwest Florida has greatly influenced the formation of soils in this area. With time, many of these soils have formed distinguishing characteristics, termed diagnostic horizons (See “Key to Soil Orders in Florida,” http://edis.ifas.ufl.edu/SS113). These horizons are identified by observing the soil with depth (Figure 1), such as the side of a pit or a road cut. In turn, these diagnostic horizons are useful for classifying the soils and relating their characteristics to commercial crop production.

The surface horizon, usually designated by a capital A, usually appears gray to black and is almost always of sandy texture (Figure 1). Moving down the soil profile and just beneath the A horizon, a leaching zone called the E horizon is often found. Nutrients and fine particles including organic matter are moved by water from this horizon. This leaching action creates the E horizon, which is usually much lighter in color than the surface horizon, often gray to white.

Located beneath this leaching zone, some soils have a distinct brown or black horizon, called the spodic horizon, that is designated by Bh (Figure 1). This horizon is composed of organic matter that is

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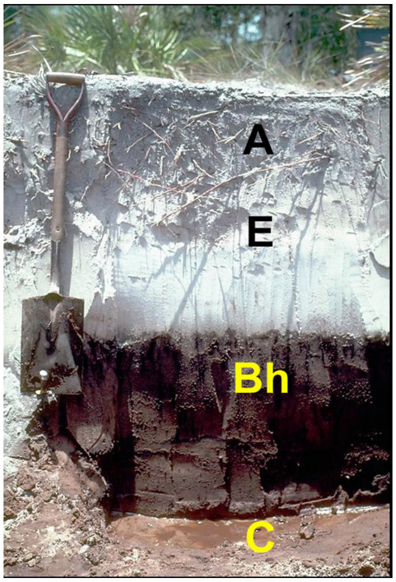

Figure 1. Immokalee soil series, showing the A, E, Bh, and C diagnostic horizons in the soil profile.

leached down the profile and by both physical and chemical means has been deposited in the lower part of the soil profile. This horizon is often high in aluminum and iron and usually has a low pH, but is almost always sandy in texture. It is this horizon that impedes water flowing vertically through the soil and causes water to accumulate above this horizon. This accumulation of water is referred to as a perched water table and is often quite beneficial for maintaining a constant water table for production of row crops such as sugarcane.

In some soils, another diagnostic horizon may be found below the leaching zone. This horizon is created by the deposition of clay particles and is called the Bt horizon (Figure 2). This diagnostic horizon is usually mottled gray in color and may be sandy or sandy loam in texture. Similar to the Bh horizon, the Bt horizon may allow the formation of a perched water table.

Below these diagnostic horizons, substratum may be present. The C horizon denotes substratum that can be a variety of textures and colors but is usually unconsolidated materials (e.g., Figures 1 and 2). The R horizon denotes substratum that is limestone bedrock (not shown).

Using these diagnostic horizons, most of the mineral soils in southwest Florida can be classified. The USDA-NRCS (Natural Resource Conservation

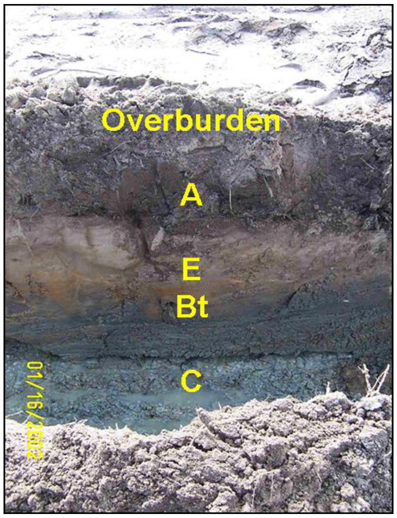

Figure 2. Riviera soil series, showing the A, E, Bt, and C diagnostic horizons in the soil profile.

Service) has prepared soil survey reports for each county in Florida (http://soils.usda.gov/). These documents are invaluable for understanding soils used for commercial sugarcane operations and contain maps showing the spatial distribution of soils in the landscape.

While some soils may be better suited than others for sugarcane production, soils often occur in associations and complexes, which describe a mixture of related and unrelated soils within the named mapping unit in the surveys. Thus, soil survey maps are considered accurate but not precise, meaning that the general management, as well as the chemical and physical characteristics within a mapping unit, is accurately described, but any one spot within the landscape may not be precisely described.

Soils originally formed in sloughs, then graded through land-leveling techniques, may be quite difficult to manage for commercial crop production. Often, these soils have been stripped of organic matter and clay that coat sand grains in other soils (Figure 3). These naturally formed uncoated sands are difficult to wet and difficult to drain. A common complaint of growers faced with cropping fields with uncoated sands is: “The places where I have problems with irrigation are the same places where I have problems with drainage.” Information concerning coated and uncoated sands is available through the NRCS County Soil Survey Reports.

Figure 3. Uncoated sands are difficult to manage for good crop production and may be the underlying cause of most poorly producing areas in sugarcane fields of southwest Florida. Soils containing uncoated sands have poor water- and nutrient-holding capacities, and are often found in the original landscape in low lying areas.

When uncoated sandy soils dominate a field, then a grower should manage water and nutrients based upon crop response on soils containing uncoated sands, ignoring the other portions of the field. In the opposite case, where uncoated sands are only a small portion of the field, then nutrient and water decisions should be based upon crop responses growing in those soils containing coated sands (Figure 4). Depending upon the shape and location of the poorly producing sugarcane areas, coupled with the soil forming processes originally present in the original landscape, these areas can be:

1. Amended to increase their productivity;
2. Kept in marginal production, but not amended; or
3. Treated as a greenbelt without direct crop production.

Sugarcane Production on Sandy Soils of Southwest Florida

While sugarcane production in Florida occurs primarily in the Everglades Agricultural Area, approximately 20% of the annual sugarcane production is on the sandy soils of southwest Florida. Variable sugarcane growth patterns can be observed on most sandy soils in southwest Florida. Variable sugarcane production can be related back to soil variability including the presence or absence of diagnostic horizons. Further soil variability is introduced during land leveling operations. Compared to the organic soils found within the Everglades Agricultural Area, southwest Florida soils are sandy and exhibit low organic matter content, both of which may limit sugarcane production. Variable productivity may be observed for as much as 25% of some fields.

Figure 4. Close-up of coated sand particles. The coating is often a combination of clay and organic matter (reddish-brown material on sand grains), which greatly improves crop production on soils that have coatings.

As reported at the 2003 Workshop, several experiments conducted by the senior author and summarized here addressed areas within fields that were classified as good production or poor production resulted in the following conclusions:

1. There was no consistent relationship between good and poor sugarcane producing areas and changes in water table depth or microbial activity (counts).
2. Soil pH, organic matter content, and soil-extractable calcium, magnesium, and potassium were all lower in poorly producing areas.
3. In poorly producing areas, sugarcane tissue contained lower concentrations of silicon, calcium, and magnesium. These lower concentrations likely resulted in the observed lowered tiller numbers and shorter stalks.

Based upon the above list, poor sugarcane production appears to be a function of several soil chemical attributes. In turn, these attributes may be directly related to the soil forming processes and landscape.

An experiment, again by the senior author, was conducted to test the use of precision agricultural techniques to remediate poor sugarcane production sites. Individual soil samples were collected using a field-grid method. Contour maps for soil pH and extractable calcium and phosphorus were constructed from the laboratory analyses. Soil pH and organic matter were correlated with most of the measured constituents. This result implied that site-specific liming and compost additions would improve yield in the poorly producing areas of the field.

To avoid the costly grid soil sampling technique, a combination of remotely sensed information with precision agricultural applications was tested in another experiment. Poor production sites were identified using color infrared imagery obtained by aerial photography. Maps for use with precision applications of nutrients and agricultural lime were developed from this imagery.

Based upon findings of the previous two experiments, a third experiment addressed the use of BS and silica slag to ameliorate poor production sites. These amendments were chosen because of their availability and cost at the time of the experiment. As expected, some nutrients were increased with just the organic source, while other nutrients were increased with just the silica slag. Furthermore, the addition of both organic waste and silica slag improved the tons of sugar per acre from the poorly producing sites. However, sugar production from the poorly producing sites was not increased to the level of the good production sites within the same field. Biosolids and silica slag were added only to the first ratoon crop. Information was collected on the second ratoon crop, but the residual effects of organic waste and silica slag on sugar production was small. Because of the warm, humid conditions that exist in southwest Florida, other experiments have shown that repeated applications of organic amendments produced the most benefit.

Use of Compost in Sugarcane Production

The benefits of adding organic amendments to sandy soils have been well documented throughout Florida (see http://edis.ifas.ufl.edu/TOPIC_Organic_Gardening or http://swfrec.ifas.ufl.edu/composting/ for more information). Some of these documented benefits include:

- Increased water holding capacity;
- Increased cation-exchange capacity;
- Decreased erosion potential;
- Increased soil microbial activity;
- Improved soil tilth.

While these benefits can contribute to productivity in any sandy soil, in poorly drained soils the effect of compost can be both positive and negative. On the positive side, organic matter will contribute to a higher water holding capacity within the soil profile. Improved water holding capacity can achieve higher rainfall retention within the soil profile compared to non-amended soils and reduce irrigation needs. Use of compost can also result in increased up flux (water moving upward in the soil profile due to capillary rise) due to introduction of finer particles (Figure 5).

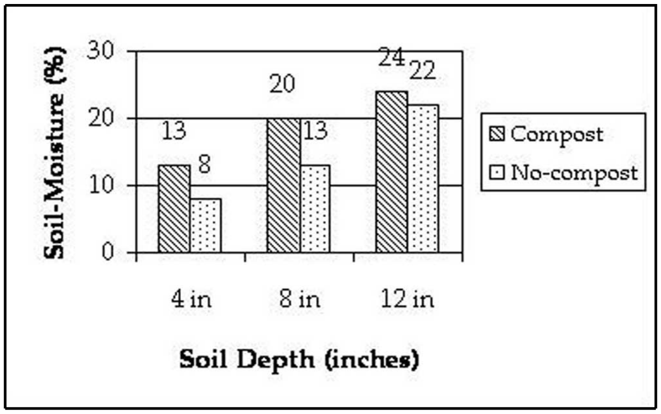

Figure 5. Improvement in moisture holding capacity of a southwest Florida sandy soil due to compost addition. Values represent the mean of biweekly sampling for 1 year after the addition of 50 tons compost per acre.

On the negative side, use of compost may or may not improve drainage. Often, drainage is a function of soil horizons or substratum well below the surface-applied organic matter. In fine sands or loamy sands, the addition of organic matter may actually improve drainage by providing pathways for the water to move downward/laterally. In sands or coarse sands, organic matter and additions may have no effect on drainage and may actually move with the water deeper into the soil profile. This loss of organic matter from the surface horizon will decrease the other benefits of organic matter for crop production.

Sources of organic materials in sufficient quantities for commercial sugarcane production are yard trimmings (YT, Figure 6), animal manures, household garbage (often called municipal solid waste or MSW), biosolids (sewage sludge or BS), wood-waste byproducts, food waste, or sugarcane mill mud. In 1999, 26.2 million tons of solid waste were produced in Florida, averaging approximately 9.5 lb daily per person. If composted, this solid waste would yield:

15.7 million tons of compost per year of MSW;

3 million tons of YT;

230,000 tons of dry BS; and

490,000 tons of animal manure.

Figure 6. Yard trash from urban areas is problematic for municipalities due to disposal costs, but can be the feedstock for composting, a desirable product for commercial growers in southwest Florida.

Agricultural productivity is greatly enhanced by putting these materials through a composting process (Figure 7). The resulting mature compost is much more predictable in its effects on crop production. Composting operations also greatly decrease the volume of the original material by 60%. Thus, transport and field spreading costs are reduced, and the composting operation also adds value to the product. Mature compost will contribute to nutrient retention rather than create nutrient deficiencies. UF/IFAS recommends that growers add only mature compost to commercial fields. If an un-decomposed (so-called immature compost) high carbon organic source, such as YT, is applied to fields, then growers should increase nitrogen fertilizer rates to account for the likelihood of a temporary nitrogen deficiency in the sugarcane. The adjusted rate should be based on the stage of crop growth and the source of the organic material.

Figure 7. Commercial composting operation turning yard trash into an organic source for crop production uses.

Growers should consider the original soil series, problem spots of which they are aware within their field, and other limiting factors, such as compost transportation and spreading costs. It is likely that the carbon source from the compost will help with crop productivity, and the effect will be a function of the compost application rate. Therefore, application rate should be viewed as a realistic return on investment from the treated area of the field.

Compost can be produced on the farm or purchased from commercial composting operations in the area. On-farm composting operations greatly reduce the cost of the compost, but require an added level of management, labor, and land allocation. Depending upon accessibility to sugar mills, the so-called mill mud is an excellent organic and nutrient source to enhance sugarcane productivity.

Mill mud is a by-product of sugar mills, but high weight from both water and entrained soil pose transportation cost limitations.

Research is underway at Southwest Florida Research and Education Center (SWFREC), Immokalee, Florida, to better understand the effect of compost on water holding capacity, drainage, and up flux from the water table to the root zone in sandy soils of southwest Florida. Also at SWFREC, compost from selected sources has been used to produce vegetables for the last 10 years. Soil organic matter has increased from the original 0.8% at the beginning of the experiment to 3%. In addition to improving water holding capacity (Figure 5) and crop yields, the need for inorganic fertilizer has been decreased by 50%. Increases of soil-test phosphorus, potassium, calcium, magnesium, micronutrients, and cation-exchange capacity within the treated soil has been due to regular additions of compost. This experimental location is now being used to demonstrate the positive effects of compost on sugarcane.

A Break-Even Yield Approach to the Economics of Amendments

Economic feasibility of repeated applications of organic and other soil amendments on sugarcane fields depend on four things: 1) the unit cost of the material; 2) recommended application rates; 3) spreading costs; and 4) the grower's target price for a ton of sugarcane. From these four pieces of information, a break-even yield can be calculated as in Equation 1.

$$\frac{(\text{Material cost (\$/ton)} * \text{Application rate (ton/ac)} + \text{Spreading costs (\$/ac)})}{\text{Grower's target price for sugarcane (\$/ton)}}$$

Equation 1. Break-even yield equation.

The “grower target price” could be a farm-gate value or a price that incorporates a profit margin. The break-even yield (with or without a profit margin) sets a yield response threshold above which it is profitable to include the soil amendment in the overall farm management plan. As an example, consider the application of silica slag, which is applied once every three years at a cost of $50 per ton. The recommended application rate is 3 tons per acre. Spreading costs are estimated to be $5 per acre and the grower price for sugar cane is $35.00 per standard ton. The break-even yield for the slag amendment is 4.4 tons. In other words, for the slag amendment to be profitable, sugarcane yields must increase by more than 4.4 tons in that three-year period. A lower grower price would increase break-even yields. On the other hand, a higher grower price would reduce the burden of higher yields from the organic amendment. This same economic approach also applies to additions of organic matter.

Overall, the effects of compost are more pronounced with regular additions--for example, annually. The rate of annual addition must meet the economics of the production system, but also must be evaluated on its long-term effect in improved crop production. Independent of the rate or the frequency of addition, compost continues to decompose when added to the soil. In the humid, hot conditions of southwest Florida, residual effects are small but cumulative.

In mineral soils, the weight of an acre furrow slice (one acre of soil to a six-inch depth) is assumed to be 2,000,000 pounds per acre. If the organic matter content of the soil before compost addition is 1%, then the weight of the organic matter in an acre furrow slice is 20,000 pounds.

Annual additions of 10 tons of wet compost per acre (moisture content is approximately 50%) will increase soil organic matter of the soil by 0.5% after 4 to 5 years. The remainder of the compost is lost due to decomposition. From these estimates, it is obvious that repeated additions, such as on an annual basis, are required to improve sugarcane crop production, especially on poorly producing areas of the field.

The use of precision agricultural techniques to apply compost in sufficient quantity to poorly producing areas within the field will likely prove to be the best solution to variable sugarcane yields in southwest Florida.