Nutrient Requirements for Sugarcane Production on Florida Muck Soils[1]

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The soils of the Everglades Agricultural Area (EAA) and adjacent areas are physically, chemically, and morphologically diverse. Over 4,400 years were required for organic soils of the EAA to form from decaying remains of sawgrass (*Cladium jamaciense* Crantz) and other marsh plants accumulated under flooded conditions. All the Histosols (organic soils) used for sugarcane production in Florida are Haplosaprists. These organic soils are generally highly decomposed (notable lack of intact plant fibers relative to other types of organic soils), are mostly black in color, and are referred to as "muck" soils. However, under the first year of cultivation, many sapric soils are distinguished by their brownish-red color, which darkens to black as exposed peat fibers undergo decomposition. Management of sugarcane grown on these organic soils is uniquely characteristic of the Florida industry.

The principal organic soils used for sugarcane production are generally characterized by high organic matter content, varying depths of organic matter profile deposition, abrupt underlying limestone rock or sand boundary substratum, and little profile development or definition within the organic profile. These soils are classified according to mineral content, thickness or depth of the organic horizon, and whether the underlying material is limestone or sand (Table 1). Most Histosols in sugarcane production have low mineral content and have limestone as the material under the organic layer. One exception in terms of mineral content is Torry muck, which formed in some areas of the eastern and southern shores of Lake Okeechobee as the lake overflowed and deposited mineral soil, primarily clay. These Torry mucks are highly fertile and have lower subsidence rates due to their higher mineral content. Okeelanta mucks have sand as the material below the organic layer and make up a small percentage of soils in the EAA. All of the other major organic soils have low mineral content with limestone as the underlying material. The difference in these soil series is the depth of the organic layer with soil depth decreasing in the following order: Terra Ceia, Pahokee, Lauderhill, and then Dania (Table 1).

With drainage of these organic soils, soil depth has been reduced through microbial oxidation of organic matter. With the adoption of best management practices, soil subsidence has been reduced to an estimated 0.5 inches/yr, with previousestimates of 1 inch or more each year. Therefore, over the passage of time, declining soil depth with subsidence has resulted in soils transitioning from one soil series classification (deeper) to a different soil series classification (shallower) (Table 1).

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Nitrogen

Histosols range from 0.5 to over 3.5% total nitrogen (N), with EAA Histosols averaging 2-4% N (Porter and Sanchez 1994). Widespread drainage of soils in the Everglades after the 1920s resulted in oxidation of these soils and mineralization of large quantities of organic N. Microbial oxidation has been reported to be responsible for 50 to 75% of the soil subsidence. The reported subsidence rates for Everglades Histosols range from 0.13 to 1.71 inches/yr, depending on soil type, carbon content, water table level, bulk density, and temperature. Although other factors such as compaction, shrinkage caused by drying, and erosion contribute to soil subsidence, oxidation of soil organic matter is the principal cause of subsidence.

Research has determined that oxidation of 0.5 inches of organic soil in the EAA mineralizes about 780 lb N/acre (Terry 1980). Rainfall contributes 2% and irrigation water provides 1% of the total N inputs. From the total amount of N entering the system, mineralization accounts for 97% of the total. Between 11 and 36 lbs N/acre/yr are reported lost through agricultural runoff waters, 70 and 90 lb N/acre through sugarcane crop removal, and the rest primarily through denitrification (atmospheric losses). Some growers have applied N during mid-December through February for the plant or ratoon crop, when the soils are cool and moist. Application of N during this period can result in succulent leaf growth and may increase the risk of frost damage should temperatures fall below 32° F. *Therefore, for these reasons N fertilizer recommendations are not given or required for sugarcane grown on organic soils*.

Phosphorus

Most virgin Histosols contain from 0.01 to over 0.3% phosphorus (P) (Lucas 1982). Approximately 30 to 85% of the total P is in the organic form and must be mineralized to be utilized by the plant. Cultivated soils have a higher proportion of total P in inorganic form than virgin Histosols. The amount of plant-available P is quite variable and depends on soil pH, ash content, quantities of Al and Fe sesquioxides, and amount of Ca and free carbonates. The chemical nature of organic soils is greatly dependent upon the oxidation and reduction (redox) relationships as influenced by water-control management. Therefore, redox-potential variations in water table management will also affect availability of plant-available P. In some respects, P availability in organic soils is similar to that in mineral soils. However, the chemistry of P in organic soils used for sugarcane production is more dynamic than in mineral soils due to soil oxidation, large fluctuations in moisture, and cation and anion additions through irrigation waters and mineralization.

Based on soil test Mehlich 3-extractable P levels performed by the University of Florida/IFAS Everglades Soil Testing Laboratory (Belle Glade), fertilizer P recommendations range from 0 to 75 lb P_2O_5/acre for the plant cane and first ratoon crops, 0 to 60 lb P_2O_5/acre for the second ratoon crop, and 0 to 50 lb P_2O_5/acre for subsequent ratoon crops. Details regarding P fertilizer recommendations for sugarcane grown on organic soils are available in the EDIS publication SS-AGR-348, *Phosphorus Fertilizer Recommendations for Sugarcane Production on Florida Organic Soils*, available at http://edis.ifas.ufl.edu/sc091.

Potassium

The total potassium (K) content of organic soils ranges from 0.5 to 2.0%. When calculated on a volume basis, K is less than 490 lb/AFS (an Acre Furrow Slice is a soil volume with a 1-acre area and 6-inch depth) on an organic soil compared to 30,000 lb/AFS on a loam soil. For this reason K is applied in larger amounts than other nutrients in Florida. Two other unusual characteristics of K on organic soils in the EAA are:

1. Potassium is weakly held on exchange sites, despite the fact that organic soils have high cation exchange capacities (CEC), and;

2. Since K is released readily into the soil solution and is not held tightly by soil CEC sites, movement out of the soil profile readily occurs during periods of high water movement, fertilization, and mineralization.

These characteristics are observed because of the high mineralization rate releasing large quantities of cations and anions, highly variable water conditions, dominance and saturation of Ca on cation exchange sites, and the generally low clay content of these soils. Based on the acetic acid soil test performed by the UF/IFAS Everglades Soil Testing Laboratory (Belle Glade), fertilizer K recommendations range from 0 to 250 lb K_2O/acre for the plant cane and first ratoon crops, and 0 to 150 lb K_2O/acre for the second ratoon and all subsequent ratoon crops.

Silicon, Calcium, and Magnesium

Silicon (Si) is abundant in mineral soils, averaging 32% Si by weight. However, Si contents within EAA Histosols (other than Torry mucks) are quite low, often less than 4%. Substantial increases in sugarcane tonnage and sucrose production have been determined with application of calcium silicate to soils low in soluble Si. Recently, acetic acid-extractable soil Si has been calibrated with sugarcane yield response for calcium silicate application rates ranging from 0 to 3 tons/acre. Details regarding calcium silicate recommendations for sugarcane grown on organic soils are available in the EDIS publication SS-AGR-350, *Calcium Silicate Recommendations for Sugarcane on Florida Organic Soils*, available at http://edis.ifas.ufl.edu/sc092.

Since marl and limestone deposits generally underlie the organic soils used for sugarcane production, calcium (Ca) and magnesium (Mg) nutritional problems are a rarity. The Ca and Mg mineral contents of most Everglades organic soils generally are 2 and 0.3%, respectively. However, Mg deficiencies can be found in certain soils. These may include Okeelanta mucks, which overlie a sandy substratum. They can be more acidic and have less plant-available Mg than other organic soils. Also, Mg levels should be monitored with repeated applications of calcium silicate due to the antagonistic relationship of Ca and Mg plant uptake.

Sulfur and Micronutrients

The EAA Histosols range from 0.2 to 4.2% sulfur (S) content. Sulfur is released through mineralization of the organic matter in quantities that are considered to be more than sufficient to supply all sugarcane S nutrient requirements. However, elemental S application can increase availability of micronutrients by decreasing pH of alkaline soils. The previous recommendation of 500 lb S/acre in the furrow at planting with soil pH $\geq$ 6.6 is under review and has not generally been followed because it is not considered to be cost-effective. Furrow applications of elemental S (rather than broadcast applications) are used in general for sugarcane production in the EAA because of the high buffering capacity of the organic soil to pH reduction. Broadcast application requires much higher S rates that are not economically viable.

Because of the diversity and unusual properties of soils used in the Florida sugarcane industry, micronutrient deficiencies of boron (B), copper (Cu), iron (Fe), manganese (Mn), and zinc (Zn) have been observed. The most common micronutrient deficiency in sugarcane in the EAA is manganese (McCray et al. 2010). Furrow applications of elemental S may be beneficial for increasing Mn availability under conditions of extremely high soil pH. Growers may also consider foliar Mn sprays when widespread visual symptoms appear. Manganese deficiency is a particular problem with soil pH $\geq$ 7.5. It is commonly seen in soils adjacent to limestone roads and on ditchbanks because of increased Ca carbonate and associated high soil pH at these locations. Manganese deficiency can manifest itself first in younger leaves as an interveinal chlorosis. Pictures of these and other deficiency symptoms can be viewed in the EDIS document SS-AGR-128, *Sugarcane Plant Nutrient Diagnosis*, available at http://edis.ifas.ufl.edu/sc075.

Boron deficiency has been observed on strongly acid, shallow organic soils overlying a sandy substratum and on sandy soils. Copper deficiency was once a major problem in the Everglades before it was known that application of this element was essential, and its deficiency has been largely eliminated by a history of copper sulfate applications. Copper deficiencies may still be observed on acid mucks as well as on organic soils previously fertilized with high rates of P.

Generally, Fe deficiency is not common in sugarcane grown in the EAA. However, on the eastern and southeastern fringe areas of the EAA, Fe deficiencies are observed. Iron contents in EAA Histosols range from 0.3 to greater than 0.7%. These Fe contents are somewhat low compared to those of other organic soils worldwide. Rice (*Oryza sativa* L.) grown on low-Fe soils can suffer Fe-related deficiency symptoms before the crop is flooded.

Zinc deficiency is not a major problem in organic soils in the EAA, but Zn nutrition could become a problem with the increasing pH of these soils. At planting, the IFAS recommendation for sugarcane grown on organic soils is to apply 5 lb Mn/acre, 2 lb Zn/acre, 2 lb Cu/acre, and 1 lb B/acre. Since there are no micronutrient soil tests currently available for sugarcane on organic soils, the best way to monitor micronutrient nutrition is leaf analysis. More information regarding leaf nutrient analysis is available in the EDIS document SS-AGR-259, *Sugarcane Leaf Tissue Sample Preparation for Diagnostic Analysis*, available at http://edis.ifas.ufl.edu/sc076, and in the EDIS document SS-AGR-335, *Sugarcane Nutrient Management Using Leaf Analysis*, available at http://edis.ifas.ufl.edu/ag345.

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Table 1. Histosol soil series found in the Everglades Agricultural Area.

Soil series	Soil name	Mineral content	Thickness of organic material†	Underlying material	Percentage of EAA organic soils	
					1978‡	1988§
		%	inches		%	%
Torry	euic, hyperthermic Typic Haplosaprist	>35	>51	Limestone	7.0	7.1
Terra Ceia	euic, hyperthermic Typic Haplosaprist	<35	>51	Limestone	37.9	9.5
Okeechobee	euic, hyperthermic Hemic Haplosaprist	<35	>51	Limestone	2.6	2.6
Pahokee	euic, hyperthermic Lithic Haplosaprist	<35	36-51	Limestone	43.9	27.4
Lauderhill	euic, hyperthermic Lithic Haplosaprist	<35	20-36	Limestone	4.7	39.6
Dania	euic, hyperthermic, shallow Lithic Haplosaprist	<35	<20	Limestone	0.2	10.2
Okeelanta	sandy or sandy skeletal, siliceous, euic, Hyperthermic Terric Haplosaprist	<35	16-50	Sand	3.6	3.6

†Soil depth ranges from Soil Survey Division (2001).
‡Estimated from Soil Survey Staff (1978).
§USDA (1988).