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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. It required over 4,400 years for organic soils of the EAA to form from decaying remains of saw grass (*Cladium jamaciense* Crantz) and other marsh plants accumulated under flooded conditions. Histosols (organic soils) of the EAA are classified according to their organic matter content, degree of decomposition, mineral or clay content, and depth to bedrock or mineral horizon. All the 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, low clay mineral 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 the thickness or the depth of the organic horizon to bedrock. Upon drainage, high organic matter oxidation rates account for soil subsidence rates of 0.5 to 1.5 inches yr^{-1}. 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). The classification of Histosols in the EAA used for sugarcane production in Florida are described in detail in the EDIS publication SS-AGR-246, *Application of the Soil Taxonomy Key to the Organic Soils of the EAA*, available at http://edis.ifas.ufl.edu/AG151.

SOIL 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^{-1} (> 1.2 inches yr^{-1} average) depending on soil type, carbon content, water

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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.

Soil N mineralization rates have been reported to range between 320 to 1340 lbs N acre^{-1} yr^{-1} through microbial oxidation. 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. From 11 lbs to 36 lbs N acre^{-1} yr^{-1} are reported lost through agricultural runoff waters, 70 to 90 lbs acre^{-1} 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.*

SOIL 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 upon the 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 upon soil test water-extractable P levels performed by the University of Florida/IFAS Everglades Soil Testing Laboratory (Belle Glade), fertilizer P recommendations range from 0-33 lbs P acre^{-1} (0 to 75 lbs P_2O_5 acre^{-1}) for the plant cane and first ratoon crops, 0-31 lbs P acre^{-1} (0 to 70 lbs P_2O_5 acre^{-1}) for second ratoon crops, and 18 lbs P acre^{-1} (40 lbs P_2O_5 acre^{-1}) for all subsequent ratoon crops.

SOIL 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 lbs AFS^{-1} (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 lbs AFS^{-1} on a loam soil. For this reason K is applied in larger amounts than other nutrients in Florida. Some other unusual characteristics of K on organic soils in the EAA are:

1. Large amounts of K are mineralized which remain in soluble form;

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

3. 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 organic soils. Based upon the acetic acid soil test performed by the UF/IFAS Everglades Soil Testing Laboratory (Belle Glade), fertilizer K recommendations range from 0 to 208 lbs K acre^{-1} (0 to 250 lbs K_2O acre^{-1}) for the plant cane and first ratoon crops, and 0 to 125 lbs K acre^{-1}(0 to 150 lbs K_2O acre^{-1}) for the second ratoon and all subsequent ratoon crops.

OTHER SOIL NUTRIENTS

Silica (Si) is abundant in mineral soils, averaging 32% Si by weight. However, Si contents within EAA Histosols are quite low, often less than 4%. Sugarcane production response data have not yet been specifically calibrated for Si application. The collective experience within the sugarcane grower community suggests that for soils testing low in Si (acetic acid extractable soil test values $\leq$ 10 ppm Si in the soil extract, performed by the UF/IFAS Everglades Soil Testing Laboratory, Belle Glade), broadcast applications of Si-slag up to 3 tons acre^{-1} at planting could be beneficial.

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, in

limited regions of the EAA where soil pH ranges from 3.8 to 4.0, much lower Ca and Mg contents are found. These soils are Okeelanta mucks overlying a sandy substratum. Sugarcane Mg deficiencies have been observed on these soils.

The EAA Histosols range from 0.2 and 4.2% sulfur (S) content. Therefore, the soil S content is considered more than adequate to supply all sugarcane S nutrient requirements. After flooding, evapotranspiration leads to accumulation of $CaSO_4$ on the soil surface which is visible. Application of S at 500 lbs $acre^{-1}$in the furrow is suggested at planting when the soil pH > 6.6 on the premise that the acidic conditions (soil pH reductions) encouraged by S additions within the rooting zone will support increased micronutrient plant availability.

Because of the diversity and unusual properties of soils used in the Florida sugarcane industry, boron (B), copper (Cu), iron (Fe), manganese (Mn), Si, and zinc (Zn) deficiencies have been observed. 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 are still observed on acid mucks, and on organic soils previously fertilized with high rates of P.

On the eastern and southeastern fringe areas of the EAA, Fe deficiencies are observed. Iron contents in EAA Histosols range from less than 0.3% to greater than 0.7% Fe. These Fe contents are somewhat low compared to other organic soils worldwide. Rice (*Oryza sativa* L.) grown on low-Fe soils can suffer Fe-related deficiency symptoms before the crop is flooded. Manganese deficiencies are very commonly seen on both organic and sand soils used for sugarcane production. This problem is observed on soils generally above pH 7.5. Many problem soils are adjacent to limestone roads and spoil banks. Zinc deficiency is not a problem on organic soils, although it can be a problem on high pH mineral soils located west of the EAA.

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