UF | IFAS Extension
UNIVERSITY of FLORIDA

UF/IFAS PEER REVIEWED SS-AGR-228
https://doi.org/10.32473/edis-SC028-2023

Nutritional Requirements and Fertilizer Recommendations for Florida Sugarcane[1]

J. Mabry McCray and Ronald W. Rice[2]

Introduction

This publication is intended primarily for Florida sugarcane (*Saccharum* spp.) growers, but it may also be useful to researchers and others interested in sugarcane nutrition. For any crop to grow and remain healthy, certain elements (nutrients) must be made available to the plants from the soil and/or air. The "essential" elements include C, H, O, N, P, K, Ca, Mg, S, B, Cl, Cu, Fe, Mn, Mo, Zn, and Ni. In Florida and some other areas of the world, application of Si may markedly enhance sugarcane production. This element qualifies as a "functional" or "beneficial" nutrient because, in the absence of Si, the plant can still complete its life cycle; however, production and general vigor may be reduced. In the Florida sugarcane industry, elements that are of nutritional concern include N, P, K, Mg, Si, B, Cu, Fe, Mn, and Zn. Deficiency or excess of one or more of the above elements may limit yields. An excess of one element may cause a deficiency of another. Growers striving to produce high crop yields should pursue management strategies that deliver a balanced supply of nutrients to the plant. Because plants need relatively large quantities of N, P, K, Ca, Mg, S, and Si, these elements are referred to as "macronutrients." The remainder of the required plant elements are usually called "micronutrients."

Most if not all soils require some level of fertilizer or amendment input to produce high crop yields. Efficient fertilizer use is a primary component of a farmer's Best Management Practice (BMP) program. BMPs are economically sensible practices shown by research to improve crop yields, make the best use of all farm inputs, and protect water quality and other natural resources. Fertilizer BMPs include soil testing, using split applications of nutrients when beneficial and practical, and applying fertilizers at rates that are consistent with soil test results and realistic yield expectations. The use of fertilizer BMPs is part of the 4Rs of nutrient stewardship: right fertilizer source, right fertilizer rate, right fertilizer timing, and right fertilizer placement.

Soil Testing

Today's high-yielding crops put tremendous pressure on the soil for nutrients. This makes soil testing important for efficient sugarcane production. Applying the proper amount of nutrients saves the producer money, helps protect the environment, maximizes crop yields, conserves valuable resources, and prevents nutrient imbalances. More specifically, a well-managed fertilizer program promotes rapid canopy development, increases crop resistance to disease and insects, and lowers irrigation requirements. Rapid canopy development, in turn, aids in weed control (Odero and Dusky 2021).

1. This document is SS-AGR-228, one of a series of the Agronomy Department, UF/IFAS Extension. Original publication date August 1993. Revised August 2006, December 2009, and January 2023. This publication is also a part of the Florida Sugarcane Handbook, an electronic publication of the Agronomy Department. Visit the EDIS website at https://edis.ifas.ufl.edu for the currently supported version of this publication.

2. J. Mabry McCray, scientist, sugarcane nutrition, Agronomy Department, UF/IFAS Everglades Research and Education Center; and Ronald W. Rice, county Extension director, and Extension agent IV, Ph.D., UF/IFAS Extension Palm Beach County; UF/IFAS Extension, Gainesville, FL 32611.

It is important for growers to send soil samples to a commercial, private, or university Extension laboratory that makes recommendations based on soil test calibrations applicable to the soils and crops of their farm operation. Field research is the basis for all soil test calibrations, and fertilizer recommendations developed are based on interpretations of field trial research that quantifies plant growth and yield responses to added fertilizer inputs. One of the options that sugarcane growers in south Florida have is the Everglades Soil Testing Laboratory at the UF/IFAS Everglades Research and Education Center (UF/IFAS EREC) in Belle Glade.

Collecting and Submitting Soil Samples

A representative sample is a prerequisite for a meaningful and reliable soil test. The error associated with soil sampling is typically much greater than that associated with chemical analysis, so great care must be taken with sampling procedure. Generally, fields to be sampled should be cultivated and ready for fertilization. Sampling depth for crops should be based on rooting depth of the crop. For sugarcane, most of the roots are in the upper 12 inches of soil, so a 12-inch sample is a good representative sample depth. Sometimes, sugarcane growers take a 6-inch soil sample. History of previous samples should be considered.

For a composite soil sample, it is recommended to take samples starting about 100 feet from the road near one end of the field and to continue collecting samples in a zigzag pattern across the field to have approximately 20 cores for a 40-acre block. Samples should not be taken within 100 feet of a marl road or 30 feet of a field ditch or lateral because these areas typically contain higher pH soil from the road or ditch cleaning operations that will skew the soil test results. A composite soil sample should not combine areas with different fertilizer or cropping histories because the soil test values can be too different and result in application of too much or too little fertilizer for part of the area. The cores for a sampled block should be composited and thoroughly mixed. If grid soil samples are taken or zones within a block are taken, then GPS can be used to separate sampling areas. Composite samples will be taken for each sampling zone; generally, for grid samples, fewer cores per sample will be needed. To prevent contamination of the soil sample, use plastic rather than galvanized buckets for mixing. A subsample should be placed in a clean soil sample bag (plastic or paper) and labeled properly. Certain information must be provided with every sample. Information sheets for providing these data are available from the Everglades Soil Testing Lab. Soil tests are available for pH, P, K, Ca, Mg, Si, and Fe. Contact your county Extension agent for additional details regarding soil sampling, testing, or sample submission procedures.

Leaf Nutrient Analysis

Recent research has shown that plant tissue testing, when used in conjunction with soil testing, can be a valuable tool for refining fertilizer recommendations and improving crop yields (see Ask IFAS publication SS-AGR-335, "Sugarcane Nutrient Management Using Leaf Analysis," at https://edis.ifas.ufl.edu/publication/AG345). Tissue testing is also useful in diagnosing, verifying, or preventing future nutritionally related plant disorders or imbalances. In fact, detection of micronutrient imbalances is one advantage tissue testing has over soil testing. No suitable soil tests have been developed for accurate micronutrient recommendations for Florida sugarcane. Collection and analysis of the "top-visible dewlap" (TVD) leaf without the midrib are used to measure the nutrient status of sugarcane in Florida (see Ask IFAS publication SS-AGR-229, "Sugarcane Leaf Tissue Sample Preparation for Diagnostic Analysis," at https://edis.ifas.ufl.edu/publication/SC076). Also, tissue sampling is usually done during the "grand growth period" when the crop is approximately 4–6 months of age.

Efforts to interpret plant tissue testing results have led to two nutritional concepts: "Critical Nutrient Level" (CNL) and "Nutrient Balance." The CNL is defined as the nutrient concentration at which production losses reach 5% to 10% and may be considered the minimum acceptable level of nutrient concentration. At concentrations below the CNL, substantial losses in production would be expected. The CNL is the lower end of the marginal zone of nutrient concentration and slightly below the optimum or sufficient zone. The optimum zone of nutrient concentration is the preferred range for each nutrient, but increasing the concentration of a nutrient above the lower end of the optimum range is unlikely to appreciably affect the plant growth rate. In fact, excessively high concentrations of a given nutrient may promote nutrient imbalances or adverse toxicity symptoms.

The concept of "Nutrient Balance" is highlighted within the Diagnosis and Recommendation Integrated System (DRIS). A DRIS database is composed of a very large number of field observations that relate plant tissue nutrient concentrations with plant yields. Optimum nutrient ratios (generally ranges) are then identified that are part of a high-yielding population of the crop. When diagnosing plant tissue test results, nutrient concentration ratios are compared to those from the high-yielding population to determine indices for each nutrient. Negative indices indicate the nutrient is limiting, positive indices indicate the nutrient is excessive or out of balance, and indices near zero indicate the nutrient is in balance with other nutrients. The details of DRIS are beyond the scope of this fact sheet but are explained in greater detail in Ask IFAS publication SS-AGR-129, "Sugarcane Plant Nutrient Diagnosis," at https://edis.ifas.ufl.edu/publication/SC075.

A previous study determined that summer fertilizer supplements for Florida sugarcane based on spring leaf analysis were not cost-effective on a large scale (McCray et al. 2010). Growers are instead encouraged to use leaf analysis to make adjustments to amendments or fertilizer inputs that will be applied to the next season's crop rather than trying to estimate an additional fertilizer application to the current crop.

Nutrient Mobility

As the term "mobile" suggests, some elements can be readily moved through the plant from older plant parts to younger, actively growing plant tissues, while other elements become "fixed" (immobile) in the plant tissue during growth. Nitrogen, P, K, Na, Mg, and to some extent S are considered mobile. Boron, Fe, and Ca are quite immobile, whereas Zn, Mn, and Cu are generally considered immobile, but less rigidly so. Specific visual symptoms or patterns of plant nutrient deficiencies (chlorotic/pale striping along the leaf blade, "burning" at the leaf tip, etc.) as well as the location on the plant (old leaves, newly emerging growth, stalk, etc.) where these symptoms are found reflect, in part, the relative mobility (or immobility) of a given plant nutrient. Thus, a general understanding of nutrient mobility is important when trying to diagnose nutrient deficiency symptoms in sugarcane. When a nutrient is mobile, deficiency symptoms typically appear on lower older leaves. If a nutrient is immobile, deficiency symptoms typically appear on new growth. For more details, including photographs of nutrient deficiency symptoms in sugarcane, see Ask IFAS publication SS-AGR-129, "Sugarcane Plant Nutrient Diagnosis," at https://edis.ifas.ufl.edu/publication/SC075.

Macronutrients

Nitrogen (N)

GENERAL GUIDELINES

No N fertilizer is recommended for sugarcane grown on muck soils. Under south Florida growing conditions on organic soils, N deficiencies are rarely seen in sugarcane. Muck soils have high organic matter (OM) content, and in our warm climate with aeration of the soil, mineralization of the organic matter releases inorganic N compounds that are readily available for plant uptake and growth. A deficiency may appear if organic N cannot be mineralized under unfavorable conditions, such as flood. For example, young sugarcane plants grown on shallow mucks during cool, wet periods have shown N deficiency symptoms. However, in field trials of N fertilizer application on shallow mucks, yield responses have been rare. On shallow mucks, other factors are generally more limiting for sugarcane growth than N; therefore, no N fertilizer is recommended for sugarcane on these soils.

On the other hand, N deficiencies can readily occur in sugarcane grown on sandy soil. Multiple applications of N fertilizer will be required during the growing season to sustain adequate sugarcane production on mineral soils (sands), which have much lower organic matter content than muck soils. Failing to supply adequate N during critical growth periods can result in stunted plants, premature ripening, and reduced biomass and sugar yields.

UF/IFAS N fertilizer recommendations for sugarcane grown on both organic and mineral soils are not based on soil testing. In fact, soil testing for N is generally not a helpful tool because the soil-N pool can change rapidly depending on environmental (rainfall, temperature) and crop management (tillage, irrigation) factors. While muck soils supply adequate N for sugarcane production, sands and transitional soils (sandy mucks and mucky sands) require N fertilization.

Mineralization of soil OM releases plant-available N to the growing crop. Soil OM mineralization rates are generally much higher during hot summer weather. Although this coincides with the grand growth period of sugarcane, it also coincides with the rainy season, which influences the movement of N (released from soil OM) through the soil profile. Additionally, south Florida sand soils tend to have very low soil OM contents, so the soil-N supply will likely be diminished by soil-N movement during frequent south Florida rainfall events.

It is also widely recognized that the sand soils cropped to south Florida sugarcane are variable in terms of native soil OM content, cation exchange capacity (CEC), and to some degree, soil pH. These factors affect native soil-N supply and can vary considerably across adjacent fields and even within any given field. Regardless of this variability, the native soil OM and CEC for any of these sand soils are considered low.

Hot south Florida growing conditions encourage the chemical transformation of applied N fertilizer sources into nitrate (NO_3^-) form, which is readily available for uptake by plant roots. The negatively charged NO_3^--N cannot be attached to the negatively charged soil particles; thus, they can be quickly moved through the soil by rainfall and water movement. Because sugarcane biomass accumulation and N requirements are greatest during the hot and humid summer months of the rainy season, some fraction of the applied N fertilizer may become unavailable to the sugarcane plant either due to leaching below the root zone of sands or through the process of denitrification. To minimize N fertilizer losses, sandland sugarcane growers should split soluble N fertilizers into multiple applications during the growing season so the N supply to plant roots is adequate. An alternative to an all-soluble N fertilizer program is using a combination of soluble and controlled-release N sources that will require fewer applications each year. Controlled-release fertilizer is more expensive, but there are savings in application costs. Additionally, N availability can be maintained more evenly throughout the season while avoiding large N losses with heavy rainfall.

Of all the nutrient elements, nitrogen has the greatest influence on cane ripening. Cane will store a higher percentage of sucrose when N is limited 6–8 weeks prior to harvest. Although a late-season N deficiency can promote improved sugarcane ripening, this scenario is unlikely to be achievable on organic soils.

DEFICIENCY SYMPTOMS

Because N is a mobile nutrient, N deficiency symptoms are first observed on older leaves (since N is mobilized from older tissues in favor of supporting growth in new tissue). Deficiency symptoms can eventually be seen over the entire plant. Leaf blades become uniformly pale green to yellow, stalks become short and slender, and internode growth and vegetative growth decrease. If the deficiency is prolonged, the tips and margins of older leaves become necrotic.

N FERTILIZER RECOMMENDATIONS

Nitrogen fertilizer recommendations for sugarcane on sand soils are 220 lb N/acre for plant cane and 200 lb N/acre for ratoon crops (Table 1). If using an all-soluble N program, 5 split applications are suggested for plant cane and 4 split applications are suggested for ratoon crops. If a mix of soluble and controlled-release N sources is used, 2 or 3 split applications can be made. Because of the volume of fertilizer material required (including N and other nutrients) and the length of the growing season, it is not likely that a single fertilizer application will be sufficient for sugarcane grown on sand. For more details about N fertilizer recommendations for sugarcane on sands, see Ask IFAS publication SS-AGR-401, “Nitrogen Fertilizer Recommendations for Sugarcane Production for Sugar on Florida Sand Soils,” at https://edis.ifas.ufl.edu/publication/SC101.

As stated before, no N fertilizer is recommended for sugarcane grown on muck soils (Table 1). However, for the transitional soils, some N is required. For mucky sands (6%–12% OM), 110 lb N/acre is recommended in 2 split applications. For sandy muck soils (13%–20% OM), 30 lb N/acre is recommended.

An optional approach for determining N fertilizer rate for transitional soils (mucky sands and sandy mucks) is to interpolate between recommended N rates for sands and mucks based on actual soil organic matter (OM) percentage. Soil OM percentage in Table 1 is based on the loss-on-ignition method, and so this method should be used in determination of soil OM percentage for calculation of N rate by interpolation. Growers who choose this optional approach to determine N fertilizer rate for transitional soils would not need to determine soil OM content at every planting, but they should consider running this analysis every 6–8 years, or every other sugarcane planting cycle. The interpolation formula is given below:

y = y1 + ((y2 - y1)/(x2 - x1) X (x - x1))

x = Actual soil OM%

y = N rate at actual OM%

y1 = N rate at 3% OM (3% OM is used as the upper end of the range of typical true sands)

y2 = N rate at 20% OM (20% OM is used as the lower end of the range of muck soils)

x1 = 3% OM

x2 = 20% OM

Example calculation of plant cane N rate for a soil with 8% OM:

y = 220 + ((0 - 220)/(20 - 3) X (8 - 3))

y = 220 + (-12.9 X 5)

y = 220 - 64.5

y = 155.5 lb N/acre for a soil with 8% OM

Phosphorus (P)

GENERAL GUIDELINES

Phosphorus is likely to be deficient in organic and mineral soils in Florida without added P fertilizer. Limited P slows root development and results in inadequate use of available moisture and nutrients. Deficiency is much more common in ratoon crops, and deficiency symptoms tend to increase with age of planting. Careful control of available P levels is essential for high yields of sugarcane and sucrose. Use of soil testing as a BMP is important for reducing P loads in drainage water.

DEFICIENCY SYMPTOMS

Because phosphorus is a mobile nutrient, deficiency symptoms typically appear first in older tissues. Phosphorus deficiency causes an overall stunting of plant growth. Stalk internode length, total stalk length, and stalk diameter are reduced. At first, distinct foliar symptoms may not be observed. Later, leaves may become slender and blue-green in color. Red or purple color may also be seen, particularly at tips and margins exposed to direct sunlight. Eventually, leaf foliage dies back from the leaf tip and along the leaf margins.

P FERTILIZER RECOMMENDATIONS

Phosphorus fertilizer recommended by the UF/IFAS Everglades Soil Testing Laboratory ranges from 0 lb P_2O_5/acre to 75 lb P_2O_5/acre (Tables 2 and 3). The Mehlich 3 soil extractant is used for all soils, but separate recommendations are made for sands and mucks. For more details about P recommendations for muck soils, see Ask IFAS publication SS-AGR-348, "Phosphorus Fertilizer Recommendations for Sugarcane Production on Florida Organic Soils," at https://edis.ifas.ufl.edu/publication/SC091. For P recommendations on sands, see Ask IFAS publication SS-AGR-466, "Phosphorus Fertilizer Recommendations for Sugarcane on Florida Mineral Soils," at https://edis.ifas.ufl.edu/publication/SC108.

An optional approach for determining P fertilizer rate for transitional soils (mucky sands and sandy mucks) is to interpolate between recommended P rates for sands and mucks based on actual soil OM percentage, as previously described for N rates. The interpolation formula is given below:

$y = y1 + ((y2 - y1)/(x2 - x1) \text{ X } (x - x1))$

x = Actual soil OM%

y = P_2O_5 rate at actual OM%

y1 = P_2O_5 rate at 3% OM from Table 3 (3% OM is used as the upper end of the range of typical true sands)

y2 = P_2O_5 rate at 20% OM from Table 2 (20% OM is used as the lower end of the range of muck soils)

x1 = 3% OM

x2 = 20% OM

Example calculation of P_2O_5 rate for plant cane for a soil with 13% OM and Mehlich 3 P of 50 g/m^3:

$y = 60 + ((0 - 60)/(20 - 3) \text{ X } (13 - 3))$

$y = 60 + (-3.5 \text{ X } 10)$

$y = 60 - 35$

y = 25 lb P_2O_5/acre for plant cane for a soil with 13% OM

Potassium (K)

GENERAL GUIDELINES

Sugarcane utilizes large quantities of potassium. Deficiencies are commonly observed on well-drained, coarse, sandy soils. These sands have low nutrient-holding capacity; therefore, K can be lost through leaching in these soils. Even on muck soils, K can be moved out of the soil profile during periods of high rainfall because K is weakly held on soil exchange sites. Compared to most other nutrients, sugarcane response to K fertilization tends to be immediately apparent. One application of K should be sufficient for a crop on muck soils; if using soluble sources on sands, split applications will be required for each crop.

DEFICIENCY SYMPTOMS

A potassium deficiency can result in depressed growth, slender stalks, and "firing" (an orange or reddish-brown discoloration) on older leaves. Because K is readily mobile, deficiencies are first observed in older plant leaves. Young leaves are generally all dark green. The most distinguishing characteristic of this deficiency is a red discoloration on the upper surface of the leaf blade midrib. Discoloration on both sides of the midrib may indicate a fungal disease. Under severe deficiency, the leaf spindle will distort, producing a characteristic "bunched top" or "fan" appearance. Poor bud germination and decreased resistance to drought and disease are associated with K deficiency.

K FERTILIZER RECOMMENDATIONS

K fertilizer recommendations by the UF/IFAS Everglades Soil Testing Laboratory range from 0 lb K_2O/acre to 250 lb K_2O/acre. Separate recommendations are made for mucks and sands (Tables 4 and 5). For more details about K fertilizer recommendations for muck soils, see Ask IFAS publication SS-AGR-428, "Potassium Fertilizer Recommendations for Sugarcane on Florida Organic Soils," at https://edis.ifas.ufl.edu/publication/AG428. For more details about K fertilizer recommendations for sand soils, see Ask IFAS publication SS-AGR-468, "Potassium Fertilizer Recommendations for Sugarcane on Florida Mineral Soils," at https://edis.ifas.ufl.edu/publication/SC110.

Calcium (Ca)

GENERAL GUIDELINES

Calcium deficiencies in Florida sugarcane are unlikely because this element is abundant in the soil-water environments where sugarcane is traditionally grown. Nevertheless, Ca is a macronutrient that is vitally important for plant growth. An acute shortage of Ca will lead to rapid deterioration and plant death. Most of the organic soils in Florida overlay limestone bedrock, and Ca is moved into the surface soil profile by diffusion and mass flow with soil water.

DEFICIENCY SYMPTOMS

Calcium deficiency is not a concern for sugarcane production in Florida. A Ca-deficient plant, however, is characterized by limited top and root growth and slender stalks. Older leaves acquire a "rusty" appearance and show signs of mottling and chlorosis. The spindle leaf turns brown and dies, and young leaves can become distorted. If the deficiency is severe, the terminal bud and plant may die. Calcium is considered an immobile plant element.

Magnesium (Mg)

GENERAL GUIDELINES

Magnesium deficiency is sometimes seen in sugarcane grown on acidic sand soils and organic soils. Magnesium is a component of the chlorophyll molecule and is therefore essential for photosynthesis. Potassium and Mg are antagonistic nutrients in terms of plant uptake, so high K fertilization can promote Mg deficiency symptoms. Although Mg is not routinely recommended for application on muck soils, there are situations when Mg can limit sugarcane growth on these soils. Leaf analysis can be used to determine if Mg application is needed.

Previously for sands and mucky sands, a 6 lb Mg/acre application was recommended when the acetic acid soil test value was less than 100 lb Mg/acre. This has been determined to be insufficient to correct Mg deficiency for these soils. There is not a specific Mg recommendation at this time, but a more substantial application of Mg is required when soil test Mg is low and leaf Mg values indicate deficiency. Dolomite is a good Mg source when lime is needed for acidic sands, but for higher pH soils, other soluble Mg fertilizer sources may be used. When there is chronic Mg deficiency or low soil test Mg, growers should consider including Mg in plant cane and ratoon crop fertilizer.

DEFICIENCY SYMPTOMS

Magnesium deficiency is characterized by intense rust-like freckling that is especially prevalent on older leaves. Severe Mg deficiency may cause the stalk to become stunted and severely "rusted" and brown. Magnesium is considered a mobile plant nutrient.

Sulfur (S)

GENERAL GUIDELINES

Sulfur deficiencies are unlikely to occur in sugarcane grown on organic soils because the quantity of S supplied directly from the muck soil through mineralization of organic matter is more than enough to satisfy the crop nutrient requirement of sugarcane. Soil microorganisms can oxidize elemental S, and organic S compounds in the soil are converted into sulfate forms that are available for plant uptake. Also, some popular fertilizer blends used to deliver N, P, K, or Mn to the crop may also contain appreciable amounts of sulfur. Sand soils can be limiting in available sulfur; including some sulfate sources for sugarcane grown on sands can prevent possible deficiencies. Finally, S is also present in the atmosphere as sulfur dioxide and sulfur trioxide, which enter the soil-water system via rainfall. With these possible sources, S deficiency is also unlikely to be a problem for sugarcane grown on mineral soils. The UF/IFAS Everglades Soil Testing Laboratory does not perform an S soil test and has never offered S fertilizer recommendations for the purpose of delivering S to the sugarcane crop. The section on soil pH discusses recommendations for elemental S application for pH reduction of high pH soils.

DEFICIENCY SYMPTOMS

Sulfur is somewhat mobile in the plant. Sulfur deficiency is characterized by a general chlorosis and yellowing of leaves, especially younger ones. The young leaves may develop a faint purplish tinge on their margins. In time, plants will lack vigor, leaves will be shorter and narrower, and stalks will be small in diameter.

Silicon (Si)

GENERAL GUIDELINES

Silicon is considered a "functional" or "beneficial" (rather than essential) plant nutrient. In Florida, Si amendments may increase cane and sugar yields as much as 25% and may support more successful ratoon crops. Yield increases with Si application may be attributed to various mechanisms, including increased disease and insect resistance, reduced water loss through evapotranspiration, and increased mechanical strength of cells. Field research has led to Ca silicate application recommendations for muck soils and sands. These recommendations are also applicable for rice when grown in rotation with sugarcane.

DEFICIENCY SYMPTOMS

Silicon deficiency is characterized by minute, circular white leaf spots (freckles). The freckling is more severe on older leaves. Older leaves may senesce prematurely, and the stools exhibit poor tillering and ratooning characteristics.

SI AMENDMENT RECOMMENDATIONS

Recommendations of Ca silicate range from 0 tons/acre to 3 tons/acre based on the acetic acid soil test, with separate recommendations for mucks and sands (Tables 6 and 7). These recommendations are for pre-plant incorporation and are intended to supply adequate Si through the ratoon crops. Growers should consider taking soil samples early in the growth of the last ratoon crop for successively planted sugarcane to estimate Ca silicate needs for the planting season because of the lead time needed for ordering the amendment. These soil samples would not replace the normal soil samples needed in disked fields before planting, but they could be used specifically to determine available soil Si earlier in the year. There is a lot of variation in Ca silicate materials depending on the source, and other Si materials may also be applied to supply available silicon. The amount of available Si should be considered when using a material as an amendment or fertilizer. Field trials with any new material should be conducted to determine the viability of the source. The recommendations included here are based on field trials with Ca silicate containing approximately 20% total silicon. For more details about Si recommendations for muck soils, see Ask IFAS publication SS-AGR-350, "Calcium Silicate Recommendations for Sugarcane on Florida Organic Soils," at https://edis.ifas.ufl.edu/publication/SC092. For more details about Si recommendations for sand soils, see Ask IFAS publication SS-AGR-467, "Calcium Silicate Recommendations for Sugarcane on Florida Mineral Soils," at https://edis.ifas.ufl.edu/publication/SC109.

An optional approach for determining Ca silicate rate for transitional soils (mucky sands and sandy mucks) is to interpolate between recommended rates for sands and mucks based on actual soil OM percentage as previously described for N and P rates. Growers will need to consider minimum practical application rates and potential yield response based on the results of the interpolation. A one-ton rate of Ca silicate is likely the lowest practical application rate for a uniform broadcast application. The interpolation formula is given below:

$y = y1 + ((y2 - y1)/(x2 - x1) X (x - x1))$

x = Actual soil OM%

y = Ca silicate rate at actual OM%

y1 = Ca silicate rate at 3% OM from Table 7 (3% OM is used as the upper end of the range of typical true sands)

y2 = Ca silicate rate at 20% OM from Table 6 (20% OM is used as the lower end of the range of muck soils)

x1 = 3% OM

x2 = 20% OM

Example calculation of Ca silicate rate for plant cane for a soil with 10% OM and acetic acid Si of 70 g/m^3:

$y = 2 + ((0 - 2)/(20 - 3) X (10 - 3))$

$y = 2 + (-0.12 X 7)$

$y = 2 - 0.8$

y = 1.2 tons/acre

Micronutrients

Boron (B)

GENERAL GUIDELINES

Boron deficiency has been observed on Florida sugarcane grown on sand soils. Boron is readily leached from the root zone. Boron deficiency is accelerated under extremely dry soil conditions. The recommended application rate for B, based on apparent crop requirement, is 1 lb B/acre for all soils. The B application should be delivered directly into the furrow at planting. No recommendations are made for ratoon cane.

DEFICIENCY SYMPTOMS

Boron deficiency is very distinct because boron is relatively immobile (not readily translocated from older tissues to young growth). Young leaf blades contain clear lesions (or "water sacks") sometimes accompanied by exudation of water droplets from the upper leaf surface. Young leaves become distorted and necrotic, leaf blades become narrow and brittle, leaf tips may desiccate (dry out and look burned), and young plants become bunched with many tillers. The spindle leaves turn white, dry out, and eventually appear dead. This spindle leaf symptom may appear similar to those associated with the fungal disease "pokkah boeng" (a Javanese term that describes a malformed, twisted, or disturbed top) as well as symptoms associated with damage from some herbicides.

Copper (Cu)

GENERAL GUIDELINES

Copper deficiencies were a major problem when the organic soils of the Everglades were first cleared and planted to agricultural crops. There was little plant-available Cu in the native muck soils. Part of the problem is that copper binds with organic matter: in soils with high levels of organic matter, more copper is necessary to meet plant demands than in soils with lower amounts of organic matter. Copper is an immobile nutrient; therefore, meristematic tissues and young leaves are first affected by deficiency. Excessive P fertilization can exacerbate Cu deficiency. Copper deficiency of relatively mature cane is characterized by a wilted appearance of the younger leaves. Most deficiencies have been observed on organic soils and are easily corrected through foliar sprays or fertilizer. Copper recommendations based on apparent crop requirement are 2 lb Cu/acre for mucks and sandy mucks and 1 lb Cu/acre for sands and mucky sands. The Cu application should be delivered directly into the furrow at planting. No recommendations are made for ratoon cane.

DEFICIENCY SYMPTOMS

Dark-green splotches appear on a slightly chlorotic and wilted leaf blade. If unchecked, poor stool development and "droopy top" can result. Although no necrosis is seen at first, severe Cu deficiency may cause leaf necrosis, shortened internodes, reduced tillering and vigor, and reduced growth and yields. On the other hand, the crop may "outgrow" mild Cu deficiencies after the young plant develops a more mature root system.

Iron (Fe)

GENERAL GUIDELINES

Iron deficiency has not been a major concern in Florida sugarcane production. Iron deficiencies that have been identified have been geographically localized. A recent survey of Florida sugarcane fields suggested that Fe may be a minor concern on mineral soils. Poorly developed and physically damaged root systems resulting from alkaline soils or soil insect pests can induce Fe deficiency. Plants normally outgrow Fe deficiency symptoms, but symptoms may persist with excessive root damage and low soil Fe conditions. Iron foliar sprays can be used to correct chlorotic leaf symptoms, but they may not increase or affect yields. Further research is needed on Fe, particularly on mineral soils. Although there is no official UF/IFAS Fe recommendation for sugarcane, an application of 5 lb Fe/acre at planting is suggested if leaf tissue Fe concentrations were low in the previous season's crop.

DEFICIENCY SYMPTOMS

Many times, plants showing deficiency occur randomly among plants that appear normal. Since Fe is relatively immobile, deficiency symptoms typically appear in young, actively growing plant tissues. Young shoots may emerge in a completely chlorotic condition. Deficiency symptoms in young leaves include light-green striping between parallel leaf veins along the full length of the leaf blade. The stripes are similar to those seen in Mn deficiency, although Mn deficiency symptoms generally involve striping from the tips to the middle of the leaf blade. In severe deficiencies, the areas between the veins become increasingly chlorotic to white.

Manganese (Mn)

GENERAL GUIDELINES

Manganese deficiencies are commonly seen on high pH organic soils and may occasionally be seen on sands. These deficiencies may be seen with pH > 7.0 and especially with pH ≥ 7.5, as high pH limits plant availability of Mn. Deficiency is also associated with soils high in Mg and Ca. An effective method for preventing or decreasing the severity of Mn deficiency is to place granular elemental S in the furrow together with Mn when planting sugarcane. Elemental S recommendations are listed in the section on soil pH. The general recommendation for all soils is to apply 5 lb Mn/acre at planting, but in high pH situations, this value may be increased, including some Mn in the elemental S application. Also, growers have the option of applying 5 lb Mn/acre as a foliar spray when visual symptoms are observed.

DEFICIENCY SYMPTOMS

Since manganese is an immobile nutrient, deficiency symptoms typically affect younger leaves first. The deficiency is characterized by pale-green to white interveinal stripes (chlorosis) alternating with normal color from the tip to the middle of the leaf blade. Leaf splitting or fraying may also be apparent. Manganese visual symptoms are often more evident in the spring when soil conditions are dry before the summer rains begin. The severity of Mn deficiency often decreases as soil moisture increases and soil Mn becomes more available to the plants.

Zinc (Zn)

GENERAL GUIDELINES

Zinc deficiency more commonly occurs on high pH sand soils. Zinc deficiency can be enhanced by high applications of banded P and K, over-liming, and high soil pH. The recommended application rate for Zn is 2 lb Zn/acre for all soils. The Zn application should be delivered directly into the furrow at planting. No recommendations are made for ratoon cane.

DEFICIENCY SYMPTOMS

Zinc is considered fairly immobile; thus, deficiency symptoms typically appear in younger leaves. Young leaves have light-green stripes that are in the leaf veins, not between the veins as with Mn deficiency. The leaves are also small and asymmetrical. Necrosis of the leaf tips may occur when the Zn deficiency is severe. A Zn-deficient plant has reduced tillering and ratooning ability.

Soil pH

General Guidelines

Organic soils are highly buffered against pH change. In earlier years in the Everglades Agricultural Area when organic soils were deeper, these muck soils were acidic, and sugarcane may have responded to lime applications to increase pH. In recent years, the muck soils have become shallower, and soil pH has increased with more incorporation of Ca carbonate from underlying limestone bedrock. This has often led to micronutrient deficiencies with pH > 7.0, with more deficiencies with pH ≥ 7.5. Micronutrient deficiencies can also be seen on sands, but not as frequently as with muck soils. Lowering soil pH of the entire root zone is prohibitively expensive, but applying elemental sulfur as a band in the furrow when planting sugarcane is a cost-effective way to target the sugarcane row for decreasing soil pH and increasing micronutrient availability. This is especially important for Mn availability, which is often limiting, especially in alkaline organic soils. Table 8 gives elemental S recommendations for in-furrow pre-plant application for each soil type. The maximum rate for muck soils is 500 lb/acre at pH ≥ 7.5 with an elemental S range of 250–500 lb/acre to allow growers flexibility, depending on deficiency severity for a particular field or application area. The maximum S rate for sands remains at 300 lb/acre, as in previous recommendations. For more details about elemental S recommendations, see Ask IFAS publication SS-AGR-429, "Elemental Sulfur Recommendations for Sugarcane on Florida Organic Soils," at https://edis.ifas.ufl.edu/publication/AG429.

Sand soils in sugarcane production can have suboptimal surface soil pH. A yield increase due to liming is expected if soil pH is less than 6.0. Dolomite should be used as the liming material because it contains Ca and Mg, and Mg is often limiting in south Florida sands. A 2 ton/acre application of dolomite (broadcast applied and disk-incorporated prior to planting) should increase soil pH by approximately one pH unit for sand soils.

References

Anderson, D. L., and J. E. Bowen. 1990. *Sugarcane Nutrition*. Atlanta: Potash & Phosphate Institute.

Elwali, A. M. O., and G. J. Gascho. 1984. "Soil Testing, Foliar Analysis, and DRIS as Guides for Sugarcane Fertilization." *Agronomy Journal* 76:466–470. https://doi.org/10.2134/agronj1984.00021962007600030024x

McCray, J. M. 2019. "Potassium Fertilizer Recommendations for Sugarcane on Florida Organic Soils." SS-AGR-428. Gainesville: University of Florida Institute of Food and Agricultural Sciences. https://edis.ifas.ufl.edu/publication/AG428

McCray, J. M. 2019. "Elemental Sulfur Recommendations for Sugarcane on Florida Organic Soils." SS-AGR-429. Gainesville: University of Florida Institute of Food and Agricultural Sciences. https://edis.ifas.ufl.edu/publication/AG429

McCray, J. M., S. Ji, G. Powell, G. Montes, and R. Perdomo. 2010. "Sugarcane Response to DRIS-Based Fertilizer Supplements in Florida." *Journal of Agronomy and Crop Science* 196:66–75. https://doi.org/10.1111/j.1439-037X.2009.00395.x

McCray, J. M., K. T. Morgan, and L. Baucum. 2019. “Nitrogen Fertilizer Recommendations for Sugarcane Production for Sugar on Florida Sand Soils.” SS-AGR-401. Gainesville: University of Florida Institute of Food and Agricultural Sciences. https://edis.ifas.ufl.edu/publication/SC101

McCray, J. M., and R. Mylavarapu. 2020. “Sugarcane Nutrient Management Using Leaf Analysis.” SS-AGR-335. Gainesville: University of Florida Institute of Food and Agricultural Sciences. https://edis.ifas.ufl.edu/publication/AG345

McCray, J. M., R. W. Rice, and L. E. Baucum. 2018. “Calcium Silicate Recommendations for Sugarcane on Florida Organic Soils.” SS-AGR-350. Gainesville: University of Florida Institute of Food and Agricultural Sciences. https://edis.ifas.ufl.edu/publication/SC092

McCray, J. M., R. W. Rice, and I. V. Ezenwa. 2021. “Sugarcane Leaf Tissue Sample Preparation for Diagnostic Analysis.” SS-AGR-259. Gainesville: University of Florida Institute of Food and Agricultural Sciences. https://edis.ifas.ufl.edu/publication/SC076

McCray, J. M., R. W. Rice, I. V. Ezenwa, T. A. Lang, and L. Baucum. 2019. “Sugarcane Plant Nutrient Diagnosis.” SS-AGR-128. Gainesville: University of Florida Institute of Food and Agricultural Sciences. https://edis.ifas.ufl.edu/publication/SC075

McCray, J. M., R. W. Rice, and A. L. Wright. 2021. “Phosphorus Fertilizer Recommendations for Sugarcane Production on Florida Organic Soils.” SS-AGR-348. Gainesville: University of Florida Institute of Food and Agricultural Sciences. https://edis.ifas.ufl.edu/publication/SC091

McCray, J. M. 2022. “Potassium Fertilizer Recommendations for Sugarcane on Florida Mineral Soils.” SS-AGR-468. Gainesville: University of Florida Institute of Food and Agricultural Sciences. https://edis.ifas.ufl.edu/publication/SC110

McCray, J. M. 2022. “Phosphorus Fertilizer Recommendations for Sugarcane on Florida Mineral Soils.” SS-AGR-466. Gainesville: University of Florida Institute of Food and Agricultural Sciences. https://edis.ifas.ufl.edu/publication/SC108

McCray, J. M. 2022. “Calcium Silicate Recommendations for Sugarcane on Florida Mineral Soils.” SS-AGR-467. Gainesville: University of Florida Institute of Food and Agricultural Sciences. https://edis.ifas.ufl.edu/publication/SC109

Odero, D. C., and J. A. Dusky. 2021. “Weed Management in Sugarcane.” SS-AGR-09. Gainesville: University of Florida Institute of Food and Agricultural Sciences. https://edis.ifas.ufl.edu/publication/WG004

Table 1. Nitrogen fertilizer recommendations for Florida sugarcane by soil type.

Crop	Sands	Mucky sands	Sandy mucks	Mucks
	<6% OM	6-12% OM	13-20% OM	>20% OM
	----------------------------------lb N/acre------------------------------			
Plant cane	220	110	30	0
Ratoon crops	200	110	30	0
Split applications: For soluble N programs on sands, 5 splits for plant cane and 4 splits for ratoon crops are suggested. Fewer splits are needed with a controlled release program. For soluble N programs on mucky sands, 2 splits are recommended.				
Soluble N/application: For sands, each split application should include no more than 50 lb soluble N/acre.				
Rainfall exception: For sands, an additional 30 lb N/acre is allowed for the annual N total for a specific location when > 4 inches rainfall is received in a 2-day period and within 20 days after a soluble N application.				

Table 2. Recommended phosphorus fertilizer for each sugarcane crop for mucks and sandy mucks based on pre-plant Mehlich 3-extractable soil P.

Pm (g/m^3)	Plant	Ratoon 1	Ratoon 2	Ratoon 3+
	----------------------------------lb P_2O_5/acre---------------------------			
< 8	75	75	60	50
9–15	60	60	50	50
16–20	50	50	40	40
21–25	40	40	40	40
26–30	0	30	30	40
31–35	0	0	20	30
36–40	0	0	0	20
>40	0	0	0	0

Table 3. Recommended phosphorus fertilizer for each sugarcane crop for sands and mucky sands based on pre-plant Mehlich 3-extractable soil P.

Pm (g/m^3)	Plant	Ratoon 1	Ratoon 2+
	--------------------- P_2O_5/acre-------------------		
<30	75	75	60
31–55	60	60	50
56–80	40	40	40
81–100	0	40	40
101–120	0	0	40
>120	0	0	0

Table 4. Potassium fertilizer recommendations for Florida sugarcane grown on mucks and sandy mucks based on acetic acid-extractable soil K.

Acetic acid K	Plant	Ratoon 1	Ratoon 2	Ratoon 3+
lb K/acre	--------------------lb K_2O/acre--------------------			
0–19	250	200	200	150
20–29	250	200	150	150
30–39	250	200	150	150
40–49	200	150	150	150
50–59	200	150	150	150
60–69	150	150	150	150
70–79	150	150	150	150
80–89	150	150	150	150
90–99	100	150	150	150
100–109	100	150	150	150
110–119	100	150	150	150
120–129	100	150	150	150
130–139	100	150	150	150
140–149	100	150	150	150
150–159	0	150	150	150
160–169	0	100	150	150
170–179	0	100	150	150
180–189	0	100	150	150
190–199	0	100	150	150
200–209	0	0	150	150
210–219	0	0	150	150
220–229	0	0	150	150
230–239	0	0	150	150
240–249	0	0	100	150
250–259	0	0	100	150
260–269	0	0	100	150
270–279	0	0	100	150
280–289	0	0	100	150
290–299	0	0	100	150
300+	0	0	0	150

Table 5. Potassium fertilizer recommendations for Florida sugarcane grown on sands and mucky sands based on pre-plant acetic acid-extractable soil K.[1]

Acetic acid K	All crops
lb/acre	lb K_2O/acre
<50	250
51–80	200
>80	150

[1] Apply in at least 2 split applications each crop year. If using an all-soluble fertilizer program, at least 3 split applications are recommended for sands.

Table 6. Calcium silicate recommendations for sugarcane grown on mucks and sandy mucks based on acetic acid-extractable soil Si.

Acetic acid Si	Ca Silicate
g Si/m³	tons/acre
0–5	3.0
6–10	2.5
11–15	2.0
16–20	1.5
21–25	1.0
>25	0

Table 7. Calcium silicate recommendations for Florida sugarcane grown on sands and mucky sands based on acetic acid-extractable soil Si.

Acetic acid Si	Ca Silicate
g Si/m³	tons/acre
0–20	3.0
21–40	2.5
41–75	2.0
76–110	1.5
111–150	1.0
>150	0

Table 8. Elemental sulfur recommendations for Florida sugarcane for each soil type for furrow application based on pre-plant soil pH.

Soil pH	Granular Elemental Sulfur	
	Mucks, sandy mucks	Sands, mucky sands
	----------------lb/acre--------------	
7.0–7.1	100	100
7.2	150	150
7.3–7.4	200	200
> 7.5	250–500	250–300