

# Review of Current Sugarcane Fertilizer Recommendations: A Report from the UF/IFAS Sugarcane Fertilizer Standards Task Force<sup>1</sup>

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## Introduction

Sugarcane is Florida's most valuable row crop, produced on approximately 400,000 acres. Approximately 80% of Florida sugarcane is grown on organic “muck” soils (histosols) south of Lake Okeechobee that comprise the Everglades Agricultural Area (EAA). These soils are fertile, highly productive and have relatively high water and nutrient holding capacities. Approximately 20% of sugarcane in Florida is grown on sandy soils bordering the EAA. Sugarcane grown on sandy soils typically records lower yields than sugarcane grown on muck soils due to the poor water holding and nutrient retention capacity of the sandy soils. Current sugarcane fertilizer recommendations for both organic and sandy soils were developed decades ago. The current production environment includes considerably higher yielding cultivars and an expansion into sandy soil with low organic matter and poor cation exchange capacities. The University of Florida/Institute of Food and Agricultural Sciences (UF/IFAS) established a Sugarcane Fertilization

Standards Task Force in 2006. The task force consisted of UF/IFAS agronomists and soil scientists from the Everglades Research and Education Center in Belle Glade and Southwest Florida Research and Education Center in Immokalee, multi-county agents from UF/IFAS Extension Offices in Palm Beach and Hendry counties, and local grower representatives. The objectives of this task force were to: 1) review current fertilization recommendations for sugarcane, 2) review all pertinent data that have been generated (particular emphasis on recent unpublished data), 3) identify pertinent data that can be utilized in making fertilizer recommendations, 4) identify gaps in existing data, 5) develop recommended changes, if any, to current fertilization recommendations, and 6) develop a strategic plan for needed fertilizer research including demonstrations and on-farm trials.

## Current Sugarcane Fertilizer Recommendations

Current fertilizer recommendations for sugarcane production are (as are other agronomic and

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horticultural crops) based on soil testing and estimated crop nutrient requirements. Recommendations for sugarcane production were reviewed to determine if adequate information was available to determine appropriate nutrient recommendations under Florida environmental conditions. Best management practices (BMPs) utilize these recommendations to counter balance the nutritional needs of the crops for optimum or near-optimum growth and yield, while at the same time reducing the risk of potential ground and surface water contamination. The task force determined that the fertilizer elements in most need of review were nitrogen (N), phosphorus (P), magnesium (Mg), sulfur (S), and silicon (Si). Potassium (K) was not included in this list because grower and environmental concerns regarding K application to sugarcane were of lower priority than other nutrients.

### ***Nitrogen***

Little N is applied to sugarcane grown on histosols of the Everglades Agricultural Area (EAA) in southern Florida because soil mineralization in these soils high in organic matter releases large quantities of N on an annual basis. Sugarcane grown on the sandy soils (entisols and spodosols) adjacent to the EAA typically under-produces sugarcane grown on muck soils due to the lower water holding and nutrient retention capacity of the sandy soil compared with that of muck. Therefore, improved management practices are needed to make sugarcane production on sandy soils more cost effective. In a review, Anderson stated that N is an essential nutrient for sugarcane growth having a critical nutrient level (defined as the nutrient concentration level in a plant at which yield will likely decline by 5 to 10%) of 1.8%. The critical nutrient level is normally determined at stage 4 (expansion of the plant internodes and increases in plant height) which normally occurs in Florida between May and August.

Few sources of original data could be found for N rate studies conducted in Florida between 1960 and 1990. Everglades Research Station Reports in 1961 suggested 90 to 100 pounds per acre of N be applied annually, with 50 pounds per acre applied at planting and 40 pounds per acre side-dressed in April on sands

of less than 5% organic matter (OM). The recommendation decreased to a side-dressing of 30 pounds per acre as OM increased. In a later report (1971) the recommendation was restated to be 90 to 110 pounds per acre for sands and mucky sands. Recommended applications were 30 to 50 pounds per acre at first application (N rate varied with P and K soil test), and three supplemental applications of 20 pounds per acre each. An extra 20 pounds per acre was recommended in the event of excessive rain, for a total maximum of 130 pounds per acre. In subsequent reports, N recommendations were increased to 140 to 150 pounds per acre for sandy soils. Recommended applications were similar to their previous recommendation with 50 to 60 pounds per acre applied at first application, and three supplemental applications of 30 pounds per acre. The supplemental application in case of excessive rain was maintained at 20 pounds per acre bringing the annual maximum N application to 180 pounds per acre, and is the current sugarcane recommendation for sandy soil in Florida.

### ***Phosphorus***

Water-extractable soil P (Pw) is currently used for sugarcane fertilizer P recommendations. Recommendations range from 0 to 75 pounds  $P_2O_5$  per acre with no P recommended for the plant cane crop with Pw values higher than 6 lbs per acre. All P recommendations for plant and ratoon crops are based on soil samples taken before planting. Current fertilizer recommendations include 40 pounds  $P_2O_5$  per acre for ratoon crops at Pw values higher than 6 lbs per acre to ensure adequate P availability as soil P is depleted with cropping. These recommendations are based on field work done between 1968 and 1972 and are used on both organic and mineral soils in south Florida.

### ***Magnesium***

Magnesium availability in organic soils of the EAA is generally considered to be adequate for sugarcane production. The Everglades Soil Testing Laboratory does not recommend Mg fertilizer for sugarcane grown on organic soils. A survey of commercial sugarcane fields in south Florida in 2004 found few muck fields with leaf Mg concentration less than optimum 0.15-0.32%, but there were a

substantial number of fields with negative Mg Diagnostic and Recommendation Integrated System (DRIS) indices suggesting possible imbalance of Mg uptake relative to other nutrients in some situations on organic soils. Current IFAS recommendations call for adding 6 pounds per acre when the acetic acid soil test Mg value is less than 100 pounds per acre. This recommendation may be outdated at this point and may not be adequate. There is current research examining Mg nutrition on mineral soils. Based on available information at this time regarding sugarcane production on sands, growers should supply Mg by using dolomite to maintain soil pH at 5.5 or higher.

### **Sulfur**

Although S is an essential plant nutrient, the UF/IFAS literature addressing crop nutrition concerns for sugarcane grown on the organic soils of the EAA does not address S use from the standpoint of directly supplying S nutrition to the plant. Instead, loosely-based UF/IFAS recommendations for S applications to sugarcane evolved from the realization that acidifying properties of various S sources could bring about reductions in soil pH, which in turn would favor increased availability of micronutrient elements, particularly Mn. From this perspective, S application to sugarcane is not a fertilization effort, but rather a soil conditioning effort.

### **Silicon**

Silicon is described as a functional or beneficial plant nutrient, but not as essential. Sugarcane and rice yields have been increased with the application of calcium silicate slag to soils low in soluble Si. Application of calcium silicate for sugarcane production on sands and low-mineral organic soils in Florida is an accepted practice by growers. Economic analysis of the use of calcium silicate indicates that grower revenues can be increased if applications are directed to soils with insufficient soluble Si. Florida sugarcane growers currently apply up to a 3 tons per acre rate of calcium silicate slag to soils testing low in available Si. There is not an official UF/IFAS recommendation for Si application for sugarcane production, but a general suggestion is made that a 3 tons per acre rate will likely support a favorable yield improvement for soils testing less than 10 ppm Si.

## **Review of Recent Sugarcane Fertilizer Research**

Research on sugarcane nutrition in Florida was reviewed to document the current knowledge base and identify gaps in knowledge that would suggest needs for additional research. Literature from other sugarcane growing regions was also included where applicable.

### **Nitrogen**

Low leaf N concentration limited leaf photosynthesis and thus sugar yields. Under non-limiting N conditions (290 pounds per acre, in a single application), a relationship of leaf N and total crop N with days after planting or ratoon re-growth was found to exist for growing conditions on an unspecified soil in Queensland, Australia. It was also found that N accumulation ceased before biomass accumulation. As a result, crop N accumulation reached a maximum at 198 and 151 days after planting or ratoon growth, respectively, and did not change over the next 150 and 200 days, however, biomass continued to accumulate over this period. Leaf N concentration decreased throughout the study from approximately 2% just after planting or start of ratoon growth, to a range of 1.5 to 1.3% from 100 to 300 days after planting or ratoon re-growth.

A recent N rate study on sandy soils in Florida found no significant yield (stalk weight or sugar) increase at annual N rates above 150 pounds per acre. Three year average cane weight yield was 30 and 34 tons per acre for November and January harvests, respectively. While yearly sugar yield was not significantly greater with increased N rate, nearly 5 tons per acre increase in yield (15%) was observed when yields at annual application rates of 150 and 350 pounds per acre were compared. In the same study, mean leaf N increased by only 0.02% from 1.05 to 1.07% for the 150 and 350 pounds per acre annual N rates, respectively. In a three year study on sandy soils in Florida, the same amount of N per year was applied 13 times over three years increased yield by 12.8% when compared to seven applications over three years. The high N frequency treatment yielded an average of 34 tons per acre of sugarcane and 4 tons per acre of sugar over three years, compared to

30 tons per acre of sugarcane and 3.5 tons per acre of sugar with the low N frequency treatment. Therefore, nutrient use efficiency (NUE) can be increased by increased numbers of applications possibly by use of fertigation through drip irrigation or use of controlled release forms of N.

Placement of fertilizer was found to be an important factor in N uptake from a clay soil in Queensland, Australia. Urea placed on the soil surface had significantly reduced N uptake compared with urea incorporated into the soil. Total N loss was reduced from 59.1% to 45.6%, or a savings of 13.5% of annual N applied.

Various studies in Louisiana have demonstrated increased sugarcane yields resulting from water table management. Under Florida sandy soil conditions, it was concluded that a 24 inch water table depth produces optimal yields, and provides necessary upward water flux. Furthermore, they speculated that this distance increased yield because the water table was not close enough to impact root health or remove N from the root zone due to leaching or denitrification. Other reports indicate NUE [defined as the ratio of crop biomass N to N applied] increased to 53% for drip irrigated sugar cane compared with 29% for subsurface irrigated crops.

### **Phosphorus**

Soil testing is used to determine appropriate P fertilizer application rates on both organic and mineral soils. There has been a substantial amount of research done on organic soils in Florida in the last 20 years with sugarcane production response to P fertilizer. Soil-test P values produced with 0.5 N acetic acid extractions ( $P_a$ ) related better to production of sugar/acre than soil-test values produced using water as the extractant ( $P_w$ ). A P soil test calibration for sugarcane on organic soils using the Bray 2 extractant (0.03 M  $NH_4$  in 0.1 M HCl) has been developed.

It has been reported that under low initial soil-P test levels, increasing fertilization rates beyond 32 pounds per acre of P (75 pounds per acre of  $P_2O_5$ ) did not significantly increase sugar yields. In this work sugar production responses to P fertilizer were found in the ratoon crops, indicating the importance

of maintaining adequate soil P levels through the ratoon crops. Recent field work indicates that the primary yield response to P fertilizer is found at  $P_a$  soil test values less than 27 lbs per acre.

Water-extractable P is currently used for sugarcane fertilizer P recommendations on organic soils, but this measure of soil test P does not relate to sugar production as well as the acetic acid soil test. At lower pH, water extracts a higher amount of soil P, but that does not translate into greater plant availability of soil P and does not lead to greater sugarcane or sugar production.

### **Magnesium**

Availability of soil Mg is often a limiting factor in sugarcane production on mineral soils in Florida. Sugar yields on acid sands have been found to increase in the ratoon crop by dolomite application. Liming acidic soil has been found to be important in maintaining productivity over a multi-year growth cycle. Maintaining adequate levels of soil Mg has also been shown to be critical for optimum sugarcane production. Dolomite has been found to be an excellent amendment for acid sandy soils because of its liming ability and its Mg content.

### **Sulfur**

Early (late-1920s) EAA crop production research efforts focused on developing management strategies to address widespread crop nutrient deficiency disorders that were encountered on recently cleared raw sawgrass peat soils. Sulfur application rates are based on earlier literature review and soil-test results. Suggestions for S applications ranged from 500 lbs per acre to 2 tons per acre to increase soil pH by 0.3 to 1 unit.

### **Silicon**

Mechanisms proposed to explain yield responses to Si application include induced resistance to drought stress; aluminum (Al), manganese (Mn), and iron (Fe) toxicity alleviation; increased P availability; reduced lodging; improved leaf and stalk erectness; freeze resistance; and disease and pest resistance. Although suggestions of increased P availability with application of calcium silicate slag have been made, leaf P or soil P concentrations have not been found to

be increased with slag application. The extractant currently used by the Everglades Soil Testing Laboratory is 0.5 N acetic acid and is used for both organic and mineral soils for Si extraction. This extractant has performed well compared with other extractants in tests with upland rice. Leaf analysis is also a good indicator of Si status and work in Florida has shown that leaf Si values less than 0.5% indicate insufficient Si and a likely production response to applied calcium silicate. This leaf Si critical value agrees with the value of 0.53% leaf Si that was found to support 95% relative sugarcane yield was in Australia. Work in Florida indicates that some sugarcane production response is likely up to about 0.7% leaf Si. Areas where sugarcane production responses have been found in Stateplace Florida are the mineral soils and low-mineral organics. Torry muck soils are high in mineral content from historic overflows of Lake Okeechobee, support leaf Si values greater than 1%, and do not respond to applied calcium silicate. Sandy soils in south Florida have a high percentage of total Si, but generally have low levels of available Si, and so sugarcane grown on these mineral soils generally demonstrates a production response to applied calcium silicate.

### **Data Gaps and Recommended Research Priorities**

Gaps currently exist to one extent or another in our knowledge of sugarcane nutrition. The majority of these gaps exist in the relationships of N and P fertilizer application rate to crop biomass and sugar yield on sandy soils. Likewise, large gaps exist in our knowledge of how these elements impact water quality. Improvements in NUE for both N and P are essential to reducing the impact of sugarcane production on the environment.

#### ***Nitrogen***

Relationships of annual N rate and yield from sugarcane producing areas outside of south Florida were generally on soils with finer texture and greater water and nutrient retention and recent N rate studies on sandy soils in Florida were inconclusive. Therefore, additional data regarding N rate on sandy soils are required to determine if annual applications greater than 180 pounds per acre are justifiable.

Recent sugarcane cultivars have not been adequately tested for NUE in sandy soils. Selection of cultivars for use on sandy soils based on nitrogen NUE need to be performed in pot or small plot experiments with exceptional cultivars tested in large field plots in conjunction with plant breeders at the USDA ARS Sugarcane Field Station at Canal Point. Increases in NUE by the use of fertigation (application of nutrients through drip irrigation) or controlled release fertilizers (fertilizer materials that breakdown or release nutrient slowly over time) would greatly benefit sugarcane production on the sandy soils of south Florida and reduce the potential for water quality impacts. However, current low commodity prices may not support the installation of fertigation systems or the application of controlled release fertilizers, both having higher cost per unit of N applied. It has been demonstrated that split applications of fertilizers increase sugarcane yields. Additional data also needs to be collected on biomass and N accumulation over time at the selected annual N rate to determine the proper timing of fertilizer applications.

The combination of improved N rate effect and N accumulation data will provide the information needed to determine N BMPs for sugarcane production that will insure sustainable yields while protecting the water quality of south Florida. To collect adequate data on N use in as efficient a manner as possible, the above studies should be integrated with P soil test studies proposed by the task force.

#### ***Phosphorus***

The sugarcane soil test P calibration for organic soils in Florida should be updated as soon as possible. It is important to replace the water extractable test with an extraction more closely correlated with sugar production. All available data should be used to determine the new calibration. Other extractants currently being studied include modified acetic acid, Mehlich 3, and Bray 2. The current maximum P rate of 75 pounds per acre of  $P_2O_5$  is supported by other work. The acetic acid soil test should be compared with other extractants to determine the best choice, but there is a strong need to replace the water extractant for sugarcane P fertilizer recommendations as soon as possible.

### ***Magnesium, Silicon, and Sulfur***

Magnesium fertilizer recommendations should be reexamined, particularly for mineral soils because of the potential impact on sugarcane production, but this is a lower priority than N, P, S, and Si research. The task force recommends the implementation of S-related studies, particularly those investigating sugarcane agronomic and sugar responses to S rate and S source. A sulfur research working group has been established to coordinate IFAS sulfur research on sugarcane yields and environmental concerns. Sugarcane growers are using the acetic acid Si soil test to make decisions about silica application, but at this point there are not specific Si recommendations for sugarcane. Current research with calcium silicate is nearing completion and then should be evaluated in addition to previous work to determine Si recommendations for sugarcane grown on organic and mineral soils.

### **Conclusions**

Most current nutrient recommendations for sugarcane production were made 30 or more years ago for histosols containing high organic matter levels. These soils have higher water and nutrient holding characteristics compared with most sandy soils in Florida. Cultivars and production practices have changed greatly since the current recommendations were made. Much of the field data used to establish current recommendations are no longer available or contain incomplete soil characteristic data. Sugarcane production on sandy entisols and spodosols has increased since most recommendations were established making soil characteristic data important in determining applicability of current recommendations on these sandy soils. Application rate and timing research on many nutrients are currently being conducted on both organic and mineral soils. Additional data on annual N and P application rate on sandy soil are needed along with soil P test calibration for both organic and sandy soils. Likewise, field testing of Si, Mg, and S rates need to continue, before appropriate recommendations can be established, particularly on sandy soils.