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Sugarcane Nutrient Management Using Leaf Analysis[1]

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Introduction

Leaf nutrient analysis has been widely used as a diagnostic tool to complement soil testing in sugarcane production (Anderson and Bowen 1990; Gascho and Elwali 1979; Samuels 1969). Leaf analysis can be particularly useful in determining the nutrient status of Florida sugarcane because soil samples are routinely only taken before sugarcane is planted and not during ratoon crops because of problems in obtaining representative soil samples after banding of fertilizers (Gascho and Kidder 1979). Also, leaf analysis can provide information about nitrogen and micronutrients, which are not included in the standard soil tests.

Leaf analysis has been used intensively by a limited number of Florida sugarcane growers and has the potential for an expanded role in growers' fertility programs. Leaf analysis evaluation methods and visual symptoms of nutritional problems are described in a companion EDIS publication by McCray et al. (2010c) (http://edis.ifas.ufl.edu/SC075). The purpose of the following document is to provide growers with sufficiency categories of leaf nutrient concentrations and with nutrient management suggestions for each category.

Results of Leaf Analysis Survey

A survey of leaf nutrient concentrations in commercial Florida sugarcane fields was conducted from 2004 to 2006 (McCray et al. 2009; McCray et al. 2010b). Fields were selected to be representative of plant cane, first ratoon, and second ratoon crops, mineral and organic soils of the area, and major sugarcane cultivars. Leaf samples were collected during the period of April–August each year and included comparisons of sampling dates (McCray et al. 2009). Leaf samples were collected and prepared for analysis using protocols described in a companion EDIS publication by Ezenwa et al. (2008) (http://edis.ifas.ufl.edu/SC076). Leaf nutrient concentrations measured in the survey were assessed using critical values and optimum ranges previously defined by Anderson and Bowen (1990) and McCray et al. (2010c). Nutrients with the highest percent deficiency on mineral soils were silicon, nitrogen, iron, and magnesium (Table 1). Silicon and manganese were the nutrients with the highest percent deficiency on organic soils (Table 2). Ratoon

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crops generally had more leaf nutrient concentrations below optimum levels than plant cane for both mineral and organic soils.

We estimated percentages of survey fields on organic and mineral soils that were limited by insufficient nutrient concentration for nine nutrients (Table 3; McCray et al. 2010b). Approximately 17% of fields surveyed on mineral soils were estimated to have leaf magnesium concentrations limiting relative sugarcane yield (tons cane/acre; TCA) to less than 75% of optimum yield. There were a high percentage of surveyed fields on mineral soils that were limited by insufficient silicon, with 47% of fields having yield reductions estimated between 11 and 25%. On organic soils, there were approximately 10% of the surveyed fields with estimated yield reduction > 25% due to insufficient leaf manganese. Also, 25% of surveyed fields on organic soils had estimated yield reduction between 11 and 25% due to insufficient silicon.

Leaf Nutrient Requirements

Information from the leaf nutrient survey was used to make slight revisions to previous optimum ranges and critical values as shown in the leaf nutrient requirements in Table 4. The leaf nutrient concentrations defined as the critical value for each nutrient could result in a potential 5–10% yield reduction from optimum. Also included in Table 4 are nutrient concentrations at which an estimated 25% reduction in final yield may occur. It is important to keep in mind that there are many crop growth factors determining yield, and so other factors will influence the impact of increasing the leaf concentration of a single nutrient. For example, if leaf nitrogen concentration is increased from 1.6 to 2.0%, other nutrients or growth factors may also have to be corrected to get a full 25% yield increase. It is important to examine nutrient sufficiency of all nutrients, as well as to consider the impact of other growth factors such as water availability, drainage, weed control, etc.

Suggested Sample Dates

Comparisons of leaf nutrient concentrations between samples taken in April–May and samples taken in June–August have indicated that leaf manganese and iron concentrations increase with an increase in soil moisture during the summer (McCray et al. 2009). This may occur because of localized areas within the soil of more chemically reduced conditions (oxidation/reduction reactions) in soils that are aerated but with higher soil moisture because of summer rains compared to the normally very dry period of April–early May. Solubility of manganese and iron are each increased as they are reduced to the Mn^{2+} and Fe^{2+} ions. This explains the often observed manganese deficiency symptoms in spring that disappear or become less pronounced with the summer rains.

The grand growth period of sugarcane in Florida (June 1 to October 15) is the period of most rapid nutrient uptake (Coale et al. 1993) and so is an appropriate time to evaluate leaf nutrient status. Since this period also generally coincides with the rainy season of late May through October in South Florida, leaf manganese and iron concentrations taken during the grand growth period will generally reflect an increase in soil moisture compared to the normally drier period of April and early May. Soil moisture conditions will obviously vary from year to year and within a given year. Nutrients other than manganese and iron do not appear to be influenced to a large degree by spring versus summer sampling, but sampling leaf tissues early during the grand growth period will work well for evaluating the sufficiency of all nutrients. For these reasons June and July are suggested as preferred months for collecting sugarcane leaf samples in Florida. Samples can also be collected in August and later, but entering fields will be more difficult later in the season. Sample collection and processing is discussed in a companion EDIS publication by Ezenwa et al. (2008) (http://edis.ifas.ufl.edu/SC076).

Sufficiency Categories and Management Strategies

Table 5 lists sufficiency categories for nine nutrients so that the status of each of these can be compared for a given sample/field. Calcium is not included since a true calcium deficiency is rare, and low leaf calcium concentrations are often indicative of other growth or nutritional problems. Table 6 provides basic management strategies for each sufficiency category, and Figure 1 shows a generalized nutrient response curve with the region of each category noted on the curve. The ideal region for all nutrients is the sufficient category because there is no further yield response within this range, and nutrient levels are not in excess. If leaf nutrient concentration is in the sufficient plus or high category, reducing future application rates could be considered, assuming these are nutrients routinely applied in fertilizer. When nutrients are in the deficient or very deficient categories, inclusion of these nutrients in the next application or increasing the planned rate is most likely needed. When a nutrient is in the marginal category, the potential benefit of increasing the concentration to optimum has to be weighed against the cost. It is possible for the maximum economic yield to be slightly down the response curve in the marginal region, depending on the cost/benefit of additional fertilizer. Nitrogen on mineral soils and silicon on organic and mineral soils are examples of nutrients with which cost versus benefit should be closely examined. With these two nutrients it can be difficult to maintain concentrations in the sufficient range, but leaf analysis will help a grower make informed decisions. An effective increase or decrease in rate of a given fertilizer nutrient will depend on soil type, available soil nutrients, and other specifics for a given field. The nutrient sufficiency categories are intended to rank the nutrients in terms of sufficiency and estimate the impact each nutrient is having on yield.

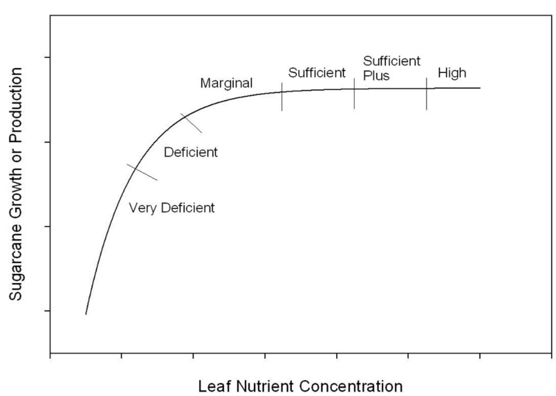

Figure 1. General nutrient response curve showing sufficiency categories.

A recent study of summer fertilizer supplements based on spring leaf analysis indicated that these supplements are too late in the annual growth cycle to result in substantial yield improvements (McCray et al. 2009). A more cost-effective approach is to use leaf and soil analysis to optimize the next amendment or fertilizer application. This will not require adding unplanned fertilizer applications and will allow for long-term improvements in growers' nutrient management programs. Having leaf nutrient sufficiency categories for a given sample/field will allow a grower to target specific nutrients that are most limiting to sugarcane production.

As part of this approach, two suggested strategies for leaf analysis are:

1. To sample representative fields across a farm to assess the fertilizer program each year and
2. To sample fields in the last ratoon year before replanting to assist in making amendment decisions (calcium silicate, dolomite, and elemental sulfur).

This plan would not require sampling every field, every year, and should provide a reasonable annual picture of nutrition for a farm. Leaf analysis can provide a relatively inexpensive source of nutritional information to supplement soil testing for making improved nutrient management decisions.

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Table 1. Percentages of mineral soil fields within four categories of leaf nutrient concentration status in a survey of Florida sugarcane fields in 2004, 2005, and 2006 (McCray et al. 2009).†

Nutrient Status‡	N	P	K	Ca	Mg	Si	Fe	Mn	Zn	Cu
	-----------------------------Percent of Survey Fields------------------------------									
	Plant Cane (n=53)									
Deficient	18.9	1.9	1.9	1.9	3.8	49.1	15.1	0	0	3.8
Marginal	45.3	43.4	11.3	NA§	18.9	35.8	NA	NA	0	3.8
Optimum	35.8	54.7	86.8	69.8	77.3	15.1	84.9	100.00	98.1	84.9
>Optimum	0	0	0	28.3	0	NA	0	0	1.9	7.5
	Ratoon (n=55)									
Deficient	34.6	7.3	1.8	1.8	20.0	74.6	36.4	1.8	3.6	0
Marginal	32.7	23.6	1.8	NA	23.6	20.0	NA	NA	3.7	3.6
Optimum	32.7	69.1	96.4	96.4	56.4	5.4	63.6	98.2	92.7	89.1
>Optimum	0	0	0	1.8	0	NA	0	0	0	7.3

†Mineral soils in this table are limited to fields with organic matter content < 5%.
‡Deficient: < critical value; Marginal: ≥ critical value and < optimum;
Optimum: within optimum range; >Optimum: > upper end of optimum range.
§NA, Not applicable as a category for a particular nutrient based on leaf nutrient ranges defined by Anderson and Bowen (1990) and McCray et al. (2010c).

Table 2. Percentages of organic soil fields within four categories of leaf nutrient concentration status in a survey of Florida sugarcane fields in 2004, 2005, and 2006 (McCray et al. 2009).†

Nutrient Status‡	N	P	K	Ca	Mg	Si	Fe	Mn	Zn	Cu
	----------------------------Percent of Survey Fields----------------------------									
	Plant Cane (n=131)									
Deficient	1.5	1.5	1.5	9.9	2.3	25.2	4.6	42.0	0	1.5
Marginal	8.4	17.6	0.8	NA§	9.2	29.8	NA	NA	1.5	3.0
Optimum	74.1	79.4	65.6	81.7	86.2	45.0	93.9	57.2	88.6	71.8
>Optimum	16.0	1.5	32.1	8.4	2.3	NA	1.5	0.8	9.9	23.7
	Ratoon (n=126)									
Deficient	6.3	6.4	2.4	4.0	3.2	38.9	18.2	37.3	3.2	0.8
Marginal	16.7	23.8	3.2	NA	10.3	27.8	NA	NA	4.0	7.1
Optimum	74.6	69.8	80.9	80.9	84.1	33.3	79.4	60.3	89.6	70.6
>Optimum	2.4	0	13.5	15.1	2.4	NA	2.4	2.4	3.2	21.5

†Fields included in this table had organic matter content ≥ 30%.
‡Deficient: < critical value; Marginal: ≥ critical value and < optimum;
Optimum: within optimum range; >Optimum: > upper end of optimum range.
§NA, Not applicable as a category for a particular nutrient based on leaf nutrient ranges defined by Anderson and Bowen (1990) and McCray et al. (2010c).

Table 3. Percentages of fields within four categories of relative sugarcane yield as limited by each of nine leaf nutrient concentrations in a survey of Florida sugarcane fields in 2004, 2005, and 2006 (McCray et al. 2010b).

Relative TCA[†]	N	P	K	Ca	Mg	Si	Fe	Mn[‡]	Zn
	----Percent of Survey Fields----								
	Organic Matter Content < 5% (n=108)								
< 75%	9.26	4.63	0.00	0.00	16.67	1.85	11.11	0.00	1.85
75-89%	11.11	6.48	1.85	1.85	16.67	47.22	25.00	3.61	5.56
90-99%	24.07	26.85	6.48	11.11	8.33	33.33	12.04	3.61	5.56
Not Limited	55.56	62.04	91.67	87.04	58.33	17.60	51.85	92.78	87.03
	Organic Matter Content ≥ 30% (n=261)								
< 75%	0.38	3.83	0.77	1.92	4.60	0.38	4.60	10.47	1.53
75-89%	2.30	2.30	1.15	4.98	8.05	24.90	8.43	9.30	3.45
90-99%	3.45	18.39	1.92	6.90	8.05	21.46	11.49	16.28	4.60
Not Limited	93.87	75.48	96.16	86.20	79.30	53.26	75.48	63.95	90.42

[†]Relative sugarcane yield expresses yield (tons cane/acre; TCA) as a percentage of a baseline optimum of 71 TCA (90% of the mean TCA of the upper 1% of TCA values in the survey population). Survey field percentages were based on comparisons with leaf nutrient concentrations derived from boundary lines for each nutrient.
[‡]These percentages for Mn are based on a boundary line derived from leaf samples taken in June, July, and August of each year (during the rainy season in South Florida). Percentages for all other nutrients are based on boundary lines derived from leaf samples taken from late April through July of each year. Sample numbers (n) for Mn on mineral and organic soils were 83 and 86, respectively.

Table 4. Sugarcane leaf nutrient concentration optimum ranges and concentrations at which a 5–10% or 25% production loss from optimum might be expected.[†]

Nutrient	Optimum Range	Est. 5–10% Loss (Critical Value)	Est. 25% Loss
	----%----		
N	2.0–2.6	1.8	1.6
P	0.22–0.30	0.19	0.17
K	1.0–1.6	0.9	0.8
Ca	0.22–0.45	0.20	0.18
Mg	0.15–0.32	0.13	0.11
Si	≥0.60	0.50	0.20
	----mg/kg----		
Fe	55–105	50	40
Mn	20–100	16	12
Zn	17–32	15	13
Cu	4–8	3	2

[†]Sugarcane production loss estimates assume that the nutrient under consideration is the only factor limiting growth. All growth factors, including other nutrient levels, should be considered when making nutrient management decisions. Leaf nutrient concentrations are for top visible dewlap leaf blades (without midrib). Suggested sampling period is June–July.

Table 5. Sugarcane leaf nutrient sufficiency ranges for defining nutrient management categories.

Sufficiency Category[†]	N	P	K	Mg	Si	Fe	Mn	Zn	Cu
	--------%					--------mg/kg			
Very Deficient	<1.6	<0.17	<0.80	<0.11	<0.20	<40	<12	<13	<2.0
Deficient	1.60–1.79	0.17–0.18	0.80–0.89	0.11–0.12	0.20–0.49	40–49	12–15	13–14	2.0–2.9
Marginal	1.80–1.99	0.19–0.21	0.90–0.99	0.13–0.14	0.50–0.59	50–54	16–19	15–16	3.0–3.9
Sufficient	2.00–2.30	0.22–0.26	1.00–1.30	0.15–0.24	0.60–0.80	55–80	20–60	17–25	4.0–6.0
Sufficient Plus	2.31–2.60	0.27–0.30	1.31–1.60	0.25–0.32	0.81–1.00	81–105	61–100	26–32	6.1–8.0
High	>2.60	>0.30	>1.60	>0.32	>1.00	>105	>100	>32	>8.0

[†]Very Deficient: Estimated production losses > 25%
Deficient: Estimated production losses 6–25%
Marginal: Estimated production losses 1–10%
Leaf nutrient concentrations are for top visible dewlap blades (without midrib). Suggested sampling period is June–July.

Table 6. Nutrient management suggestions for sugarcane leaf nutrient sufficiency ranges. Amendment or fertilizer adjustments should also consider soil analysis, crop history, and other site-specific information available to the grower.

Sufficiency Category	Management
Very Deficient	Major limitation. Target this nutrient at next application.
Deficient	Substantial limitation. Target this nutrient at next application.
Marginal	Minor limitation. This nutritional limitation is not causing major problems but should be addressed. Cost/benefit should be considered to increase and maintain leaf concentration within sufficient category.
Sufficient	This is the target zone. Maintain nutrient at this level.
Sufficient Plus	It is possible to reduce nutrient applications to a small degree if this is an applied nutrient.
High	It should be possible to reduce the rate of application of this nutrient at the next application if it is an applied nutrient. Leaf nutrients in this category are rarely at a toxic level but are well beyond response levels and may result in imbalances with other nutrients.