Introduction

Fertilizer use efficiency in Florida citrus groves can be enhanced by "program fertilization," where annual fertilizer applications are scheduled after considering a number of grove characteristics. The information necessary to formulate an efficient fertilization program for a particular grove includes tree age, past production, fertilization history, and diagnostic information. This fact sheet details the value of grove nutritional diagnostic information in determining fertilizer programs that increase fertilizer efficiency while maintaining maximum yield and desirable fruit quality.

Usefulness of Leaf-tissue and Soil Testing

Leaf tissue testing is useful to evaluate tree nutritional status with respect to most nutrients, but is particularly effective for 1) macronutrients, primarily nitrogen (N) and potassium (K), that readily move with soil water, and 2) the micronutrients copper (Cu), manganese (Mn), zinc (Zn), and iron (Fe). Leaf tissue analysis is a much better indicator of the effectiveness of soil-applied fertilizer for these elements than soil analysis. In addition, if particular elements have not been applied as fertilizer, leaf tissue analysis indicates the availability of those nutrients in the soil. An annual leaf tissue sampling program can establish trends in tree nutrition resulting from fertilizer practices carried for several years.

Both leaf tissue and soil testing can be valuable, but leaf analysis provides more useful information about citrus nutrition than soil analysis. With the results of a soil test, one tries to predict how much of a particular nutrient will be available to plants in the future. Obviously, the further into the future that the prediction is made, the less accurate it will be. Predictive soil testing works best with 1) short term crops, and 2) nutrients which are not very mobile in the soil. Thus, for long-term crops such as citrus, predictive sampling should be used for only those nutrients which have slight mobility in most soils.
including phosphorus (P), calcium (Ca), and magnesium (Mg). Soil testing has limited value for the more mobile nutrients such as N and K.

**Leaf-tissue Sampling Programs**

The benefits of leaf tissue sampling are fully realized by establishing an annual sampling program. In this way, trends in tree nutrition over several years may be noted.

The grove should be sampled to minimize soil and tree type variability. The sampling scheme is the one area of the nutritional testing process controlled by the individual taking the sample. Thus, the manager needs to ensure that the leaf sample is representative of a particular area. For sampling purposes, the grove should be partitioned into management units of not more than 20 acres. Each unit should contain similar soil series and scion/rootstock types. For small groves, the entire grove may be partitioned into these units, and a sample taken from each.

For large groves, where sampling the entire grove is unfeasible, indicator blocks may be used. An indicator block is a designated zone within a uniform span of grove from which the sample is taken (e.g. a 20-acre block within a uniform 100-acre span of grove). Aerial photos are useful for the selection of these blocks. The sample results obtained from the indicator block are assumed to represent the entire span, and management decisions made from the sample data are applied to the entire span. The same block should be sampled repeatedly in succeeding years.

A more elaborate approach to citrus leaf tissue sampling involves the use of global positioning satellites (GPS) and a geographic information system (GIS). Groves are sampled in a regular, grid-like pattern, and the geographic position of each sample is recorded using GPS technology. After the samples are analyzed, the results are processed with GIS and contour maps are made. The grower uses the maps to determine the spatial variation of tree nutritional status, and areas of high or low nutrition can be identified. This method is more expensive than the traditional sampling described above, but may provide a higher level of information that can improve management decisions.

**Analytical Procedures for Leaf Samples**

If samples require hand-washing (necessary for accurate Fe determination), it is best done when the leaves are still in a fresh condition. Laboratories do not normally hand-wash leaves, so washing should be done by the person taking the sample at the time he/she takes the sample. When the sample arrives at the laboratory, the following steps are typically taken: 1) the leaves are dried and finely-ground; 2) a known weight of tissue is either digested in acid (for N analysis) or ashed in a furnace (for all other elements); 3) the concentration of elements in the digest or ash are measured; 4) nutrient concentrations are expressed as either percentage or parts per million (ppm) in the tissue. Procedures for plant tissue analysis usually do not vary among laboratories because the entire amount of each nutrient in the leaves is measured. Thus, results from different laboratories can be directly compared.

**Leaf-analysis Interpretation**

Well-defined categories of classification for citrus leaf tissue analysis values from mature, bearing trees exist from years of experimentation in Florida and California. The categories are "deficient," "low," "optimum," "high," and "excess." Leaf analysis standards are shown in Table 1. Remember that this classification applies only to the standard age leaf sample taken from mature trees as described above. The categories are not valid for young, non-bearing trees. Maintenance of leaf sample elemental concentrations in the "optimum" range is desirable. Those consistently above this range indicate possible over-fertilization. Analysis values can be interpreted by the grower and fertilization rates adjusted in the appropriate direction, such that future leaf values reach the "optimum" range.

Archival copy: for current recommendations see http://edis.ifas.ufl.edu or your local extension office.
Soil-sampling Programs

As with leaf sampling, the benefits of soil sampling are fully realized if samples are taken annually from the same production units (or indicator blocks), because trends in soil pH or extractable nutrients can be established.

The traditional soil sampling technique is as follows:

One 6-inch deep soil core is removed from the dripline (within the herbicide band) of 15 to 20 "average" trees scattered throughout the block. The cores should be composited into the same bag and air-dried before being sent for analysis. Samples should be taken in the latter part of the summer rainy season (July-September), before fall fertilization.

Analytical Procedure for Soil Samples

Once the soil sample has been sent to the laboratory, the following steps are usually taken: 1) the soil sample is dried; 2) the dry soil is passed through a screen to remove roots, stones, etc.; 3) a known weight of soil is shaken with a chemical extracting solution for a specified time; 4) the concentrations of extracted P, K, Ca, and Mg in the solution are determined (micronutrients are sometimes also included); 5) nutrient concentrations are usually expressed as ppm in the soil.

An important component of the analytical procedure that the laboratory client should know is the extracting solution used. Extractants vary in strength, and not all laboratories use the same type. The amount of nutrients extracted from a soil sample by one laboratory will not be comparable with those of another if the extracting solutions differ.

Soil-test Interpretation

A soil test interpretation verbally explains the relative meaning of soil test values. Interpretation uses the categories "very low," "low," "medium," "high," and "very high" to relate to various levels of an extracted nutrient. However, soil test results have no meaning unless they are calibrated with crop response. Each laboratory must have a calibration-based interpretation of its soil test results for each extractant that it uses.

The category "very low" indicates that the soil can supply little of the Crop Nutrient Requirement (CNR), thus most of the nutrient must come from applied fertilizer. The categories "low" and "medium" mean that proportionally more of the CNR can be supplied from the soil, resulting in reduced need for fertilization. When a soil tests "high" or "very high," all of the CNR can be satisfied from the soil alone and no fertilization with that nutrient is required.

While soil extractants (particularly Mehlich-1) have been calibrated for many agronomic and vegetable crops in Florida, they have not been extensively calibrated for citrus. However, there are sufficient data correlating tree performance with soil-test P values to be useful in formulating fertilizer programs. The minimum adequate P soil test levels for citrus groves on acidic sandy soils are 30 ppm P for the Mehlich-1 extractant, 40 ppm P for the Bray P1 extractant, and 65 ppm P for the Bray P2 extractant. This means that above these levels, no response is expected from added fertilizer. P can accumulate in the soil as a result of fertilization over a number of years, therefore testing soils for P is important because of the likelihood that P fertilization can be reduced or eliminated as a grove matures.
Soil and Leaf-tissue Sampling Checklist

Soil and leaf analysis helps formulate fertilization programs or diagnose nutritional deficiencies. Use this checklist as a guide for starting a soil and leaf tissue testing program:

1. Sampling programs are most effective if done annually.

2. Use leaf tissue testing for all nutrients, especially the mobile soil nutrients (N and K) and micronutrients (Cu, Fe, Mn, and Zn).

3. Use soil testing for pH and immobile soil nutrients (P, Ca, and Mg).

4. Use the standard sampling procedures for soil and leaves described in this fact sheet.

5. Be aware that spray residues or dust on leaf surfaces affect sample results; wash leaves for accurate Fe analysis, and avoid leaves with spray residues.

6. Be aware that a number of soil extracting solutions exist, and they can differ in their ability to extract plant nutrients, especially P.

7. Test interpretations should be used to make fertilization or liming decisions. Wise use of the analytical information allows optimal citrus production and minimizes the fertilizer pollution of the environment.

Further Reading


Table 1. Leaf analysis standards for mature, bearing citrus trees based on 4 to 6-month-old spring-cycle leaves from nonfruiting terminals.

<table>
<thead>
<tr>
<th>Element</th>
<th>Deficient</th>
<th>Low</th>
<th>Optimum</th>
<th>High</th>
<th>Excess</th>
</tr>
</thead>
<tbody>
<tr>
<td>N (%)</td>
<td>&lt;2.2</td>
<td>2.2-2.4</td>
<td>2.5-2.7</td>
<td>2.8-3.0</td>
<td>&gt;3.0</td>
</tr>
<tr>
<td>P (%)</td>
<td>&lt;0.09</td>
<td>0.09-0.11</td>
<td>0.12-0.16</td>
<td>0.17-0.30</td>
<td>&gt;.30</td>
</tr>
<tr>
<td>K (%)</td>
<td>&lt;0.7</td>
<td>0.7-1.1</td>
<td>1.2-1.7</td>
<td>1.8-2.4</td>
<td>&gt;2.4</td>
</tr>
<tr>
<td>Ca (%)</td>
<td>&lt;1.5</td>
<td>1.5-2.9</td>
<td>3.0-4.9</td>
<td>5.0-7.0</td>
<td>&gt;7.0</td>
</tr>
<tr>
<td>Mg (%)</td>
<td>&lt;0.20</td>
<td>0.20-0.29</td>
<td>0.30-0.49</td>
<td>0.50-0.70</td>
<td>&gt;0.70</td>
</tr>
<tr>
<td>Cl (%)</td>
<td>?</td>
<td>?</td>
<td>0.05-0.10</td>
<td>0.11-0.25</td>
<td>&gt;.25</td>
</tr>
<tr>
<td>Na (%)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.15-0.25</td>
<td>&gt;.25</td>
</tr>
<tr>
<td>Mn (ppm)</td>
<td>&lt;17</td>
<td>18-24</td>
<td>25-100</td>
<td>101-300</td>
<td>&gt;300</td>
</tr>
<tr>
<td>Zn (ppm)</td>
<td>&lt;17</td>
<td>18-24</td>
<td>25-100</td>
<td>101-300</td>
<td>&gt;300</td>
</tr>
<tr>
<td>Cu (ppm)</td>
<td>&lt;3</td>
<td>3-4</td>
<td>5-16</td>
<td>17-20</td>
<td>&gt;20</td>
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<tr>
<td>Fe (ppm)</td>
<td>&lt;35</td>
<td>35-59</td>
<td>60-120</td>
<td>121-200</td>
<td>&gt;200</td>
</tr>
<tr>
<td>B (ppm)</td>
<td>&lt;20</td>
<td>20-35</td>
<td>36-100</td>
<td>101-200</td>
<td>&gt;200</td>
</tr>
<tr>
<td>Mo (ppm)</td>
<td>&lt;0.05</td>
<td>0.06-0.09</td>
<td>0.10-1.0</td>
<td>2.0-5.0</td>
<td>&gt;5.0</td>
</tr>
</tbody>
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