Use of Soil and Tissue Testing for Sustainable Crop Nutrient Programs

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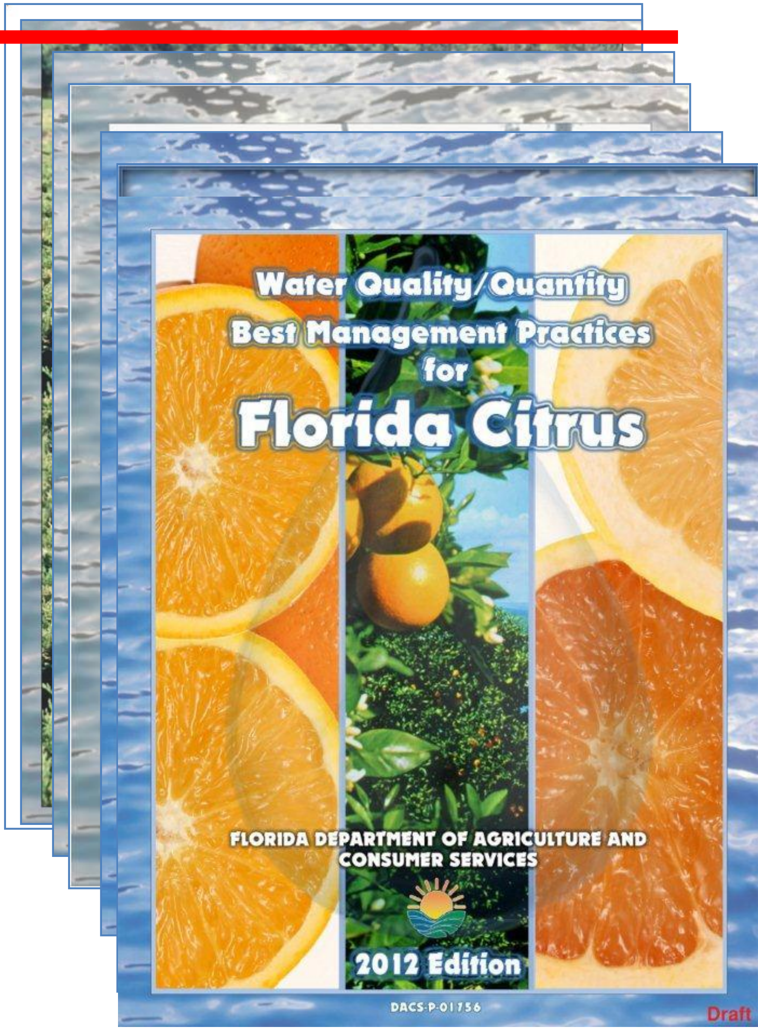
FDACS-OAWP BMP Manuals

- Vegetable & Agronomic Crops
- Container Nursery
- Sod
- Cow/Calf
- Specialty Fruit & Nut
- Commercial Equine
- Consolidated Citrus



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BMP Manuals

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- Provides BMPs on:
  - Land preparation
  - Nutrient management
  - Irrigation management
  - Drainage Management
  - Sediment and erosion control
  - Water resource protection
  - Integrated pest management

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Benefits of Implementing BMPs

- A presumption of compliance with state water quality standards for the pollutants addressed by the BMPs.
- Release from fines for damages from pollutants addressed by the BMPs.
- Technical assistance with BMP implementation.
- Eligibility for cost-share for certain BMPs (as available).
- The Florida Right to Farm Act generally prohibits local governments from regulating an agricultural activity that is addressed through rule-adopted BMPs.
- Producers who implement FDACS-adopted BMPs might qualify for exemptions from WMD surface water permitting and/or satisfy other permitting requirements.

Agricultural Nutrients

- Excess nitrogen and phosphorus are the most common causes of water quality impairments in Florida. These nutrients can enter surface waters through stormwater or irrigation runoff, or leach through soils into ground water.
- In aerobic well-drained soils, urea and ammonium forms of nitrogen are usually transformed by bacteria to nitrate which is a plant-available form. Due to its high mobility, nitrate can also leach into ground water.
- Phosphorus is another primary plant nutrient and moves into water sources with sediments or leaching.
- N and P tend to be the (growth) limiting nutrient for lakes.

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Agriculture and Water Quality

- Elevated levels of phosphorus, nitrogen, sediment, bacteria, and organic material contribute to the degradation of water quality.
- The potential for discharges from agricultural operations to cause water quality problems varies, depending on soil type, slope, drainage features, and nutrient and irrigation management practices.
- Nutrient-related pollutant discharges can come from:
  - excess use,
  - inefficient placement,
  - or poor application timing of commercial fertilizer

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BMPs and Fertilizer

- Best Management Practices (BMPs) adopted all current UF/IFAS recommendations.
- Adequate fertilizer rates may be achieved by combinations of UF/IFAS recommended base rates and supplemental applications.
- Fertilizer recommendations were determined based on Mehlich-1 (M1) extractable nutrients prior to planting. We have now changed to Mehlich-3.

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Crop Nutrition

- Nutrient Best Management Practices
- Essential nutrients
- Nutrient deficiency symptoms
- Nutrient cycling
- Soil and Plant sampling, analysis and interpretation

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Nutrient Best Management Practices

Ecologically based nutrient management with low impact on profitability

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Improving Nutrient Use

Efficient water and nutrient use will:

- Use nutrient management plan to accurately determine nutrient applications
- Maintain adequate water and soil nutrient levels to maximize plant growth and health
- Increase growth and yield
- Decrease production cost and resource depletion: facilitates sustainable production
- Reduce nutrient losses and environmental impacts

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Additional Benefits of Best Management Practices

- Promote rapid canopy development
- Increases crop resistance to disease and insect
- Potentially lower irrigation required
- Increased canopy growth can aid in weed control

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Improving Nutrient Use Efficiency

Efficient water and nutrient use will:

- Maintain adequate water and soil nutrient levels to maximize plant growth and health
- Increase growth and yield
- Decrease production cost and resource depletion: facilitates sustainable production
- Reduce nutrient losses and environmental impacts

Limitations on Potential Crop Production

Potential annual production limitations:

- **Soil type characteristics**
  - **pH, organic matter, water-holding capacity, and cation exchange capacity**
- **Production methods**
  - **Irrigation, and drainage systems**
- **Variety**
  - **Size, water and nutrient efficiency, yield**

Nutrient Management Plan

- Annual plan should include:
  - Soil test results
  - Plant tissue test results
  - Realistic production goals
    - Based on past production, or potential production
- Nutrient budget for N, P, and K
  - Rates, Methods, Materials, and Timing
- Manage soil pH for optimum uptake

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Nutrient Management

– An increasingly accepted and successful approach called the *4R Nutrient Stewardship Program* that captures the key elements of effective nutrient management:

- **Right Source** – a balanced supply of essential nutrients, considering both naturally available sources and specific products, in plant available forms;
- **Right Rate** – nutrients applied to the soil to supply nutrients to satisfy plant demand;
- **Right Time** – consideration of crop uptake, soil supply, nutrient loss risks, and field operation logistics; and
- **Right Place** – based on root-soil dynamics, nutrient movement, and soil variability within the field to maximize plant uptake and limit potential losses from the field.

The 5^{th} R, Right Irrigation

- Water is the carrier for nearly all pollutants. Managing irrigation inputs and drainage to keep moisture and fertilizer primarily in the root zone will reduce nutrient-related impacts. Irrigating in excess of the soil's water-holding capacity or excessive drainage will lead to increased runoff or leaching, and may lead to higher production costs or lower marketable yields.

Soil and Plant Tissue Analysis and Interpretation

Proper collection of samples and interpretation on results are as important as the analysis

What is are Essential Plant Nutrients

Plant uses a lot.
Easily lost from soil.

Plant uses a lot.
Can be “fixed” in clay soil, or leached from sandy soil.

N – P – K

Plant uses a moderate amount.
Many soils “fix” P, rendering it unavailable to plants.

elements that functions in plant metabolism and is essential for completion of the plant life cycle.

Relative essential element composition of an average plant

	Element	No. atoms relative to Mo
MICRO-NUTRIENTS Required in small amounts	Molybdenum	1
	Copper	100
	Zinc	300
	Manganese	1,000
	Boron	2,000
	Iron	2,000
	Chlorine	3,000
MACRO-NUTRIENTS Required in large amounts	Sulfur	30,000
	Phosphorus	60,000
	Magnesium	80,000
	Calcium	125,000
	Potassium	250,000
	Nitrogen	1,000,000
	Oxygen	30,000,000
	Carbon	35,000,000
	Hydrogen	60,000,000

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Macronutrients in plants

Nutrient	Concentration in plants (%)
Sulfur	0.1 – 0.4
Phosphorus	0.1 – 0.4
Magnesium	0.1 – 0.4
Calcium	0.2 – 1.0
Potassium	1.0 – 5.0
Nitrogen	1.0 – 5.0

- P is essential for plant growth
- Much less P is needed compared with N and K

Essential Nutrients – macronutrients

Nutrient	Critical level	Optimal	Excessive
S (%)	--	--	--
Fe (mg kg^{-1})	--	50-105	>105
Mn (mg kg^{-1})	--	12-100	>100
Zn (mg kg^{-1})	15	16-32	>40
Cu (mg kg^{-1})	3	4-8	>9
B (mg kg^{-1})	4	--	>45

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Nutrient Mobility in Plants

- **Mobile Nutrients**
  - Move readily through the plant
  - Move from older leaves to younger leaves
  - Appear more in actively growing tissues
  - N, P, K, Na, Mg, sometimes S
  - Deficiency appears in older leaves
- **Fixed Nutrients**
  - Do <u>NOT</u> move from tissue to tissue in plants
  - Tissue concentrations related to uptake rate from the soil
  - B, Ca, Cu, Fe, Mn, Zn
  - Deficiency appears in younger leaves

Soil and Leaf Testing

- Nitrogen and Potassium leach rapidly in Florida sandy soils, only tested in leaves
- Most minor nutrients also leach or are made unavailable in soil

Property or nutrient	Soil testing	Leaf testing
pH	√	
Organic matter	√	
N		√
P	√	√
K		√
Ca	√	√
Mg	√	√
Cu	√	√
Zn, Mn, Fe, B		√

Soil Analysis or Plant Tissue Analysis

- Soil Analysis typically used to determine application needs prior to planting
- Extractable vs. available
- Deficiencies, toxicities and imbalances
- Plant analysis typically used during the season to determine if proper amount of nutrient are available “potential uptake conditions”

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Soil Sampling Method

- Take sample cores to a 15 cm (6 inch) depth
- Composite 5-10 samples by management unit
- One sample per management unit
- Minimum of 20-30 cores per 15 hectares (~ 30 ac)
- Random patterns across field avoiding edges

Soil Sampling

- Objectives:
  - Provide an index of nutrient availability for plant growth
  - Predict the probability of obtaining profitable response to fertilizer application
  - Provide a basis for recommendations on the amount of fertilizer to apply

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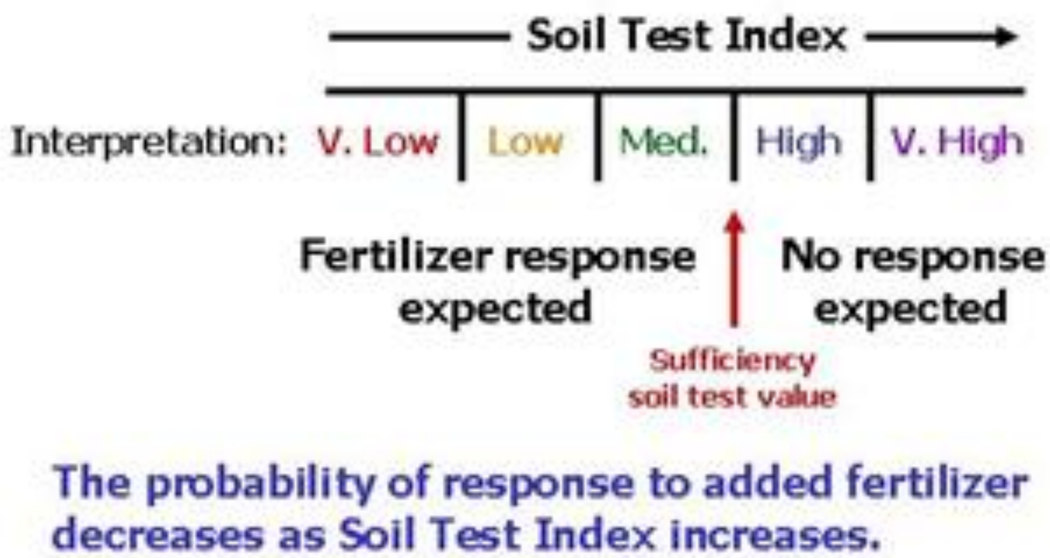
Soil Test Results

- Soil test results are extractable nutrients
- An index of available nutrients
- Not a measure of plant-available nutrients
- Not be used to calculate available nutrients



Soil Test Interpretation

Example: Citrus

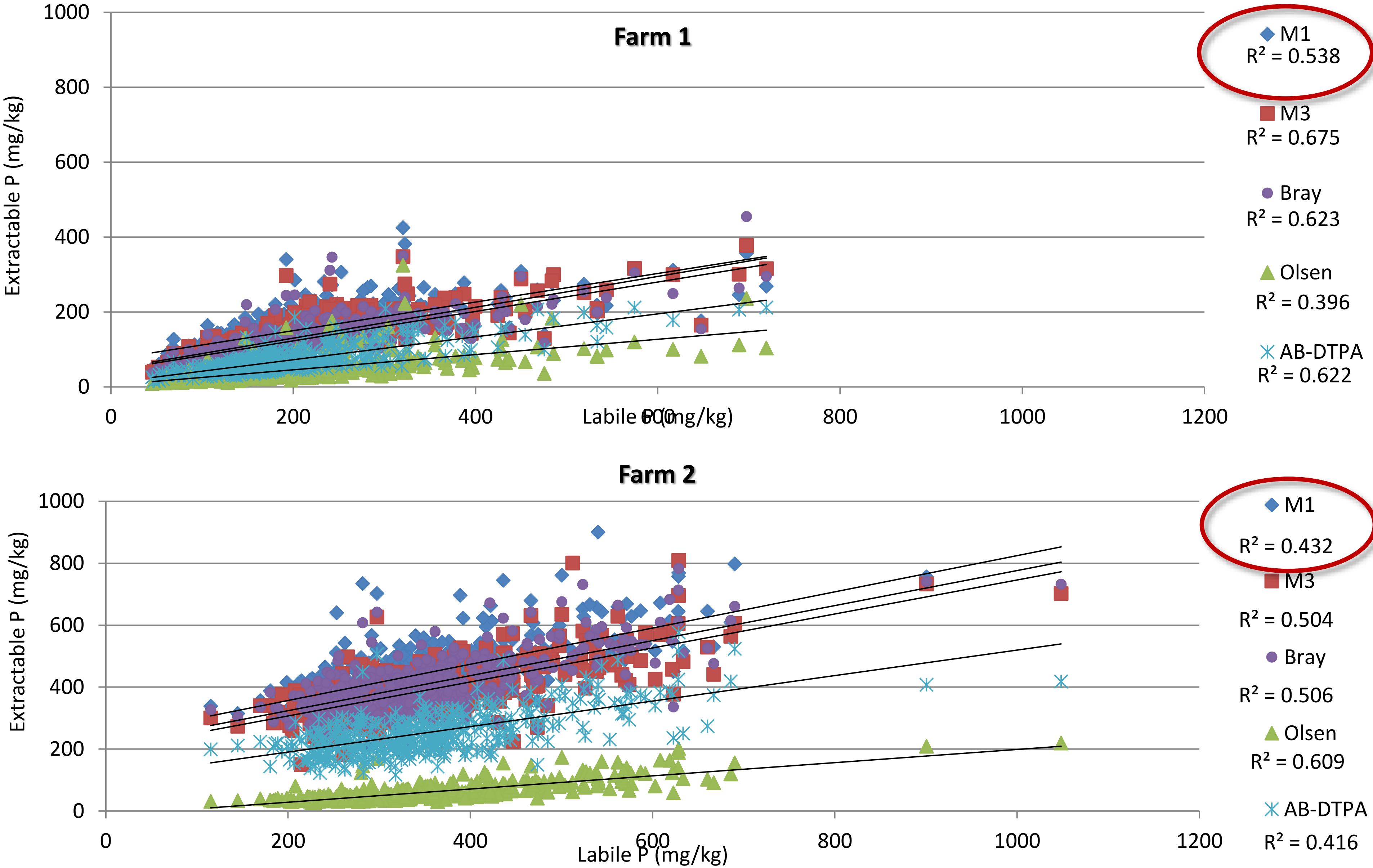
Soil test rating	M1 Soil-test P (ppm)	Probability that crop will respond to P fertilizer
Very low	< 10	Very good
Low	10 – 15	Good
Medium	16 – 30	It might, it might not
High	31 – 60	About zero
Very high	> 60	No chance

- **Soil test results are extractable nutrients**
- **An index of available nutrients**
- **Not a measure of plant-available nutrients**
- **Not be used to calculate available nutrients**

Extractants

- Soil test results are an index of available and can not be used to calculate available nutrients
- Water extracts only nutrient in solution
- Bray 1 can only be used for soil with pH less than 7.4
- Mehlich 1 and 3 best results on soils below pH 7.2 but can be used on higher pH soils
- Olsen should only be used for Calcarious soils

Labile P vs. Extractable P



Soil Nutrients Recommendations Using Mehlich-3

Table 1. Comparison of Mehlich-1 and Mehlich-3 soil extractants

	Mehlich-1	Mehlich-3
Valid pH Range	pH < 6.5	Most normal soil pH ranges
Extraction of P	Limited in soils with high Fe and Al accumulations	Fluoride facilitates dissociation of phosphates from Fe and Al oxides
Extraction of Micronutrients	Dilute acid mixture, only some micronutrients extracted	EDTA (chelate) extracts micronutrients
Exchangeable Cations	Poor extractant for high CEC soils	Ammonium nitrate extracts exchangeable cations

- Changed from Mehlich 1 to Mechlich 3 in 2014
- Most Florida soils have increased in pH
- Mehlich 3 best extractant to provide fertilizer recomendations

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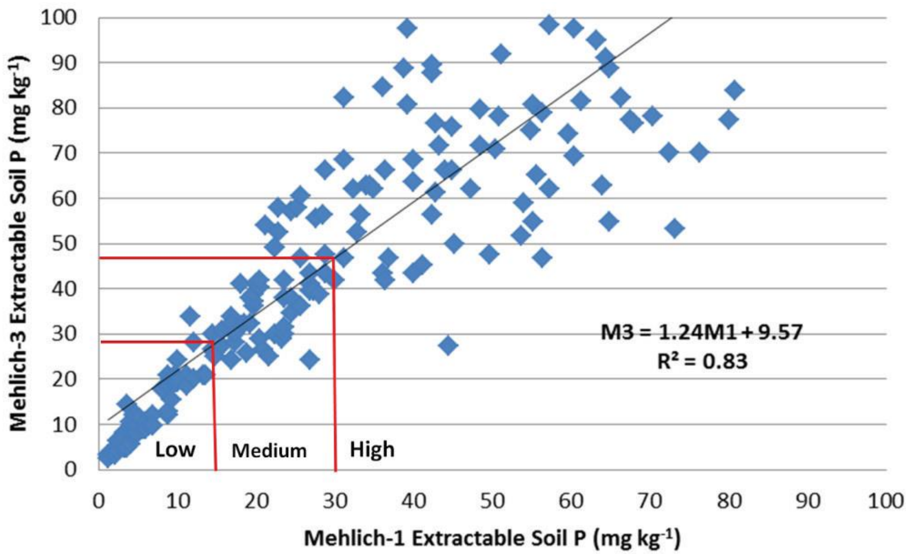
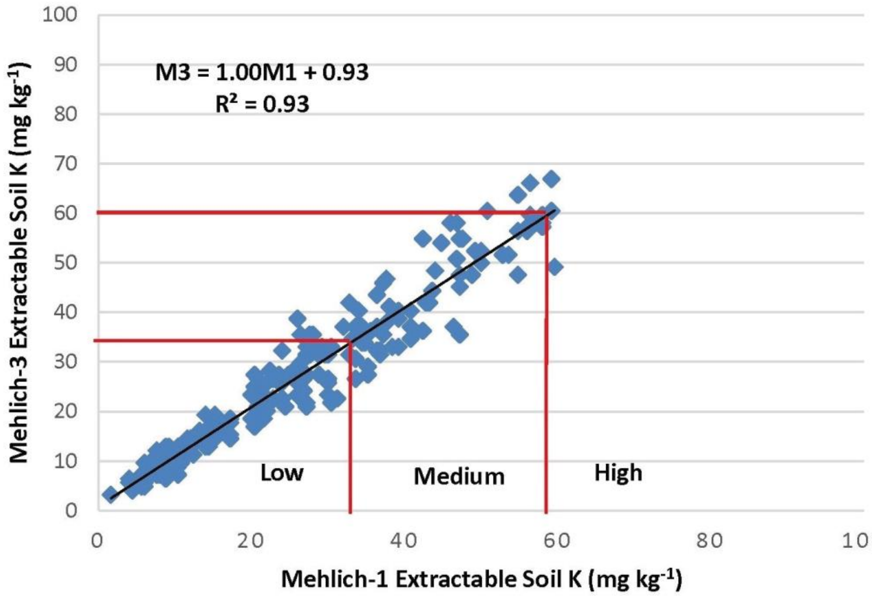
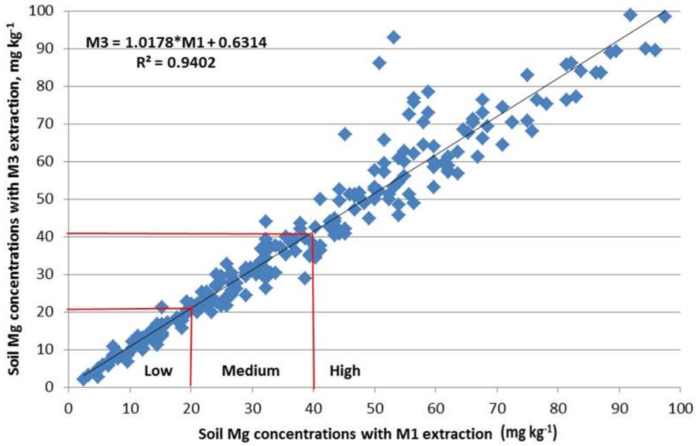
Comparing Soil Test Results for Mehlich 1 and Mehlich 3







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Current Mehlich 3 Soil Test Interpretation

	Mehlich-3, mg kg^{-1}		
Nutrient	LOW	MEDIUM	HIGH
P	≤25	26–45	>45
K	≤35	36–60	>60
Mg	≤20	21–40	>40

Availability

- P increasingly available with increased pH
- P increasingly not available above pH 7.0 in high Ca soils
- P most available in the pH range of 5.5 to 6.5
- P soil tests suggest that P can accumulate and remain available for years

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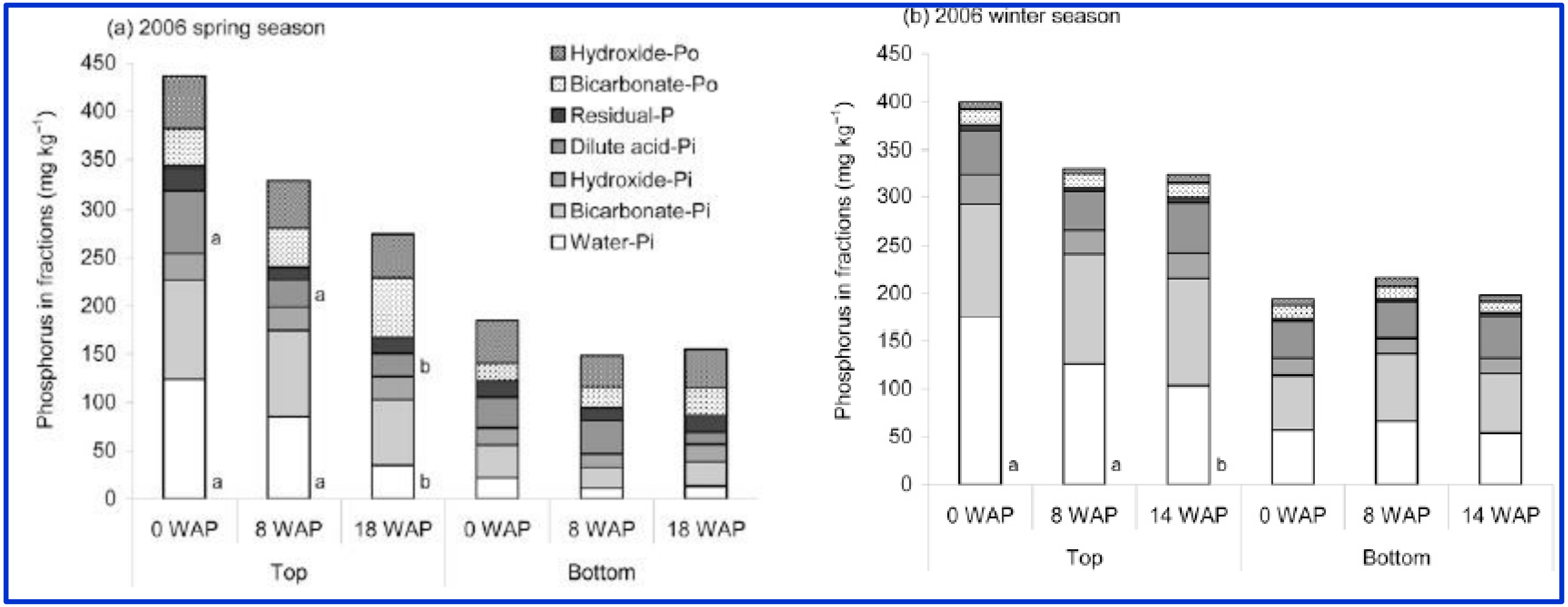
Phosphorus

- **Reduced Availability**
  - "Fixed" by soil calcium
  - Available to plant for short period of time
  - Accumulates over time in-soluble forms

$$H_2PO_4 \xrightleftharpoons{Ca} CaHPO_4 \cdot 2H_2O \xrightleftharpoons{Ca} Ca_8H_2[PO_4]_6 \cdot 5H_2O \xrightleftharpoons{Ca} Ca_{10}H_2[PO_4]_6 \cdot 5H_2O \xrightleftharpoons{F} Ca_{10}F_2[PO_4]_6 \cdot 5H_2O$$

P Availability Over Time

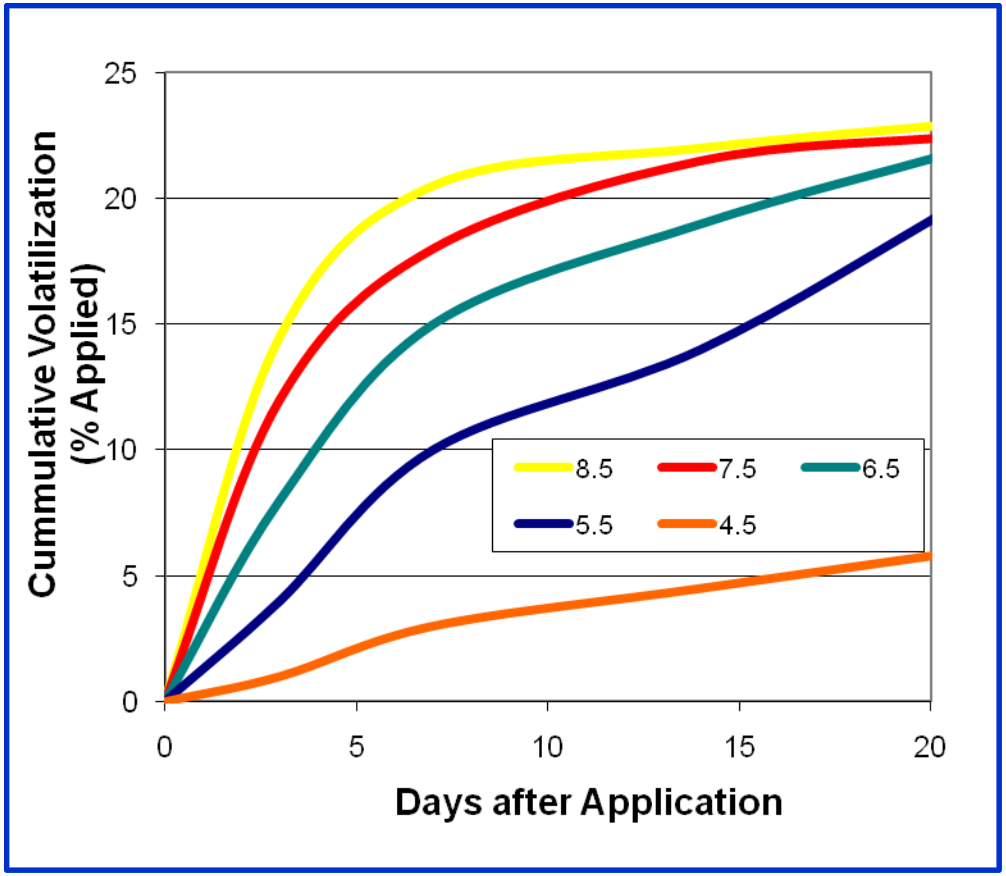


- Available P mostly water and some bicarbonate extractable
- Increasingly less soluble (less available) with increase as you move up Bar
- Indication of reduced concentration of dilute acid and water extractable P with time

Soil pH

- Optimum range – 5.5 to 6.5
- Determines micronutrient availability
- Reduced effect on N and P transformation
- Adjusted using Ca and S
- pH management is used to supply Ca, S and Mg

Effect of Soil pH



Source: Z.L. He et al. 1999. Ammonia Volatilization from Different Fertilizer Sources and Effects of Temperature and Soil pH. Soil Science 164:750-758.

- Cumulative volatilization with time is dependent on soil pH
- minimum volatilization below pH 5

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Soil/P retention capacity

RPA (Relative P Adsorption capacity)

0.0 — 1.0

very low — very high

P_{max} (P adsorption maximum)

units of ppm

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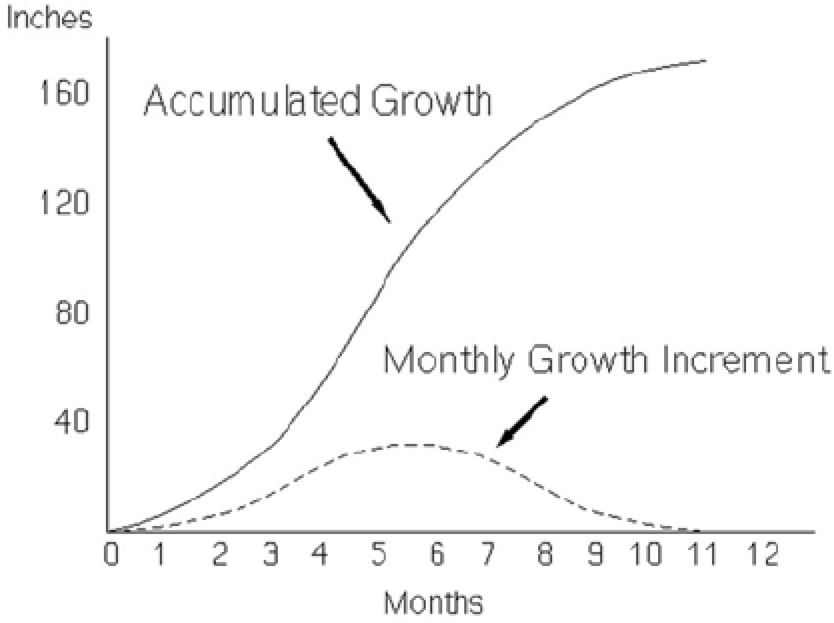
Leaf Analysis

- Nutrient level varies through growth period
- Leaf petiol sap testing
- Leaf analysis
- Two methods of interpreting analytical results:
  - Critical Nutrient Level
  - Diagnosis and Recommendation Integrated System (DRIS)

Leaf Analysis - Interpretation

- **Samples for Critical Nutrient Level recommendation must be taken at Stage 4 “grand growth” period**
- **Samples for Diagnostic Recommendations Integration System (DRIS) recommendations not sensitive to tissue age**



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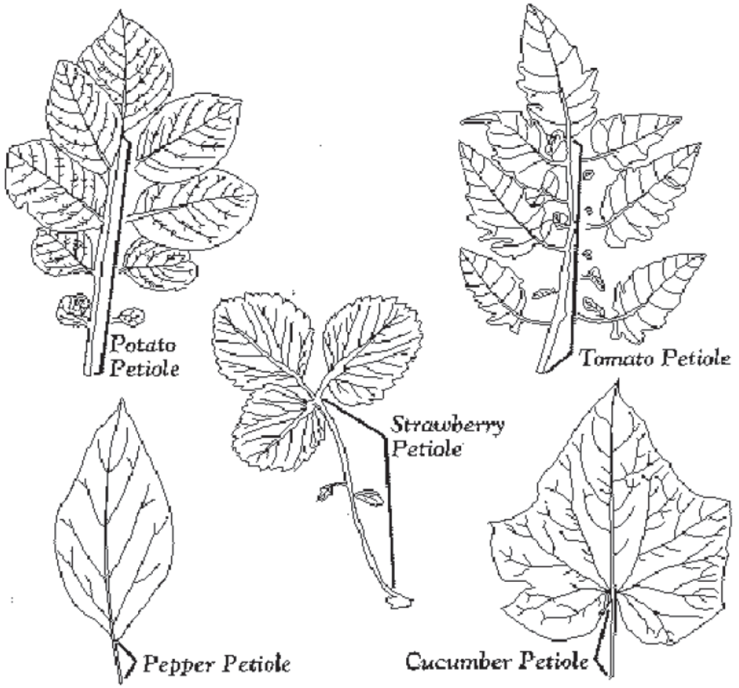
Leaf Petiol Sap testing



Tomato Leaf Sap Sufficiency Range

Table 17. Critical (deficiency) values, adequate ranges, high values, and toxicity values for macronutrients for vegetables (most-recently-matured whole leaf plus petiole (MRM leaf) unless otherwise noted).

Crop	Plant Part	Time of Sampling	Status	N	P	K	Ca	Mg	S
				------------		%	-----------		
Tomato	MRM leaf	5 leaf stage	Deficient	<3.0	0.3	3.0	1.0	0.3	0.3
			Adequate	3.0	0.3	3.0	1.0	0.3	0.3
			range	5.0	0.6	5.0	2.0	0.5	0.8
			High	>5.0	0.6	5.0	2.0	0.5	0.8
	MRM leaf	First flower	Deficient	<2.8	0.2	2.5	1.0	0.3	0.3
			Adequate	2.8	0.2	2.5	1.0	0.3	0.3
			range	4.0	0.4	4.0	2.0	0.5	0.8
			High	>4.0	0.4	4.0	2.0	0.5	0.8
			Toxic (>)	-	-	-	-	-	-
	MRM leaf	Early fruit set	Deficient	<2.5	0.2	2.5	1.0	0.25	0.3
			Adequate	2.5	0.2	2.5	1.0	0.25	0.3
			range	4.0	0.4	4.0	2.0	0.5	0.6
			High	>4.0	0.4	4.0	2.0	0.5	0.6

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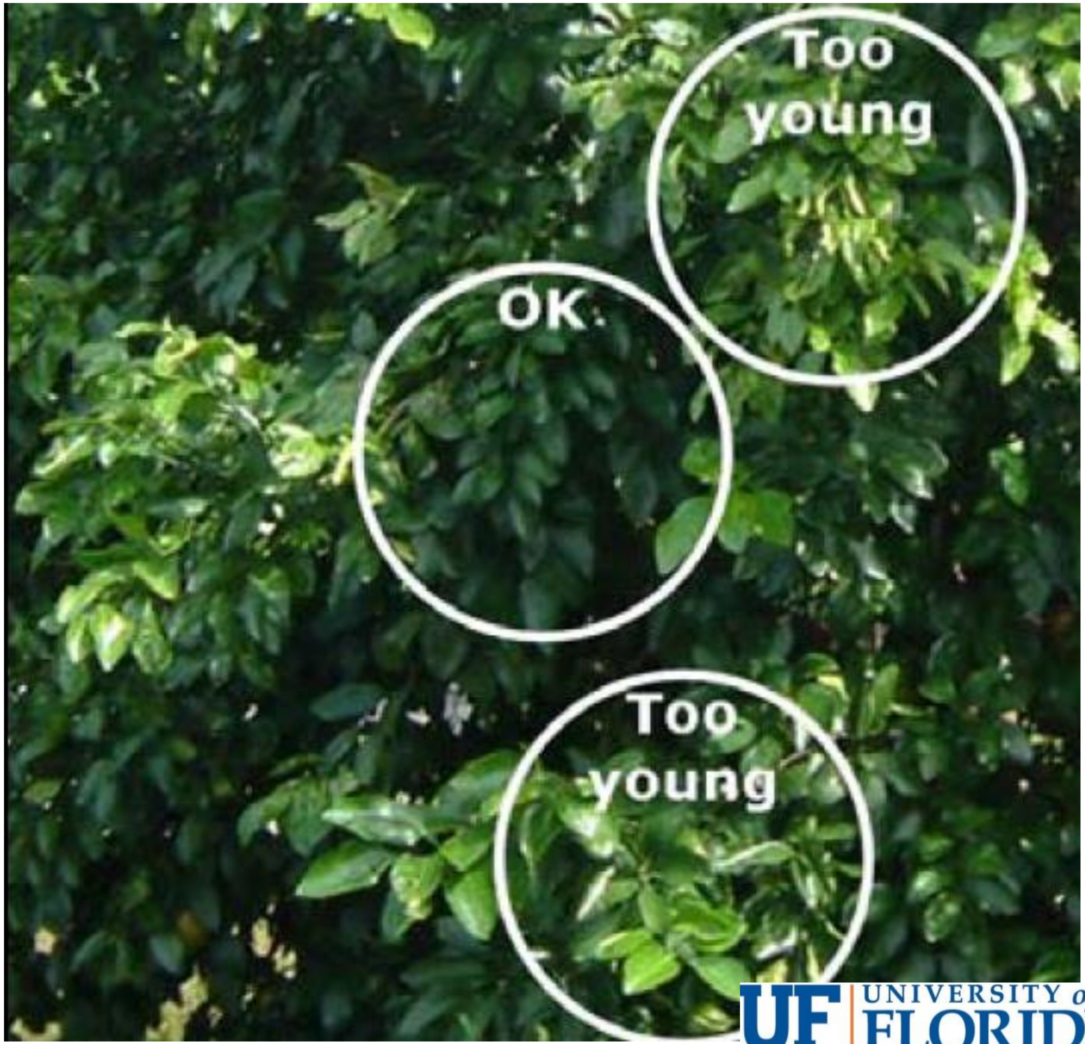
Leaf Sampling Technique

- A sampled citrus grove block should be no larger than 20 acres
- Each leaf sample should consist of about 100 leaves taken from non-fruiting twigs of 15 to 20 uniform trees
- Select only one leaf from a shoot and remove it with its petiole (leaf stem)



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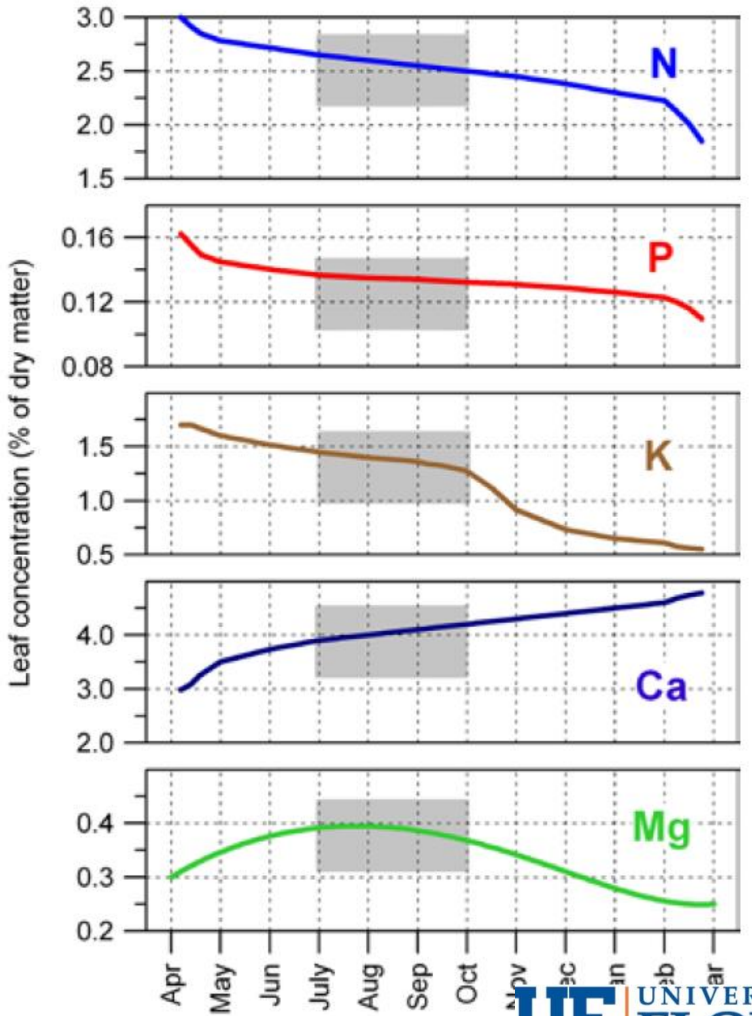
Leaf Nutrient Concentrations

- Leaf nutrient concentrations continuously change.
- As leaves age from spring through fall, N, P, and K concentrations decrease, Ca increases, and Mg first increases and then decreases
- Leaf mineral concentrations are relatively stable from 4 to 6 months after emergence in the spring



Leaf Nutrient Concentrations

Element	Unit of measure	Deficient	Low	Optimum	High	Excess
N	%	< 2.2	2.2 – 2.4	2.5 – 2.7	2.8 – 3.0	> 3.0
P	%	< 0.09	0.09 – 0.11	0.12 – 0.16	0.17 – 0.30	> 0.30
K	%	< 0.7	0.7 – 1.1	1.2 – 1.7	1.8 – 2.4	> 2.4
Ca	%	< 1.5	1.5 – 2.9	3.0 – 4.9	5.0 – 7.0	> 7.0
Mg	%	< 0.20	0.20 – 0.29	0.30 – 0.49	0.50 – 0.70	> 0.70
Cl	%	---	---	< 0.2	0.20 – 0.70	> 0.70[1]
Na	%	---	---	---	0.15 – 0.25	> 0.25
Mn	mg/kg or ppm[2]	< 18	18 – 24	25 – 100	101 – 300	> 300
Zn	mg/kg or ppm	< 18	18 – 24	25 – 100	101 – 300	> 300
Cu	mg/kg or ppm	< 3	3 – 4	5 – 16	17 – 20	> 20
Fe	mg/kg or ppm	< 35	35 – 59	60 – 120	121 – 200	> 200
B	mg/kg or ppm	< 20	20 – 35	36 – 100	101 – 200	> 200
Mo	mg/kg or ppm	< 0.05	0.06 – 0.09	0.10 – 2.0	2.0 – 5.0	> 5.0

- These standards are based on long-term field observations and experiments conducted in different countries with different citrus varieties, rootstocks, and management practices, and are used to gauge citrus tree nutrition throughout the world.

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Interpretation of Leaf Analysis

Nutrient	What if it is less than optimum in the leaf? Options:	What if it is greater than optimum in the leaf? Options:
N	1. Check yield. 2. Check tree health. 3. Review water management. 4. Review N fertilizer rate.	1. Check soil organic matter. 2. Review N fertilizer rate.
P	1. Apply P fertilizer (see Chapter 8).	1. Do nothing.
K	1. Increase K fertilizer rate (see Chapter 8). 2. Apply foliar K fertilizer.	1. Decrease K fertilizer rate.
Ca	1. Check soil pH. 2. Check soil test Ca status. 3. Consider applying lime or soluble Ca fertilizer depending on soil pH.	1. Do nothing.
Mg	1. Check soil test Mg status. 2. Check soil pH. 3. Consider applying dolomitic lime or soluble Mg fertilizer depending on pH.	1. Do nothing.
Micronutrients	1. Check soil pH and adjust if needed. 2. Apply foliar micronutrients. 3. Include micronutrients in soil-applied fertilizer.	1. Check for spray residue on tested leaves. 2. Do nothing.

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DRIS – Diagnosis and Recommendation Integrated System

- Nutrient ranked in order of relative deficiency
- Considers nutrient interactions and balances
- Moderates effect of growth stage, geographic area, sample variability
- Potential problem – indices must add up to 0 so fertilizer recommendation is determined when one may not be needed

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DRIS Indices

Nutrients	Balanced	Imbalance
N/P	7.91 – 9.51	<7.11 or >10.32
N/K	1.36 – 1.72	<1.19 or >1.89
K/P	4.94 – 6.33	<4.24 or >7.03
Ca/N	0.13 – 0.17	<0.11 or >0.20
Ca/P	1.08 – 1.54	<0.84 or >1.77
Ca/Mg	1.13 – 1.64	<0.87 or >1.90
Mg/N	0.10 – 0.13	<0.08 or >0.15
Mg/P	0.80 – 1.17	<0.61 or >1.36
Mg/K	0.13 – 0.20	<0.09 or >0.23

Conclusion

- Crop nutrition program should be based on:
  - Economically sound practices
  - Ecologically sound practices
  - Knowledge of essential nutrients
  - Understanding of nutrient cycles in the soil
  - Effects of soil/plant interaction with nutrients
  - Proper soil and tissue testing
  - Appropriate test interpretations

Conclusions

- Soil and Leaf sampling is a key BMP
- Information on leaf and soil samples should be taken in a consistent manner over a period of years to provide the best information
- Soil sample extraction has changed but the sampling practices have not, and interpretation is similar
- Leaf nutrient ratios differ during the growing season and must be maintained to insure tree health
- Nutrient ratios may be key to sustaining yields with greening trees (work continues)

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Thank you for your attention

Questions

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