Macronutrients: Their Role in Citrus Production

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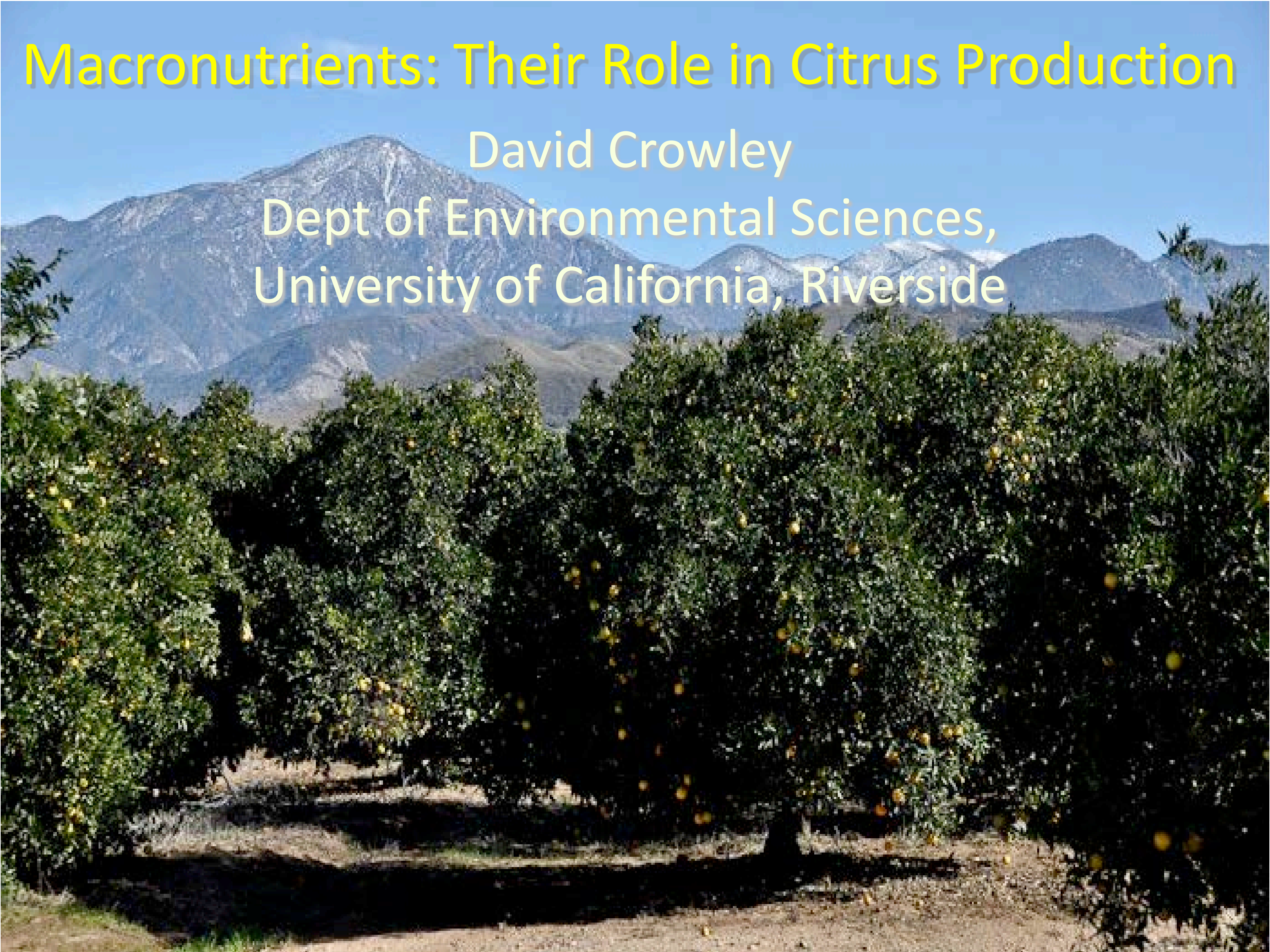
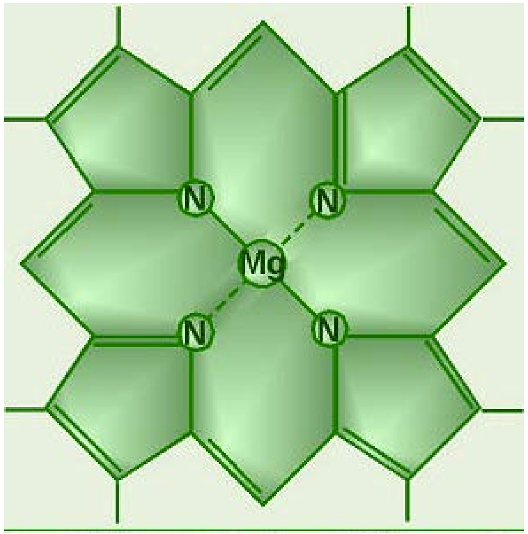


Citrus Nutrition

- Functions of macro- and micro-nutrients
- Interpreting soil and plant analysis reports
- Managing nitrogen, phosphorus, potassium
    - Deficiency symptoms
    - Fertilizer recommendations
- Trace metals

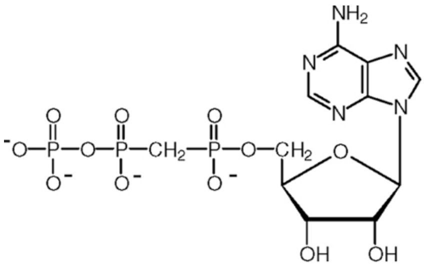
Functions of Essential Elements

- Nitrogen (N)
  - Nitrogen is utilized by plants to make amino acids, which in turn form proteins, found in protoplasm of all living cells. Also, N is required for chlorophyll, nucleic acids and enzymes



Functions of Essential Elements

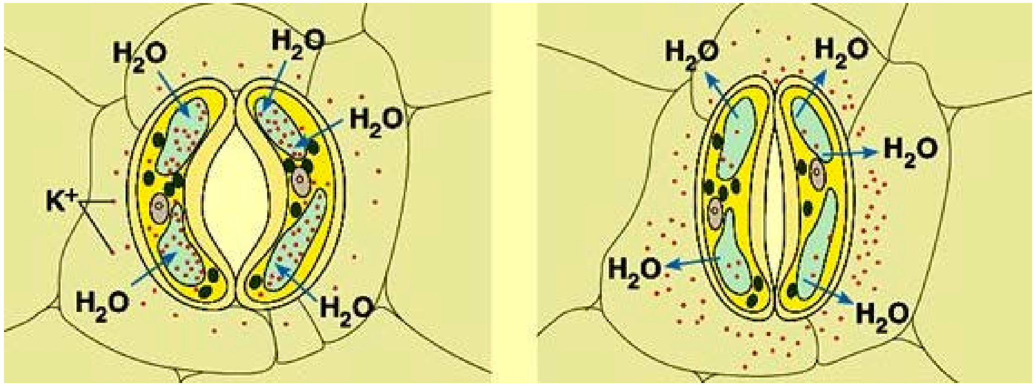
- Phosphorus (P)
  - Phosphorus is used to form nucleic acids (RNA and DNA), it is used in storage and transfer of energy (ATP and ADP)



  - P fertilizer stimulates early growth and root formation, used to drive nutrient uptake, cell division, metabolism
  - Generally sufficient in most California soils. Least response by plants in summer with extensive root systems (tree crops). Mainly taken up by mycorrhizae

Functions of Essential Elements

- Potassium (K)
  - Potassium is required by plants for translocation of sugars, starch formation, opening and closing of guard cells around stomata (needed for efficient water use)



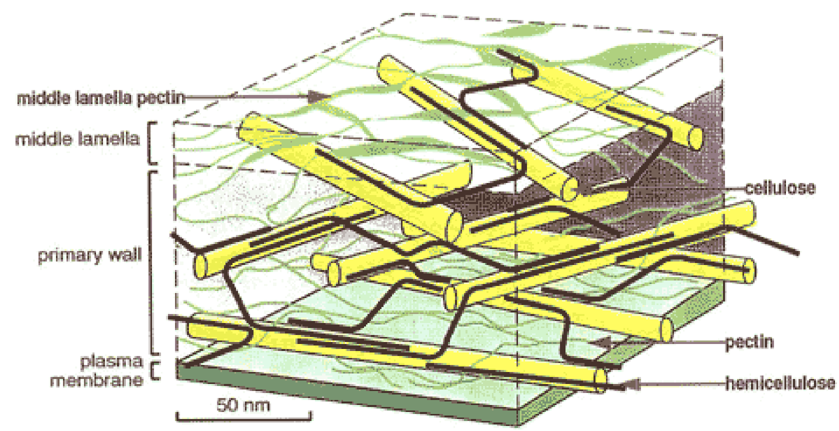
  - Increases plant resistance to disease
  - Increases size and quality of fruit
  - Increases winter hardiness

Functions of Essential Elements

- Calcium
  - Essential part of cell walls and membranes, must be present for formation of new cells
  - Has been shown to make root tips less leaky, therefore less attractive to Phytophthora zoospores

Deficiencies:

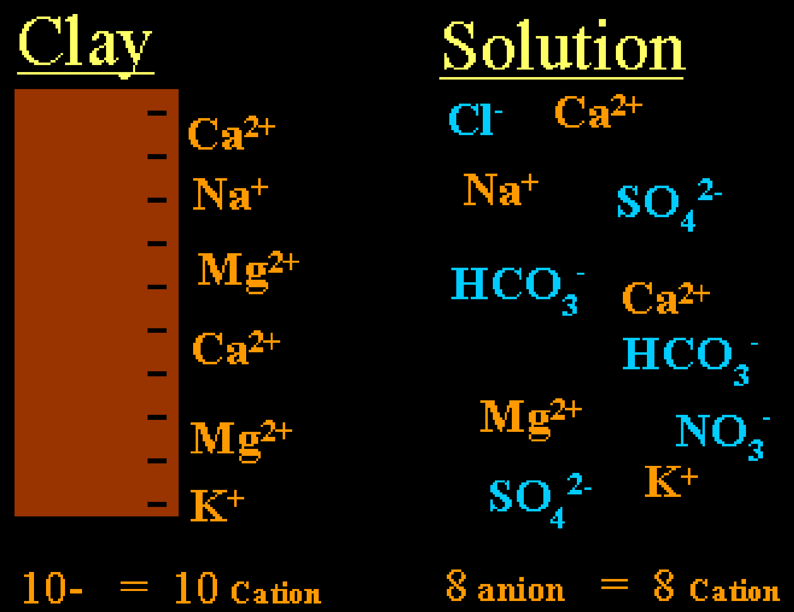
poor root development
leaf necrosis and curling,
blossom end rot,
bitter pit, fruit cracking,
poor fruit storage, and water soaking



Ranges of Elements in Citrus Leaves

Elements	Unit	Deficient: Less than	Adequate	Excess: More than
Nitrogen	(N) %	1.6	1.6 -2.4	2.4
Phosphorus	(P) %	0.05	0.08-0.25	0.3
Potassium	(K) %	0.35	0.75-2.0	3.0
Calcium	(Ca) %	0.5	1.0 -3.0	4.0
Magnesium	(Mg)%	0.15	0.25-0.80	1.0
Sulfur	(S) %	0.05	0.20-0.60	1.0
Boron	(B) ppm‡	10-20	50-100	100-250
Iron	(Fe) ppm	20-40	50-100	-
Manganese	(Mn) ppm	10-15	30-500	1,000
Zinc	(Zn) ppm	10-20	30-150	300
Copper	(Cu) ppm	2-3	5-15	25
Molybd	(Mo) ppm	0.01	0.05-1.0	-
Chloride	(Cl) %	-	-	0.25-0.50
Sodium	(Na)%	-	-	0.25-0.50

Key Principles



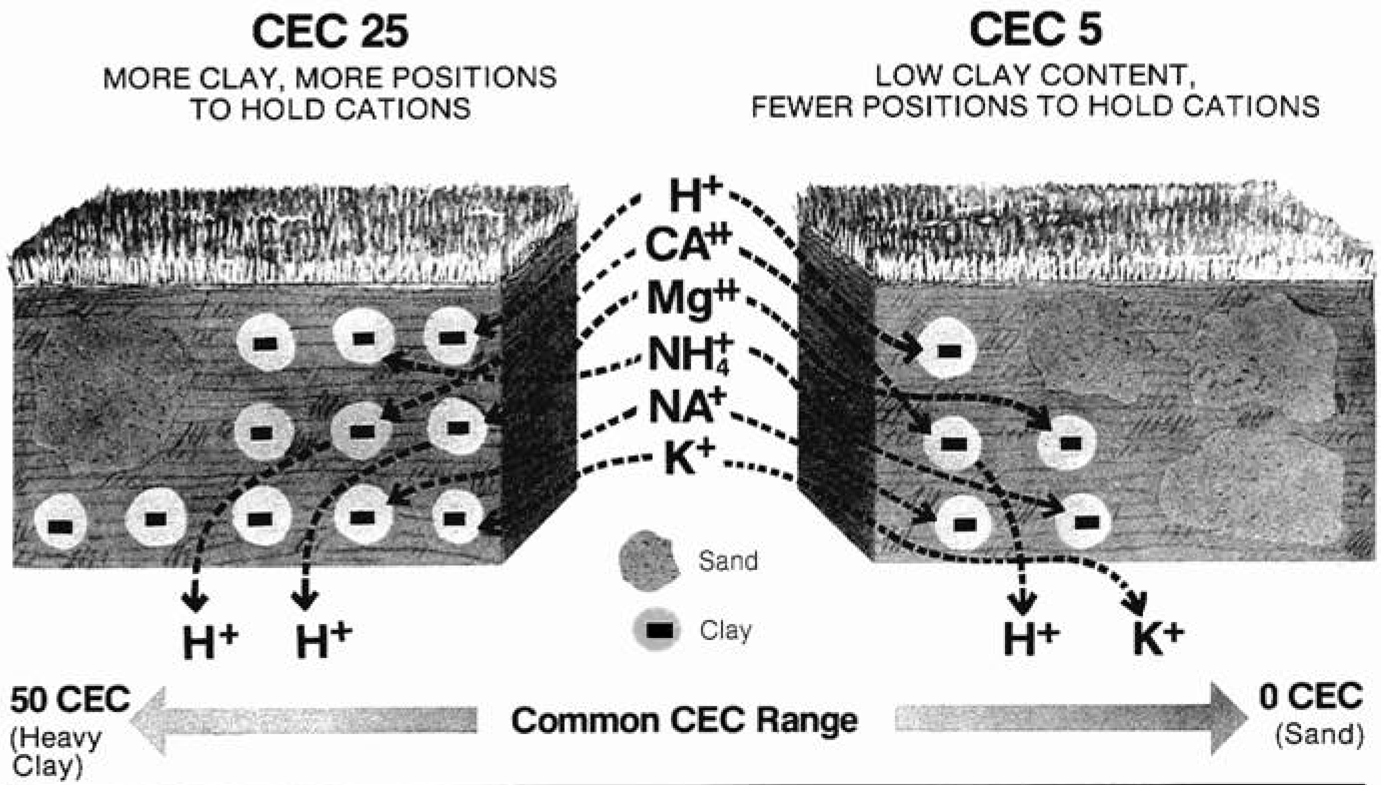
Soluble Cations

Electrically neutralized by soluble anions of equal total charge.

Exchangeable Cations

Electrically neutralized by surfaces of solids with negative charge

A SCHEMATIC LOOK AT CATION EXCHANGE



SOME PRACTICAL APPLICATIONS	
Soils with CEC 11-50 Range	Soils with CEC 1-10 Range
• High clay content • More lime required to correct a given pH • Greater capacity to hold nutrients in a given soil depth • Physical ramifications of a soil with a high clay content • High water-holding capacity	• High sand content • Nitrogen and potassium leaching more likely • Less lime required to correct a given pH • Physical ramifications of a soil with a high sand content • Low water-holding capacity

FRUIT GROWERS LABORATORY, INC.
Analytical Chemists
www.fglinc.com

March 4, 2011

Fruit Growers Laboratory, Inc.
853 Corporation Street
Santa Paula, CA 93060

SOIL ANALYSIS SPM10Y745A:16-18

Customer ID : 2-22872
Sampled On : October 8, 2010
Sampled By : Stephen Qi
Received On : October 11, 2010
Depth : Yes

Soil Analysis - Primary and Secondary Nutrients

Sample Area	Variety	Lbs/AF Nitrate-N	Lbs/AF Phosphorus	Lbs/AF Exch. K	Lbs/AF Sol. K	Lbs/AF Exch. Ca	Lbs/AF Sol. Ca	Lbs/AF Exch. Mg	Lbs/AF Sol. Mg	Lbs/AF Exch. Na	Lbs/AF Sol. Na	Lbs/AF Sulfate
Soil Sample # 01	Hass	72.4	184	672	64.4	13500	453	2380	123	220	116	288
Soil Sample # 02	Hass	162	292	2250	640	18400	1550	2840	496	320	415	3320
Soil Sample # 03	Hass	131	56	449	43.8	11000	494	1810	128	440	346	788
Optimum Range - Average		50.8 - 90.8	64 - 124	334 - 2230	92.3 - 405	11400 - 15200	192 - 680	1160 - 2310	87.1 - 235	0 - 1090	0 - 1460	150 - 3880

Soil Analysis - Micro Nutrients and Base Saturation

Sample Area	Lbs/AF Zinc	Lbs/AF Manganese	Lbs/AF Iron	Lbs/AF Copper	Lbs/AF Boron	Lbs/AF Chloride	meq/100g CEC	% CEC - Ca	% CEC - Mg	% CEC - K	% CEC - Na	% CEC - H
Soil Sample # 01	712	33.6	70.4	14.8	1.68	97.9	22.4	75.0	21.9	1.92	1.05	0.00
Soil Sample # 02	680	81.6	102	33.6	1.94	1070	30.6	75.2	19.1	4.71	1.15	0.00
Soil Sample # 03	286	48.8	78.8	6.40	1.44	360	18.2	75.3	20.4	1.58	2.63	0.00
Optimum Range - Average	4.72 - 161	7.44 - 241	47.2 - 207	1.42 - 41.4	1.31 - 8.51	18.0 - 663	14.0 - 35.0	60.0 - 80.0	10.0 - 20.0	0.900 - 6.00	0.00 - 5.00	0.00 - 3.00

____s Soil Analysis - Additional Elements

Sample Area	--- pH	mmhos/cm ECe	SAR	% Limestone	Tons/AF Lime Req	Moisture %	Moisture Low Opt High	% Saturation
Soil Sample # 01	7.33	0.81	0.6	< 0.10	0	10.6		51.3
Soil Sample # 02	7.36	3.14	1.2	< 0.10	0	7.8		65.0
Soil Sample # 03	6.94	1.21	1.8	< 0.10	0	8.5		35.4
Optimum Range - Average	6 - 8	0.00 - 2.50	0.00 - 7.00	0.00 - 4.00	---	5.06 - 35.4		40.0 - 50.0

Good Problem Low High Indicates physical conditions and/or phenological and amendment requirements.

Note: Color coded bar graphs have been used to provide you with 'AT-A-GLANCE' interpretations.

Soil Sampling Guidelines

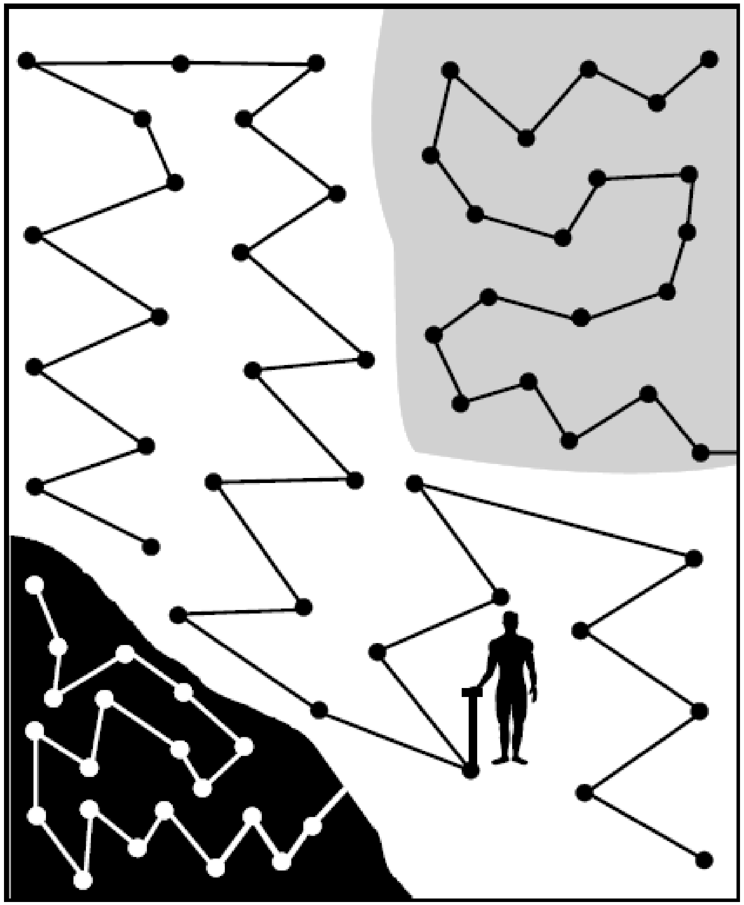


Figure 2. Sampling patterns for a field with three distinct soil types.

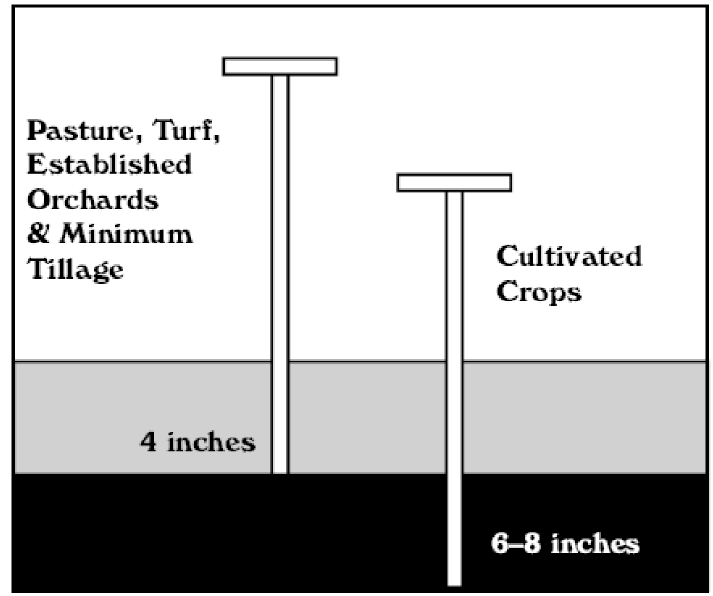


Figure 3. Proper sampling depth varies depending on the kind of crop you plan to grow.

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October 26, 2010

Fruit Growers Laboratory, Inc.
853 Corporation Street
Santa Paula, CA 93060

PLANT ANALYSIS SPM10Y740A:1-15
Customer ID : 2-22872
Sampled On : September 30, 2010
Sampled By : Stephen Qi
Received On : October 4, 2010
Depth : Yes

Plant Tissue Analysis

Sample Area	% Nitrogen	% Phosphorus	% Potassium	% Calcium	% Magnesium	ppm Zinc	ppm Manganese	ppm Iron	ppm Copper	ppm Boron	% Sodium	% Chloride
Tree # 01	2.97	0.289	1.37	1.12	0.311	50.1	51	50	16	173	0.005	0.0446
Tree # 02	2.42	0.227	1.16	1.51	0.472	37.8	54	42	14	206	0.006	0.0832
Tree # 03	2.70	0.288	1.56	0.726	0.258	35.8	33	46	15	230	0.005	0.0272
Tree # 04	2.71	0.317	1.82	1.24	0.358	43.1	46	52	14	289	0.006	0.106
Tree # 05	2.60	0.278	1.67	1.53	0.387	49.4	63	59	12	195	0.006	0.145
Tree # 06	2.05	0.157	0.646	2.72	0.766	70.6	105	68	10	92.2	0.006	0.245
Tree # 07	2.67	0.208	1.06	1.51	0.426	41.4	52	46	12	114	0.008	0.0990
Tree # 08	2.87	0.222	1.27	1.69	0.444	46.1	69	53	17	169	0.006	0.117
Tree # 09	2.81	0.261	1.48	1.39	0.395	39.0	42	44	13	198	0.007	0.0818
Tree # 10	2.97	0.273	1.63	1.10	0.293	41.8	41	53	13	123	0.006	0.0348
Tree # 11	2.64	0.221	1.04	1.81	0.477	35.0	67	47	13	135	0.007	0.0713
Tree # 12	2.53	0.226	1.08	1.24	0.346	36.2	54	44	13	124	0.005	0.104
Tree # 13	2.32	0.219	1.32	1.25	0.365	38.1	52	47	9	90.1	0.007	0.0882
Tree # 14	2.50	0.228	1.43	1.10	0.299	33.8	40	43	13	121	0.005	0.115
Tree # 15	2.90	0.222	1.43	1.54	0.408	43.2	63	56	12	93.4	0.006	0.0580
Optimum Range - Average	2.20 - 2.40	0.0800 - 0.440	1.00 - 3.00	1.00 - 4.50	0.250 - 1.00	30.0 - 250	30 - 700	50 - 300	5 - 65	12.0 - 100	0.00 - 0.250	0.00 - 0.250

Plant Tissue Analysis

Sample Area	% N/K	% N/P	% P/Zn	% K/Mg	% N/Ca
Tree # 01	2.17	10.3	57.7	4.41	2.65
Tree # 02	2.09	10.7	60.1	2.46	1.60
Tree # 03	1.73	9.38	80.4	6.05	3.72
Tree # 04	1.49	8.55	73.5	5.08	2.19
Tree # 05	1.56	9.35	56.3	4.32	1.70
Tree # 06	3.17	13.1	22.2	0.843	0.754

Taking a leaf sample

Which leaf: The second or third spring-flush leaf from a non-fruiting shoot.

When to sample: Preferably October when leaves are 4–6 months old. Avoid growth which has made a second flush.

Where on the tree: At about shoulder height from all sides of the tree, or both sides of closely planted rows.

Number of trees: Take leaves from about 20 trees throughout a uniform and representative section of one block, following a zigzag or ‘X’ pattern in the sampled area.

Number of leaves: 60–100 leaves per sample.

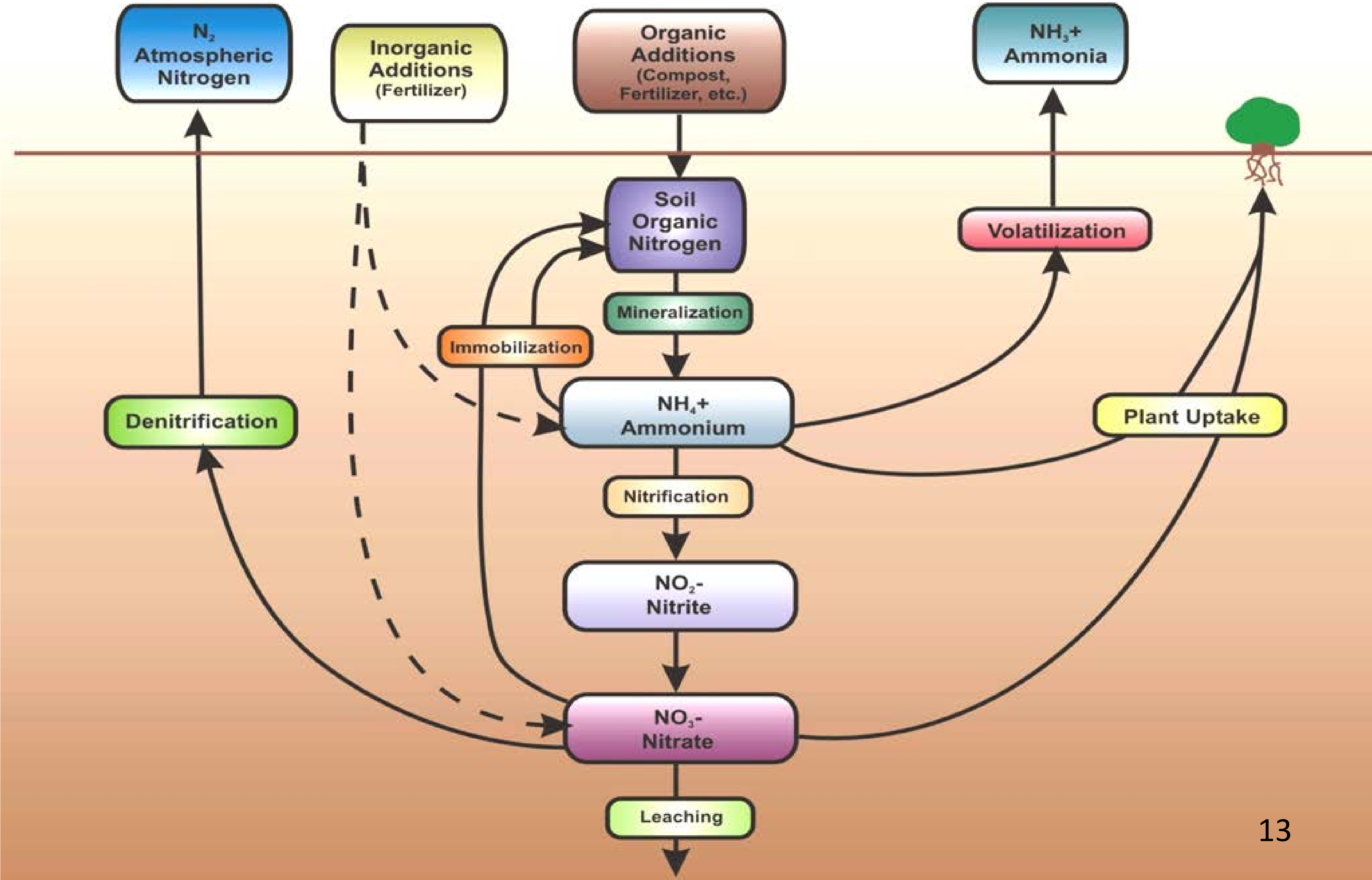
Nitrogen

Deficient	Satisfactory	Excessive
< 1.6	1.6 – 2.4	> 2.4

Nitrogen deficiency symptoms in lemon, showing normal leaf (left), and increasingly chlorotic leaves (left to right).

http://ag.arizona.edu/pubs/crops/az1007/az1007-2.html

Nitrogen cycle

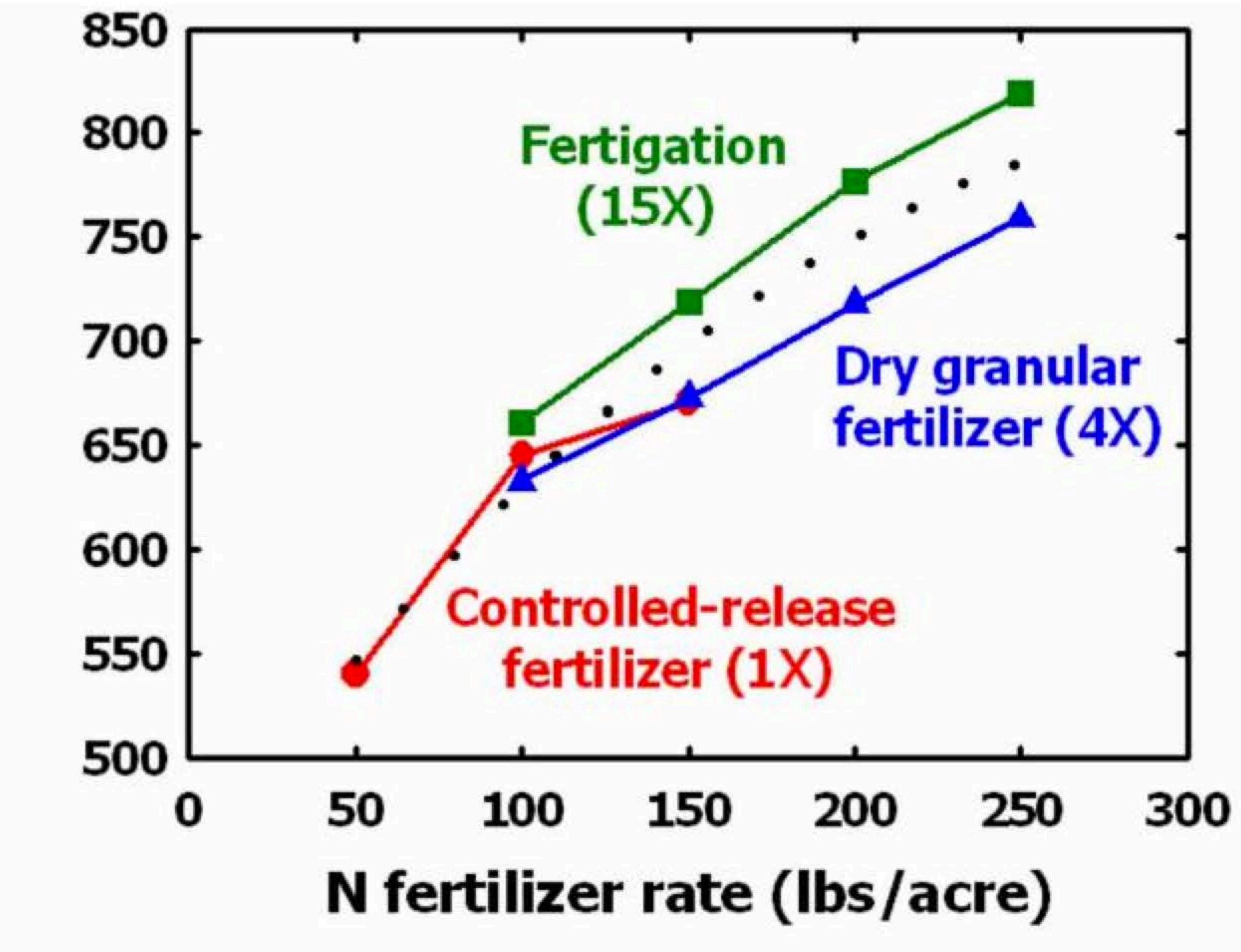


Nutrient Availability and Uptake

- Nitrogen fertilizers are typically spread out over 3 applications to meet plant demand and avoid leaching.

- Alternative methods for N fertilization include
  - Fertigation
  - Controlled Release Fertilizers
  - Foliar applications of urea
  - Organic management

Figure 4. Orange yield (Hamlin) with nitrogen fertilizer rate from CRF applied once per year, dry granular applied in four equal amounts per year, and fertigation applied in 15 equal increments per year.



Winter pre-bloom foliar application of low-biuret urea on yield of Washington navel orange.

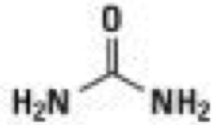
Ali and Lovatt, 1994

Month urea Applied	3-Year Cummulative Yield (kg/tree)
None (control)	256 b
November	305 a
December	308 a
January	338 a
February	321 a
Significance	P<0.001

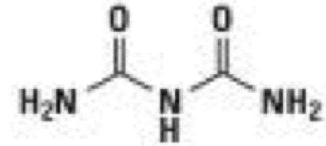
http://horttech.ashspublications.org/content/9/4/607.full.pdf

Urea fertilizers can contain Biuret, which is toxic to citrus and causes trace metal deficiency symptoms

Biuret Toxicity



Urea



Biuret

Fertilizer Overuse

Overuse of fertilizer will pollute the soil and irrigation water.

Excessive fertilizer applications may reduce the yield, and damage fruit quality.

Fruit may have thicker peel, a lower sugar content and may be late in turning color.

Over-fertilization with Nitrogen

Fruit has thick peel, low sugar content and delayed color break.

Summary Guidelines for Nitrogen

Tree age determines how much fertilizer the tree receives yearly.

A citrus tree in California needs between 0.12 lb. of nitrogen at planting and 1.5 lbs. as adult tree over 6 years old.

At a year old, the tree needs .25 lb. of nitrogen. Add .25 lb. of nitrogen per year of age until 6 years.

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Fertilizer Calculator

English Units | Metric Units | Calculate

Primary Nutrient:	Nitrogen (N)	**Nutrient Information**
Amount of Primary Nutrient:	165	lbs.
Fertilizer:	Ammonium Nitrate	**Fertilizer Information and MSDS**
Price of Fertilizer:	1	/ lb.
Fertilizer Formula:	NH_4NO_3	
Amount of Fertilizer:	471.43	lbs.
Price of Primary Nutrient:	2.86	/ lb.
Secondary Nutrient:		
Amount of Secondary Nutrient:		lbs.
Price of Secondary Nutrient:		/ lb.

Using the Fertilizer Calculator
Sources of Fertilizer Calculator
Nutrient Removal Calculator
Scientific Calculator

Chart of the Effect of Soil pH on Nutrient Availability
Country Specific Normal Leaf Level Ranges
Soil Levels
Nutrient Interaction Chart
Law of the Minimum - Liebig's Law

Plant Stress by S. Kant and U. Kafkafi - Hebrew University

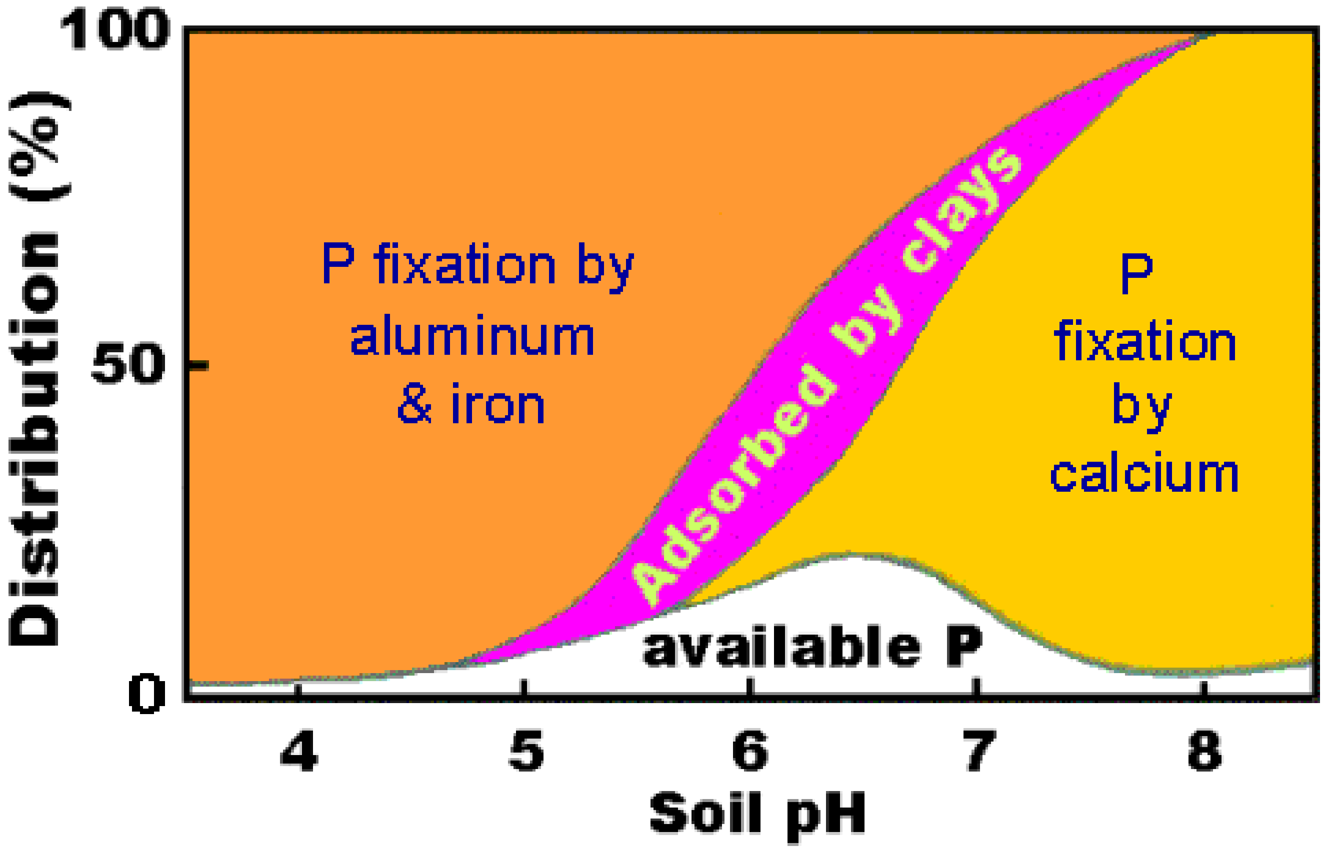
Created by Reuben Hofshi and Shanti Hofshi

Phosphorus Functions in Plants

- Energy storage and transfer
  - Phosphate compounds are "energy currency"
  - (such as ADP and ATP)
- Structural component of biochemicals
  - Seed formation
  - Calcium and magnesium phytate
  - Membrane phospholipids
  - DNA
- Root growth, rapid crop establishment
- Early maturity, quicker recovery

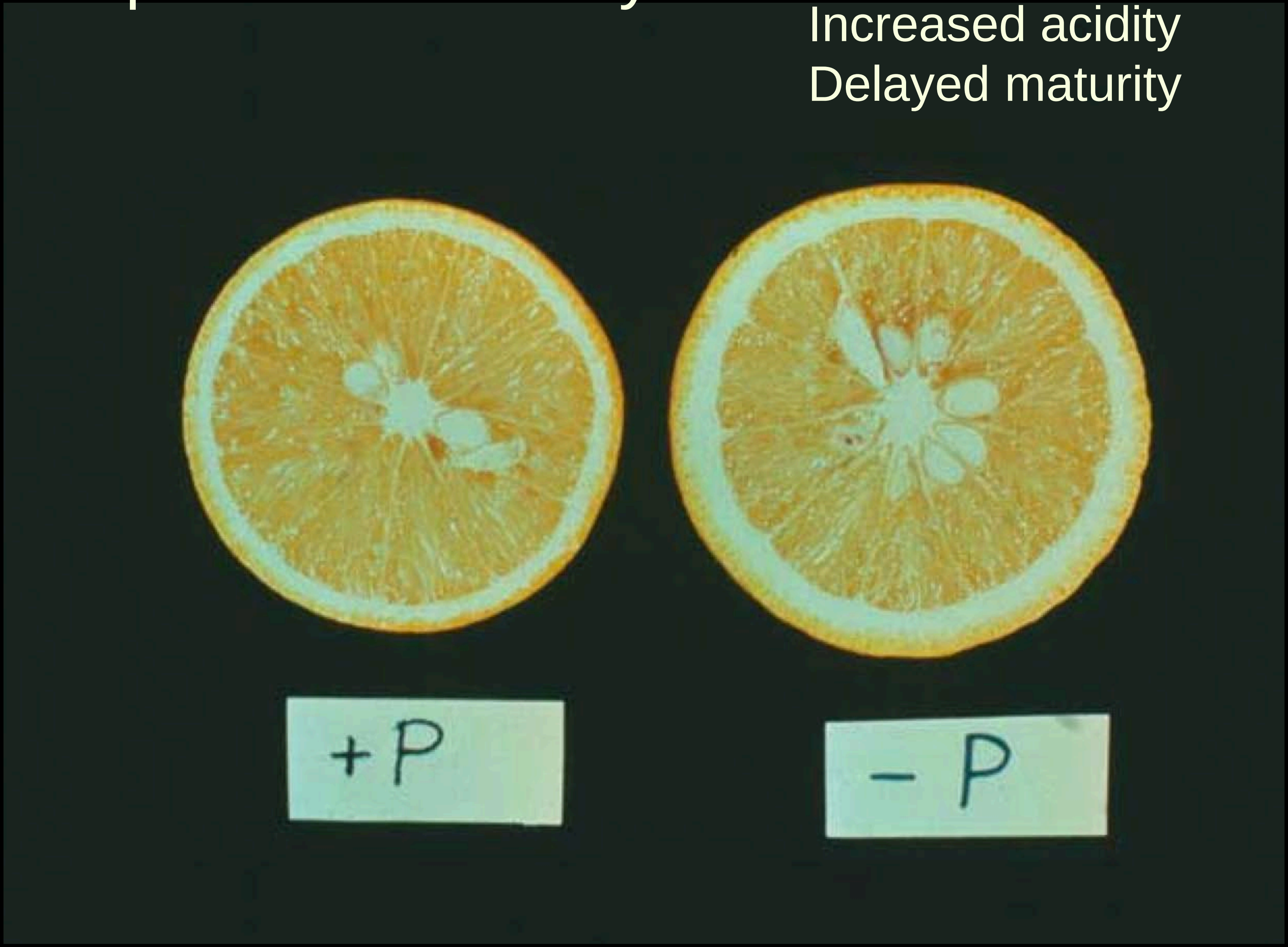
Influence of pH on Distribution of Inorganic Phosphorus in Soils

Phosphorus "Fixation"



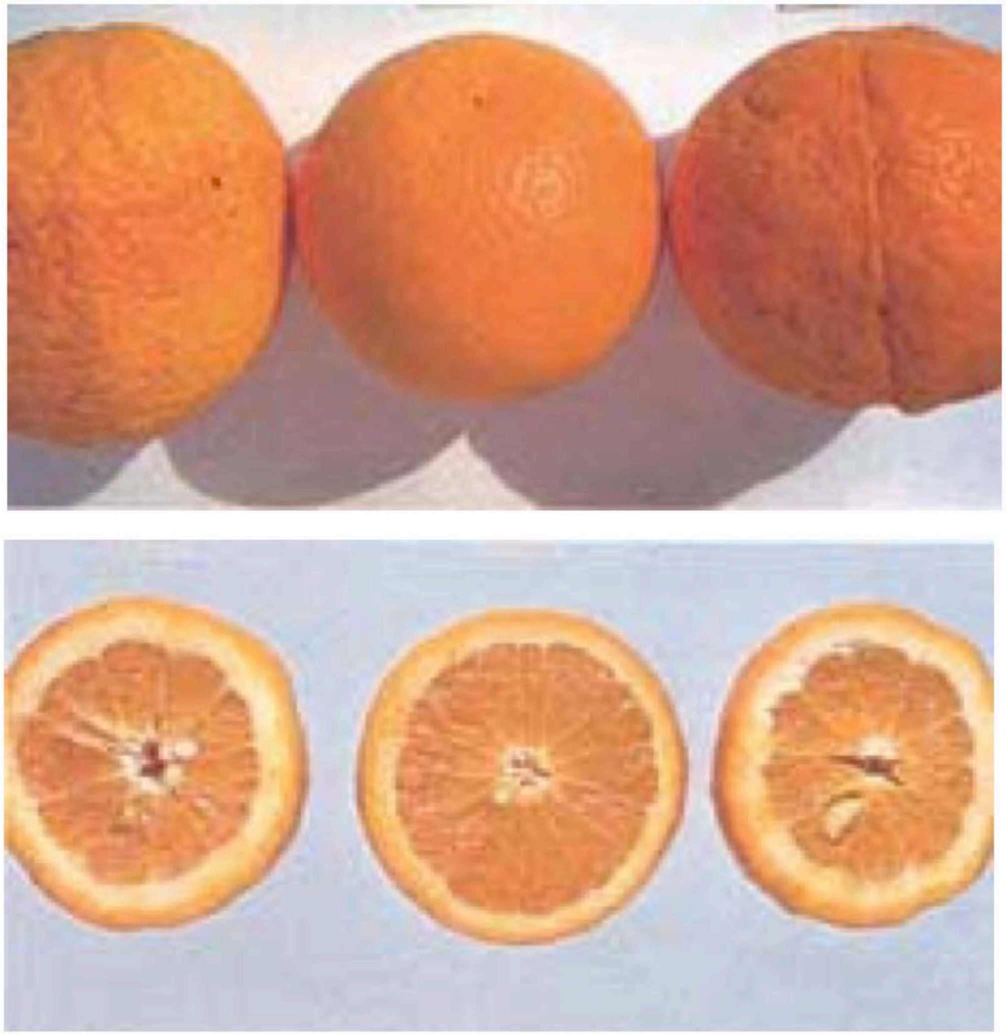
Phosphorus Deficiency

Thick coarse rind
Increased acidity
Delayed maturity



Phosphorus Nitrogen Interactions on Fruit Quality

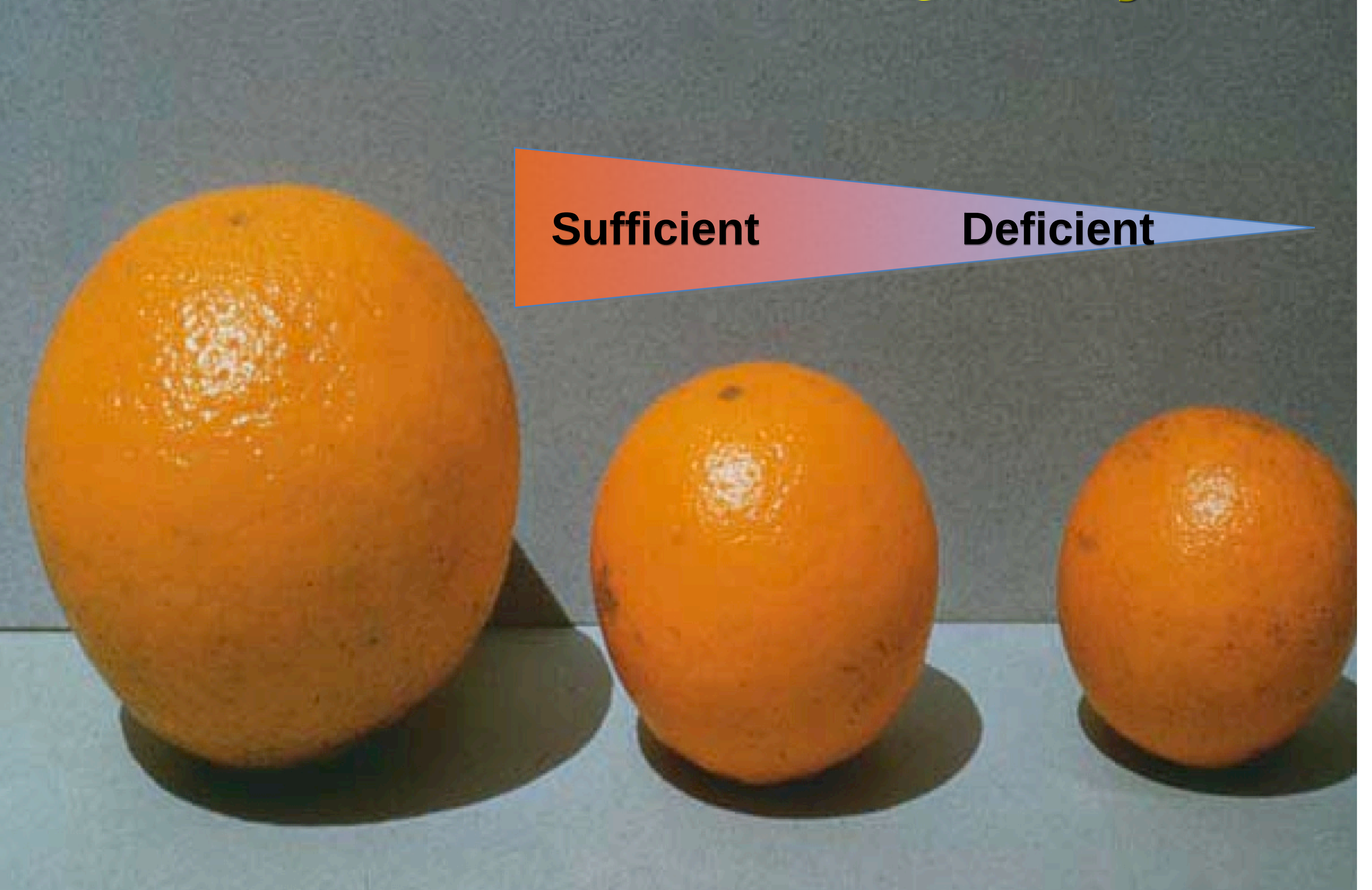
High N Low P | Normal N Normal P | High N Low P



Fruit produced on trees with excessive N and low P:

Misshapen fruit
Thick, coarse rinds
Open centers
Coarse flesh

Potassium and Fruit Quality



Magnesium Deficiency

Note inverted V of green at leaf base

- acid sandy soils – particularly in high rainfall areas
- cold wet conditions
- soils where there have been heavy inputs of potassium

Potassium and Phosphorus Fertilizer Recommendations

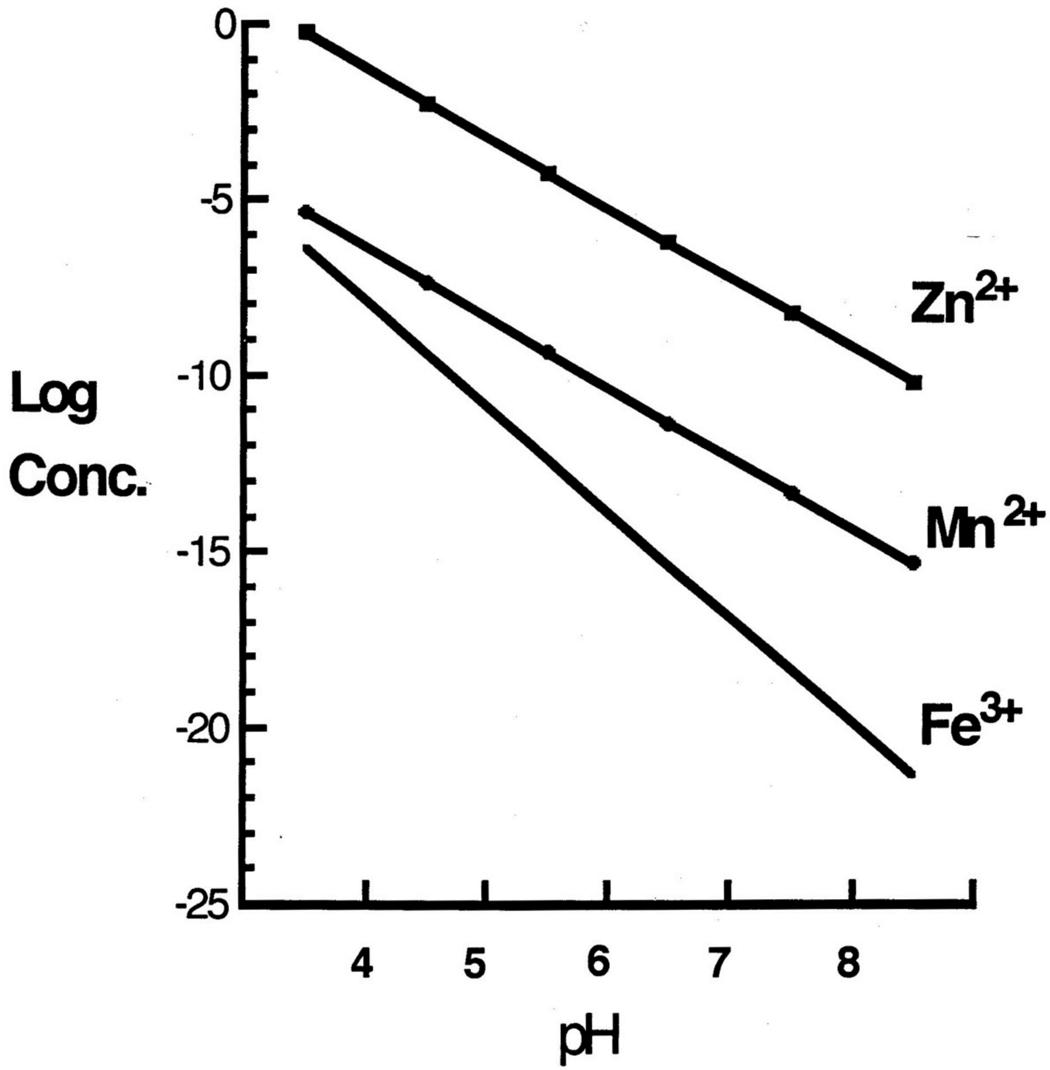
- Potassium and phosphorus stay where they are applied (usually the surface).
- Banding in a furrow or on the surface is the best way to apply superphosphate and potash fertilizer. Deep placement (15–20 cm) ensures good uptake as the roots grow through the band.
- Organic matter improves phosphorus movement. Mulches encourage roots to forage nearer the surface.

Trace Elements

What about the micronutrients?

Macronutrients	Secondary Nutrients	Micronutrients
Nitrogen (N)	Calcium (Ca)	Zinc (Zn)
		Iron (Fe)
Phosphorus (P)	Magnesium (Mg)	Manganese (Mn)
		Copper (Cu)
Potassium (K)	Sulfur (S)	Boron (B)
		Molybdenum (Mo)

Soil pH effects on metal solubility



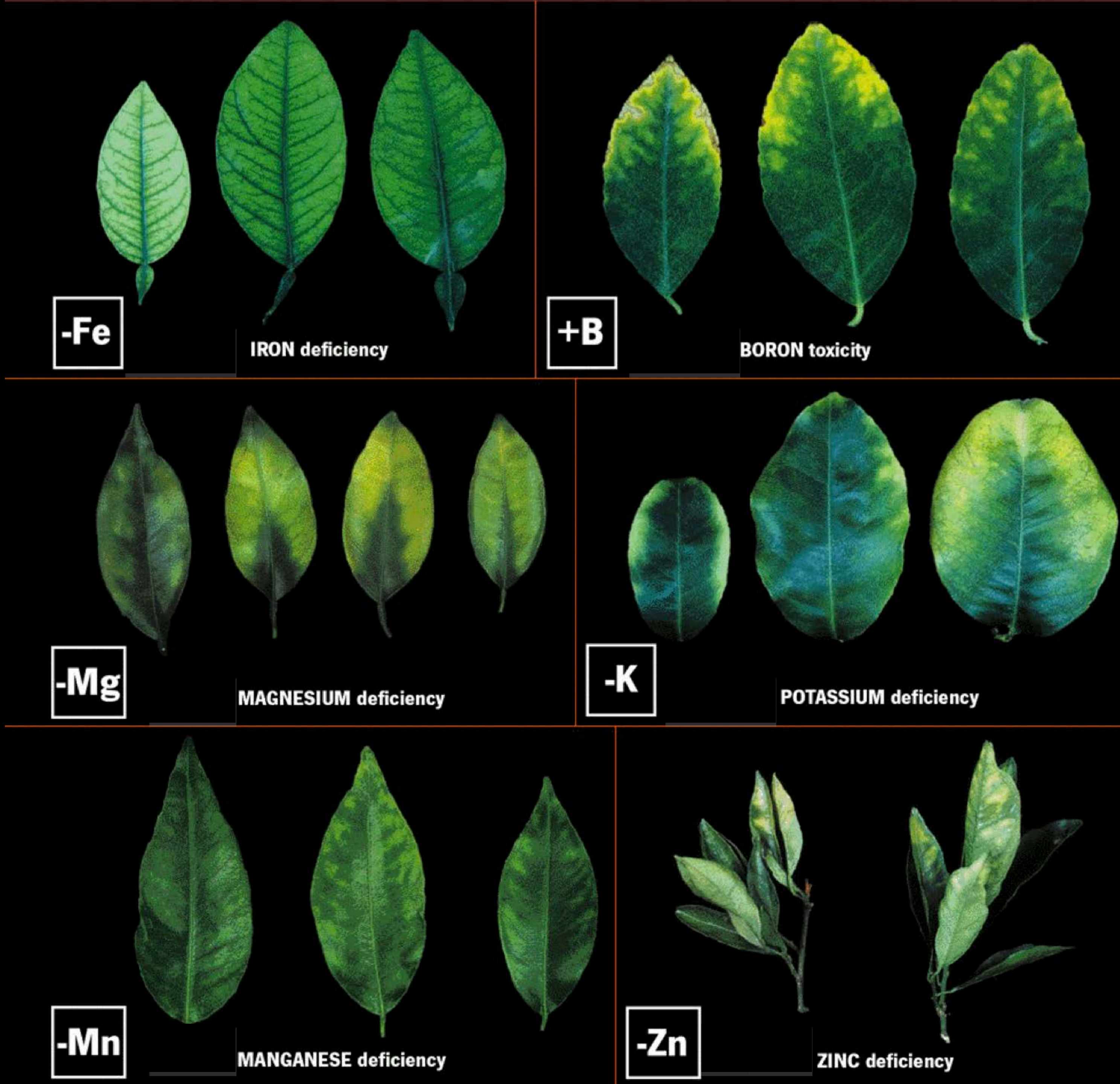
Trace Metal Deficiencies

High pH soils (low solubility)
- Natural lime outcrops
- After heavy liming of soil

Sandy, low pH soils (metal leaching)

Biological
- poor root growth
- poor conditions for mycorrhizal fungi

- poorly drained and/or aerated soils
- Phytophthora root rot


-Fe
IRON deficiency
+B
BORON toxicity
-Mg
MAGNESIUM deficiency
-K
POTASSIUM deficiency
-Mn
MANGANESE deficiency
-Zn
ZINC deficiency

Zinc Deficiency

Deficient	Satisfactory	Excessive
< 19	19 – 50	> 50

Mottled leaves
Symptoms progress to:

interveinal chlorosis,
tip necrosis
small leaf size
twig dieback

Manganese deficiency on lemon

http://ag.arizona.edu/pubs/crops/az1007/az1007-2.html

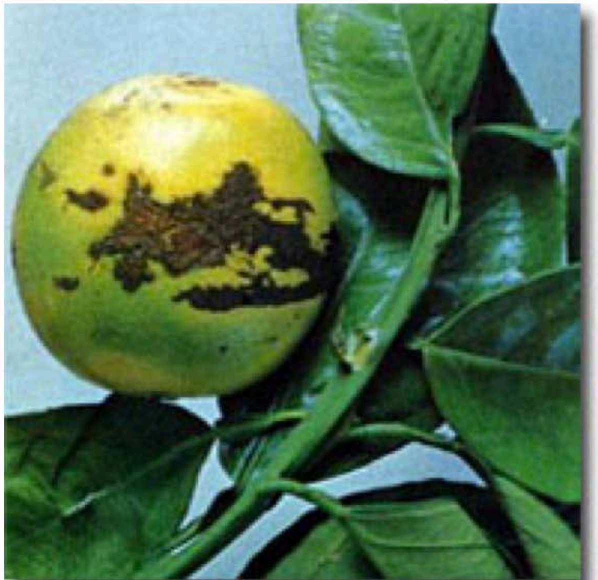
Iron Deficiency

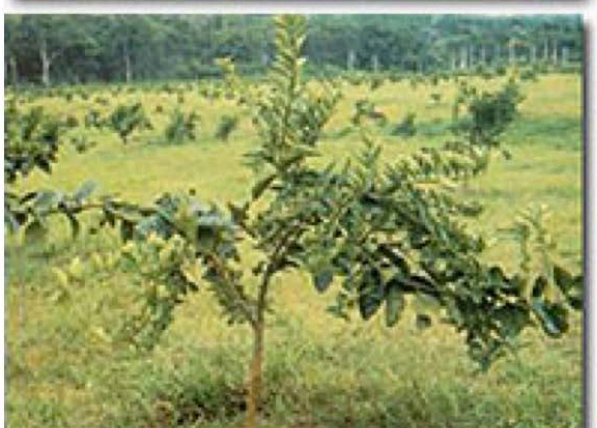
Deficient	Satisfactory	Excessive
< 30	30 – 130	> 130

Iron deficiency symptoms in lemon, showing normal (right), and increasingly chlorotic leaves.

http://ag.arizona.edu/pubs/crops/az1007/az1007-2.html

Copper Deficiency





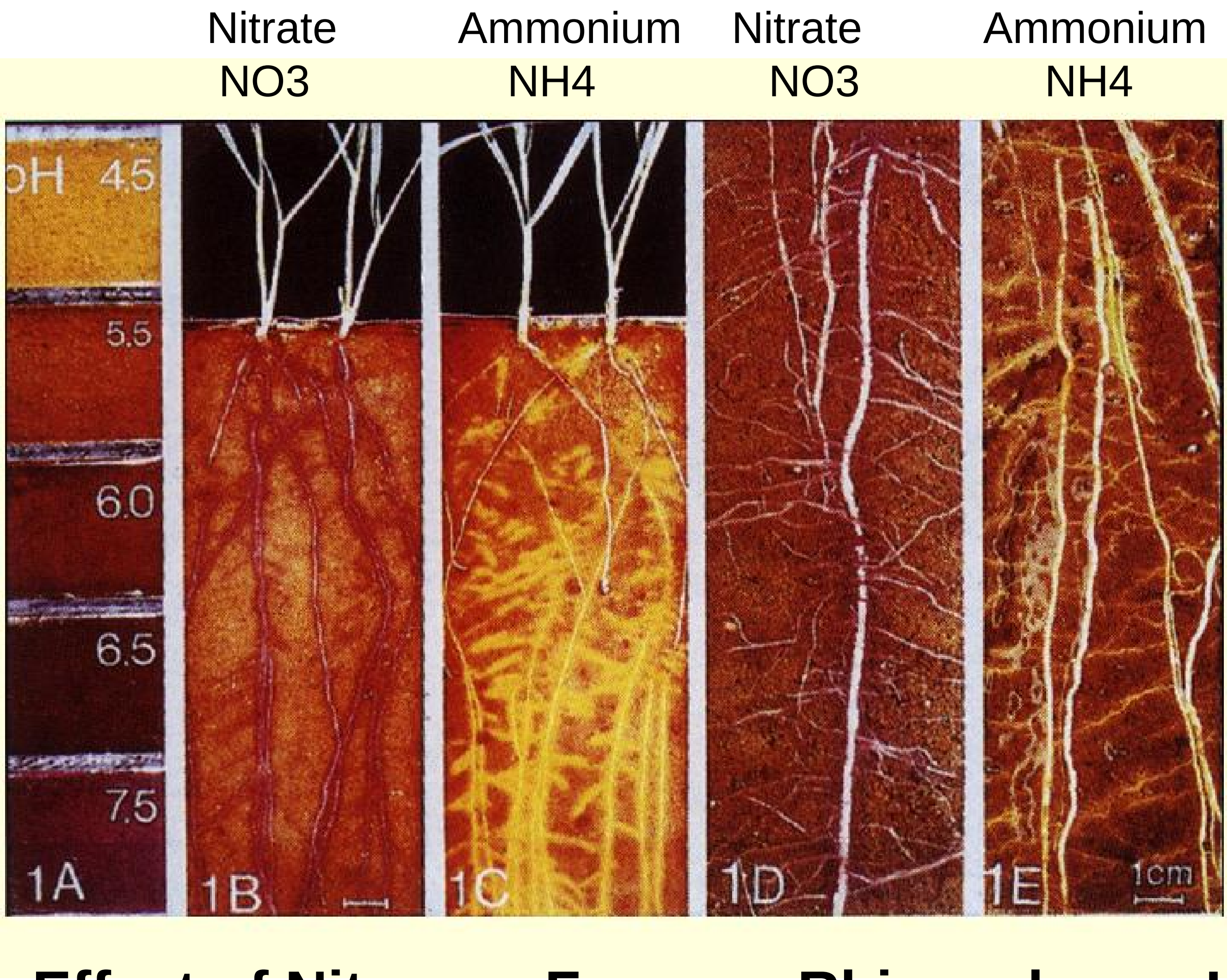
Rare

Occurs first on new growth

Leaves uniform in color, long-willow looking leaves, bushy appearance, dieback

Fruit splitting, gumming

Acid Forming Processes: Uptake of NH_4 Nitrogen



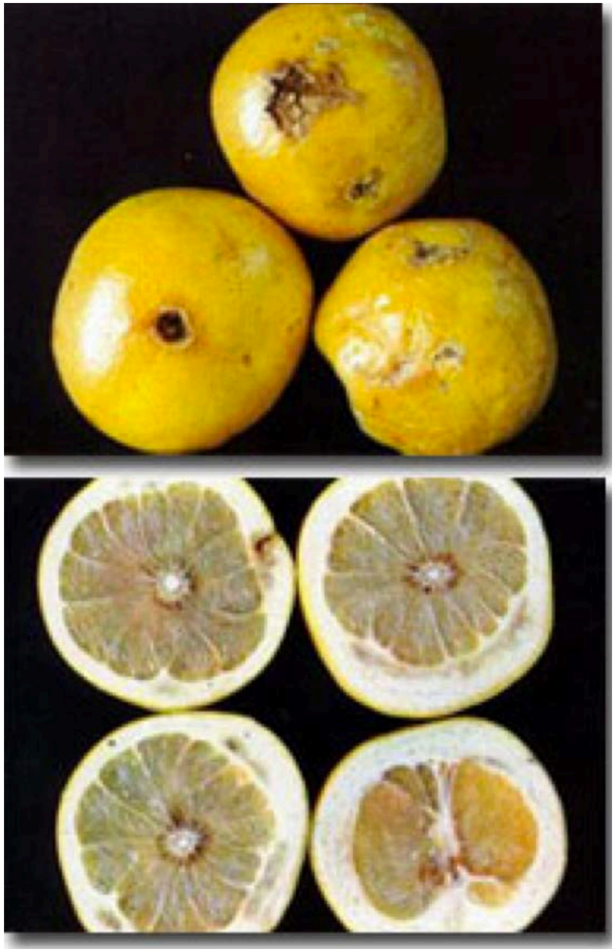
Effect of Nitrogen Form on Rhizosphere pH

Citrus rootstocks ranked by susceptibility to Fe chlorosis

lowest susceptibility	Sour orange *(C. aurantium)* Rough lemon *(C. jambhiri)* Cleopatra mandarin *(C. reticulata)* *C. macrophylla* *C. volkameriana*
moderate susceptibility	Sweet orange *(C. sinensis)* Carrizo citrange *(C. sinesis x P. trifoliata)*
highest susceptibility	Trifoliate orange *(P. trifoliata)* Swingle citrumelo *(C. paradisi x P. trifoliata)*

Boron Deficiency

Old leaves show scorching or yellowing on the margins and tips, sometimes with small brown spots.



Mishaped fruit, thick peels, plugging of stem / peel

http://www.agnet.org/library.php?func=view&id=20110804103731&type_id=2

Boron Toxicity

Boron toxicity (like salt toxicity) starts as tip yellowing and tip burn, but subsequent yellowing of the apex tends to be mottled. It progresses into a yellowing of interveined areas near the tip.

Rootstocks and scions differ in susceptibility to boron toxicity.

Citrus on rough lemon stock are more affected than those on sweet orange or *P. trifoliata* rootstock. Lemons are the most susceptible scion, followed by mandarins, grapefruit and oranges.

Correction of Trace Metal Deficiencies

Soil Treatments

- Acidification: N-furic, elemental sulfur
- Application of zinc sulfate, iron sulfate…
- Applications of chelated metals (iron and zinc)

Foliar Applications

- Canopy applications of metal salts
- Canopy applications of metal chelates

Foliar Applications of Trace Metals

Foliar Materials:

Chelates (EDTA, Metalosate..)

Zn, Mn, Fe Sulfate

Summary trace metals

Iron, zinc, and manganese deficiencies are the most common and can occur both in acid (leached soils) and alkaline soils (low availability).

Deficiencies may be seasonal and temporary.

Trace metal deficiencies can be solved using:

- efficient root stocks
- soil acidification (high pH soils)
- chelate applications to soil or foliage
- foliar sprays with metal salts

Summary

Many deficiencies have similar symptoms or may co-occur.

Soil and leaf analyses accurately reveal plant nutrition problems, and guide methods for fertilization depending on the soil type.

Future directions in plant nutrition will involve computer modeling and online decision support tools for optimizing yields, fruit quality, and plant health.