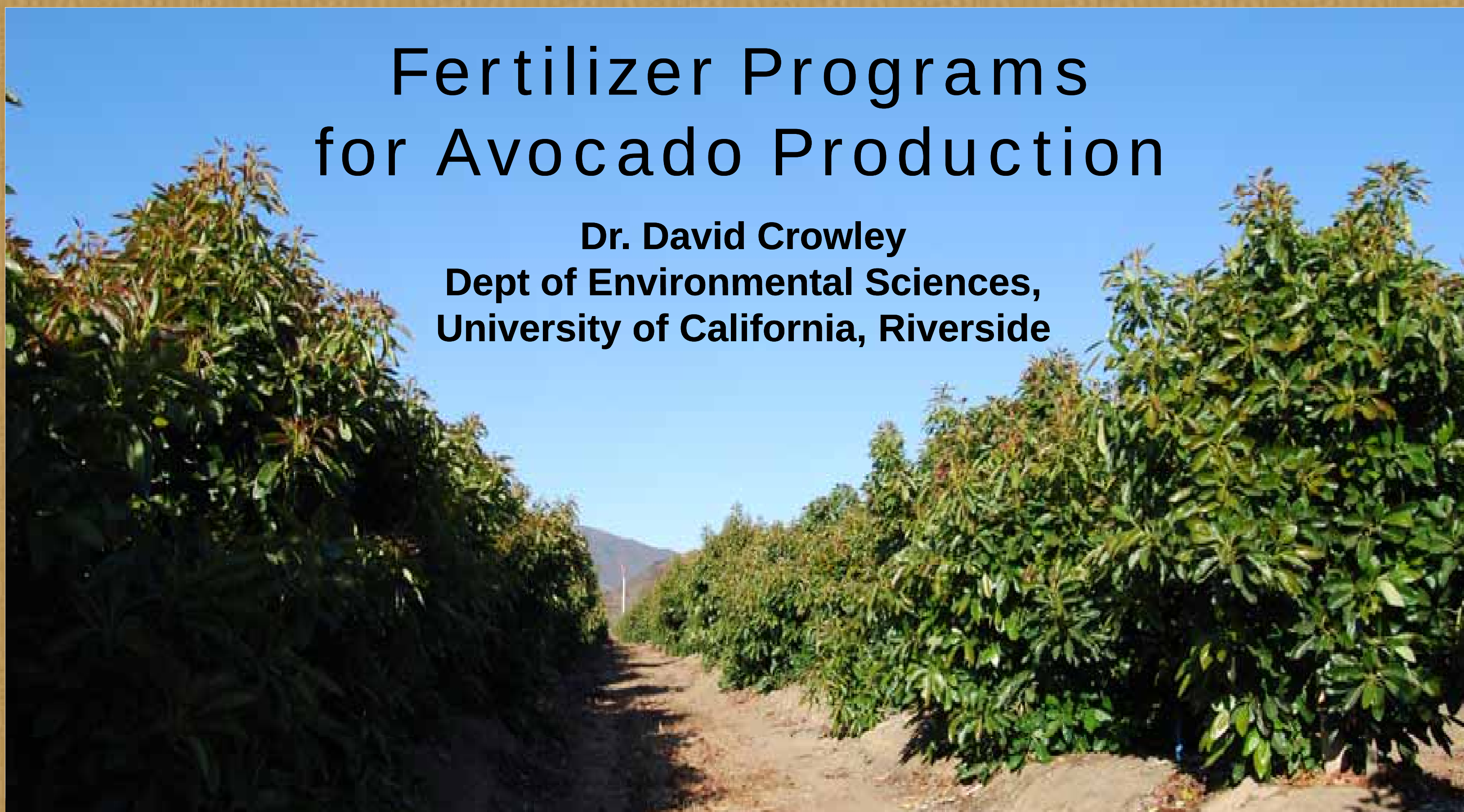
Welcome to the

2011 INDEX FRESH

Seminar Series

Fertilizer Programs for Avocado Production

Dr. David Crowley
Dept of Environmental Sciences,
University of California, Riverside



New Technologies for Avocado Production

Evaluation of rootstocks for salinity tolerance

Soil inoculation with PGPR

(plant growth promoting rhizobacteria)

- Control of phytophthora root rot
- Production of plant growth hormones
- Suppression of stress ethylene
  - Improved water use efficiency
  - Improved salinity tolerance

Online Decision Support Tools

- Irrigation and Fertilizer Management
- Neural network based disease and yield forecasting models

Use of charcoal (biochar) amendments

- Improved CEC, pH, bulk density, soil structure
- Improved water holding, aeration, root growth
- Increased microbial activity

California Avocado Association 1933 Yearbook 18: 39-49

Fertilizing Avocado Groves

(With especial reference to the use of and the supplementing of manure)

L. D. Batchelor
University of California, Citrus Experiment Station

California Avocado Society 1952 Yearbook 37: 201-209

NUTRIENT COMPOSITION AND SEASONAL LOSSES OF AVOCADO TREES

S. H. Cameron, R. T. Mueller, and A. Wallace

Eutrophication of water by nitrogen and phosphorus runoff:

Healthy Roots: The Key to Management of Avocado Mineral Nutrition

Use of Organic Amendments
- Mulch
- Composts

Irrigation Management
- Chloride & salts
- Leaching

Disease control
- Phytophthora
- Root Rot

Law of the Minimum - Liebig's Law

Justus von Liebig, generally credited as the "father of the fertilizer industry", formulated the law of the minimum: if one crop nutrient is missing or deficient, plant growth will be poor, even if the other elements are abundant.

Liebig likens the potential of a crop to a barrel with staves of unequal length. The capacity of this barrel is limited by the length of the shortest stave (in this case, phosphorus) and can only be increased by lengthening that stave. When that stave is lengthened, another one becomes the limiting factor.

http://www.avocadosource.com/

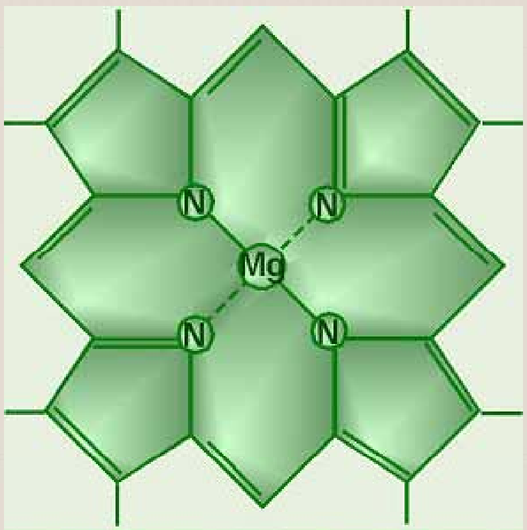
The Essential Elements

- **Primary Elements Required for Growth**
  - Carbon, Hydrogen and Oxygen
    - Supplied from carbon dioxide and water, essential for photosynthesis
  - Nitrogen
  - Phosphorous
  - Potassium

Nutrient	Units	Range
Nitrogen	% N	2.2 - 2.6
Phosphorous	% P	0.08 - 0.25
Potassium	% K	0.75 - 2.0
Sulphur	% S	0.2 - 0.6
Calcium	% Ca	1.0 - 3.0
Magnesium	% Mg	0.25 - 0.8
Zinc	ppm Zn	40 - 80
Copper	ppm Cu	5.0 - 15
Sodium	% Na	less than 0.25
Chloride	% Cl	less than 0.25
Iron	ppm Fe	50 - 200
Boron	ppm B	40 - 60
Manganese	ppm Mn	30 - 500

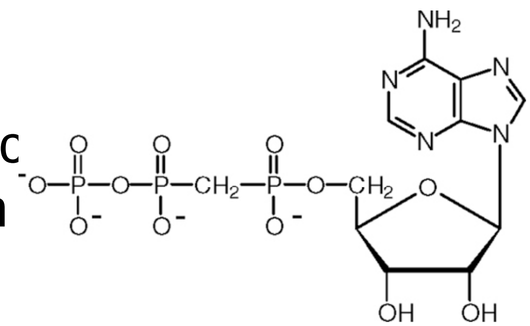
Functions of Essential Elements

- **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

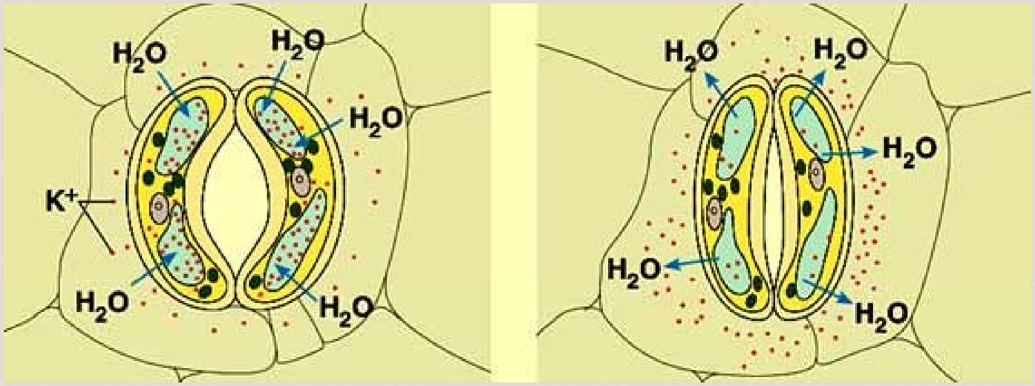
Phosphorus (P)



- 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

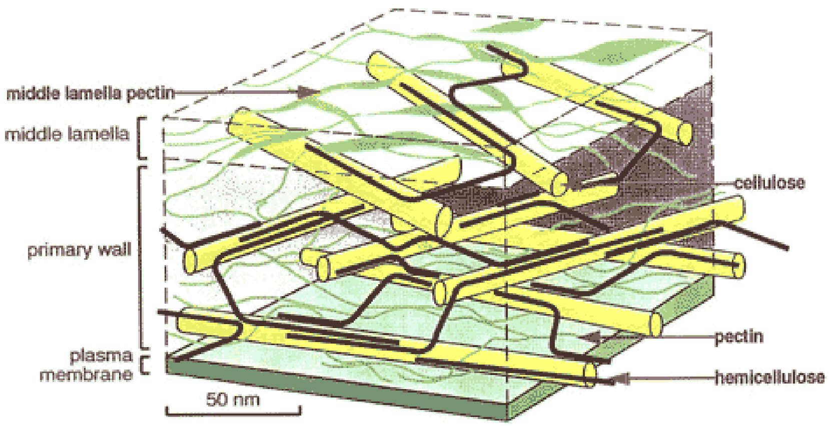
Potassium (K)



- 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 avocado root tips less leaky, therefore less attractive to Phytophthora zoospores
- Deficiencies:
  - Poor root development
  - Leaf necrosis & curling,
  - Blossom end rot,
  - Bitter pit, fruit cracking,
  - Poor fruit storage, and water soaking



Nitrogen Deficiency

Slow growth, stunting, reduced yields

Yellow-green color to leaves (a general yellowing)

More pronounced in older leaves since N is a mobile element that will move to younger leaves

Don't confuse with root rot and gopher damage

While avocado requires fertilization, it is difficult to show a fertilizer response for any nutrient!

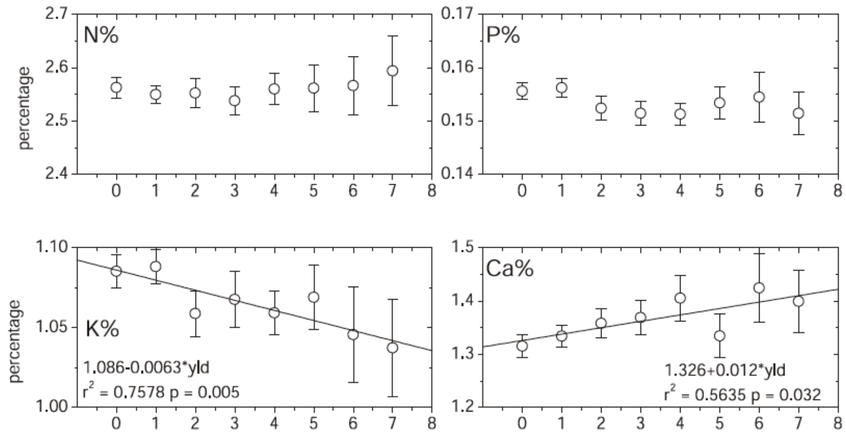


Table 2. Range of leaf mineral values (average plus or minus one standard deviation) of 'Hass' avocado trees with different yields taken from leaf tests in the same year as the harvest.

	Yield class (t/ha)						
Element	0-5	5-10	10-15	15-20	20-25	25-30	>30
N%	2.5-2.6	2.4-2.6	2.4-2.7	2.4-2.7	2.4-2.6	2.4-2.7	2.2-2.8
P%	0.15-0.16	0.14-0.16	0.14-0.16	0.14-0.16	0.13-0.16	0.15-0.18	0.13-0.16
K%	1.0-1.1	1.0-1.1	1.0-1.1	1.0-1.1	0.9-1.2	0.9-1.1	0.9-1.1
Ca%	1.3-1.4	1.3-1.5	1.4-1.6	1.3-1.7	1.2-1.8	1.6-1.7	1.1-1.7
Mg%	0.34-0.38	0.35-0.41	0.38-0.43	0.38-0.44	0.35-0.44	0.41-0.48	0.30-0.48
S%	0.24-0.27	0.24-0.27	0.26-0.29	0.25-0.28	0.22-0.31	0.25-0.28	0.21-0.29
Fe ppm	48-69	50-65	54-68	51-57	44-99	52-71	54-74
Mn ppm	146-192	140-237	117-234	127-196	124-233	120-192	73-186
Zn ppm	33-39	31-43	35-48	35-43	35-68	37-53	34-53
B ppm	29-33	25-35	30-39	26-42	21-44	28-39	29-49

Dixon et al.

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Total Fruit Nutrient Removal Calculator for Hass Avocado in California

Calculate the amount of nutrients that are removed when you harvest your crop. Enter your production below. **No commas or periods please!**

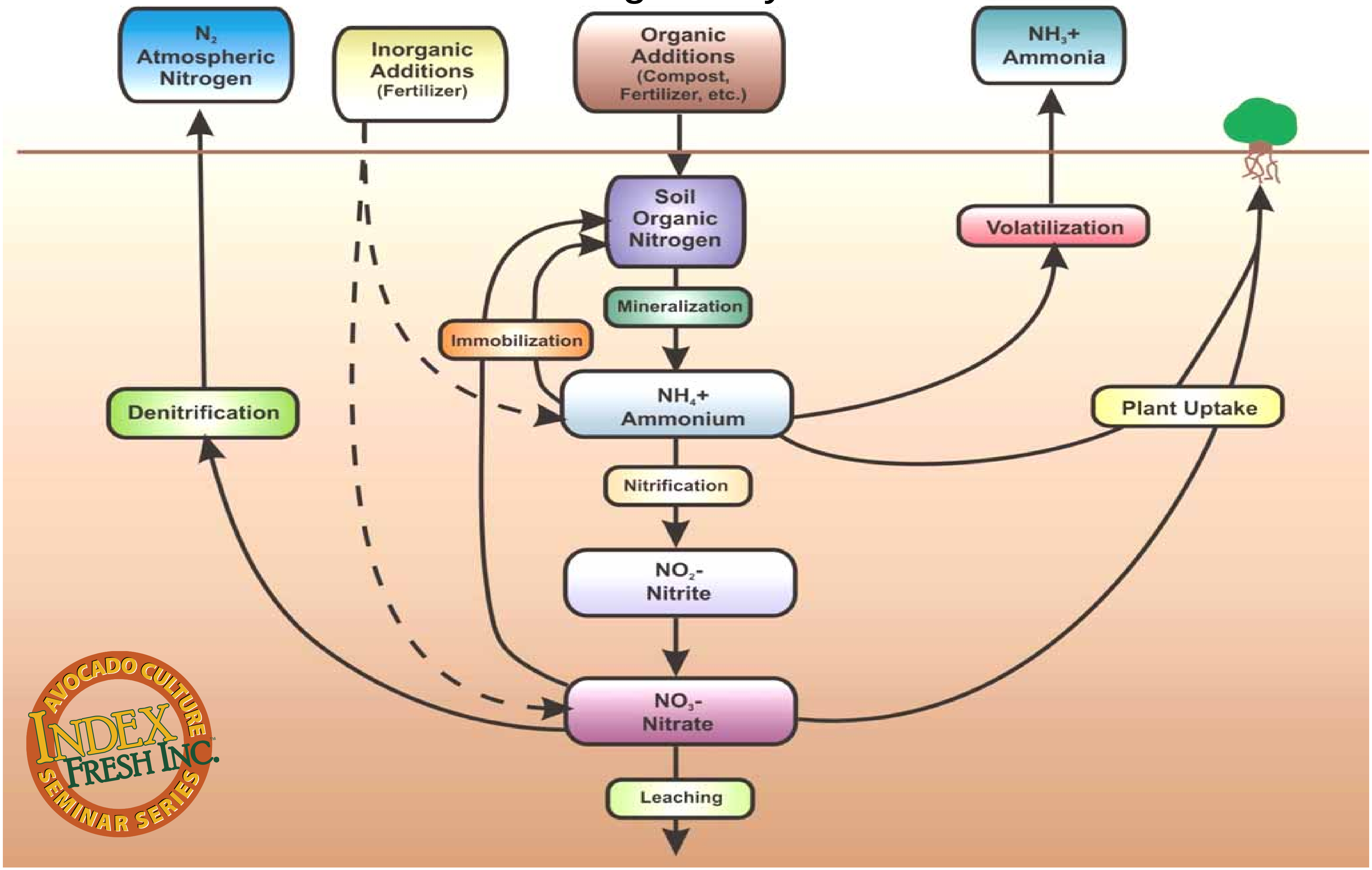
Production Volume: 6000 lbs.

Calculate

Nitrogen:	16.827 lb.	Arsenic:	0.0096 oz.
Phosphorus:	6.3588 lb.	Barium:	0.1728 oz.
P_2O_5:	14.5617 lb.	Cadmium:	0.0384 oz.
Potassium:	40.2906 lb.	Chromium:	0.0672 oz.
K_2O:	48.7516 lb.	Cobalt:	0.0096 oz.
Iron:	1.1232 oz.	Lead:	0.1248 oz.
Manganese:	0.2112 oz.	Lithium:	0.1536 oz.
Zinc:	3.7056 oz.	Mercury:	0 oz.
Copper:	1.3824 oz.	Nickel:	0.3456 oz.
Boron:	9.5328 oz.	Selenium:	0.048 oz.
Calcium:	3.3516 lb.	Silicon:	2.2752 oz.
Magnesium:	6.7608 lb.	Silver:	0.0096 oz.
Sodium:	6.1728 lb.	Strontium:	0.4224 oz.
Sulfur:	12.1866 lb.	Tin:	0.0864 oz.
Molybdenum:	0 oz.	Titanium:	0 oz.
Aluminum:	2.2464 oz.	Vanadium:	0 oz.
		Chloride:	6.7314 lb.

http://www.avocadosource.com/

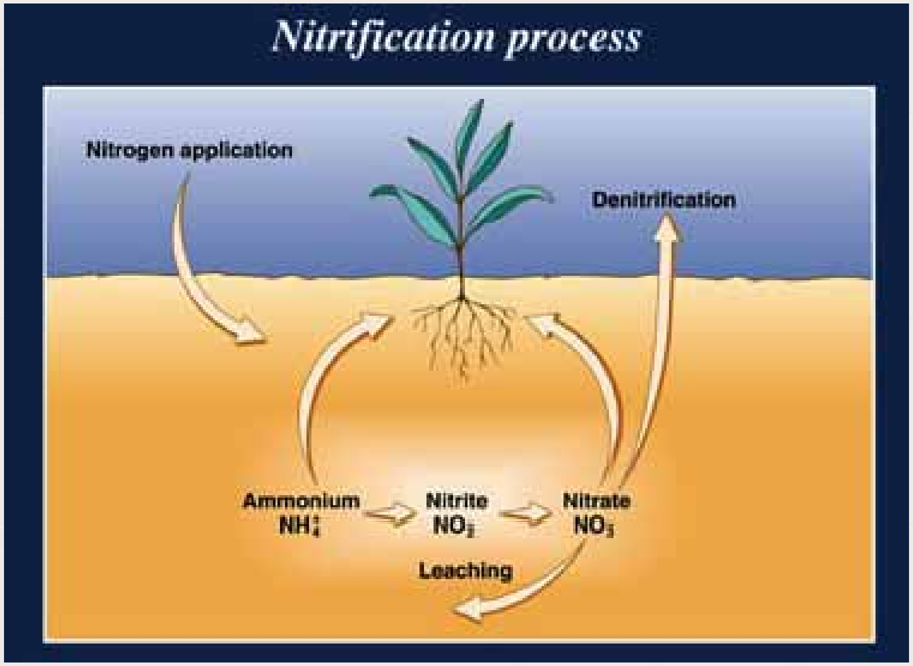
Nitrogen Cycle



Nutrient Availability and Uptake

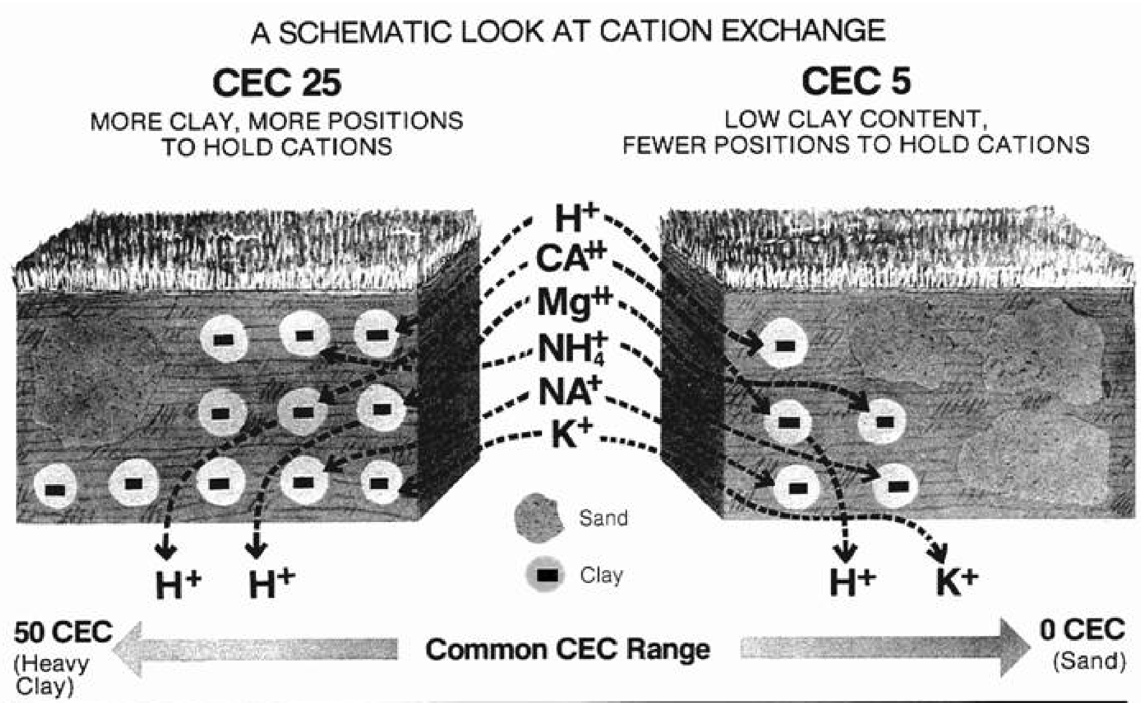
- Most of N is taken up as nitrate (NO_3^-)
- Some may be taken up as ammonium (NH_4^+)
- Nitrate is highly mobile in soil and moves to the roots quickly (and is leached out readily)
- Ammonium binds to soil particles and is converted to nitrate by bacteria

Nutrient Availability and Uptake



- Ammonium to nitrate takes 1-2 weeks at 75F
- Ammonium to nitrate takes 12 weeks or more at 50F
- Ammonium to nitrate is optimum at pH between 5.5 & 7.8
- Under anaerobic conditions, nitrate is lost from the soil as nitrous oxide, nitric oxide and N_2 gases

Practical Considerations: Know Your Soil – Nutrients are easily leached from sandy soils



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

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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

Analytical Results for Smith - DUSA

Hass 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

Hass 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

Hass Soil Analysis - Additional Elements

Sample Area	--- pH	mmhos/cm ECe	SAR	% Limestone	Tons/AF Lime Req	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.

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

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

Analytical Results for Snow - DUSA

Hass Plant Tissue Analysis

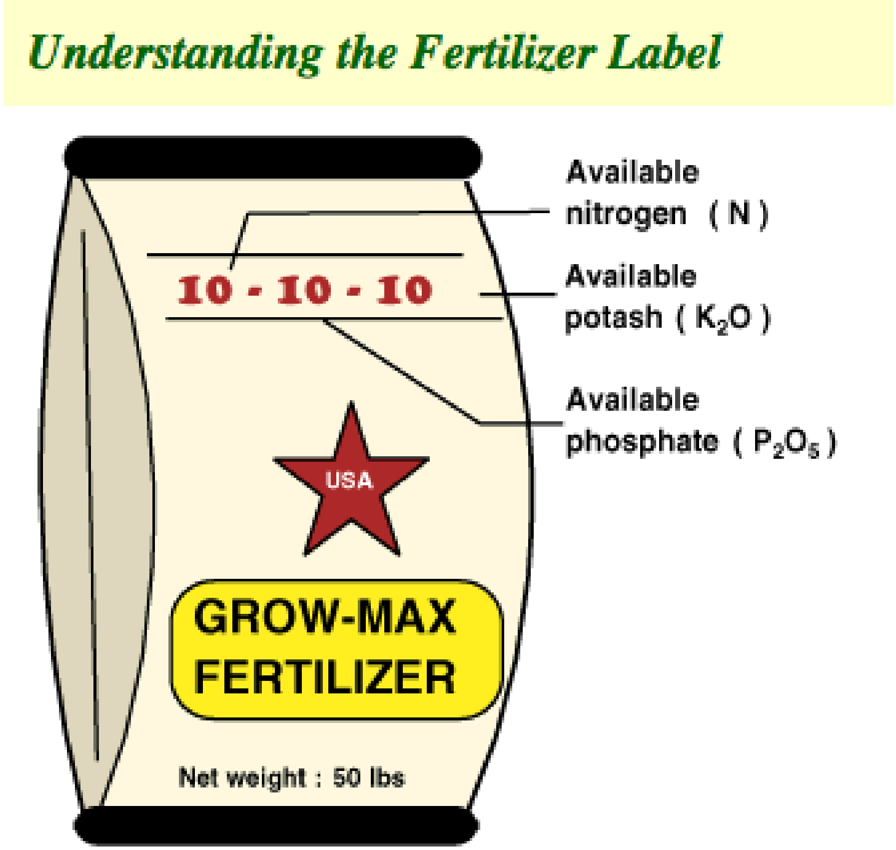
Sample Area	% Nitrogen	% Phosphorus	% Potassium	% Calcium	% Magnesium	ppm Zinc	ppm Manganese	ppm Iron	ppm Copper	ppm Boron	% Sodium	% Chloride
Tree # 01	2.97	0.289	1.37	1.12	0.311	50.1	51	50	16	173	0.005	0.0446
Tree # 02	2.42	0.227	1.16	1.51	0.472	37.8	54	42	14	206	0.006	0.0832
Tree # 03	2.70	0.288	1.56	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

Hass 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

Fertilizers

- N-P-K ratio is the "grade" and is required to be on all bags of fertilizer
- 21-7-14 means that in 100 lbs of fertilizer you will get 21 lbs of N, 7 lbs of phosphate (P_2O_5) and 14 lbs of potash (K_2O)



The Salt Index

Fertilizer salts can be toxic if concentrated, especially formulations containing chloride

Material and analysis	Salt Index	
	Per equal wts. of materials	Per unit of nutrients*
Nitrogen/Sulfur		
Ammonia, 82% N	47.1	0.572
Ammonium nitrate, 34% N	104.0	3.059
Ammonium sulfate; 21% N, 24% S	68.3	3.252
Ammonium thiosulfate, 12% N, 26% S	90.4	7.533
Urea, 46% N	74.4	1.618
UAN, 28% N (39% am. nitrate, 31% urea)	63.0	2.250
32% N (44% am. nitrate, 35% urea)	71.1	2.221
Phosphorus		
APP, 10% N, 34% P_2O_5	20.0	0.455
DAP 18% N, 46% P_2O_5	29.2	0.456
MAP 11% N, 52% P_2O_5	26.7	0.405
Phosphoric acid, 54% P_2O_5		1.613**
72% P_2O_5		1.754**
Potassium		
Monopotassium phosphate, 52% P_2O_5, 35% K_2O	8.4	0.097
Potassium chloride, 62% K_2O	120.1	1.936
Potassium sulfate, 50% K_2O, 18% S	42.6	0.852
Pot. thiosulfate, 25% K_2O, 17% S	68.0	2.720
** Salt index per 100 lbs of H_3PO_4	* One unit equals 20 lb.	

Single Element Formulations Nitrogen

- Ammonium nitrate (34-0-0)
- Ammonium sulfate (21-0-0-24S)
- Calcium nitrate (15.5-0-0)
- Urea (46-0-0)
- Solutions
  - Ammonium nitrate 20% N
  - Calcium ammonium nitrate 17% N
  - Urea ammonium nitrate 32 % N
  - Urea sulfuric acids (variable)

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Compound Fertilizers

These are fertilizers which contain two or more of the major elements which are chemically combined.

Examples:

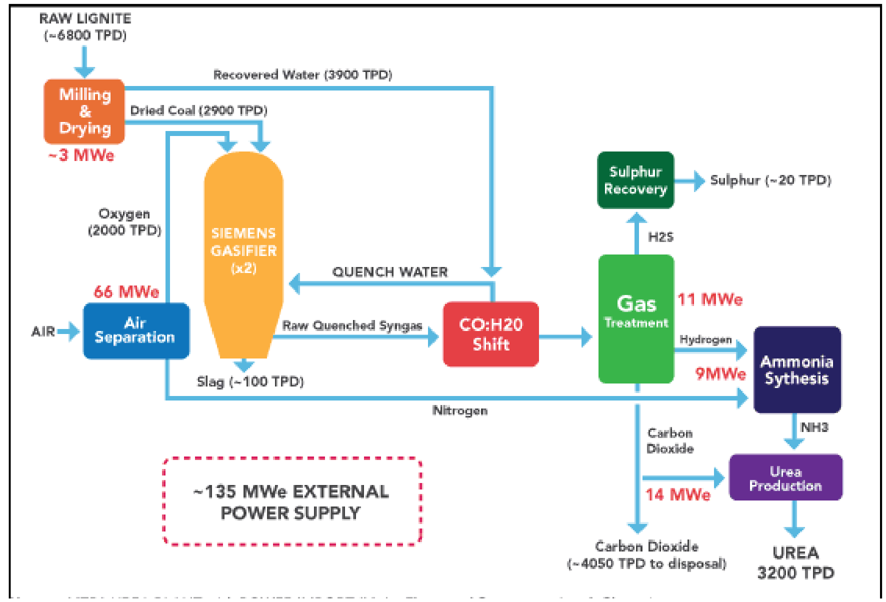
- Diammonium Phosphate
- DAP 18-46-0
- Mono Ammonium Phosphate
- MAP 11-52-0
- NPK 23-23-0
- NPK 20-20-0
- NPK 17-17-17

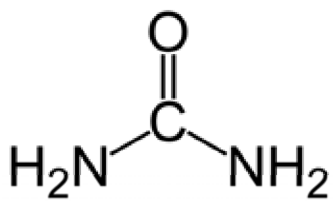
Anhydrous Ammonia

Ammonia (82-0-0) — Used as an applied fertilizer or as a building block for other fertilizer products. Stored as a liquid under pressure or refrigerated, it becomes a gas when exposed to air and is injected into the soil.

Urea

Urea is synthesized from coal – not for organic use





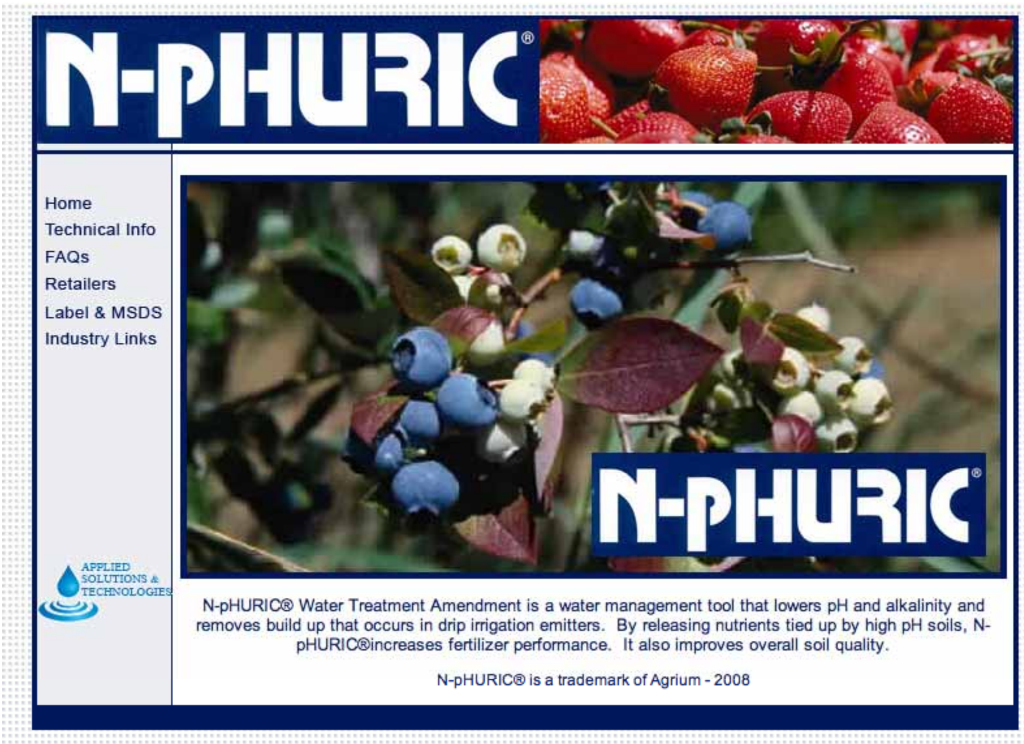
$$CH_4N_2O + H_2O \xrightarrow{\text{urease}} 2\,NH_3 + CO_2$$

urea — water — ammonia — carbon dioxide

Urea – Conversion to Ammonia

Urea (46-0-0) — A solid nitrogen product typically applied in granular form. It can be combined with ammonium nitrate and dissolved in water to make liquid nitrogen fertilizer known as urea ammonium nitrate or UAN solution.

Nitrogen fertilizers affect soil pH.



- **Ammonium containing fertilizers such as urea will lower the soil pH**
- **Nitrate fertilizers will raise soil pH and can cause problems with Zinc and Iron deficiencies**
- **Some special products include sulfur compounds that will lower pH and can help to dissolve calcium carbonate, keeping irrigation emitters open.**

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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

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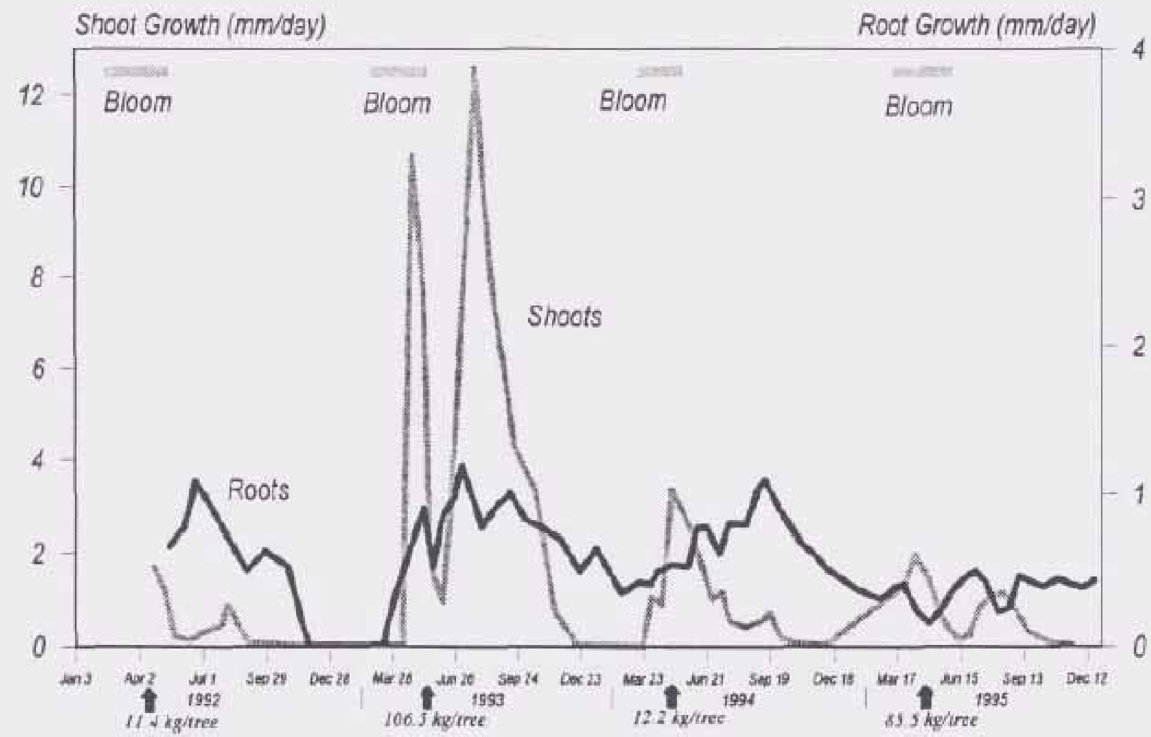
Timing of fertilizer applications to meet nutrient demand during flowering and fruit set

Figure 1. Vegetative and root growth cycles of 'Hass' avocado at the South Coast Research and Extension Center.



Arpaia et al

J. Amer. Soc. Hort. Sci. 126(5):555–559. 2001.

Properly Timed Soil-applied Nitrogen Fertilizer Increases Yield and Fruit Size of 'Hass' Avocado

Carol J. Lovatt[1]
Department of Botany and Plant Sciences, University of California, Riverside, CA 92521-0124

Table 3. Effect of time and amount of soil-applied N on annual and cumulative yield per tree.

Month extra N applied	Year 1	Year 2	Year 3	Year 4	4-Year cumulative yield
	kg fruit/tree				
None[z] (control)	47.6 abc[y]	150.6	20.1	33.4	220.8 c
January	36.0 bc	138.3	19.4	34.8	218.9 c
February	24.1 c	146.7	9.8	32.4	212.9 c
April	82.4 a	109.1	47.0	50.4	287.9 ab
June	37.6 bc	139.4	13.8	37.6	231.5 bc
November	67.4 ab	150.9	15.9	71.9	306.1 a
F test	*	NS	NS	NS	**

[z]Standard grower practice.
[y]Mean separation within columns by Duncan's multiple range test, $P \leq 0.05$.
[NS,*,**]Nonsignificant or significant at $P = 0.05$ or 0.01, respectively.

AVOCADO CULTURE INDEX FRESH INC. SEMINAR SERIES

Spring (April) applied fertilizer increases avocado yields

Table 1. Effect of time and amount of soil-applied N across 4 years on yield of 'Hass' avocado.

	Yield/tree			
	All fruit		Fruit packing carton sizes 40–60	
Month extra N applied	Total wt (kg)	No.	Total wt (kg)	No.
None[z] (control)	58.5 bc[y]	306 ab	38.4 b	166 b
January	56.1 bc	284 b	34.9 b	152 b
February	56.1 bc	280 b	31.7 b	140 b
April	71.8 ab	349 ab	55.1 a	234 a
June	53.2 c	272 b	38.1 b	162 b
November	76.5 a	384 a	54.9 a	235 a
Significance of F test[x]				
N	*	*	**	***
Year	****	****	****	****
N × year	*	NS	NS	NS

[z]Standard grower practice.
[y]Mean separation within the columns by Duncan's multiple range test, $P \leq 0.05$.
[x]Data analyzed using repeated measures model with year as the repeated measures factor.
NS,*,**,***,****Nonsignificant or significant at $P = 0.05, 0.01, 0.001$, or 0.0001, respectively.

Lovatt 2001

AVOCADO CULTURE INDEX FRESH INC. SEMINAR SERIES

Spring and Fall applied nitrogen reduces alternate bearing

Table 2. Effect of time and amount of soil-applied N on alternate-bearing index.

Month extra	Alternate-bearing index			
N applied	Years 1–2	Years 2–3	Years 3–4	4-Year avg
None[z] (control)	77 a[y]	98 a	87	90 a
January	70 ab	83 ab	88	79 ab
February	83 a	98 a	95	92 a
April	65 ab	75 b	76	72 b
June	78 a	89 ab	88	85 ab
November	53 b	89 ab	84	75 ab
F test	**	*	NS	*

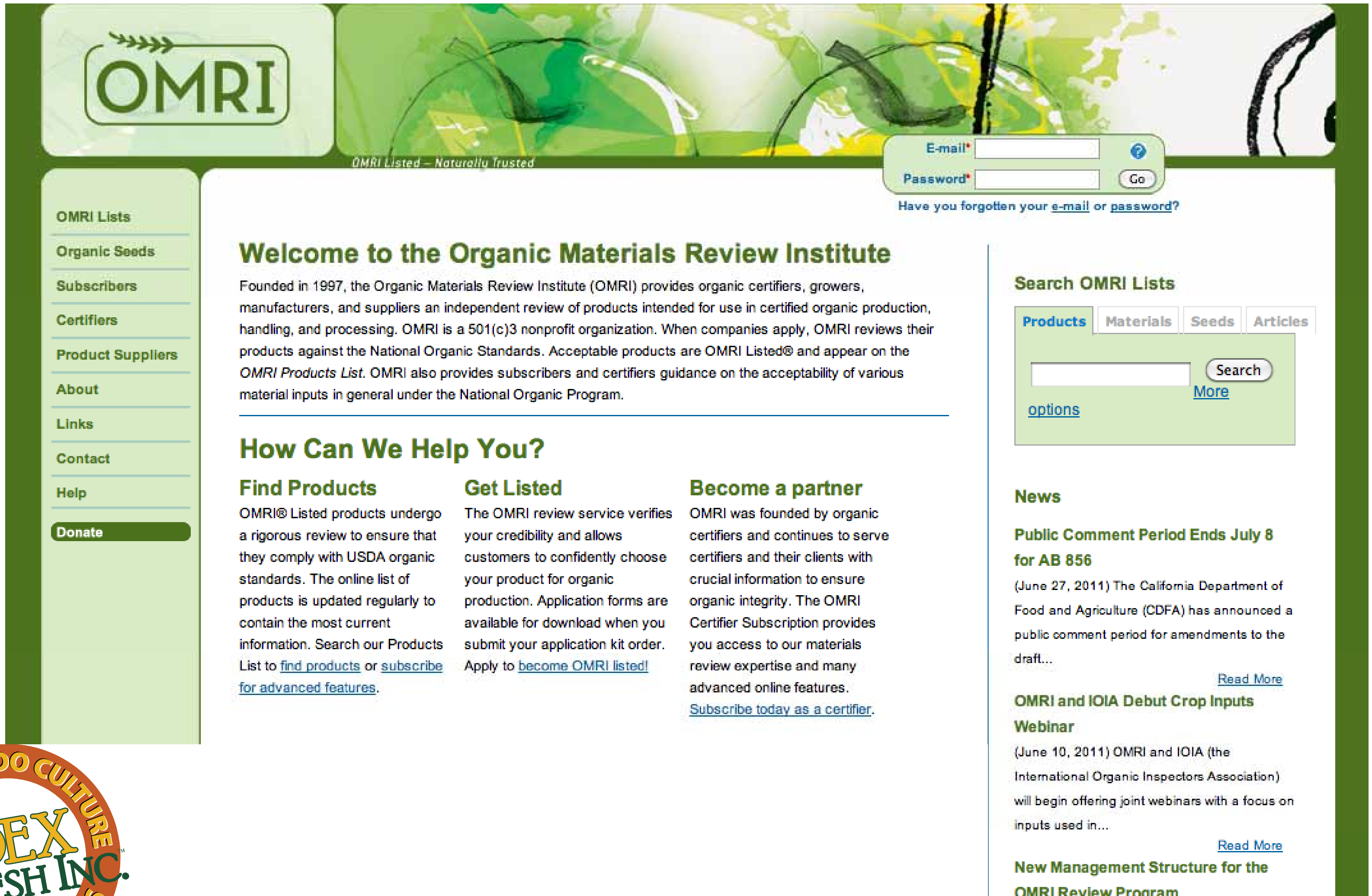
[z]Standard grower practice.

[y]Mean separation within columns by Duncan's multiple range test, $P \leq 0.05$.

[NS,*,**]Nonsignificant or significant at $P = 0.05$ or 0.01, respectively.

Lovatt 200l

What about organic fertilizers?



http://www.omri.org/omri-lists

OMRI Lists

OMRI publishes two lists in print and online. Basic searches are available below.

OMRI Products List

The *OMRI Products List* is the most complete directory of products for organic production or processing. The List includes over 2,100 products, which are known as "OMRI Listed®."

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http://www.omri.org/omri-lists

Nitrogen Mineralization Versus Immobilization

Mineralization

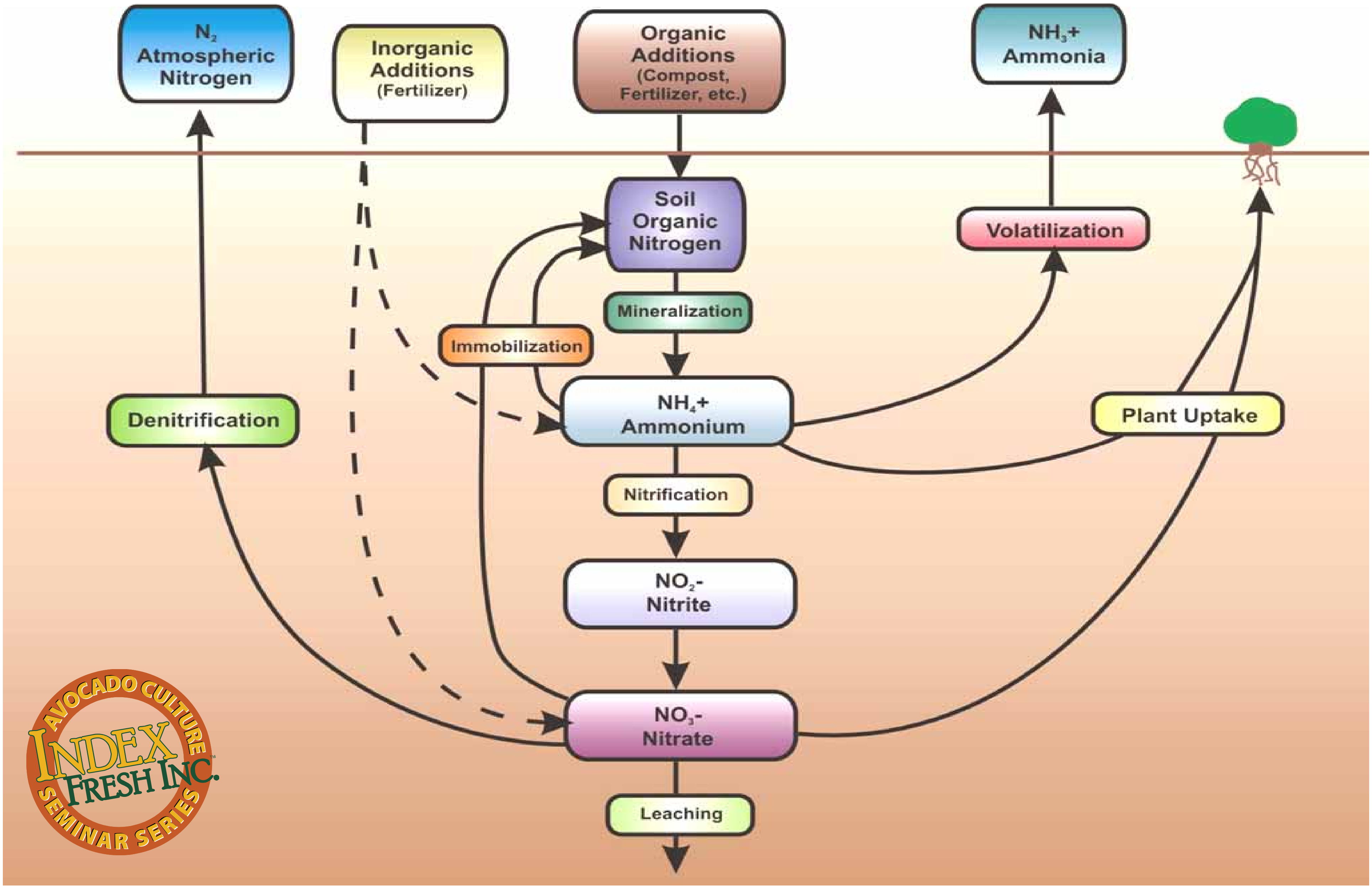
Organic nitrogen (many forms) → Inorganic nitrogen Ammonium (NH_4^+)

Immobilization is the *reverse* of mineralization

Immobilization

Organic nitrogen (many forms) ← Inorganic nitrogen Ammonium (NH_4^+) Nitrate (NO_3^-)

Nitrogen cycle



Influence of carbon to nitrogen ratio on nitrogen availability

<20	20–30	>30
Net gain of NH_4^+ and NO_3^-	Neither gain nor loss	Net uptake of NH_4^+ and NO_3^-

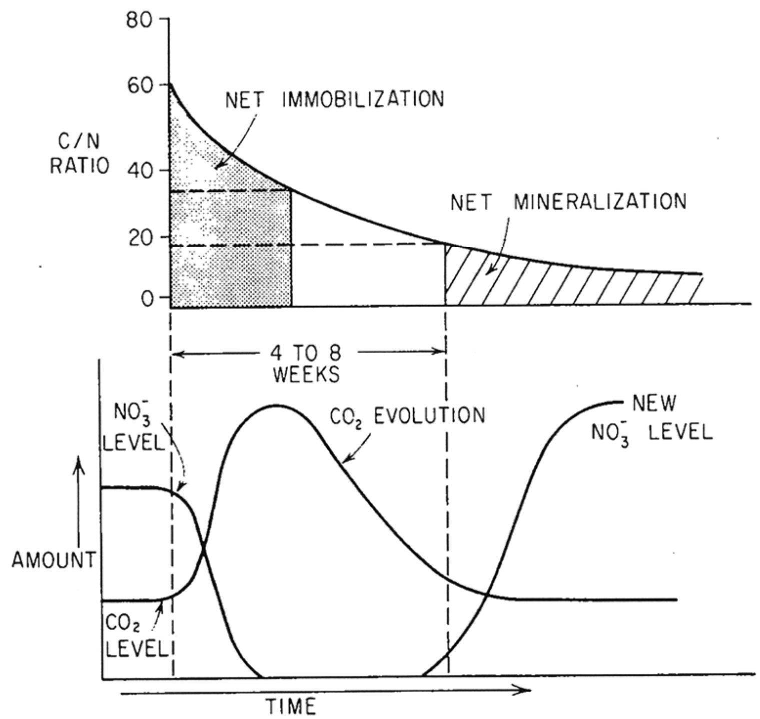
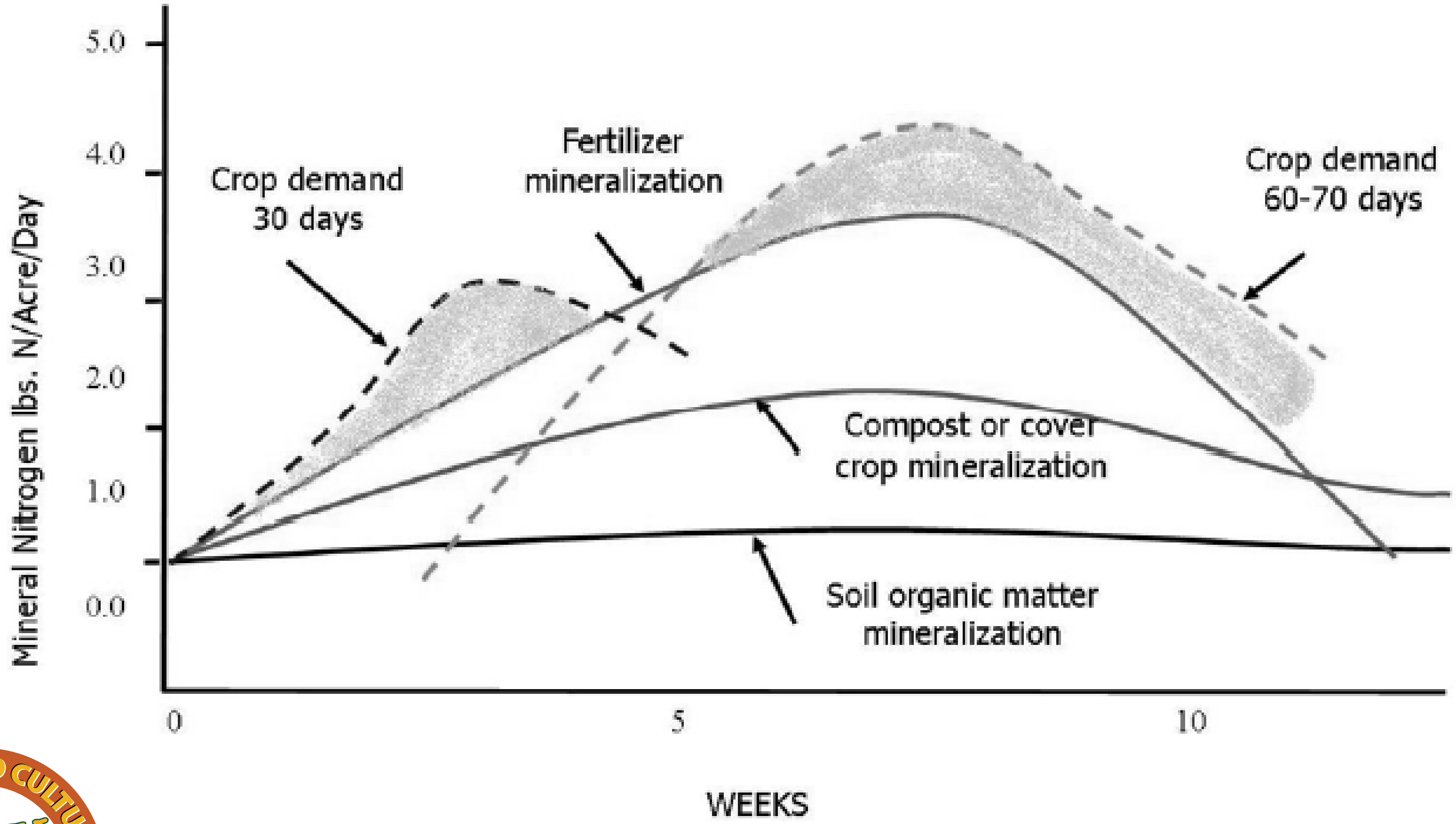


FIGURE 5-5. Changes in nitrate levels of soil during the decomposition of low-nitrogen crop residues. (Courtesy of B. R. Sabey, Univ. of Illinois.)

Typical C/N Ratios of Some Organic Materials

Material	C/N Ratio
Microbial Tissues	6 – 12
Sewage Sludge	5 – 14
Soil humus	10 – 12
Animal manures	13 – 25
Legume residues	13 – 25
Cereal residues straw	60 – 80
Wood, Forest Waste	150 – 500

Synchrony Between Mineralization of Various Sources of N and Crop Demand

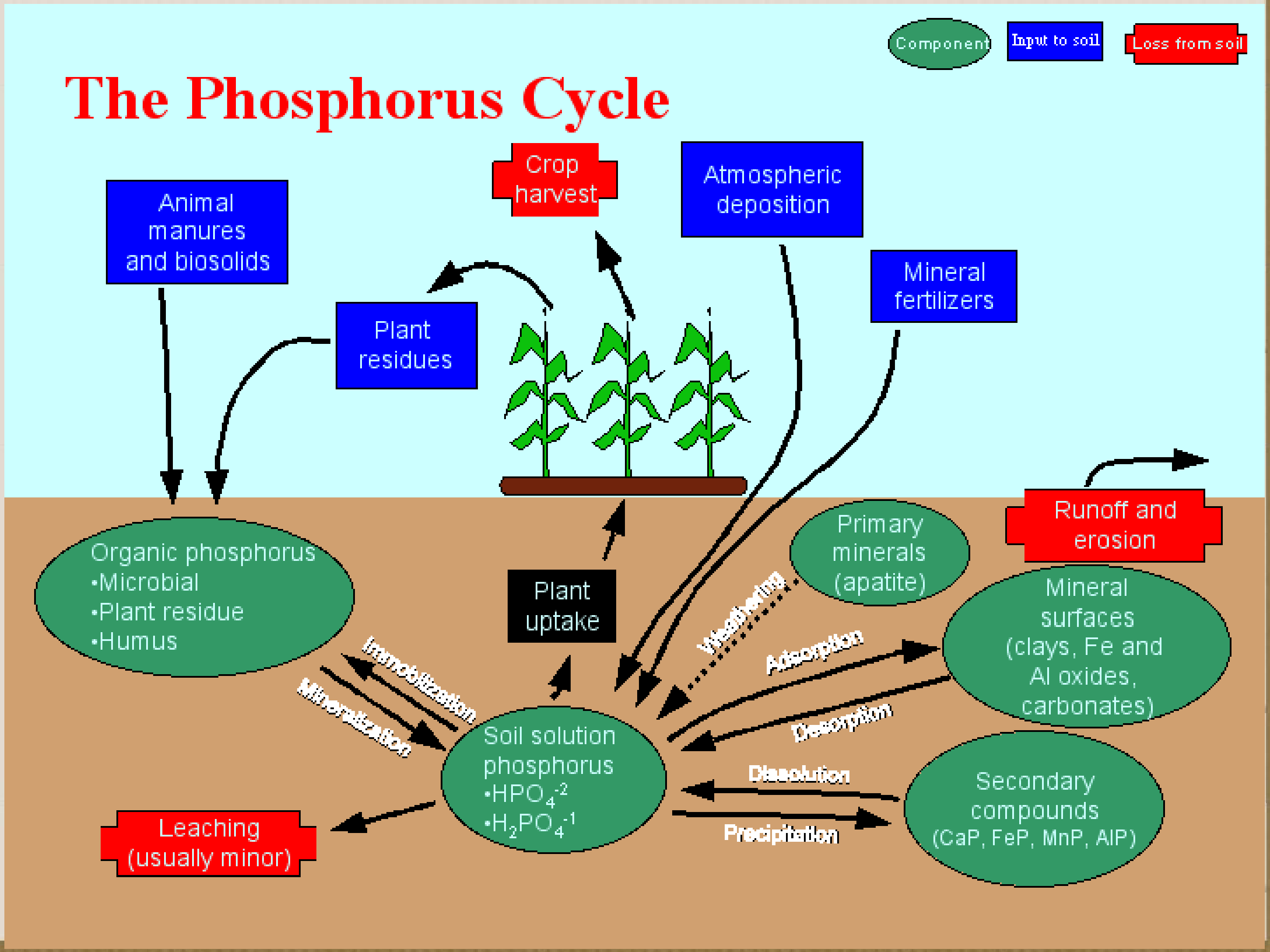


Salt Index Ratings: Organic Fertilizers

	Salt Index
Sodium Nitrate, 16.5% N	100
Potassium Sulfate, 50% K_20, 18% S	42.6
Gypsum, 23% Ca, 17% S	8.1
Manure Salts, 20%	112.7
Manure Salts, 30%	91.9
Seabird Guano 12-12-1	42.9
Feather Meal 12% N	1.4
Bone Meal 3% N, 15% P_2O_5	1.8
Blood Meal 13% N, 1.5 P_2O_5	2.8
Meat & Bone Meal 8-5-1	3.9

Organic Nitrogen Inputs and the Soil Food Web, Tim Stemwedel, COFI

Phosphorus

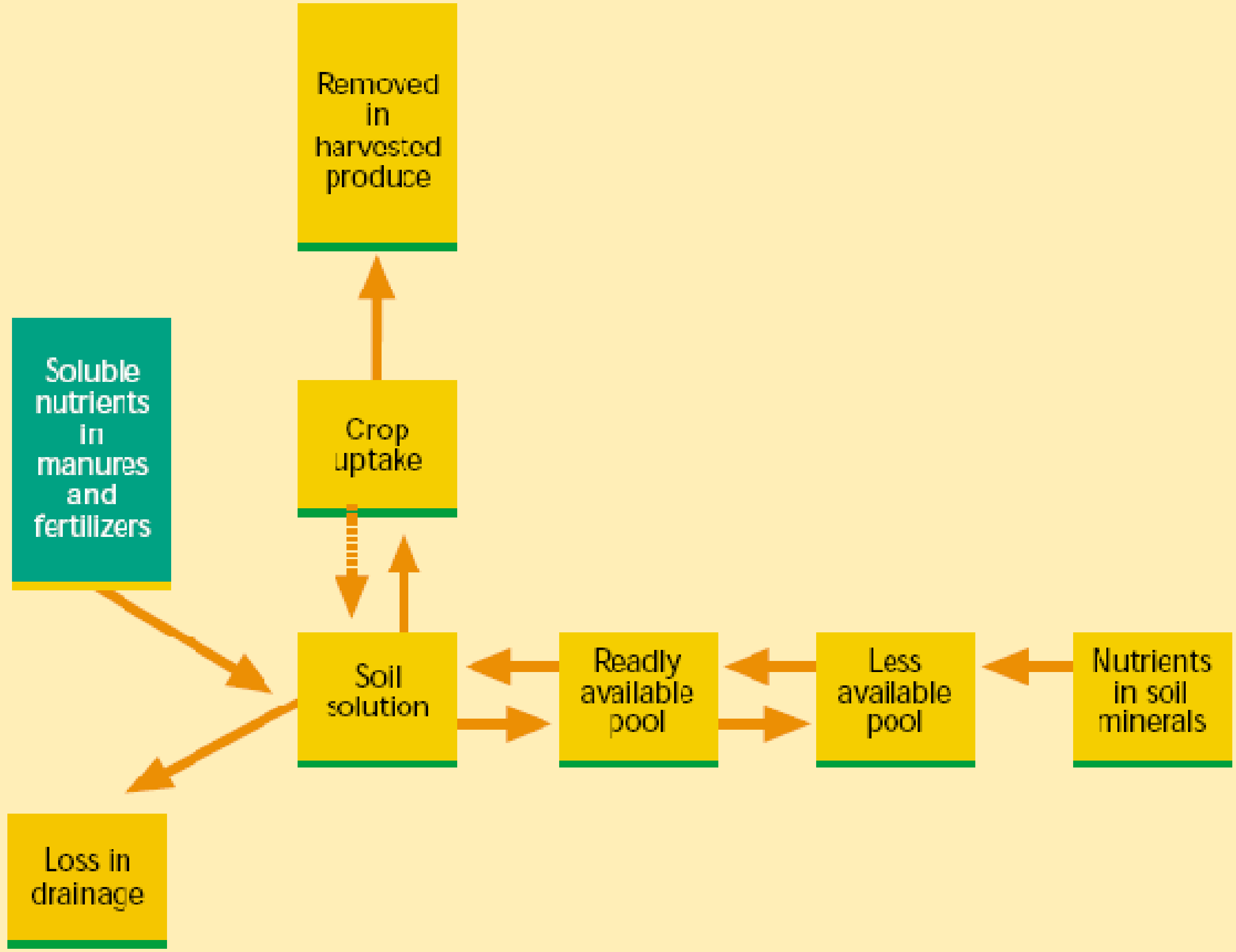


Component
Input to soil
Loss from soil
The Phosphorus Cycle
Animal manures and biosolids
Crop harvest
Atmospheric deposition
Mineral fertilizers
Plant residues
Runoff and erosion
Primary minerals (apatite)
Organic phosphorus
•Microbial
•Plant residue
•Humus
Plant uptake
Weathering
Adsorption
Mineral surfaces (clays, Fe and Al oxides, carbonates)
Immobilization
Mineralization
Desorption
Soil solution phosphorus
•HPO_4^{-2}
•$H_2PO_4^{-1}$
Dissolution
Precipitation
Secondary compounds (CaP, FeP, MnP, AlP)
Leaching (usually minor)

Phosphorus in Soils

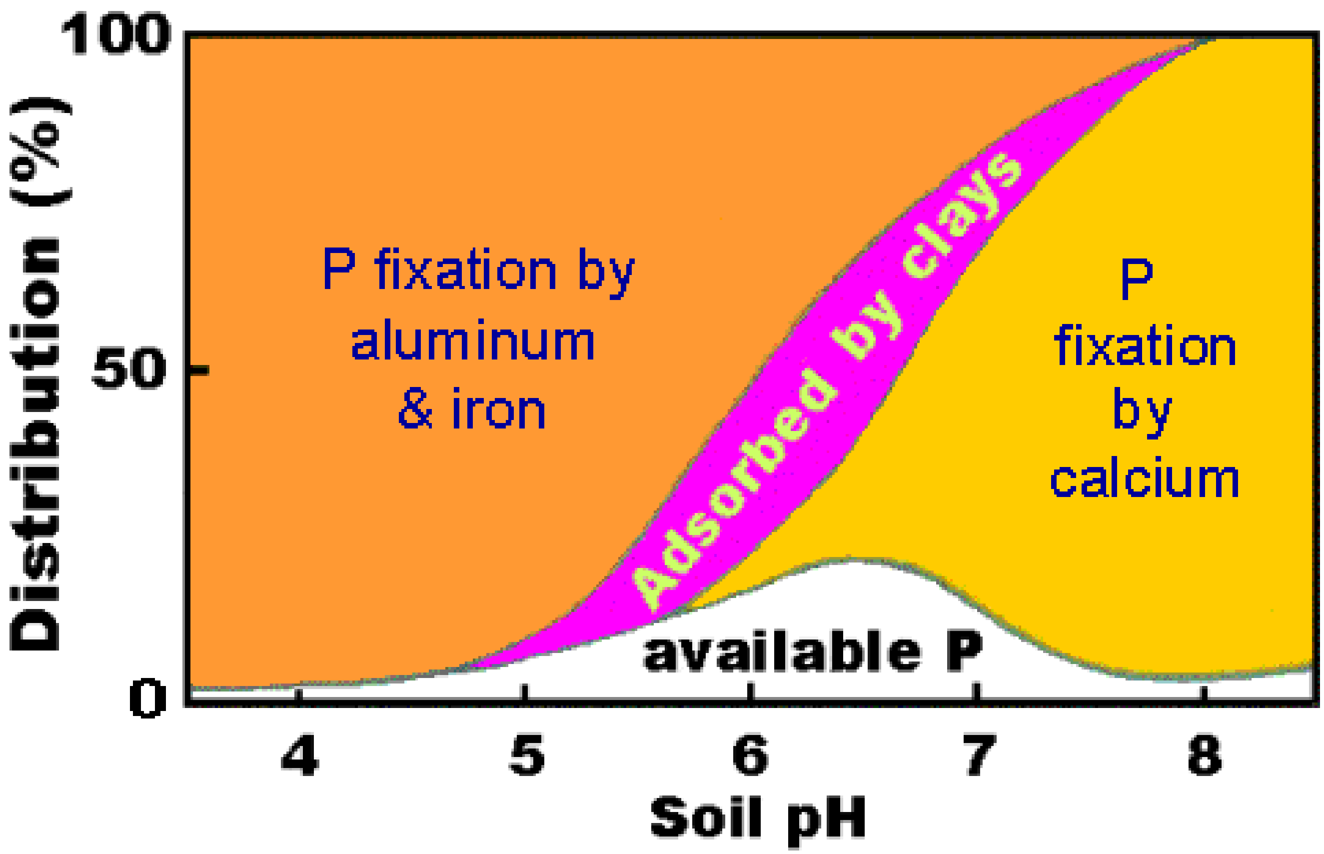
- Total P in many soils (0 to 6 in.) ranges from 400 to 2,000 lb/A…but only a fraction of that is available for plant uptake each season

After fertilization with phosphorus fertilizers, most of the fertilizer materials immediately precipitate as minerals that become decreasingly available over time.



Influence of pH on Distribution of Inorganic Phosphorus in Soils

Phosphorus "Fixation"



Formulations - Phosphate

- Starts with phosphate rock from mines in N. Africa, and Montana, Wyoming, Idaho and Utah
- Finely ground phosphate rock used in organic production (best on acid soils)
- Phosphoric acid (0-52-0)
- Superphosphate (0-20-0-12S)
- Ammonium phosphate (11-52-0)
- Liquid ammonium phosphate (8-24-0)

Nutrient Availability and Uptake

- Potassium (K)
  - Taken up as K^+ ions and remains in ionic form in the plant
  - 90-98% of K occurs in primary materials and is unavailable to the plants
  - 1-10% is trapped in expanding lattice clays and is slowly available
  - 1-2 % is in soil solution and readily available

Formulations-Potassium

- Potassium chloride (cheapest, but not recommended for avocados)
- Potassium sulfate
- Potassium nitrate
- Solubility in water (%K_2O) at 20C
  - KCl 16.1
  - KSO_4 5.4
  - KNO_3 11.2

Summary - Application Timing

- N fertilizers should be applied frequently, especially where soil is light and lacking fertility; usually at least once a month for 9 months during growing season.
- P and K fertilizers do not leach readily and can be applied less frequently
- Heavy soils can be fertilized less frequently

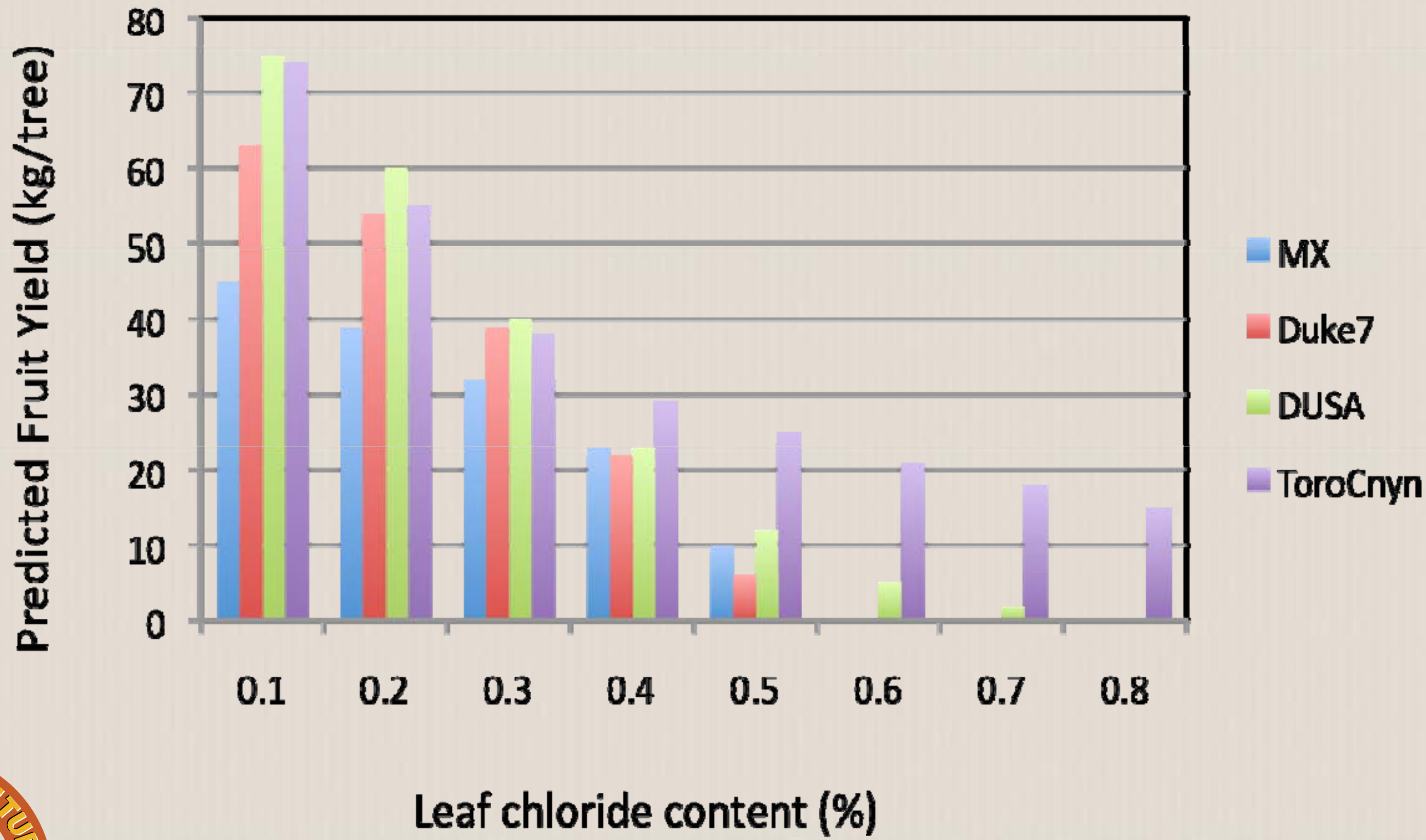
Summary - Application Methods

- Foliar – Not very effective on avocado due to thick waxy cuticle on leaf surface
- Soil - Should be applied only in area wetted by the sprinkler, high cost for labor
- Fertigation – Many advantages, including precise location of fertilizer where roots grow, low cost of application, difficulty applying P unless phosphoric acid is used

Application Amounts

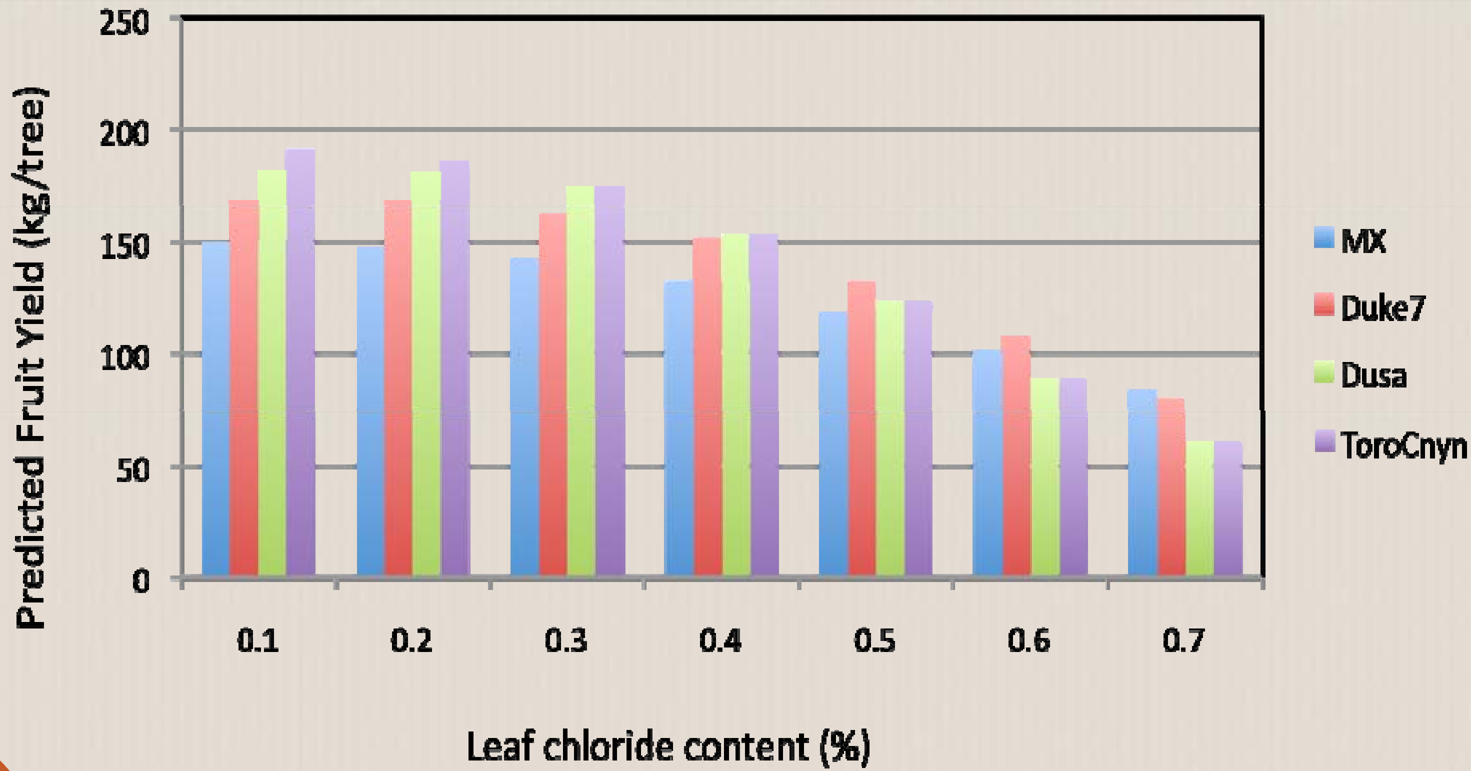
- Use leaf analysis to determine N, P and K
- N should be around 2.2%
- Generally, 1 – 1.5 lbs actual N per tree per year is about right
- If P is higher than 0.14%, do not apply P
- K is applied at 200-300 lbs/acre (K2O), but do not apply if K is higher than 1.2%

Fruit yield as affected by leaf chloride content for Hass avocado grafted on to different rootstocks under "average" nutrient conditions.



Yield values predicted from an artificial neural network model using fixed values for all nutrients except chloride (values fixed at average levels for entire orchard: N 2.4%, P 0.18%, K 1.2%, Ca 1.5%, Mg 0.4%, Na 0.015%, Zn 30 ppm, Fe 84 ppm, B 40 ppm.

Fruit yield as affected by leaf chloride content for Hass avocado grafted on to different rootstocks under “optimal” nutrient conditions.



Predicted fruit yield for trees with foliar nutrient values optimized for maximum yields, while varying leaf tissue chloride content for each rootstock. Optimized nutrient levels were N 1.7%, P 0.26%, K 1.3%, Ca 1.14%, Mg 0.28%, Na 0.015%, Zn 31ppm, Fe 100 ppm, B 40 ppm.

Additions (Gains) of Soil Nitrogen

Source	kg N/ ha / yr Range	Typical
Atmospheric	1-50	10
N2 fixation free living	0.1-50	<10
N2 fixation – legumes	20-600	150
Fertilizer N	0 - ?	180
Manures, waste	0 - ?	variable

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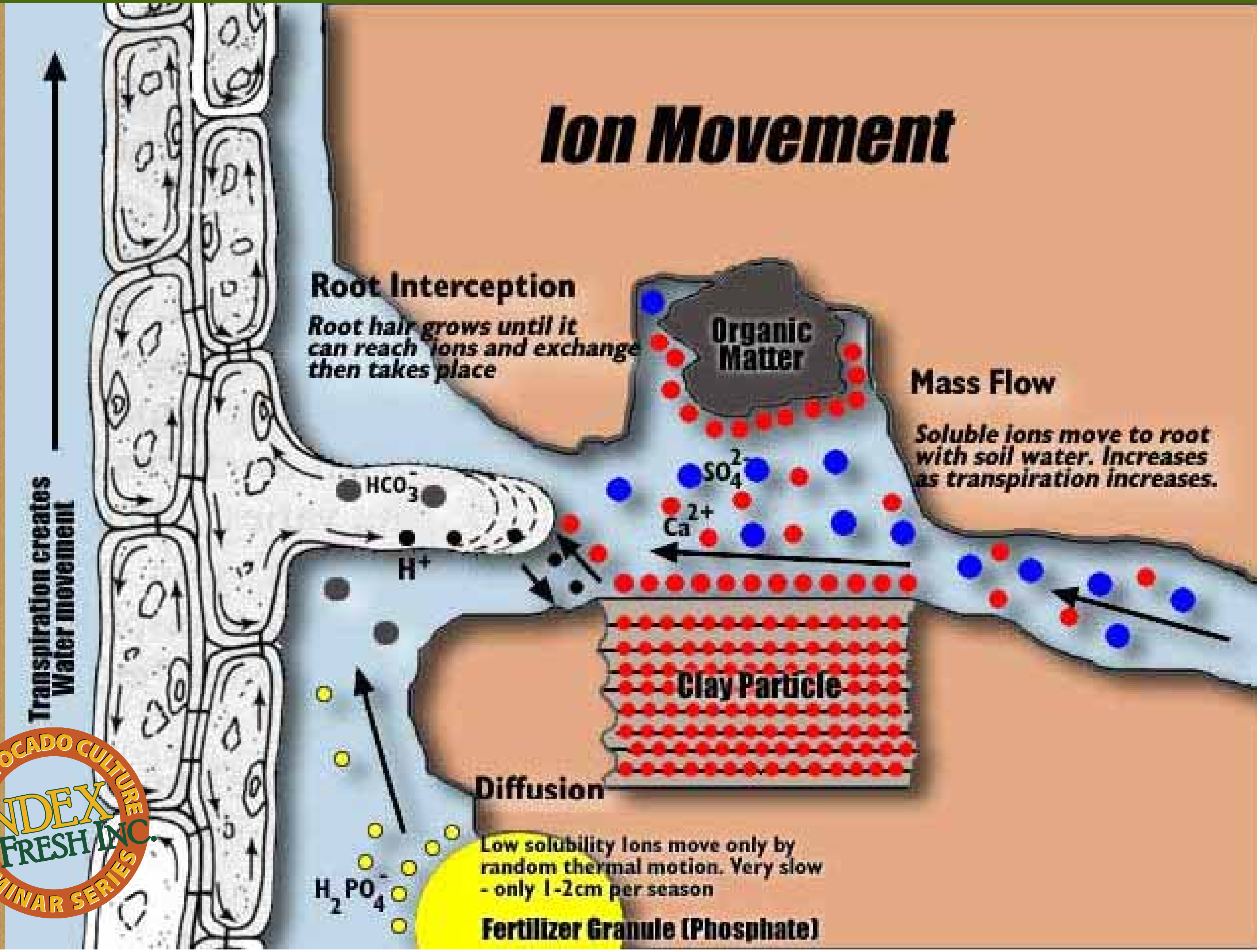


AVOCADO CULTURE INDEX FRESH INC. SEMINAR SERIES

Mulching Avocados

Dr. David Crowley, Professor

318 Science Laboratories I
Phone: (951) 827-3785
david.crowley@ucr.edu

Mulching Avocados

- Mulch is not compost and should be composed of organic material, preferably wood
- Ideally the size should be at least one inch square but any thickness will work and can contain some green waste.
- Don’t use sawdust but with a thicker material, small amounts are OK.
- Avoid weeds and willow or poplar as these root readily from cuttings and will cause a weed problem.

Mulching Avocados

- Apply anytime of the year but do so only to a moist not wet (saturated) soil.
- Apply no thicker than 4 inches, less if there is green waste that will start to compost.
- The compost process generates a lot of heat if the mulch is too thick.
- Apply about 2 feet from outside the drip line into the trunk but be very careful not to get mulch touching the trunk.

Mulching Avocados

- Mulch should last 3-4 years or more so having woody material is important.
- Don’t use inorganic mulches for avocados as the mulch needs to be well aerated and allow air, water and fertilizer to move through readily.
- Mulch can suppress weeds but only if thick enough and usually only temporarily.

Mulching Avocados

- Mulch will conserve soil moisture but is no substitute for irrigation.
- Wet mulch helps to stop fires on the grove.
- Mulch that is composed of chunks of wood and little sawdust will not extract much Nitrogen, sawdust will drawn down Nitrogen dramatically harming the trees.

Mulching Avocados

- Over time mulch will build up the soil organic matter leading to a much better quality soil.
- Always use woody material that is the cheapest, from your own grove first use all tree trimmings, chip up avocado prunings etc.
- Mulch can be from freshly cut up plant material, you don't need to "age" the mulch.

A Comprehensive Guide to Soil and Leaf Analysis

Chad Lessard

Certified Crop Adviser
Director of Agricultural Services / CCA
Fruit Growers Laboratory, Inc.

Sampling Techniques

- **Predictive Sampling**
  - Used to make routine fertilizer and amendment recommendations
  - Soil samples in conjunction with tissue samples are preferable
- **Diagnostic Sampling**
  - Used to characterize and improve problem areas
  - Samples taken from poor growth areas and compared to vigorous growth areas
  - Soil samples will give more insight than tissue

Sampling Methods

- **Soil Sampling**
  - Within uniformly managed blocks
  - Where the feeder roots and the water meet
  - At least 25-30 random cores per block
  - Sample when the soil is dry
  - Try to sample at least 1 month before making major nutrient management decisions
  - With a few exceptions soil chemistry changes very little throughout the year

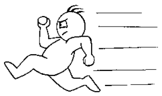
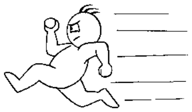
Sampling Methods

- **Tissue Sampling**
  - Timing is Important!
    - Phenologically
    - Hold time from sampling to analysis
  - Within uniformly managed blocks
  - The most recently matured leaf
  - Necessary leaf quantity differs among crops but a good rule of thumb for every crop is…

Actually a rule of hand

Capturing the Elusive Recently Matured Leaf

- **Why?**

Sample Area	% Nitrogen	% Phosphorus	% Potassium
SA-121Y	2.64	0.344	1.74
SA-121RM	2.25	0.158	1.08
SA-121O	1.66	0.128	1.17
Optimum Range - Average	2.20 - 2.40	0.0800 - 0.440	1.00 - 3.00

% Calcium	% Magnesium	ppm Zinc	ppm Manganese
0.412	0.177	43.4	20
1.49	0.441	22.8	32
2.07	0.527	16.0	41
1.00 - 4.50	0.250 - 1.00	30.0 - 250	30 - 700

Plant Tissue Analysis

- **Constituents**
  - **Most commonly deficient plant essential nutrients**
    - **Nitrogen**
    - **Phosphorus**
    - **Potassium**
    - **Calcium**
    - **Magnesium**
    - **Zinc**
    - **Manganese**
    - **Iron**
    - **Copper**
    - **Boron**
    - **Sulfur**
  - **Uncommonly deficient plant essential nutrients**
    - **Molybdenum**
    - **Nickel**
    - **Cobalt**
    - **Chloride (regularly analyzed to monitor toxicities)**

Nutrients and Avocados

Element	Role	Deficiency Symptom
Nitrogen	Vegetative Growth	Chlorotic older leaves

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Nutrients and Avocados

Element	Role	Deficiency Symptom
Nitrogen	Vegetative Growth	Chlorotic older leaves
Phosphorus	Energy transfer / Root growth	Purple tint to leaf / Difficult to see

Nutrients and Avocados

Element	Roles	Leaf Deficiency Symptoms
Nitrogen	Vegetative Growth	Chlorotic older leaves
Phosphorus	Energy transfer / Root growth	Purple tint to leaf / Difficult to see
Potassium	Regulates water / Fruit quality	Intraveinal and marginal chlorotic older leaves

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Nutrients and Avocados

Element	Role	Deficiency Symptom
Nitrogen	**Vegetative Growth**	**Chlorotic older leaves**
Phosphorus	**Energy transfer / Root growth**	**Purple tint to leaf / Difficult to see**
Potassium	**Regulate water / Fruit quality**	**Intraveinal and marginal chlorotic older leaves**
Calcium	**Cell structure / Fruit set**	**Spotted Necrotic younger leaves**

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Nutrients and Avocados

Element	Role	Deficiency Symptom
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Phosphorus	Energy transfer / Root growth	Purple tint to leaf / Difficult to see
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Calcium	Cell structure / Fruit set	Spotted Necrotic younger leaves
Magnesium	Base molecule of chlorophyll	Intraveinal chlorosis of younger leaves


- Mg

Nutrients and Avocados

Element	Role	Deficiency Symptom
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Potassium	Regulate water / Fruit quality	Intraveinal and marginal chlorotic older leaves
Calcium	Cell structure / Fruit set	Spotted Necrotic younger leaves
Magnesium	Base molecule of chlorophyll	Intraveinal chlorosis of younger leaves
Sulfur	Chlorophyll synthesis	Uniform chlorotic plants with spindly stems


-S

Nutrients and Avocados

Element	Role	Deficiency Symptom
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Magnesium	Base molecule of chlorophyll	Intraveinal chlorosis of younger leaves
Sulfur	Chlorophyll synthesis	Uniform chlorotic plants with spindly stems
Iron	Photosynthetic reduction processes	Intraveinal chlorosis of younger leaves / white leaves

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Nutrients and Avocados

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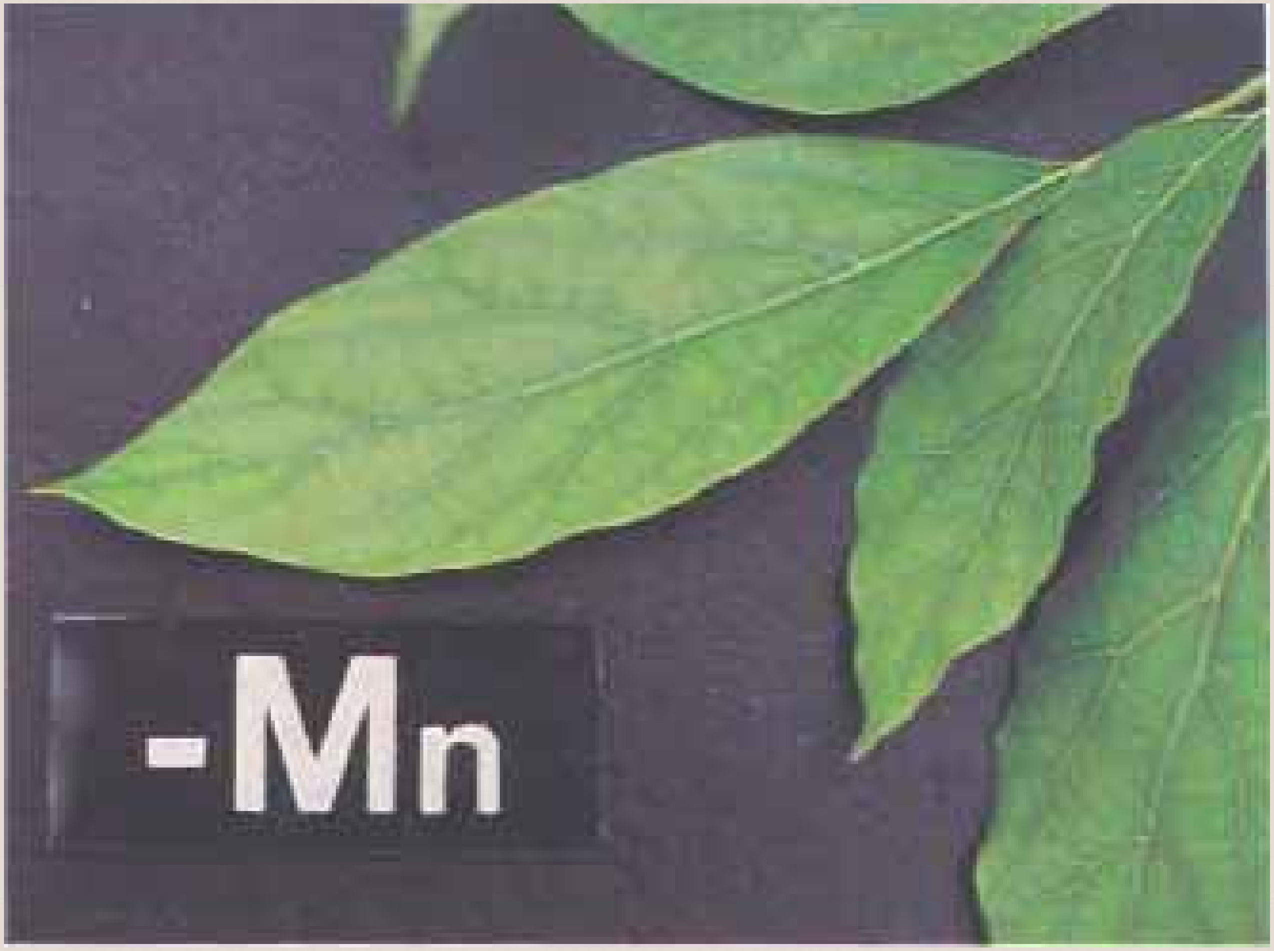
Iron	Photosynthetic reduction processes	Intraveinal chlorosis of younger leaves / white leaves
Manganese	Evolution of oxygen	Intraveinal chlorosis of younger leaves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Nutrients and Avocados

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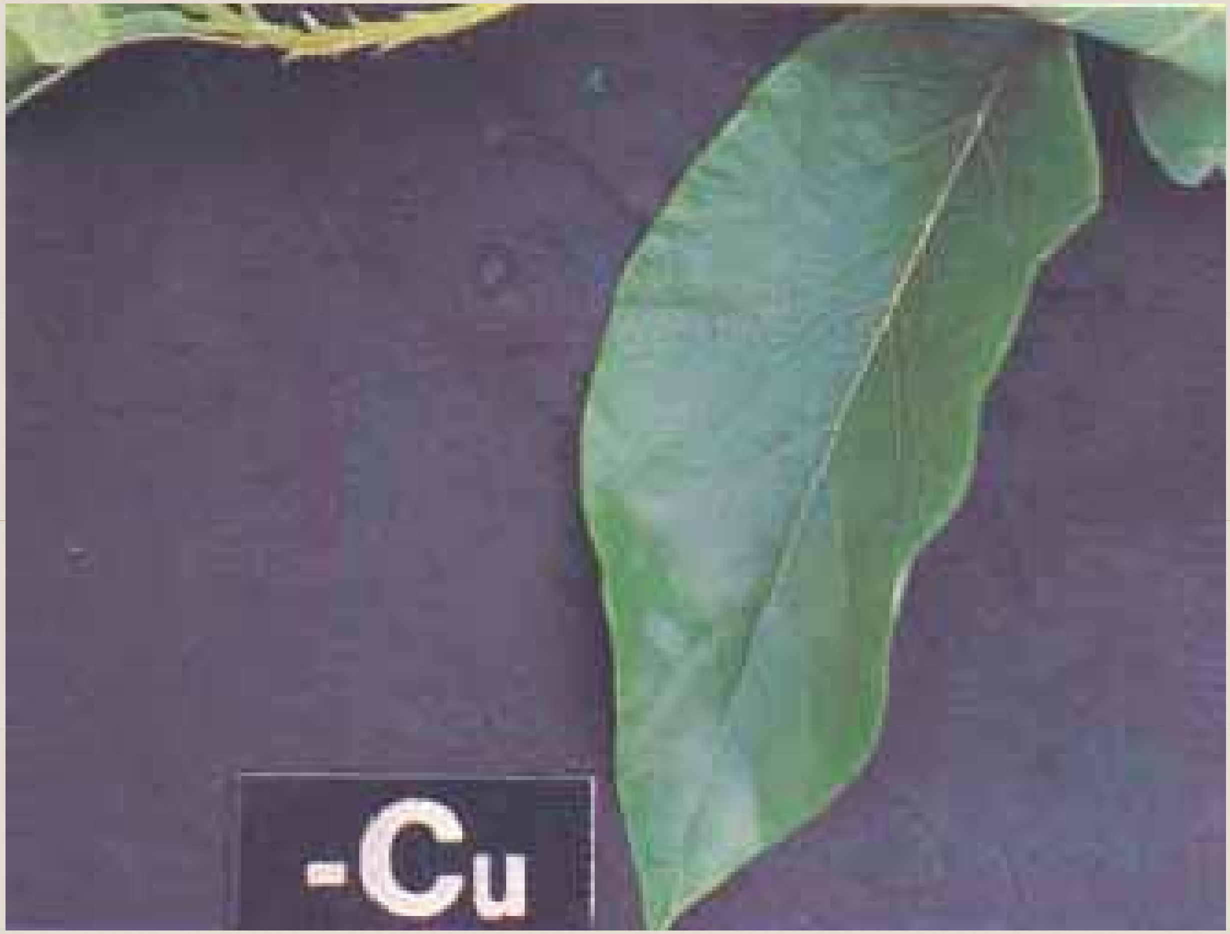
Magnesium	Base molecule of chlorophyll	Intraveinal chlorosis of younger leaves
Sulfur	Chlorophyll synthesis	Uniform chlorotic plants with spindly stems
Iron	Photosynthetic reduction processes	Intraveinal chlorosis of younger leaves / white leaves
Manganese	Evolution of oxygen	Intraveinal chlorosis of younger leaves
Copper	Unique enzyme production	Varies with crop but typical die-back of terminal growth


-Cu

Nutrients and Avocados

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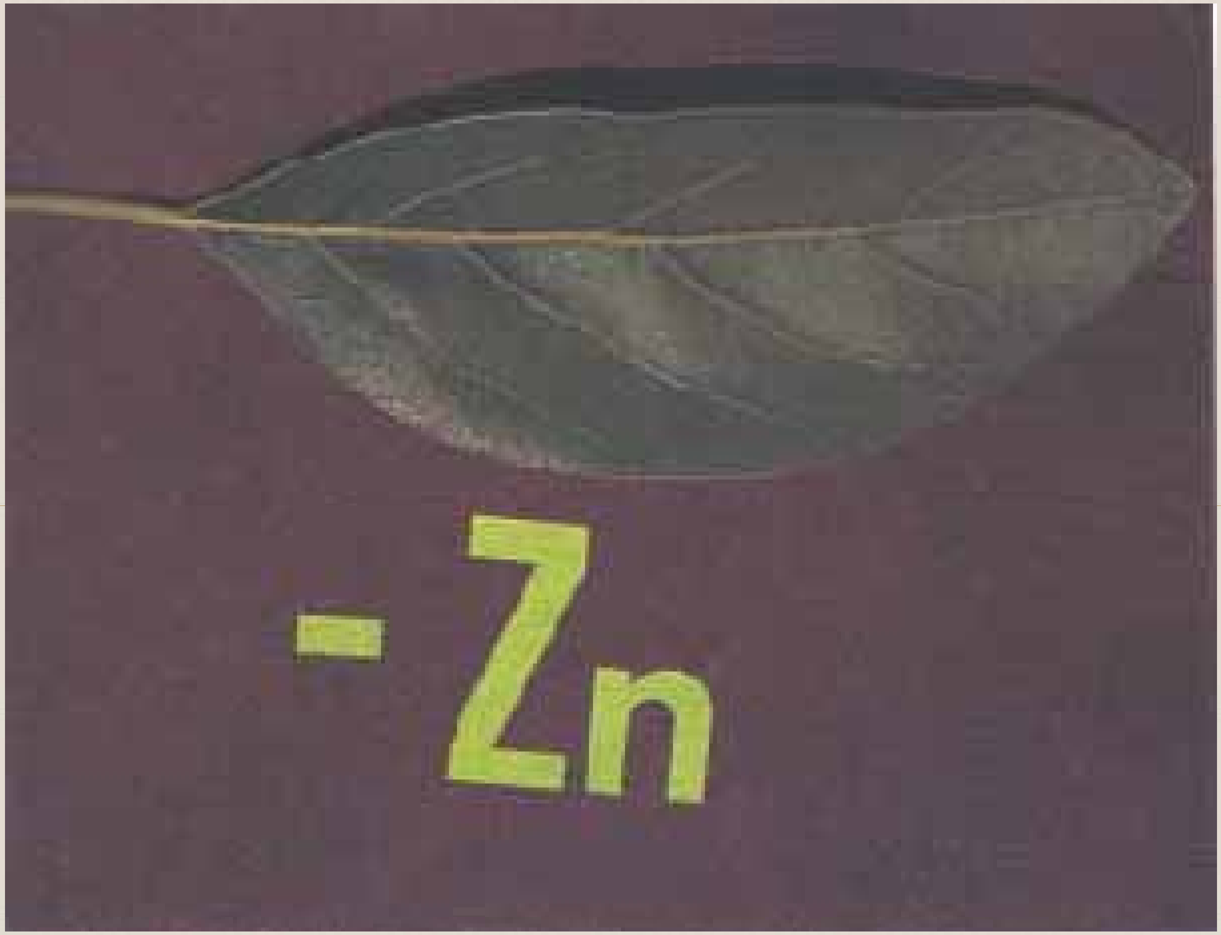
Manganese	Evolution of oxygen	Intraveinal chlorosis of younger leaves
Copper	Unique enzyme production	Varies with crop but typical die-back of terminal growth
Zinc	Production of growth hormones	Mottled young leaves / bushy rosetted leaves


- Zn

Nutrients and Avocados

Element	Role	Deficiency Symptoms
Nitrogen	Vegetative Growth	Chlorotic older leaves
Phosphorus	Energy transfer / Root growth	Purple tint to leaf / Difficult to see
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Zinc	Production of growth hormones	Mottled young leaves / bushy rosetted leaves
Chloride	Reducing your avocado yields	Tip Burn

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Soil Analysis

- **Constituents**
  - Primary Nutrients and Macronutrients
    - N, P, K, Ca, Mg, S
  - Exchangeable and Soluble portions of cations
  - Secondary Nutrients and Micronutrients
    - Fe, Zn, Mn, Cu, B, Cl, and sometimes Mo
  - Other chemical properties
    - pH, cation exchange capacity, soil salinity, limestone and sodium

HASS SOIL ANALYSIS

Test Description	Result	Units	Optimum Range	Graphical Results Presentation				
				Very Low	Moderately Low	Optimum	Moderately High	Very High
Primary Nutrients								
Nitrate-Nitrogen	20.8	Lbs/AF	76 - 120					
Phosphorus-P_2O_5	55	Lbs/AF	180 - 310					
Potassium-K_2O (Exch)	879	Lbs/AF	570 - 3800					
Potassium-K_2O (Sol)	27.3	Lbs/AF	140 - 520	1%				
Secondary Nutrients								
Calcium (Exch)	21900	Lbs/AF	16000 - 22000					
Calcium (Sol)	458	Lbs/AF	260 - 740			54%		
Magnesium (Exch)	2740	Lbs/AF	1600 - 3300					
Magnesium (Sol)	124	Lbs/AF	120 - 260			24%		
Sodium (Exch)	270	Lbs/AF	0.0 - 1600					
Sodium (Sol)	194	Lbs/AF	0.0 - 1200			20%		
Sulfate	227	Lbs/AF	230 - 4000					
Micro Nutrients								
Zinc	21.6	Lbs/AF	6.8 - 180					
Manganese	28.8	Lbs/AF	11 - 260					
Iron	22.4	Lbs/AF	68 - 240					
Copper	3.20	Lbs/AF	2.0 - 45					
Boron	0.760	Lbs/AF	1.6 - 8.8					
Chloride	56.7	Lbs/AF	27 - 670					
CEC	33.7	meq/100g	14 - 35					
% Base Saturation								
CEC - Calcium	81.0	%	60 - 80					
CEC - Magnesium	16.7	%	10 - 20					
CEC - Potassium	1.39	%	0.90 - 6.0					
CEC - Sodium	0.858	%	0.0 - 5.0					
CEC - Hydrogen	0.00	%	0.0 - 3.0					
				Strongly Acidic	Moderately Acidic	Near Neutral	Moderately Alkaline	Strongly Alkaline
pH	7.82	---	6.0 - 7.5					

HASS SOIL ANALYSIS

Test Description	Result	Units	Optimum Range	Graphical Results Presentation				
				Very Low	Moderately Low	Optimum	Moderately High	Very High
Primary Nutrients								
Nitrate-Nitrogen	11.6	Lbs/AF	40 - 80					
Phosphorus-P_2O_5	64	Lbs/AF	140 - 280					
Potassium-K_2O (Exch)	685	Lbs/AF	700 - 4700					
Potassium-K_2O (Sol)	11.2	Lbs/AF	94 - 470	0%				

Common Nitrogen Questions

Q. Why is nitrate-nitrogen only analyzed in the soil and not ammonium and/or total nitrogen?

A. Under conditions favoring plant growth, most forms of soil nitrogen are rapidly converted to nitrate.

$$2\ NH4+ + 3\ O2 \rightarrow 2\ NO3- + 2\ H20 + 4H+$$

Q. Why is the nitrate bar blue?

A. The blue bar indicates there really is no “optimum range.” Soil nitrate requirements are primarily dependant on the growth stage of your crop and soil temperature.

Nitrogen Management

- **Nitrogen uptake efficiency during critical stages**
  - **25% when applied to the soil in a single annual application**
  - **50 – 60% when applied to the soil in 3 to 4 increments**
  - **90% when applied to citrus foliage in increments**
    - **However, the total nitrogen requirements of citrus can not be met without leaf damage**
    - **Only about half of the total nitrogen requirements can be met foliarly**
    - **None of the nitrogen requirements for avocados may be met foliarly**

HASS SOIL ANALYSIS

Test Description	Result	Units	Optimum Range	Graphical Results Presentation				
				Very Low	Moderately Low	Optimum	Moderately High	Very High
Primary Nutrients								
Nitrate-Nitrogen	11.6	Lbs/AF	40 - 80					
Phosphorus-P_2O_5	64	Lbs/AF	140 - 280					
Potassium-K_2O (Exch)	685	Lbs/AF	700 - 4700					
Potassium-K_2O (Sol)	11.2	Lbs/AF	94 - 470	0%				

Common Phosphorus Questions

Q. Why is phosphorus reported as P2O5?

A. Phosphorus fertilizer is sold as P2O5 equivalent
To convert from P2O5 to P multiply by 0.44

Q. Why are there two different methods for soil P analysis?

A. Depending on the pH, phosphorus exists as two different ions so there are two different extraction solutions to mimic actual P available to your crop.

Phosphorus Management

- **Different precipitates of P**
  - **Important to monitor pH for P**

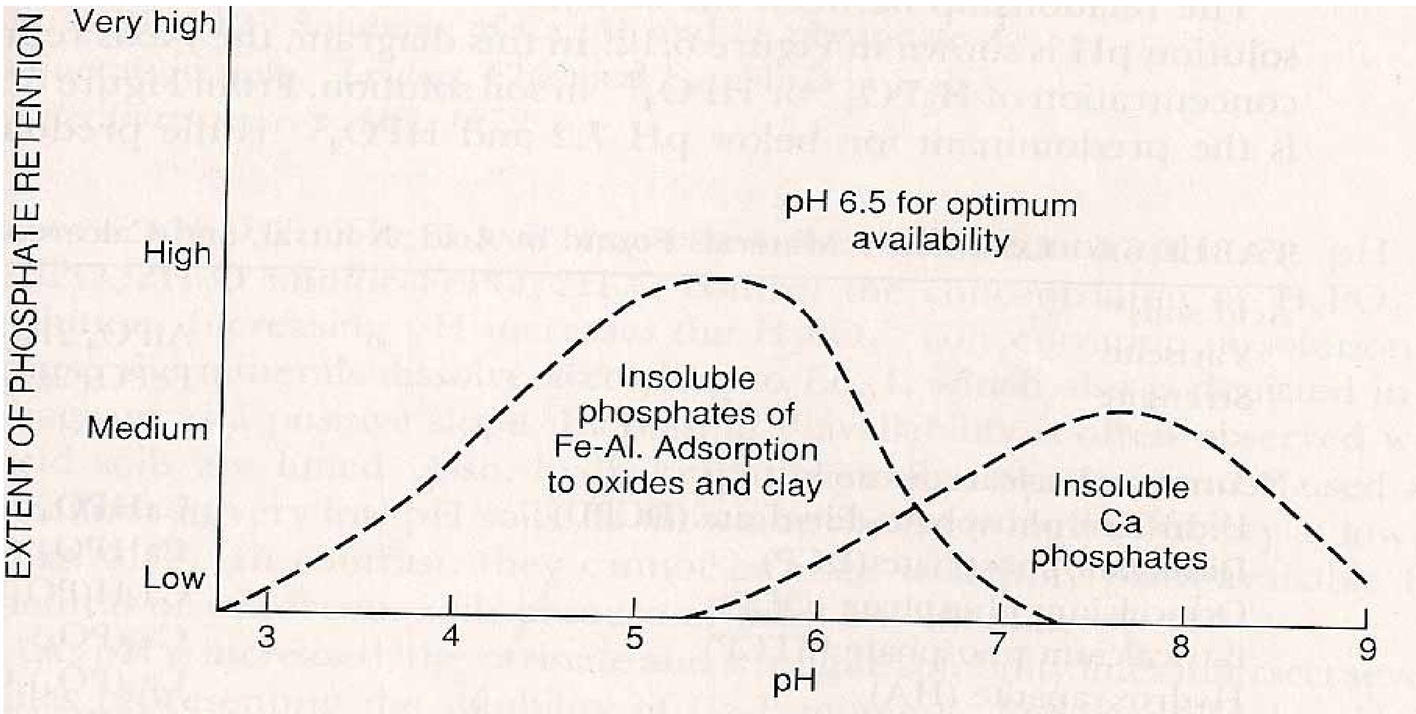


FIGURE 6.11 Soil pH effect on P adsorption and precipitation. *Adapted from*

Phosphorus Management

- Fertilization management
  - High soluble Ca, Fe, and Al form insoluble phosphorus precipitates
    - So don't apply P with these types of fertilizers
  - High carbon to phosphorus ratio can immobilize P
  - Phosphorus is not very mobile in the soil
    - Use water soluble forms of P fertilizer and an acid mix to help keep the P in solution

HASS SOIL ANALYSIS

Test Description	Result	Units	Optimum Range	Graphical Results Presentation				
				Very Low	Moderately Low	Optimum	Moderately High	Very High
Primary Nutrients								
Nitrate-Nitrogen	11.6	Lbs/AF	40 - 80					
Phosphorus-P_2O_5	64	Lbs/AF	140 - 280					
Potassium-K_2O (Exch)	685	Lbs/AF	700 - 4700					
Potassium-K_2O (Sol)	11.2	Lbs/AF	94 - 470	0%				

Common Potassium Questions

Q. Why are there two different potassium results?

A. Potassium is measured in two ways.

1. Exchangeable (Exch)

The exchangeable portion is the potassium available as a reserve in your soil. This moves into solution as the soluble K is taken up.

2. Soluble (Sol)

The soluble portion is the potassium most readily available.

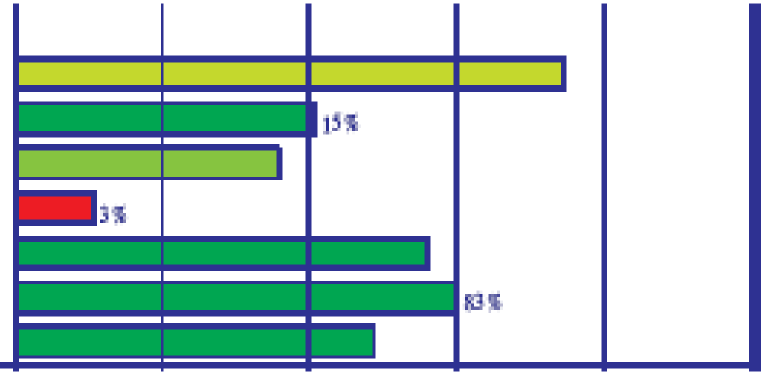
Potassium Management

- Potassium in the soil is mostly available by mass flow…so…
  - Leaching is possible
    - Coarse, sandy, and soils in areas of high rainfall
  - Citrus can use soil or foliar applied K
    - If foliar application use KNO_3
  - Avocados can't absorb foliar applications thus, water soluble forms of K should be applied to the soil
    - Potassium thiosulfate appears to be the most available source

Potassium Management

- **Potassium and crop yields**
  - Most directly related nutrient to high crop yield
  - High N and P increases yields but also increases the total demand for K to support that yield
  - K released from the exchangeable sites in the soil is often too slow to supply ample amounts in a high yield system

Secondary Nutrients			
Calcium (Exch)	15200	Lbs/AF	10400 - 13900
Calcium (Sol)	176	Lbs/AF	160 - 641
Magnesium (Exch)	870	Lbs/AF	1050 - 2110
Magnesium (Sol)	19	Lbs/AF	73 - 219
Sodium (Exch)	750	Lbs/AF	0 - 1000
Sodium (Sol)	1150	Lbs/AF	0 - 628
Sulfate	1840	Lbs/AF	190 - 4030



Calcium, Magnesium Sodium & Sulfur

Q. Why are these nutrients considered secondary?

A. This just means they are not needed in as large of of quantities as the primary nutrients

-Although, secondary nutrient deficiencies can depress plant growth just as much as primary nutrient deficiencies.

-At times some plants can even require more S and Ca than P. Avocado crop removal rates show this to be true.

Calcium Management

- **Calcium is rarely deficient in our soils**

  Low rainfall = high calcium = rare deficiencies
  - In our area calcium toxicity is more likely than calcium deficiency:
    - – Limestone induced chlorosis
    - – High pH due to lime and deficiencies in phosphorus and some micronutrients
    - – Managing high calcium soils
      - » pH change is extremely difficult
      - » Plant selection (avoid limestone sensitive rootstocks)

Magnesium Management

- **Magnesium uptake is greatly influenced by potassium and calcium so watch ratios to prevent deficiencies**
  - –Base saturation is a good indicator of correct nutrient ratios in the soil
  - –K to Mg ratio
    - For field crops: anything less than 5:1
    - For vegetables: about 3:1
    - For fruit trees: about 2:1
  - –Ca to Mg ratio
    - Should not exceed 15:1 for any crop
    - Apply foliar magnesium nitrate to citrus for deficiencies
      - –For avocados use magnesium sulfate applied to the soil

Sodium Management

- **Sodium is not generally a plant essential nutrient but is still reported…why?**
  - It's necessary to calculate the cation exchange capacity (CEC)
  - Most importantly, high sodium can cause soil structural problems
    - Na has a large hydrated radius…larger than K, Ca and Mg
      - This causes dispersion in the soil
      - Breaks up soil aggregation
      - Causes a massive structure
      - Poor water infiltration

Sodium Management

- **What can I do about my high sodium soil?**
  - If you have sufficient calcium in the soil
    - Leach with plenty of low sodium water at an acidic pH (sulfuric acid) to flush the sodium and let calcium replace it on the CEC
  - If no high soil calcium ***then*** Gypsum, Gypsum, Gypsum
    - Leach with plenty of low sodium water

				Strongly Acidic	Moderately Acidic	Near Neutral	Moderately Alkaline	Strongly Alkaline
CEC	34.0	meq/100g	8.0 - 35					
% Base Saturation								
CEC - Calcium	78.8	%	60 - 80					
CEC - Magnesium	14.5	%	10 - 20					
CEC - Potassium	4.82	%	2.0 - 5.0					
CEC - Sodium	1.90	%	0.0 - 5.0					
CEC - Hydrogen	0.00	%	0.0 - 3.0					
pH	7.51	---	6.0 - 7.5					

Cation Exchange Capacity, pH, % Base Saturation, and the Lyotropic Series

The "Easy" Definitions:

- **Cation Exchange Capacity – The total amount of cations a soil can hold on its negatively charged particles (the clay and humus).**

- **pH – A measurement estimating the "active" hydrogen ions**

- **Percent Base Saturation – The percent of a certain cation that is held on the CEC in comparison to others**

- **Lyotropic Series – The order in which cations will bond with the negative charges in your soil $Al^{3+} > Ca^{2+} > Mg^{2+} > K^{+} = NH_4^{+} > Na^{+}$**

INDEX FRESH INC.™ SEMINAR SERIES

How to use your tissue analysis report with your soils report

A frequently asked question:

Q. Why does my soil report show ample nutrient levels and my leaf tissue report shows deficiencies?

A. Because plants are not always capable of taking up the necessary amounts of nutrients to support their rate of growth and yield.

Avocado and Citrus Crop Removal

Nutrient Removal in lbs/acre	800 boxes Of Oranges	1000 boxes of Lemons	7000 lbs/acre of Avocados
Nitrogen	64	75	23
Phosphorus	8	9	2
Potassium	66	80	35
Sulfur	1.6	3.2	3.6
Calcium	20	30	1
Magnesium	4.2	5	1.5
Zinc	0.03	0.12	0.02
Manganese	0.02	0.05	0.01
Iron	0.13	0.12	0.4
Copper	0.02	0.05	0.01
Boron	0.1	0.14	0.05
Chloride	0.02	0.02	0.01

**Generally crop removal x 1.5 = fertilizer requirements*

Questions?

For more info:

Chad Lessard

www.fglinc.com

chadle@fglinc.com

Fruit Growers Laboratory, Inc.