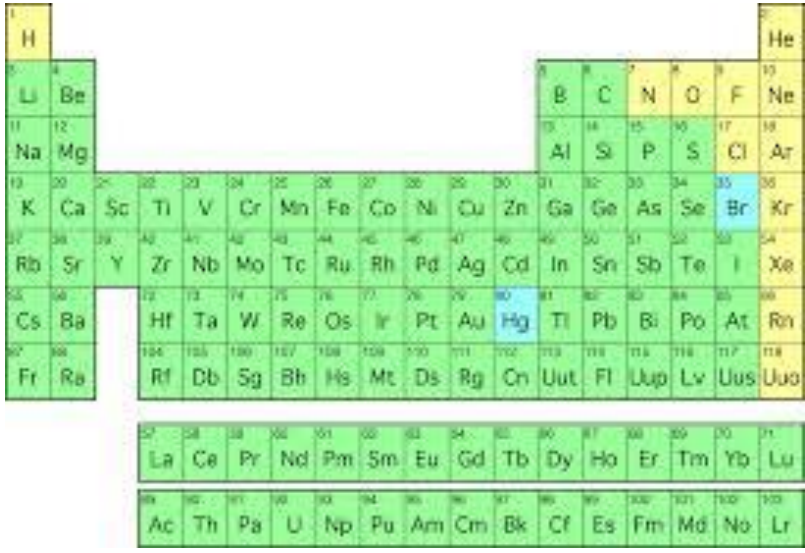
INTERPRETING SOIL & LEAF ANALYSIS

Nutrient use in Tree Fruit

- 94% of plant dry weight is carbohydrates (C, H, O)
  - Primary sugars are sorbitol, fructose, sucrose and starch
- 6% is minerals

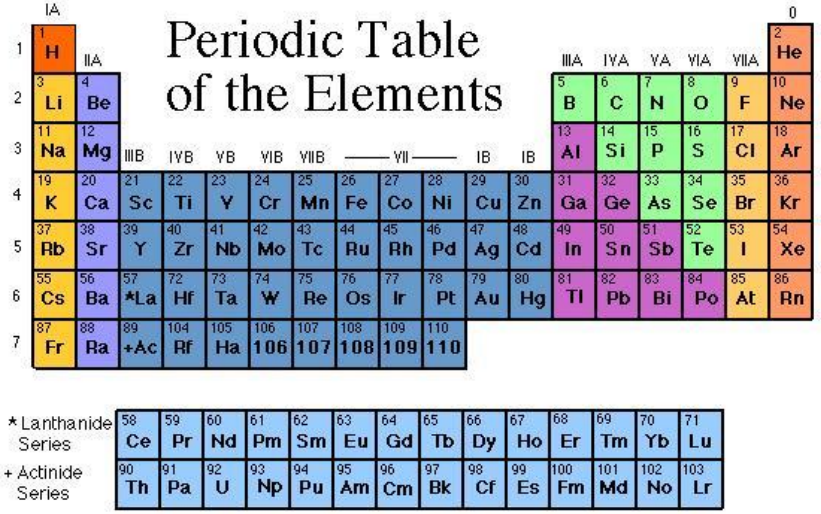


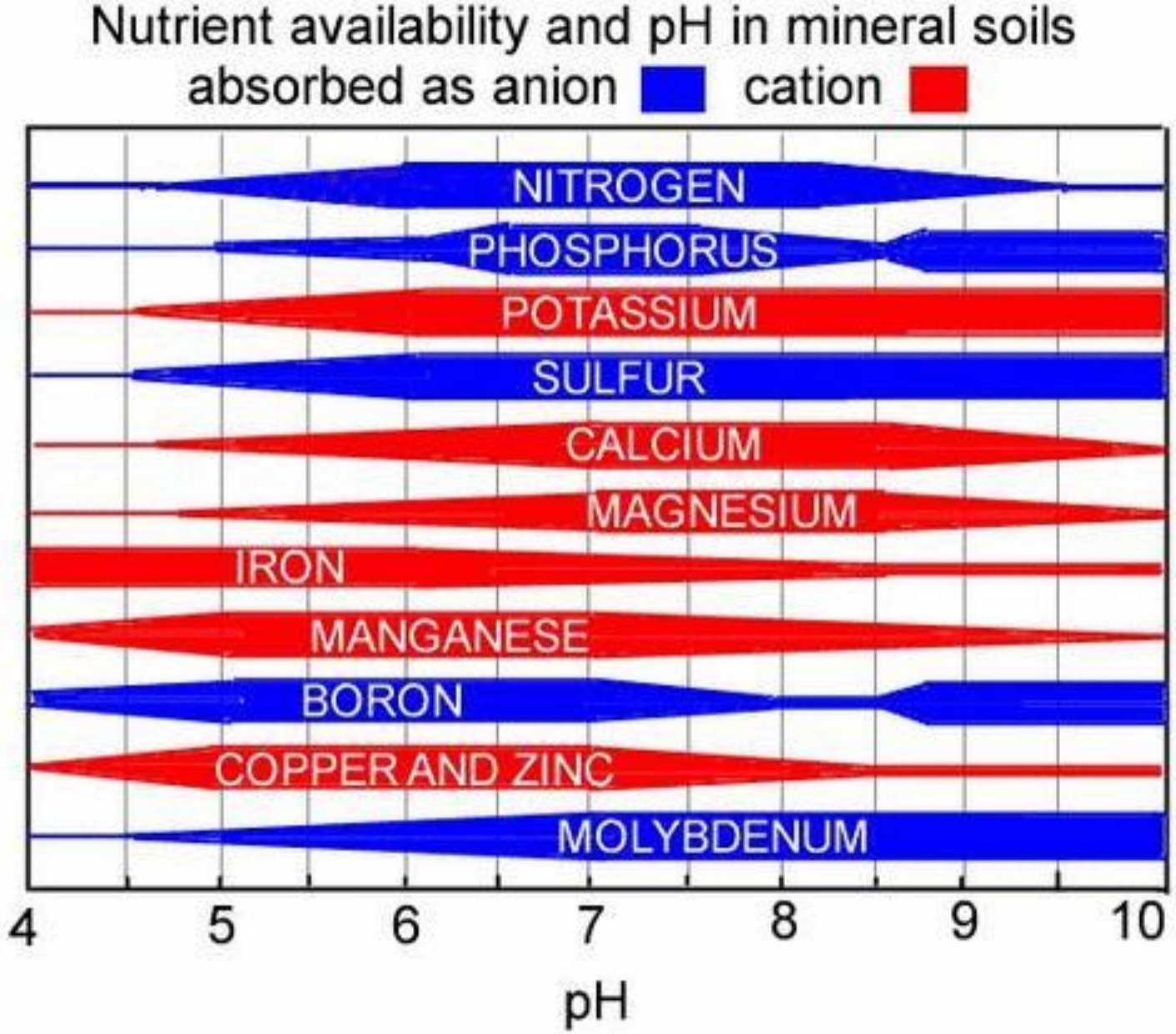
Essential Elements

- C HOPKNS CaFe Mg Cl MoB CuMnZn
- Se, Ni, Co, Si, Na
- Non-mineral – C, H, O
- Macronutrients – N, P, K, Ca, Mg, S
- Micronutrients – Fe, Cl, Mo, B, Cu, Mn, Zn

Elements to Manage

- Nitrogen
- Phosphorus
- Potassium
- Magnesium (?)
- Boron
- Calcium




Nutrient availability and pH in mineral soils
absorbed as anion
cation
NITROGEN
PHOSPHORUS
POTASSIUM
SULFUR
CALCIUM
MAGNESIUM
IRON
MANGANESE
BORON
COPPER AND ZINC
MOLYBDENUM
4
5
6
7
8
9
10
pH

Mineral Uptake

- Roots are primary organs of uptake
- Elements taken up in the form of ions
  - Fe^{++}, NO_3^-, NH_4^+, B^+, Ca^{++}
  - Organic vs. Synthetic
- Uptake has passive and active components
- Occurs throughout the year
  - Although majority occurs early spring and late fall

Nutrient Uptake Pathways

1. Root interception: Ca, (Zn)
2. Mass flow of water: N, Ca, Mg, S, B, (K), (Zn)
3. Diffusion: P, K, (Zn)

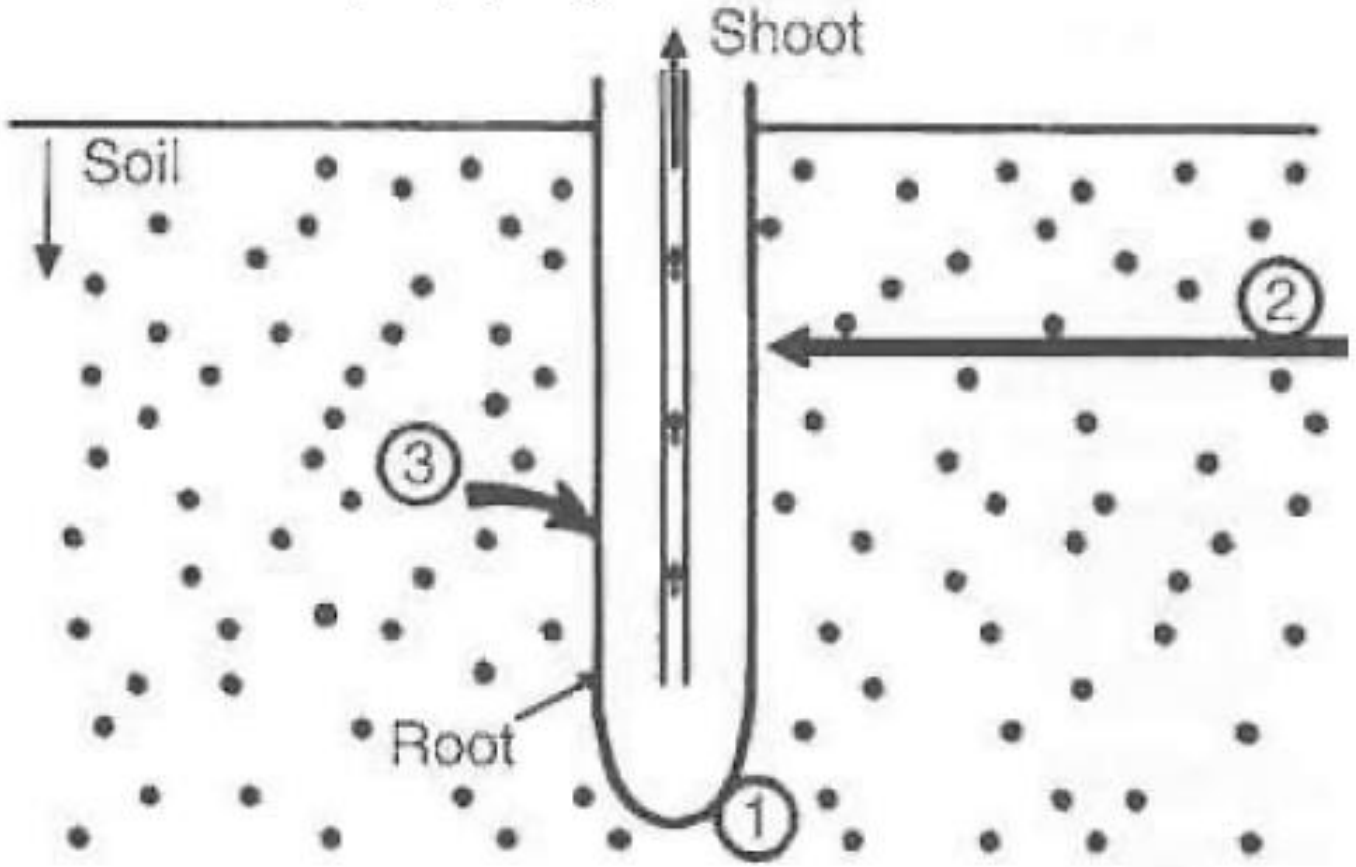


Image courtesy P. Andrews, WSU

Tree Fruit Root Distribution

- Not uniform (even less so in nonuniform soil)
- Most apple roots within 30” of surface
  - 70% within 12 inches of surface
- Most peach roots within 24” of surface
  - Majority within 10 inches of surface

Estimated Lb./A Removed under Traditional Plantings

Apples				
Yield	N	P_2O_5	K_2O	Mg
~600 bu	20	8	50	2
Leaves, Stems	80	38	130	22
Total	100	46	180	24
Peaches				
Yield	N	P_2O_5	K_2O	Mg
600 BU	35	10	65	12
Leaves, Stems	60	30	55	10
Total	95	40	120	32

Nutrients Lost Due to Crop

Lb/A Removed with Fruit					
Yield					
bu/A	N	P	K	Ca	Mg
1870	31.6	7.2	81.2	4.2	3.7
1318	21.3	5.3	61.6	3.0	2.7
1530	25.7	6.3	79.5	4.1	3.7
1211	32.3	6.3	71.4	3.3	3.2
1488	27.8	6.3	74.1	3.7	3.3

Palmer & Dryden, 2006

Nutrient Recycling - Nitrogen

- N @ 23-50% is reabsorbed before leaf abscission
  - (Titus & Kang, 1982)
- N migrates back to spurs & branches, later to roots
- N is stored in proteins high in arginine & asparagine
- Proteins are hydrolyzed in spring to support growth

Nitrogen Recycling

- Foliar application of radioactive isotope of N in the fall
  - 48% of N was withdrawn from leaves
    - 95% remained in the branch
      - 65% found in dormant bark
      - 29% in wood
      - 6% in flower buds
  - Next spring
    - 46% was remobilized for flower bud growth

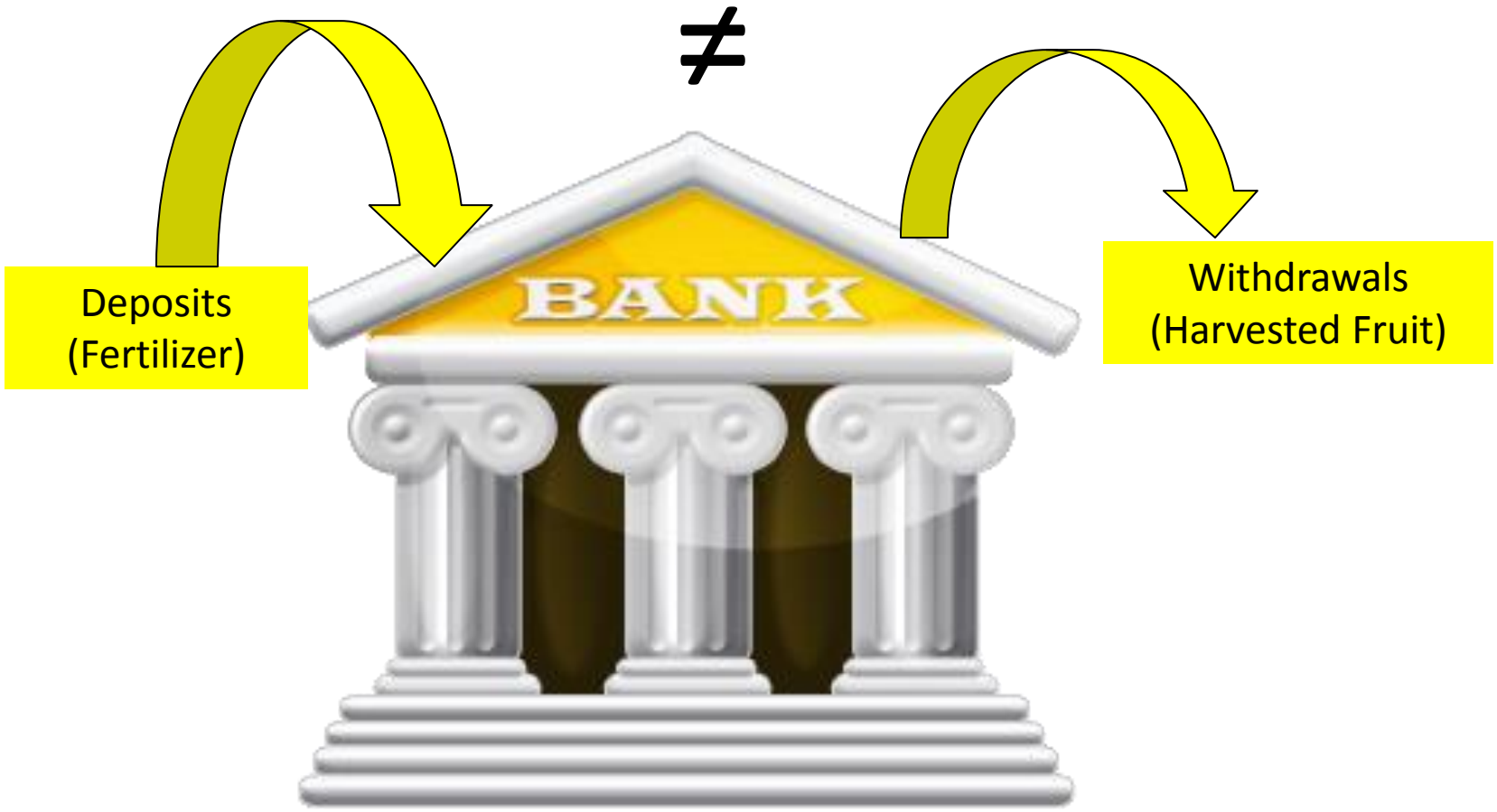
Gauk et al. 2004 Can. J. Plant Sci. 84:259

Soil Analysis
vs.
Leaf Analysis

Annual versus Perennial

What is available versus What is taken up

What is the Difference?



Returns

Leaf litter
Pruning wood

When is a Soil Test Appropriate?

- Pre-plant – ALWAYS !
- Every 3 years to primarily look at soil pH
- Validate explain leaf results
- Shows the reservoir

Tests Used

- pH: 1:1 soil : water
- P, K, Mg Ca : Mehlich 3 Extractant
- Acidity: SMP Buffer pH
- Cation Exchange Capacity (CEC)
  - Summation of cations
  - H, K, Mg, Ca

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(814) 863-0841 Fax (814) 863-4540

Agricultural Analytical Services Laboratory
The Pennsylvania State University
University Park PA 16802

SOIL TEST REPORT FOR:	ADDITIONAL COPY TO:
JOHN JONES HARMONY LANE SMITHVILLE PA 11111	SAM COOK HILLTOP ENTERPRISES SMITHVILLE PA 11111

DATE	LAB #	SERIAL #	COUNTY	ACRES	FIELD ID	SOIL
02/20/2001	S00-00003	0044599			For-224	

SOIL NUTRIENT LEVELS				Below Optimum	Optimum	Above Optimum
Soil pH		6.1				
Phosphate	(P_2O_5)	101	lb/A			
Potash	(K_2O)	53	lb/A			
Magnesium	(MgO)	186	lb/A			
Calcium	(CaO)	2502	lb/A			

RECOMMENDATIONS FOR: ***Apples-Maintain***

Limestone: 3000 lb/A

Magnesium (Mg): NONE

Phosphate (P_2O_5): 150 lb/A

Potash (K_2O): 150 lb/A

MESSAGES

Nitrogen should be applied based on leaf analysis and shoot growth. In absence of a current season's leaf analysis, shoot growth on bearing trees should be 12 to 18 inches. Another general guideline is to apply 0.02 lb of actual N per tree per year of tree age. If following this guideline, do not exceed 0.30 lb of actual N per tree per year.

If terminal growth was excessive, fruit color was inadequate or major renovative pruning was performed, a reduction in the rate of N application is in order.

Optimum pH for tree fruits is 6.0 - 6.5. Although the sample pH is equal to or above the minimum value of 6.0, lime is recommended to maintain soil above the minimum pH over the next 3 years.

LABORATORY RESULTS:										Optional Tests:		
[1]pH	[2]P lb/A	Exchangeable Cations (meq/100g)					% Saturation of the CEC			Organic Matter %	Nitrate-N ppm	Soluble salts mmhos/cm
		[3]Acidity	[2]K	[2]Mg	[2]Ca	[4]CEC	K	Mg	Ca			
6.1	44	3.9	0.1	0.5	4.5	8.9	0.6	5.2	50.5	3.8		

Test Methods: [1]1:1 soil:water pH, [2]Mehlich 3 Extractant, [3]SMP Buffer pH, [4]Summation of Cations

Tree Fruit-1

Part 1 -

SOIL NUTRIENT LEVELS				Below Optimum	Optimum	Above Optimum
Soil pH		6.1				
Phosphate	(P_2O_5)	101	lb/A			
Potash	(K_2O)	53	lb/A			
Magnesium	(MgO)	186	lb/A			
Calcium	(CaO)	2502	lb/A			

Part 2 - Recommendations

RECOMMENDATIONS FOR: *Apples-Maintain*	
Limestone:	3000 lb/A
Magnesium (Mg):	NONE
Phosphate (P_2O_5):	150 lb/A
Potash (K_2O):	150 lb/A

MESSAGES

Part 3 – Lab Results

LABORATORY RESULTS:										Optional Tests:		
[1]pH	[2]P lb/A	Exchangeable Cations (meq/100g)					% Saturation of the CEC			Organic Matter %	Nitrate-N ppm	Soluble salts mmhos/cm
		[3]Acidity	[2]K	[2]Mg	[2]Ca	[4]CEC	K	Mg	Ca			
6.1	44	3.9	0.1	0.5	4.5	8.9	0.6	5.2	50.5	3.8		
Test Methods: [1]1:1 soil:water pH, [2]Mehlich 3 Extractant, [3]SMP Buffer pH, [4]Summation of Cations												

Determines the amount of lime to add

Based on a pH goal of 6.5

Lime recommendation

- Look at the bottom table of Exchangeable cations
- Based on the acidity in meq/100 g
- The lower the acidity value is the less lime is needed
- Goal is to raise pH to 6.5

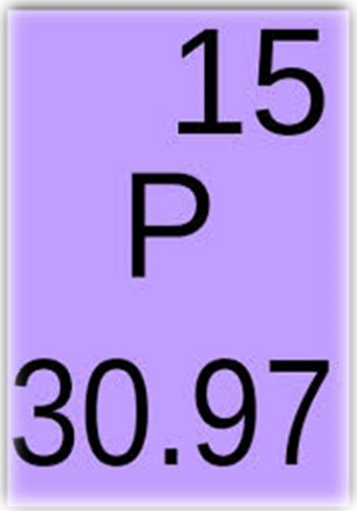
Phosphorus and Potassium

- Rates vary by:
  - Crop
  - Established or “To Plant”

Phosphorus Recommendations

Apples to Plant

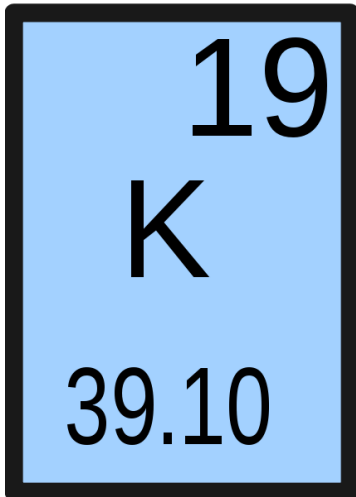
- Lbs. P_2O_5/A ÷ 4.6 = ppm P
  - Optimum soil test of 50 – 100 ppm P
  - 0 – 10 ppm = 200 lb.
  - 15 – 30 ppm = 175 lb.
  - 35 – 50 ppm = 150 lb.



Potassium Recommendations

Apples to Plant

- Lbs. K_2O /A ÷ 2.4 = ppm K
  - Optimum soil test 150 – 300 ppm
  - 0 – 30 ppm = 170 lbs.
  - 40 – 60 ppm = 150 lbs.
  - 70 – 100 ppm = 120 lbs.
  - 110 – 150 ppm = 80 lbs.



Magnesium

- Given in lb Mg per acre
- Lbs. MgO/A ÷3.2 = ppm Mg
- Goal value of 50 ppm for all tree fruit crops
- Less than 50 ppm in the soil the rate will vary from 50 to 100 lb. Mg/A

Cation Exchange Capacity (CEC)

- Measure of the capacity of a soil to hold and release nutrient ions
- Sum of Exchangeable cations
  - Acidity (H), + K + Mg + Ca
- Soils high in clay and organic matter will have a high CEC

Percent Base Saturation

- Percentage of exchange sites occupied by the basic cations
  - relationship with soil acidity
- meq/100 g ÷ CEC x 100
- For Ca
  - 4.5 ÷ 8.9 x 100 = 50.5

LABORATORY RESULTS:										Optional Tests:		
[1]pH	[2]P lb/A	Exchangeable Cations (meq/100g)					% Saturation of the CEC			Organic Matter %	Nitrate-N ppm	Soluble salts mmhos/cm
		[3]Acidity	[2]K	[2]Mg	[2]Ca	[4]CEC	K	Mg	Ca			
6.1	44	3.9	0.1	0.5	4.5	8.9	0.6	5.2	50.5	3.8		

Test Methods: [1]1:1 soil:water pH, [2]Mehlich 3 Extractant, [3]SMP Buffer pH, [4]Summation of Cations

Soil Nitrogen Tests?

- Nitrogen exists in soil in many forms
  - Inorganic Ionic = <2% (NH_4 , NO_2 & NO_3)
  - Organic → ionic forms (mineralization)
- To assess N supplying power need to measure rate of mineralization
- Mineralization varies by pH, types of organic materials and C:N ratios

Bould, C. 1963. J. Sci. Fd. Agric., vol 14

Soil Test Summaries back to 1989

Soil Fertility Testing Recommendation Handbooks

Tree Fruit

agsci.psu.edu/aasl/soil-testing/soil-fertility-testing

List of Regional Soil Testing Labs

- Penn State
  - http://agsci.psu.edu/aasl/soil-testing
- University of MD (list)
  - http://extension.umd.edu/hgic/soils/soil-testing
- Rutgers University
  - http://njaes.rutgers.edu/soiltestinglab/
- Virginia Tech
  - http://www.soiltest.vt.edu/

Leaf Analysis Advantages

- What is actually taken up
- Reliable nitrogen values
- Micronutrients
- Integrates crop ;psf
- Integrates seasonal effects
  - Drought
  - temperature

Problems with Foliar Analysis

- Link between analysis and yield is imprecise
  - Rootstock, soils?
- Supply from soil is not sole influence on leaf concentration
  - Yield is a function of #fruit buds and # setting
- Content is influenced by changes in dry matter acquisitions

Nutrient Ranges in TFPG Table 1-2

Table 1–2. Nutritional ranges used to interpret leaf analysis values for apples, peaches, nectarines, pears, and cherries.

APPLES

	Deficient	Low	Normal	High
		Dry matter (%)		
Nitrogen	<1.60	<1.80	1.80–2.80	>2.80
Phosphorus	<0.11	<0.15	0.15–0.30	>0.30
Potassium	<0.70	<1.20	1.20–2.00	>2.00
Calcium	<0.31	<1.30	1.30–3.00	>3.00
Magnesium	<0.03	<0.20	0.20–0.40	>0.40
		ppm		
Manganese	<5	<22	22–140	>140
Iron	<25	<40	40–100	>100
Copper	<4	<6	6–25	>25
Boron	<11	<35	35–80	>80
Zinc	<6	<20	20–200	>200

PEACHES AND NECTARINES

	Deficient	Low	Normal	High
		Dry matter (%)		
Nitrogen	<2.00	<2.50	2.50–3.40	>3.40
Phosphorus	<0.10	<0.15	0.15–0.30	>0.30
Potassium	<1.70	<2.10	2.10–3.00	>3.00
Calcium	<0.50	<1.90	1.90–3.50	>3.50
Magnesium	<0.03	<0.20	0.20–0.40	>0.40
		ppm		
Manganese	<10	<19	19–150	>150
Iron	<40	<51	51–200	>200
Copper	<4	<6	6–25	>25
Boron	<11	<25	25–50	>50
Zinc	<6	<20	20–200	>200

PEARS

	Deficient	Low	Normal	High
		Dry matter (%)		
Nitrogen	<1.35	<1.60	1.60–2.40	>2.40
Phosphorus	<0.15	<0.18	0.18–0.26	>0.26
Potassium	<0.16	<0.20	0.20–2.00	>2.00
Calcium	<0.10	<1.30	1.30–3.00	>3.00
Magnesium	<0.05	<0.30	0.30–0.60	>0.60
		ppm		
Manganese	<5	<20	20–200	>200
Iron	<40	<50	50–400	>400
Copper	<2	<6	6–25	>25
Boron	<5	<35	35–80	>80
Zinc	<5	<20	20–200	>200

CHERRIES

	Deficient	Low	Normal	High
		Dry matter (%)		
Nitrogen	<2.00	<2.30	2.30–3.30	>3.30
Phosphorus	<0.20	<0.23	0.23–0.38	>0.38
Potassium	<0.80	<1.00	1.00–1.90	>1.90
Calcium	<0.30	<1.60	1.60–2.60	>2.60
Magnesium	<0.03	<0.49	0.49–0.65	>0.65
		ppm		
Manganese	<5	<18	18–150	>150
Iron	<40	<50	50–250	>250
Copper	<3	<6	6–25	>25
Boron	<5	<39	39–80	>80
Zinc	<5	<20	20–200	>200

Penn S

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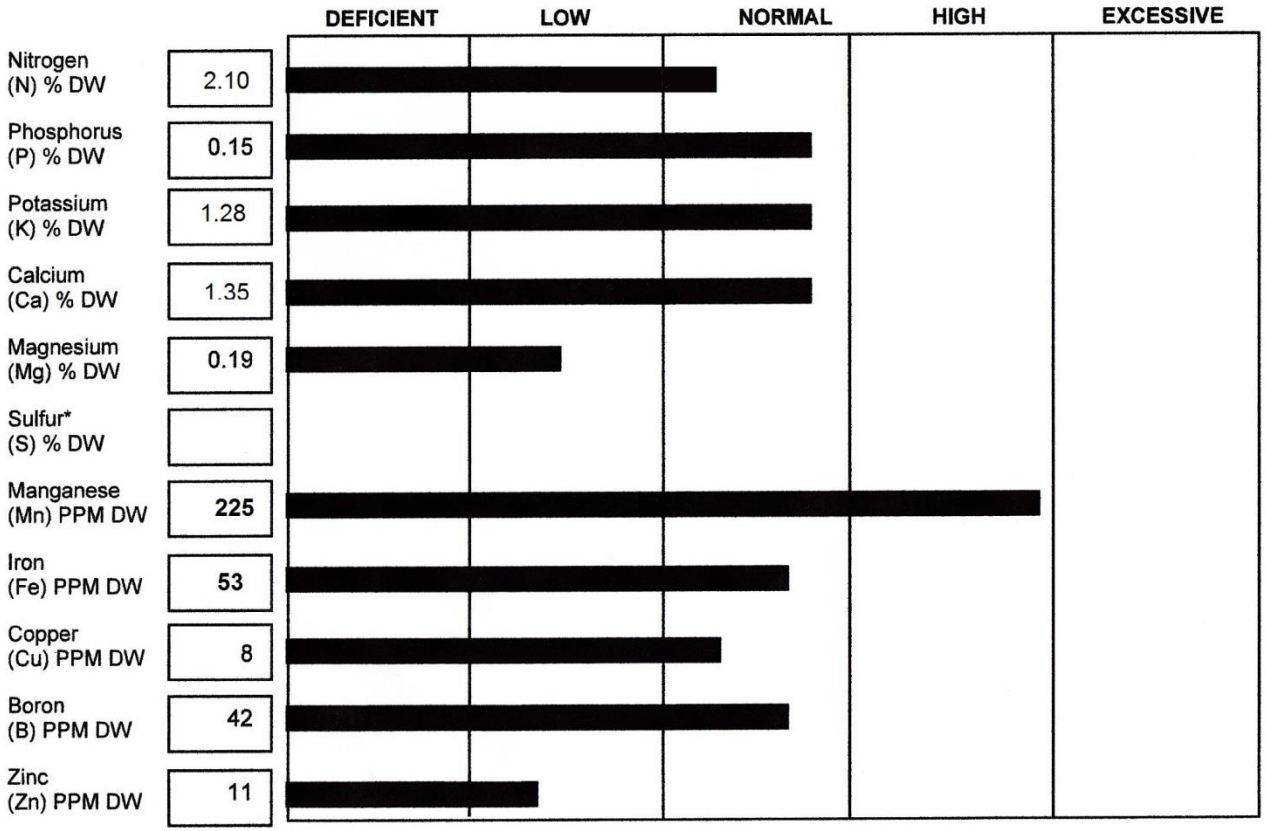
(814) 863-0841 Fax (814) 863-4540
Agricultural Analytical Services Laboratory
The Pennsylvania State University
University Park PA 16802

PLANT TISSUE ANALYSIS FOR:	ADDITIONAL COPY TO:
Jane J. Doe Doe Farms R.R.#2 Box 14 Wysox PA 18854	

KIT ID	LAB ID	FIELD NAME	HOUSE	BENCH	RECEIVED	COMPLETED	COUNTY
12345	PK00001	1			01/05/2000	01/10/2000	

Crop: Apple **Variety:** Any



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Agricultural Analytical Services Laboratory
http://www.aasl.psu.edu

The Pennsylvania State University
University Park, PA 16802

Phone: (814) 863-0841
Fax: (814) 863-4540

A

LABORATORY NUMBER	NAME (PLEASE PRINT) BUSINESS (IF ANY)		NAME OF COMMERCIAL FIRM
SERIAL NO.	STREET OR R.D. NO.		STREET
DATE	CITY STATE ZIP CODE		CITY STATE ZIP CODE
	PHONE EMAIL		PHONE EMAIL

PLANT ANALYSIS INFORMATION SHEET: ALL FRUIT CROPS

Note: Payment of $24.00 must be submitted with plant sample (check payable to Penn State University)

County_____ Field No. _____

Crop _____ Variety_____

*For recommendations, please choose crop/variety from back of this form.

Was a leaf sample submitted from this block last year? Yes [ ] No [ ]
(If yes, enter sample number _____)

Was a soil sample submitted with this block last year? Yes [ ] No [ ]
(If yes, enter sample number _____)

Sampling time for grapes: bloom sample [ ] veraison sample [ ]
Will the fruit be used for fresh market [ ] or processing [ ]
Spacing _____ ft x _____ft (For raspberries and strawberries, indicate initial spacing only.)

Rootstock (If applicable) _____
Age of plants sampled _____ (years)

Lime: _____ tons/acre of _____ applied on _____
(type) (date)

Fertilizer: _____ __lbs/tree of _____ _____applied on _____
(analysis) (date)

(or)

_____ __lbs/acre of _____ applied on _____
(analysis) (date)

Were foliar nutrients applied this year? Yes [ ] No [ ]
If yes, list rates/acre _____

Weed control:
Chemical used _____
Amount of active ingredient/acre _____
Date applied _____

The soil is: Gravelly [ ] Sandy [ ] Shaley [ ] Eroded [ ]
Silt [ ] Clay [ ] Loam [ ]

The topography is: Flat [ ] Sloping [ ] Steep Grade [ ]

Rainfall this season was: Light [ ] Normal [ ] Heavy [ ]

Free water drains away: Slowly [ ] Quickly [ ]
Plant appearance:
Terminal growth is: Short [ ] Medium [ ] Long [ ]
Grape or raspberry canes are: Poor [ ] Vigorous [ ] Excessive [ ]
Strawberry beds are: Sparse [ ] Medium [ ] Very dense [ ]
Leaf color is: About right [ ] Light Green [ ] Yellow [ ] Brown [ ]

COMPLETE THIS SECTION FOR SPECIAL PROBLEMS ONLY:

If the leaf is discolored, does the color variation occur:
Along leaf margin [ ] Between main veins [ ] Between small veins [ ]
Along veins [ ] Over the entire leaf [ ] In spots [ ]

Leaves were first affected at shoot: Tip [ ] Middle [ ] Base [ ]

Symptoms were first seen: June [ ] July [ ] August [ ] September [ ]

Leaf drop was: Early [ ] Late [ ] Normal [ ]

Leaves dropped first on: New wood [ ] Spurs [ ] Shoot tip [ ] Shoot base [ ]

Fruit color is: Poor [ ] All right [ ] Unusually well colored [ ]

Fruit quality is: Poor [ ] Acceptable [ ] Excellent [ ]
Crop size is: Poor [ ] Average [ ] Heavy [ ]

Items of Importance on Information Sheet

- Previous sample?
  - Leaf
  - Soil
- General features of the block
  - age, rootstock, fertilizer, herbicide
- Rainfall
- Fertilizer

Items of Importance on Information Sheet

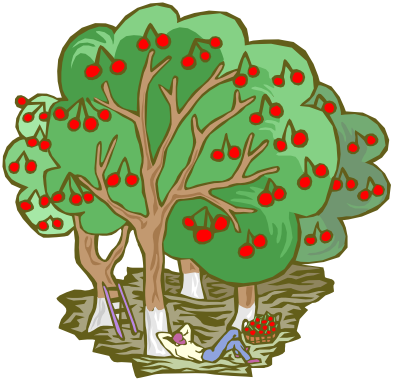
- Terminal growth
- Leaf color
- Problem Section
  - discoloration
  - location on shoot

Nutritional Ranges for Apple

	Deficient	Low	Normal	High
	% Dry Matter			
Nitrogen*	< 1.60	< 1.80	1.80 - 2.80	>2.80
Phosphorus	< 0.11	< 0.15	0.15 - 0.30	> 0.30
Potassium	< 0.70	< 1.20	1.20 - 2.00	> 2.00
Calcium	< 0.31	< 1.30	1.30 - 3.00	> 3.00
Magnesium	< 0.03	< 0.20	0.20 - 0.40	> 0.40
	ppm			
Manganese	< 5	< 22	22 - 140	> 140
Iron	< 25	< 40	40 - 100	> 100
Copper	< 4	< 6	6 - 25	> 25
Boron	< 11	< 35	35 - 80	> 80
Zinc	< 6	< 20	20 - 200	> 200

	Nonbearing	Early Bearing	Mature
Paulared, McIntosh, Empire, G. Delicious, Gala, Jonagold, Mutsu	2.4 – 2.6	2.0 – 2.4	1.8 – 2.1
Delicious, Fuji, Braeburn	2.4 – 2.6	2.2 – 2.4	2.2 – 2.25
York, Rome, Stayman	2.4 – 2.6	2.2 – 2.6	2.2 – 2.4

Table 1-3 TFPG



Crop & Orchard Interactions

- No Crop
  - N, Ca, Mg lower
  - K is higher
- Low Water
  - K, Ca uptake lower
- Light Pruning
  - K is lower
- Heavy Crop
  - N, Ca, Mg higher
  - P, K are lower
- High Water
  - K is higher
  - P is lower (soils)
- Heavy Pruning
  - N, P, K higher

Cultivar Factors

- Higher N to increase tonnage on pro
  like York
- Cultivars like Gala that set heavy crops need more nitrogen
- Early maturing cultivars need less so N is dissipated by harvest time
- Large fruited cultivars like Jonagold and Honeycrisp need moderate amounts of N

Nitrogen concentration and total amount of N of young apple trees

	Percent N in the tissue		Amount of N (g)	
Tree Tissue	Fruiting	non-fruiting	Fruiting	non-fruiting
Leaves	2.85	2.18	34.2	42.6
Fruits	0.50	-	28.0	-
Others	1.00	1.08	12.4	60.9
Total N / Tree	0.93	1.35	74.6	103.5

Adjustment of N by Previous Year's Results

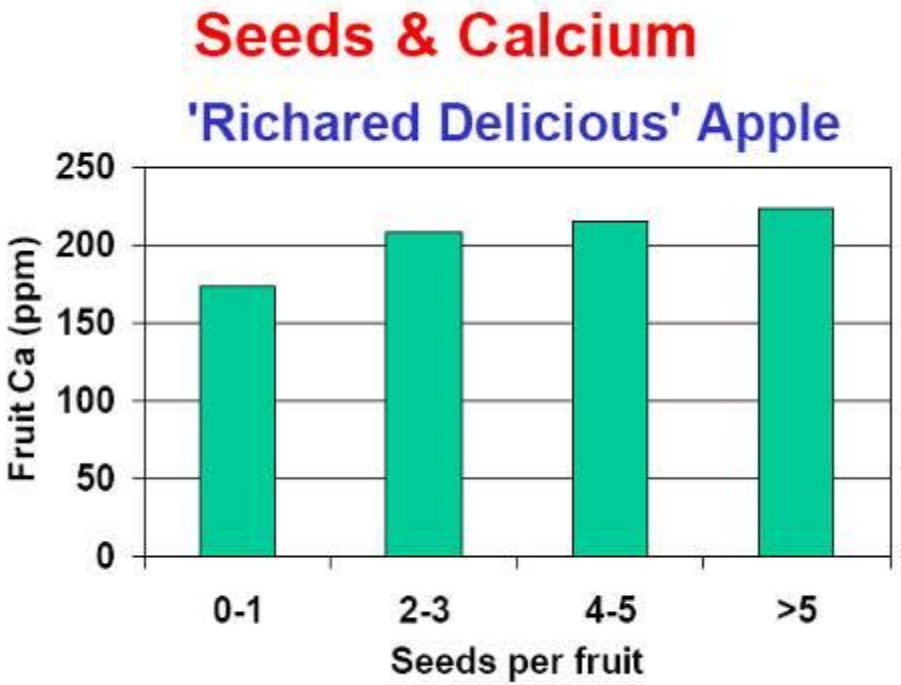
- Apples & Pears
  - + or - by 10%/each tenth - or +
- Stone Fruit
  - + or – by 5%/each tenth% - or +

Increase by 10% for each tenth below optimum rate

Example: If %N is 0.2% below normal increase rate by 20%

Factors affecting Ca

- Light crop load
- Low seed number
  - pollination



Bramlage et al, 1990

Potassium Management

- Leaf K levels in the range of 1.5 to 1.8% are optimum for McIntosh & Empire
- Range for most other varieties is 1.2 to 2.0% (except York Imperial)
- Work towards N : K ratios of 1.25 to 1.50
- Utilize cheapest form of K for fertilizer, however do not use KCl on stone fruit

Magnesium Management

- Manage in unison with Calcium
- Ca : Mg soil ratios

  5 : 1 is preferable

  > 10 : 1 Mg is low

  > 20 : 1 Mg is deficient
- Leaf levels range from 0.2 to 0.65%

Nutrient Ratios

A Little Less Understood

- **N:Ca** – Low ratios usually result in fruit with better storage potential
- **Mg:Ca or Mg+K:Ca** – High ratios usually result in insufficient Ca for good storage potential because Mg & K are antagonists to Ca accumulation in fruit

The Future?

- Fruitlet Analysis for storage decisions
- Less information
- Handling samples - freeze drying
- Sample size ?
- Best tissue ?


Questions