Optimizing Fertility Management -- Caneberries

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What Nutrients Do I Need?

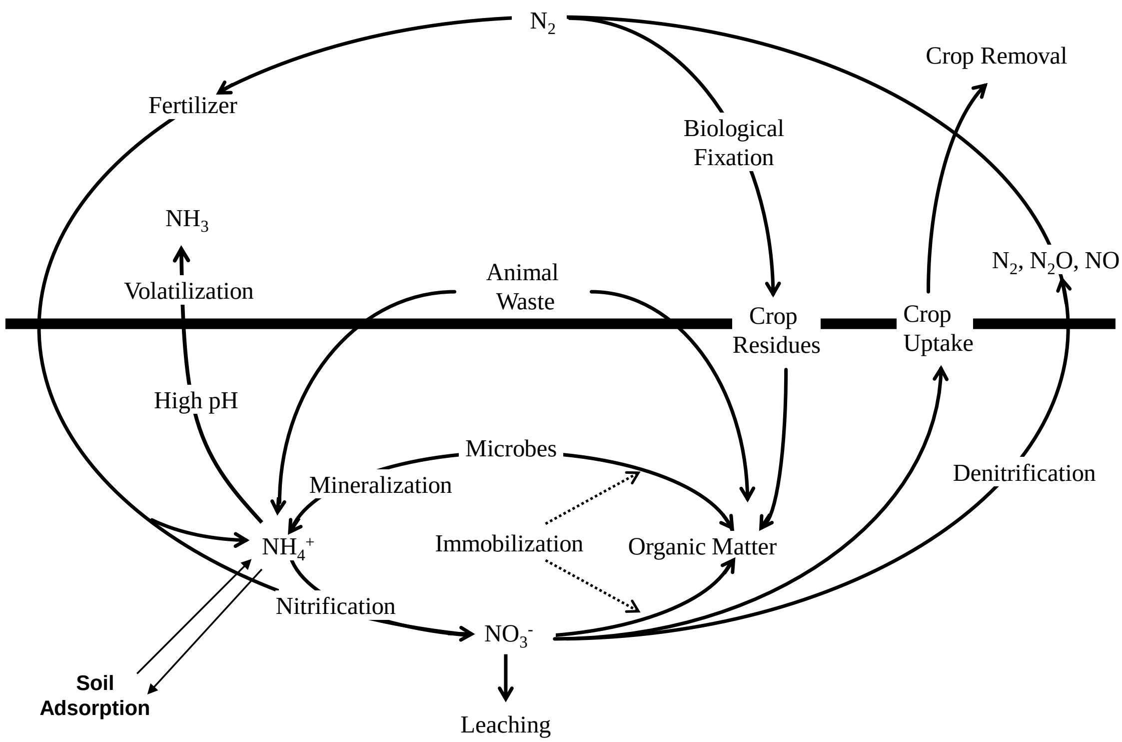
- Primary nutrients (% levels in tissue):
  - Nitrogen, Potassium and Phosphorous
  - Sulfur (generally only on sandy, low organic matter soils, and/or high elevation soils irrigated with very "clean" water).
- Micronutrients (ppm or ppb in tissue):
  - Zinc, Iron, Calcium, Copper, Manganese and Boron
    - Iron and Zinc especially on high pH soils (> 7.5)

Nutrient Cycles

- All nutrients go through some or all of the cycles of uptake, release, transformation, volatilization, leaching, precipitation/fixation, etc.
- Understanding the cycles of the major nutrients is key to optimum management in any setting.
- Begin by covering the primary nutrients (N, P and K) and their cycling in soils.
- Follow with nutrient management keys and example diagnostics for fruits.

Nitrogen

Nitrogen Cycle



Phosphorus

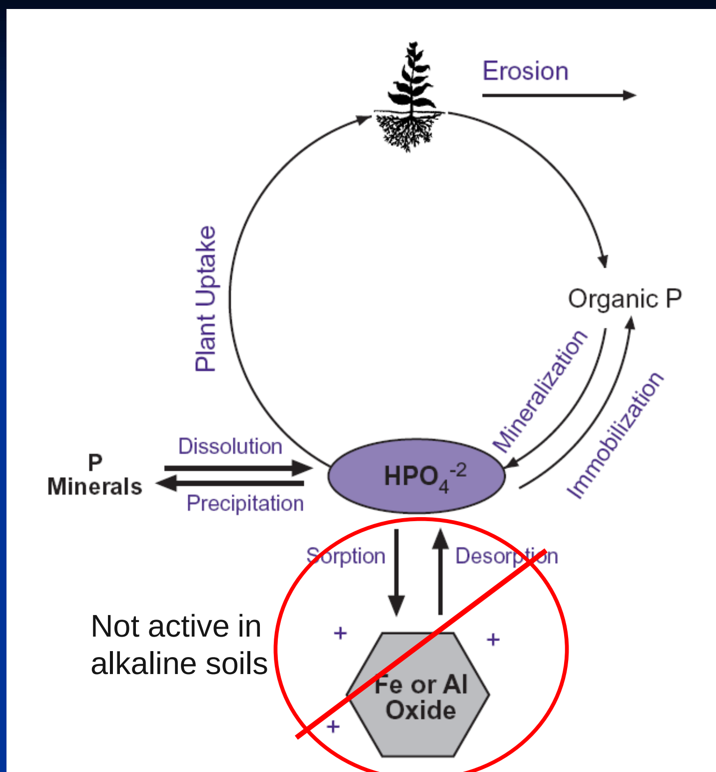


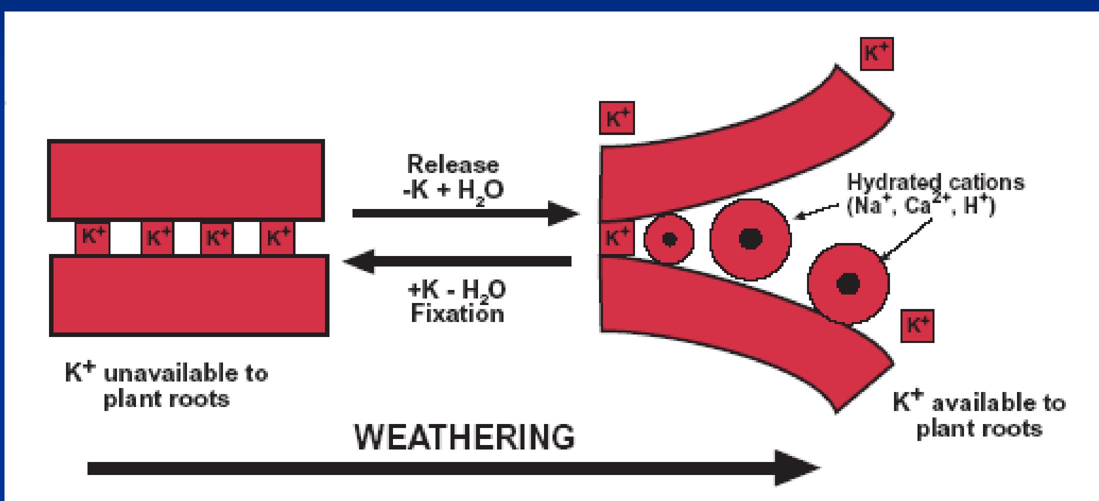
Figure 1. Phosphorus cycle.

Table 1. Definitions of each P form.

Phosphorus form	Example molecular formula	Notes
Phosphate	HPO_4^{-2}, $H_2PO_4^-$	Form that plants can use
Sorbed P	—	Can slowly become available
Mineral P		
Calcium phosphates	$CaHPO_4$	
Aluminum phosphate	$AlPO_4$	Relatively insoluble
Iron phosphate	$FePO_4$	
Organic P	—	Slowly supplies available P to plants and microorganisms

Potassium

Fixation and Release



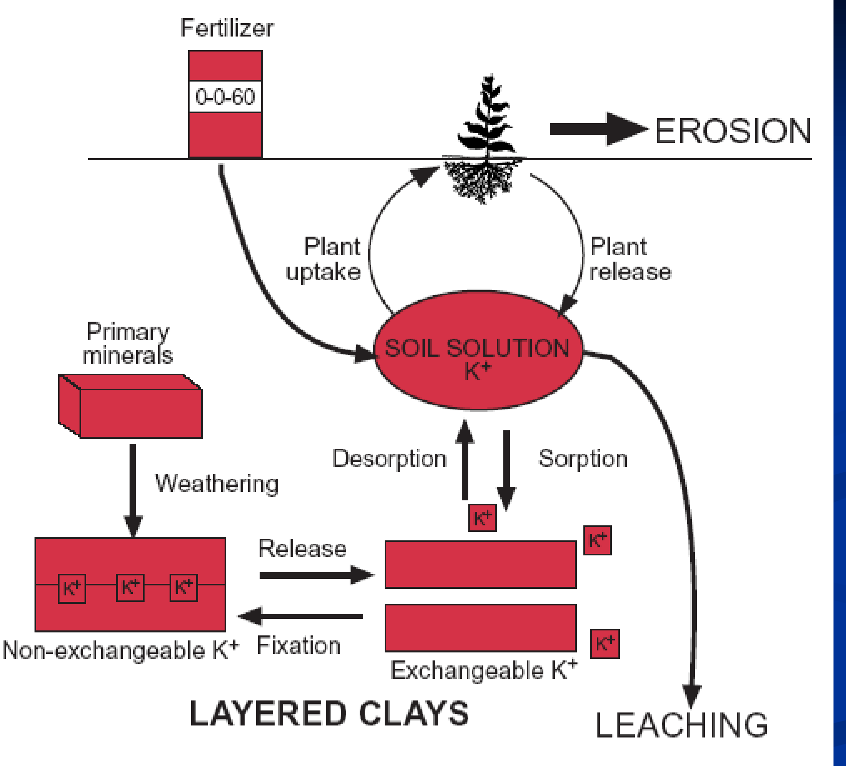


Figure 2. The potassium cycle.

How Much Nutrient Do I Need?

- Amount needed depends on:
  - Soil properties (e.g., clay content and K supply, organic matter levels, etc.)
  - Crop management history (previous fertilizer application, organic matter applications, yield goal/history of production, etc.)
  - Soil test results (levels of plant available nutrients, esp P, K and Ca for fruits) and recent tissue test levels.
  - Annual management of N required, generally

Tissue Sampling Tips

- Do not mix cultivars
- Collect 50 leaves from fully expanded leaves on primocanes
- One leaf per cane
- Cover no more than 5 acres per sample, no more than 50 leaves per sample
- Keep petiole and leaf together
- Air-dry or mail to lab immediately (mid week to avoid sitting over a weekend)

Soil Test Levels

FRUIT TREES INTERPRETATIONS + RECOMMENDATIONS

	Interpretations				
	Very Low	Low	Adequate/Normal	High	Very High
pH	----	< 6.1	6.1 - 8.4	> 8.4 - 8.6	> 8.6
EC (salts)	< 0.05	0.05 - 0.15	0.15 - 1.5	1.5 - 3.0	> 3.0
Phosphorus	< 5	5 - < 10	10 - < 30	30 - < 50	> 50
Potassium	< 35	35 - < 75	75 - < 400	>= 400	----
Nitrogen	----	----	----	----	----
Zinc	< 0.5	0.5 to 1.0	1.0 to 50	>=50	----
Iron	<3.1	3.1 - 5	>5	>=50	----
Copper	----	<=0.2	0.2-50	>=50	----
Manganese	----	<=1	1 - 50	>=50	----
Sulfur	----	< 8	>= 8	----	----
Organic Matter	----	*None given*	*None given*	*None given*	*None given*
SAR	----	----	< 15	>=15	----

Table 6-1.
FRUIT PLANT FOLIAGE NUTRIENTS

Crop	Macronutrients: % dry weight					Micronutrients: ppm dry weight				
	N	P	K	Ca	Mg	Fe	B	Zn	Mn	Cu
Almond	2.00-2.60	0.10-0.25	0.70-1.80	1.00-2.00	0.30-0.70	50-200	30-85	20-100	30-150	5-12
Apple	1.70-2.50	0.15-0.30	1.20-1.90	1.50-3.00	0.25-0.35	50-250	20-60	15-100	25-150	5-12
Apricot	2.30-3.00	0.15-0.30	2.00-3.00	1.50-3.00	0.50-0.95	50-200	25-75	20-100	30-150	5-10
Blueberry	1.80-2.40	0.10-0.22	0.50-0.85	0.40-0.85	0.10-0.28	100-350	32-50	20-60	25-170	12-20
Brambles	2.65-3.20	0.25-0.40	1.50-2.50	0.75-2.50	0.36-0.68	50-200	30-60	20-60	50-150	4-25
Cherry	2.30-3.30	0.16-0.40	1.00-3.00	1.60-2.60	0.40-0.90	50-250	20-65	15-70	20-150	5-25
Grape	2.40-2.60	0.21-0.24	1.20-1.40	2.50-3.50	0.24-0.27	100-250	26-40	30-150	30-200	6-25
Hazelnut	1.50-2.80	0.10-0.40	0.60-1.30	0.80-2.40	0.20-0.60	50-250	35-75	28-85	24-120	8-12
Peach	2.50-3.80	0.15-0.40	1.50-2.50	1.90-3.50	0.25-0.60	100-200	20-80	15-60	20-150	6-15
Pear	1.80-2.40	0.12-0.25	1.00-2.00	1.30-3.50	0.25-0.90	100-300	20-60	20-60	20-170	6-20
Plum	2.10-3.00	0.10-0.25	2.00-3.50	1.80-3.80	0.20-0.60	50-300	30-56	18-100	25-150	5-10
Pecan	2.50-3.00	0.12-0.18	0.90-1.30	0.80-2.50	0.30-0.65	50-300	60-80	30-300	100-300	7-30
Strawberry	2.35-2.95	0.25-0.40	1.50-2.50	0.75-1.70	0.28-0.50	50-150	24-90	20-75	50-150	6-18
Walnut	2.20-2.60	0.12-0.30	1.00-3.00	1.25-2.50	0.20-0.90	50-250	35-80	20-200	25-220	5-20

Optimum concentrations of plant nutrients in the foliage of fruit plants during July and August.

Nitrogen

- Most limiting nutrient—need annual application:
  - For summer-bearing raspberries: 30-50 lbs/ac in establishment, 50-80 lb/ac thereafter
    - Note: N applied before 6 in primocane growth goes into both new growth, and fruiting canes and fruit. Later, N uptake directed almost entirely to primocanes, not to fruit. Split application to balance N partitioning
  - For primocane-bearing raspberries: add 20 lbs/ac at bloom.
  - Tissue N test should be between 2.3-3.0%

Nitrogen (cont.)

- **Low tissue analyses and abundant cane growth.** For summer-bearing red raspberries, canes should be 7 to 9 ft high and ½ inch in diameter.
  - If cane growth is luxurious, don't apply additional fertilizer. This situation usually is caused by oversupply of N.
  - Lower-than-normal tissue nutrient concentrations are common with excessive cane growth. Occurs when the tissue nutrient content is diluted by intensive growth.
  - This condition should correct itself when growth returns to normal.
- **Low tissue analyses and weak cane growth.** If canes are weak, discolored, or stunted, apply fertilizer at rates recommended

Nitrogen (cont.)

- **Normal tissue analyses and cane growth.** If tissue analyses and cane growth are within the normal range, continue with your current fertilizer program.
- **Above-normal tissue analyses and weak cane growth.** If canes are weak, discolored, or stunted, and the tissue analyses are above normal, look for stress from pests, drainage, drought, frost, or other factors.
- **Above-normal tissue analyses and cane growth.** If tissue analyses are above normal and cane growth is adequate or above normal, reduce the amount of fertilizer you have been applying, especially N.

Phosphorous and Potassium

- Available amounts best determined by soil test levels
- P important in establishment—very important in early root growth—till in before planting.
- Excess P can induce competition for soil Zn and Fe uptake
- K generally not deficient except in sandier soils, critically important in fruit quality (adequate Ca).
- P and K generally remain sufficient for 2 to 4 years after fertilizer application.

Importance of Potassium

- Nitrogen thought to be "most important" but it is really just the most dynamic and in high demand by many organisms and subject to a number of losses from soils, hence it is managed on annual need
- Phosphorus receives a lot of attention because it is hard to manage in high pH soils
- Potassium, however, is THE most important of the nutrients for overall plant performance. Not as much an annual concern because of the *usually* high supply in most soils.
- More significant loss of yield and quality, all other things held constant, when K is deficient.

Importance of K (cont)

- Catalyst in many metabolic reactions (speeds, regulates reactions)
- Primary solute adjustment mechanism in plants (in root and shoot tissues)
  - Maintenance of overall tissue turgor (new cell expansion and filling)
  - Water uptake and transfer in tissues
  - Efficiency in photosynthesis (proper leaf angle and surface area exposure)
  - Stomatal regulation (gas and water exchange)
- Facilitator of sugar and dissolved ion transfer through membranes (in both root and shoot membranes—fruit quality effects)
- More important to root growth (hence seedling establishment) than P (thus important at planting and renovation)
- Found to be an important factor in disease suppression
- Plant needs as much K (or more) than N

K Fertility Management

- Best if half broadcast, half banded (shallow knife or surface banding along dripline) in spring.
- Important to have at proper levels BEFORE spring growth, difficult to change tissue content during season
- Can be foliar applied after leaves fully expanded.
- In-season benefits are possible in micro-nutrient uptake (like Ca) and movement within the plant (hence, fruit quality effects)
- Ratio to Calcium an important consideration in western US soils – not well understood (I have seen ratio of 4 or 5:1 K:Ca in soils for fruits, but inconsistent results—trials needed in Utah)

If Soil or Tissue Test is:

- Low –
  - P – apply 60-80 lb/ac
  - K – apply 60-100 lb/ac
- Marginal –
  - P – apply 0-60 lb/ac
  - K – apply 40-60 lb/ac
- Adequate – do not apply

Sulfur

- S deficiencies are uncommon in the West due to high sulfate content of irrigation waters and soils
- Additions should be added if soil test level below 8 mg/kg (or ppm).
- Under low soil test, add 25 to 50 lbs S/ac.
- Sources are Ammonium sulfate (also an excellent N source), Potassium sulfate, soil applied elemental S (very slow release--3 to 4 years), sulfur burning and irrigation water treatment (will discuss more later).

Micronutrients

- Most common deficiencies in Ca, Fe, and Zn (and sometimes, but rarely, B)
- All can be applied through foliar sprays (ensure full canopy cover)
- Sources are generally sulfate salts of Zn, Fe, Calcium Chloride and Borate solutions
- Deficiencies best determined on tissue test levels

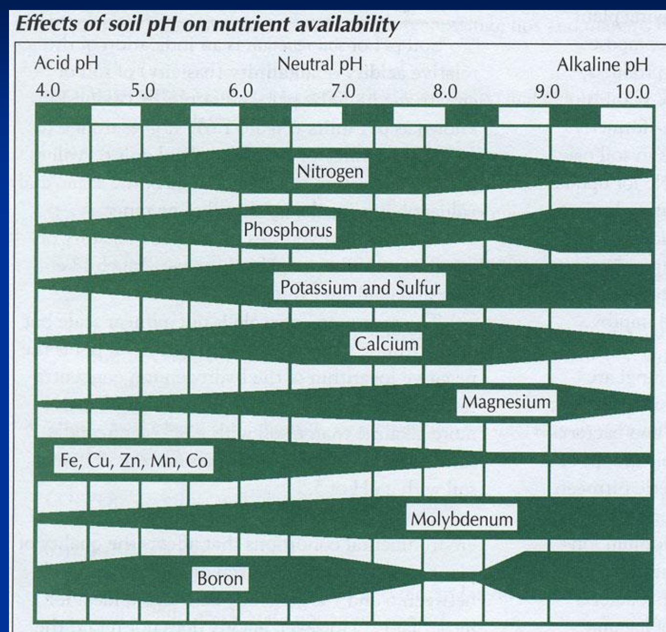
Effect of pH

What is pH?

- pH is measured as the "activity" or concentration of hydrogen ions (H^+) in the solution.
- The higher the concentration of hydrogen ions, the lower the pH (more acidic).

- Why worry about soil pH?

Relative availability of nutrients as a function of pH



Can I acidify my soil?

- Western soils have VERY large reservoirs of pH buffers in the soil (solid carbonates and other minerals)
- All buffering compounds would have to be dissolved and neutralized before the pH will drop.

Buffering reactions:

$CaCO_3 + CO_2$ (in water) $\rightarrow Ca^{2+} + 2\ HCO_3$

(Calcium Carbonate) (Bicarbonate)

$HCO_3 + H^+$ (in water) $\rightarrow CO_2 + H_2O$

(this is just one acid neutralization reaction -- no change in pH, i.e., no increase in free H^+)

Added acid (H^+) is consumed until all carbonates are dissolved, or other cations leached from the system (i.e., Total Alkalinity is neutralized).

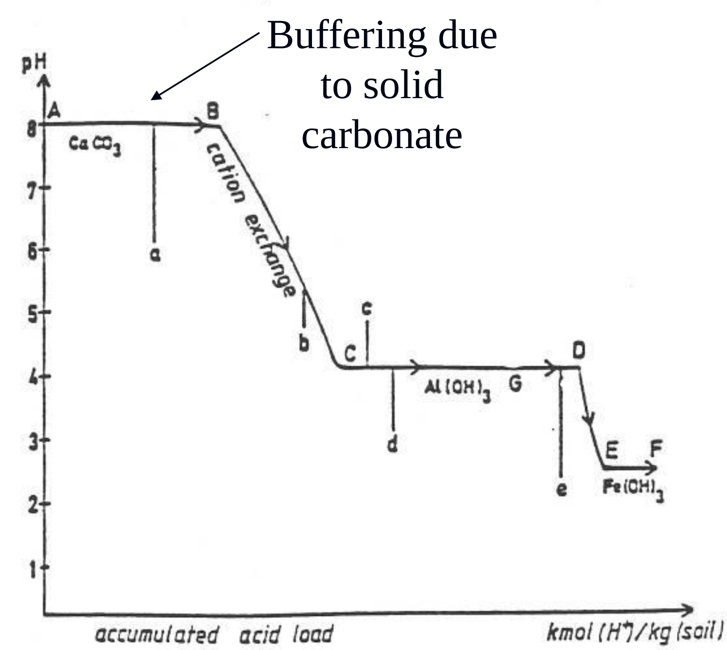


Figure A. Model of soil acidification.

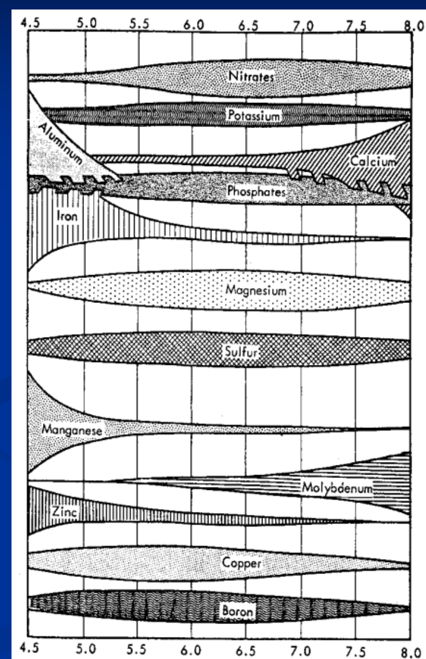
Can I acidify my soil? (cont)

- Typical Intermountain West soils contain excess lime (calcium carbonate) and range from 10 to 40% by weight.
- One percent lime is 40,000 lbs of lime per acre in the top 12 inches.
- This would require 39,200 lbs of pure sulfuric acid per acre just to dissolve and neutralize this one percent of pH buffer (but we have 10 to 40% in Utah soils)!

Water quality

- pH
- Carbonate concentration
- Salinity (esp., Ca and Mg)

- Carbonates, bicarbonates and basic cations (Ca, Mg, K and Na) in solution "buffer" changes in pH



Water Quality Hazard Parameters for Fertigation

	Hazard level		
Problem	**Low**	**Moderate**	**Severe**
Physical			
Suspended solids (ppm)	< 50	50–100	> 100
Chemical			
pH	< 7.0	7.0–8.0	> 8.0
Salt (ppm)	< 500	500–2000	> 2000
Biocarbonate (ppm)	< 100	100	> 100
Manganese* (ppm)	< 0.1	0.1–1.5	> 1.5
Total iron* (ppm)	< 0.2	0.2–1.5	> 1.5
Hydrogen sulfide (ppm)	< 0.2	0.2–2.0	> 2.0
Biological			
Bacterial population per gallon	< 2642	2642–13210	> 13210

Note: When testing for iron and manganese, the water sample needs to be acidified to a pH of 3.5 immediately after sampling.
Source: Bucks and Nakayama (1980); Burt, O'Connor, and Ruehr (1995)

Acidifying your water

- Water can be acidified by:
  - Adding acid solution directly to irrigation water.
  - Oxidizing elemental Sulfur and dissolving it into the water (using a Sulfur burner).
- Enough acid must be added to neutralize the buffer compounds/elements and then increase the concentration of H^+ to the desired level.

Sulfur Burning:

Speeds the “oxidation” of elemental Sulfur to produce Sulfuric Acid

$2 S + 3 O_2 + 2 H_2O \rightarrow 2 H_2SO_4$

H_2SO_4 (in water) $\rightarrow 2 H^+ + SO_4$

Acidifying your water (cont.)

- 1.00 mg/L (or ppm) of $CaCO_3$ dissolved in water neutralizes approximately an equal weight of Sulfuric Acid (0.98 mg/L) addition.
- One acre-foot of water is about 1.2 million L
  - 2.65 lbs of Sulfuric Acid per 1.0 ppm Carbonate
  - plus 0.03 lbs per unit pH reduction.
- "Typical" irrigation waters in the Intermountain West contain from 3 to 20 ppm Carbonate/Bicarbonate, and have a pH of about 7.5
- This would require 8 to 53 lbs of sulfuric acid per acre foot of water to reduce the pH to 5.0

Salinity?

- Damage threshold soil salinity levels for most small fruits is between 2 and 3 dS/m
- Composts/Manures (organic N and P sources)
  - Animal waste materials can be 20 to 30 dS/m
- Irrigation water above 1.5 dS/m can result in soil salinity of 3 to 4.5 dS/m, depending on soil texture
  - Watch shallow water table sources for high salt content in valley locations (sub irrigation, pumping, etc.)

Field Diagnostics for Deficiencies

Leaf Color Diagnostics

- Chlorosis or yellowing over entire leaf
  - Older leaves on annual growth = N def.
  - Younger leaves on annual growth = S def.
- Interveinal Chlorosis
  - Entire leaf, prominent dark green veins = Fe def.
  - Older leaves, starting at tip, progressing to base = Mg def.
- Marginal chlorosis developing inward = Mn def.
- Young leaves dark green, purple/red underneath = P def.

Leaf Necrosis

- Leaf "burning" along margins of older leaves = K def.
- Central and interveinal = Mg def.
- "Shothole" necrosis (w/chlorosis) = advanced N def
- Marginal leaf burning w/ chlorosis = salt injury

Leaf Morphology

- Young leaves form in cupping shape = Ca def.
- Young leaves small and in rosettes = Zn def.
- Young leaves stunted, misshapen and have wavy margins = Cu def.

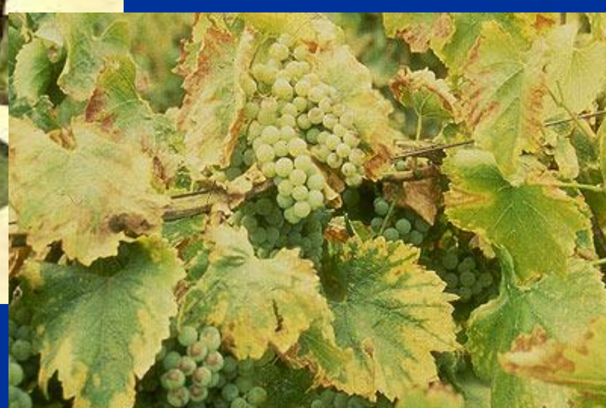
Fruit Symptoms

- Cork Spot or Bitter Pit in Apples and Pears; soft fruit prone to rotting in other fruits = Ca def.
- Gnarled, misshapen Apples and Pears; Corky/Dry flesh near pit in Peaches = B def.
- Calcium and Boron deficiencies often show up in fruit before they do in leaf and stem tissues.

Example Visual Symptoms

Nitrogen Deficiency

Potassium Deficiency



Manganese Deficiency

Iron deficiency

Sulfur deficiency

Zinc Deficiency

Magnesium Deficiency

Salt Injury - Severe

Calcium deficiency

Salt Injury

Questions?

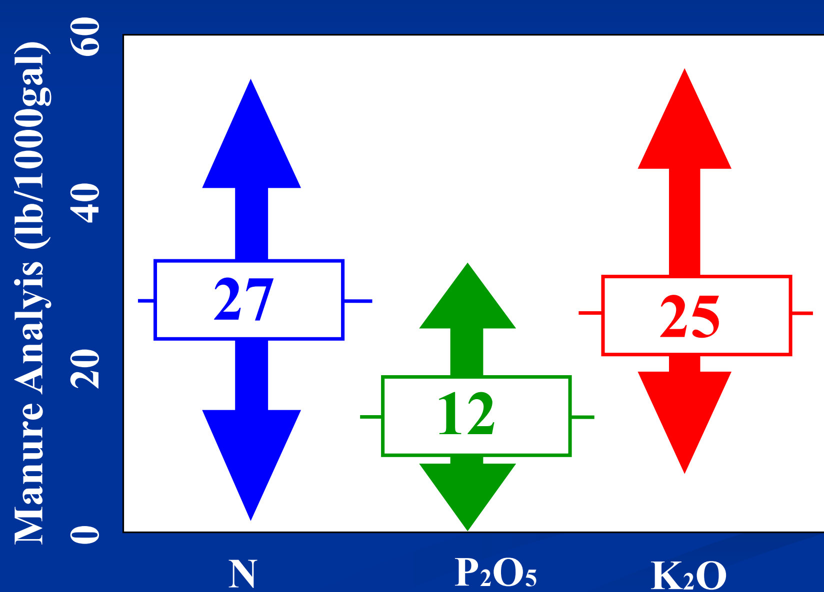
Thoughts on Manure Management

Nutrient Content of Various Manure Sources

		N	P_2O_5	K_2O	Moisture (%)
Solid Manures (lb/ton)					
Beef		11	7	10	80
Dairy		11	9	12	80
Swine		9	9	8	82
Broiler	(fresh)	55	55	45	20
	(stockpiled)	40	80	35	20
	(cake)	60	70	40	30
	(pullet)	40	68	40	25
	(breeder)	35	55	30	40
Layer		30	40	30	40
Liquid Manures (lb/1,000 gal)					
Holding Pit	Swine	36	27	22	96
	Dairy	31	15	19	94
Lagoon	Swine	4	2	4	99
	Dairy	4	2	3	98

Managing Nitrogen

- Variation in Dairy Manure Analysis



Manure Nitrogen

- Manure N Availability

Total N

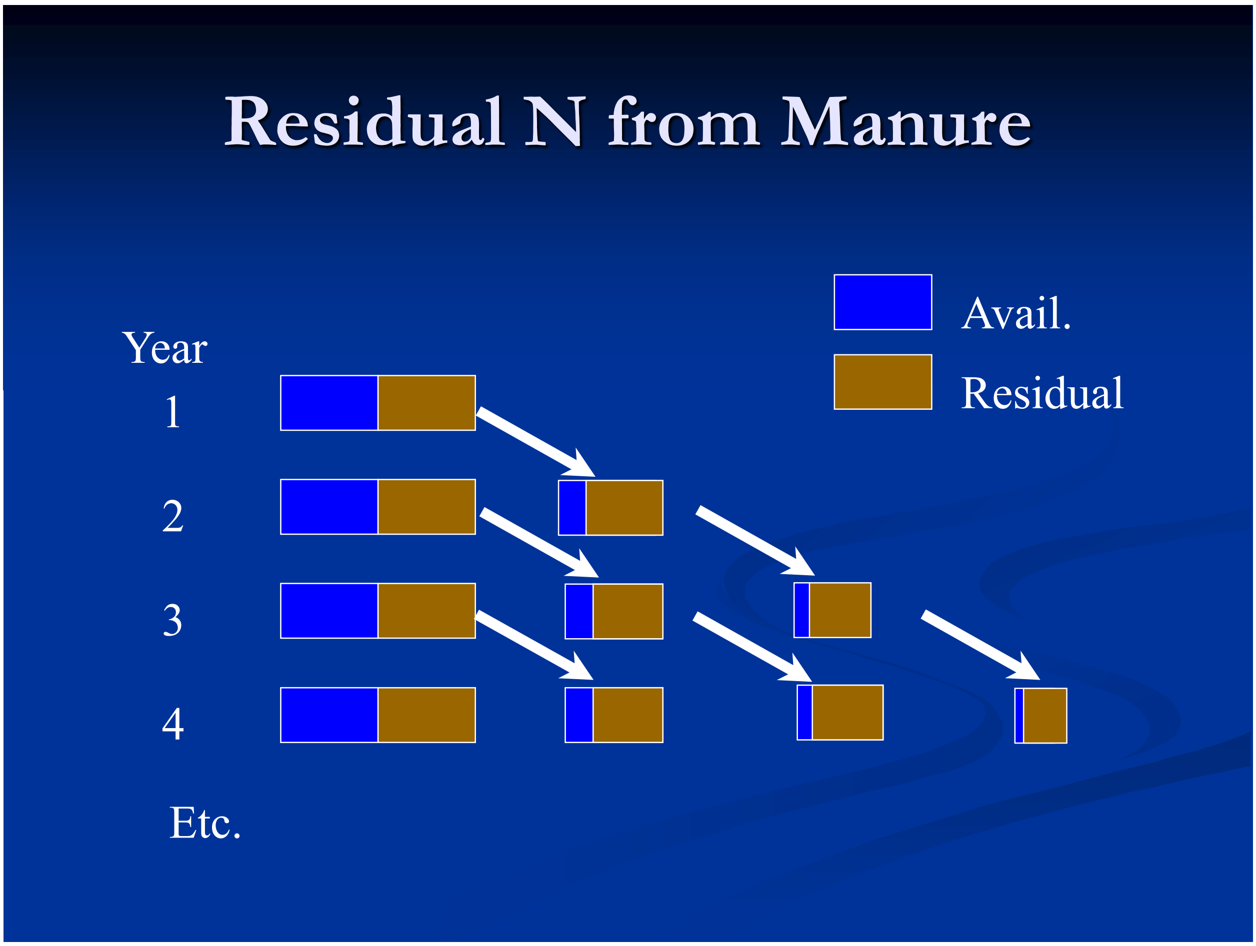
Soluble Mineral N | **Organic N**

Mineral N

Readily available similar to urea fertilizer. Susceptable to volatilization

Organic N

Must be mineralized by microbes before it becomes available.


Residual N from Manure
Avail.
Residual
Year
1
2
3
4
Etc.