Image by K. Olson-Rutz

Soil Fertility
Whitehall Gardener Club

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Clain Jones, clainj@montana.edu 994-6076

MONTANA STATE UNIVERSITY | College of AGRICULTURE | MONTANA AGRICULTURAL EXPERIMENT STATION | EXTENSION

Hands-on is the best way to learn, but we'll use clickers because….

1. I just had my nails done 33%
2. Clicker training isn't just for dogs 33%
3. There isn't enough dirt on the floor to get a good soil sample 33%

Today's topics

- Present what a soil test tells you
  - Soil nutrients
  - Soil properties
- Provide fertilizer guidelines for gardens
- Compare fertilizer sources
- Present plant symptoms of nutrient deficiencies
- Explain limitations, to know which soil properties you can influence

Why should home gardeners know something about soil nutrition?

- To grow healthy plants and tasty vegetables
- To protect the environment
- For efficient use of resources (water and $)

How do I know what to add to my soil???

Six questions to ask yourself before you add fertilizer

1. **Which elements do I need (N, P, K, S, etc.)? Soil test**
2. **How much do I apply?**
3. **What type of material do I use?**
4. Which application method is best?
5. When is the best time to apply it?
6. Will I get a return ($ or environmental) on my investment?

Soil tests help to

- Identify nutrient deficiency or imbalance
- Calculate fertilizer rates
- Increase yield and/or save on fertilizer costs, and decrease environmental risks

Soil tests are

- Best done in early spring, but not when soil is wet
- Perhaps best done in late fall in our climate

See publications listed at end for details on ‘how-to’

Soil laboratory vs home test kits

	Test	Kit cost	Cost/sample
Test kit	N, P, K, pH	$15 - $750	$1.50 - $7.50
Lab	N, P, K, pH, salts	$17 per sample + shipping	

- Sample treatment: Labs dry, grind, sieve, most home test kits do not.
- Test method used: e.g. Olsen P vs Mehlich-2 is pH dependent
- Format of results: Values (e.g. ppm) vs rating (low/med/high or deficient/adequate/surplus)
- Of 4 home kits tested, only 1 provided results similar to laboratory analysis, the others were moderately to far off in results (Sharma and Chatterjee, Crops & Soils Mar. 2019). Accurate one was most expensive.
- Before trusting a soil test kit's results, calibrate results against standard soil test methods.

How much fertilizer do I need to apply?

- Estimate the amount of fertilizer needed based on soil test results, crop needs and area to receive fertilizer
- Sometimes provided on soil test results

Soil Fertility Guidelines

CROP: VEGETABLES **RATE:** lb/1000 sq ft

Dolomite (70 score)	Lime (70 score)	Gypsum	Elemental Sulfur	Nitrogen N	Phosphate P_2O_5	Potash K_2O	Magnesium Mg	Sulfur SO_4-S	Zinc Zn	Manganese Mn	Iron Fe	Copper Cu	Boron B	
			25	2.6										

- Most fertilizer recommendations are in pounds per 1,000 square feet, or pounds per acre
- MSU publications listed at end provide guidelines and example calculations

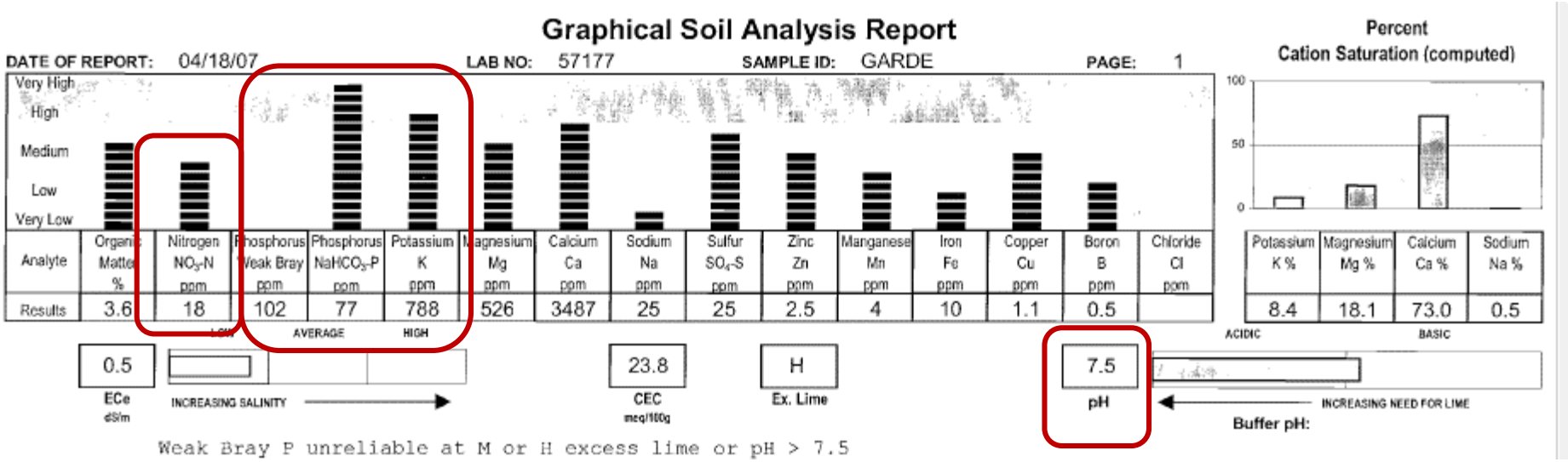
For gardens, in top 6”, see *The Soil Scoop* or MT200705AG

Soil Test	Organic Matter (%)		
Nitrate - N	**< 1.5**	**1.5 – 3.0**	**> 3.0**
lbs /acre	**lbs/1000 sq.ft.**		
<20	4	3	3
20-40	2	2	2
40-80	1	1	0.5
>80	0	0	0

	Olsen P (ppm)				
	< 4	**4 – 8**	**8 – 12**	**12 – 16**	**> 16**
lb P_2O_5/1000 sq. ft.	5	4	3	2	1

	K (ppm)			
	< 75	**75 – 150**	**150 – 250**	**>250**
lb K_2O/1000 sq. ft.	3	2	1	0

Garden soil test report – some items to calculate

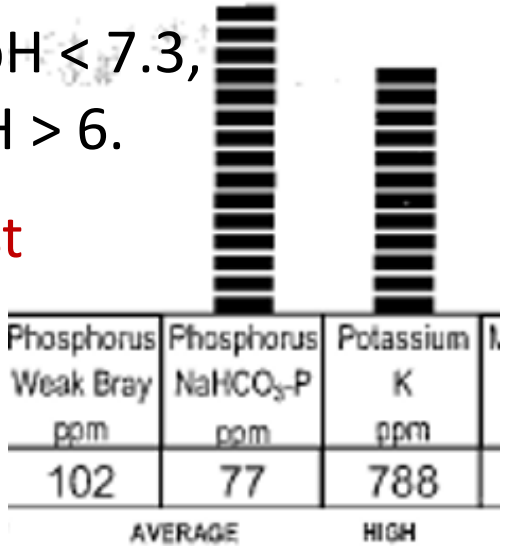


To determine N rate you need:

1. Soil sample depth to convert ppm to lb N/acre (ppm x 2 x actual depth in inches / 6)

P rate: MSU guidelines are based on Olsen P.
Bray works in pH < 7.3,
Olsen works pH > 6.

Which P test should be used in this soil?



Questions?

On to conventional vs organic materials

Feed the plant or feed the soil that feeds the plant

Conventional/chemical

- No carbon
- Easy to store
- Higher nutrient concentration
- Custom formulated
- Easy to use
- Liquid or solid available
- Usually provide quickly available nutrients

Compost/manure

- Bulkier
- Nutrient content low but diverse
- Nutrient content difficult to quantify
- Supplies organic matter
- Takes time to ‘release’ nutrients

Compost can never be applied in excess

50% A. True

50% B. False


Image by K. Olson-Rutz

- Compost can create excess N, P and K.
- N can contaminate ground water, P can contaminate surface water and excess P and K can limit uptake of other nutrients

Approximately how much total N, P, and K does 1” of manure compost supply?

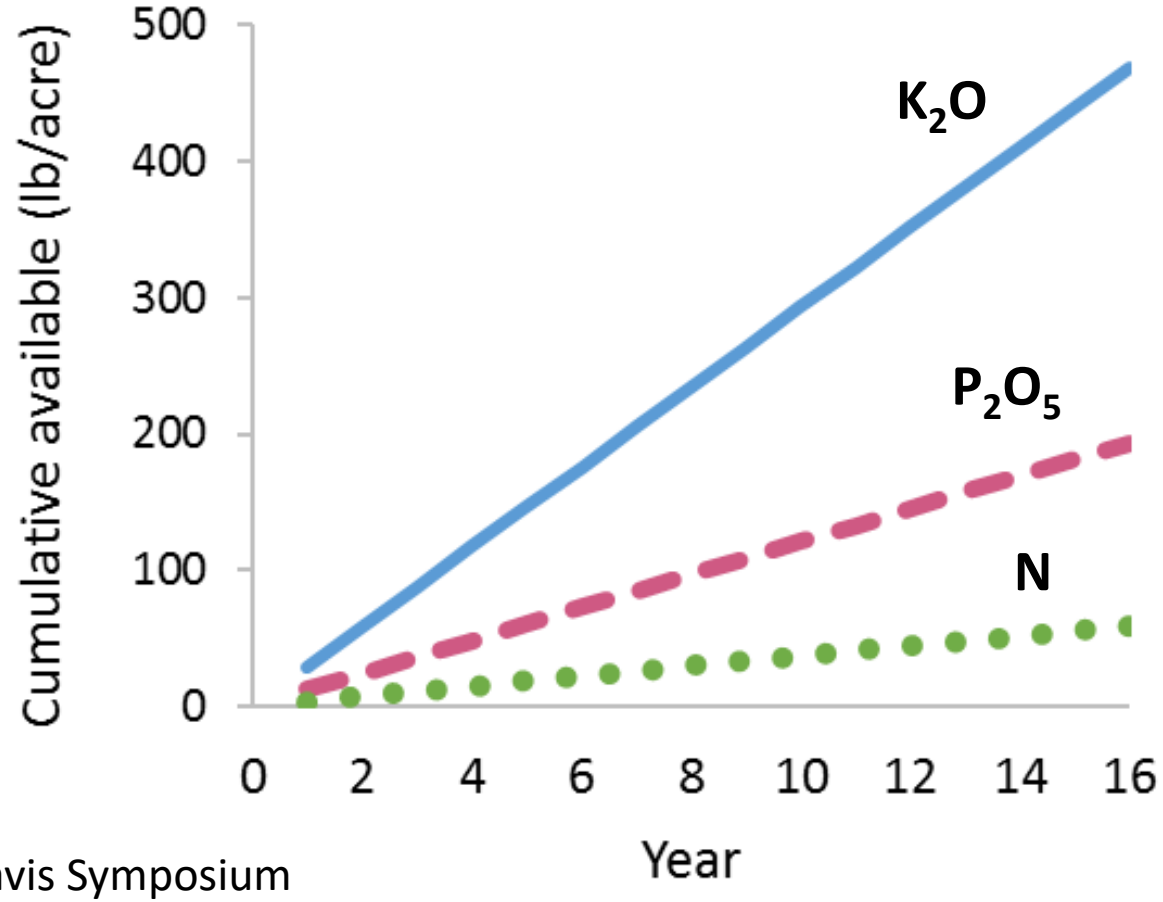
		N	P_2O_5	K_2O	
		lbs/1000 sq. ft.			
	Removed annually[1.]	2.3	0.5	2.7	
1.	Added by 1” manure	40	15	40	50%
2.	Added by 1” manure	6	1	6	50%

To add 5 lb N/1000 sq. ft. takes approx. 500 lb manure compost or 11 ton/acre

[1.] Univ. Mass, Michigan State, Oregon State, Morris et al., 2007

What happens if you meet N needs with manure?

Rapid excess buildup of P and K by adding 1” manure compost annually



Adapted from Hartz 2009 UC Davis Symposium

- Of 67 Midwest gardens 92% had excess P and 88% excess K after just 1 to 6 years of ‘uninformed’ fertilization with composted dairy manure (Hansen unpub data, Ohio State Univ)

Adding organic material is good, but…

How can you increase soil organic matter without adding too much P and K?

- Add organic matter high in C (dry leaves, wood shavings, straw, peat), but remember, high C ties up N
- Add organic matter based on plant's P needs and add N with chemical fertilizer, organic fertilizer such as blood meal, or plant legumes

Image by K. Olson-Rutz

Which of the following has a similar N:P as removed by vegetable harvest?

20%	A. Manure compost
20%	B. Yard compost
20%	C. Green/food compost
20%	D. Dry leaves
20%	E. Green pine needles

N, P, K added by 4000 lbs ≈ 1" material/1000 sq. ft.

	N	P_2O_5	K_2O	N:P_2O_5
	lbs/1000 sq. ft.			
Annual veg harvest[1]	2.3	0.5	2.7	5:1
Manure compost[2]	40	15	40	3:1
Yard compost[3]	58	8	12	7:1
Green/food compost[4]	15	9	30	1.6:1
Dry leaves[5]	40	9	18	5:1
Green pine needles[6]	57	12	25	5:1

1 Univ. Mass, Michigan State, Oregon State, Morris et al., 2007
2 MSU
3 Maryland Urban compost LeafGro and SmartLeaf
4 Waste Resources Action Programme of Wales
5 Heckman and Kluchinski 1996
6 Pietrzykowski et al., 2018

Additional considerations when fertilizing with manure

- Consider the salt content
- Herbicide residual; SOM has huge CEC, CEC holds onto herbicides - know your source!
- Can be full of weed seeds & pathogens
- Prevent water contamination from runoff and leaching


Oregon State Univ.


Chesapeake Bay Prog.

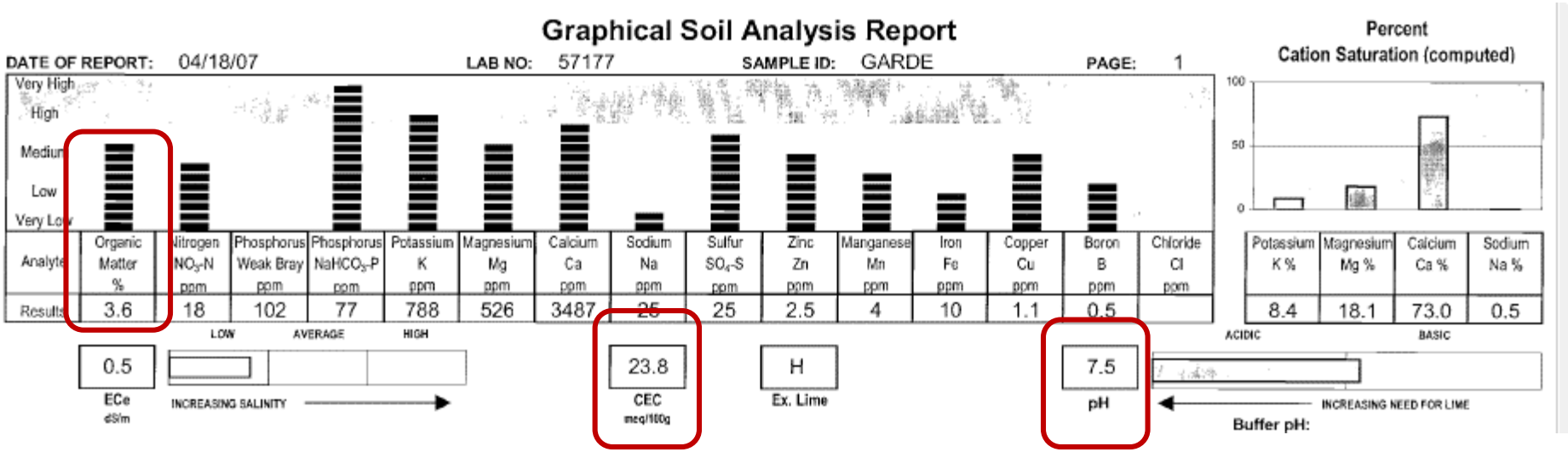
Questions?

On to other factors that influence soil nutrient management

What to else look for on a soil test report? Factors affecting plant health and production

Factor	Value	Impact/consider
Soil organic matter	≤ 1 (%)	Minimize bare soil, increase N, add legumes
	> 3 (%)	Extra N for heavy feeders (e.g. tomatoes, squash)
Soil pH	< 5	Poor seedling establishment
	< 6	Poor legume nodulation
	> 8.3	Nutrients tied up, possibly high Na
Soluble salts (EC)	> 4 (mmhos/cm)	Too saline, water stress, nutrient imbalance
Soil texture and CEC		Water and nutrient holding capacity

Gallatin Valley garden soil test report – info provided



Graphical Soil Analysis Report

DATE OF REPORT: 04/18/07 LAB NO: 57177 SAMPLE ID: GARDE PAGE: 1

Very High / High / Medium / Low / Very Low

Analyte	Organic Matter %	Nitrogen NO_3-N ppm	Phosphorus Weak Bray ppm	Phosphorus $NaHCO_3$-P ppm	Potassium K ppm	Magnesium Mg ppm	Calcium Ca ppm	Sodium Na ppm	Sulfur SO_4-S ppm	Zinc Zn ppm	Manganese Mn ppm	Iron Fe ppm	Copper Cu ppm	Boron B ppm	Chloride Cl ppm
Results	3.6	18	102	77	788	526	3487	25	25	2.5	4	10	1.1	0.5	
		LOW	AVERAGE		HIGH										

Percent Cation Saturation (computed)

Potassium K %	Magnesium Mg %	Calcium Ca %	Sodium Na %
8.4	18.1	73.0	0.5

ACIDIC BASIC

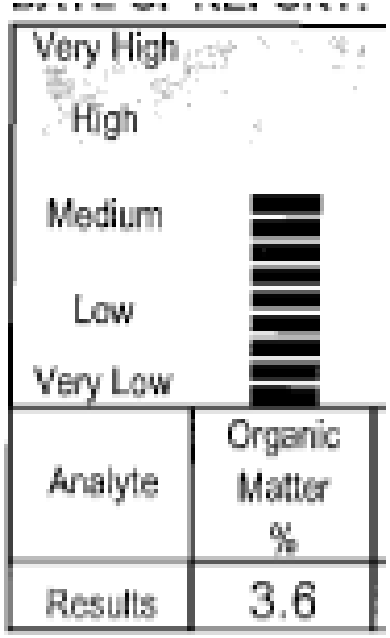
0.5 ECe dS/m — INCREASING SALINITY

23.8 CEC meq/100g

H Ex. Lime

7.5 pH — INCREASING NEED FOR LIME

Buffer pH:



- SOM
- CEC
- pH
- Texture is missing

See link below for Mason jar texture test

23.8

CEC

7.5

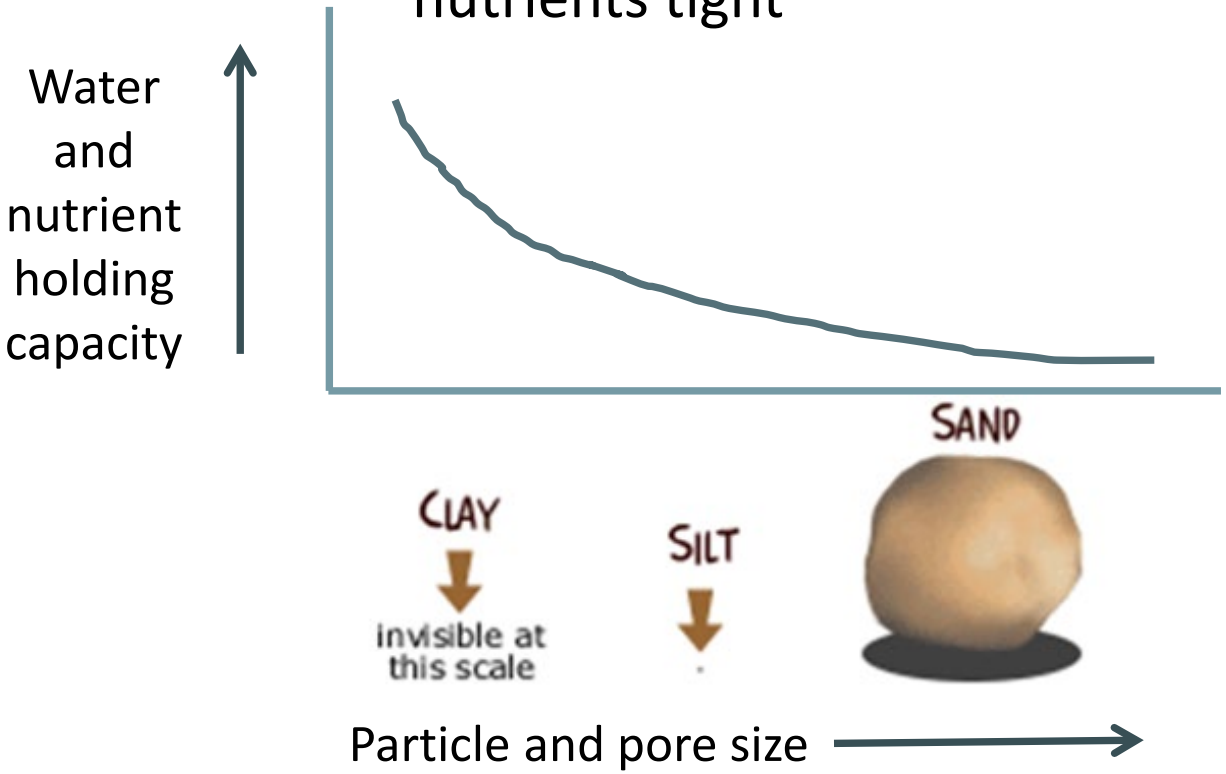
pH

http://landresources.montana.edu/soilfertility/documents/PDF/SoilTextureJarTest.pdf

Soil texture

Sand: large pore space, low surface area = low water or nutrient holding capacity

Clay: small pore space, large surface area, often negative charge on surface = holds water and nutrients tight



Ideal is **loam** to **clay loam** approx. equal parts of sand, silt, clay

Texture Effects on Soil Properties

	Drainage	Water holding capacity	Aeration	CEC
Sand	excellent	poor	excellent	low
Silt	good	good	good	medium
Clay	poor	excellent	poor	high

Soils with large surface areas, such as clay and organic matter, have more cation exchange capacity and surface area and therefore are generally more fertile.

Texture effect on soil properties

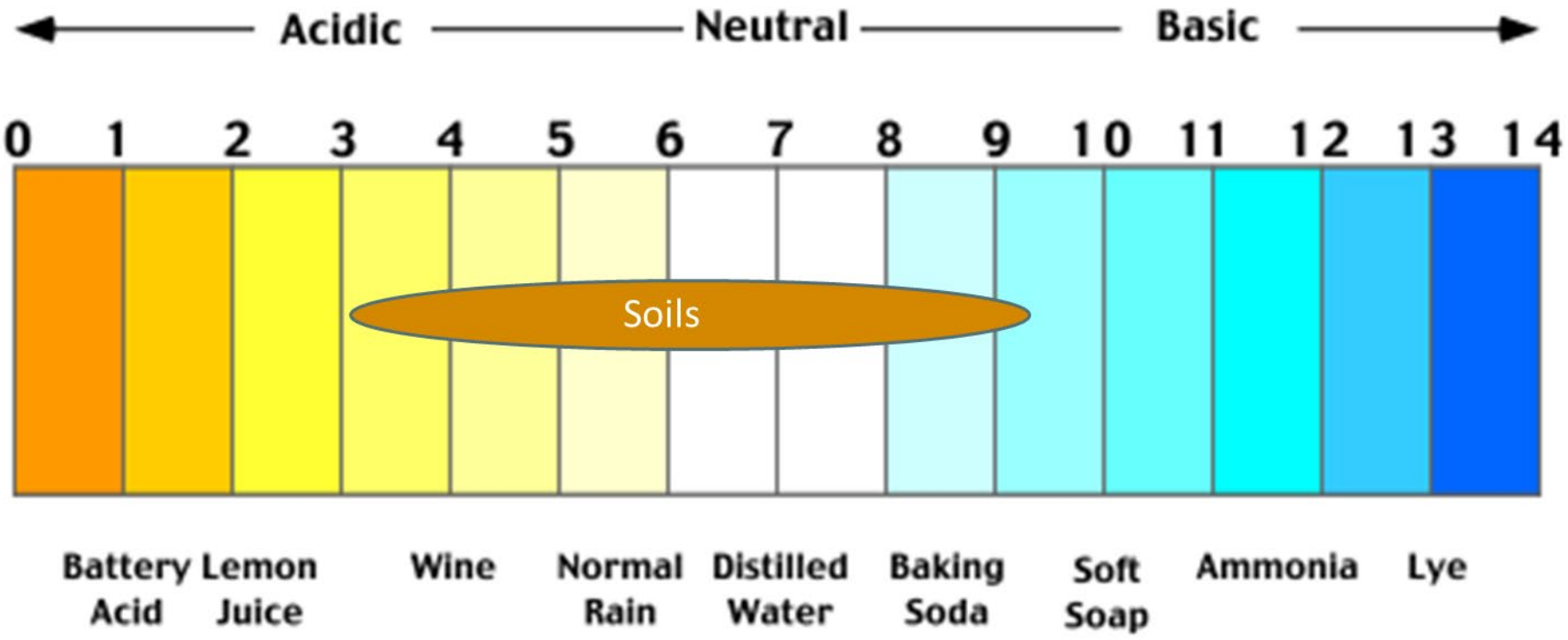
Water holding capacity would seem a benefit.
But, what are problems in clay soils?

- Surface pooling and runoff
- Compaction
- Drowned roots

Questions?

On to pH and Cation Exchange Capacity (CEC)

Soil pH

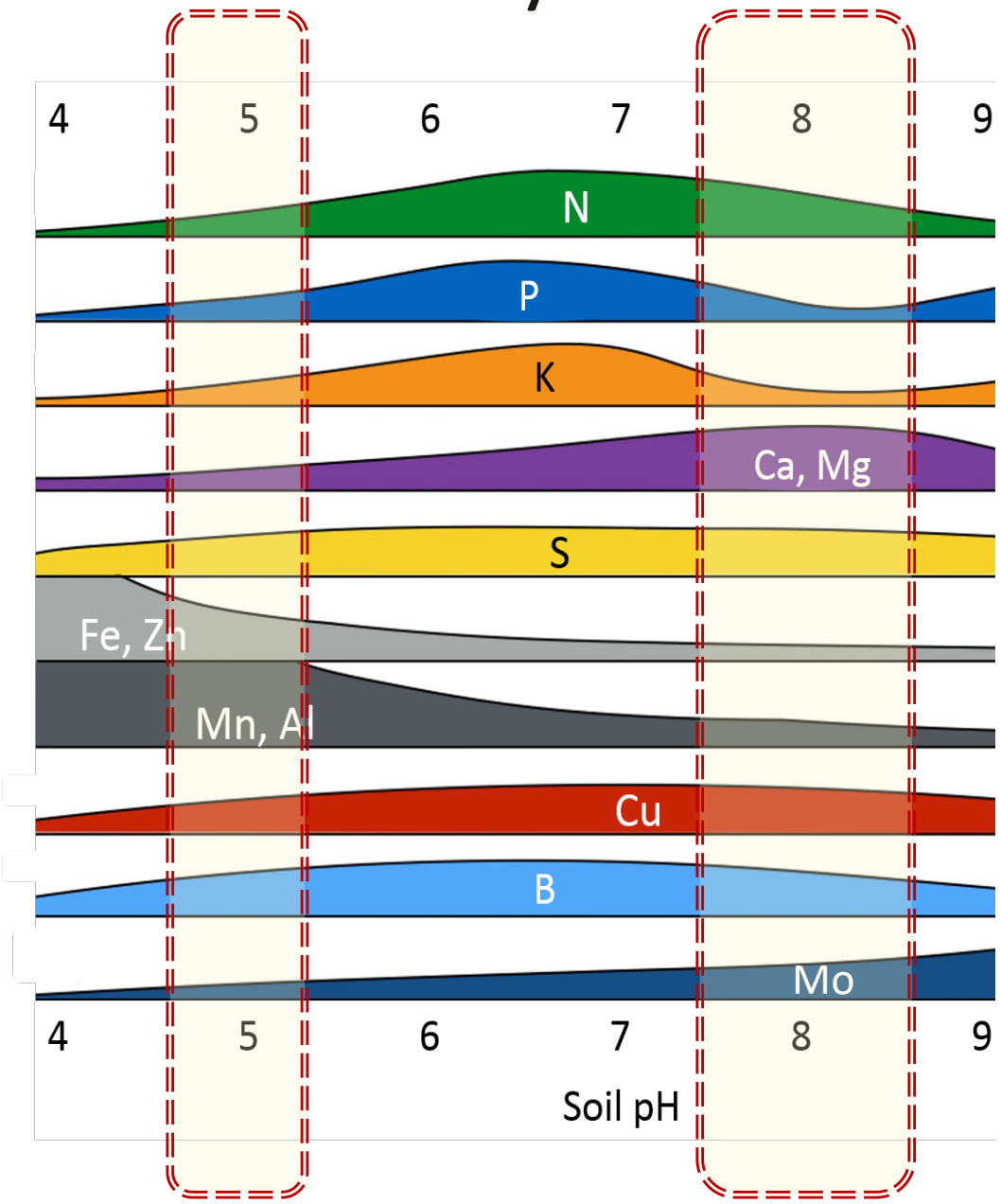


1. Vegetables vary in their preferred soil pH
2. Legumes prefer pH > 6 to fix N

pH affects soil nutrient availability

Low pH, acidic soils – may limit N, Ca, Mg, Mo because they don't stick tight and can leach away (Fe) or form minerals (P)

High pH, alkaline calcareous soils – may limit P, Fe, Mn, B, Cu, Zn because they stick tight to the soil, plant can't get them



What is the best option to lower pH in highly calcareous soils?

17% A. Add elemental sulfur (S)

17% B. Add gypsum ($CaSO_4$)

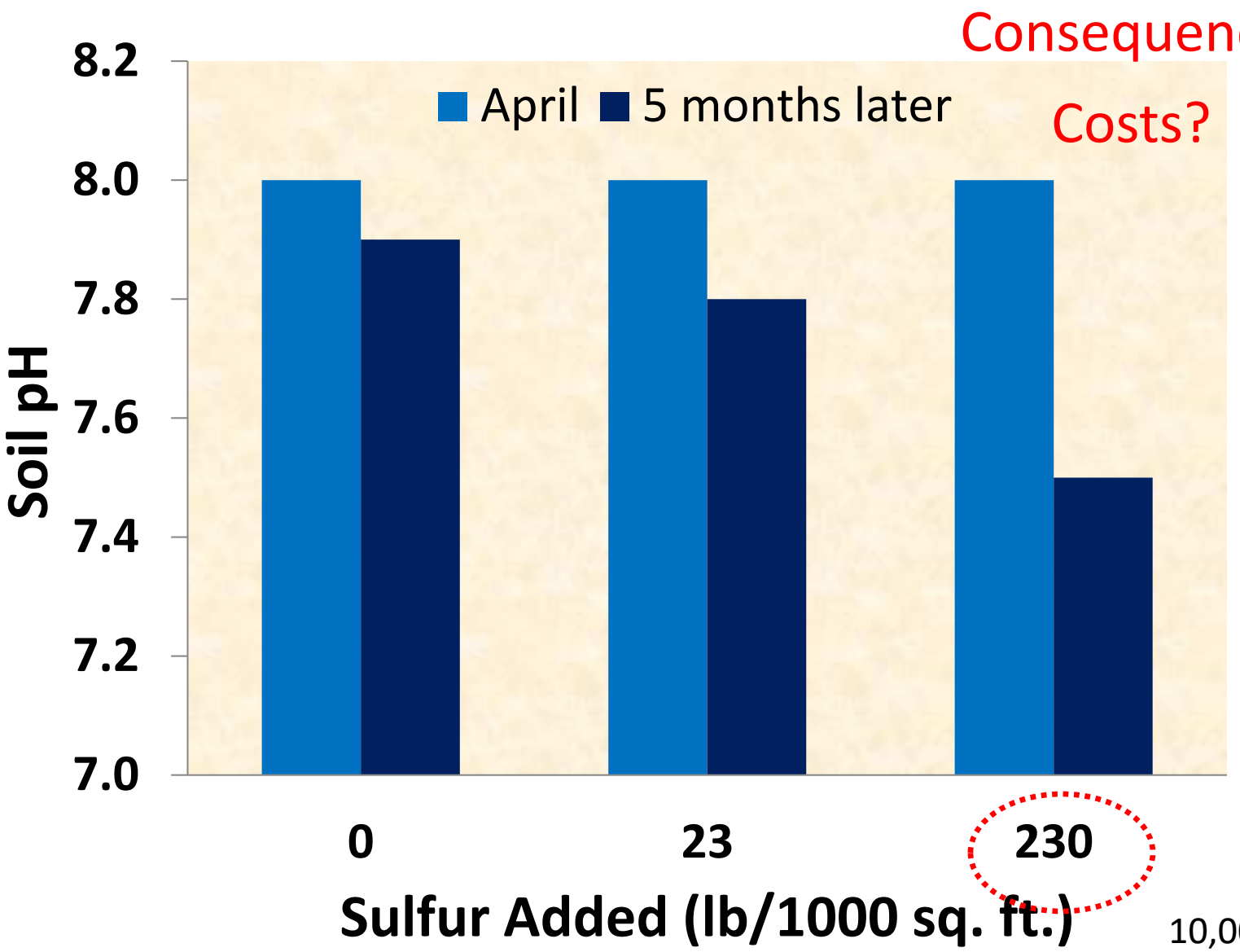
17% C. Add pine needles

17% D. No reasonable option to lower significantly and QUICKLY on LARGE scale

17% E. Use ammonia based N fertilizers (e.g., urea)

17% F. Plant legumes

Adding elemental sulfur



AgVise Laboratories

What might happen if you add 230 lbs S/1000 sq. ft.?

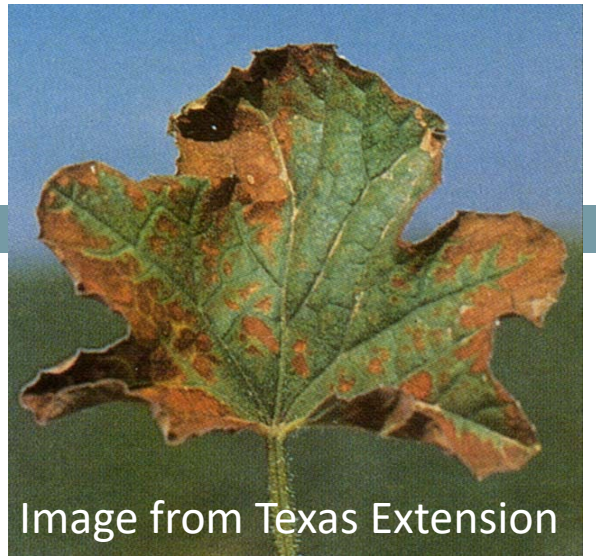


Image from Texas Extension

- Soil S levels may become toxic
- Soil salt levels may become toxic
- You spend $366/1000 sq ft

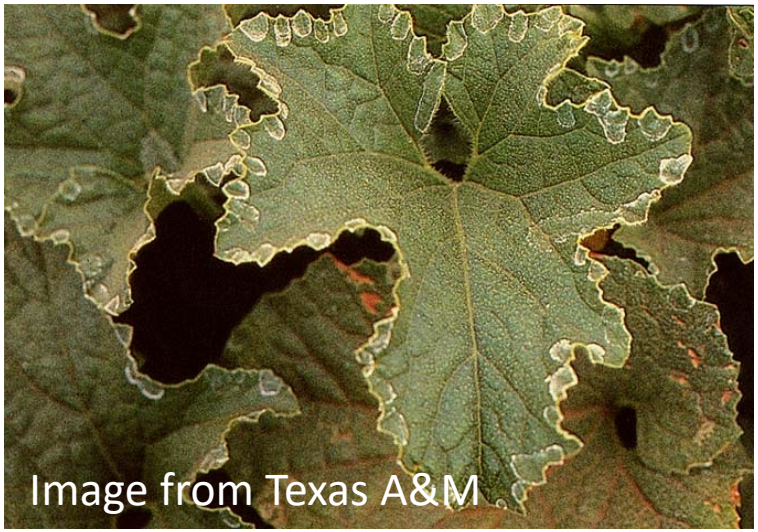


Image from Texas A&M

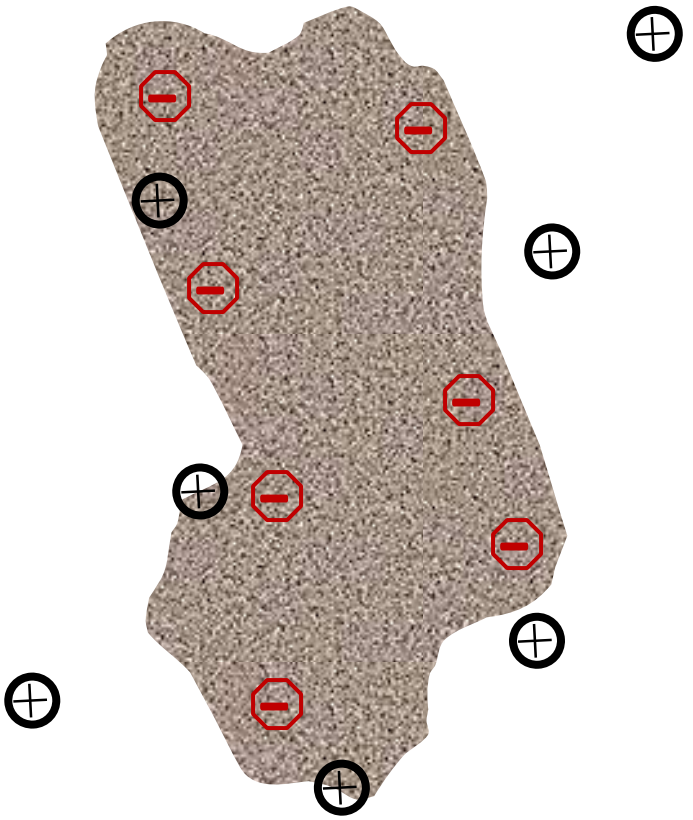
Select plants suitable to your soil's pH

The Mission and Flathead Valleys grow blueberries, the Gallatin Valley grows sweet peas!

Cation Exchange Capacity CEC – the parking spaces for nutrients in the soil

- CEC is the total neg. charge on a soil
- A high CEC soil (> 15) has the capacity to attract and hold nutrients with positive charges, e.g., K^+, Zn^{+2}, NH_4^+
- Soils with large surface areas, such as clay and SOM, have more CEC and therefore are generally more fertile.
- What else might high CEC soils hold onto?

Herbicides



Management influenced by CEC and texture

- Water
  - low CEC soils – short frequent irrigation (daily) – to avoid leaching nutrients
  - high CEC soils – tend to be clay, slow irrigation less often (e.g., low flow emitters, every 3-4 days)
- Nutrients
  - low CEC soil, a little at a time to avoid leaching loss
  - High CEC, incorporate them – to avoid runoff and get to plant roots

Low soil organic matter is rarely an issue in gardens

Questions?

On to visual assessment

Visual assessment

- May identify what has been lacking to this point, likely can correct in time in garden environments.
- Sulfur soil tests are not reliable. Use visual symptoms (yellow or light green upper leaves)

Image by K. Olson-Rutz

pea image by C. Jones

tomato image from Wikipedia

Image by IPNI

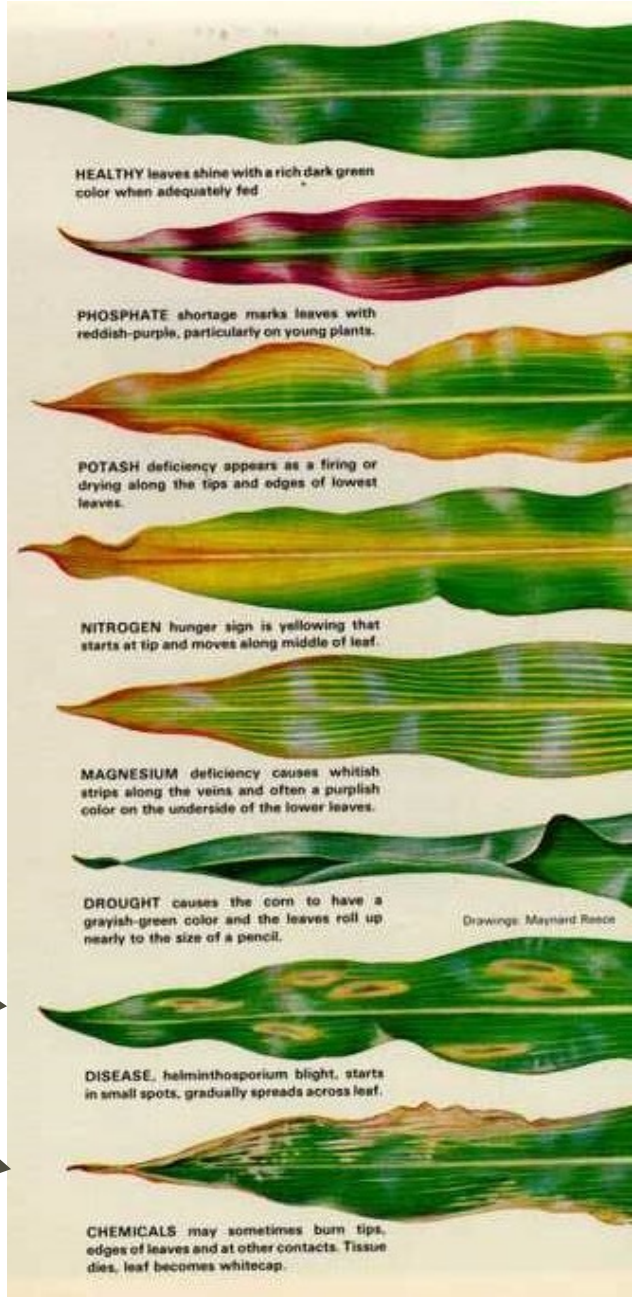
Examples posted at

http://landresources.montana.edu/soilfertility/nutrientdeficiencies.html

Visual assessment of tissue

Other issues can cause symptoms that look like nutrient deficiency symptoms

- Insects
- Salinity
- Moisture stress
- Disease
- Herbicides



Ontario Ministry of Ag., Food & Rural Affairs

Summary

- Understanding soils leads to wise nutrient use and promotes maximum plant health and yields
- Soil testing is an important tool to help prevent or correct plant growth problems, and protect the environment from over-fertilization
- The foundation of a healthy garden is a healthy soil
- Observe and adjust to your specific conditions

Questions?

For additional information:

Home garden soil testing and fertilization guidelines
http://landresources.montana.edu/soilfertility/home-gardening.html

Nutrient deficiency symptoms
http://landresources.montana.edu/soilfertility/nutrientdeficiencies.html

The Soil Scoop
http://landresources.montana.edu/soilfertility/soilscoop.html

MSU Extension catalog
http://store.msuextension.org

- *Using Manure as Fertilizer* (EB0184)
- *Home Composting* (MT199203AG)
- *Manure Composting* (MT201206AG)