Soil Testing and Soil Health: Forage Focus

Sanders County Soils Workshop
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Clain Jones, Soil Fertility Specialist

clainj@montana.edu 994-6076

Image by
Ann Ronning

Why should land owners know something about soils?

- For healthy plants, tasty vegetables, good forage yields, and cover for livestock and wildlife
- To protect the environment
- For efficient use of resources (water, fertilizer, $)

Today's topics

- Explain soil health vs quality
- Present what can be learned from a soil test
  - Soil nutrients
  - Soil properties
- Explain limitations, to know which properties you can influence
- Provide fertilizer guidelines and example calculation for forage
- Compare fertilizer sources
- Consider options other than soil tests to guide soil nutrient management

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%

Response Counter

What describes a good soil?

- Good aeration, drainage and tilth
- Organic matter and organisms!
- Doesn’t crust after planting
- Soaks up heavy rains with little runoff
- Stores moisture for drought periods
- Has few clods and no hardpan
- Resists erosion and nutrient loss
- Produces healthy, high quality vegetables and crops

Soil Quality vs Soil Health

Soil Quality = properties that change little, if at all, with land use management practices

- Texture
- pH
- Cation Exchange Capacity

Which is measured with conventional soil tests?

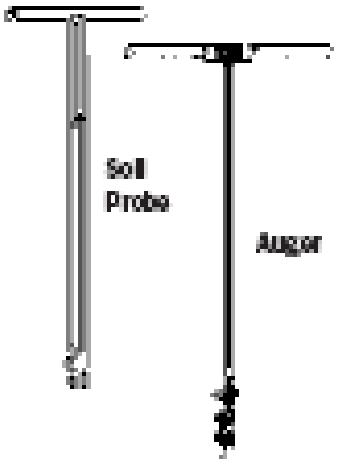
Soil Health = dynamic properties which may be subjective to measure, but can be changed

- Aggregation
- Microbial activity
- Tilth
- Nutrient availability
- Water holding capacity
- Compaction

SOM often is included in both lists

Soil test

- To identify nutrient deficiency or imbalance
- To help calculate fertilizer rates
- Can increase yield and/or save on fertilizer costs, and decrease environmental risks
- Best done in early spring, but not when soil is wet, therefore in our climate perhaps best done in late fall
- See publications listed at end for details on ‘how-to’



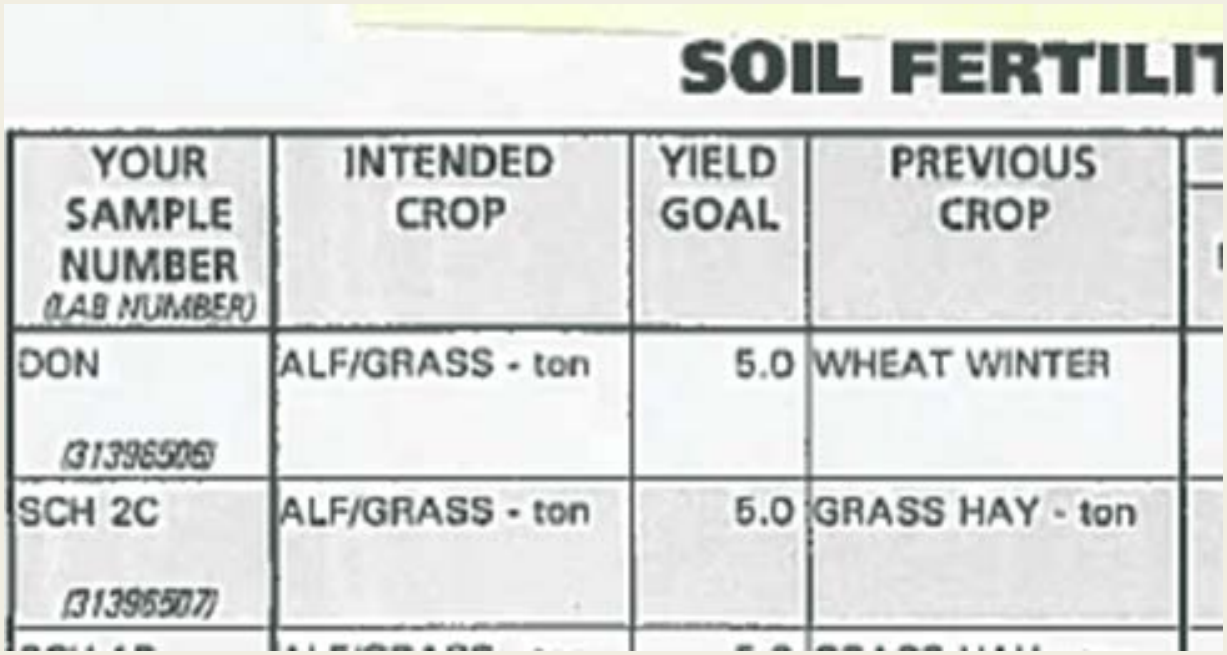
What to look for on a soil test report? Factors affecting plant health and production

Factor	Value	Impact/consider
Nutrient content	Nutrient dependent	Too little = hungry plants, too much = contaminate water, burn plants
Soil organic matter	≤ 1 (%)	Minimize bare soil, increase N, add legumes
	> 3 (%)	Little need for extra N on pasture
Soil pH	< 5	Poor seedling establishment
	< 6	Poor legume nodulation
	> 8.3	Nutrients tied up
Soluble salts (EC)	> 4 (mmhos/cm)	Too saline, water stress, nutrient imbalance
Soil texture and CEC		Water and nutrient holding capacity

Soil test report for 2 fields near Hot Springs, Sanders Co.

SOIL FERTILITY RECOMMENDATIONS (POUNDS PER ACRE)

YOUR SAMPLE NUMBER (LAB NUMBER)	INTENDED CROP	YIELD GOAL	PREVIOUS CROP	SOIL AMENDMENTS: LIME LBS/A OF	LIME TON	GYPSUM TONS/A		ELEMENTAL SULFUR LBS/A	N NITROGEN	P_2O_5 PHOSPHATE	K_2O POTASH	Mg MAGNESIUM	S SULFUR	Zn ZINC	Mn MANGANESE	Fe IRON	Cu COPPER	B BORON
DON (31396506)	ALF/GRASS - ton	5.0	WHEAT WINTER			0.3	OR	50	55	130	175	--						
SCH 2C (31396507)	ALF/GRASS - ton	5.0	GRASS HAY - ton						60	135	205	--						



SOIL FERTILI

YOUR SAMPLE NUMBER (LAB NUMBER)	INTENDED CROP	YIELD GOAL	PREVIOUS CROP
DON (31396506)	ALF/GRASS - ton	5.0	WHEAT WINTER
SCH 2C (31396507)	ALF/GRASS - ton	5.0	GRASS HAY - ton

Important info:

- Intended crop
- Yield goal
- Prior crop

Soil test report for 2 fields near Hot Springs, Sanders Co.

LAB NUMBER	NITRATE-N (FIA)									Total lbs/A	SULFUR S ICAP		ZINC Zn DTPA		MANGANESE Mn DTPA		IRON Fe DTPA		COPPER Cu DTPA		BORON B BORIL DTPA		EXCESS LIME RATE	SOLUBLE SALTS 1:1 mmhos/cm	
	SURFACE			SUBSOIL 1			SUBSOIL 2																		
313	ppm	lbs/A	depth (in)	ppm	lbs/A	depth (in)	ppm	lbs/A	depth (in)		ppm	RATE	ppm	RATE	ppm	RATE	ppm	RATE	ppm	RATE	ppm	RATE			
96506	8	19	0-8							19															
96507	5	12	0-8							12															

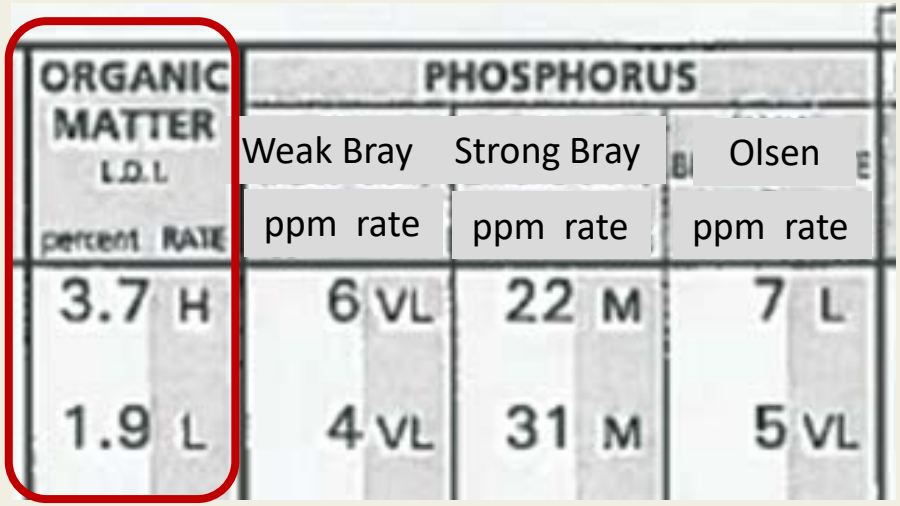
LAB NUMBER	NITRATE-N (FIA)									Total lb/ac
	SURFACE			SUBSOIL 1			SUBSOIL 2			
313	ppm	lb/ac	depth (in)	ppm	lbs/A	depth (in)	ppm	lbs/A	depth (in)	
96506	8	19	0-8							19
96507	5	12	0-8							12

To determine N rate you need:

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

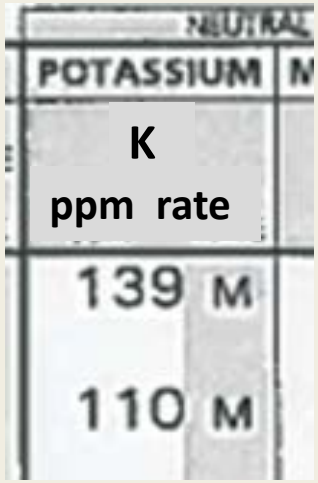
Soil test report for 2 fields near Hot Springs, Sanders Co.

LAB NUMBER *313*	SAMPLE IDENTIFICATION	ORGANIC MATTER L.O.I.	PHOSPHORUS			POTASSIUM	MAGNESIUM	CALCIUM	SODIUM	pH		CATION EXCHANGE CAPACITY C.E.C.	PERCENT BASE SATURATION (COMPUTED)				
			P1 (WEAK BRAY) Lt7	P2 (STRONG BRAY) Lt7	OLSEN BICARBONATE P	K	Mg	Ca	Na	SOIL pH 1:1	BUFFER INDEX		% K	% Mg	% Ca	% H	% Na
		percent RATE	ppm RATE	ppm RATE	ppm RATE	ppm RATE	ppm RATE	ppm RATE	ppm RATE			meq/100g					
96506	DON	3.7 H	6 VL	22 M	7 L	139 M	365 VH	2629 H	151 VH	8.1		17.2	2.1	17.7	76.4	0.0	3.8
96507	SCH 2C	1.9 L	4 VL	31 M	5 VL	110 M	243 VH	2009 H		7.5		12.4	2.3	16.3	81.4	0.0	

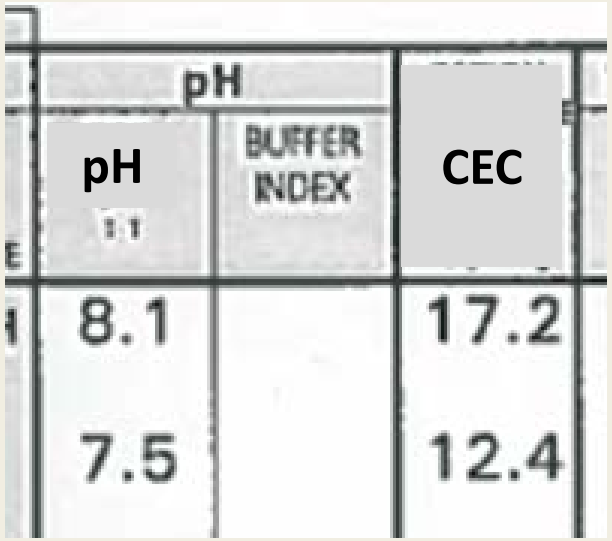


ORGANIC MATTER L.O.I.		PHOSPHORUS			
		Weak Bray		Strong Bray	Olsen
percent	RATE	ppm	rate	ppm rate	ppm rate
3.7	H	6	VL	22 M	7 L
1.9	L	4	VL	31 M	5 VL

- P: MSU guidelines are based on Olsen P. Bray works in pH < 7.3, Olsen works pH > 6.
- SOM: soil organic matter
- K
- pH and CEC

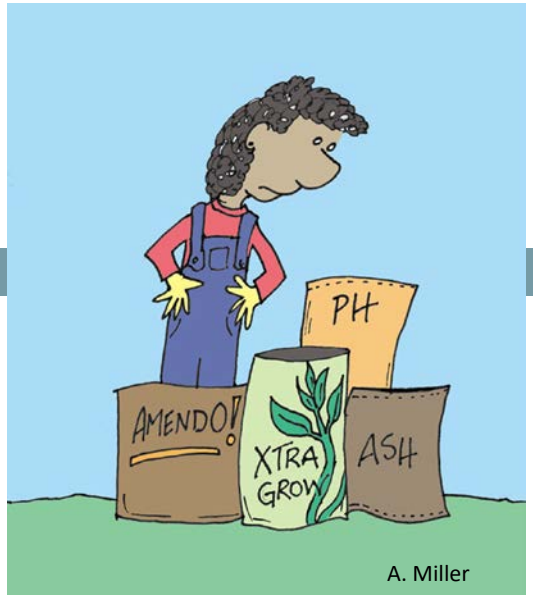


POTASSIUM	
K	
ppm	rate
139	M
110	M



pH		
pH 1:1	BUFFER INDEX	CEC
8.1		17.2
7.5		12.4

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

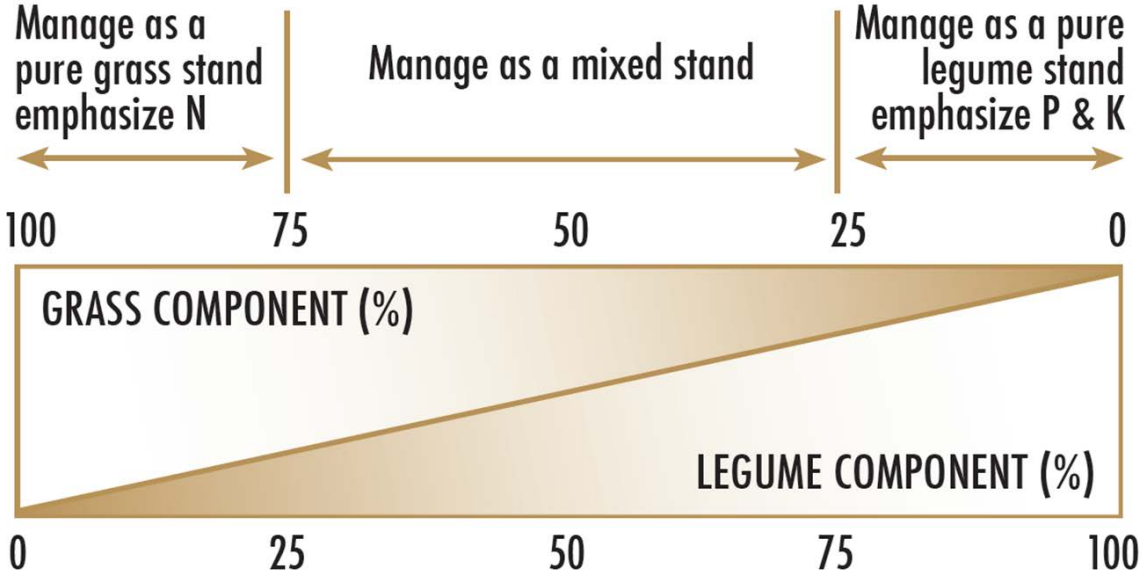


Six questions to ask yourself before you add fertilizer

1. Which elements do I need? (N, P, K, S, Ca)
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?

How much fertilizer do I need to apply?

- Estimate the amount of fertilizer needed based on soil test results and desired production
- Focus of N vs P & K fertilization in forages depends on % legume in stand.
- MSU bulletins provide rate guidelines and MT200703AG gives example calculations



Fertilizing with nutrients other than N favors legumes over grass

Your turn

	OM %	Nitrate –N lb/ac	P ppm	K ppm	pH
Test	1.8	15	13	200	7.5

Using this data and tables from the 2 forage soil scoops, how much N, P, and K are required to grow 3 ton/acre of grass?

N, P, and K rates?

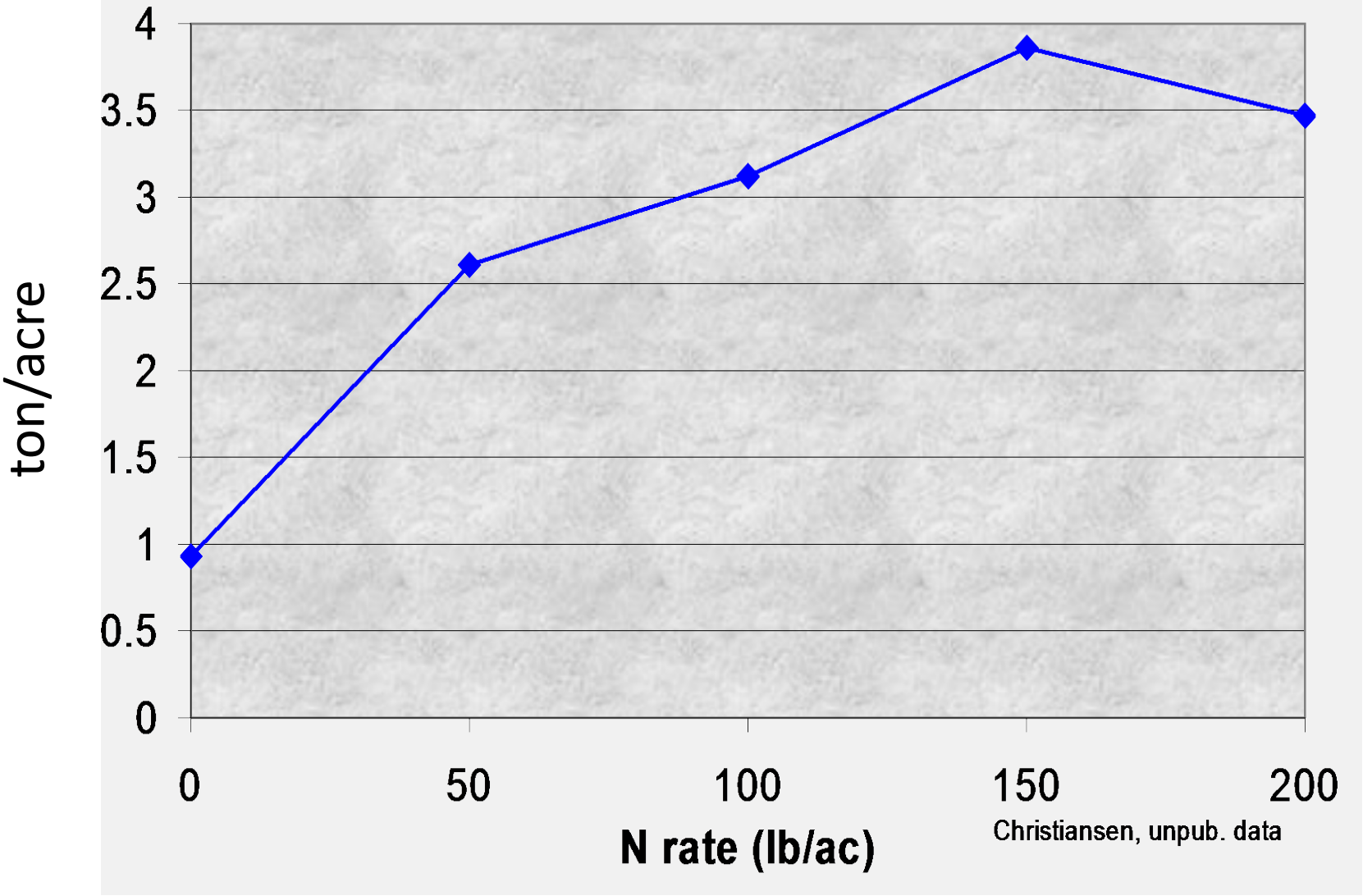
	OM %	Nitrate –N lb/ac	P ppm	K ppm	pH
Test	1.8	15	13	200	7.5

Nutrient	Forage (lb/acre)
N	60*
P_2O_5	~20
K_2O	30

*Need to subtract out soil nitrate-N from available N need

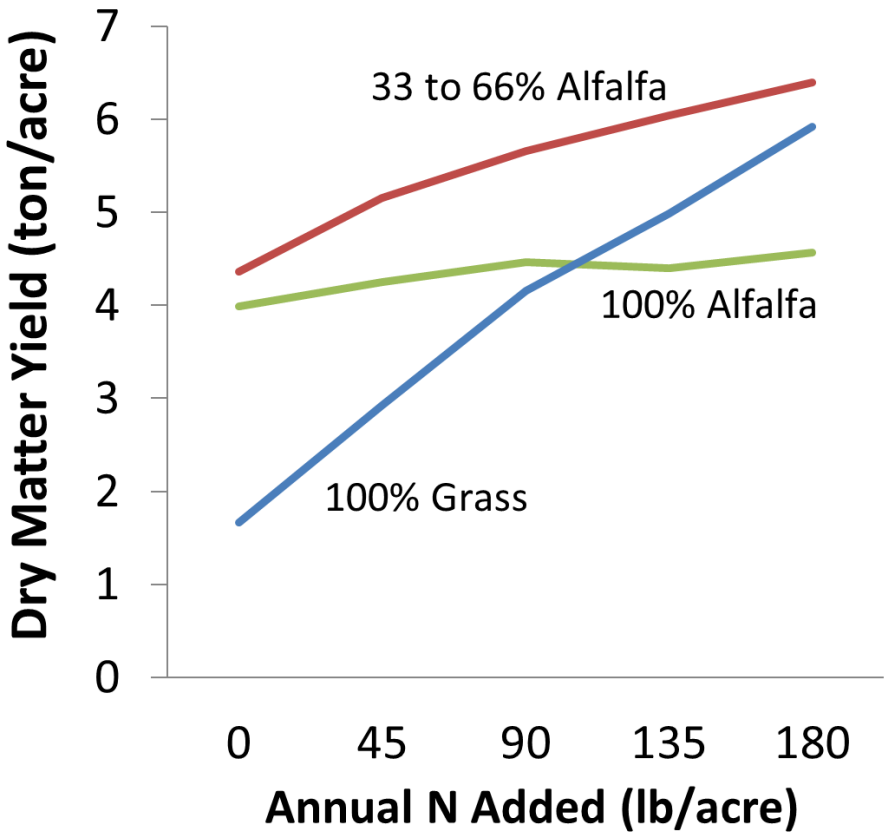
Diminishing return of increasing N

Applies to all crops, example on irrigated western wheatgrass, Blaine Co.



Challenges to high N use efficiency in perennial systems, and N options

- Urea needs 0.5” water or tillage to incorporate N
- Plant residue
  - intercepts fertilizer
  - increases volatilization
  - can tie up N
- Surface band liquid N
- Polymer coated N works for extended forage season or late cutting
- Legume in pasture mix or legume cover crop in market gardens may be best N source



Malhi et al. 2002, Eckville, Alberta

17.5” avg annual and 10.5” May-Aug precip

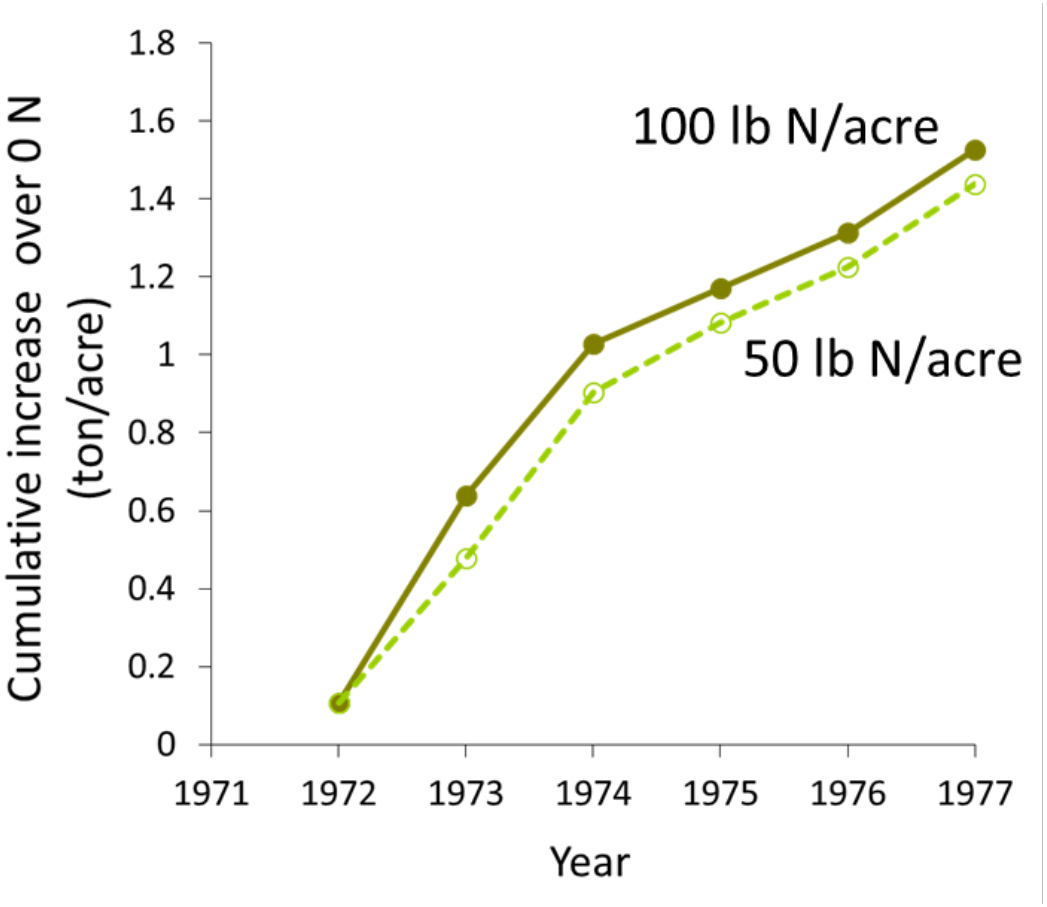
Sulfur tissue tests and visual symptoms are better than soil tests

- Standard sulfate soil test too unreliable
- Better to use
  - visual symptoms (yellow or light green upper leaves)
  - tissue tests critical values provided by lab or our documents
  - Last year production performance

Wheat, image from IPNI

Forage fertilization strategy

- If a field containing < 75% legumes will be rotated to a different crop soon, consider N for immediate gain
- If goal is low input, long-term sustainable production rather than prime quality hay, adequate P and K are key and cheaper than re- or interseeding
- If you need to buy hay or rent pasture, consider fertilizing for long term benefit
- A single 50 lb N/acre on dryland grass was more economical over 5-yrs than a single 100 lb N/acre



Lorbeer et al. 1994, Jacobsen et al.1996, Havre

P and K fertilization strategy

Is a single 100-400 lb P_2O_5/ac on dryland alfalfa as good as the same amount divided over 5 annual applications?

50% A. Yes

50% B. No

A large application produced similar yield, protein and profit as 5 small annual applications (central Alberta, Malhi et al. 2001).

Immobile nutrients can be banked – know soil test levels and if low, build up P and K when prices low

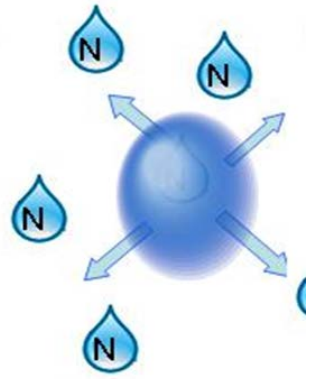
Response Counter

Questions?

On to conventional vs organic matter

Conventional/chemical fertilizers

- No carbon
- Easy to store
- Higher nutrient concentration
- Custom formulated
- Easy to use – but calibrate your equipment
- Liquid and solid
- Coated specialty products reduce leaching, volatilization, runoff losses.



Organic Fertilizers

- Bulkier
- Nutrient content low
- Nutrient content difficult to quantify
- Supply organic matter and other soil quality benefits

	General % of dry weight		
Type	N	P_2O_5	K_2O
Manure compost	0.3 - 0.5	0.1 – 0.5	0.2 – 0.6
Garden waste	1 – 1.5	0.2 – 0.5	0.5 – 1.5

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.]	3.4	0.3	3.2	
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.] Morris, Ping, and Durgy. University of Connecticut.
http://www.newenglandvfc.org/pdf_proceedings/SoilOrganicAmend.pdf

Response Counter

Application considerations

Conventional

- Do not apply on snow, before heavy rains or snowmelt
- Apply and incorporate (nitrogen) shortly before plants ‘take off’ in the spring
- Broadcast N fertilizer needs to be incorporated by tillage or ½” water ‘event’
- Provide additional N mid-season if needed

Specialty slow release

- Incorporate and apply early in growing season or use blend of quickly available source and slow release

Application considerations: organic material

- Incorporate in the fall or spread composted in the spring, once ground thaws, but before growth starts
- Do not apply on snow or frozen ground
- N can be ‘tied up’ due to high C
- Manure:
  - Creates rapid buildup of P and K if fertilizing to meet N needs. Feed to P and K demands and use legumes to supply N
  - Consider the salt, weed seed and pathogen content
  - Herbicide residual; SOM has huge CEC, CEC holds onto herbicides - know your source!

Questions?

On to other factors that influence soil nutrient management

What else from a soil test?

Published rates are developed for entire state and sometimes based on neighbor state's trials. They are likely not accurate for a particular field.

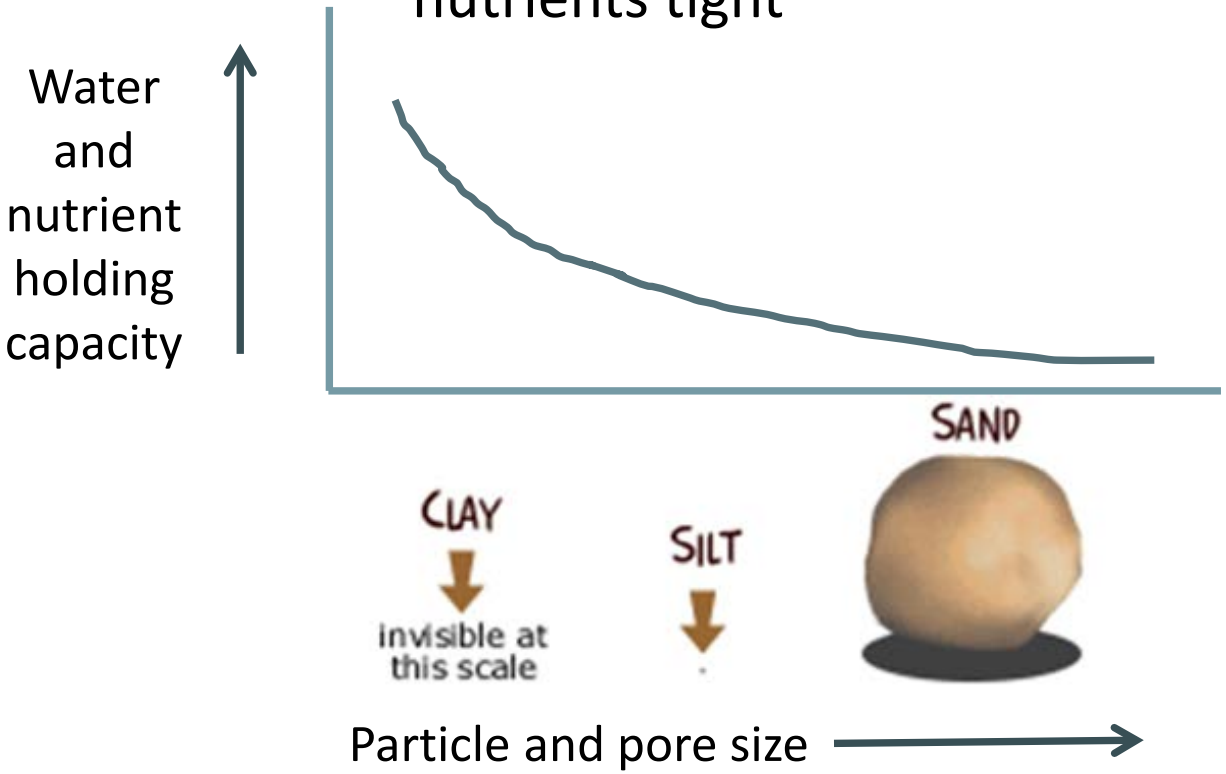
Which soil property does **NOT** influence *nutrient* availability?

22%	A.	Texture/surface area
21%	B.	pH
16%	C.	CEC (cation exchange capacity = the parking spaces in soil for nutrients)
18%	D.	SOM (soil organic matter)
24%	E.	Color

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

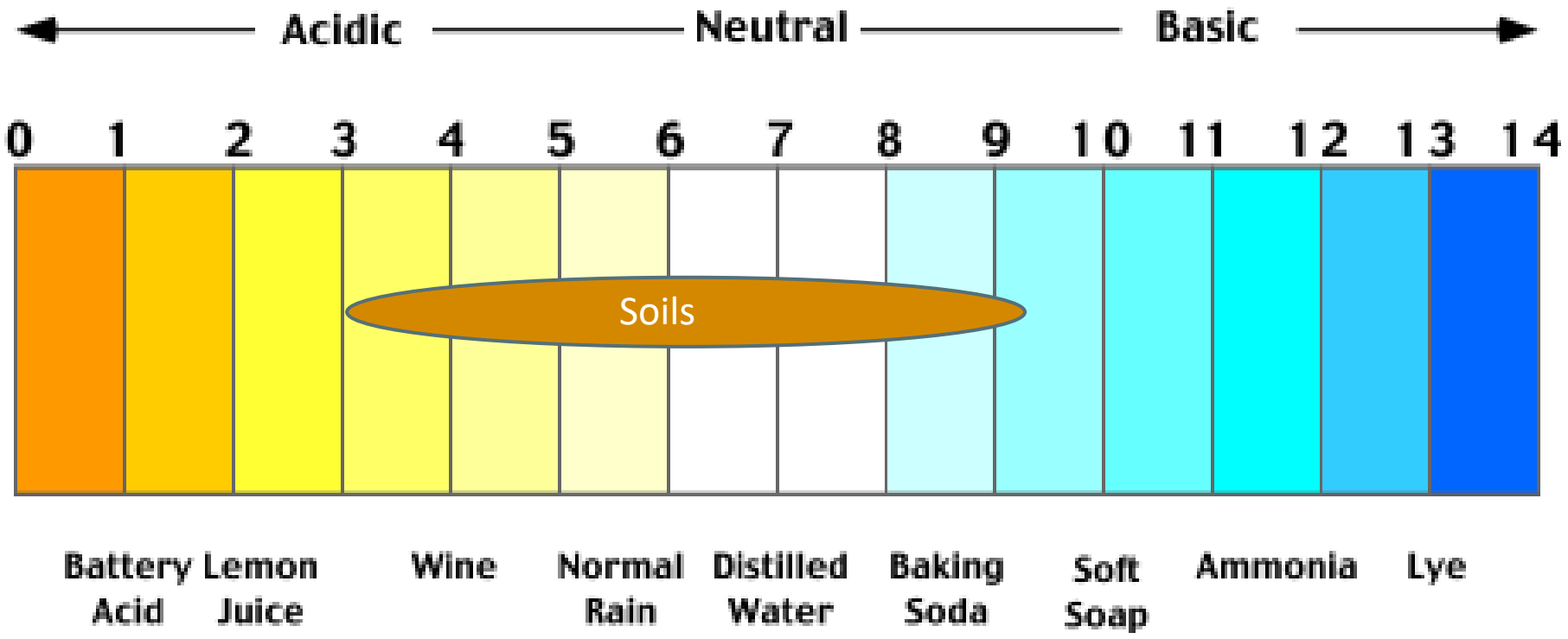
	Drainage	Water holding capacity	Aeration	CEC
Sand	excellent	poor	excellent	low
Silt	good	good	good	medium
Clay	poor	excellent	poor	high

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.

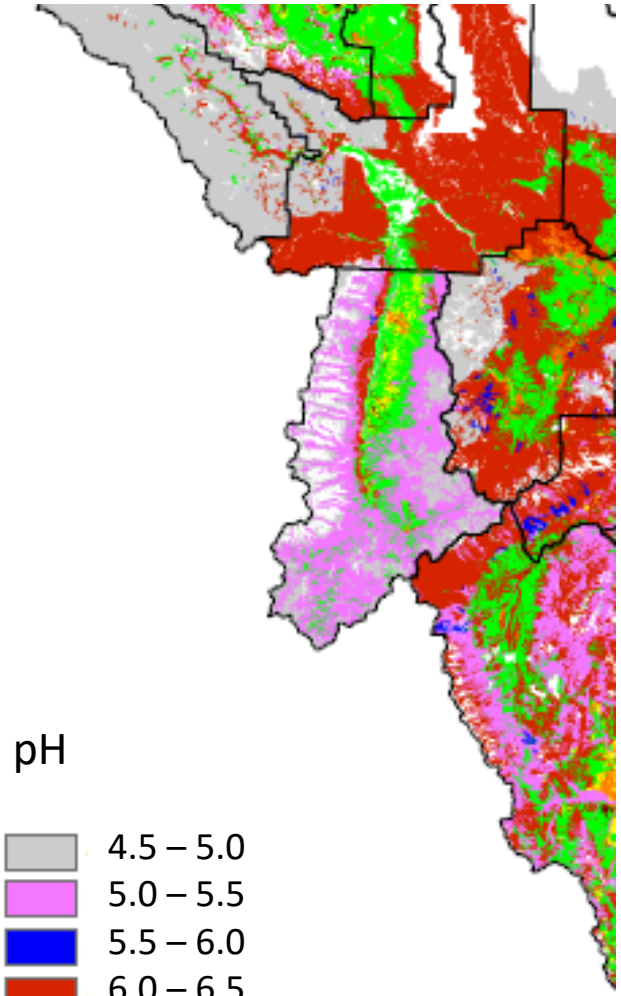
Soil pH – which is true?

Respon se Counter

1. Has no influence on nutrient availability 25%
2. Is difficult to alter 25%
3. Most vegetables prefer pH > 7.5 25%
4. Legumes prefer pH < 6 to fix N 25%

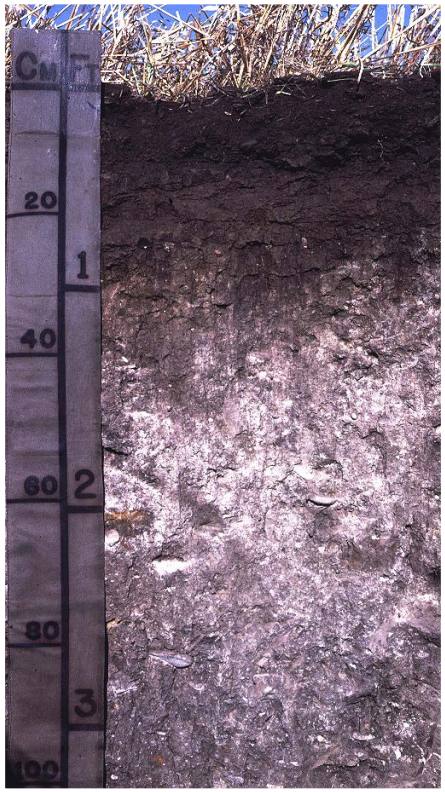


What are surface horizon pH values in this region?



Map courtesy of NRCS

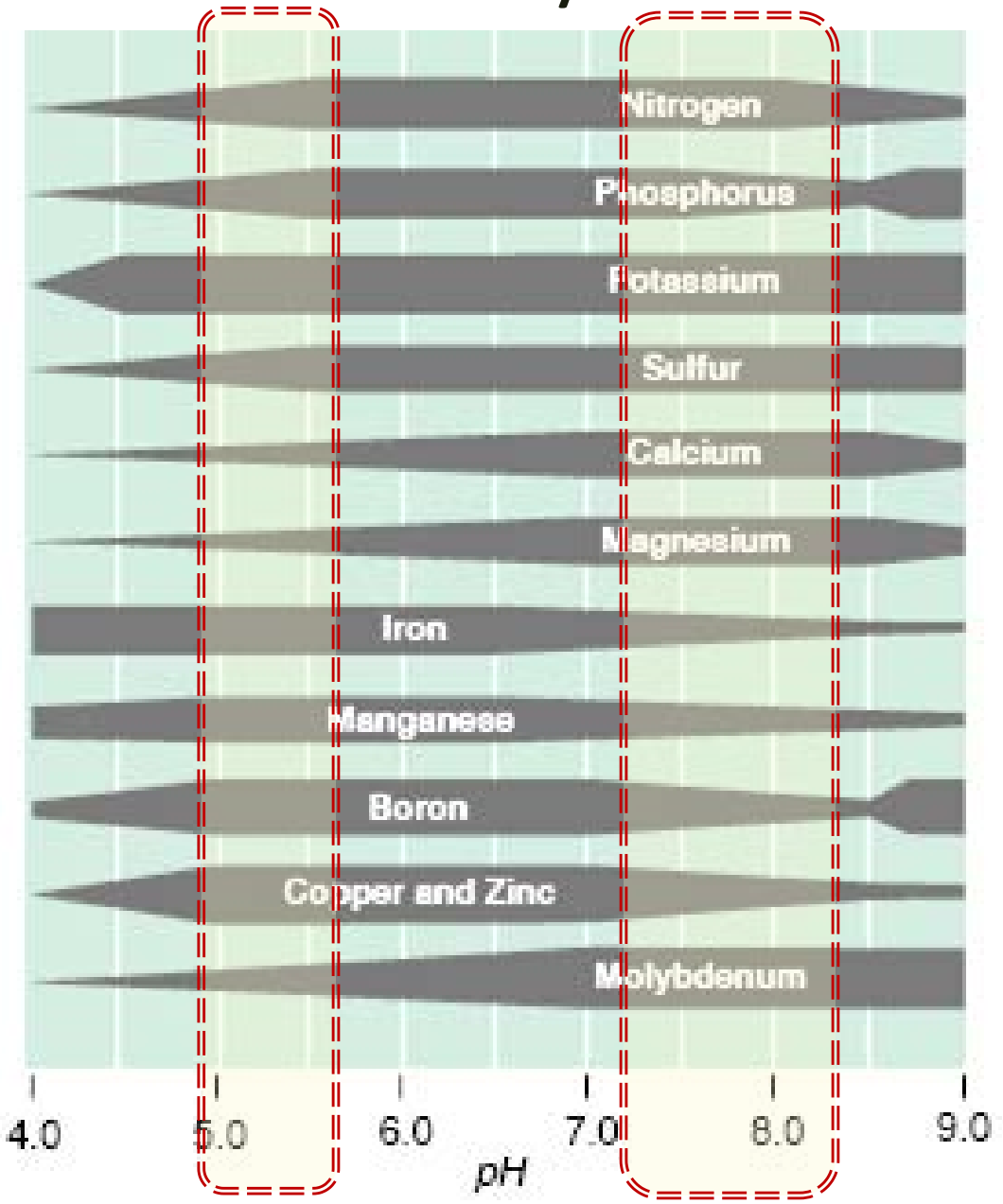
There are known areas in western Montana with top 6” pH < 5.5
Ex: Near Hamilton and Plains,
Other areas have pH levels near 8.0.



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

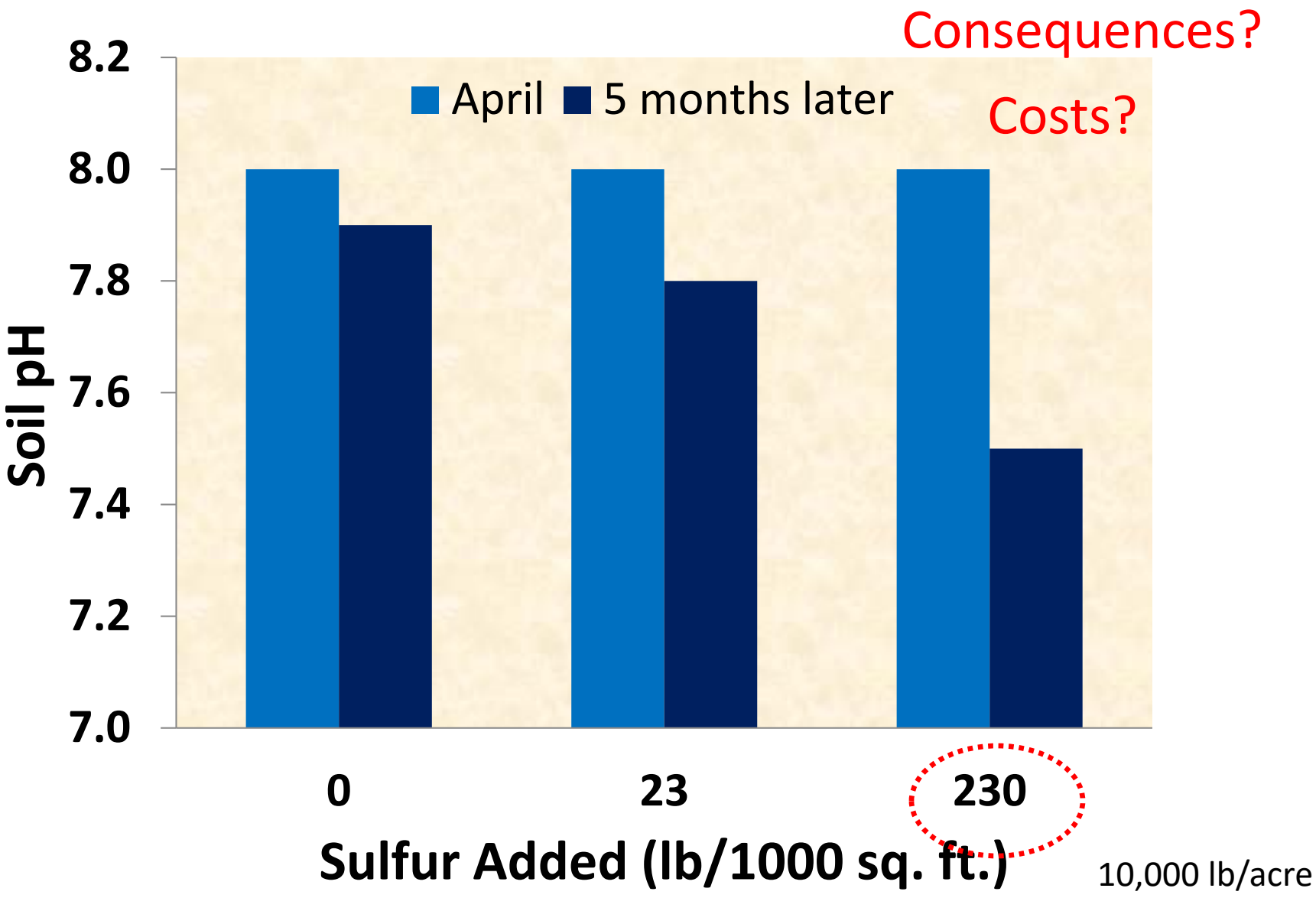
17% D. No reasonable option to lower significantly and QUICKLY on LARGE scale

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

17% F. Plant legumes

Response Counter

Adding elemental sulfur



AgVise Laboratories

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

A.	You spend $366/1000 sq ft	25%
B.	Your soil pH will drop by at least 1.5 units	25%
C.	Soil S levels will remain well below toxic	25%
D.	Soil salt levels will improve	25%

Response Counter

Same study site – added 115 lbs gypsum /1000 sq. ft. with no change in soil pH

Acid soils have many negative impacts

- Herbicide persistence (Raeder et al., 2015)
- Damaging to rhizobia (N-fixing by legumes)
- Increase in fungal diseases
- Increase Al and Mn to toxic levels

Images from Creative Commons

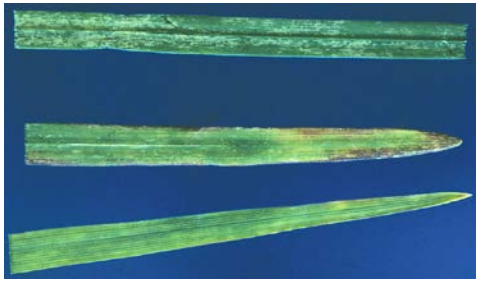
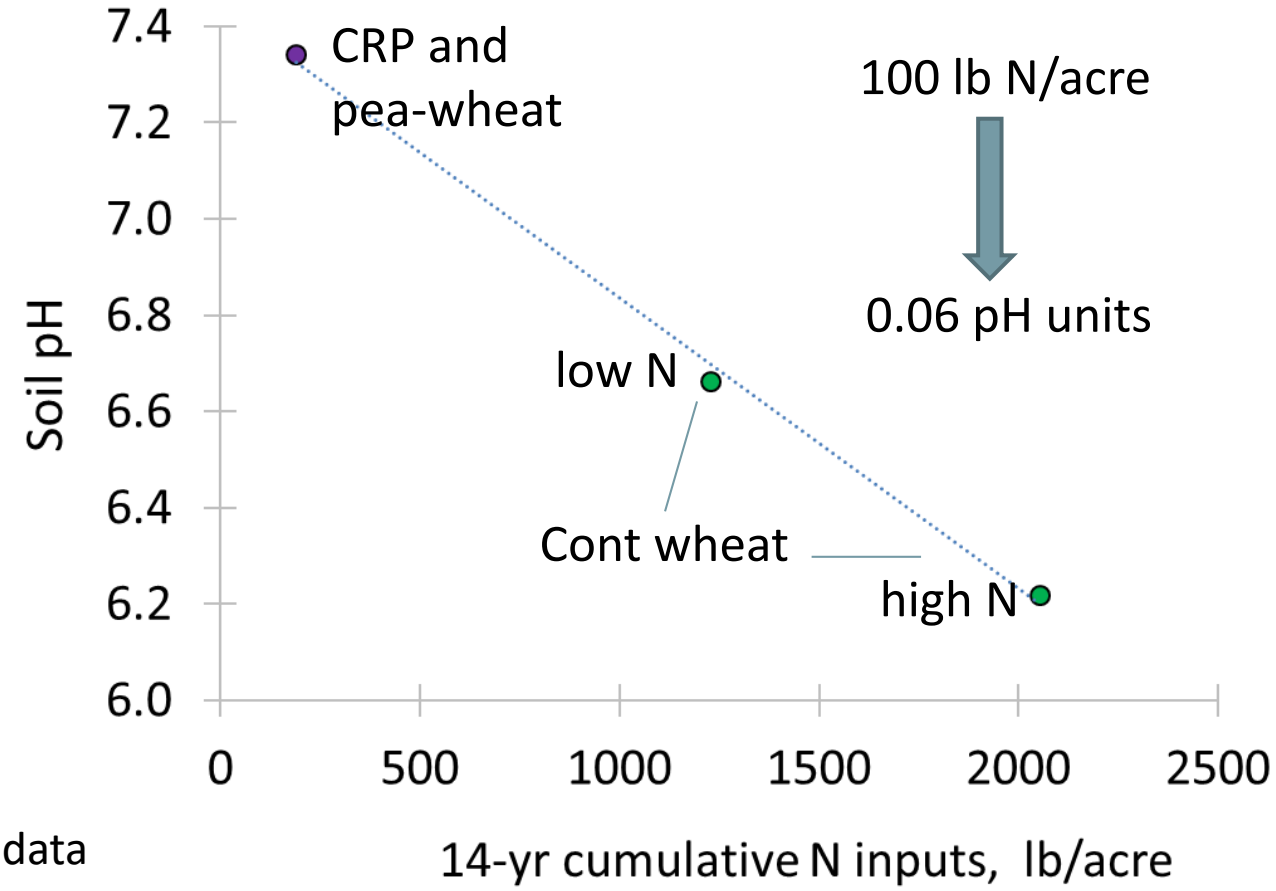


Image from CIMMYT, Int.

Factors that contribute to acidification

- Coarse soils
- Higher precipitation
- No-till (less subsoil mixing)
- Excess N fertilization
- See *Soil Acidification* Soil Scoops. Rick Engel is developing MT specific recommendations

- Low organic matter
- Stubble or hay removal



Engel, Ewing, Miller unpub data

Select plants suitable to your soil's pH

Crop	Preferred pH
Sweet pea	7 - 8
Blueberry	4.5 – 6.0
Raspberry	5.0 – 7.5
Burr clover	> 7
Alfalfa	> 5.7
Blue grama grass	> 7
White clover	< 7

You grow blueberries, the Gallatin Valley grows sweet peas!

Select species suitable for pH and soil type, see: *Dryland Pastures in MT and WY*

Questions?

On to cation exchange capacity CEC and soil organic matter SOM

SOM = Soil organic matter

Response Counter

What does SOM **NOT** do for soil?

17% A. Increase cation exchange capacity

17% B. Provide nutrients as it decomposes

17% C. Hold water which helps nutrients move from soil to plant roots

17% D. Consistently reduce soil pH

17% E. Reduce soil compaction

17% F. Increase water infiltration

High surface area and CEC (215 meq/100 g for SOM vs. 58 for clay)

Changing SOM

- We can't change CEC of mineral soil or soil pH very well, but can increase SOM to influence soil CEC
- Guesses on how long to increase SOM from 1.4 to 1.5%
- SOM can change:
  - takes a long time on cropland/pasture – MSU study, CRP (ungrazed, unharvested alfalfa) increased from 1.4% SOM to 1.48% SOM in 10 years in top foot.
  - If you harvest hay, or graze pasture you are maybe maintaining, most likely losing SOM

What is/was deficient here?

33% A. Ability to spell

33% B. Time to read the bag label

33% C. Shouldn't have handed the dog the spreader

ID of 'problem' is not always clear cut

Response Counter

Evaluate soil nutrient status in addition to soil test

- Visual assessment of tissue: may identify what has been lacking to this point, once symptoms appear, yield may already be compromised. Examples posted at http://landresources.montana.edu/soilfertility/nutrientdeficiencies.html
- Tissue concentrations, not an exact science either

How can I manage for healthy soils?

- Know your soil's properties and only add amendments as needed
- The right source, rate and timing leads to optimal fertilizer use and plant health
- Observe and adjust to your specific conditions
- Avoid compaction by:
  - Reducing traffic and tillage when wet
- Increase the organic matter content by:
  - Moderate grazing
  - Adding manure
- Maintain soil cover with vegetation

Resources

On soil fertility website under *Extension Publications*

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

- *Soil Nutrient Management for Forages: N* (EB0217)
- *Soil Nutrient Management for Forages: PKSMicros* (EB0216)
- *Soil Sampling Strategies* (MT200803AG)
- *Interpretation of Soil Test Reports for Agriculture* (MT200702AG)
- *Developing Fertilizer Recommendations for Agriculture* (MT200703AG)
- *Soil Sampling and Laboratory Selection* (4449-1)
  http://landresources.montana.edu/NM/
- *The Soil Scoop*
  http://landresources.montana.edu/soilfertility/soilscoop.html


Questions?
Photo by Ann Ronning