Soil Nutrient Management to Increase Profit and Soil Health

Lewistown Winter Fair Farm Forum

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Today's topics

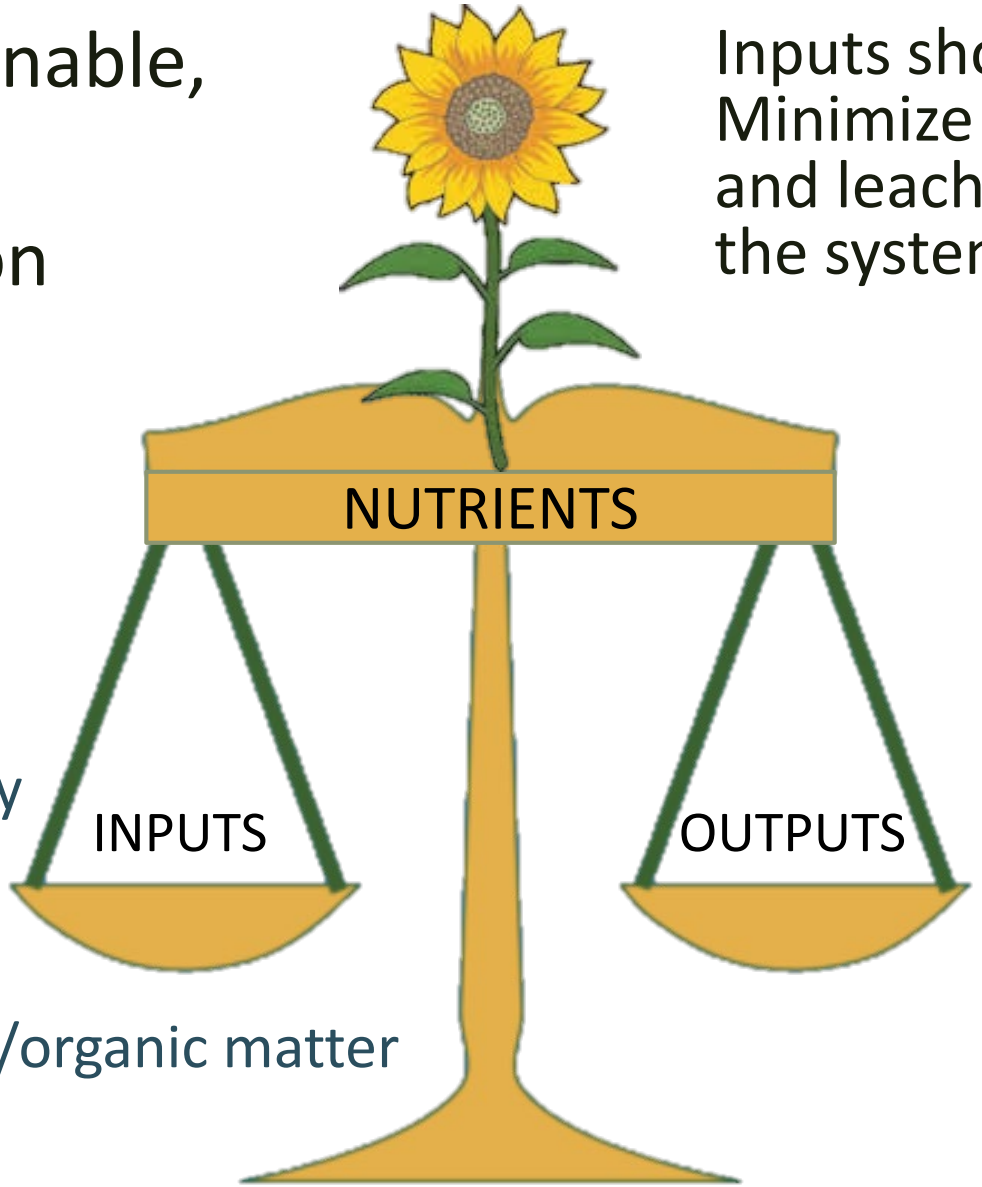
- 4Rs of Fertilization (Right rate, time, placement, source)
- What can be learned from a soil test
- How to calculate fertilizer rates
- Soil properties and how they interact with plant nutrients
- Management for healthy soil

We'll have some hands-on and we'll use clickers because….

A. They don't need to be put in airplane mode	33%
B. Clicker training isn't just for dogs	33%
C. It might be tough to get a good soil sample in this room	33%

For sustainable, healthy production

Inputs should = Outputs
Minimize erosion, runoff and leaching losses from the system



Fertilizer
Manure

N-fixation by legumes

Mineral soil/organic matter

Harvest

Erosion

Runoff

Leaching

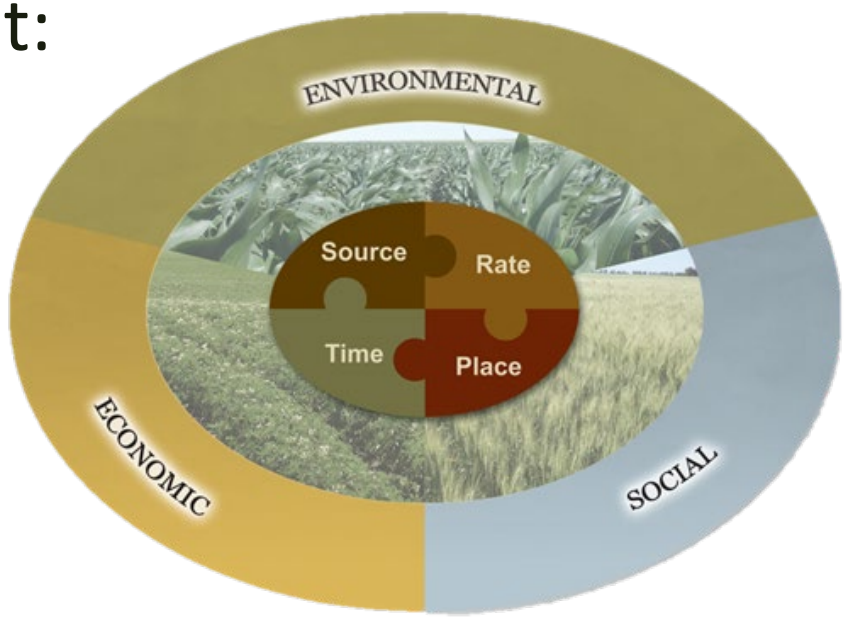
In many ag systems, outputs > inputs = mining the soil for nutrients
Loss of soil productivity leads to financial loss

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

Questions to ask before you add fertilizer

1. Which elements do I need? (e.g. N, P, K, S, Zn)
2. 4R Stewardship, the right:
   - Rate
   - Source
   - Timing
   - Placement
3. Will I get a return

   ($ or environmental) on my investment?



How much fertilizer do I need to apply?

Fertilizer rate based on:

- Soil test results
- Desired crop and yield goal
- Prior crop

Rates are provided by:

- Lab (check if they use MT rate guidelines)
- Calculations using guidelines in MSU MontGuides (listed at end) and available at http://landresources.montana.edu/soilfertility/publications.html
- MSU fertilizer rate calculator http://www.sarc.montana.edu/php/soiltest/

Soil test: a first step to wise use of fertilizer $

- To help calculate fertilizer rates
- To identify nutrient deficiency or imbalance
- 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’

Example soil test report

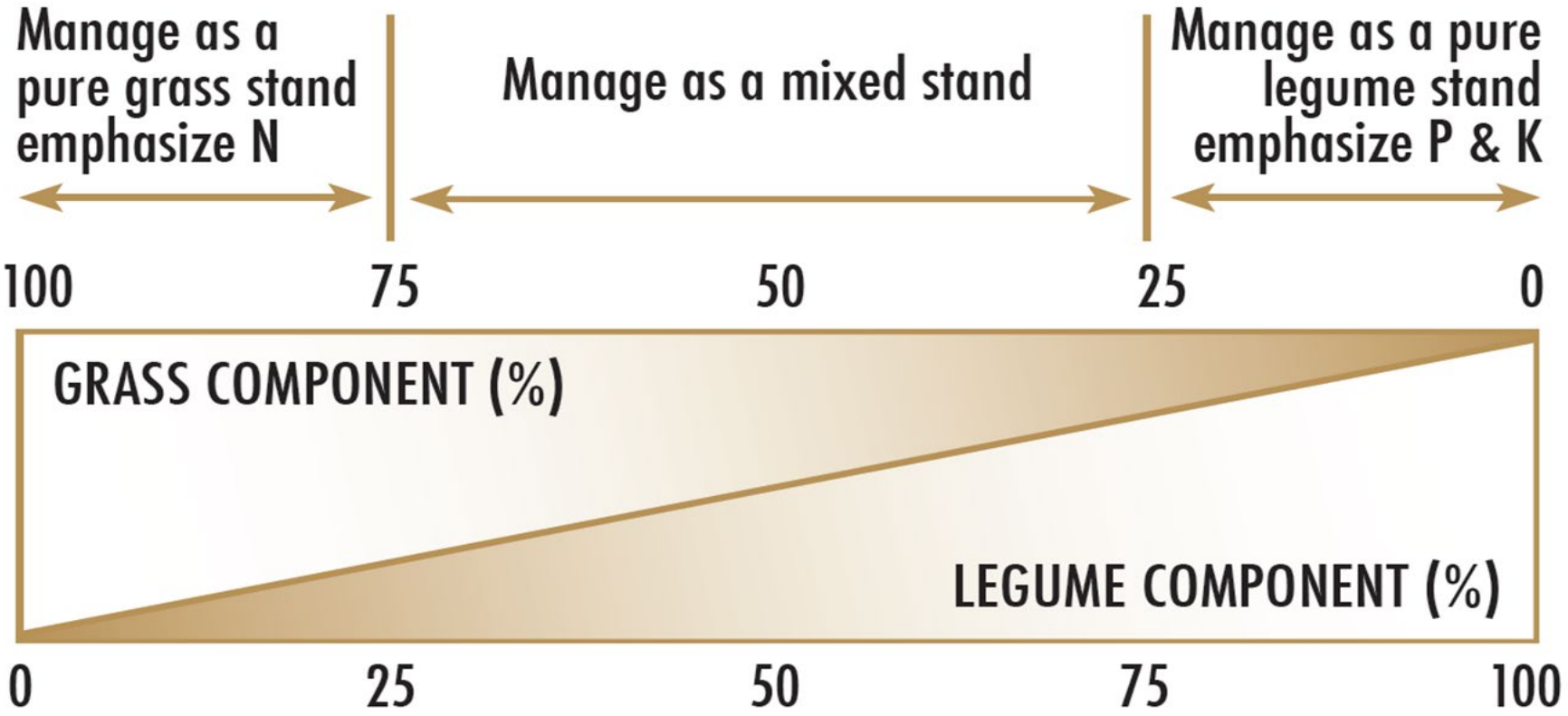
Location: Sample date:

Desired crop	Prior crop	Nitrate-N			P ppm		K ppm	OM %	pH	CEC	Salts
		ppm	lb/ac	Depth (in)	Bray	Olsen					
Forage		2	4	0-6	33	53	161	2.0	7.5	10.2	0.3
Garden		10	18	0-6	101	107	400	4.3	8.0	35	2.0
Wheat	Fallow		12	0-6	14	4	353	1.7	6.5	12	0.3
	Cereal		15	6-24							
	Legume		9	24-36							
	?										
Ideal		Crop dependent				16 - 30	250 - 500	3 - 10	6-7.5	15-30	< 4

- Ideally an actual number, rather than a rating (low, medium, high, very high or deficient, sufficient) is provided.
- Drawback of soil test kits is usually rating only, no numbers
- Sometimes a recommendation is provided. Make sure it is based on DESIRED CROP and MT GUIDELINES

N is the most common lacking nutrient except with legumes, e.g. mixed alfalfa/grass forage

Focus of N vs P & K fertilization in forages depends on % legume in stand.



Fertilizing with nutrients other than N favors legumes over grass

Example N calculation: Forage

- Know your yield goal. Use 5 ton of 20/80 legume/grass mix, and 4 lb N/ac soil test value for this example
- Compare soil test to MT guidelines

	Alfalfa/Grass			
	80/20	60/40	40/60	20/80
Yield (ton/ac)	Available N (lb/ac) need			
1	5	10	15	20
2	10	20	30	40
3	15	30	45	60
4	20	40	60	80
5	25	50	75	100
6	30	60	90	120

Fertilizer N =
Available N need – soil test N

How much fertilizer N?

A. 80 lb N/ac 25%
B. 96 25%
C. 100 25%
D. 104 25%

100 – 4 = 96 lb N/ac

Example N fertilizer rate: Garden

- Adjust for organic matter

Desired crop	Nitrate-N			OM %
	ppm	lb/ac	Depth	
Garden	10	18	0-6”	4.3

Soil test lb/ac	“crop”	Organic matter (%)		
		< 1.5	1.5 – 3	> 3
		lb/1000 sq. ft		
< 20	Lawn	6	5	4
	Garden	4	3	3
20-40	Lawn	4	3	2
	Garden	2	2	2
> 40	Lawn	2	1	1
	Garden	1	1	0.5

How much fertilizer N?

Example N calculation: Small grain

- How many lb N/ac to 24" depth?

Winter wheat

Yield goal (bu/ac)	Available N need (lb/ac)
30	78
40	104
50	130
60	156
70	182
80	208
90	234

Crop	Prior crop	Nitrate-N		OM %
		lb/ac	Depth (in)	
Winter wheat	Fallow Grain Legume	27	0-24	1.7

Wheat yield goal 50 bu/ac, how much fertilizer N?

Fertilizer N (lb/ac) =
Available N need – soil nitrate-N

A. 103 lb N/ac 33%
B. 130 33%
C. 157 33%

130 – 27 = 103 lb N/ac

If 103 lbs per acre of fertilizer N needed, how much urea (46-0-0) is needed?

The 46-0-0 means this fertilizer is 46% N, 0% P_2O_5, and 0% K_2O. So the fraction of N in urea is 0.46 (46/100).

$$\text{N fertilizer} = \frac{(103 \text{ lbs/acre})}{0.46}$$

$$= \mathbf{224 \text{ lbs urea/acre}}$$

N rate adjustments

- Soil Organic Matter (SOM)
  - <1% SOM, add 15-20 lb N/acre
  - >3% SOM, reduce 15-20 lb N/acre
- Tillage – No-till may require extra N for 6 to 15 years
- Fall vs. spring soil sample (overwinter loss or gain?)
- Prior crop: stubble (increase N), pulse (reduce N), cover crop (reduce N)
- Evaluate past N management by wheat grain protein levels. See *Practices to increase wheat grain protein* EB0206

N rate adjustments: prior crop

- Stubble: small grains stubble high carbon to N (C:N). Adjust fertilizer N up or down?

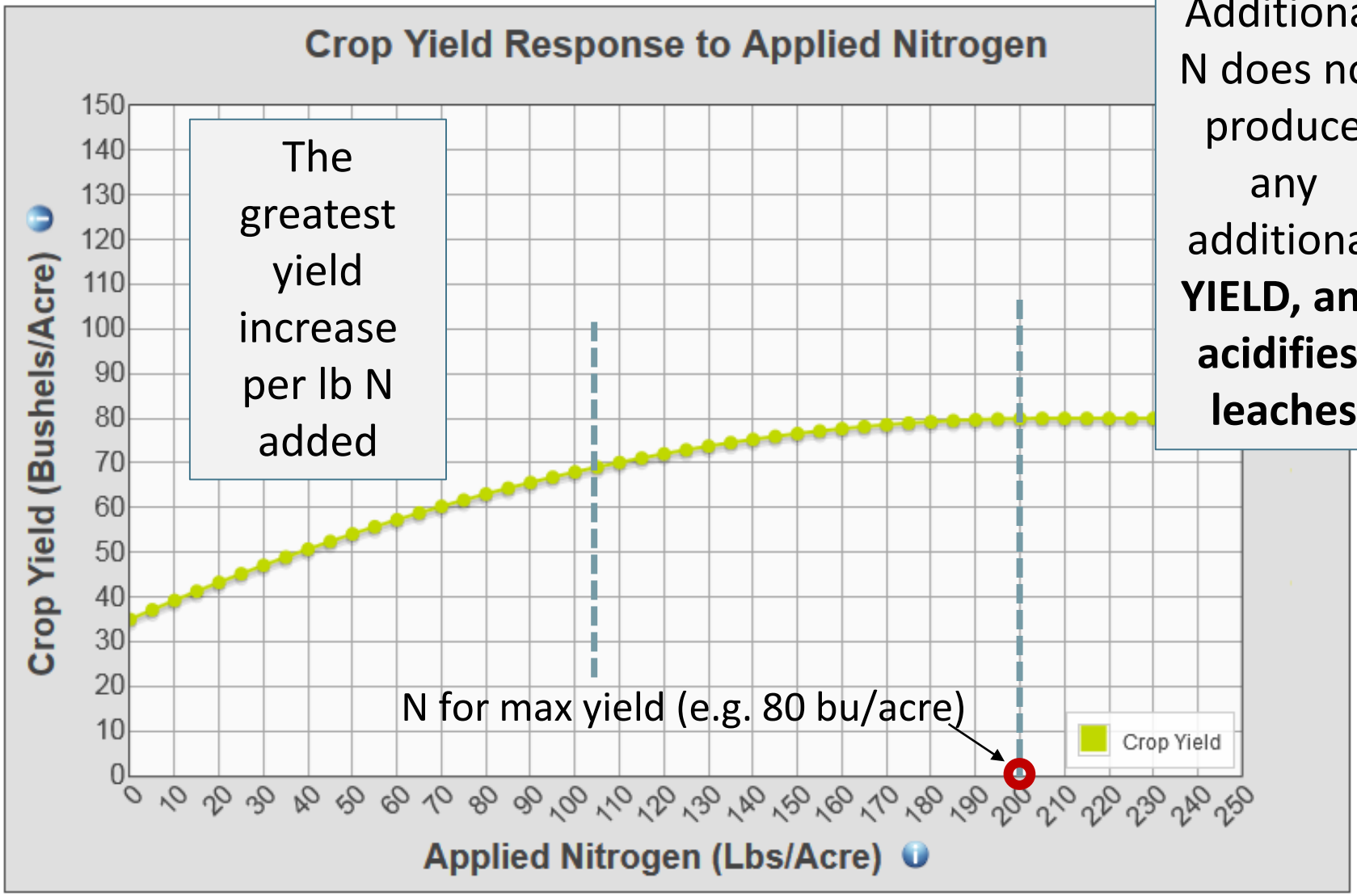
  10 lb N/1000 lb stubble up to 40 lb N

example calcs in *Developing Fertilizer Recommendations for Ag*

- Fallow: assume ½ of stubble has decomposed over previous year when adjusting
- After legume rotation: Adjust fert up or down?
  Legumes credit (add) N

Crop	N credit (lb N/acre)
Alfalfa	40
Annual legume 1 x	~10
Annual legume >3 x	~20

More is **NOT** better: Law of diminishing returns



http://econtools.msuextension.org/nitrogen/

MSU N Econ calculator The best way to maximize profit is to adjust N rates based on costs, prices, and discounts

Inputs

- N fertilizer cost, grain price, protein discount/premiums
- Yield goal – details on how to determine discussed later
- Residual soil nitrate-N from soil test
- Soil organic matter (SOM) from soil test

These calculate **FERTILIZER** N for max net return

Calculators online for barley, SW, and WW after fallow
http://econtools.msuextension.org/nitrogen/index.html

Optimize fertilizer N rate

Danger of aggressive N fertilization?

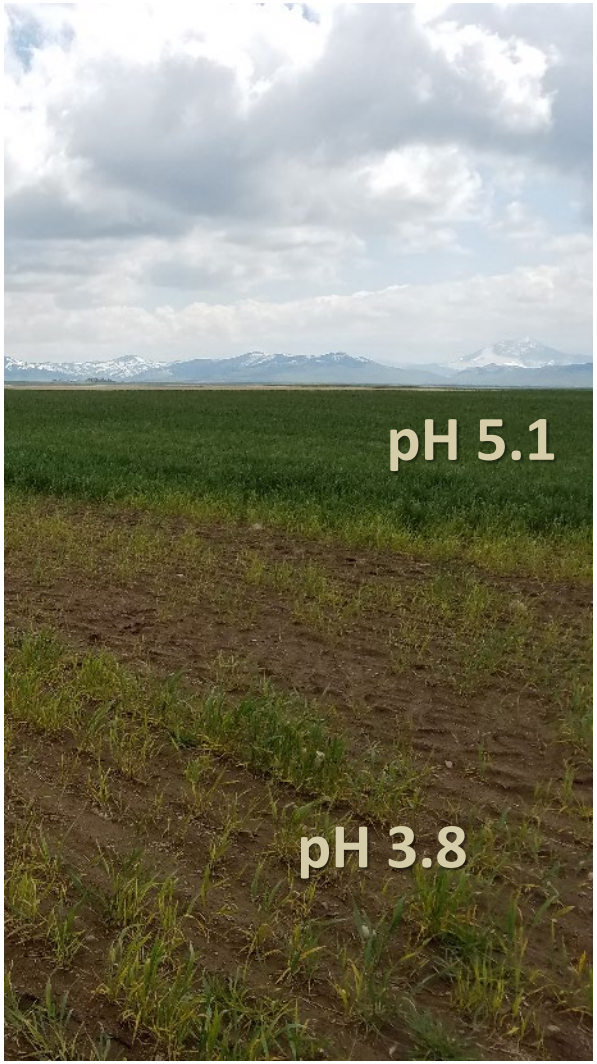
- Hot dry season, low protein discounts, lower net returns, and higher leaching/volatilization N losses.
- In wet year if all N is applied early can lead to excess tiller production and decreased yields.
- Risk of high forage nitrates
- Soil acidification
- Hairy carrots


Image by K. Olson-Rutz

Optimize fertilizer N rate

Strategies to avoid over fertilization?

- Use a conservative pre-plant N rate
- Apply a 2nd application if needed – will discuss split applications in 'Timing' section



Barley crop loss due to acidic soil
Photo courtesy Rick Engel

P calculations

MSU guidelines are based on *OLSEN P*. Type of P soil test to use is based on soil pH.

Crop	P (ppm)			pH
	M3	Bray	Olsen	
Wheat	37	14	4	6.5
Ideal			16-30	6-7.5

- Bray works in pH < 7.3
- Olsen works pH > 6
- Mehlich-3 over broad range

Can convert Mehlich-3 to Olsen in calcareous soils.

[(Mehlich P/2.05) – 14] = Olsen P

Table 18 (subset). P fertilizer guidelines based on soil analysis (EB0161)

Crop	Olsen P soil test level (ppm)				
	0	4	8	12	16*
	P fertilizer rate (lb P_2O_5 /acre)				
W Winter	55	50	45	40	35

* With P>16 ppm consider using crop removal rates (EB0161 Table 21) as P fertilization guideline.

How much fertilizer P (in lb P_2O_5/ac)?

A. 55 25%

B. 50 25%

C. 45 25%

D. 40 25%

K calculations

Desired crop	K ppm
Forage	161
Ideal	250-500

Compare soil test to MT guidelines

For straight alfalfa, how much fertilizer K?

A. 161 33%

B. ≈130 33%

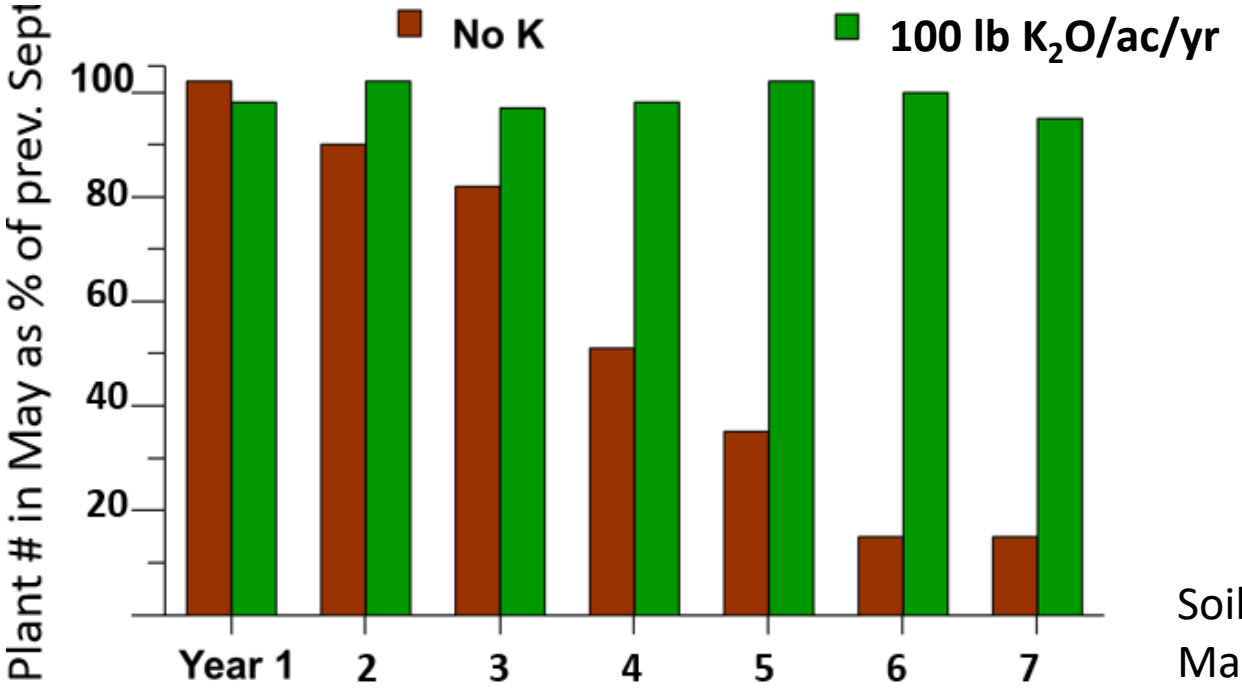
C. ≈ 95 33%

Table 19 (subset). K fertilizer guidelines based on soil analysis (EB0161)

Crop	K soil test level (ppm)					
	0	50	100	150	200	250*
	K fertilizer rate (lb K_2O/acre)					
Alfalfa	240	205	170	140	95	30
Alfalfa/grass 50/50	160	135	115	95	65	25

* With K>250 ppm consider using crop removal rates (EB0161 Table 21) as K fertilization guideline. Alfalfa/grass 50/50 guideline is likely an error in EB0161.

How might lack of K affect an alfalfa hay field?



K helps reduce alfalfa winterkill

Soil K 116 ppm (0-6”)
Manitoba, IPNI

Online MSU soil fertility guideline calculator

http://www.sarc.montana.edu/php/soiltest/

Submit Clear form

1. Topsoil sample results:			*2. Soil Nitrate Results:*				
Olsen P	6	ppm	Sample #	top	bottom	Soil test value	
Extractable K	50	ppm	1	0	6	60	ppm
Soil Organic Matter	1.5	%	2	6	12	65	
			3	0	0	0	
			4	0	0	0	

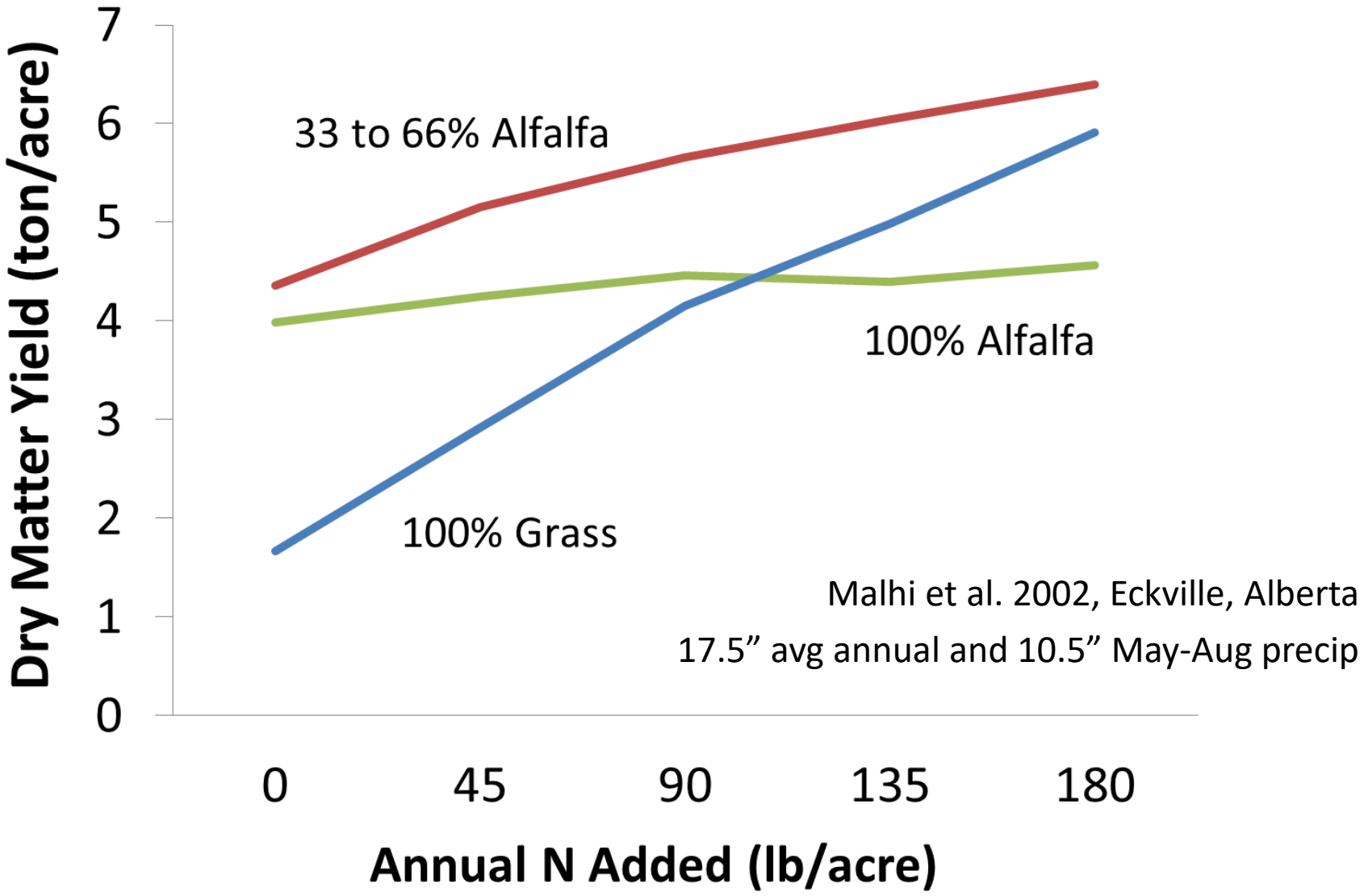
3. Crop Management:		
Last year's crop: sugarbeet	New Crop barley-malt	Yield goal of 80 bu/acre

Submit

QUESTIONS?

Other ways to add N
Legumes and compost

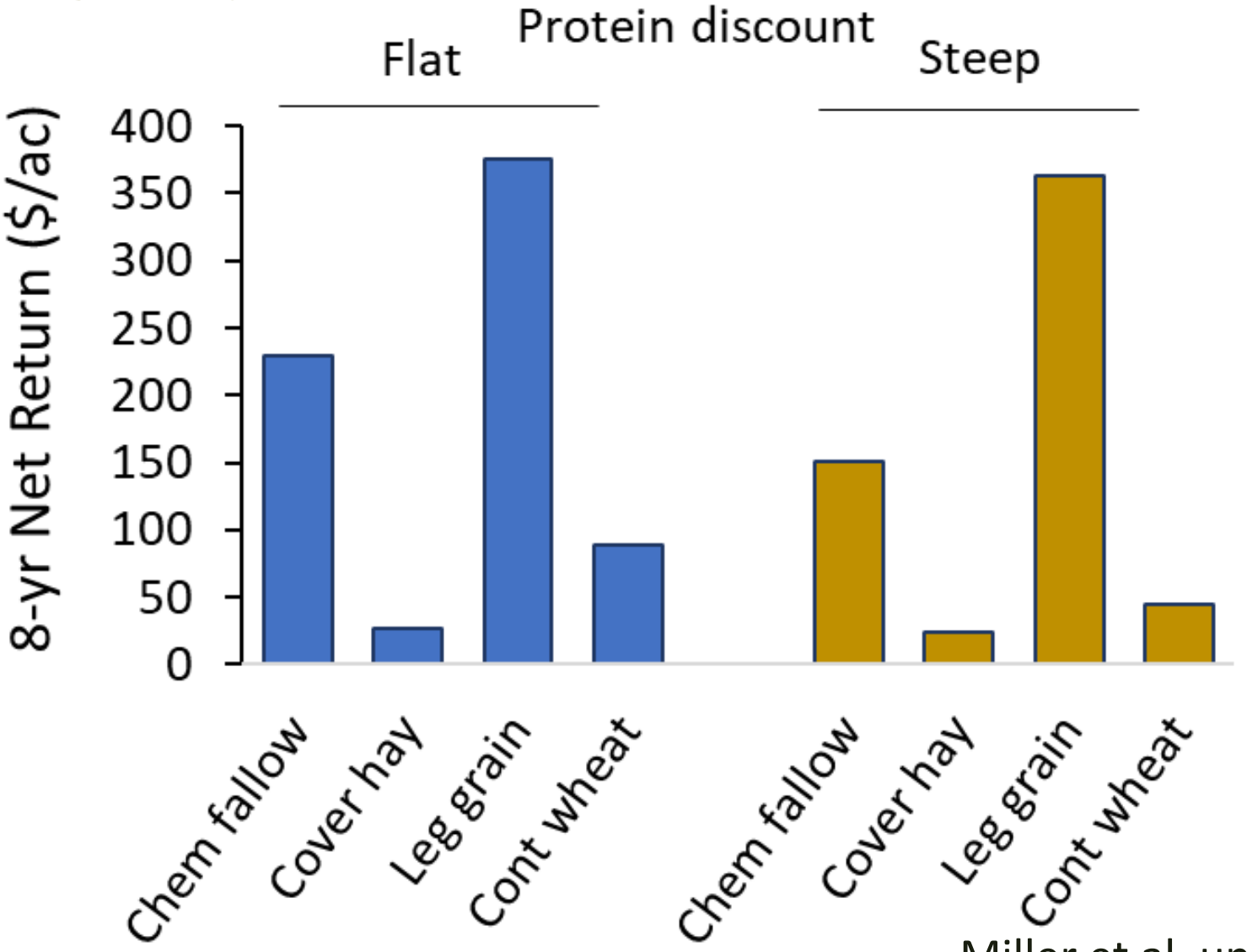
Adding N – having alfalfa in mix may be best source of N



Malhi et al. 2002, Eckville, Alberta

17.5” avg annual and 10.5” May-Aug precip

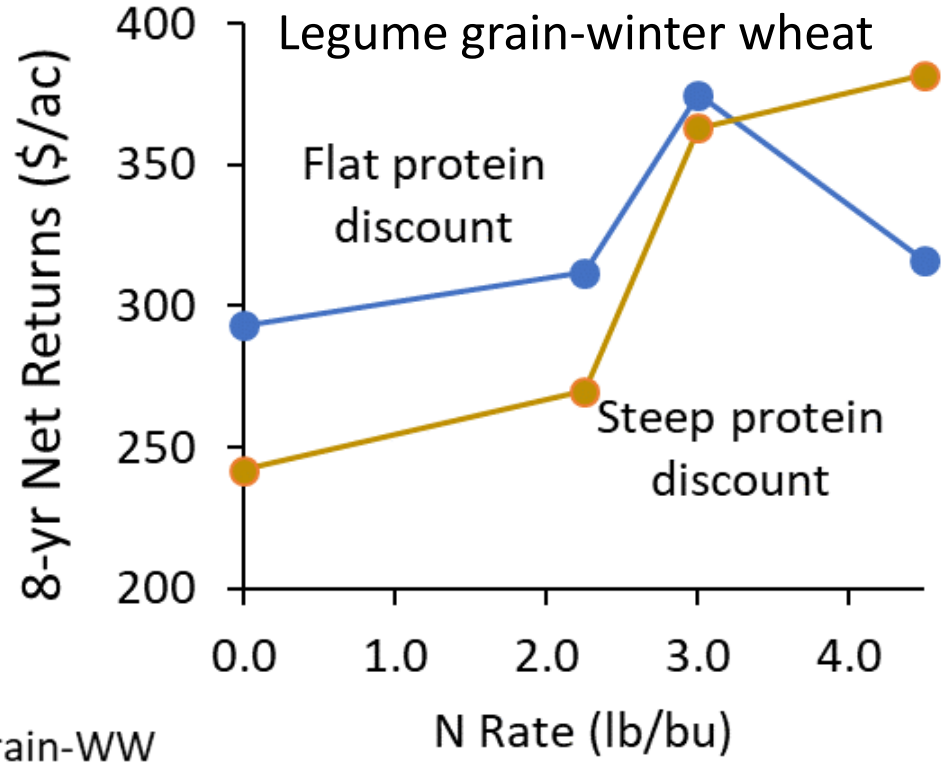
Pulse crops in rotation with winter wheat fertilized at 3 lb N/bu, help net returns in part by reducing N fertilizer costs near Big Sandy

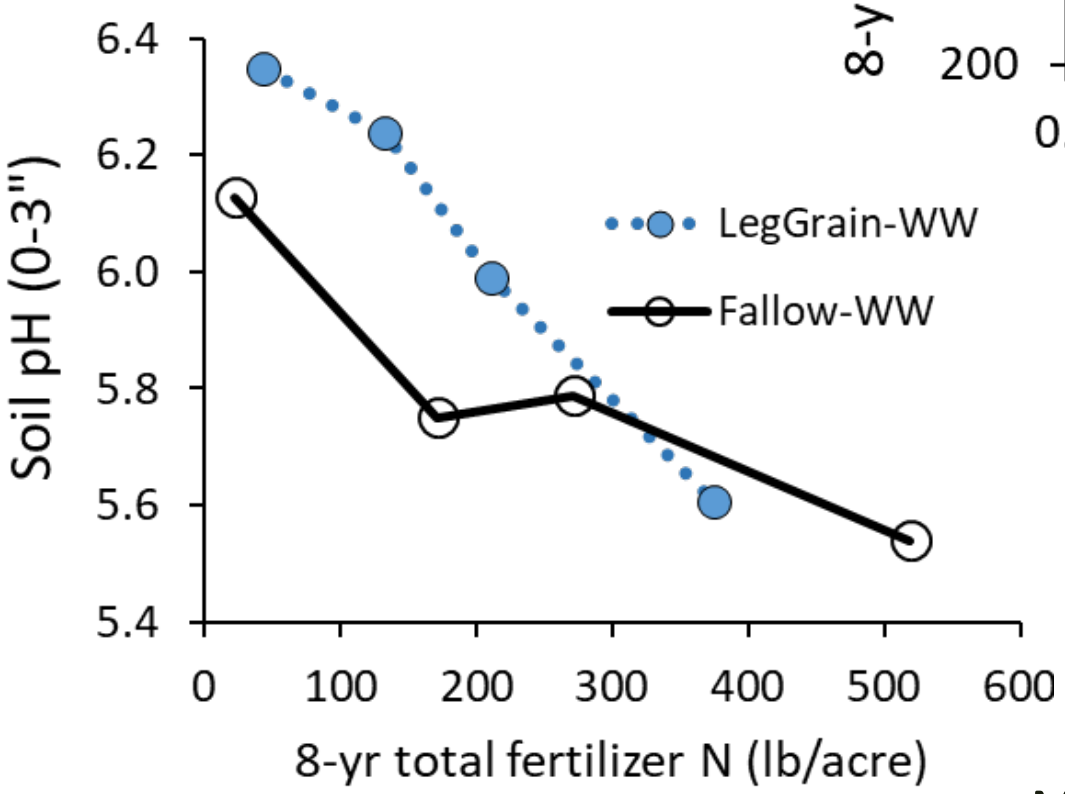


Miller et al. unpub data.

High N rates are costly

1. In lower net returns when discounts low





2. And by lowering soil pH to near toxic levels (~5.2)

Miller et al. unpub data. Big Sandy, MT

Compost can not 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

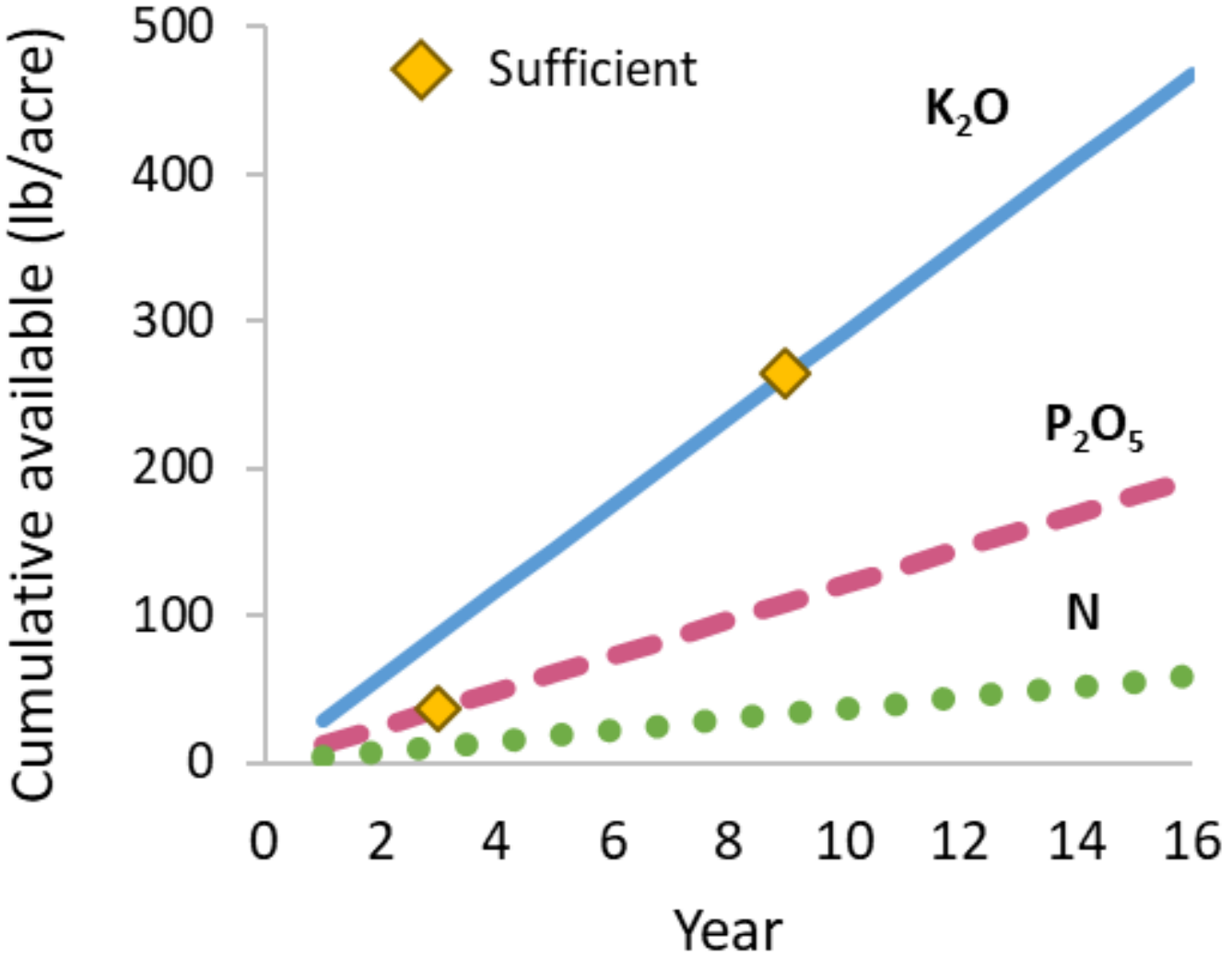
[1.] Univ. Mass, Michigan State, Oregon State, Morris et al., 2007

High P and K soil levels reflect manure addition

Desired crop	P (ppm)	K ppm	pH
	Olsen		
Garden	107	400	8.0
Forage	53	161	7.5
Wheat	4	353	6.5
Ideal	16-30	250-500	6-7.5

- 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)

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

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 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.

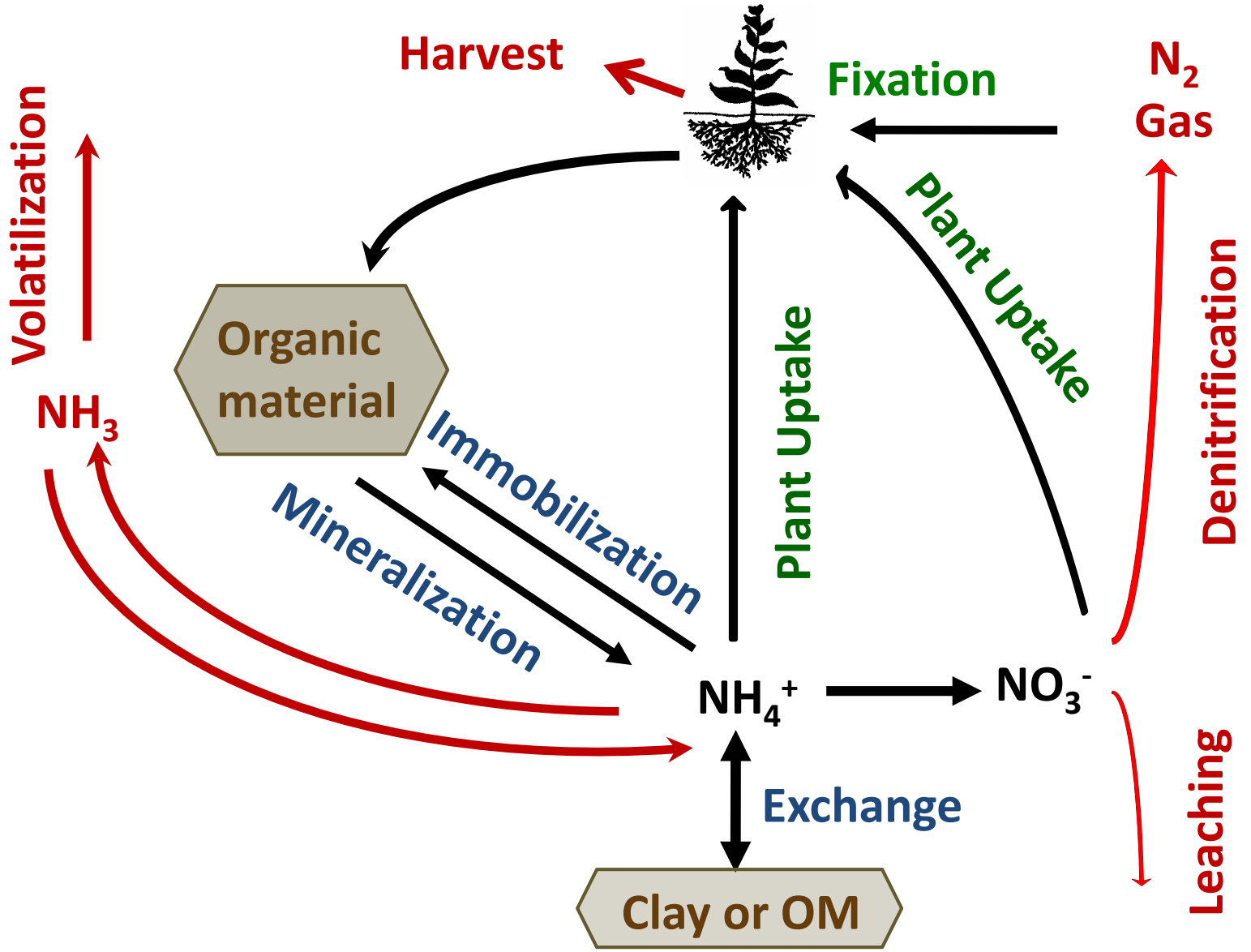
	N	P_2O_5	K_2O	N:P_2O_5
	lbs/1000 sq. ft.			
Annual veg harvest[1]	2.3	0.5	2.7	5:1
Manure compost[2]	40	15	40	3:1
Yard compost[3]	58	8	12	7:1
Green/food compost[4]	15	9	30	1.6:1
Dry leaves[5]	40	9	18	5:1
Green pine needles[6]	57	12	25	5:1

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

QUESTIONS?

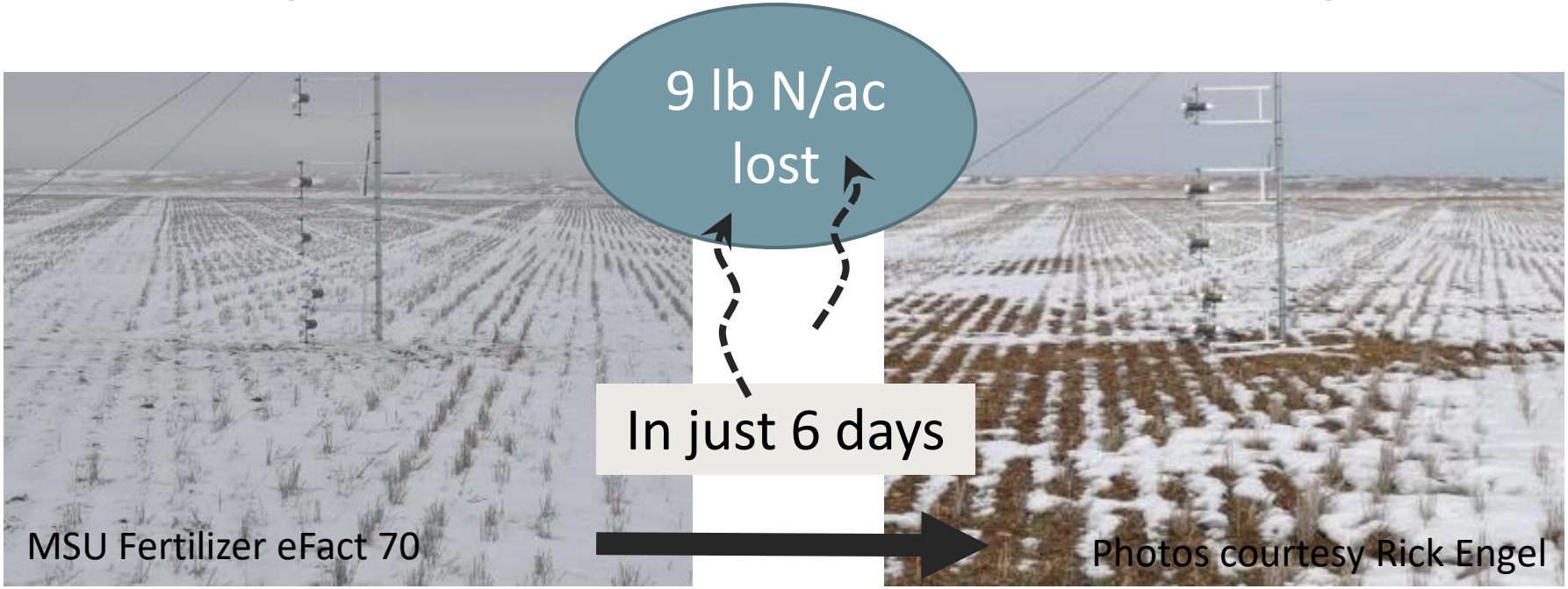
For fertilizer timing and placement to maximize efficiency, helps to understand the nutrient cycles

Most common lacking nutrient is nitrogen (N)



Most important factors affecting urea volatilization

- Surface soil moisture at time of fertilization
- Precipitation the week or 2 after
- Worst-case – moist soil surface w/ only sprinkles for the next few weeks.
- **Average urea loss over 23 trials = 16% (Engel)**



N application considerations

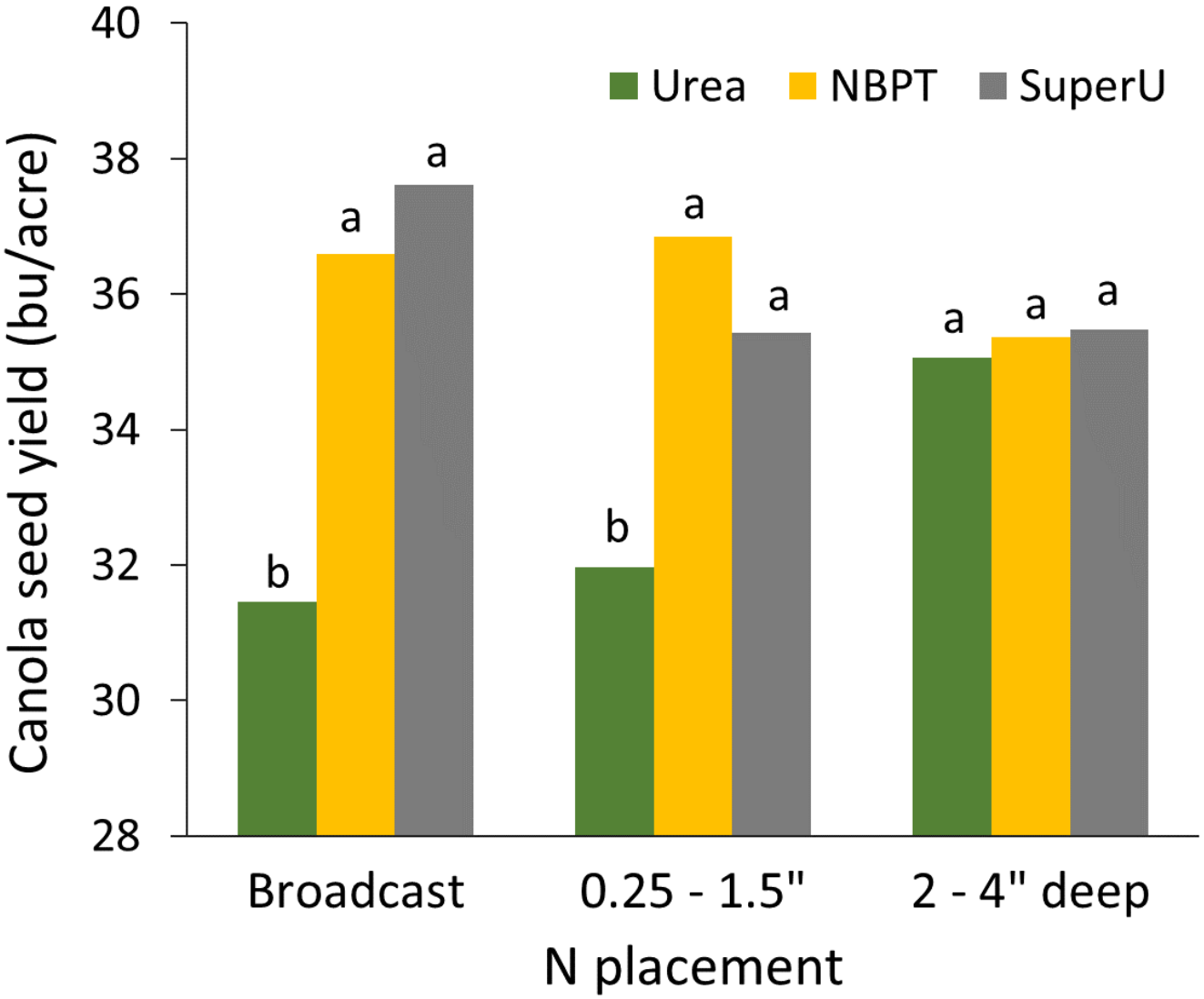
Conventional

- Do not apply on snow, before heavy rains or snowmelt
- Apply and incorporate 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
- Fertilizer is salty and can damage germination if placed too close to seed at too high rates

Specialty slow release

- Place with winter wheat seed or use blend of quickly available source and slow release

Best-case – subsurface band at least 2” deep, packed, OR use ‘urease inhibitor’ like NBPT

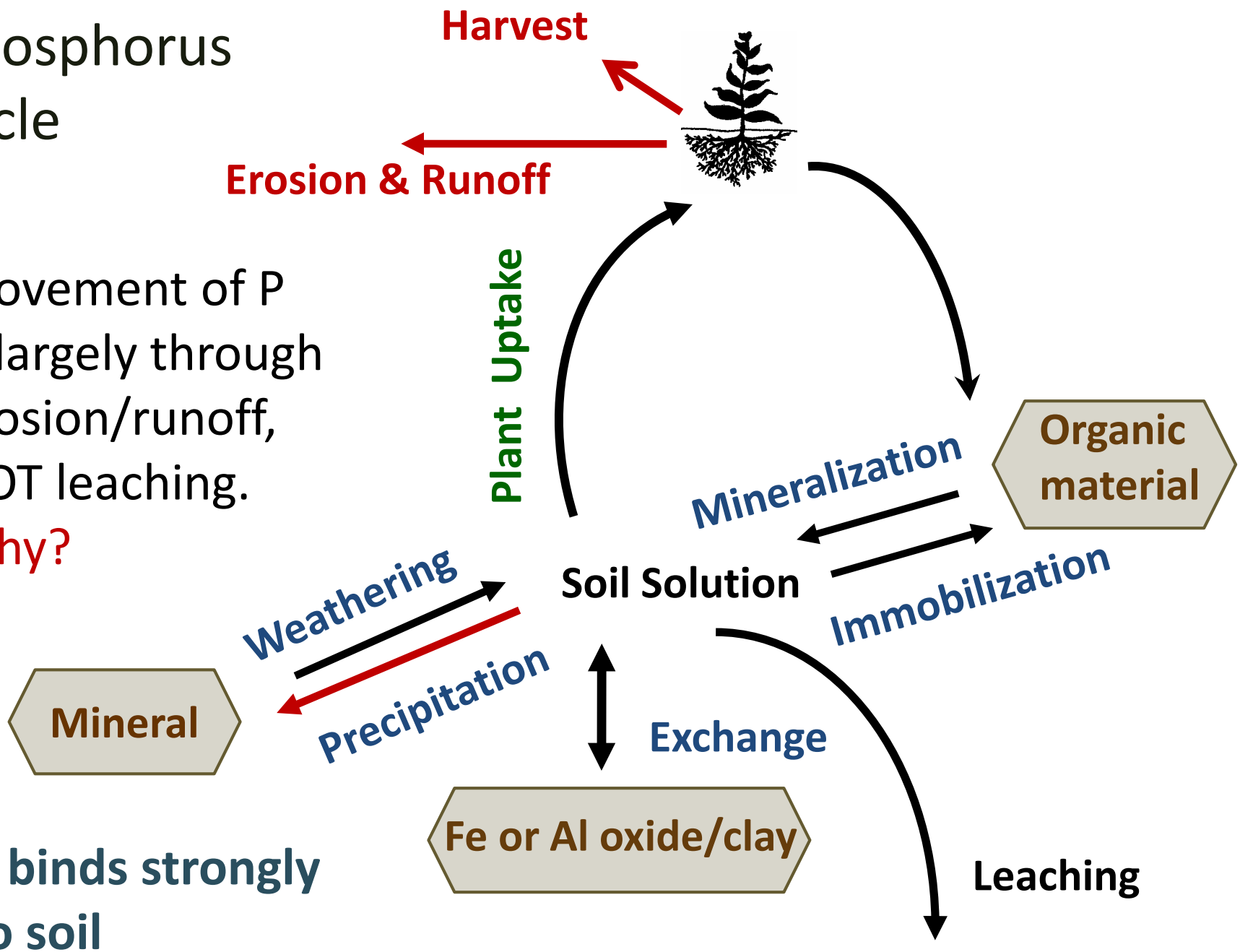


Karamanos, Barker 2016 Top Crop Manager

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

Phosphorus cycle



Movement of P is largely through erosion/runoff, NOT leaching.

Why?

P binds strongly to soil

Low soluble P concentrations due to:

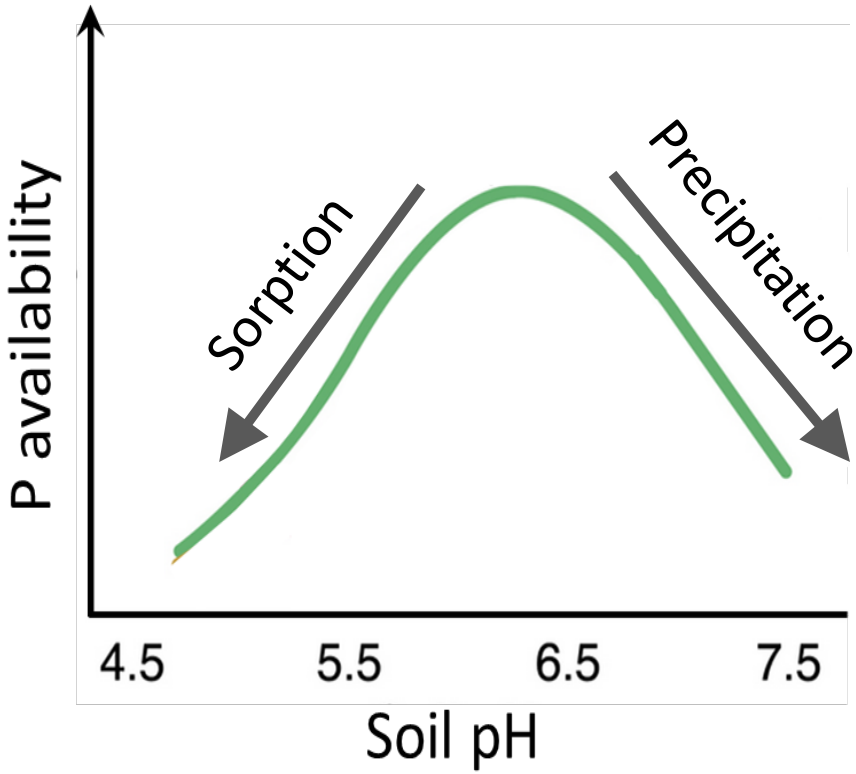
- Precipitation and low solubility of calcium phosphate minerals, in high lime soils
- Sorption (binding to soil) and precipitation with iron and aluminum increases at low pH and may becoming a concern in parts of MT

At what pH levels would you likely need to fertilize with more P?

A. Below ≈ 6 33%

B. Above ≈ 7 33%

C. Below ≈ 6 and above ≈ 7 33%



Gov. W. Australia, Dept of Ag. and Food

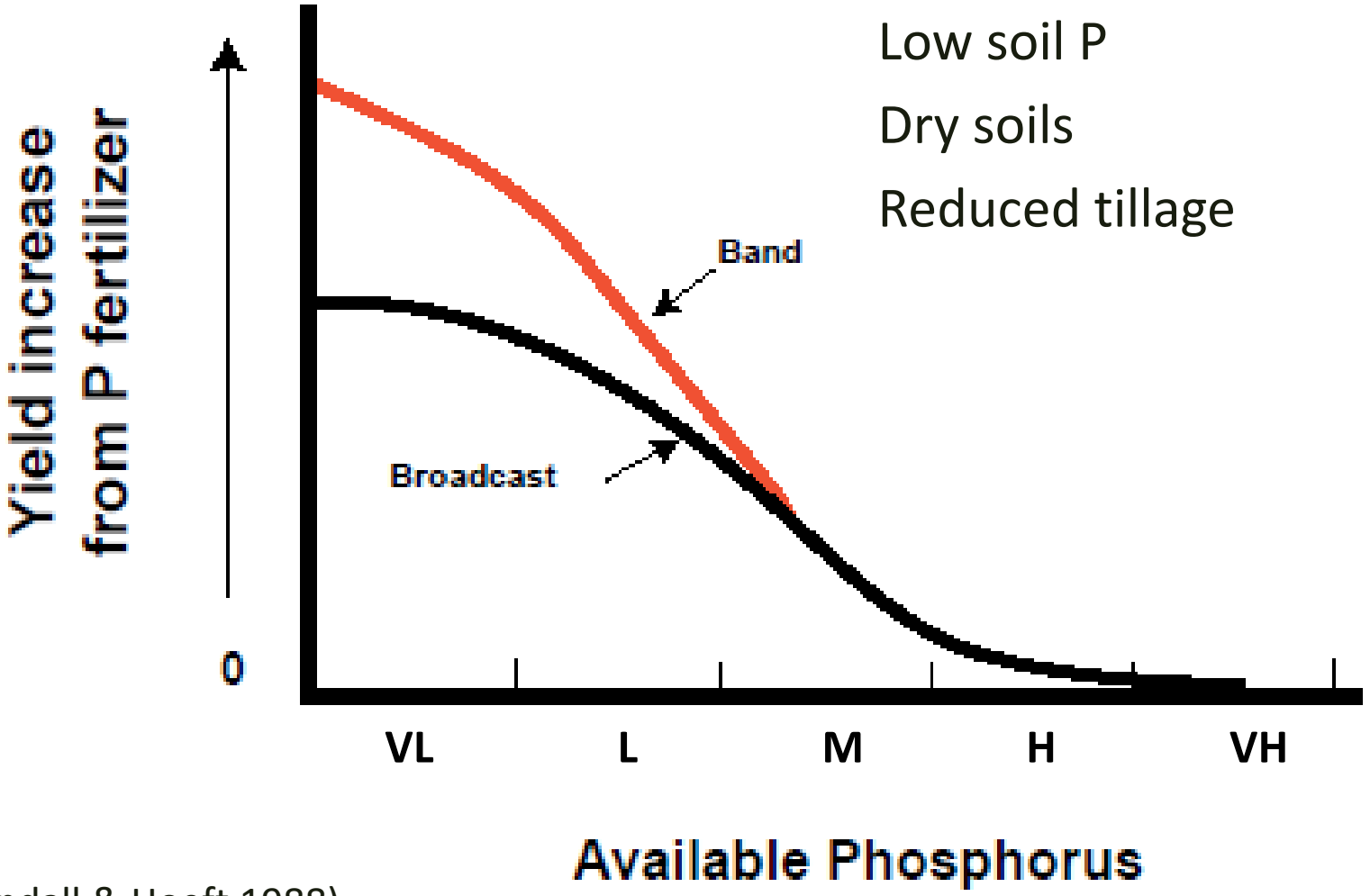
Placement of phosphate and KCl

- Incorporate prior to seeding (in tilled fields)
- Place in-furrow (single shoot) but at low rates
  - <20 lb P_2O_5/acre 11-52-0
  - <10-15 lb N plus K_2O with seed
- Place below and to side of seed (double shoot)
  - Advantage – fast uptake
  - Disadvantage – dry out soil and can cause poorer germination

P band vs. broadcast

Band better than broadcast:

- Low soil P
- Dry soils
- Reduced tillage



(Randall & Hoeft 1988)

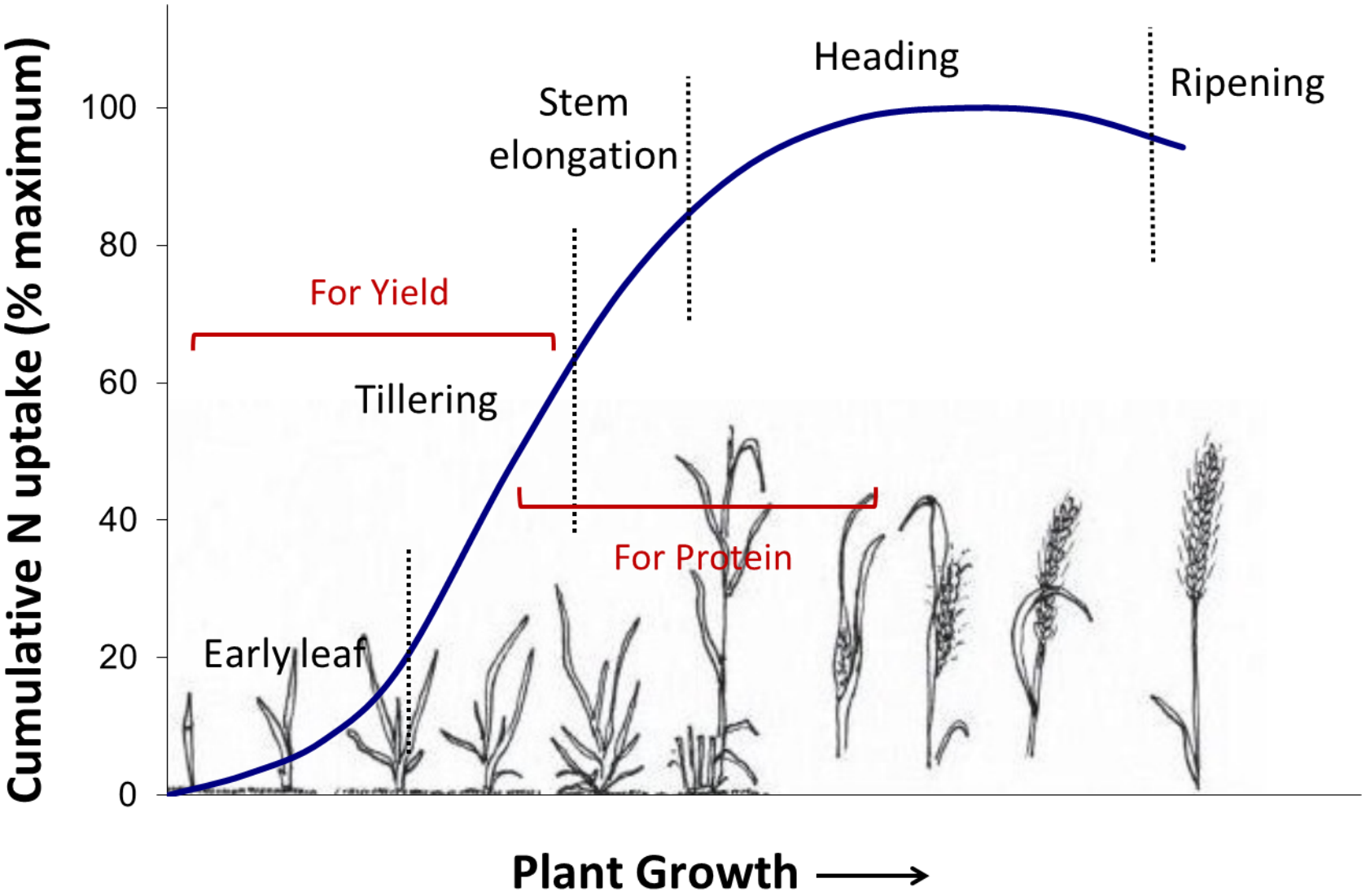
QUESTIONS?

On to Timing

Timing depends on source

- Readily available; e.g. urea (46–0–0), urea ammonium nitrate (28–0–0), MAP (11-52-0), sulfate
  - N shortly before seeding up to mid-tillering/stem elongation. See *Nutrient Uptake Timing by Crops* http://landresources.montana.edu/soilfertility/nutuptake.html
  - P, K, and S at or before seeding
- Slowly available (slow-release N, manure, rock phosphate, elemental-S)
  - take time to become available
  - apply well before needed – e.g., fall or build with prior crop(s)

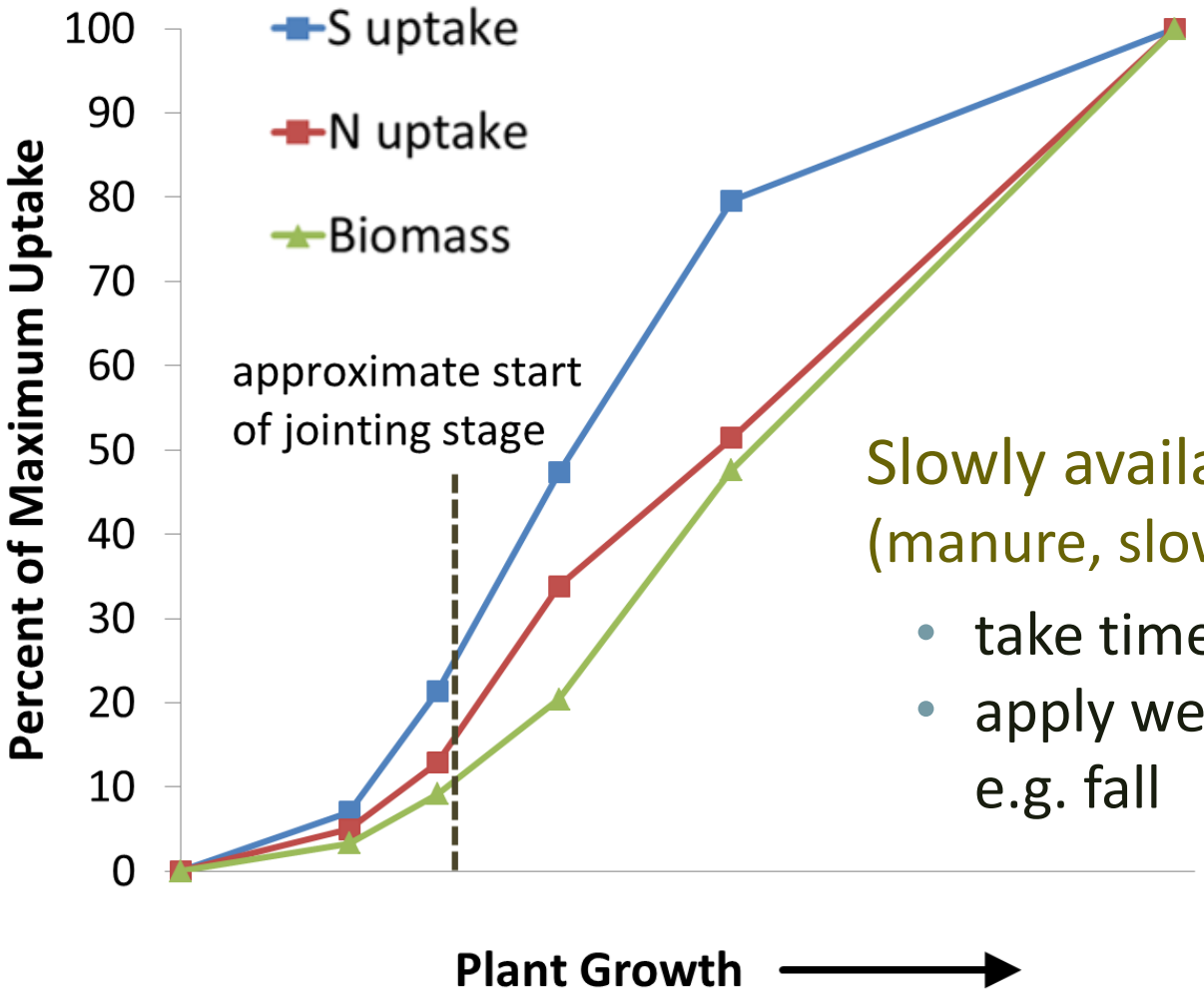
N timing for optimal uptake by wheat for yield and protein



See *Nutrient uptake timing by crops*
http://landresources.montana.edu/soilfertility/nutuptake.html

N timing on forage depends on source

Readily available N (urea, UAN): shortly after **GRASS** green-up

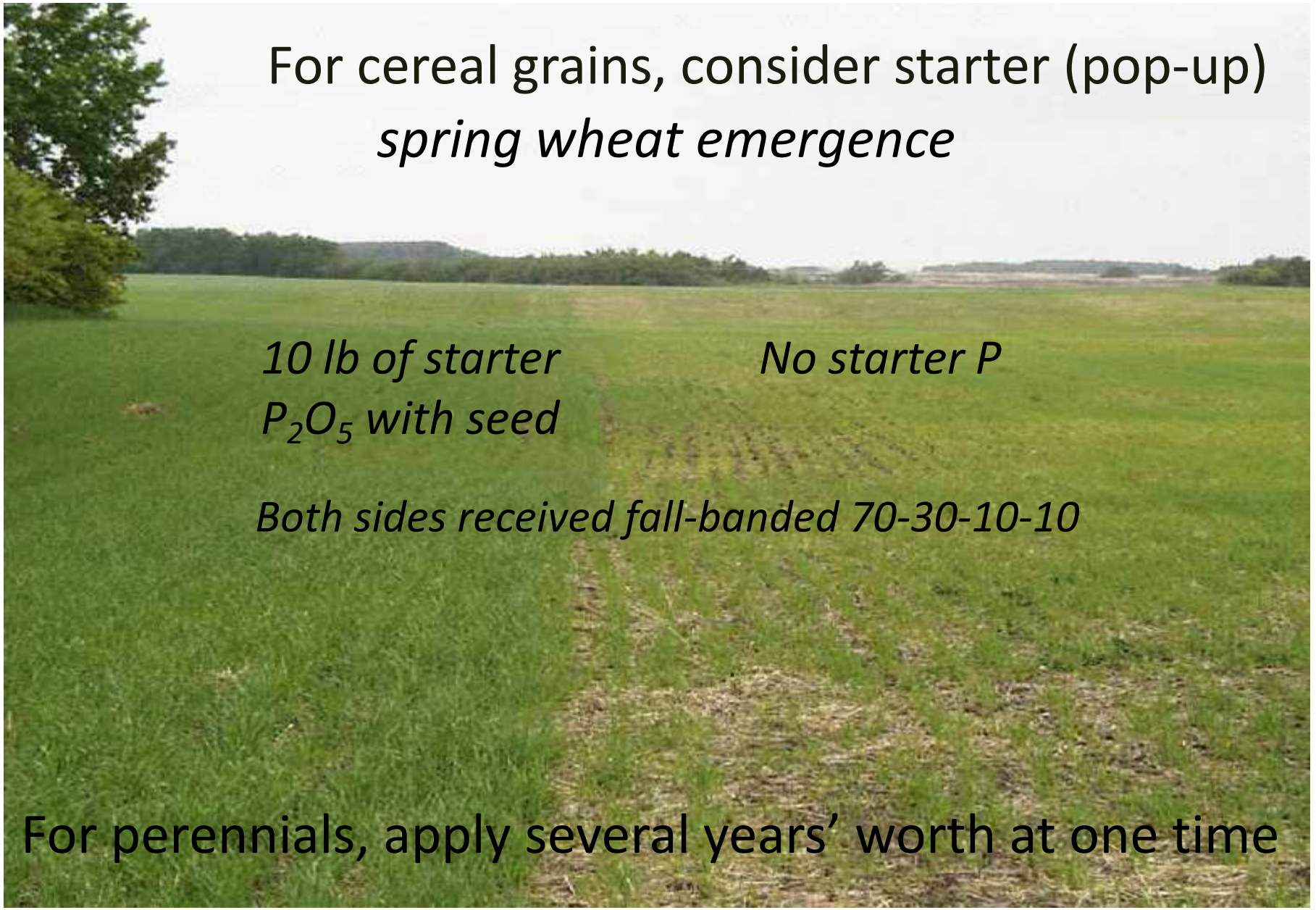


Slowly available N
(manure, slow-release N)

- take time to become available
- apply well before needed, e.g. fall

Willamette Valley, Oregon, Hart et al. 1989

Phosphorus is immobile, gets tied up in soil



For perennials, apply several years' worth at one time

K timing

Is relatively immobile – what is best timing?

- For cereal grains: subsurface band or broadcast at seeding
- For forage:
  - split between first and after last cutting to minimize luxury consumption of first harvest
  - apply after last cutting and before fall period of re-growth to feed root reserves

QUESTIONS on N, P, K?

What else can we learn from a soil test?

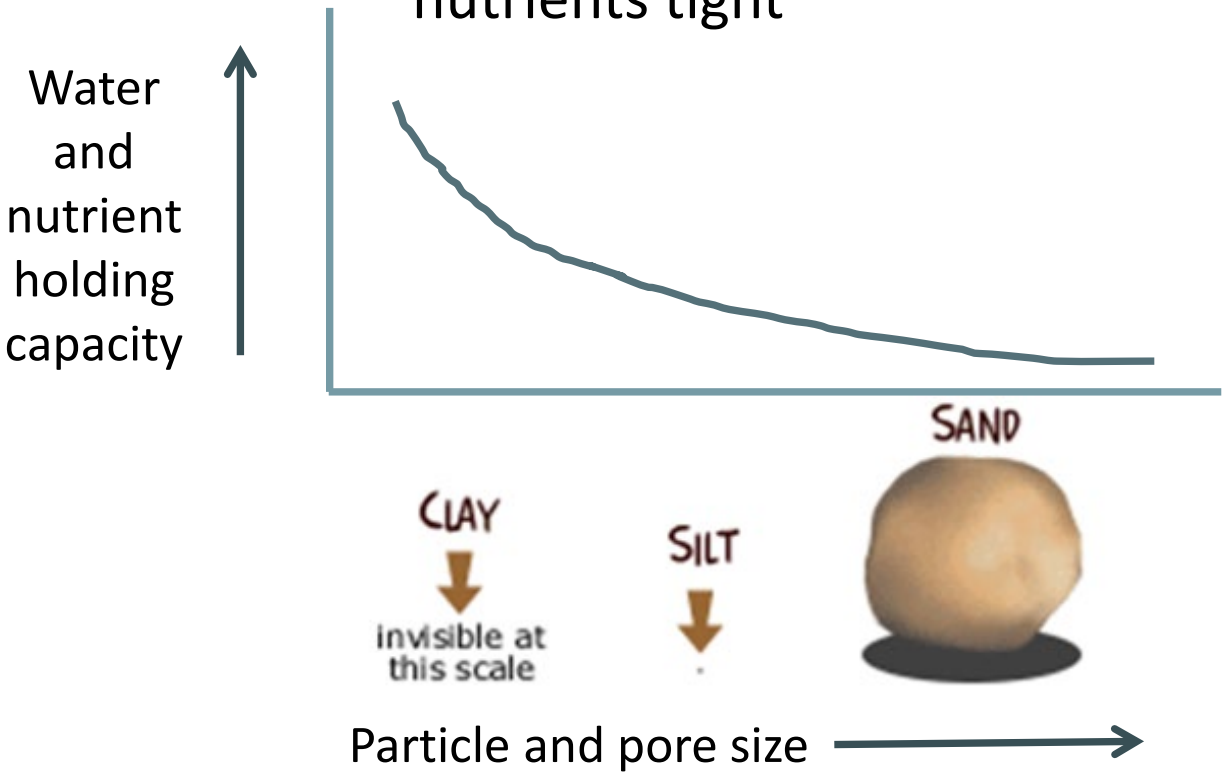
Other items on the soil test report that impact nutrient availability and to guide soil management

Factor	Value	Impact/consider
Soil organic matter	≤ 1 (%)	Minimize bare soil, increase N, add legumes
	> 3 (%)	N credit
Soil pH	< 5	Al and Mn toxicity
	< 6	Poor establishment and nodulation
	> 8.3	Nutrients tied up, likely high Na
Soluble salts (EC)	> 4 (mmhos/cm)	Too saline, water stress, nutrient imbalance
Soil texture and CEC		Water and nutrient holding capacity

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

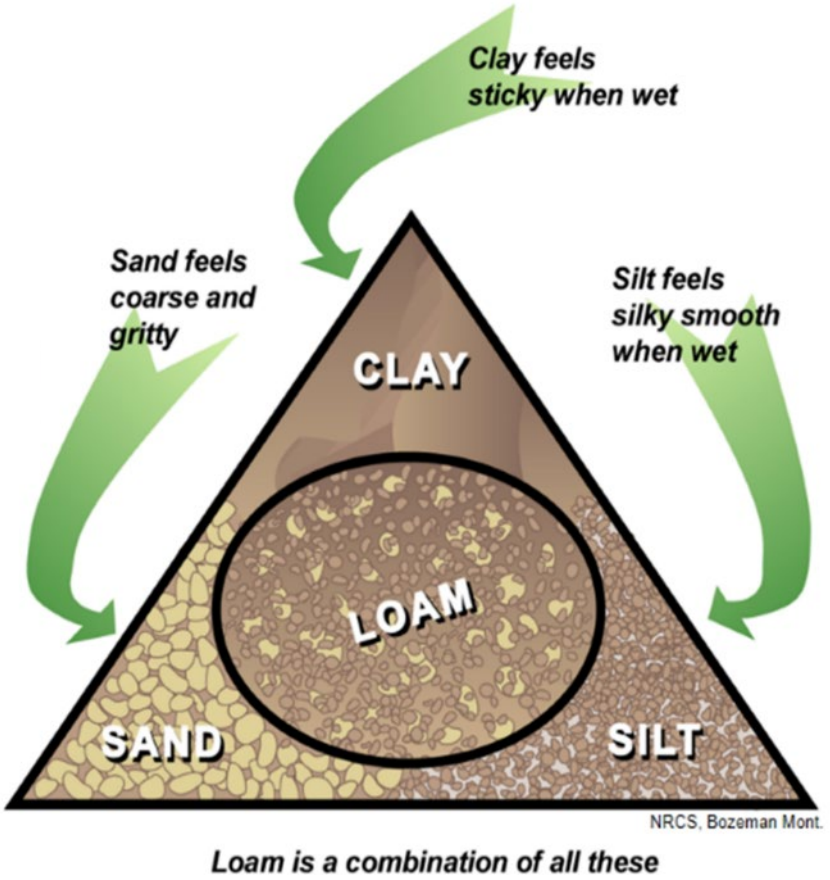
Soils with large surface areas, such as clay and organic matter, have more cation exchange capacity and surface area and therefore are generally more fertile.

Mason jar texture test

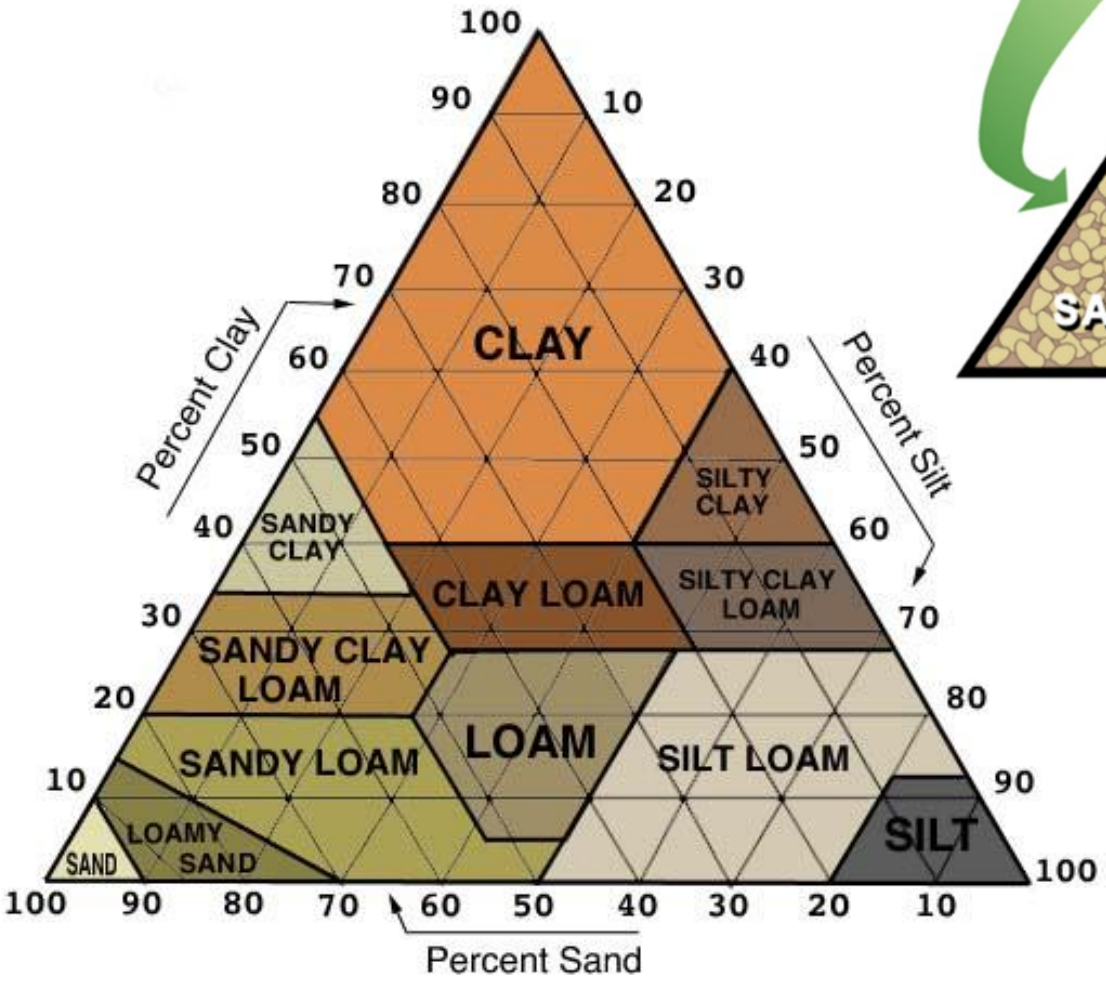
- Fill a straight sided jar 1/3 with soil
- Add water until almost full
- Add 1 tsp dishwasher soap or water softener (why?)
- Shake and let settle
- Mark sand depth at 1 min.
- Mark silt depth after 6 hours (or by color/texture change with clay at 24 hr)
- Calculate clay by difference (or measure at 24 hours)

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

Using the soil texture triangle

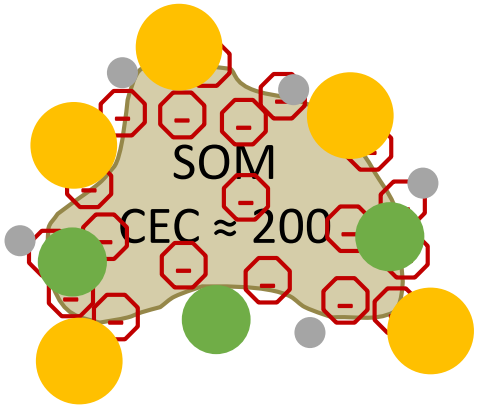


Loam is a combination of all these



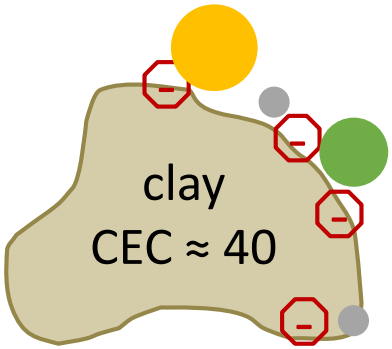
Cation Exchange Capacity (CEC)

the parking spaces for nutrients in the soil

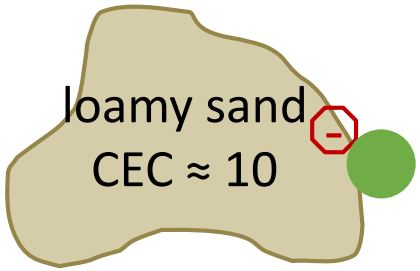


- CEC is the total neg. charge on a soil (meq/100g)
- A high CEC soil (> 15) has the capacity to attract and hold more nutrients with positive charges, e.g. K^+, Zn^{+2}, NH_4^+
- Large surface area (clay, SOM) ≈ larger CEC ≈ generally more fertile.
- What else might high CEC soils hold onto?

  Herbicides
- CEC of mineral soil is hard to change but can slowly change SOM



1 Tbsp has surface area of a football field

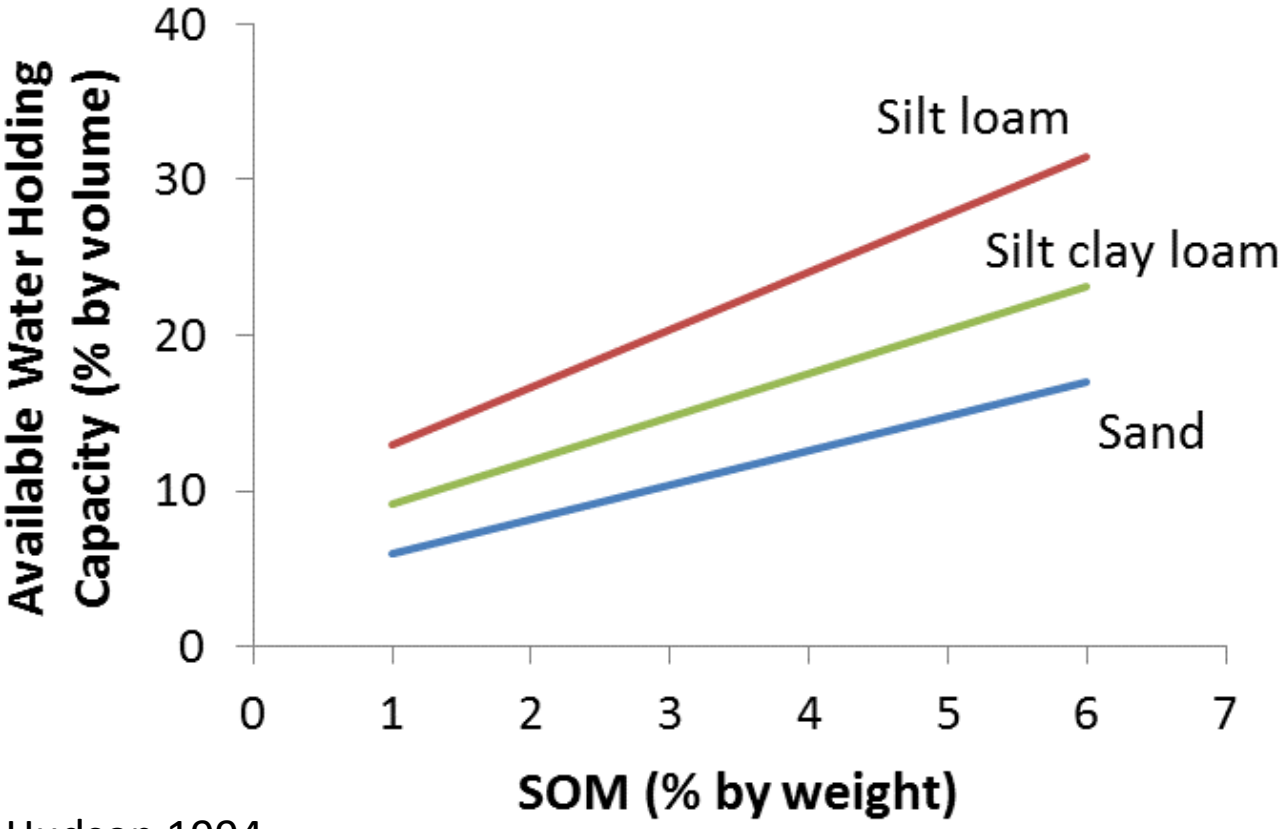


1 Tbsp sand has surface area of a kitchen table

SOM = Soil organic matter

What does SOM do for soil?

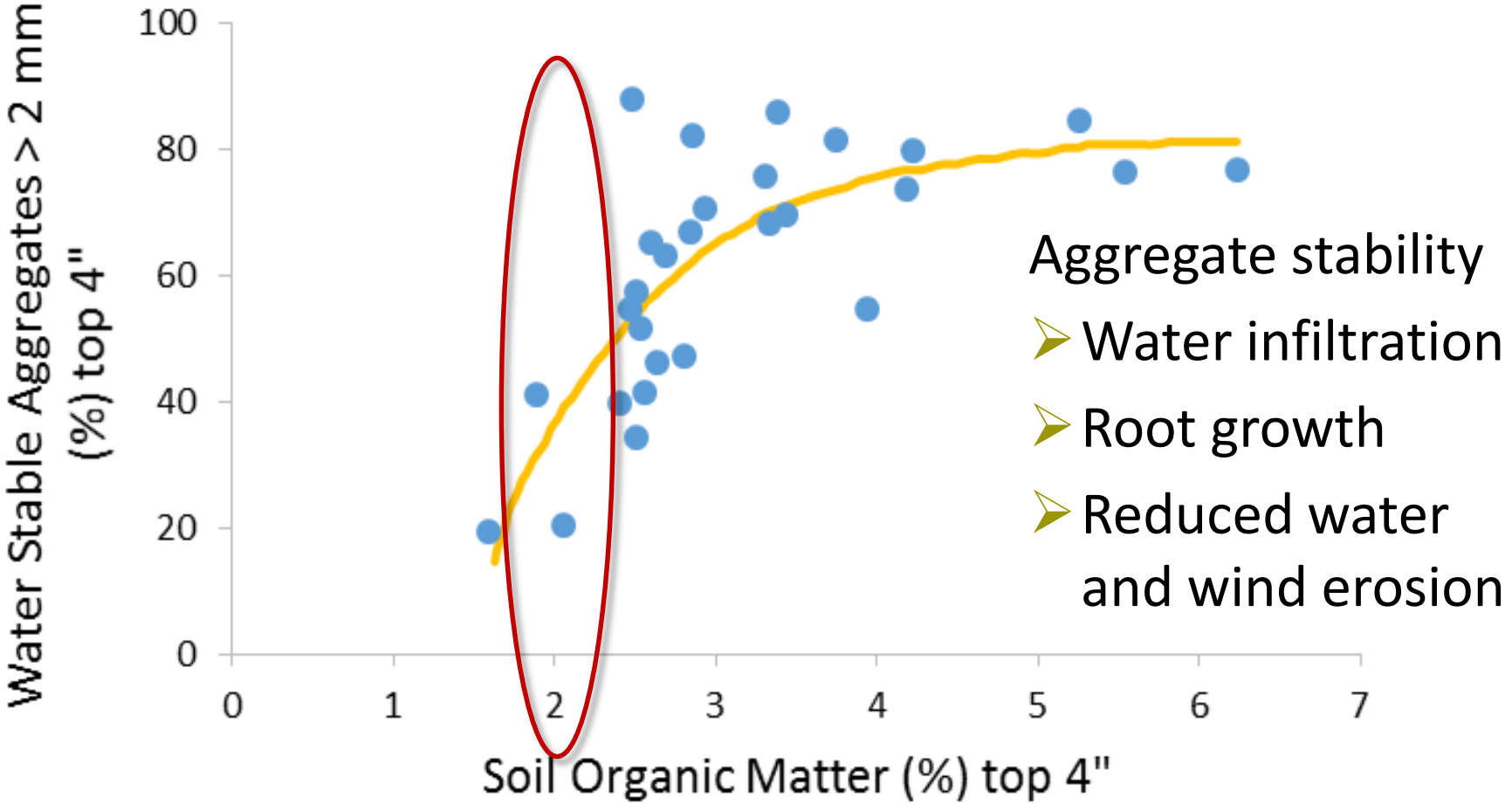
- As decomposes it releases nutrients bound in OM structure



Hudson 1994

- Increases water holding capacity which helps nutrients move from soil to plant roots and should increase yield

Small increases in SOM lead to potentially large improvement in soil structure



Fisher et al., 2007
Australia, irrigated, variety of soil types

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

20% A. Texture/surface area

20% B. pH

20% C. CEC (cation exchange capacity = the parking spaces in soil for nutrients)

20% D. SOM (soil organic matter)

20% E. Color

How can I manage for healthy soils?

- Know your soil's properties and only add amendments as needed
- Avoid compaction by:
  - Reducing tillage and traffic when wet
- Increase the organic matter content by:
  - Minimizing fallow, possibly adding cover crops
  - Moderate grazing
- Maintain cover with vegetation or residue

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

Evaluate and adjust:

- Indicators of soil nutrients: yield, quality (protein, forage nitrate), nutrient deficiencies or toxicities
- Use this year's observations to fine tune rates next year, e.g. wheat grain protein levels
- Use and develop maps, keep records
- Experiment with strip trials
- Use variable, site specific rates
- Manage to reduce N leaching and volatilization

Summary

- Understanding soil properties guides proper fertilization
- Soil tests, the online economic N calculator and MSU Extension publications are important tools to calculate fertilizer rates, maximize plant heath, protect environment
- The right rate, source, placement and timing leads to optimal fertilizer use and plant health
- Observe and adjust to your specific conditions

Resources

On soil fertility website under *Extension Publications*

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

- *Soil Sampling Strategies* (MT200803AG)
- *Interpretation of Soil Test Reports for Agriculture* (MT200702AG)
- *Developing Fertilizer Recommendations for Agriculture* (MT200703AG)
- More bulletins for specific annual crops, forage, and garden
- *Soil Sampling and Laboratory Selection* (4449-1)
  http://landresources.montana.edu/NM/
- *The Soil Scoop*
  http://landresources.montana.edu/soilfertility/soilscoop.html

Photo by Ann Ronning

Thank you!
Questions?

This presentation and more information on soil fertility is available at http://landresources.montana.edu/soilfertility