Soil Acidification

and Pesticide Management

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MSU Pesticide Education Program

Image courtesy Rick Engel

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MONTANA STATE UNIVERSITY

MSU Soil Fertility Extension

What happened here?

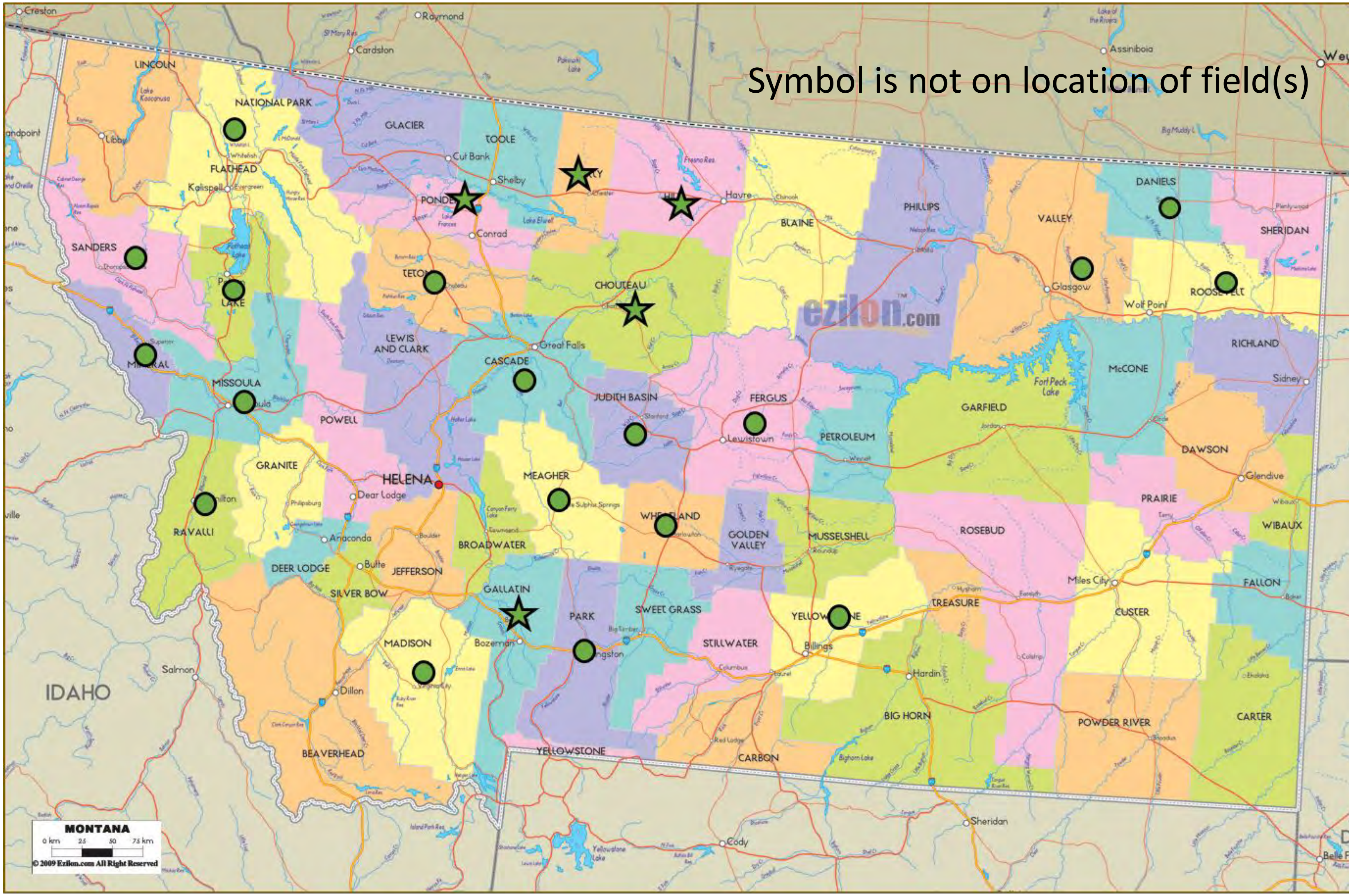
Image by Sherrilyn Phelps, Sask Pulse Growers

Objectives

Specifically, I will:

1. Show prevalence of acidification in Montana (similar issue in WA, OR, ID, ND, SD, CO, SK and AB)
2. Review acidification's cause and contributing factors
3. Show low soil pH impact on crops
4. Explain how this relates to efficacy and persistence of pesticides (specifically herbicides)
5. Discuss steps to prevent or minimize acidification

Prevalence: MT counties with at least one field with pH < 5.5



☆ Measured by MSU ● Reported by CCA, Ext. Agent, or producer

40% of 20 random locations in Chouteau County have pH < 5.5.

Natural reasons for low soil pH

- Soils with low buffering capacity (low soil organic matter, coarse texture, granitic rather than calcareous)
- Historical forest vegetation soils < pH than historical grassland
- Regions with high precipitation
  - leaching of nitrate and base cations
  - higher yields, receive more N fertilizer
  - often can support continuous cropping and N each yr

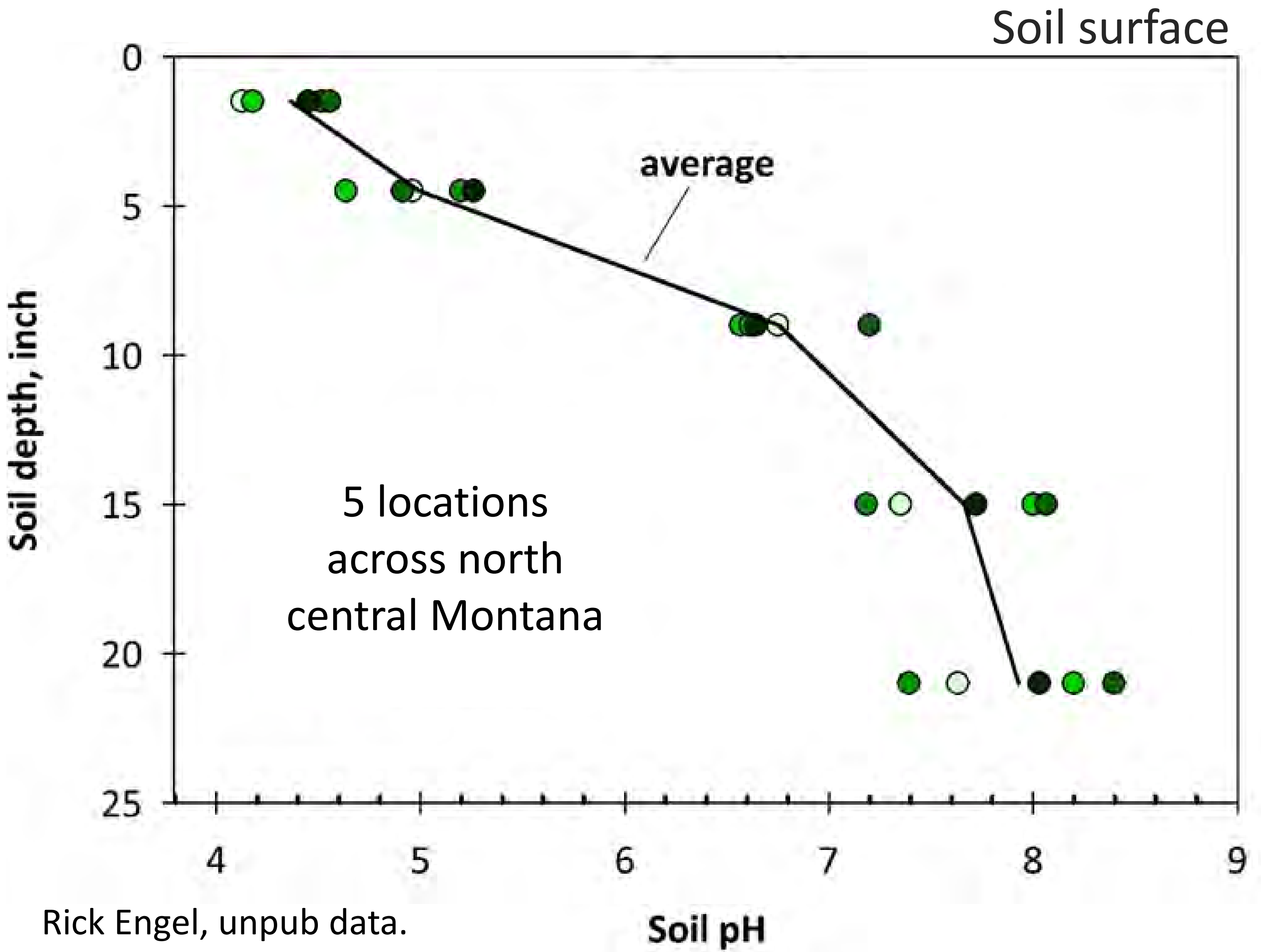
Agronomic reasons for low soil pH

- Nitrification of ammonium-based N fertilizer above plant needs

ammonium or urea fertilizer + air + $H_2O \rightarrow$ nitrate (NO_3^-) + acid (H^+)

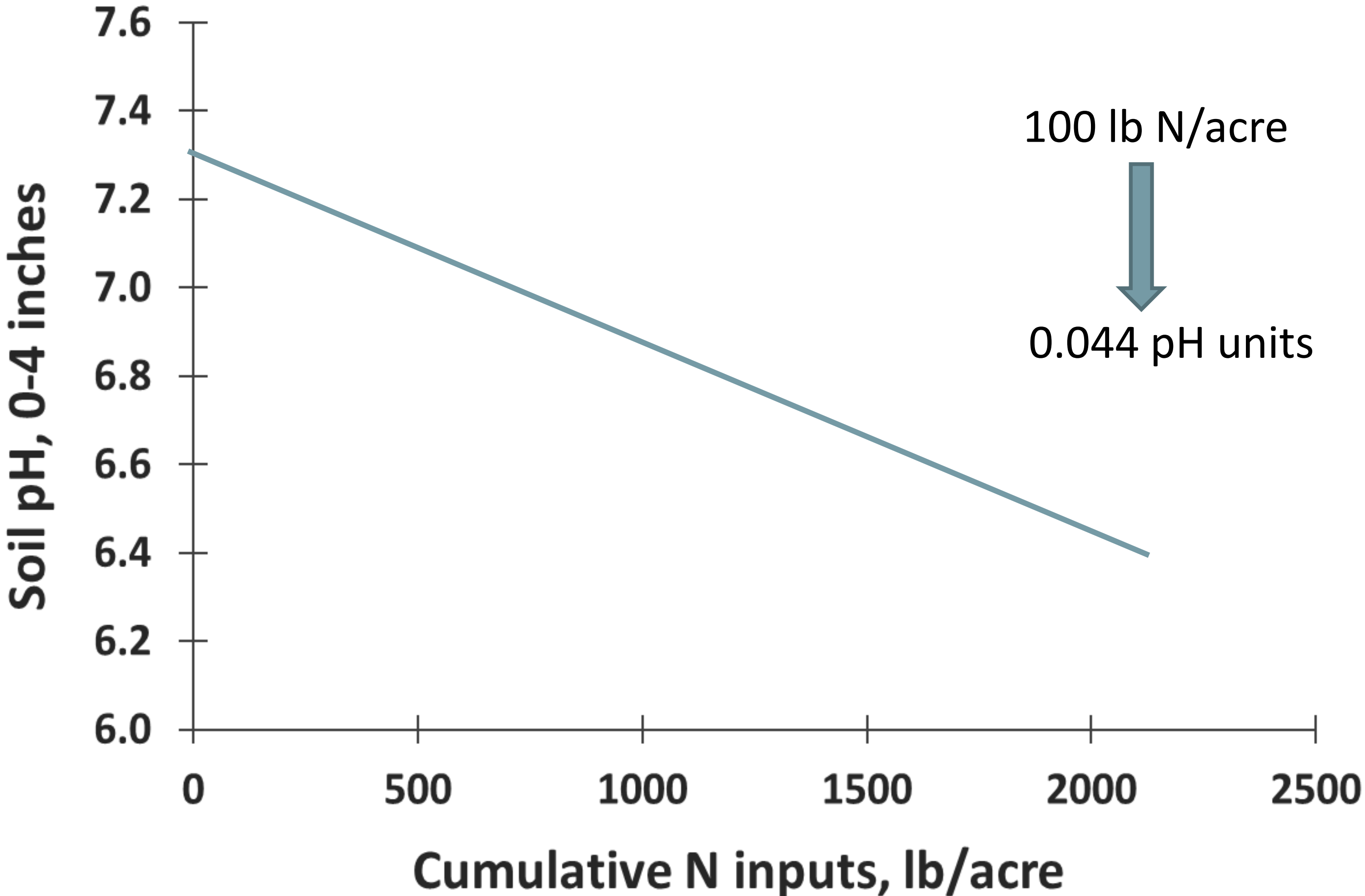
- Nitrate leaching – less nitrate uptake, less root release of basic anions (OH^- and HCO_3^-) to maintain charge balance
- Crop residue removal of Ca, Mg, K (‘base’ cations)
- No-till concentrates acidity where N fertilizer applied
- Legumes acidify their rooting zone through N-fixation. Perennial legumes (e.g., alfalfa) more than annuals (e.g., pea), but much less than fertilization of wheat.

Low soil pH in Montana's historically calcareous soils is generally only in upper 6 inches



Rick Engel, unpub data.

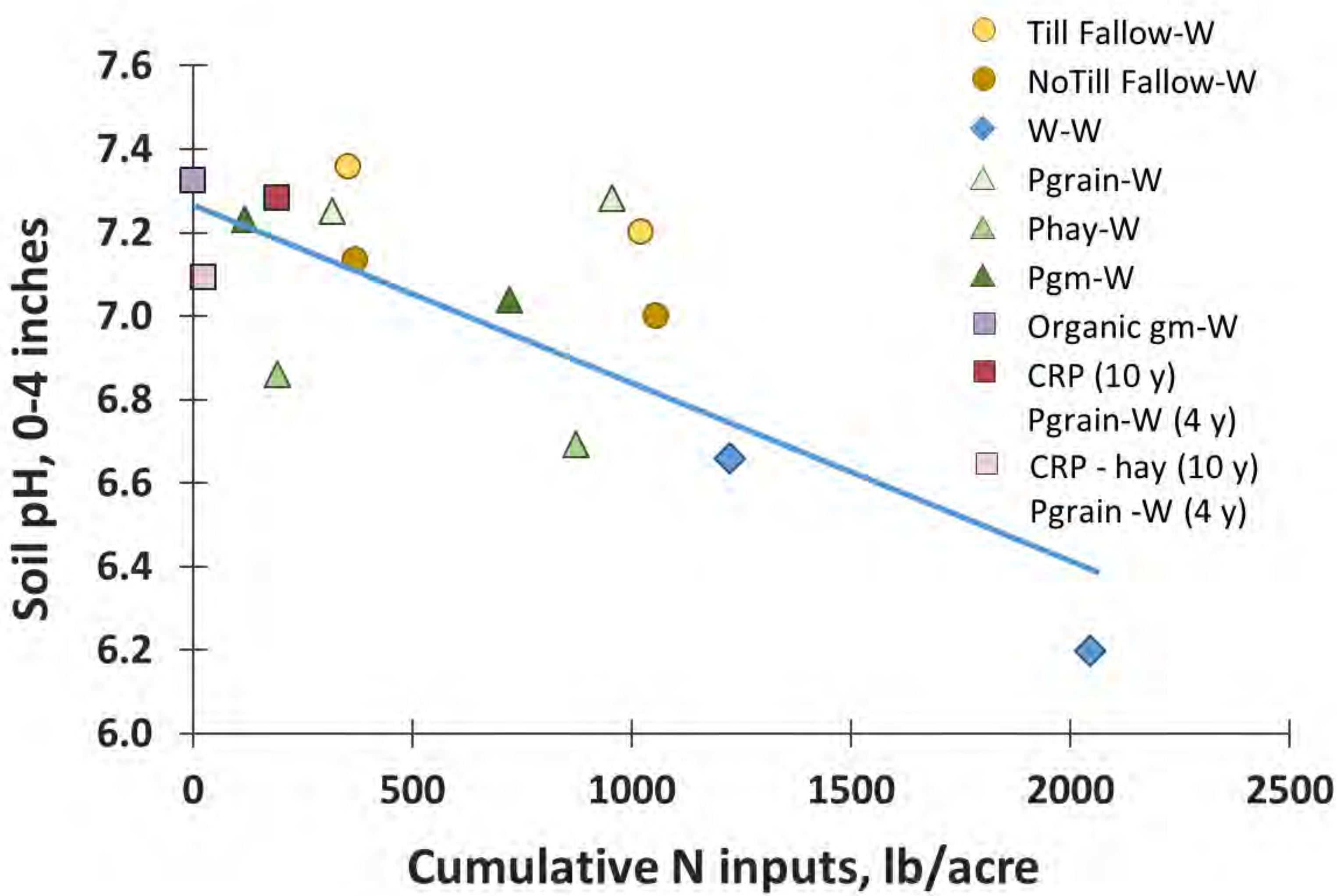
14-yr of N fertilization reduce top 4” pH on dryland cropping west of Bozeman



Silt loam

Engel, Ewing, Miller, unpub data

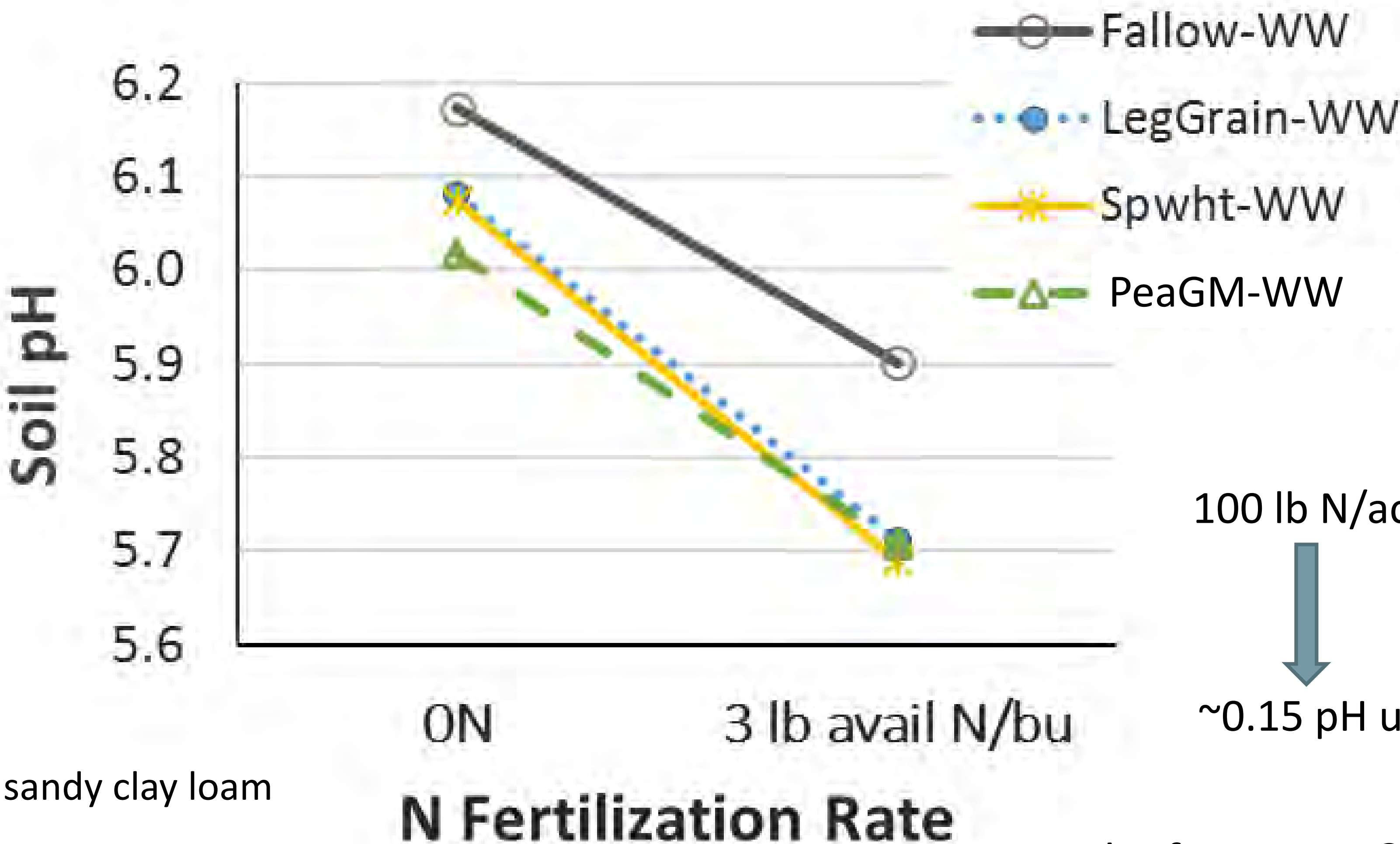
Some dryland crop rotations reduced top 4” soil pH more than others



Silt loam

Engel, Ewing, Miller, unpub data

6-yr N fertilization reduce soil pH (0-3”) west of Big Sandy



100 lb N/acre

~0.15 pH units

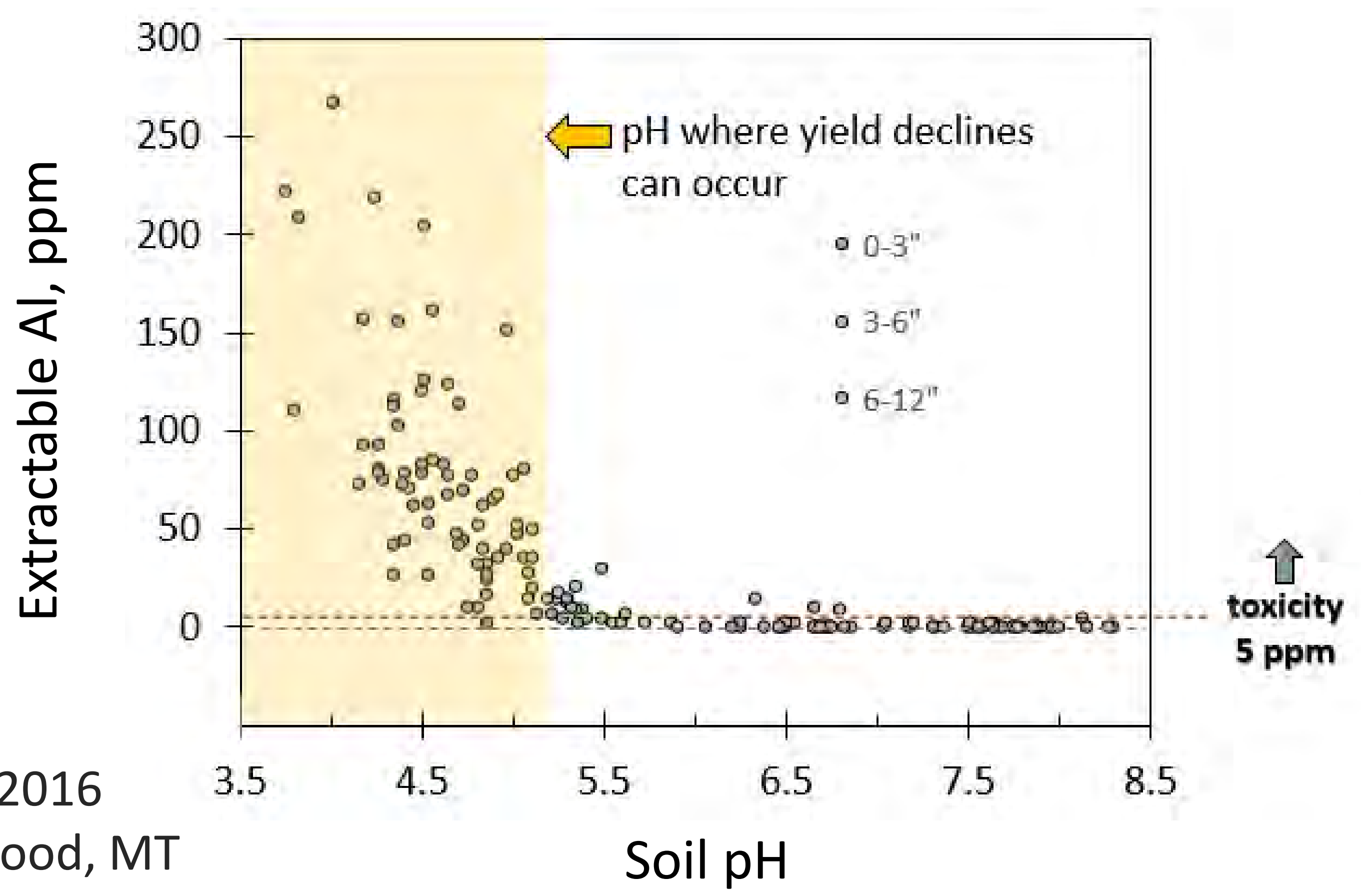
sandy clay loam

why faster rate?

Alternate year was always winter wheat; Jones and Miller unpub data

Acid soils have many negative impacts

- Damage to rhizobia (N-fixing by legumes)
- Toxic Al, Mn, and H^+ levels
- Increase in fungal diseases (Cephalosporium stripe)



Engel unpub. data, 2016
5 farms near Highwood, MT

Acid soils change efficacy and persistence of pesticides

Canola: Gov. West. Australia

Unexplained damage may be first indicator of pH change.

Barley: Thom Weir, FarmersEdge

Field pea: Gov. West. Australia

Questions?

On to pH and pesticides

Mixing-water and soil pH

MT applicators generally check water pH for tank mixes

General rule of thumb for water in tank mix:

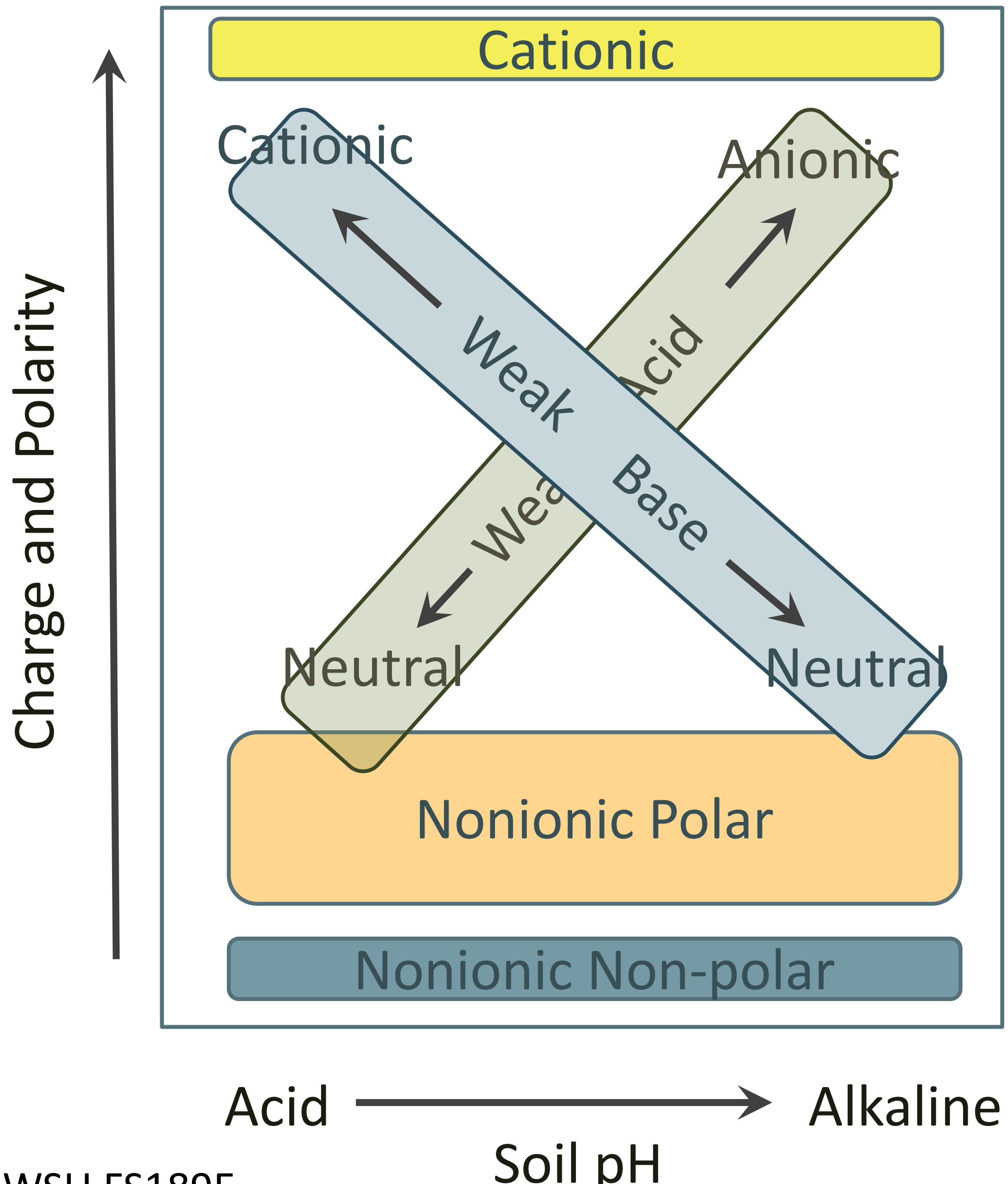
- Water pH > 7 decreases effectiveness of many fungicides, insecticides, glyphosate and a few other select herbicides.
- Water pH < 7 decreases effectiveness for sulfonylurea herbicides.

Can add buffer to change tank mix pH easily, however not practical for soil which is HIGHLY buffered.

Pesticides often classified by mode of action, but for interaction with soil pH need to classify by:

- Charge: chemicals with positive charge (cationic) will be strongly attached to soil particle (soil is usually negatively charged) while chemicals with negative charge (anionic) will be repelled.
- Polarity: A polar chemical is like a magnet with one side of the molecule more negative and the other more positive.

Chem reaction to change in pH



WSU FS189E

Cationic – sticks tight to soil regardless of pH (*e.g. paraquat*)

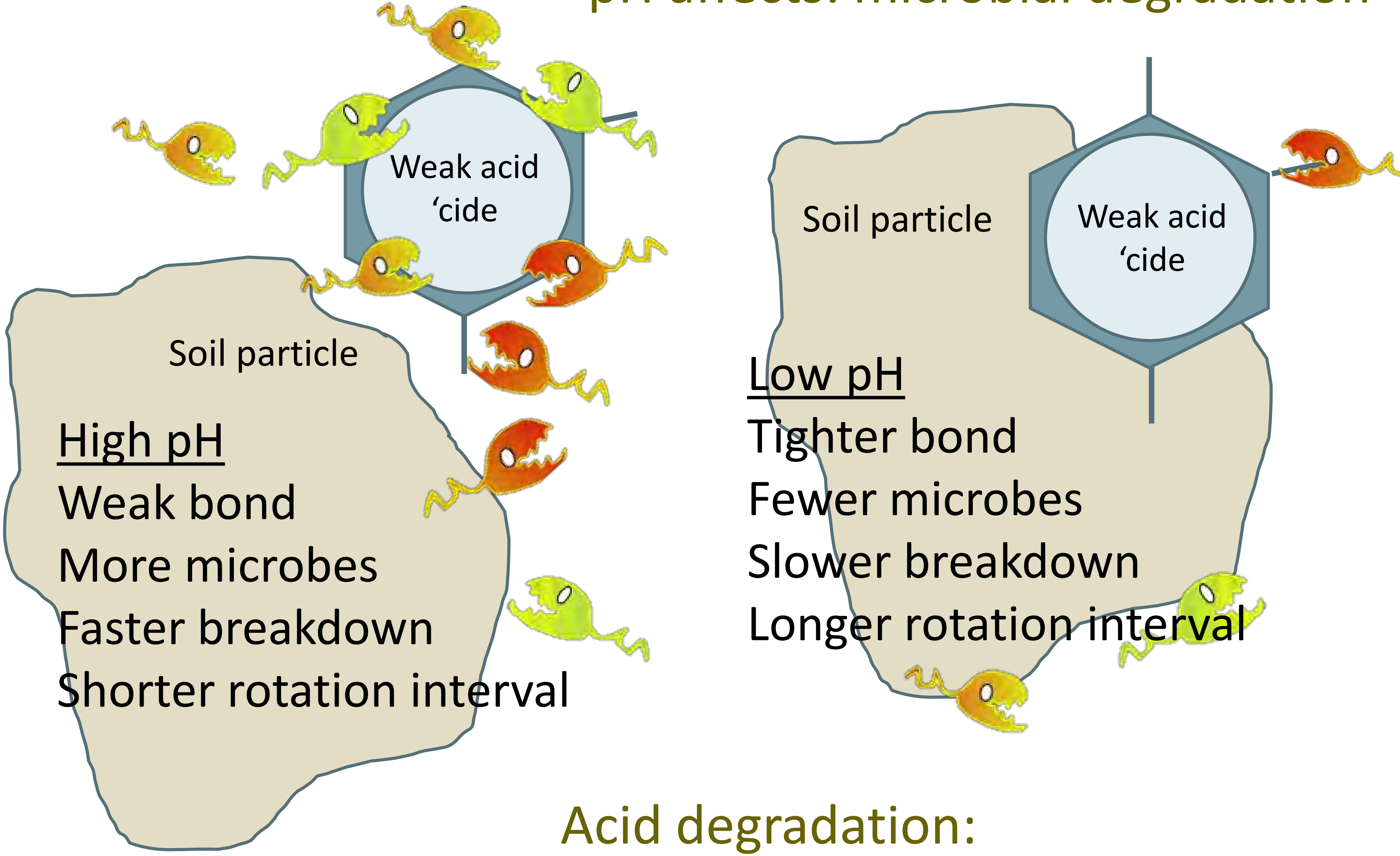
Nonionic polar – weak soil bond, regardless of pH (*e.g. trifluralin, endimethalin*)

Nonionic non-polar – very weak soil bond, regardless of pH

Weak base – sticks tighter in acidic than alkaline soils (*e.g. Triazines: prometon, metribuzin*)

Weak acid – less soluble in water with drop in pH (*e.g. dicamba, 2,4-D, imazamox, imazethapyr*)

pH affects: microbial degradation

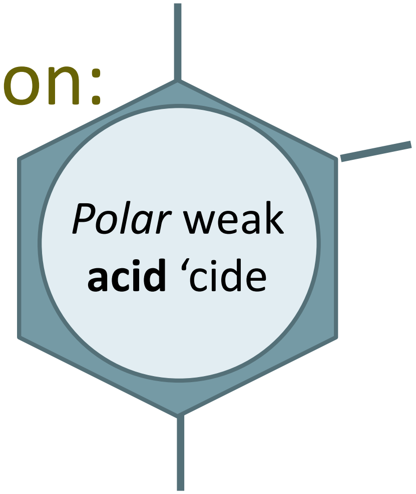


Acid degradation:

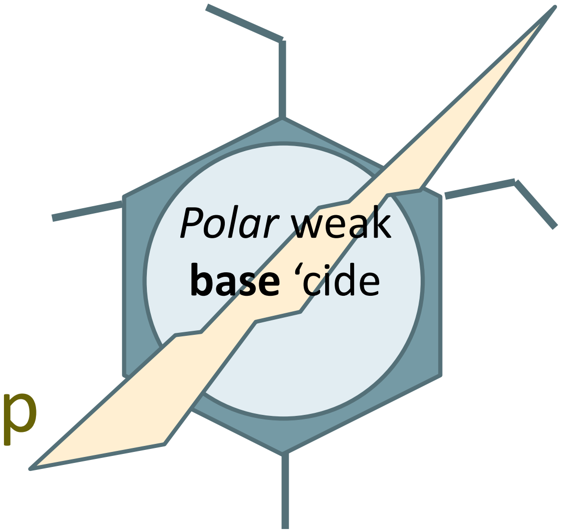
At pH < 6.8, faster degradation, shorter efficacy (e.g. sulfonylureas)

pH affects efficacy due to:

Dissociation:



Stable



Break-up

Slower dissociation (break-up) into smaller ineffective units at pH < 7, longer efficacy

Faster break-up at pH < 7, shorter efficacy

Availability: pesticides that stick tight to soil (weak bases) are less available for plant uptake at lower pH

Root uptake: for some herbicides (Imidazolinones), root uptake depends on pH gradient between soil solution and root cell. As soil pH decreases, uptake increases.

Questions?

On to specific examples

NOTE: I'm a soil fertility specialist asked to speak on this topic. You should check chemical properties of any pesticide you apply or recommend.

WEAK ACIDS' change in efficacy and persistence with drop in pH

Type and tradenames	Efficacy	Persistence
	With decreased pH	
Imidazolinones: *Imazapyr, Beyond, Pursuit*	Higher	Longer
Triazolopyrimidines: *First Rate, Python, PowerFlex*	Higher	Longer
Sulfonylureas: *Ally, Osprey, Outrider, Maverick*	Lower at pH < 7	Shorter at pH < 6.8
2,4-D, glyphosate	No change	No change

Check the label

Example: Beyond® pesticide label, 2011

Barley rotational interval based on pH, moisture, tillage		Plowing	
Region 1* and 2		No	Yes
pH and water	pH > 6.2 and > 18”	9 months	
	pH < 6.2 or < 18”	18 months	9 months
* Region definitions vary by herbicide. For Beyond, Region 1 is west of US Hwy 83			

Barley rotational interval based on pH, moisture		
Washington and select counties in Idaho** and Oregon***		
pH and water	pH > 6.2 and > 16”	9 months
	pH < 6.2 or < 16”	36 months
** Idaho: Benewah, Bonner, Boundary, Clearwater, Idaho, Kootenai, Latah, Lewis, Nez Perce, Shoshone *** Oregon: All but Malheur		

When taking soil samples to determine soil pH, use grid sampling to 3-4”

Example: Ally – check all sources, and parts of label

DuPont MSDS (aka CDMS) label

Soil pH Limitations

Do not use ALLY XP on soils having a pH above 7.9, as extended soil residual activity could extend crop rotation intervals beyond normal. Under certain conditions, ALLY could remain in the soil for 34 months or more…..

US EPA label, 2006

State	County	Crop	Soil pH	Min rotation interval (mo)
MT	Statewide	Grain	≤ 7.9	22
		Alfalfa	7.6 - 7.9	34
			≤ 7.5	22
		Oilseeds	≤ 7.9	22
On a different page of label		Grasses	≤ 7.5	4
		Wheatgrasses	7.6 - 7.9	4

https://www3.epa.gov/pesticides/chem_search/ppls/000352-00435-20060126.pdf

OTHER HERBICIDES' change in efficacy and persistence with drop in pH

Type and tradenames	Efficacy	Persistence
	With decreased pH	
Nonionic		
Triazolinones: *Spartan*	Lower	Longer
Pyroxasulfones: *Zidua, Anthem Flex*	No change	Longer
Cationic		
Paraquat	No change	No change
Weak bases		
Atrazine, triazinones, metribuzin, prometon: *Atrazine 4L, Sencor, Dimetric, Pramitol*	Lower	Longer

Small pH change, large impact

For example

- Triazolopyrimidines' strength of bond to SOM increases as pH < 7, become less available for uptake and degradation. A 0.2 pH reduction below pH 6.5 doubles the amount adsorbed. (NSDU Herbicide Carryover)
- Triazine (atrazine) binds tight to soil OM at pH < 7.5, high crop safety, low efficacy (NDSU Herbicide Carryover)

Small changes in pH across a field can mean the difference between high crop safety with low efficacy, and high crop damage with weed control

Questions?

On to acidification prevention and remediation

What to do?

- Look for evidence of decreased soil pH, or "unexplained" chemical damage
- Chemical treatments may need modification. Read and follow label directions.
- Prevention/remediation of soil acidification
- Look at N management. In long term has bearing on pesticide persistence, efficacy, non-target toxicity, and pesticide selection.

What to look for

- Unexplained poor health in low or mid-slope areas
- **Al** toxicity
  - stubby club roots, no fine branching (similar to nematode damage)

photo sources: Engel

A. Robson,
https://agric.wa.gov.au/n/4487

Above ground symptoms of Al toxicity

- small leaves, short thick internodes
- yellow along margin near tip on older leaves
- purple or brown lesions in chlorotic regions, indentations
- leaf withering and collapse in center
- similar to N deficiency

Courtesy CIMMYT.org

courtesy Engel

Acidification prevention: Soil test

1. Look at pH on prior soil tests from composited samples
   - pH < 6 likely have spots with pH near or below 5 (go to step 2)
   - 6 < pH < 7.5 don't assume no areas have low pH
   - pH > 7.5, likely don't have problem (yet).
2. Field test healthy and unhealthy areas, use soil/water slurry of top 3". Why not the standard 6"?
3. Send 0-3" depth sample to lab for pH (<5?) and KCl-extractable Al (> 5 ppm?). Test 3-6" if might till.
4. pH varies seasonally and annually, test from same area and time of year by same lab using same procedure

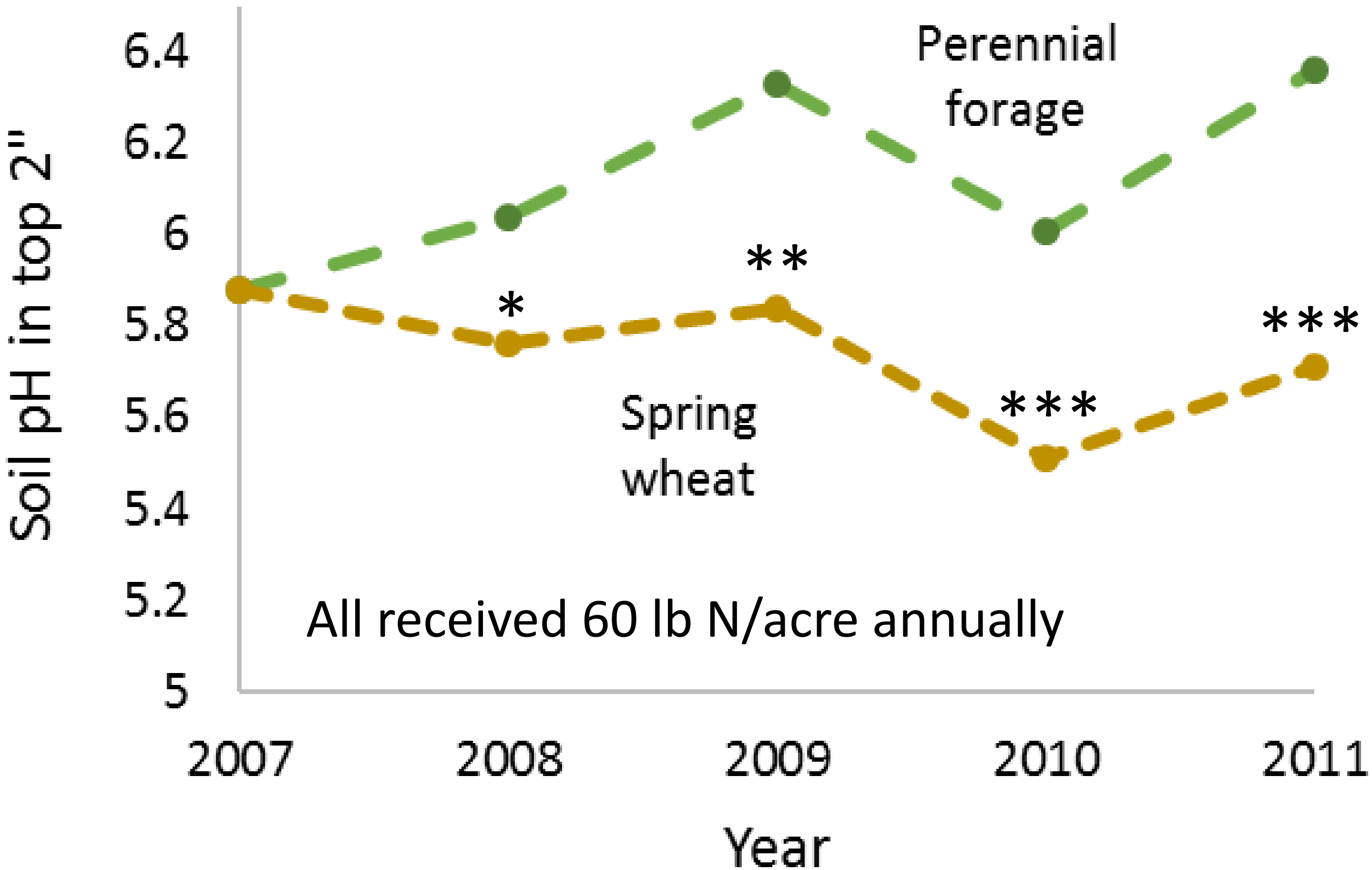
Management to prevent acidification:
Increase nitrogen fertilizer use efficiency

- Soil test close to application time. Make sure enough PKS
- Use conservative pre-plant rate, top-dress if adequate moisture
- Apply N close to peak crop uptake
- Plant lower N-needing crops, including pulses
- Plant perennial forages (list of acid-tolerant varieties on our soil acidification website)
- Reduce N rates especially when protein discounts low
- Use variable, site specific rates: Less N in low production areas limited by other than N (e.g., low pH, shallow soils)

Management to prevent acidification: Change N source?

- Minimize use of ammonium fertilizers (11-52-0, 21-0-0-24)
- Use calcium ammonium nitrate ($$) instead of urea or UAN (CAN shouldn't volatilize so can likely also lower rate)
- Include legume rotations, manure if available

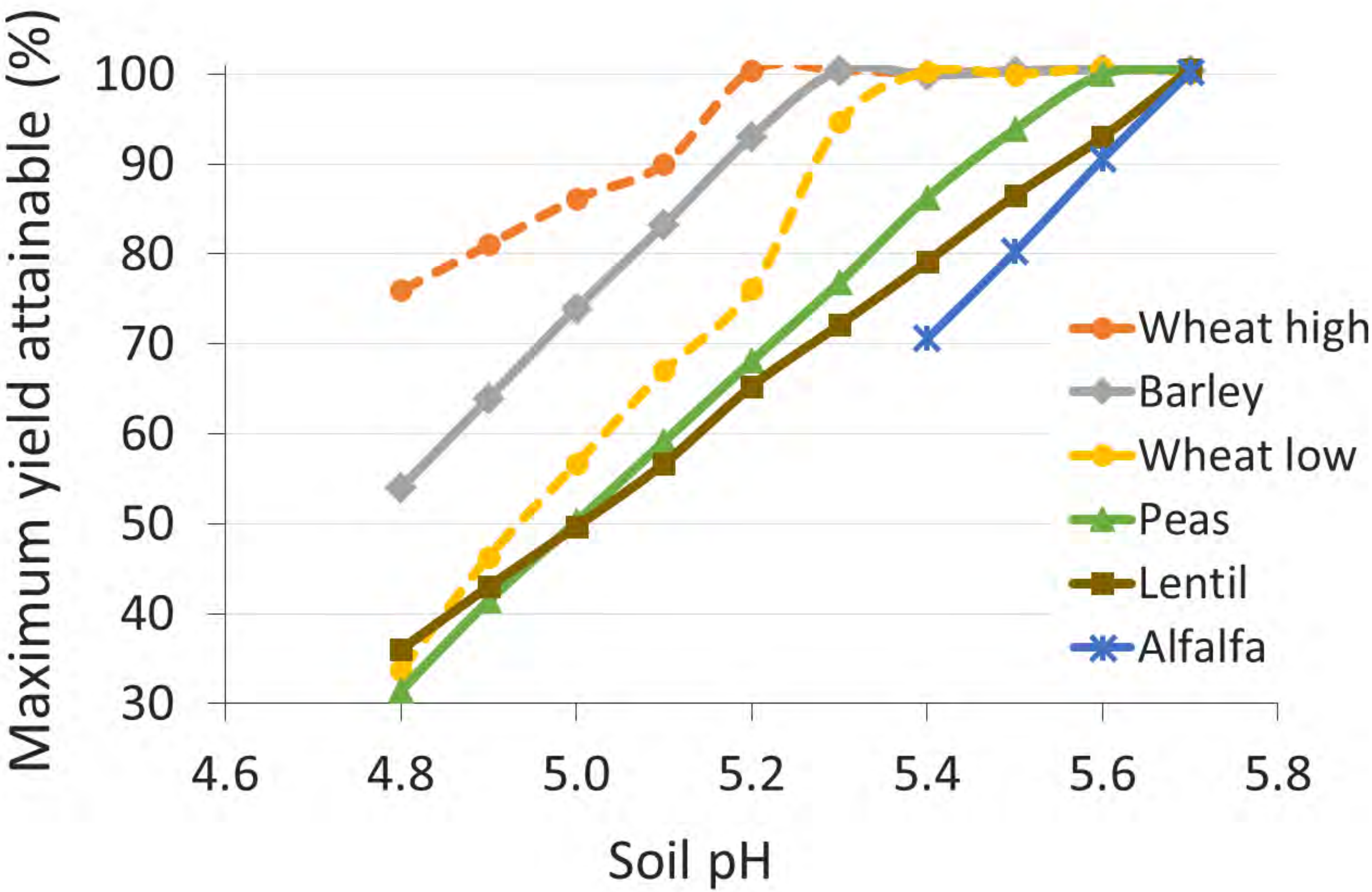
Perennial forage can maintain or increase soil pH



crops differ with * > 90%, ** > 95%, *** > 99% confidence

Mandan, ND Liebig et al., 2018

Adaptation: Crop species vary in tolerance to low soil pH legumes are least tolerant



McFarland et al., 2015

"Wheat high" are Al and acid tolerant varieties

Wheat varieties have different tolerance to pH and Al

Custer	Ok101	Jagalene	Jagger	2174	AP502CL	Ok102	2137
6.6	5.5	6.0	5.8	5.9	6.2	6.4	5.3

Threshold pH

(Kariuki et al, 2007)

MT variety trial results are available at

http://landresources.montana.edu/soilfertility/acidif/index.html

Liming

- Know:
  - Calcium carbonate equivalent (CCE; how source compares to pure $CaCO_3$)
  - Lime score (LS; adds factors for moisture and fineness to CCE)
  - Current soil pH and desired pH
    - > 5 to reduce Al toxicity
    - > 5.5 to have some buffer
    - > 6 to be good for 10+ years
  - Desired crop
- Rate: from soil test lab or calculate (WSU equation)

  Lime rate (ton/acre) = 1.86*(final desired pH – 4.6)

  Note: Researchers in WA, MT, OR, and ID are working towards specific recommendations for their states
- Only lime field areas with low soil pH

Sugarbeet lime

Stoltzfus lime spreader, Stoltz Mfg.

- good – it doesn't cost anything
- bad – shipping costs, challenging material to work with (moisture and clumping), need a wet lime spreader, contains chunks and some trash, and incorporation w/ tillage needed for best results
- rates of 3-6 tons/acre may be necessary to bring pH to pH > 6

Summary

- Cropland soils are becoming more acidic, largely due to N fertilization
- This likely affects pesticide efficacy and persistence
- Sound nutrient, crop, and residue management can slow or prevent soil acidification
- Crop and variety selection can help adapt to acid soils
- Liming, perhaps tilling, or planting perennials can mitigate acidification

Thank you!

Image from Oregon State University, Lane County, OR 1926.

For more information and links to additional resources on soil acidification see MSU's cropland soil acidification website http://landresources.montana.edu/soilfertility/acidif/index.html

If you have questions about soil and buffer pH tests go to https://www.youtube.com/watch?v=w9PWZSaFfb4