



**University of Idaho**

College of Agricultural  
and Life Sciences

# **SOIL ACIDIFICATION: MANAGEMENT AND IMPACT ON CEREAL DISEASES**

**DR. KURTIS L. SCHROEDER**

**CROPPING SYSTEMS AGRONOMY AND  
PLANT PATHOLOGY**

**DOUG FINKELNBURG**

**AREA EXTENSION EDUCATOR**

**DECEMBER 11, 2018**

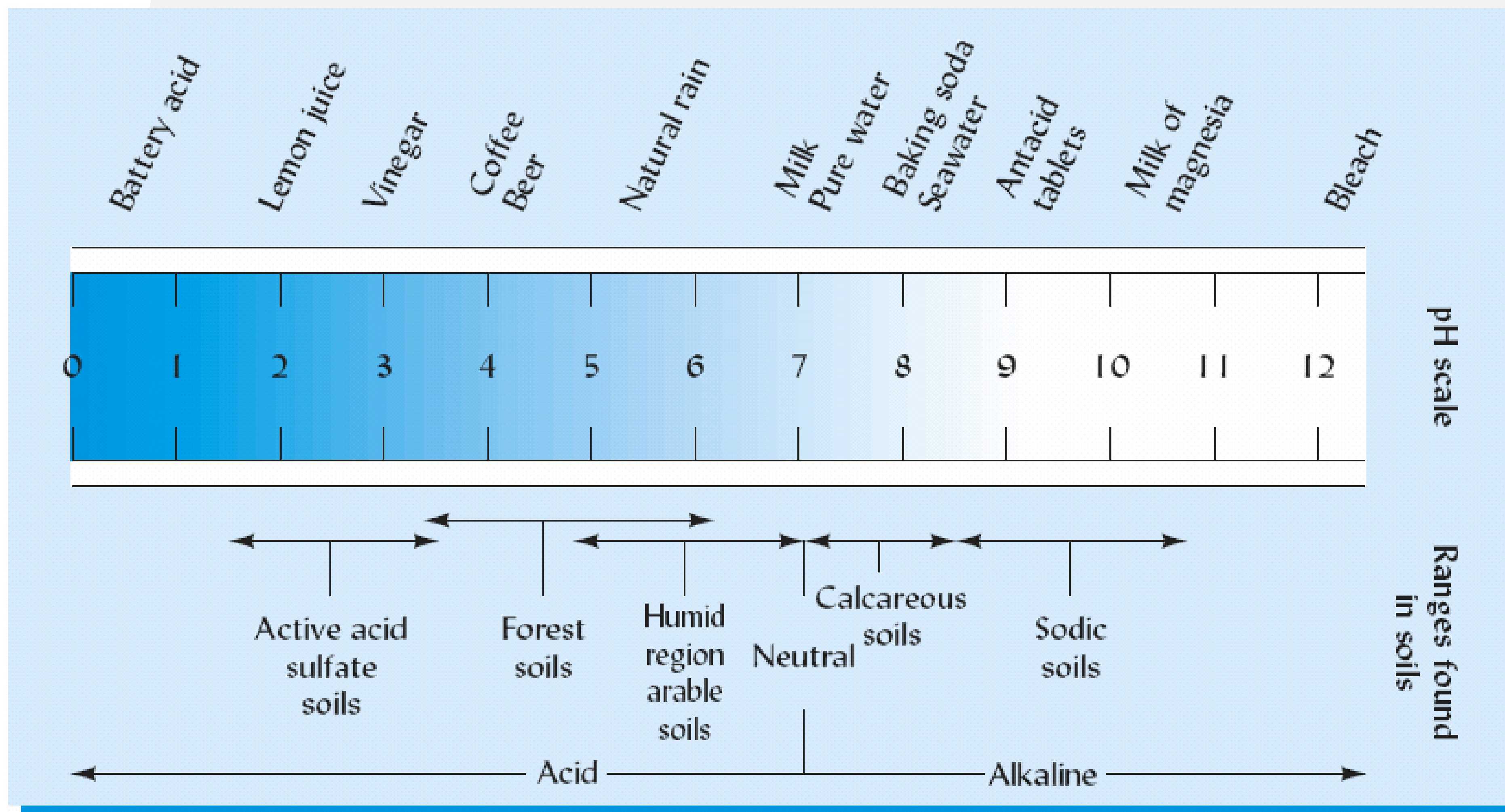
# OUTLINE

- Introduction to soil acidity
- Survey of north Idaho
- Management of soil acidity
- Hands-on demonstrations
- Interaction between soil pH and plant pathogens

# SOIL PH

- Degree of acidity or alkalinity (0 to 14 scale)
- Soil solution  $\text{pH} = -\log [\text{H}^+]$
- Each unit of pH change = 10X change in  $\text{H}^+$ 
  - pH of 5 is 10 times more acid than 6
- Impacts soil chemistry and biological properties
  - Root uptake of nutrients and toxins
  - Activity of soil microorganisms

# PH SCALE

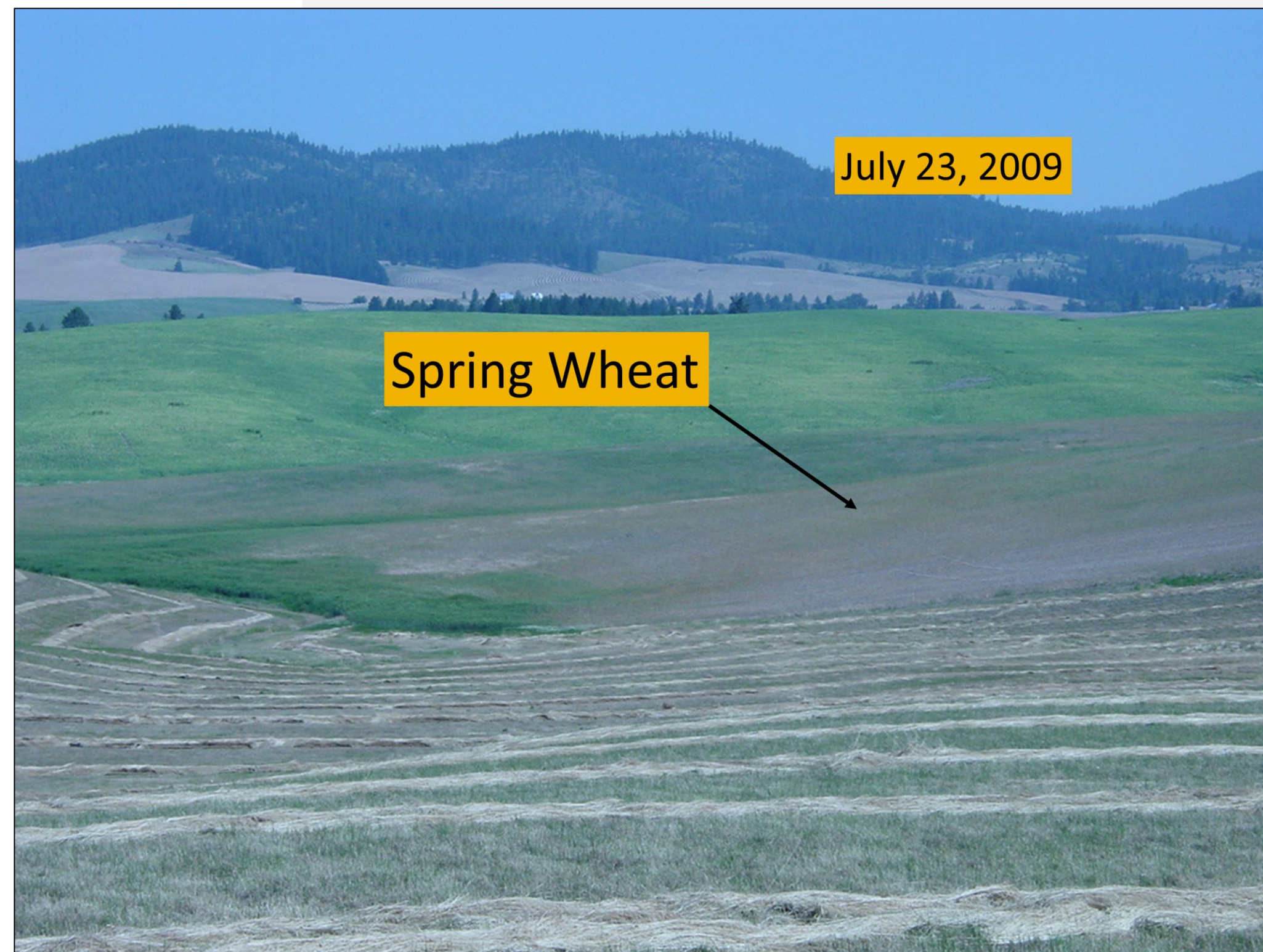




# SOIL ACIDIFICATION



- 60 years of ammonium forms of nitrogen fertilizer
- Low soil pH associated with aluminum toxicity





# PROBLEMS WITH ACID SOILS

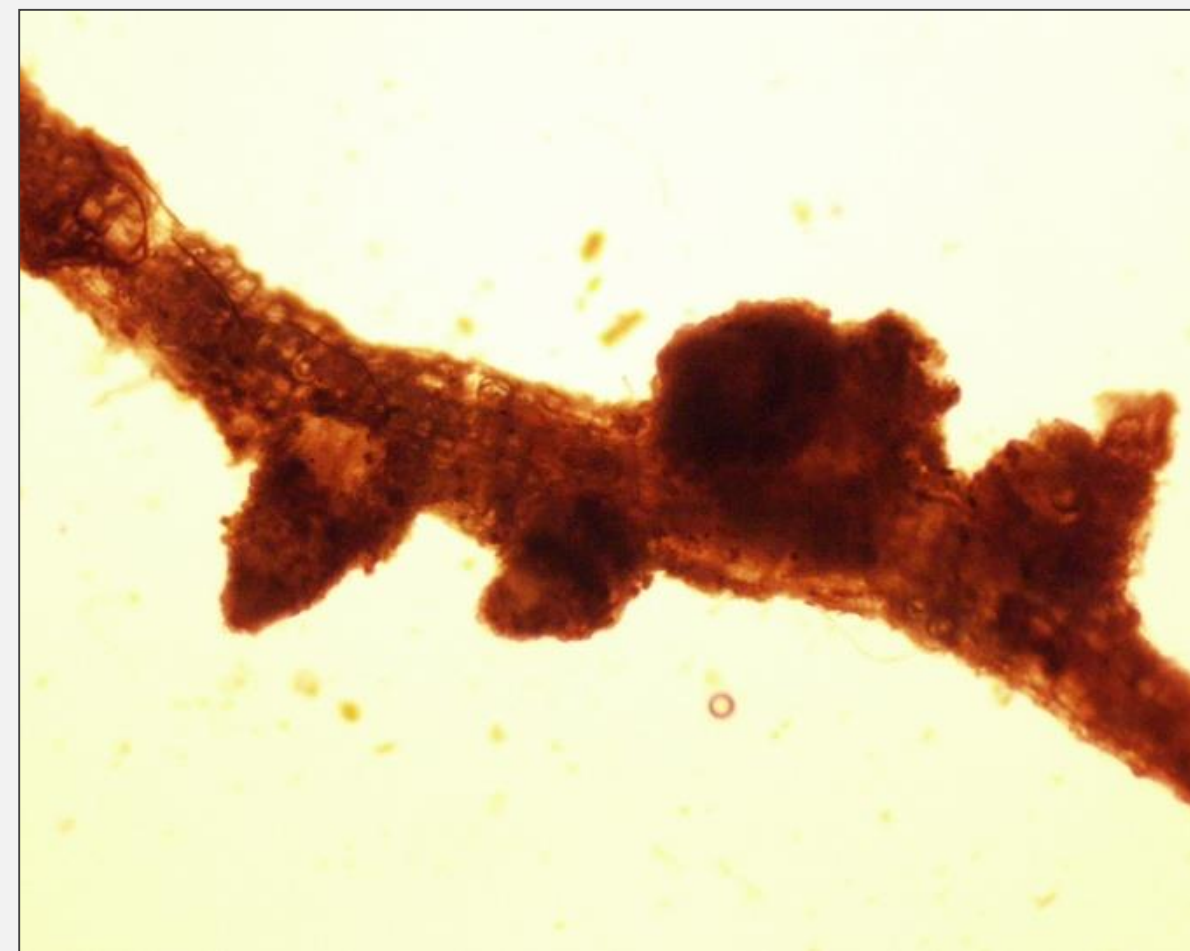
- Potential toxicity from Al, Mn, other metals
- Lack of cationic nutrients: Ca, K, Mg
- Low P availability (Fe- and Al-phosphates)
- Toxicity to rhizobia in legumes
- Impact on plant diseases

# WHY IS ALUMINUM A PROBLEM?



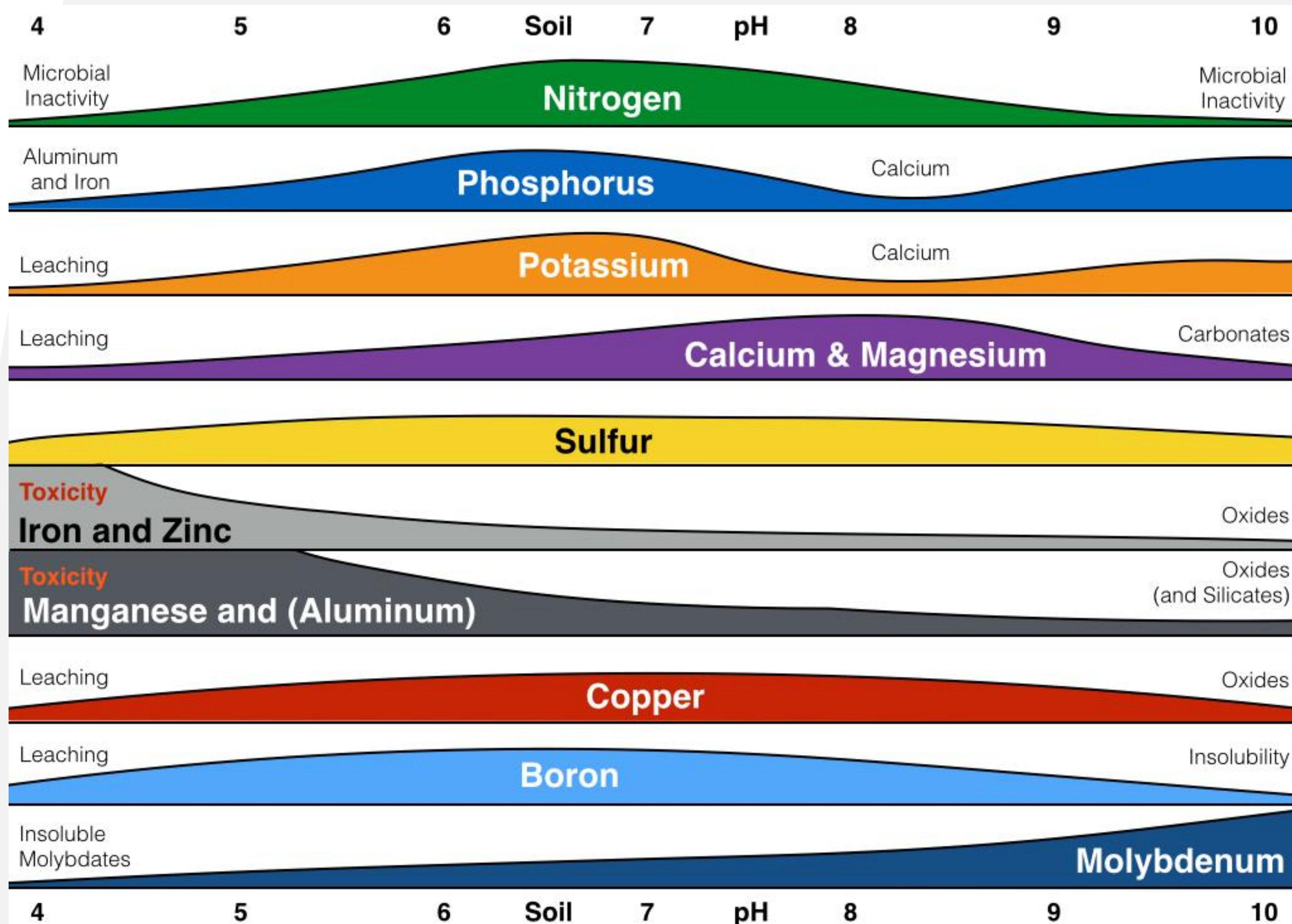
- Most abundant metal in earth's crust  
7% (70,000 ppm)
- Most is complexed on soil particles and clays as fixed forms: Al oxides and silicates
- However, free ion  $\text{Al}^{3+}$  is toxic to plants
- Root tips are most affected-growth is inhibited
- Interferes with hormone signaling
- Interferes with Ca uptake- involved in root development

# ALUMINUM TOXICITY DAMAGE ON WHEAT ROOTS





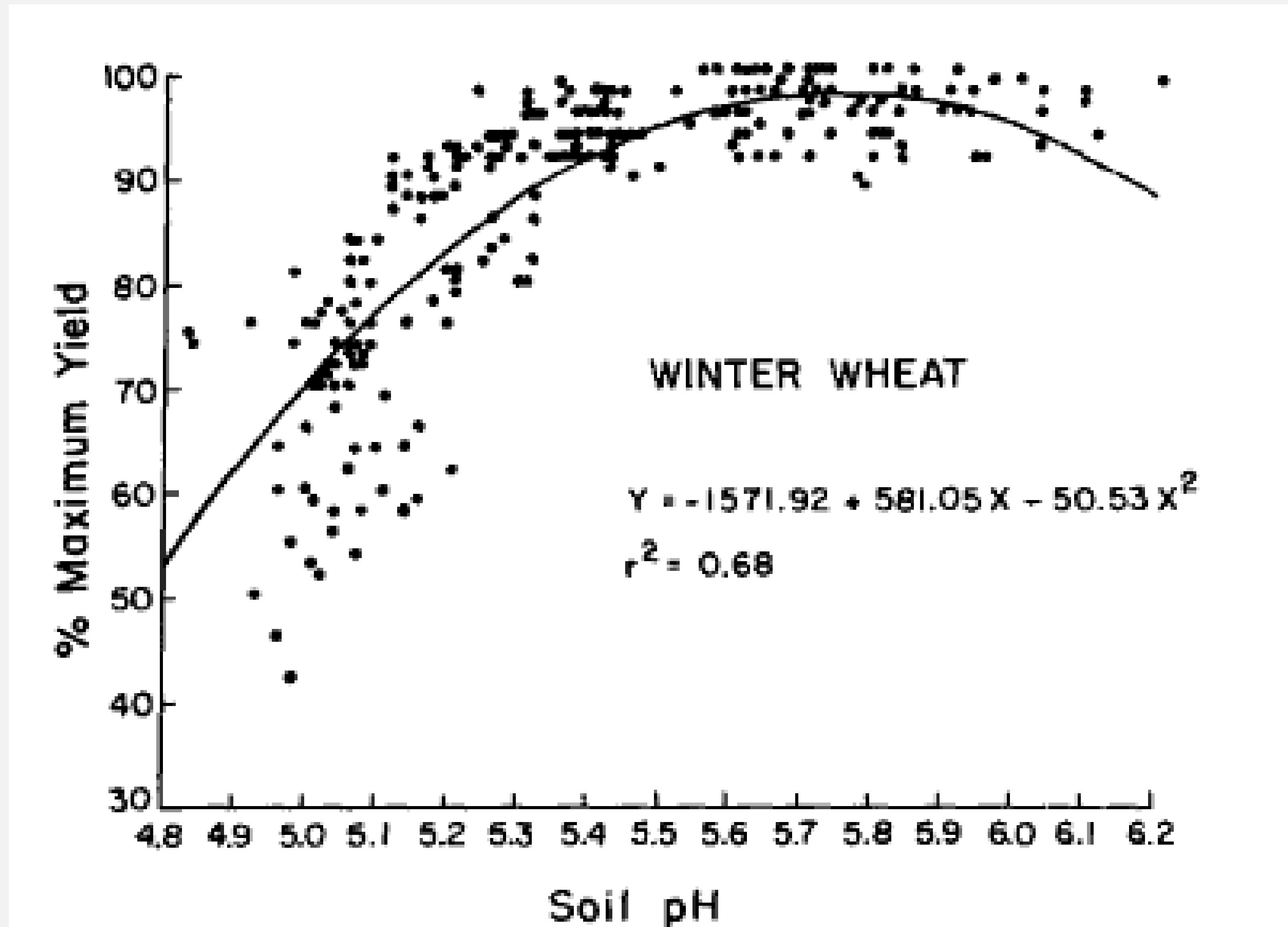
# NUTRIENT AVAILABILITY/PH RELATIONSHIP



# PH ASSOCIATION WITH YIELD REDUCTION



(Mahler and McDole, 1987)

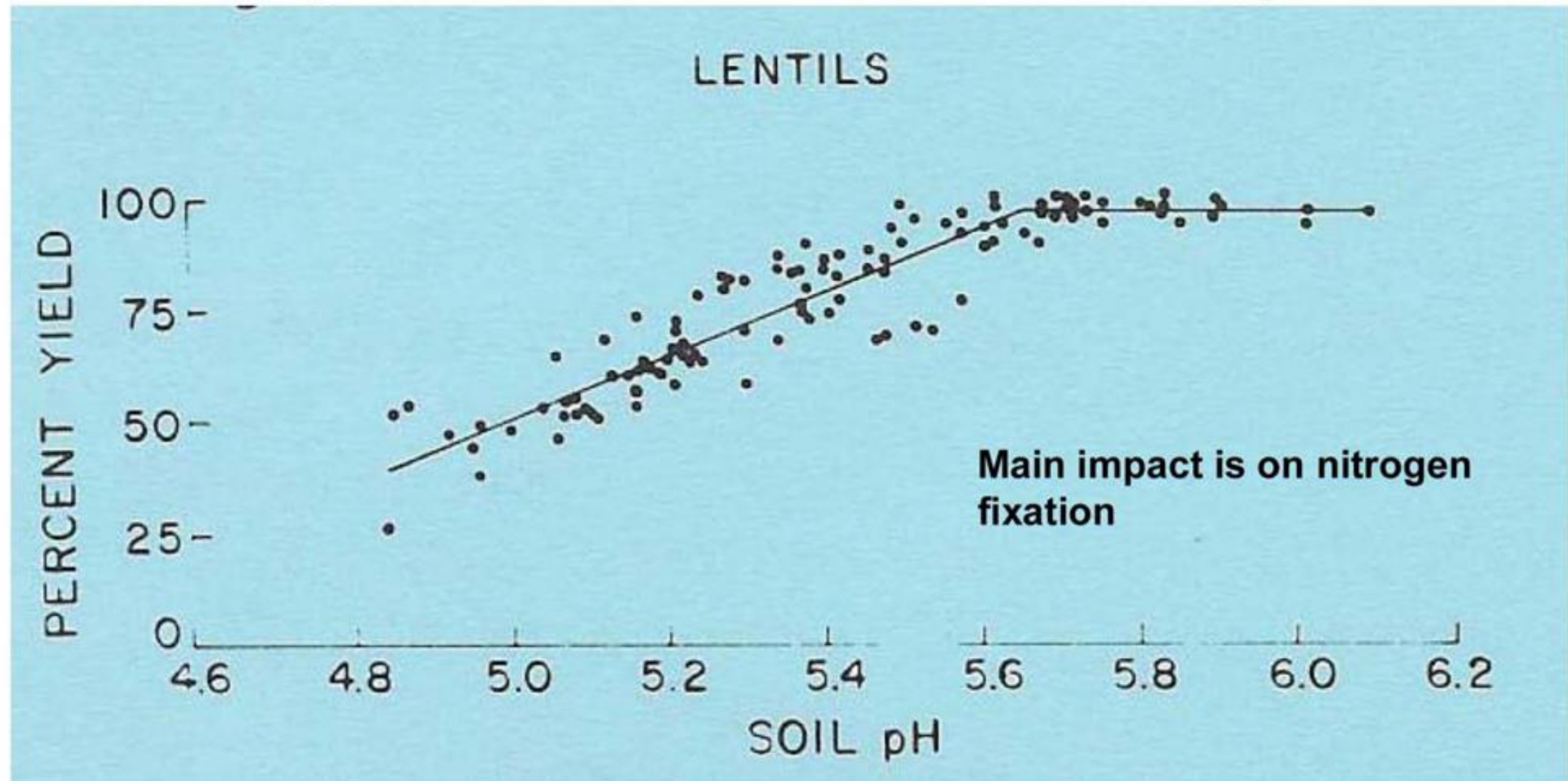




# PH ASSOCIATION WITH YIELD REDUCTION



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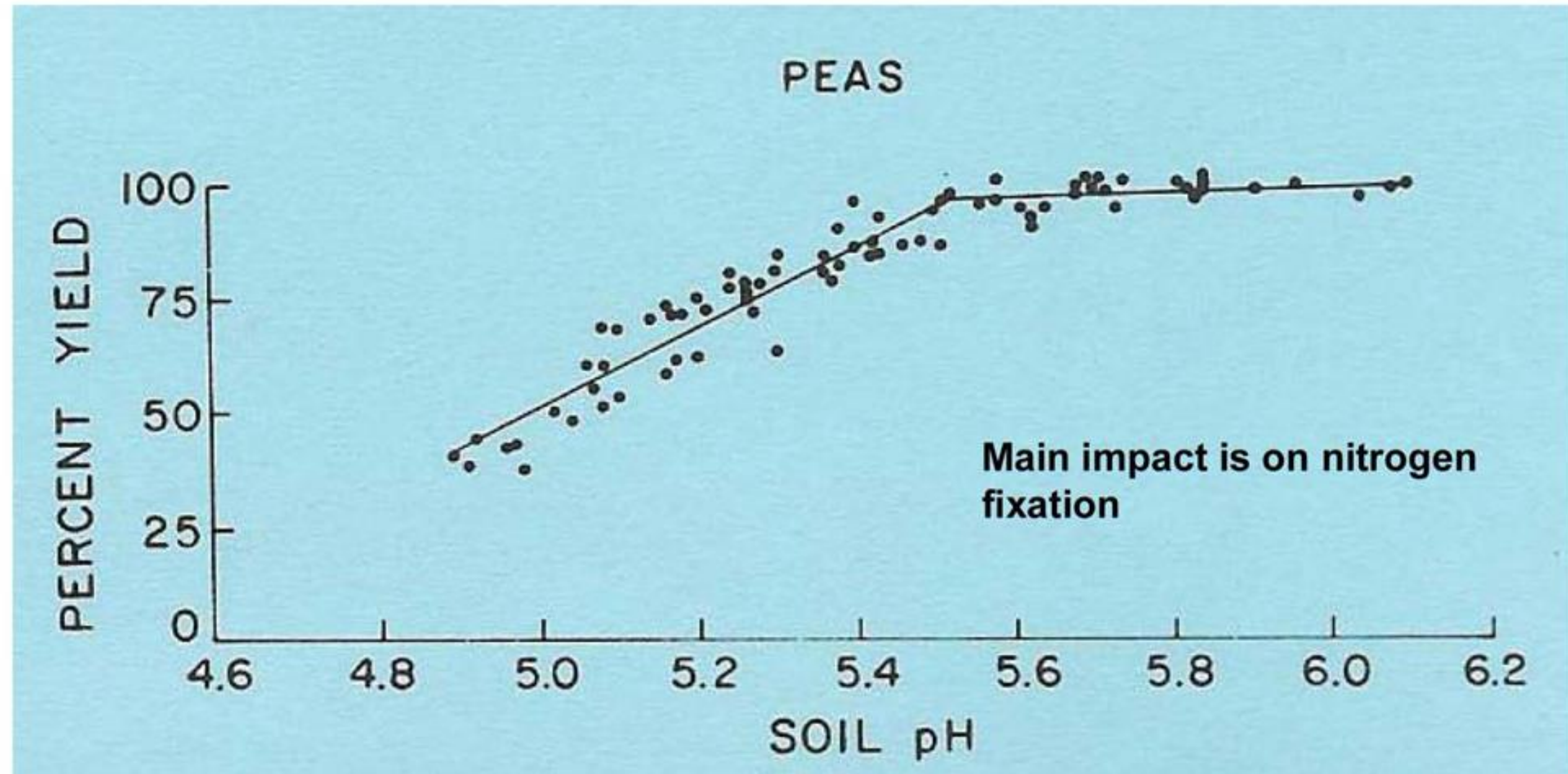




# PH ASSOCIATION WITH YIELD REDUCTION



(Mahler and McDole, 1987)

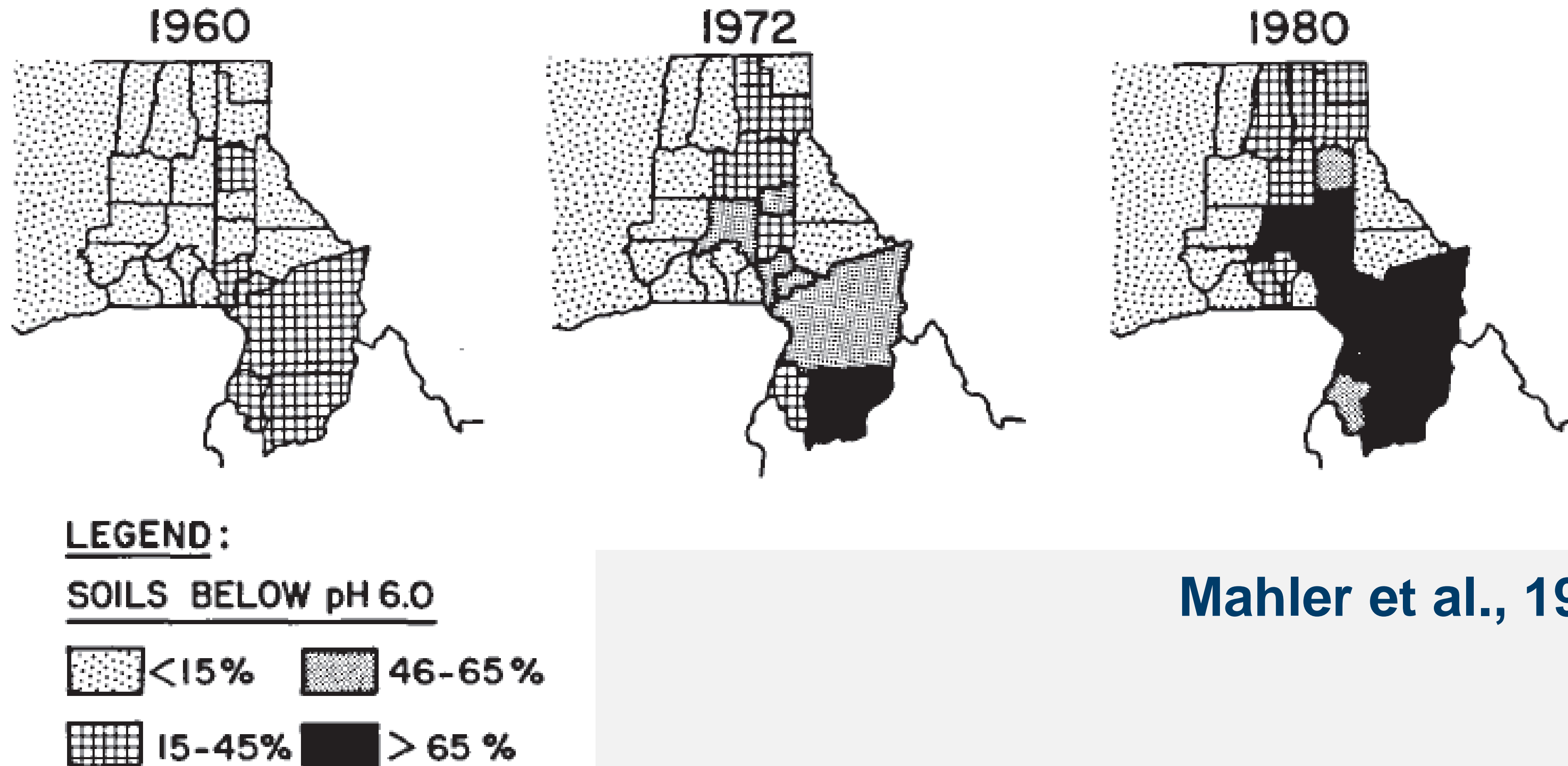






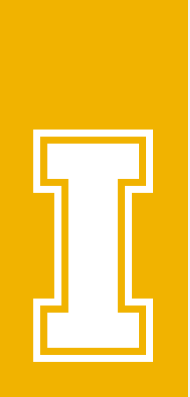
# **CHANGE IN SOIL PH – NORTH IDAHO SOIL SURVEY**

# DECLINE IN SOIL PH IN PNW



**Mahler et al., 1985**

# SOIL ACIDIFICATION IN NORTHERN IDAHO



- 1982 to 1984
- Depth of 6 inches

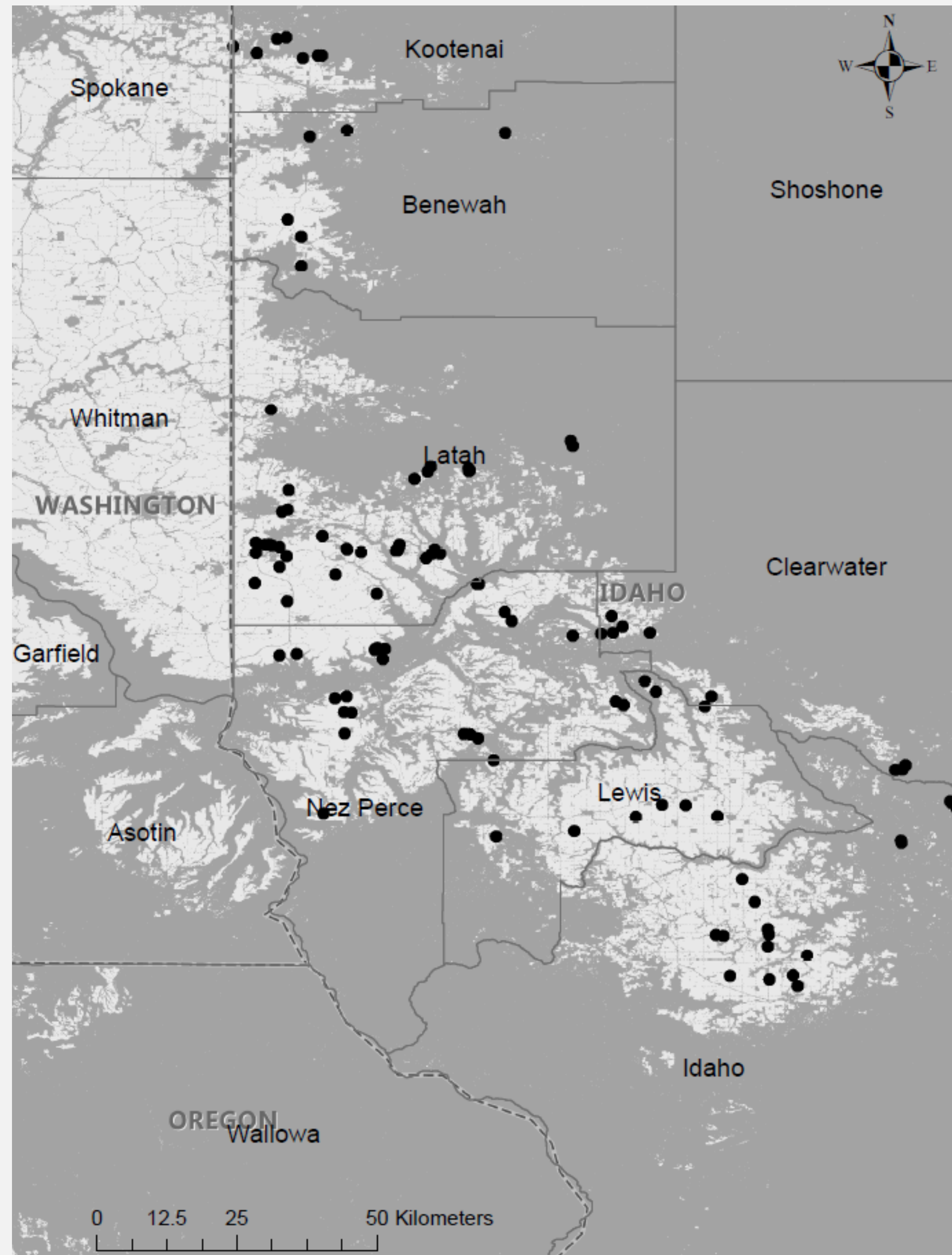
Soil pH	% of Fields
>6.4	6
6.0 – 6.4	11
5.8 – 5.9	16
5.6 – 5.8	22
5.4 – 5.5	18
5.2 – 5.3	11
5.0 – 5.1	10
<5.0	6

Mahler et al. 1985

# 2014 TO 2015 SOIL SURVEY



- 116 Fields
  - 90 Annual Crop
  - 11 Pasture
  - 6 CRP
  - 2 Native Soils





- 6-inch cores
- Sample Analyses
  - pH & OM
  - Lime Requirement
  - Base Saturation
  - Plant Available Metals
    - Al, Mn, Fe
  - Micronutrients
    - Boron, Zinc
  - Macro's
    - N, P, K, S

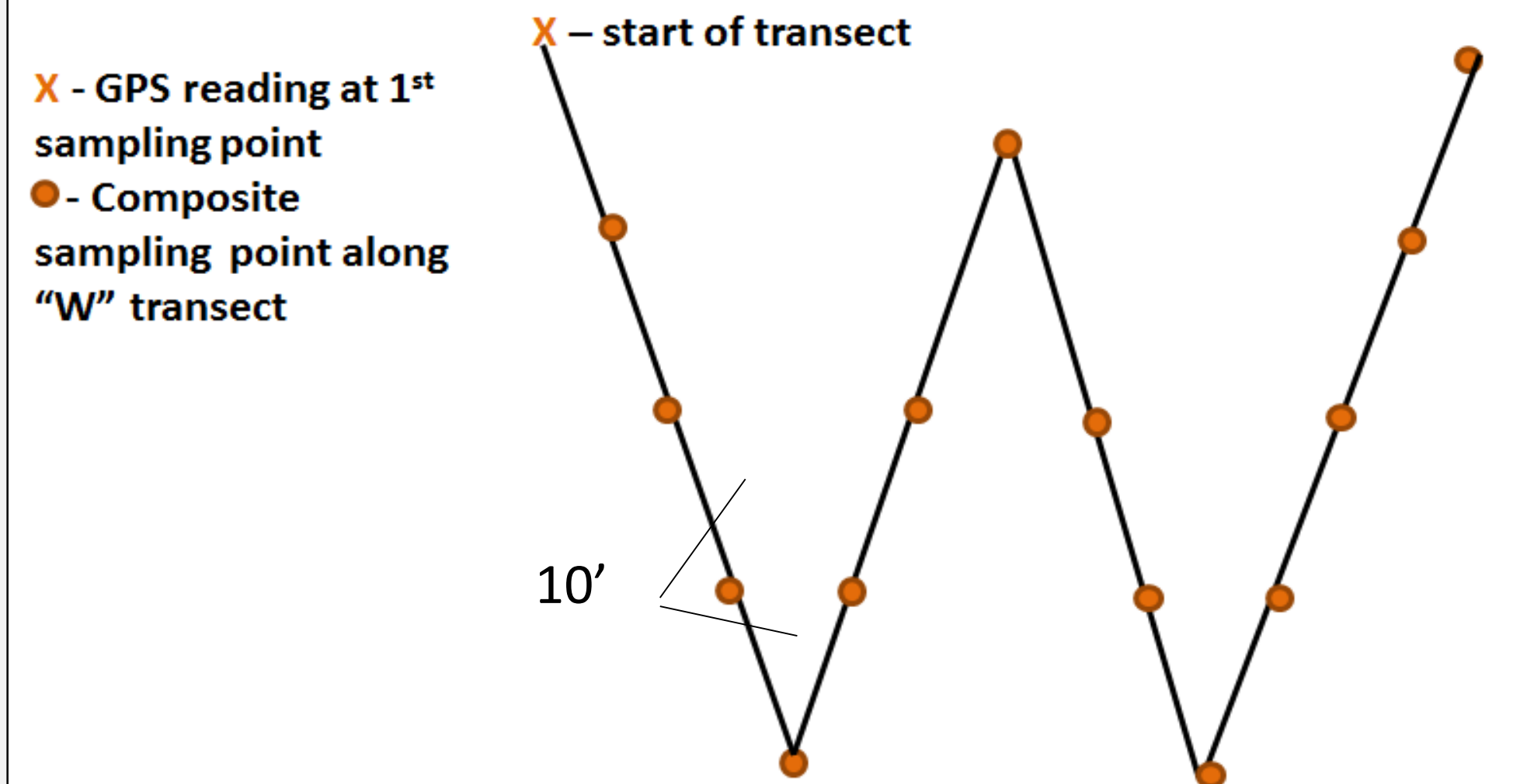


Figure 1. Transect pattern for soil pH survey composite sampling.



# SOIL PH SURVEY IN NORTHERN IDAHO



Soil pH	% of Fields in Each Category	
	1982 to 1984	2014 to 2015
>6.4	6	<1
6.0 – 6.4	11	4
5.8 – 5.9	16	3
5.6 – 5.8	22	7
5.4 – 5.5	18	9
5.2 – 5.3	11	25
5.0 – 5.1	10	26
<5.0	6	26

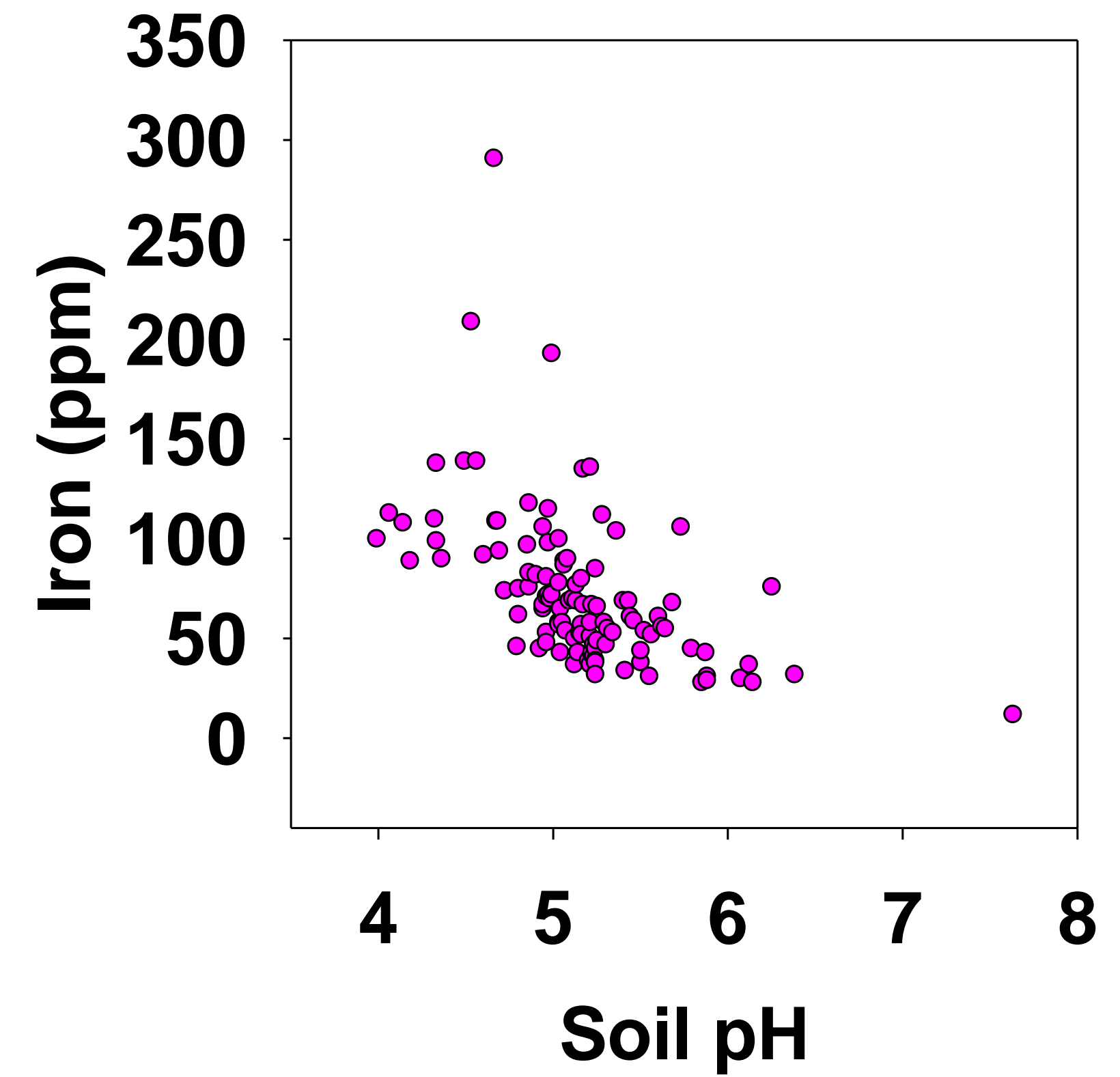
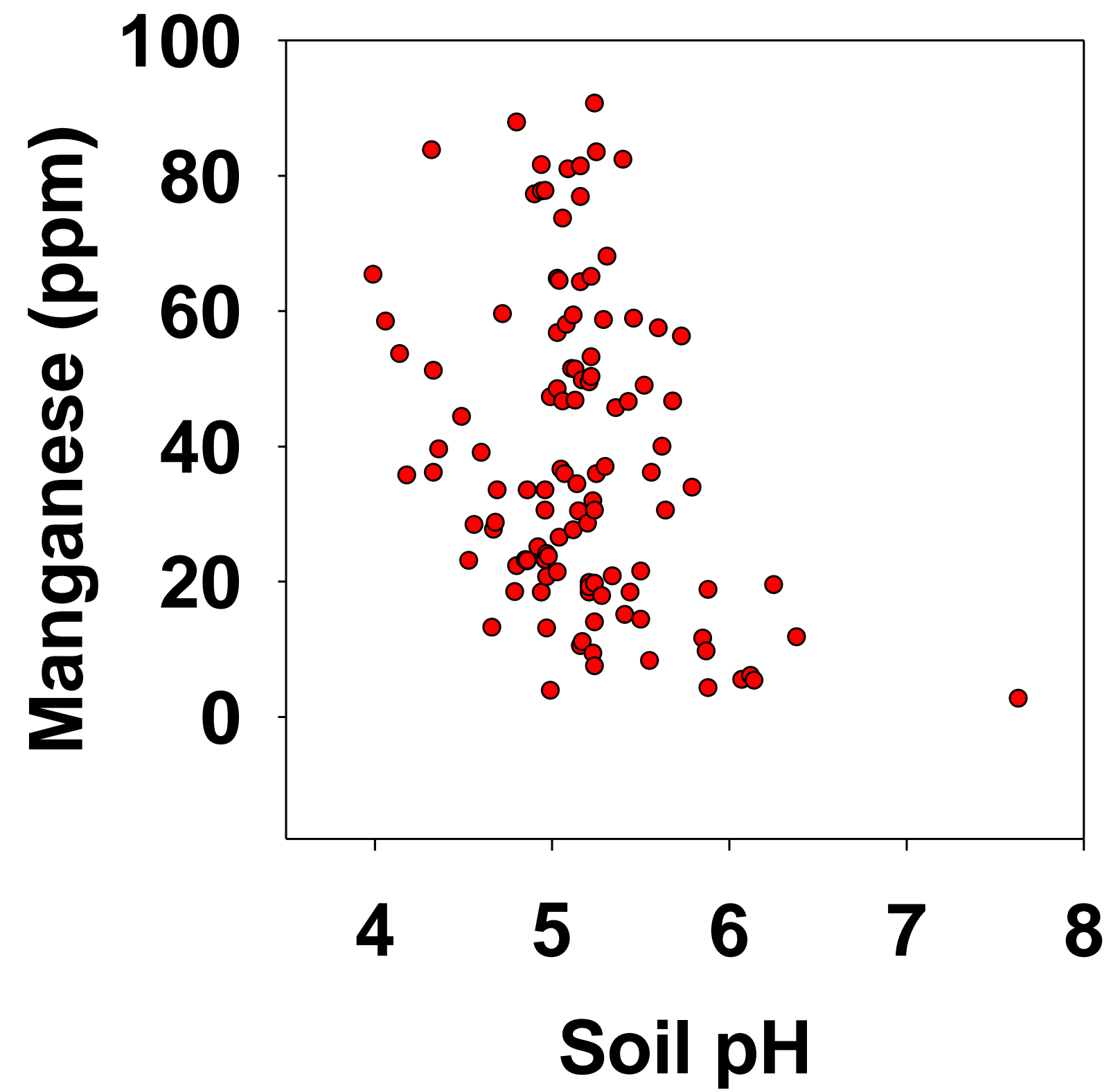
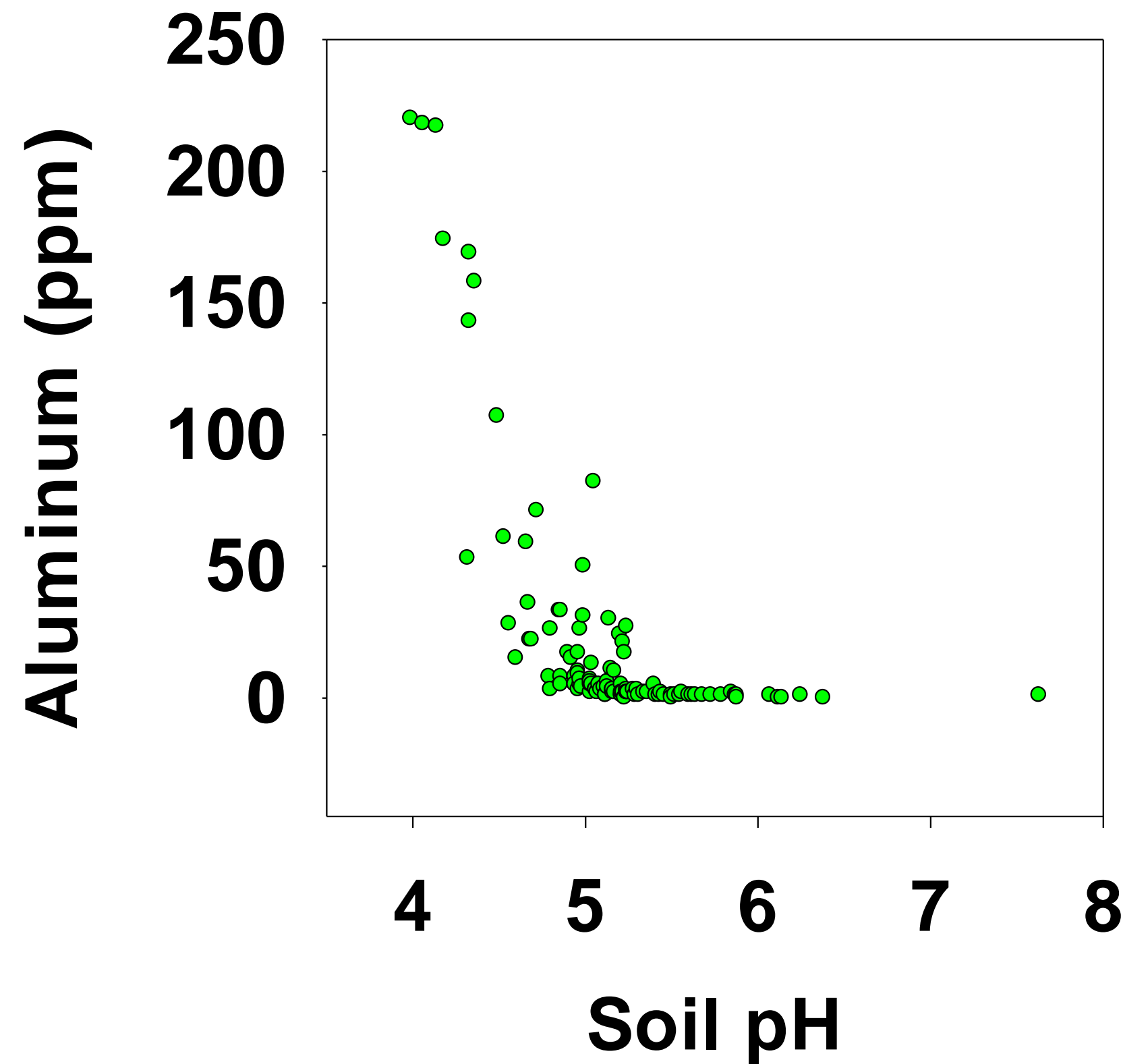
# SOIL PH SURVEY IN NORTHERN IDAHO



Soil pH	% of Fields in Each Category		Aluminum (ppm)
	1982 to 1984	2014 to 2015	
>6.4	6	<1	1
6.0 – 6.4	11	4	<1
5.8 – 5.9	16	3	1
5.6 – 5.8	22	7	1
5.4 – 5.5	18	9	1
5.2 – 5.3	11	25	5
5.0 – 5.1	10	26	15
<5.0	6	26	53

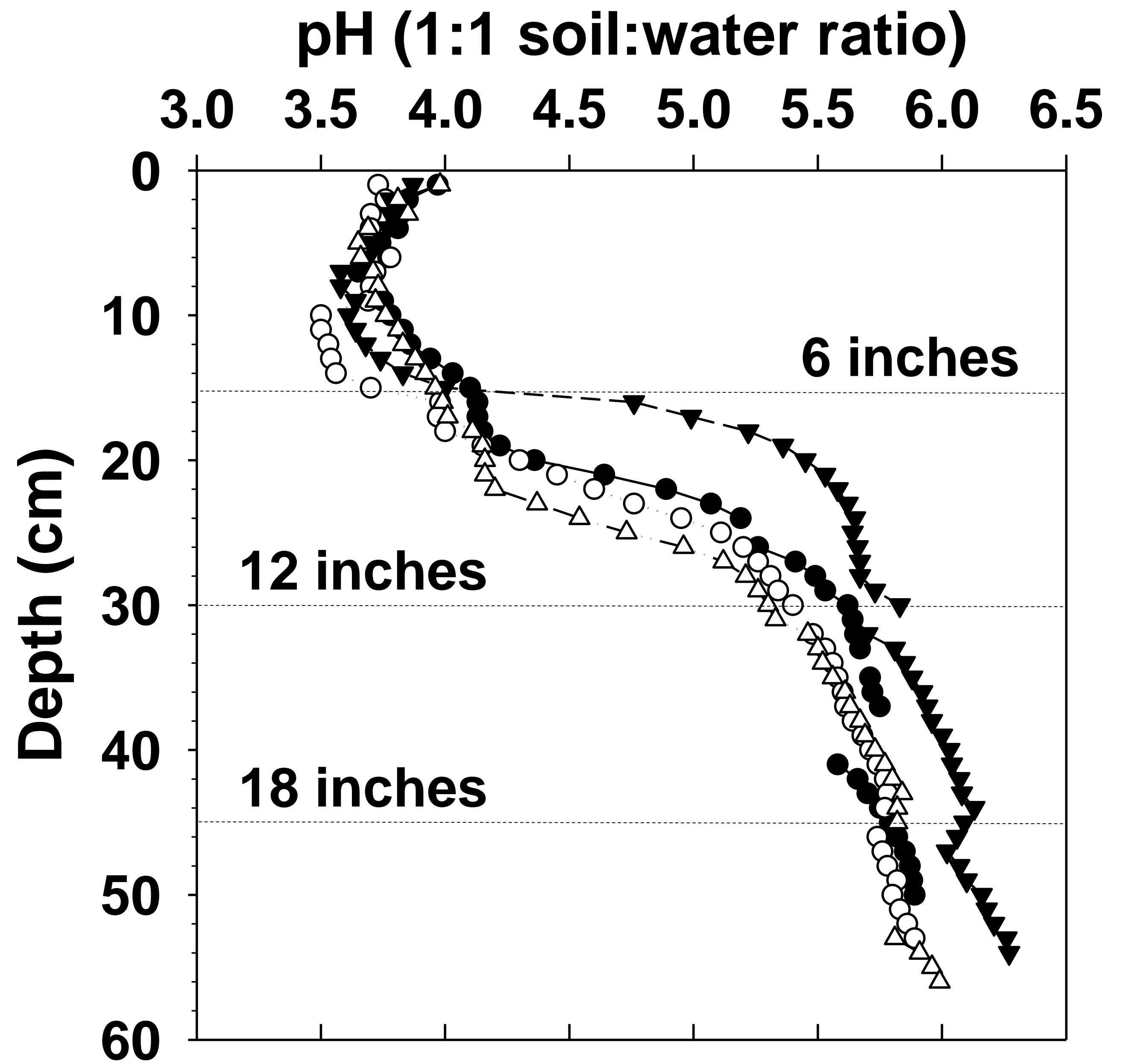
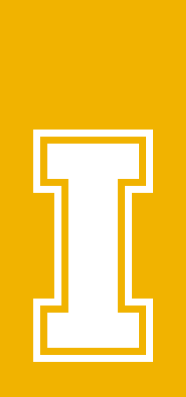


# RELATIONSHIP BETWEEN PH AND TOXIC METALS

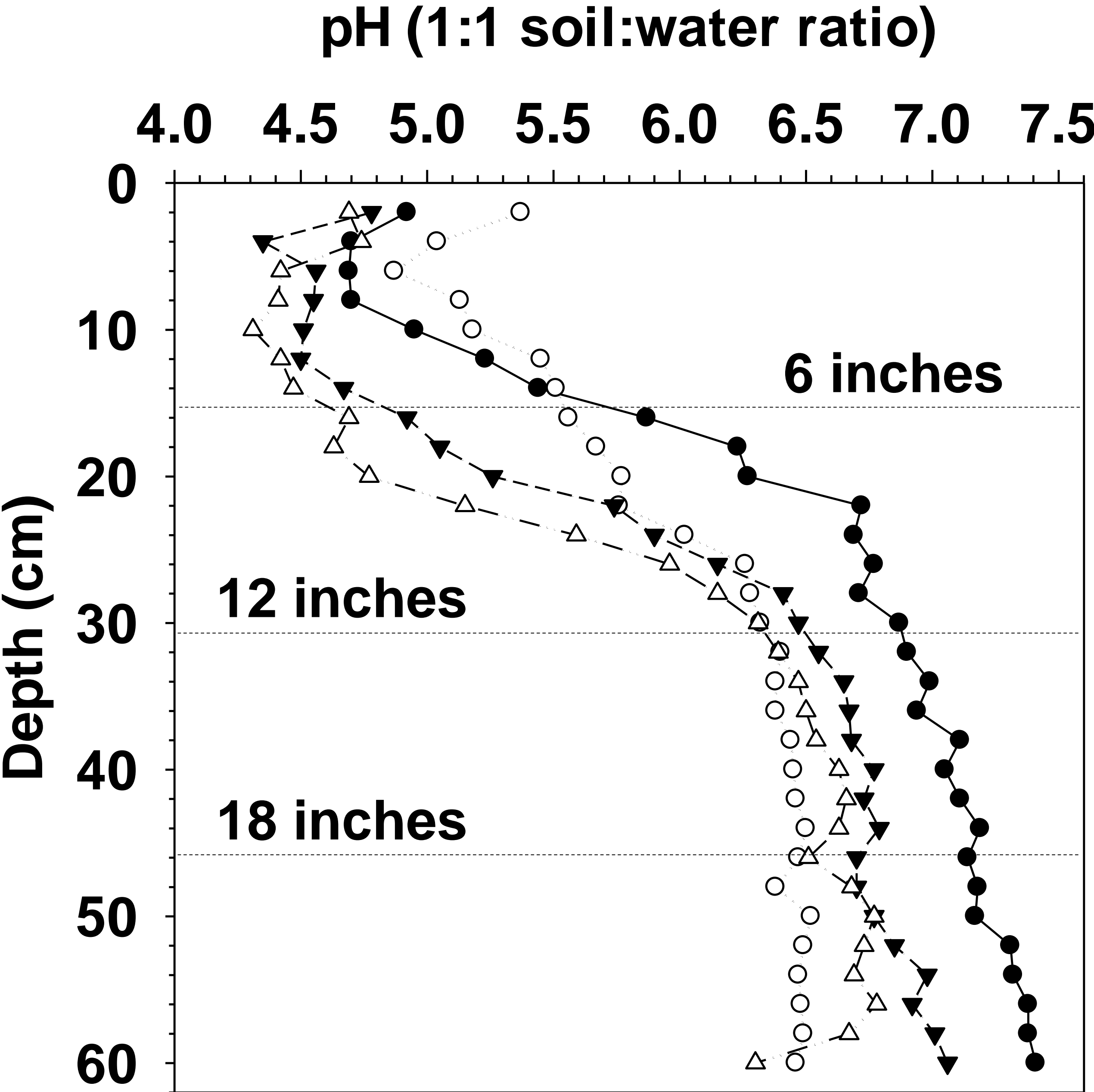
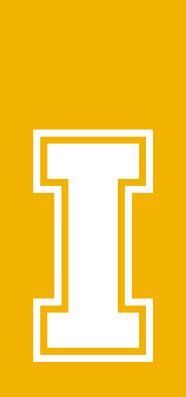




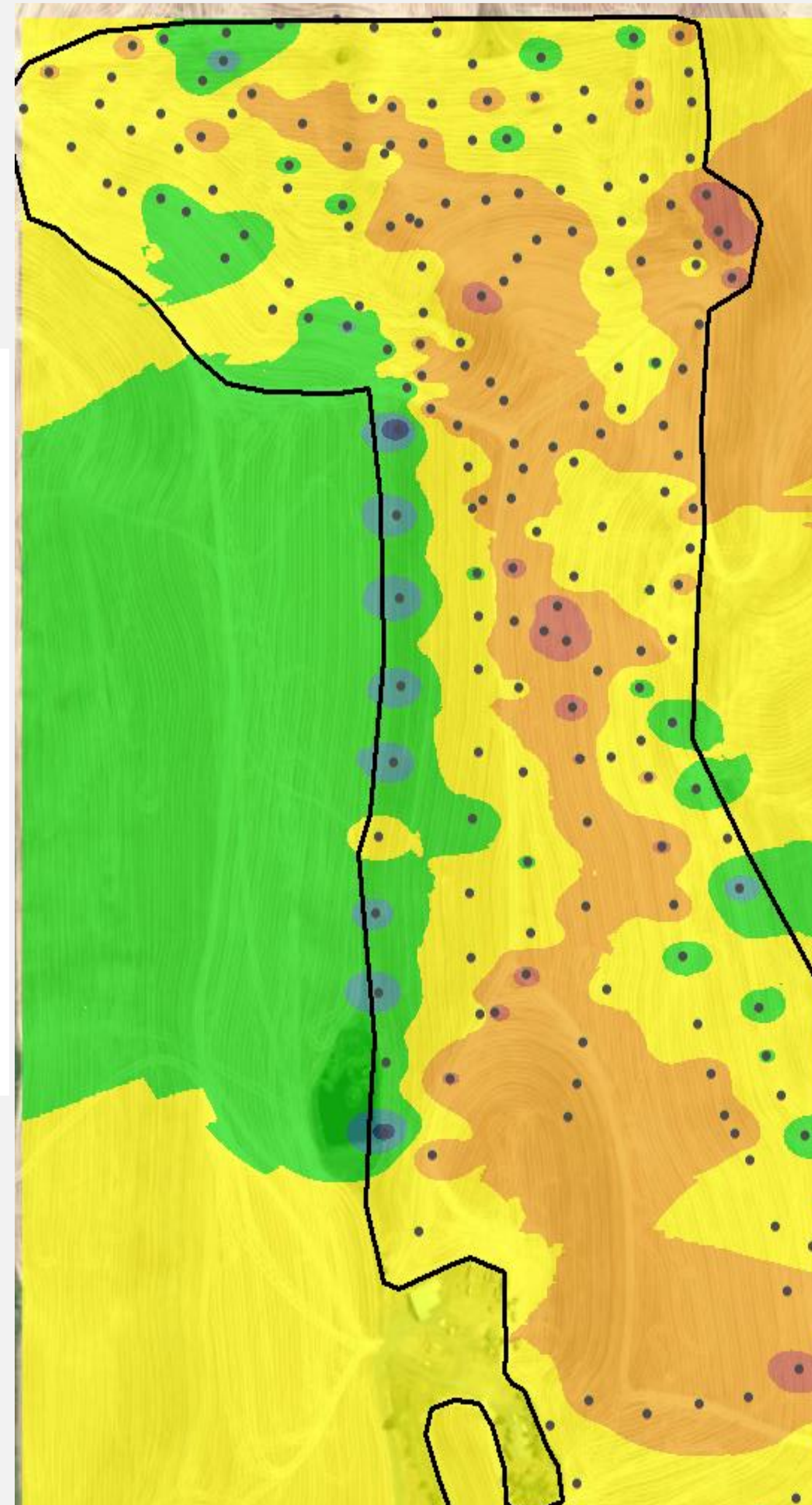
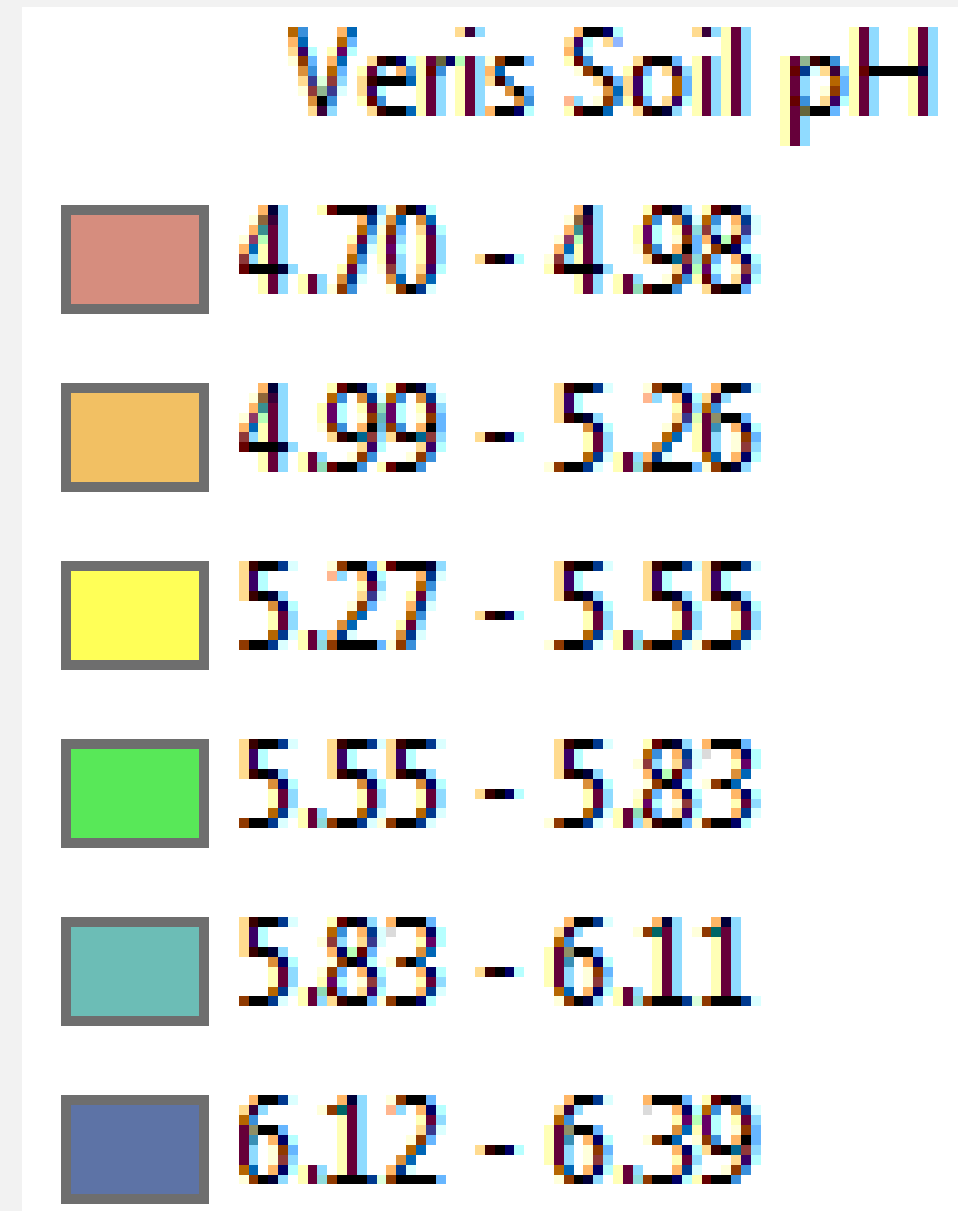
# SOIL PH PROFILE - ROCKFORD, WA



# SOIL PH PROFILE - PULLMAN, WA



# SOIL PH MAP OF 100 ACRE FIELD



Courtesy of Tabitha Brown

# **MANAGEMENT OF SOIL ACIDITY – VARIETY SELECTION**



# SCREENING FOR ALUMINUM TOLERANT WHEAT

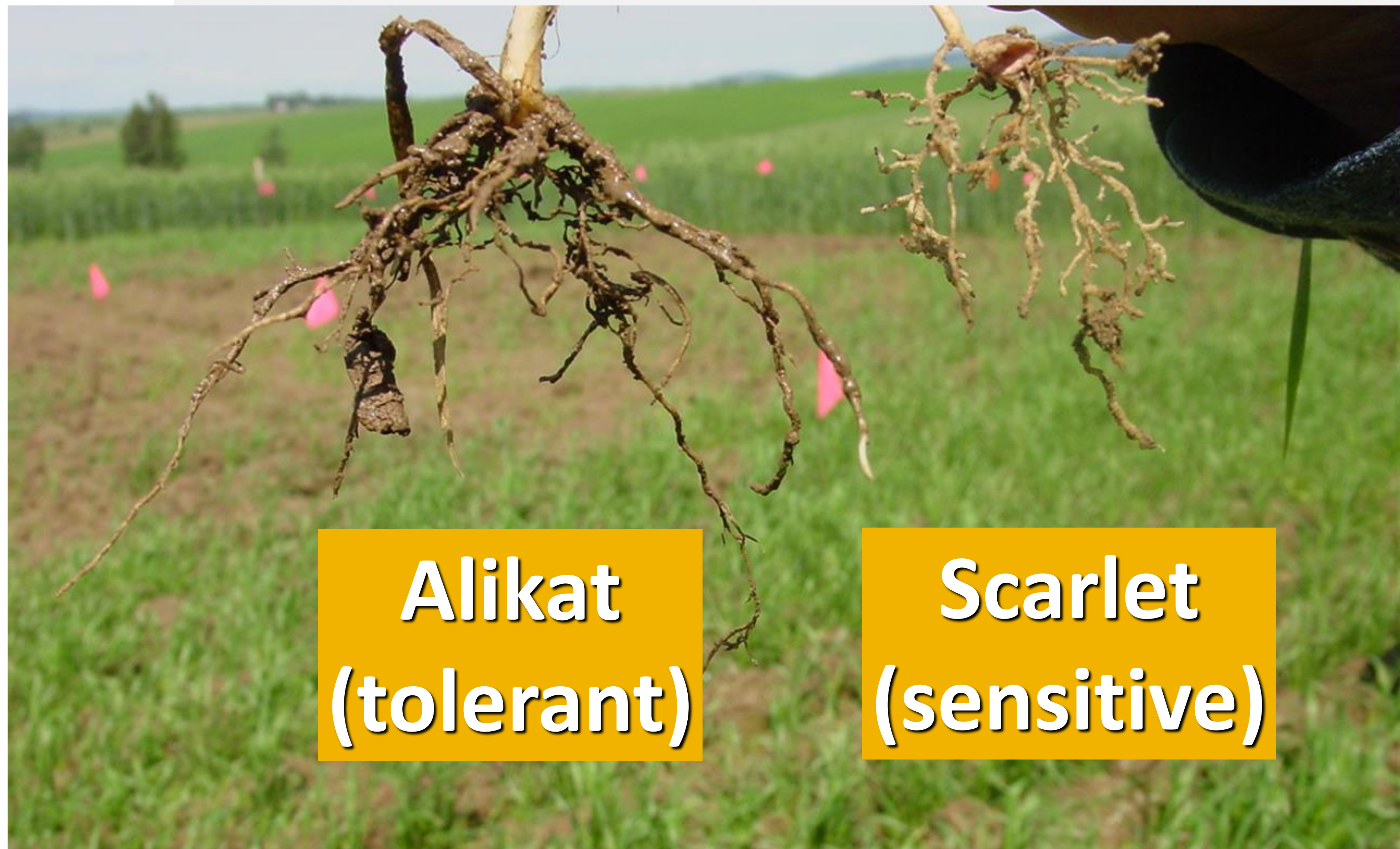




# ALUMINUM TOLERANT WHEAT

- Single gene tolerance
- A malate transporter gene
- Root tips excrete malate and malate chelates Al so  $\text{Al}^{3+}$  is not taken up
- Cultivars developed in OK and KS as well as Alberta, Canada where acid soils are a problem





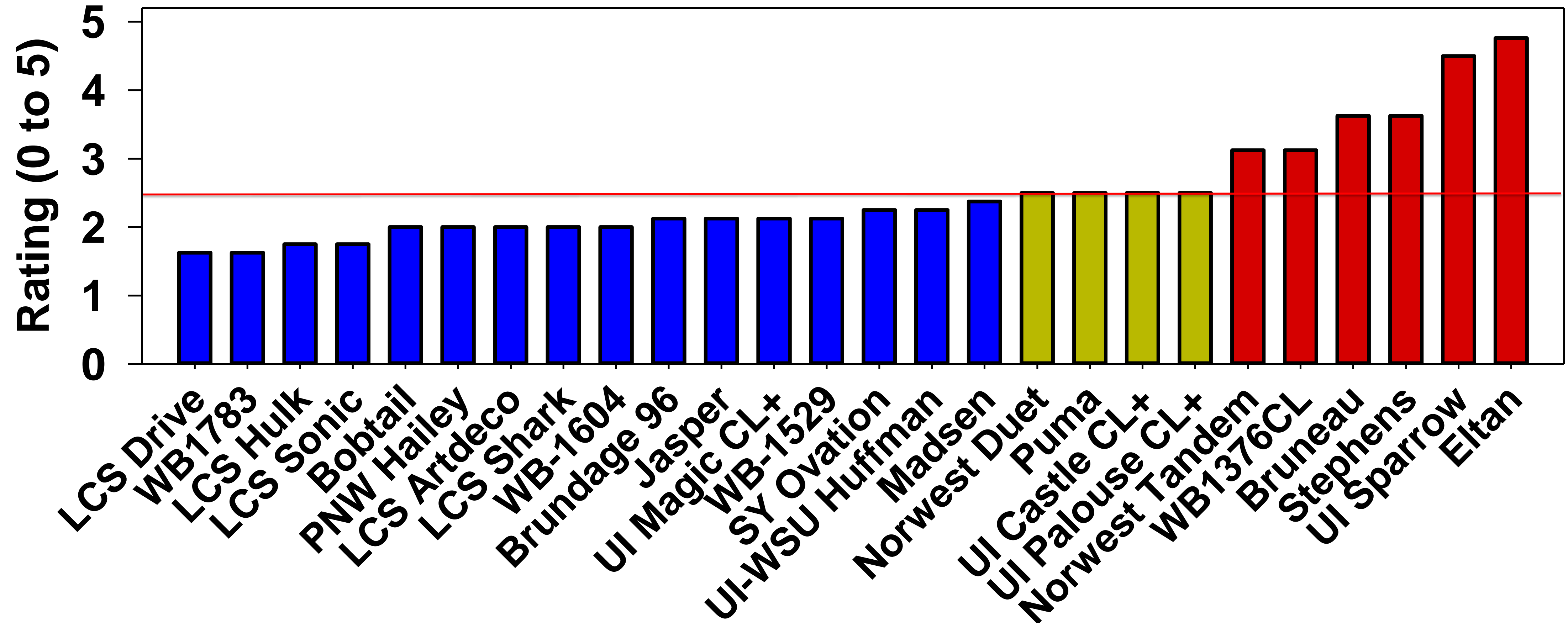
**Alikat  
(tolerant)**

**Scarlet  
(sensitive)**



# SOFT WHITE WINTER WHEAT TOLERANCE TO ALUMINUM

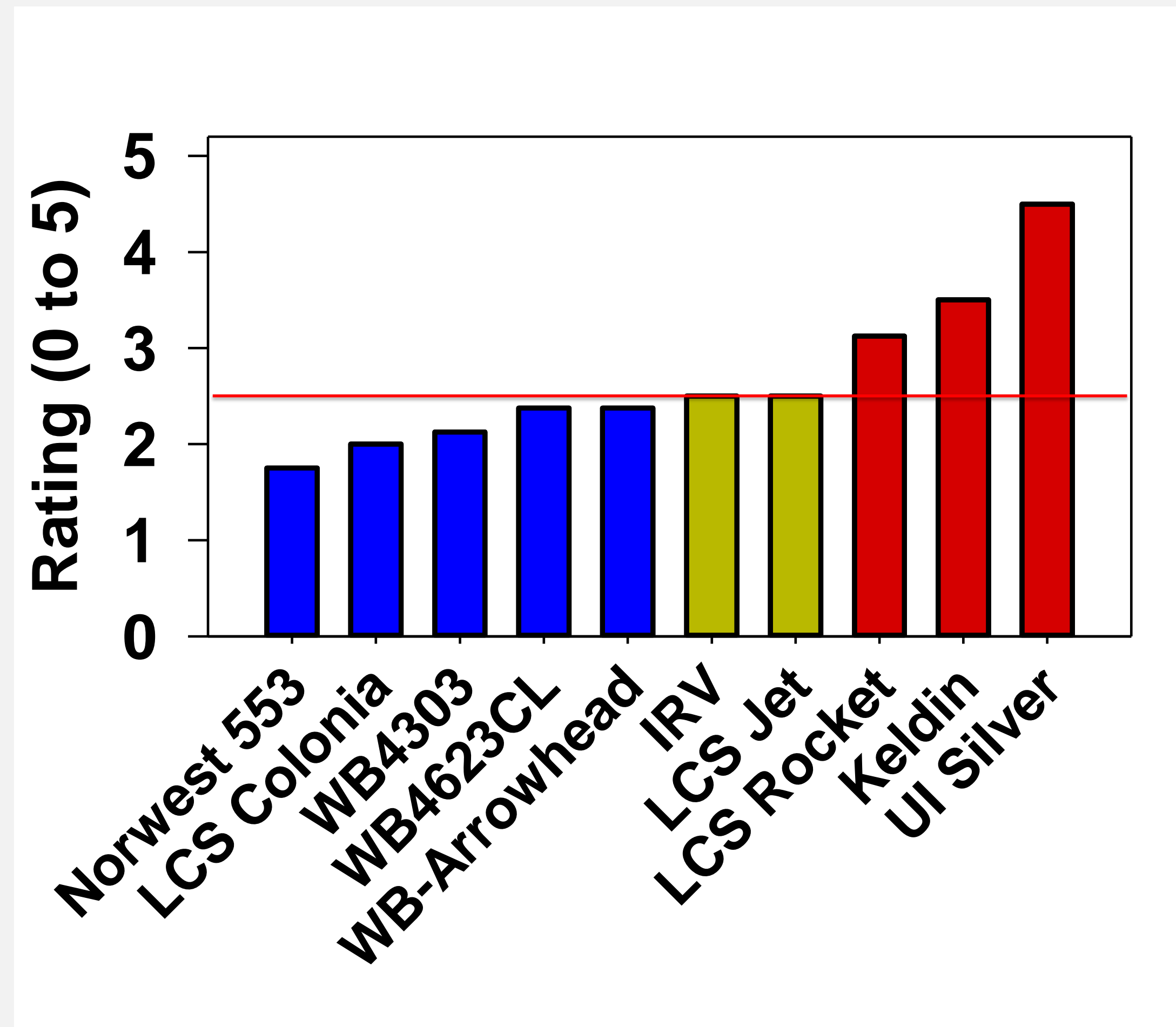
## 2017/2018 2-year average





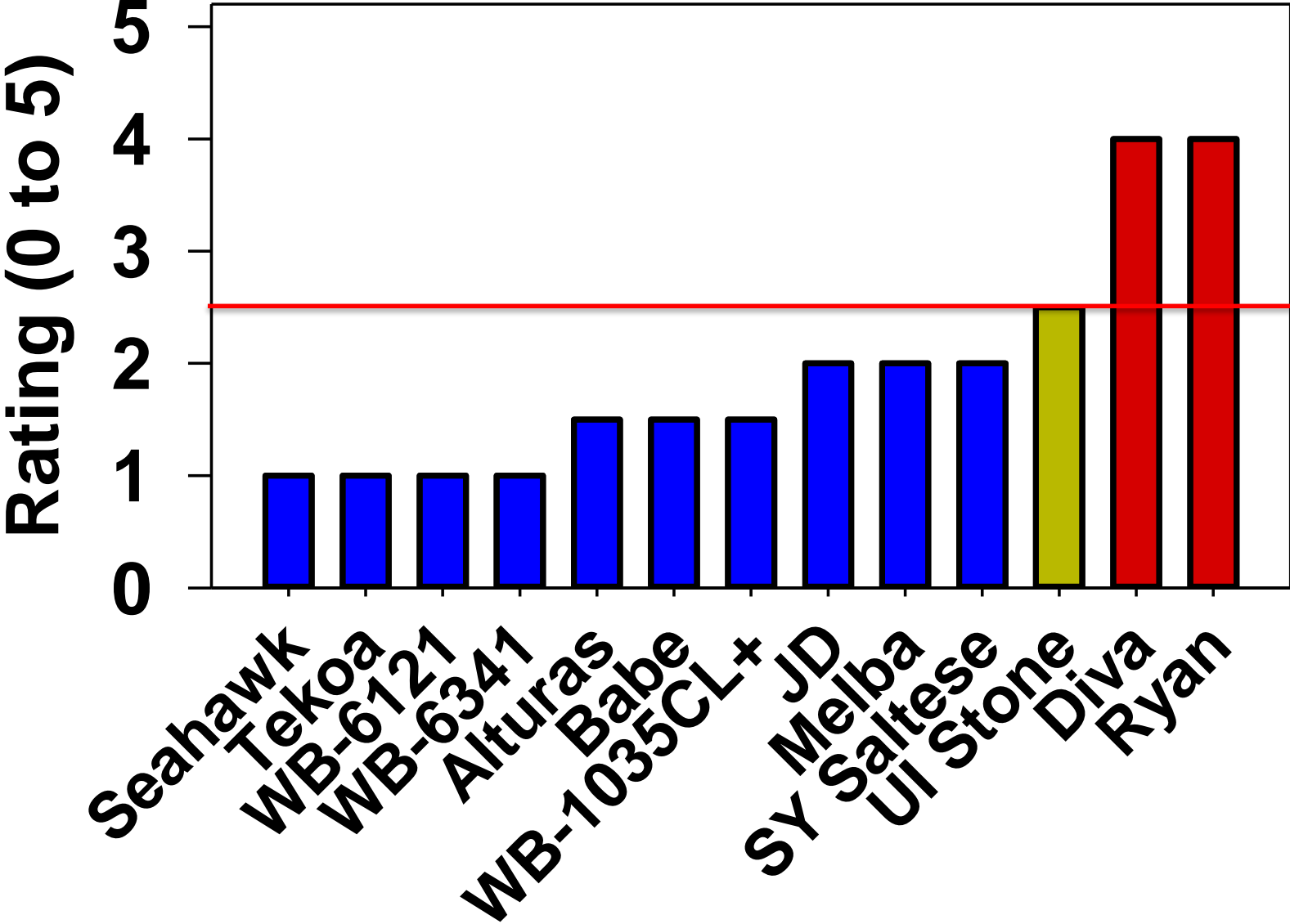
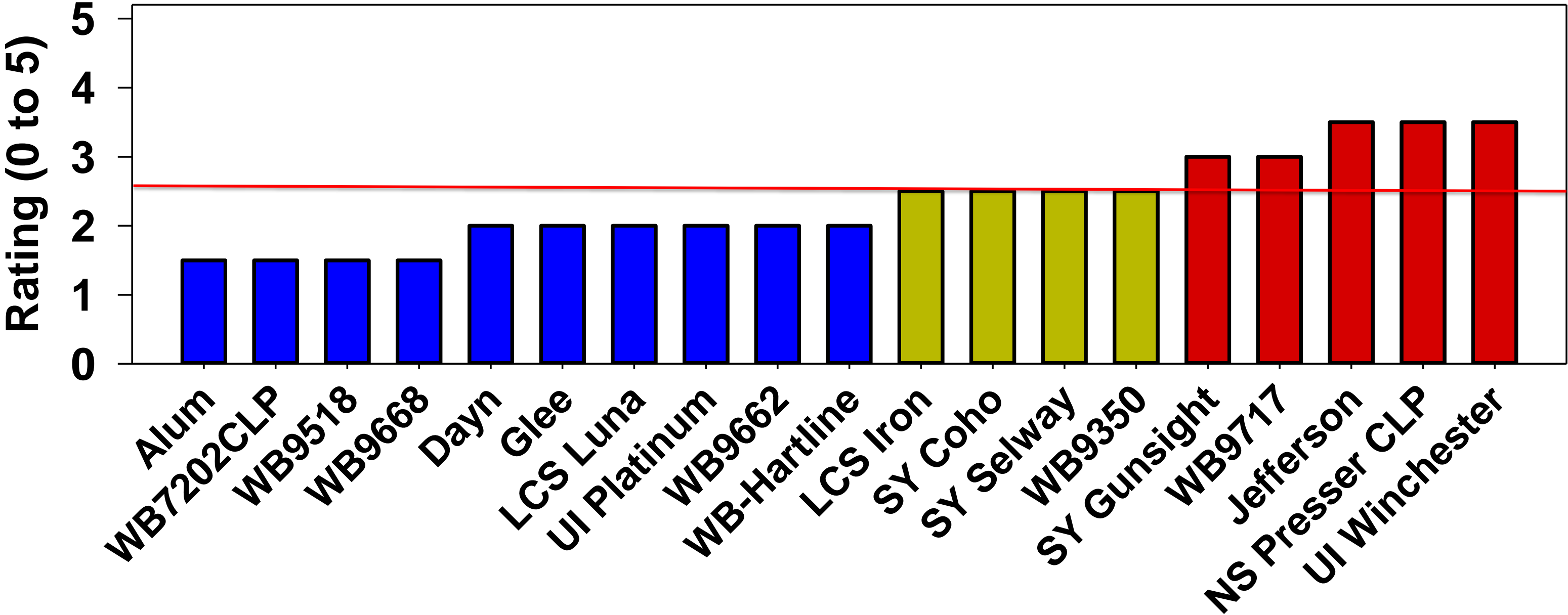
# HARD WINTER WHEAT TOLERANCE TO ALUMINUM

## 2017/2018 2-year average



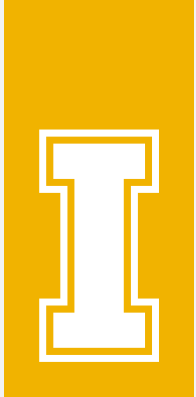
# SPRING WHEAT TOLERANCE TO ALUMINUM

## 2018 only



# **MANAGEMENT OF SOIL ACIDITY – LIMING**

# LIME SOURCES



Lime Type	Source of Lime	Dry Matter %	CaCO <sub>3</sub> Equiv.	Fineness Factor	Lime Score
Moses Lake Sugar Lime	Cascade Agronomics	92	84	85 to 98	65 to 75
Limestone (Ground)	Pioneer Enterprises	99	95	80	75 to 89
NuCal (liquid lime)	Columbia River Carbonates	99	98	100	97

- Acidification localized in upper 20 cm

# LIME PRICES AND APPLICATION COSTS, 2015

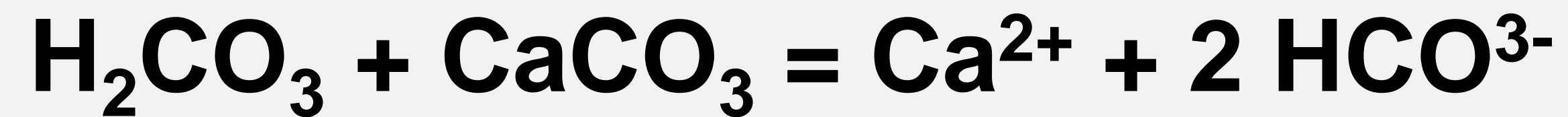


Product and Source	Product cost \$ per ton	Application cost \$ per acre
Sugar beet lime, Cascade Agronomics	54.00	11.00
Ground limestone, Pioneer Enterprises	55.00	13.00
Liquid lime, Columbia River Carbonates	280.00	15.00

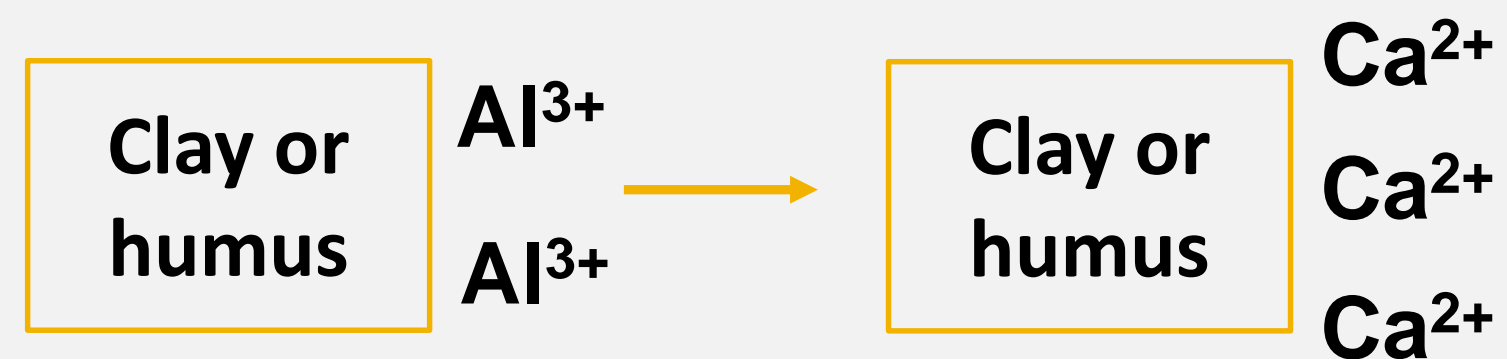
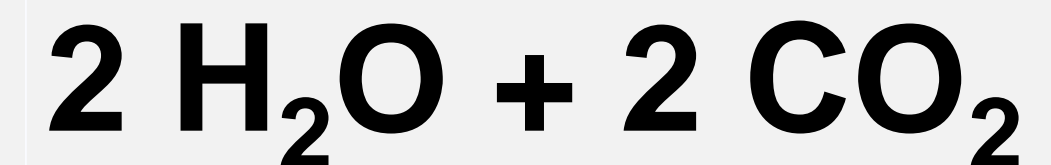
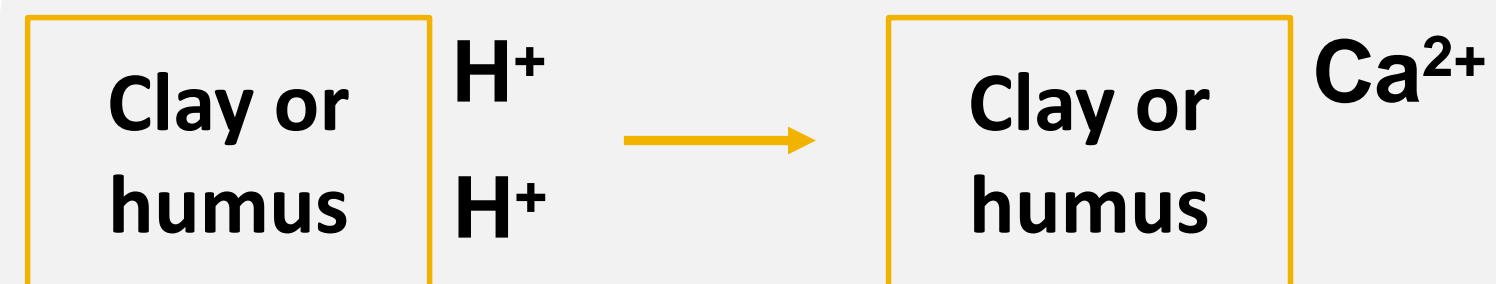
# HOW CALCIUM CARBONATE NEUTRALIZES ACID SOIL



Carbonic acid from the soil solution plus calcium carbonate yield free calcium and bicarbonate



End products:



Aluminum  
Hydroxide  
(solid)

# COMMON QUESTIONS RELATED TO LIMING



- How much lime needs to be added?
- How long will a lime application be beneficial?
- How long will it take for the lime to fully react?
- How long will an increased yield be observed?
- What is the benefit to each crop in the rotation?
- Will lime application be cost effective?
- Could variable rate application be a benefit?



# LIMING SOURCE AND RATE STUDIES



- Plots established at:  
Pullman, WA  
Potlatch, ID  
Winchester, ID

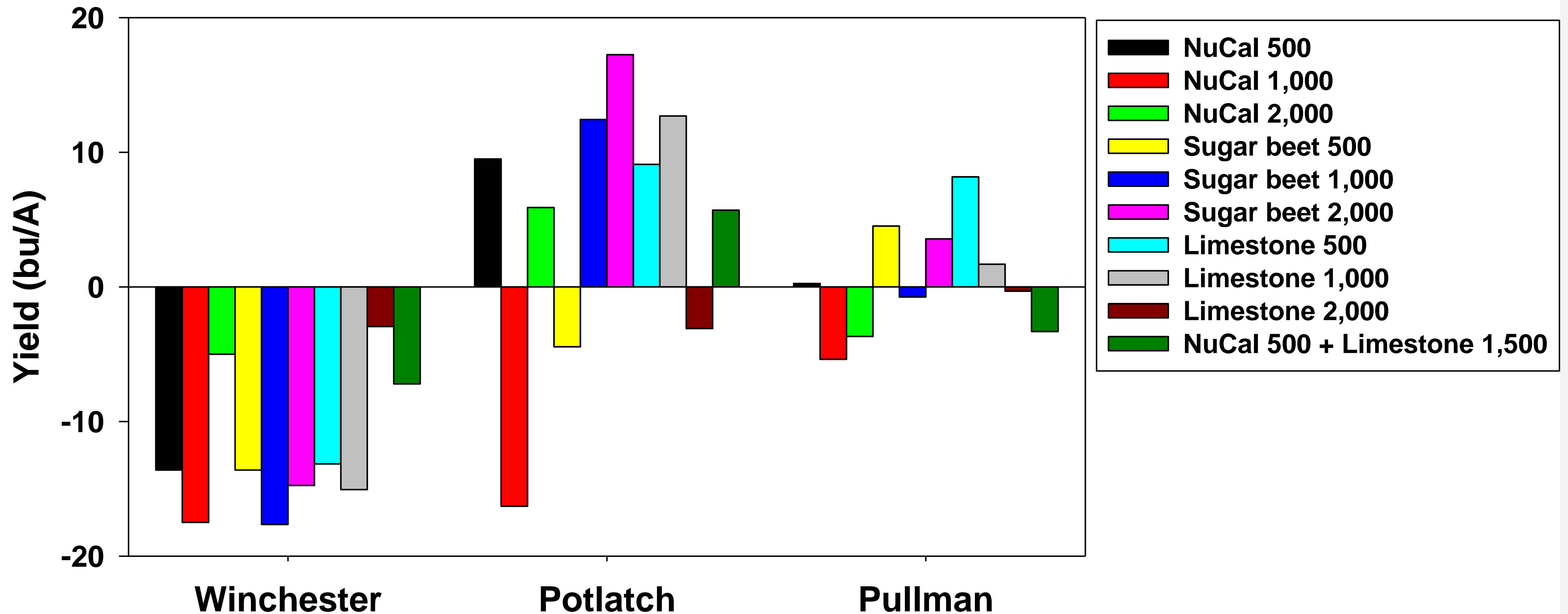


- Applied lime at 500, 1000 and 2000 lb calcium carbonate/A
- Ground limestone, sugar beet lime, NuCal fluid lime
- Winter wheat – spring pea rotation



# AVERAGE CHANGE IN YIELD OVER 3 YEARS

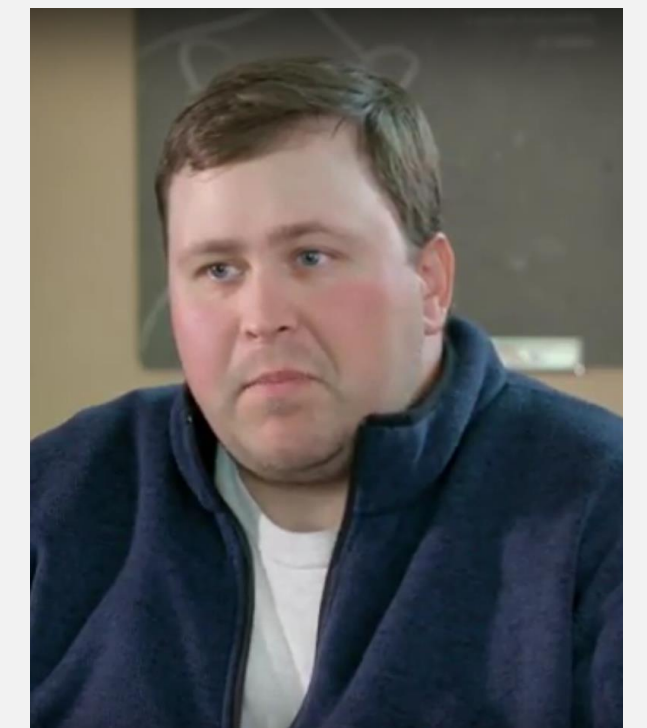
## 2014 to 2016



# EVALUATION OF HIGH LIME RATES

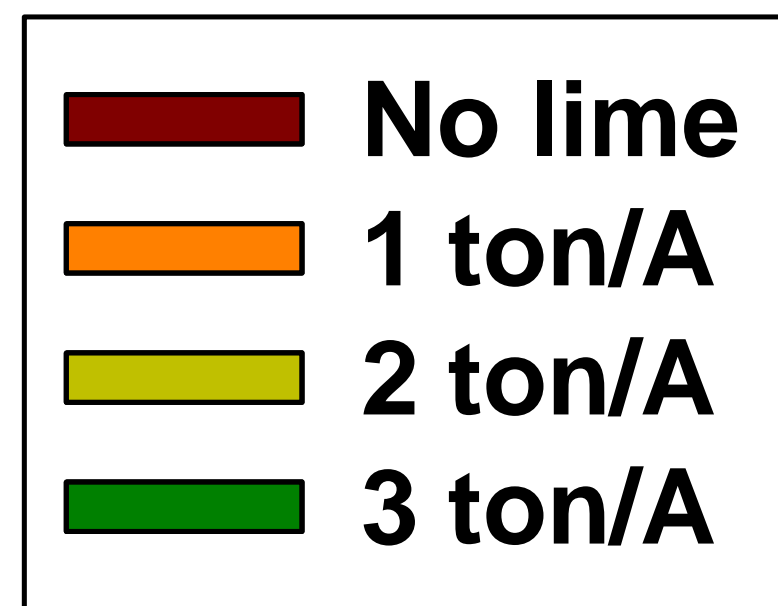
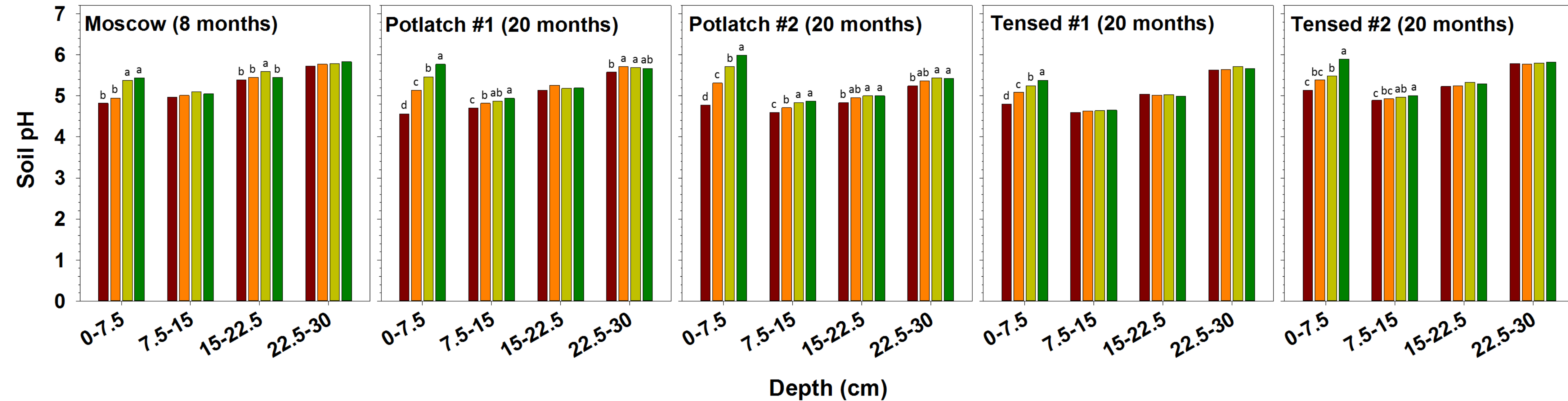


- Five sites in northern Idaho
  - Potlatch, Tensed, Moscow
- Criteria – Soil pH below 5 in upper 6 inches, aluminum above 20 ppm, uniformly acidic
- Limed at rates of 0, 1, 2 and 3 ton/A ground limestone
- Plots oriented into 8' wide x 100' long strips
- Follow standard crop rotation for the location
- Monitor for 6+ years

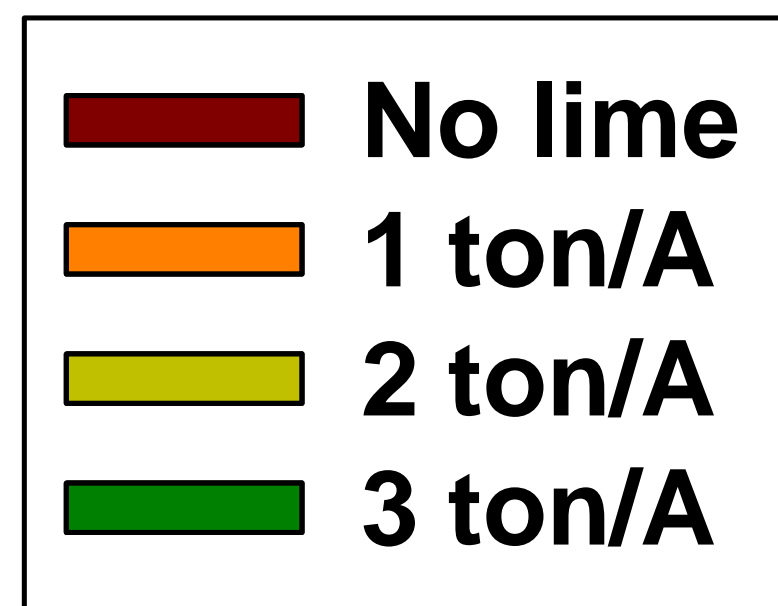
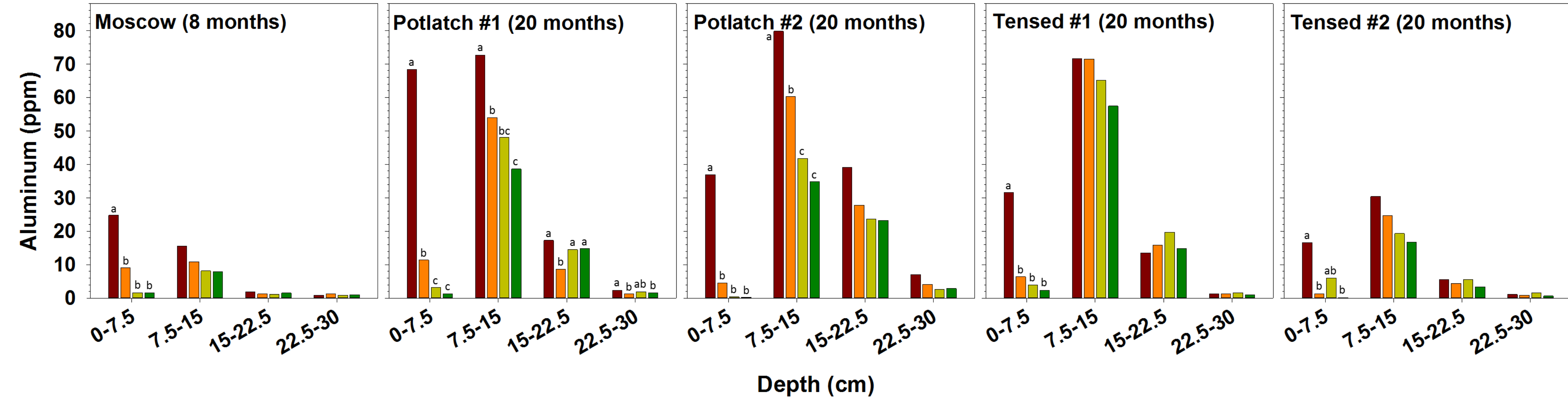


Andrew Leggett

# CHANGE IN SOIL PH 8 OR 20 MONTHS AFTER LIMING



# CHANGE IN ALUMINUM 8 OR 20 MONTHS AFTER LIMING





# YIELD INCREASE FOLLOWING LIME APPLICATION

Ground limestone (ton/A)	Mos 2018 W. Wheat	Pot#1 2017 Prevented	Pot#1 2018 W. Wheat	Pot#2 2017 W. Wheat	Pot#2 2018 Chickpea	Ten#1 2017 W. Wheat	Ten#1 2018 S. Canola	Ten#2 2017 W. Wheat	Ten#2 2018 Lentil
0	102	--	127 c	67 c	--	67 b	2351	57	911
1	103	--	131 bc	73 b	--	71 ab	2558	59	1045
2	106	--	135 ab	78 a	--	76 a	2318	58	1065
3	109	--	136 a	77 a	--	76 a	2466	60	1109

Ground limestone (ton/A)	Percent increase in yield								
1	1	--	3	9	--	6	9	4	15
2	4	--	6	16	--	13	-1	2	17
3	7	--	7	15	--	13	5	5	22





No lime

3 ton/A



# ECONOMICS OF LIMING ACIDIC SOILS IN THE PALOUSE



Liming is a capital investment rather than an operating input

- Long term effects
- Estimated ~10 years for a one-ton application of calcium carbonate
  - Many factors will influence the timeframe
  - We lack long-term empirical research on liming for this region



Painter and Schroeder

# USING NET PRESENT VALUE TO CALCULATE ANNUAL COSTS



- Annualize the cost of applying lime in order to compare it to annual benefits of liming
- An annual value for the cost is similar to a loan at a certain interest rate and number of years
- This annualized value is easily calculated using an Excel formula:
  - $PMT = (rate, number\ of\ periods, present\ value)$
- Compare annual cost to a long run average annual benefit
  - Using today's crop prices will hopefully vastly understate the annual benefits!

# ECONOMIC VALUE OF YIELD GAIN

## 2017 TRIALS, POTLATCH



			Cost	Site:	Benefit	
Ground Limestone applied per acre	Cost of treatment* \$/ac	Timeframe for liming efficacy	Annualized value of liming	Potlatch 2 (bu/ac)	Yield gain (ac)	Value of yield gain** (ac)
Control	\$0			67		
1 Ton	\$87	10	\$12	73	6	\$27
2 Ton	\$161	15	\$17	78	11	\$49
3 Ton	\$235	20	\$20	77	10	\$45

\*Cost of ground limestone is \$74 per ton plus \$13 delivery.

\*\*Assumed price of wheat is \$4 .45 per bu, farmgate (USDA-NASS, WA & ID combined, average of August - November, 2017 prices received)

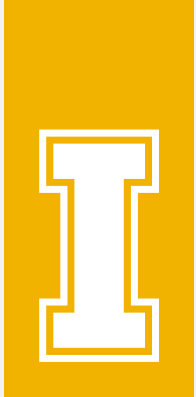
Note: Discount rate is assumed to be 6%.

Estimated value of 2017 wheat production is \$4.45 per bu

Painter and Schroeder



# ECONOMIC VALUE OF YIELD GAIN



Ground limestone (ton/A)	Moscow W. Wheat	Potlatch#1 W. Wheat	Potlatch#2 W. Wheat	Tensed#1 W. Wheat	Tensed#1 S. Canola	Tensed#2 W. Wheat	Tensed#2 Lentil
2	(\$7)	\$10	\$15	\$6	\$19	(\$3)	\$20
3	\$5	\$27	\$32	\$23	(\$22)	(\$12)	\$20
4	\$19	\$30	\$25	\$20	(\$3)	(\$6)	\$28

# IDENTIFYING THE PROBLEM



- Sample from upper 6 inches for soil pH
- Test multiple samples from one field due to variability across landscape
- Interested in knowing quantity of KCl extractable Al, CEC, base saturation in addition to soil pH
- Avoid tissue testing for Al
- Lime requirement - the amount of  $\text{CaO}$  or  $\text{CaCO}_3$  that is needed to raise the pH to a target value
  - Not a particularly reliable lime requirement test for the PNW

# OTHER STRATEGIES TO MINIMIZE SOIL ACIDITY



- **Proper management of fertilizer**
  - Avoid excessive nitrogen fertilizer application
  - Consider variable rate nitrogen application
- **Diverse crop rotation (legumes, barley)**
  - Crops that have lower or no fertilizer requirements
- **Avoid removal of residue by baling or burning**
  - Loss of OM and cations which lower buffering capacity of soil



# **HANDS-ON ACTIVITIES:**

## **HANDHELD PH METER**

## **ROTATION STRATEGIES FOR ACID SOILS**

# **INFLUENCE OF SOIL PH ON CEREAL PATHOGENS**



# **IMPACT OF SOIL PH ON FUNGI**



- Many fungi function best at pH of 5 to 7
- External pH impacts ability of fungi to take up food
- pH can influence availability of trace nutrients (Fe, Zn, Mn)
- Low pH can stress plants, making them vulnerable to infection
- Low pH can reduce the natural population of microorganisms that normally suppress pathogens

# CEPHALOSPORIUM STRIPE



T. Murray, WSU

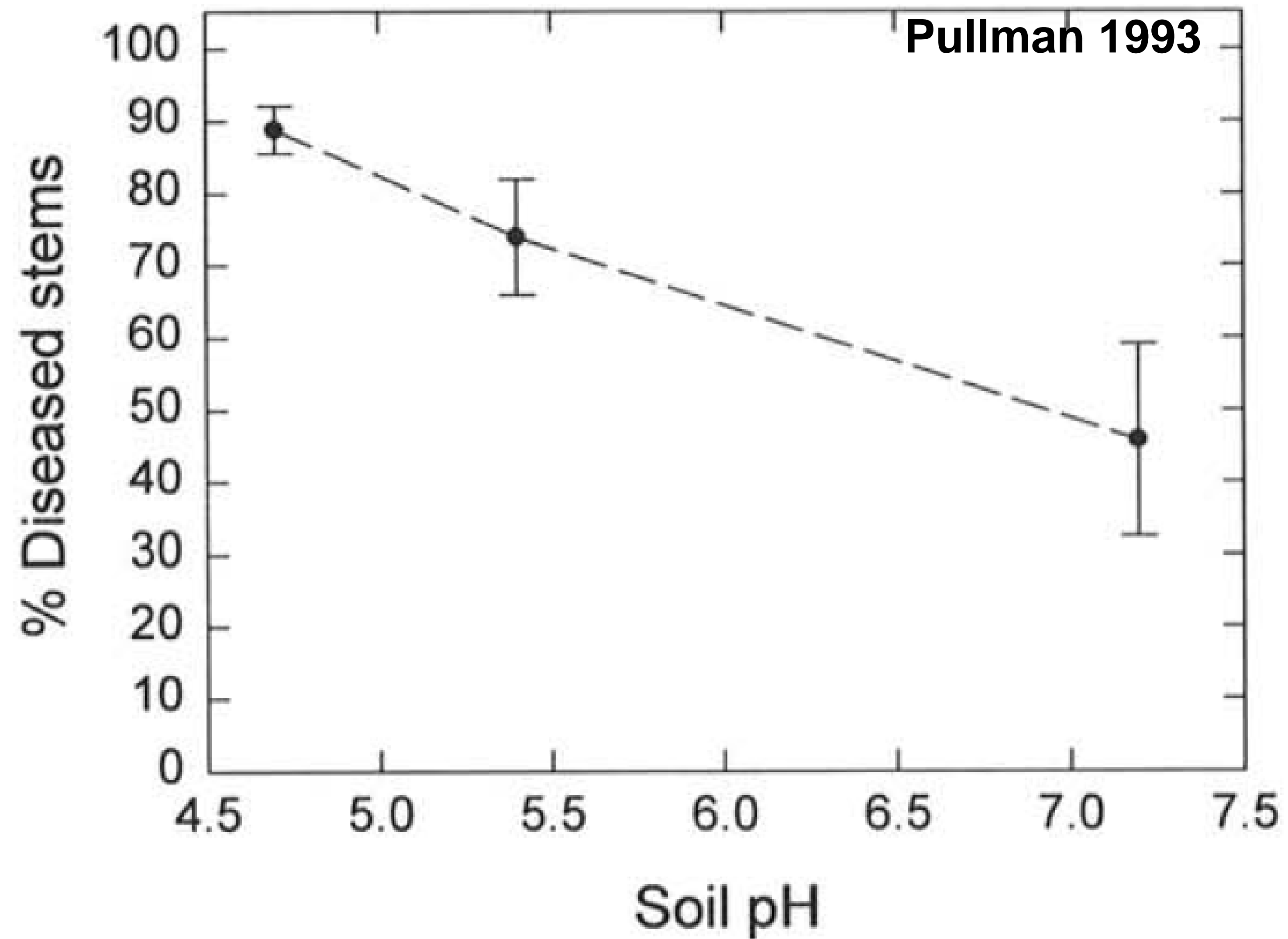
*Cephalosporium graminearum*  
Winter wheat, higher rainfall



Ohio State University Extension



# CEPHALOSPORIUM STRIPE



Stiles and Murray 1996



# TAKE-ALL



*Gaeumannomyces graminis* var. *tritici*

Irrigation or high rainfall, monoculture wheat

Increase in incidence and severity in alkaline soil





# FUSARIUM CROWN ROT



*Fusarium culmorum*  
*F. pseudograminearum*

High nitrogen rates

Plant stress



M. Burrows, Montana State University



Richard Smiley, Oregon State University



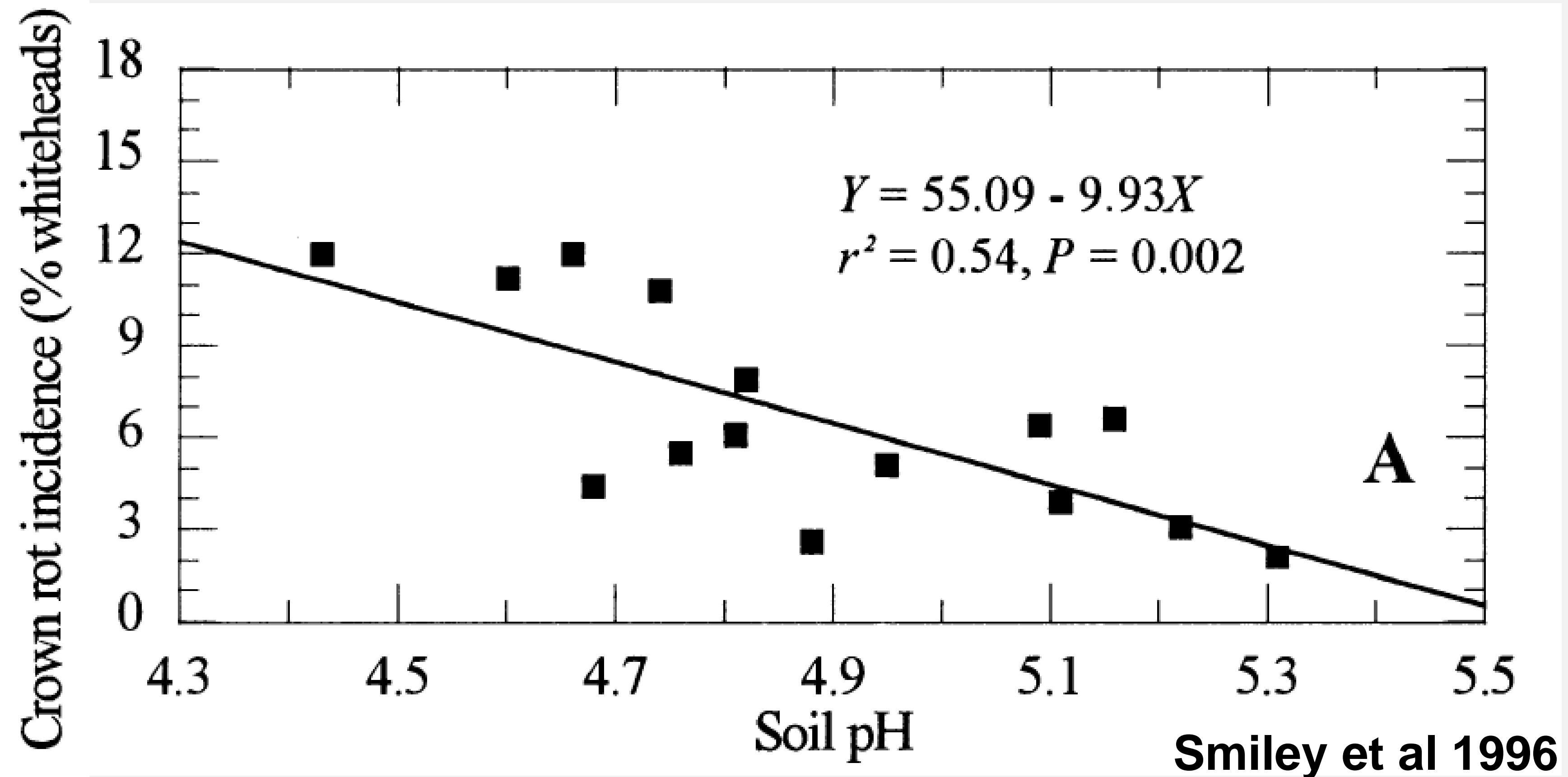
# INFLUENCE OF SOIL PH ON FUSARIUM CROWN ROT



- Smiley et al 1972
- Ammonium ( $\text{NH}_4^+$ ) forms of fertilizer increased disease incidence and severity
- Nitrate ( $\text{NO}_3^-$ ) forms of nitrogen fertilizer decreased disease incidence and severity
- Similar to response observed with Fusarium wilt diseases on other crops

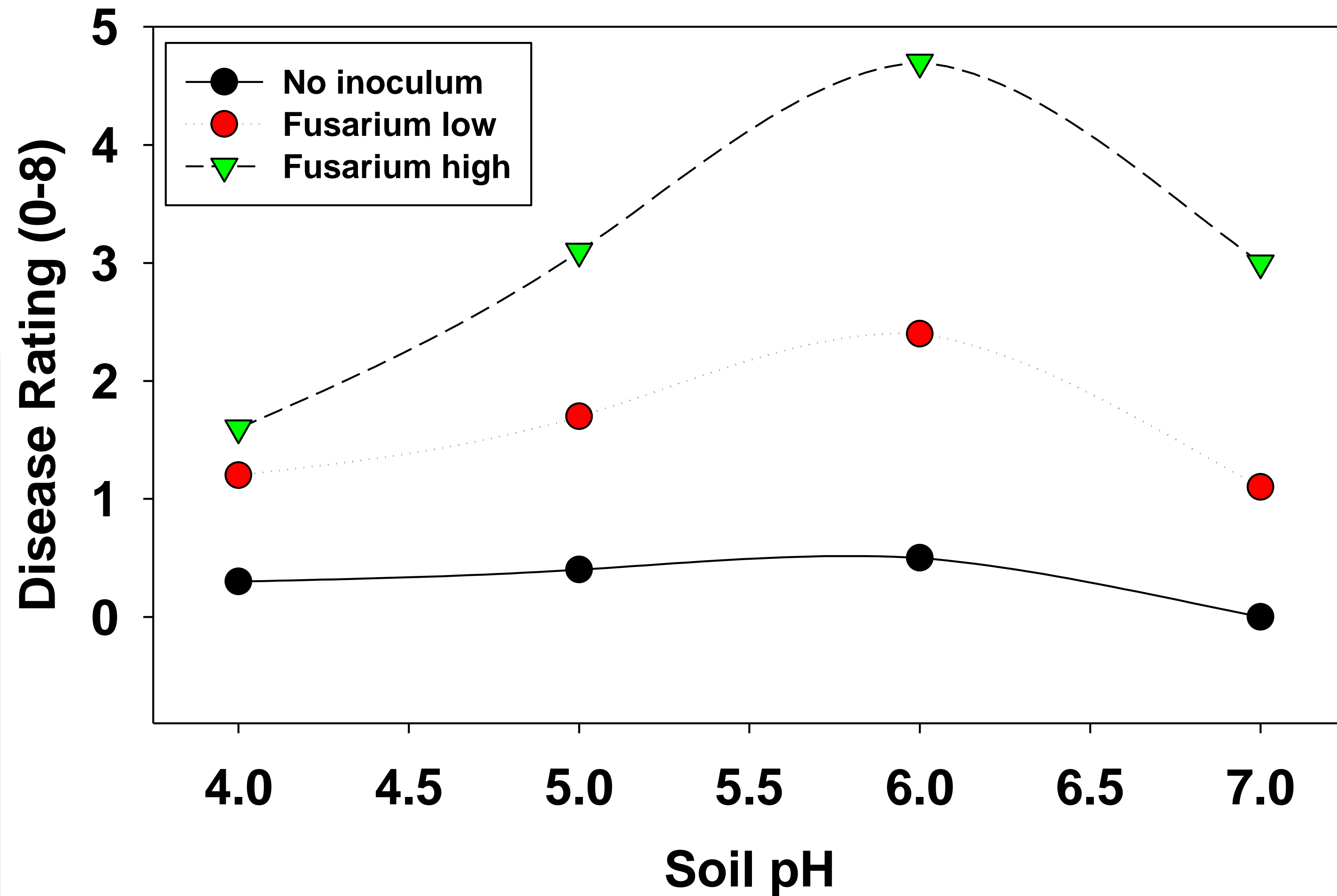


# INFLUENCE OF SOIL PH ON FUSARIUM CROWN ROT



Soil pH was also inversely correlated  
with the quantity of N applied

# ***F. CULMORUM* DISEASE RATING (0-8)**

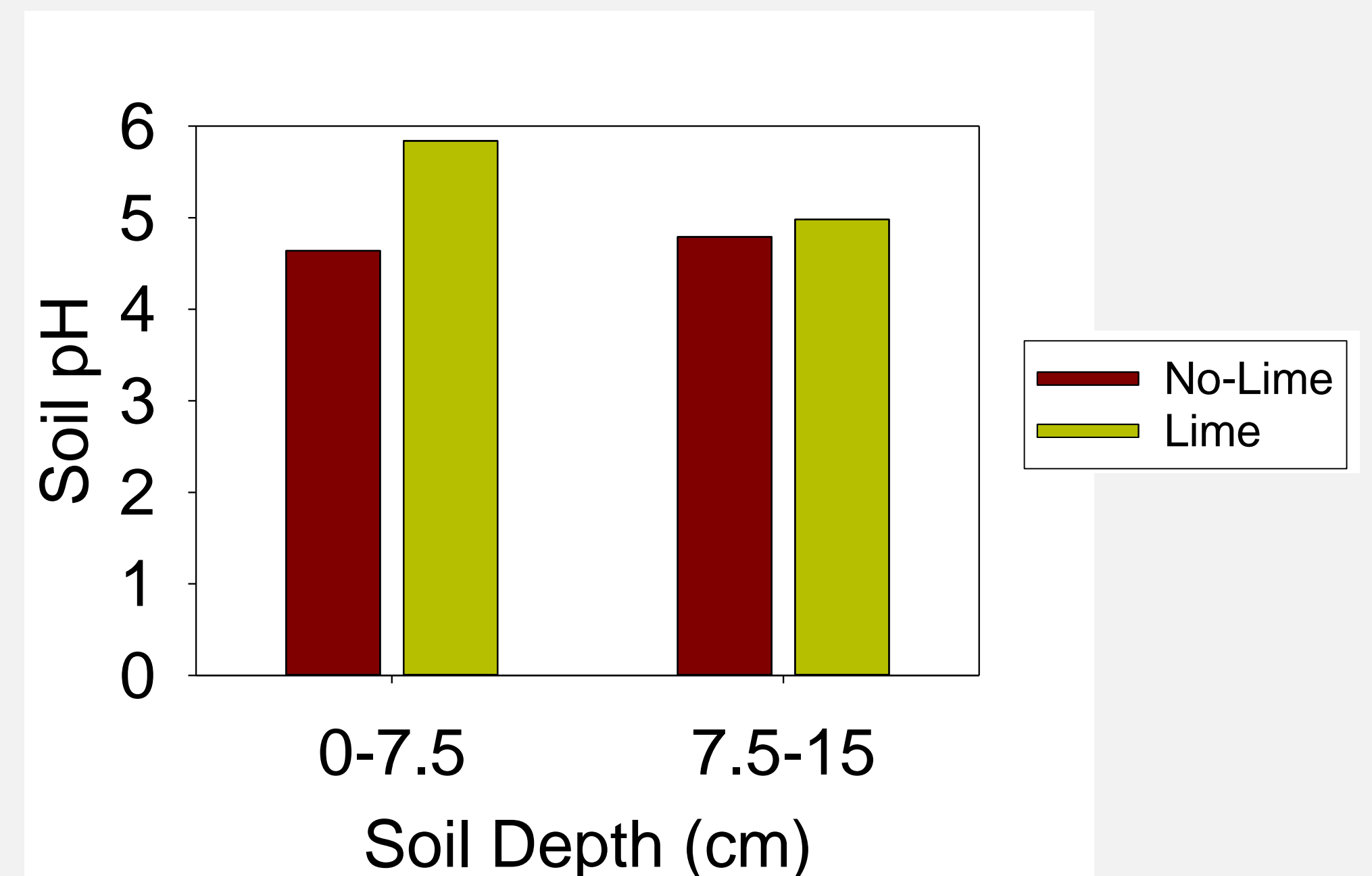




# IMPACT OF LIMING ON FUSARIUM CROWN ROT

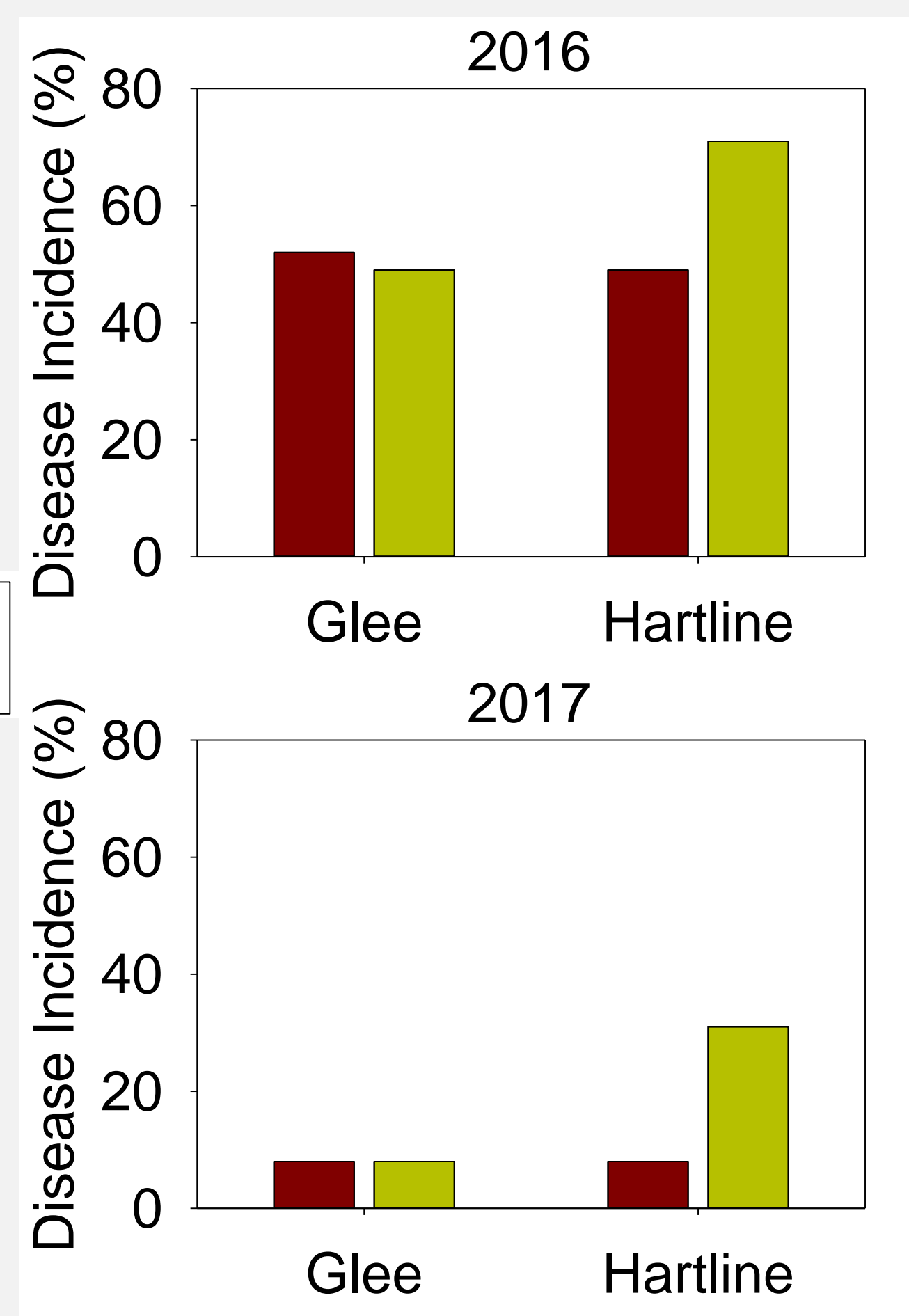
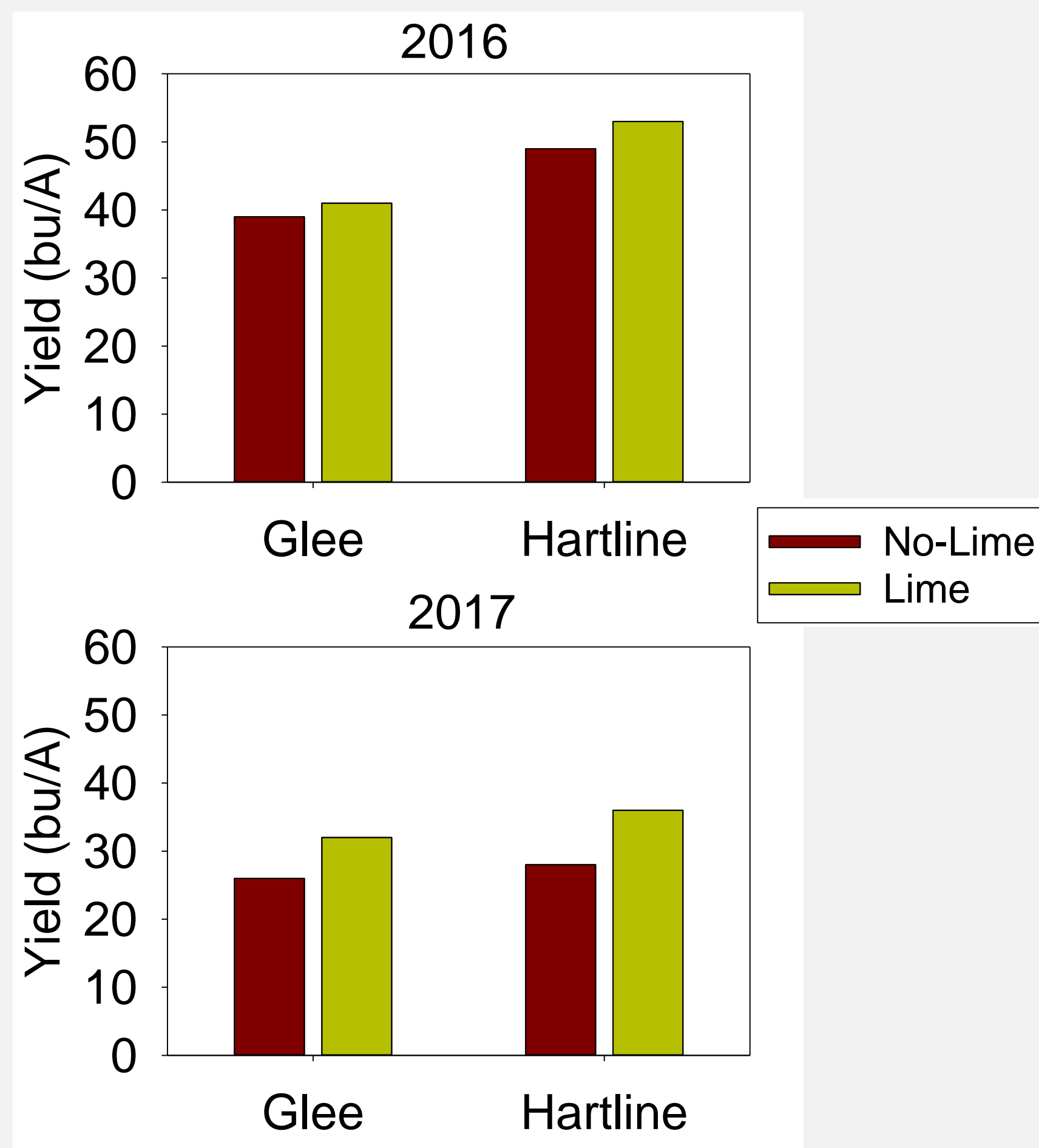


- Site at Parker farm with soil pH of 4.2 in upper 6 inches
- Applied 3 tons/A fluid lime
- Inoculated with *F. culmorum*





# ***F. CULMORUM* RESPONSE TO LIMING**

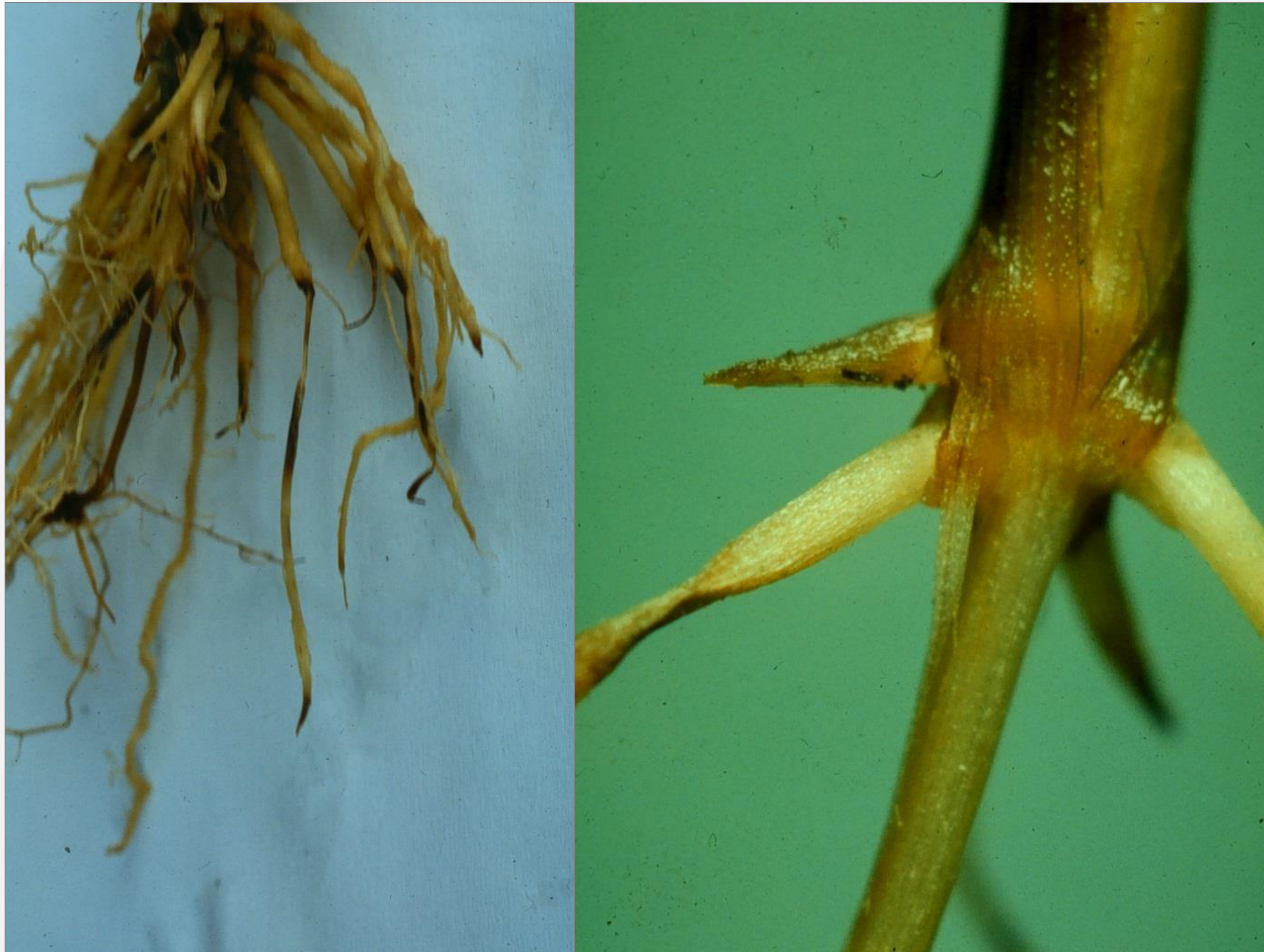






# **IDENTIFYING ALUMINUM TOXICITY IN WHEAT**

# RHIZOCTONIA ROOT ROT





# RHIZOCTONIA ROOT ROT



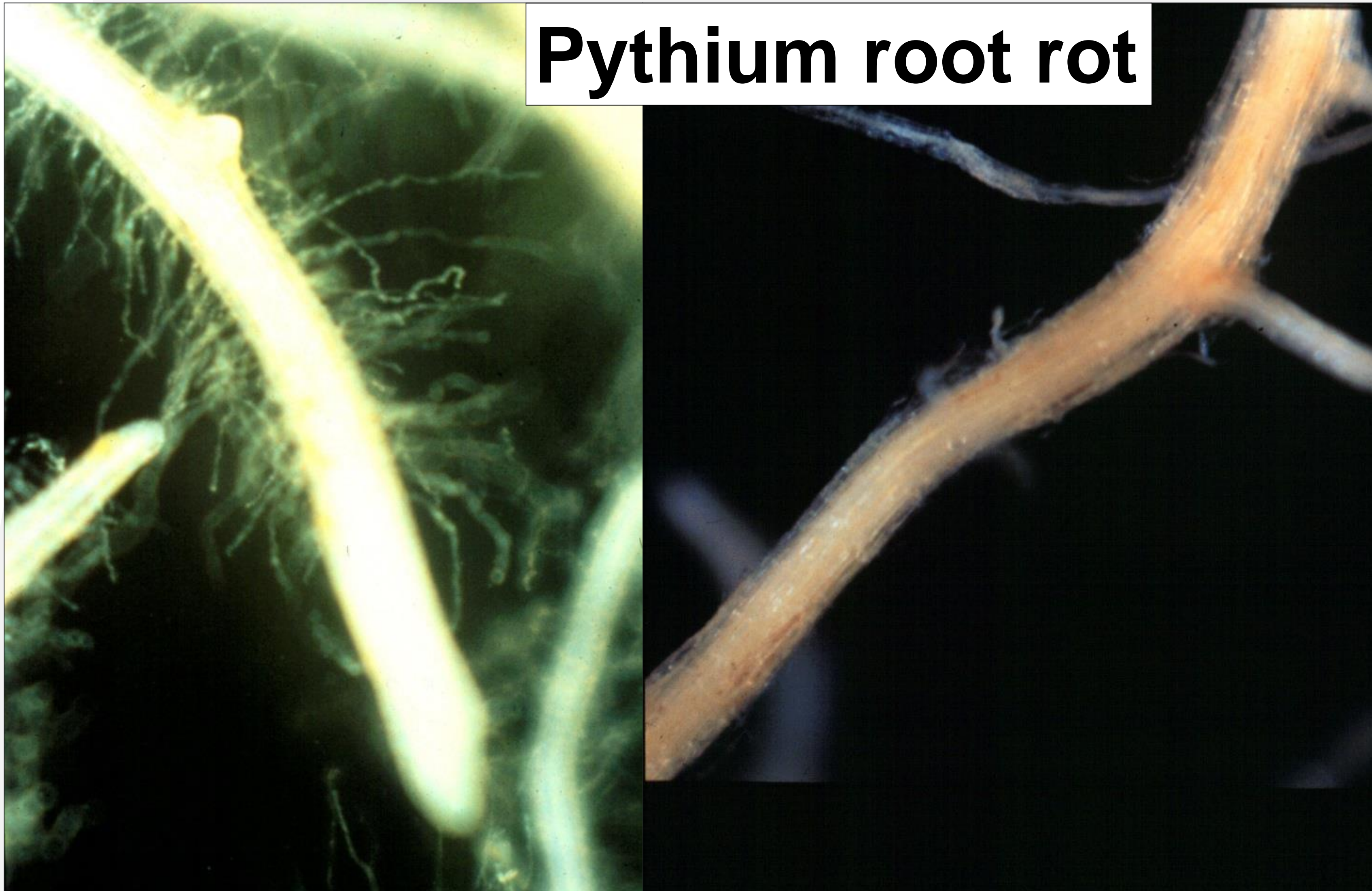


# RHIZOCTONIA ROOT ROT

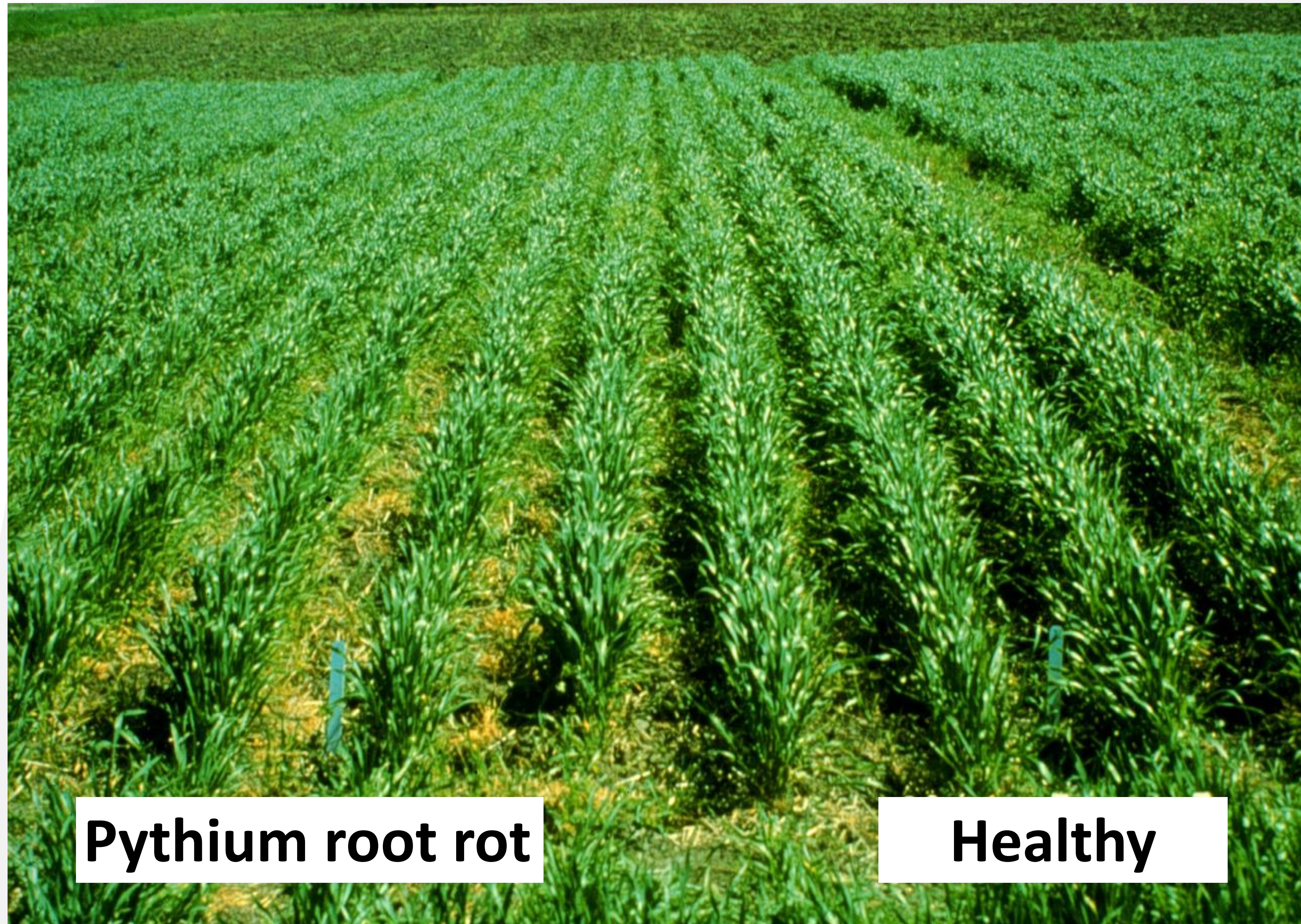




# Pythium root rot







**Pythium root rot**

**Healthy**



# PYTHIUM ROOT ROT



Mary Burrows, MSU



# ALUMINUM TOXICITY





# ALUMINUM TOXICITY





# ALUMINUM TOXICITY





# ALUMINUM TOXICITY





# IDENTIFYING ALUMINUM TOXICITY

- Reduced seedling vigor
- Reduced tillering
- Yellow and stunting of plants
- Patches may occur anywhere in a field
- Associated with low soil pH (<5) in upper 6 inches





**Thank you!**