Soil pH and Liming

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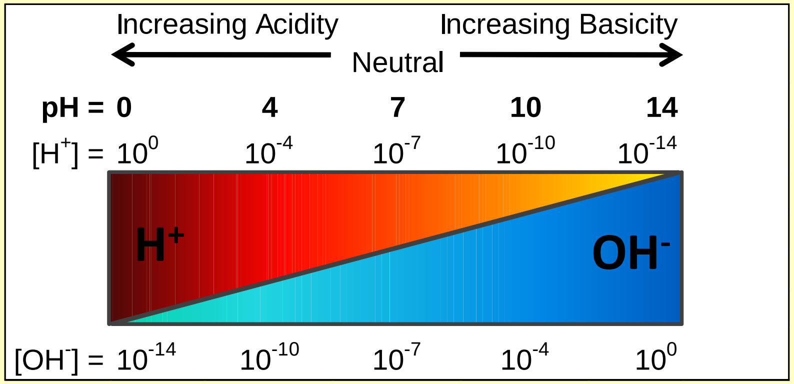
What Is pH?

- Definition of pH
  - Measure of acidity or alkalinity
  - Negative log of hydrogen ion concentration
    - As H^+ ion concentration increases, pH number decreases
    - One unit change in pH = 10 fold change in concentration of H^+ ions



Importance of soil pH

- Affects chemical and biological reactions
  - Availability of essential nutrients
    - Influences nutrient forms
  - Solubility (toxicity) of some elements (like Al)
  - Activity of microorganisms
  - Performance/carryover of some herbicides

How Soils Become Acidic

- Nitrification of ammonium
- Bases removed by crops
- Bases removed by leaching
- Acidic parent material
- *Carbonic acid from microbial and plant respiration*
- *Organic acids secreted by plant roots*

Limestone Needed to Offset Acidity from Nitrogen Fertilizers

Nitrogen Source	Pound of Aglime per Pound of N
Ammonium Sulfate	7
Ammonium Phosphates	7
Anhydrous Ammonia	4
UAN Solution	4
Urea	4
Ammonium Nitrate	4

Approximate amount. Adapted from Modern Corn Production.

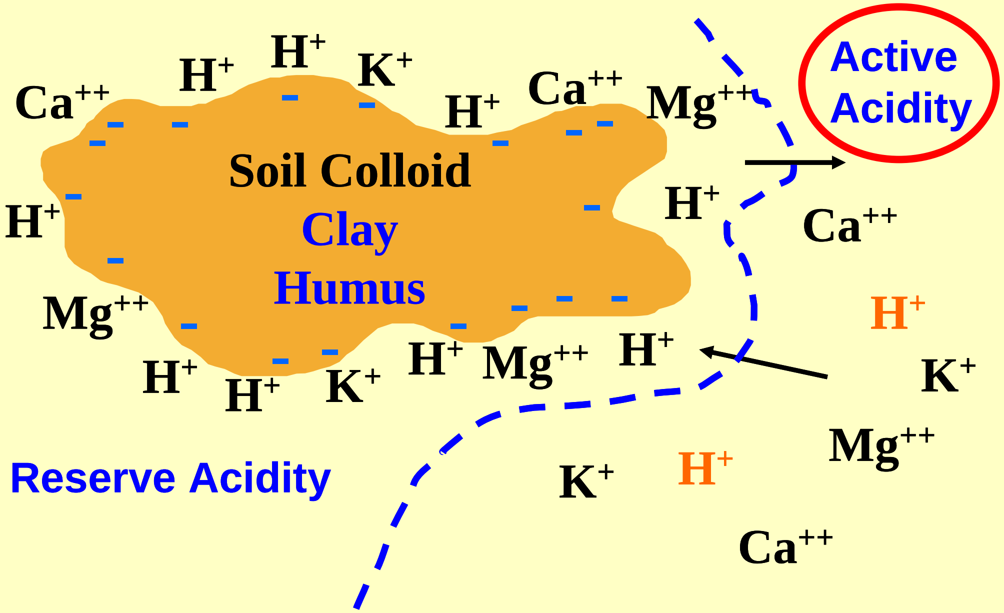
Amount of $CaCO_3$ Equivalent Needed to Replace Basic Cations in Crop Removal

Crop	Yield per acre	lb Aglime per acre
Corn Grain	150 bu	20
Corn Silage	8 ton	200
Oats	75 bu	5
Soybean	45 bu	95
Alfalfa	4 ton	515

Pierre & Banwart, 1973. Agron. J. 65:91-96.

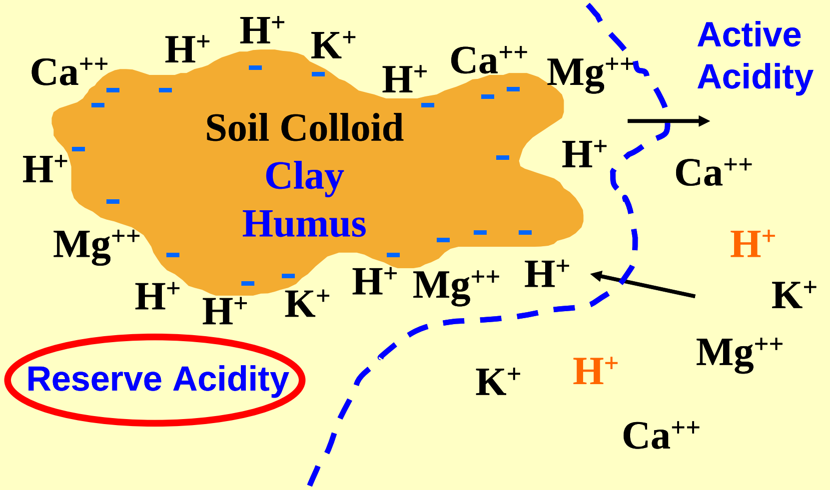
Nature of Soil Acidity

- Active acidity
  - Free hydrogen ions in soil solution
    - Measured by soil water pH
    - Very small part of total acidity in soil
    - Would take less than 1/3 lb/acre limestone to neutralize



Nature of Soil Acidity

- Reserve acidity
  - Neutralizable H ions and Al in association with organic matter and clay
  - Accounts for virtually all of the total acidity in soil
  - This is what limestone must neutralize when acid soils are limed in order to increase pH
  - Estimated by buffer pH



Chemical Soil Test Procedure
Soil Water pH

- Scoop 5-g soil sample
- Add 5 ml distilled water
- Stir for 5 sec.; Let Stand for 10 Min.
- Place pH electrodes in the slurry, swirl and read pH immediately

NCR Pub. 221

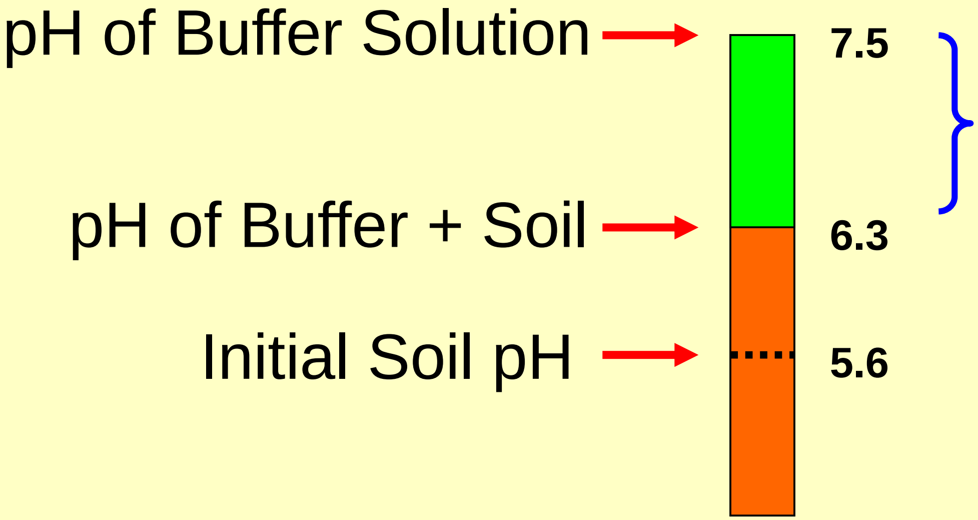
Chemical Soil Test Procedure
SMP or Sikora Buffer Lime Requirement

- Add 10 ml Buffer solution to the soil-water slurry saved from pH determination
- Shake for 10 min.; Let stand for 30 min.
- Swirl and read pH
  - Interested in the pH change from the initial buffer solution pH of 7.50
- Sikora buffer
  - New buffer used in Iowa (equivalent to SMP)
  - No hazardous chemicals

NCR Pub. 221

Determining Lime Requirement

- Measure "reserve" acidity to decide the lime amount to apply to raise pH to a given level



Index of reserve soil acidity

Calibrated with field soil pH increase from lime application to determine amount of lime needed to increase pH to some level

<u>Example</u>

Clay Loam (CEC 20): Soil pH 5.6; Buffer pH 6.1

Sandy Loam (CEC 5): Soil pH 5.6; Buffer pH 6.8

Alkaline Soils

- Soil pH > 7.0
- CEC saturated with basic cations
- pH controlled by:
  - Dissolved carbon dioxide chemistry
  - Solid Ca and Mg carbonates (1 to 20% by wt.)
    - pH 7.2 to 8.5
  - Exchangeable Na and dissolution of Na_2CO_3
    - pH 8.5 to 10.5

Calcareous Soils

- Not economical to lower pH
  - All $CaCO_3$ must be dissolved before pH can be lowered
  - If soil contains 1% lime in top 7 inches
    - Would require 68 tons concentrated sulfuric acid to neutralize
- Bray P_1 test will give false low readings on some soils with pH above 7.4
  - Use Olsen bicarbonate extractant
  - Use Mehlich-3 extractant

How Lime Application Reduces Soil Acidity

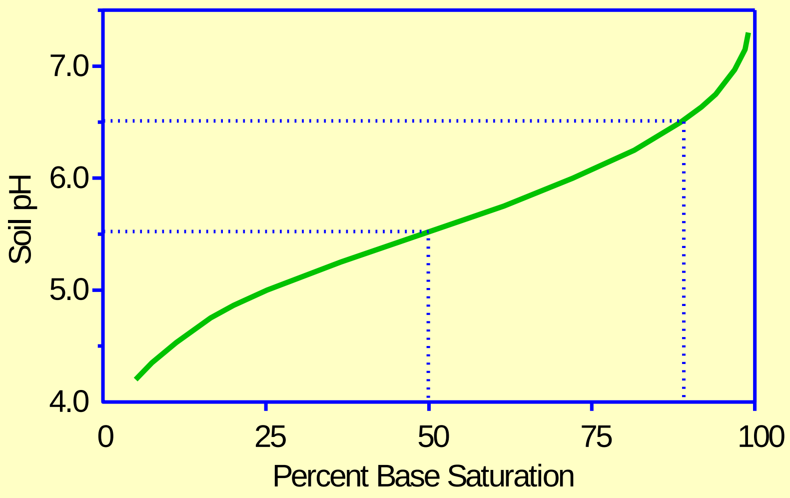
- Ca^{++} and Mg^{++} from lime replaces two H^+ ions on the cation exchange complex (reserve acidity)
- The H^+ ions combine with OH^- (hydroxyl) ions to form water
- pH increases because the acidity source (H^+) has been reduced

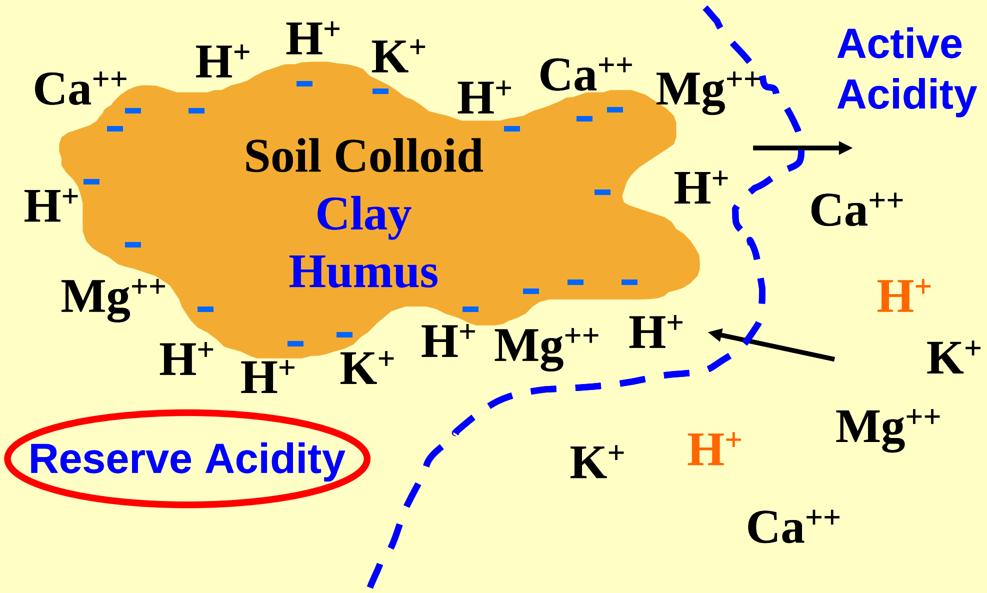
$$CaCO_3 + 2H^+ = Ca^{+2} + CO_2\uparrow + H_2O$$

$$MgCO_3 + 2H^+ = Mg^{+2} + CO_2\uparrow + H_2O$$

Liming Rate

- Depends on amount of reserve acidity to neutralize
  - Soil pH and CEC (change in base saturation)





Limestone Quality Impacts Application Rate

- Calcium Carbonate Equivalent (CCE)
  - Material in limestone that is effective in neutralizing acid
  - Ca and Mg carbonates
- Particle size
- Both combined determine limestone quality
  - Effective Calcium Carbonate Equivalent (ECCE)

How to Calculate Limestone Effective Calcium Carbonate Equivalent (ECCE)

	% of Particles Passing Each Screen		Fineness Factor		Percent Available Based on Fineness
4-mesh	100	x	0.1	=	10
8-mesh	90	x	0.3	=	27
60-mesh	55	x	0.6	=	33
Total Fineness Efficiency					70

Effective Calcium Carbonate Equivalent (ECCE):

(Total Fineness Efficiency ÷ 100) x (% CCE ÷ 100) x ([100 - % Moisture] ÷ 100) x 2000 = ECCE

Example:

(70 ÷ 100) x (92 ÷ 100) x ([100 - 2] ÷ 100) x 2,000 = 1,260 ECCE

Steps in Making Limestone Recommendations

- Check soil pH
  - Is lime needed?
- Determine $CaCO_3$ requirement
  - Use Buffer pH
- Adjust rate for limestone quality
  - lb ECCE per ton or %
- Adjust rate for incorporation depth

Suggested Soil pH Ranges for Different Crops

- Corn and soybean
  - pH 6.5 sufficient
    - (pH 6.0 sufficient for high pH subsoils)
- Alfalfa
  - pH 6.9 sufficient
- Grass pastures and grass hayland
  - pH 6.0 sufficient

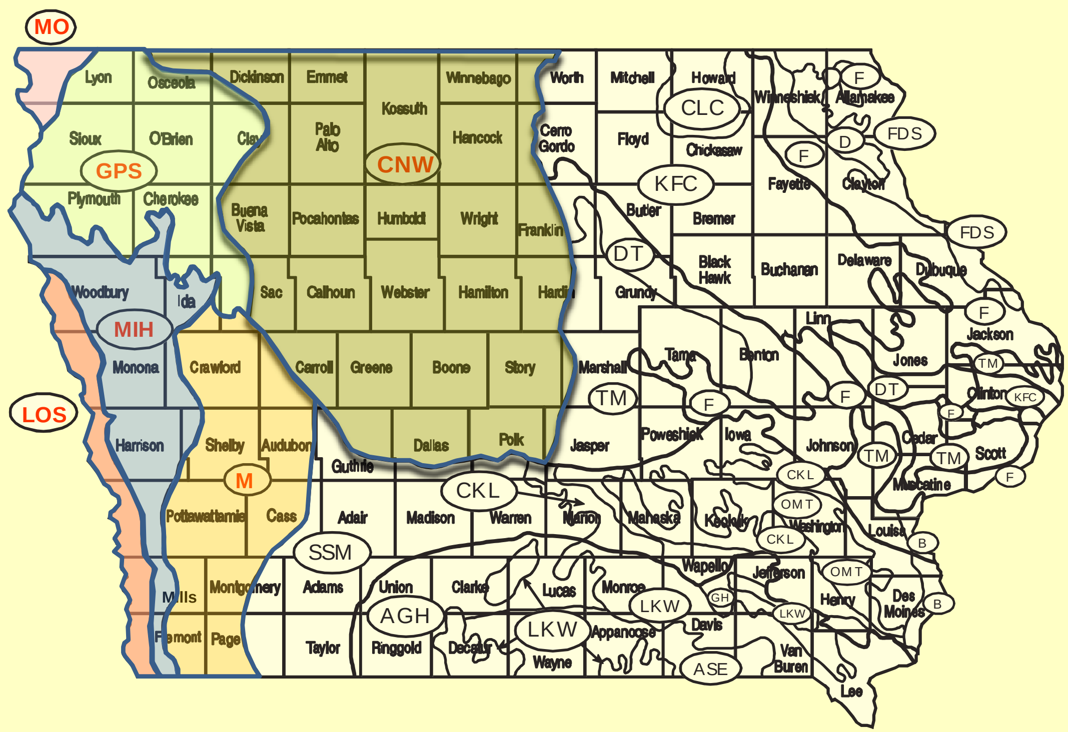
Note: High pH subsoil means calcareous within a four-foot depth of the surface.

Corn & Soybean pH/Lime Updates

Corn and Soybean	Lime if pH is	Raise to pH
- High subsoil pH	< 6.0 (no change)	6.0, not 6.5
- Low subsoil pH	< 6.5 (no change)	6.5 (no change)

Iowa Soil Associations Areas with High subsoil-pH

- Clarion-Nicollet-Webster
- Galva-Primghar-Sac
- Ida-Monona
- Luton-Onawa-Salix
- Marshall
- Moody



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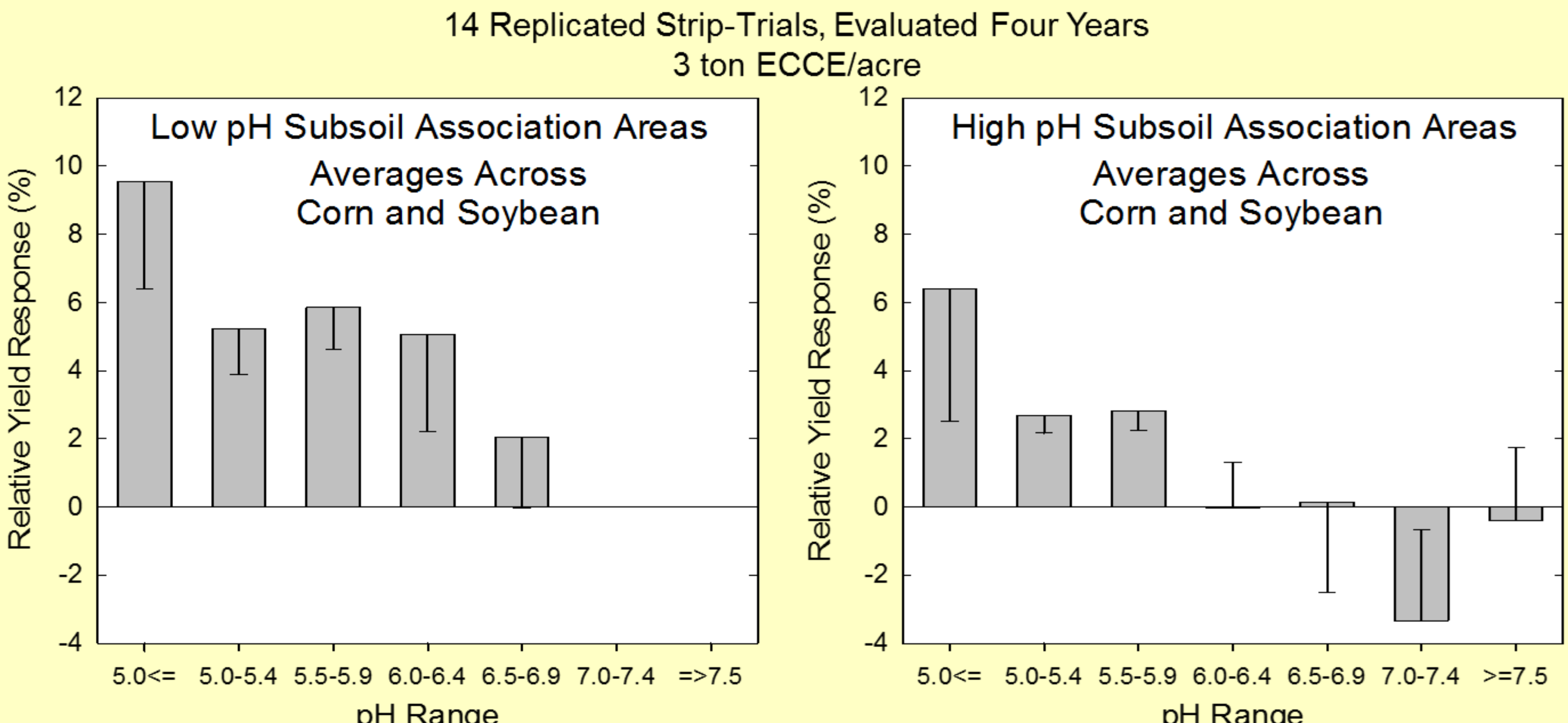

Pagani and Mallarino, 2012

How to Calculate Limestone Requirement - Example

Example	Corn - Soybean
Soil Test pH	5.7
Buffer pH	6.6
Target pH	6.5
Limestone ECCE	1,260 (63% or 0.63)

Six inch soil depth to neutralize

$CaCO_3$ rate from chart: 2,100 lb/acre

Correction for limestone quality: 2,100 lb/acre ÷ 0.63

Recommended lime rate: 3,300 lb/acre

Table 16. Lime recommendations based on SMP or Sikora buffer pH methods, given in pounds per acre of finely ground pure calcium carbonate ($CaCO_3$) to increase soil pH from its present level to pH 6.0, 6.5, or 6.9 for the soil depth to be neutralized.†

	Depth of Soil to be Neutralized								
	2 inches			3 inches			6 inches		
	Target Soil pH								
Buffer pH	pH 6.0	pH 6.5	pH 6.9	pH 6.0	pH 6.5	pH 6.9	pH 6.0	pH 6.5	pH 6.9
	Amount of Calcium Carbonate to Apply (lb/acre) ‡								
7.0	0	0	400	0	0	600	0	0	1,100
6.9	0	0	600	0	0	1,000	0	0	1,900
6.8	0	200	900	0	300	1,400	0	600	2,700
6.7	0	400	1,200	0	700	1,800	0	1,300	3,500
6.6	0	700	1,500	0	1,100	2,200	0	2,100	4,400
6.5	100	900	1,700	100	1,400	2,600	200	2,800	5,200
6.4	300	1,200	2,000	400	1,800	3,000	800	3,500	6,000
6.3	500	1,400	2,300	700	2,100	3,400	1400	4,200	6,800
6.2	700	1,700	2,600	1000	2,500	3,900	2000	5,000	7,700
6.1	900	1,900	2,800	1300	2,900	4,300	2500	5,700	8,500
6.0	1000	2,200	3,100	1600	3,200	4,700	3100	6,400	9,300
5.9	1200	2,400	3,400	1900	3,600	5,100	3700	7,100	10,100
5.8	1400	2,600	3,700	2200	4,000	5,500	4300	7,900	11,000
5.7	1600	2,900	3,900	2500	4,300	5,900	4900	8,600	11,800

† For corn and soybean, soil pH 6.5 is recommended in soil association areas without calcareous subsoil and soil pH 6.0 is recommended in areas with calcareous subsoil (see text and Figure 1). Soil pH 6.9 is recommended for alfalfa and alfalfa-grass mixtures in all soil association areas. Soil pH 6.0 is recommended for other forage legumes or legume-grass mixtures and grasses in all association areas.

‡ Amounts were derived from the following calibration equations and rounded to 100 pounds:
lb of $CaCO_3$ to raise pH to 6.0 = [38619 - (5915 x Buffer pH)] x [Depth x 0.167]
lb of $CaCO_3$ to raise pH to 6.5 = [49886 - (7245 x Buffer pH)] x [Depth x 0.167]
lb of $CaCO_3$ to raise pH to 6.9 = [58776 - (8244 x Buffer pH)] x [Depth x 0.167]

Table 16
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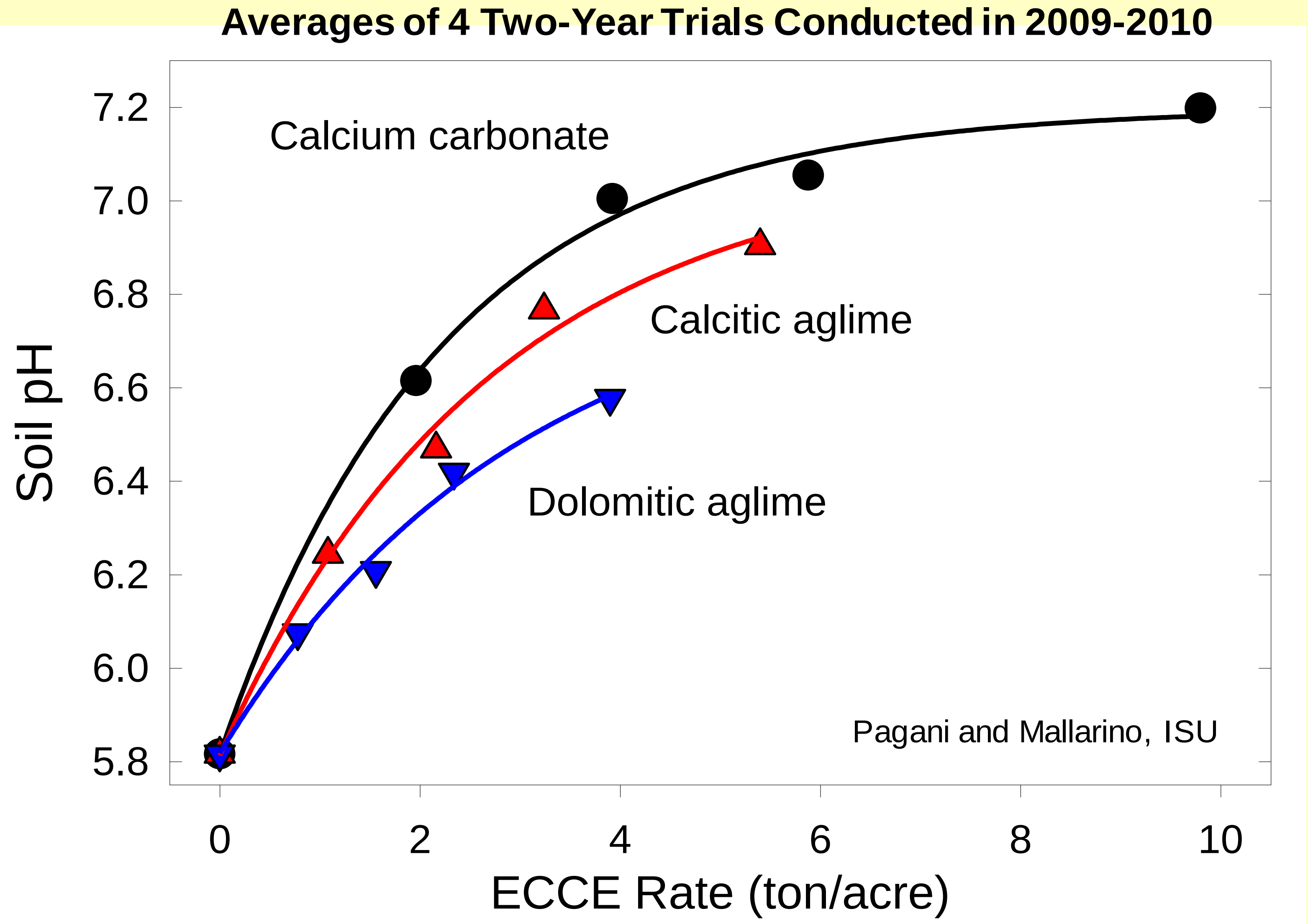
PM 1688

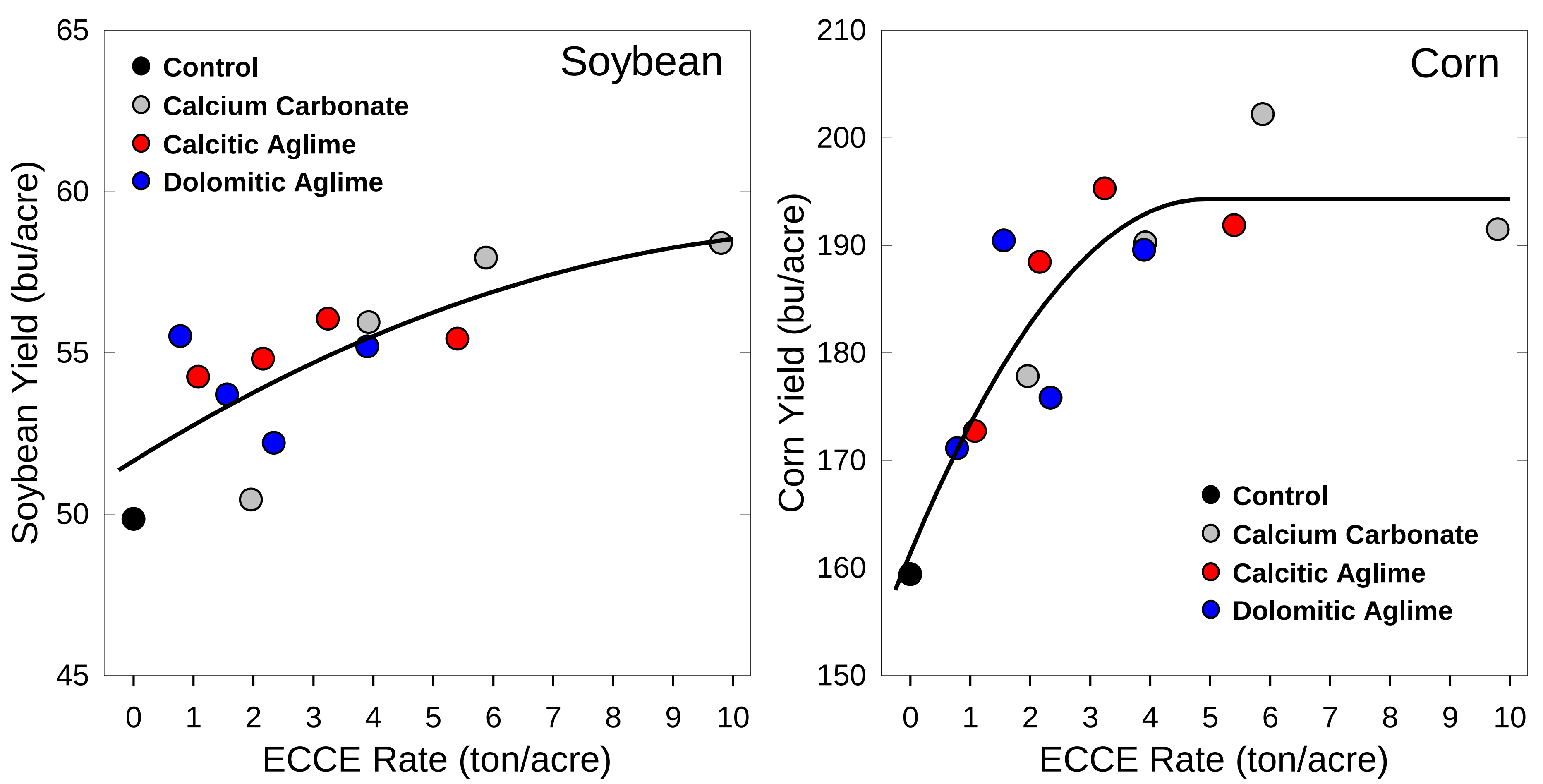
Calcitic vs Dolomitic Aglime



Approximately 105 days after early April lime application (when max pH reached).

Calcitic vs Dolomitic Aglime

Averages of 2 Responsive 2-Year Trials of 4 Conducted in 2009-2010

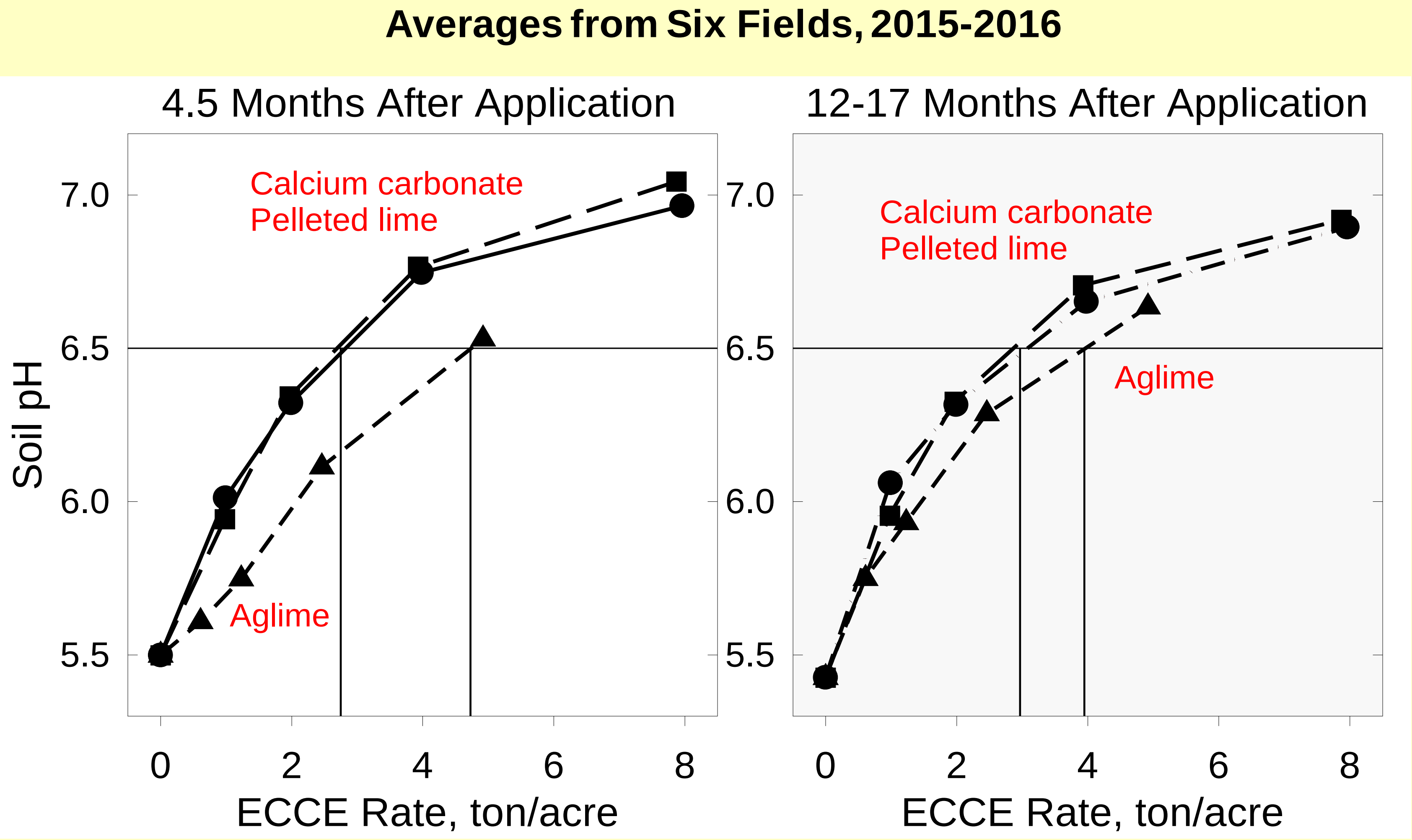


Pagani and Mallarino, ISU

Calcitic vs Dolomitic Aglime Results

- No source differences for crop yield
- The current ECCE measurement slightly over-estimated the dolomitic aglime efficiency at increasing soil pH
  - Not a major issue since didn't affect the yield response and can later check/correct soil pH
  - Dolomitic aglime adds Mg, but there is no evidence of Mg deficiency in Iowa

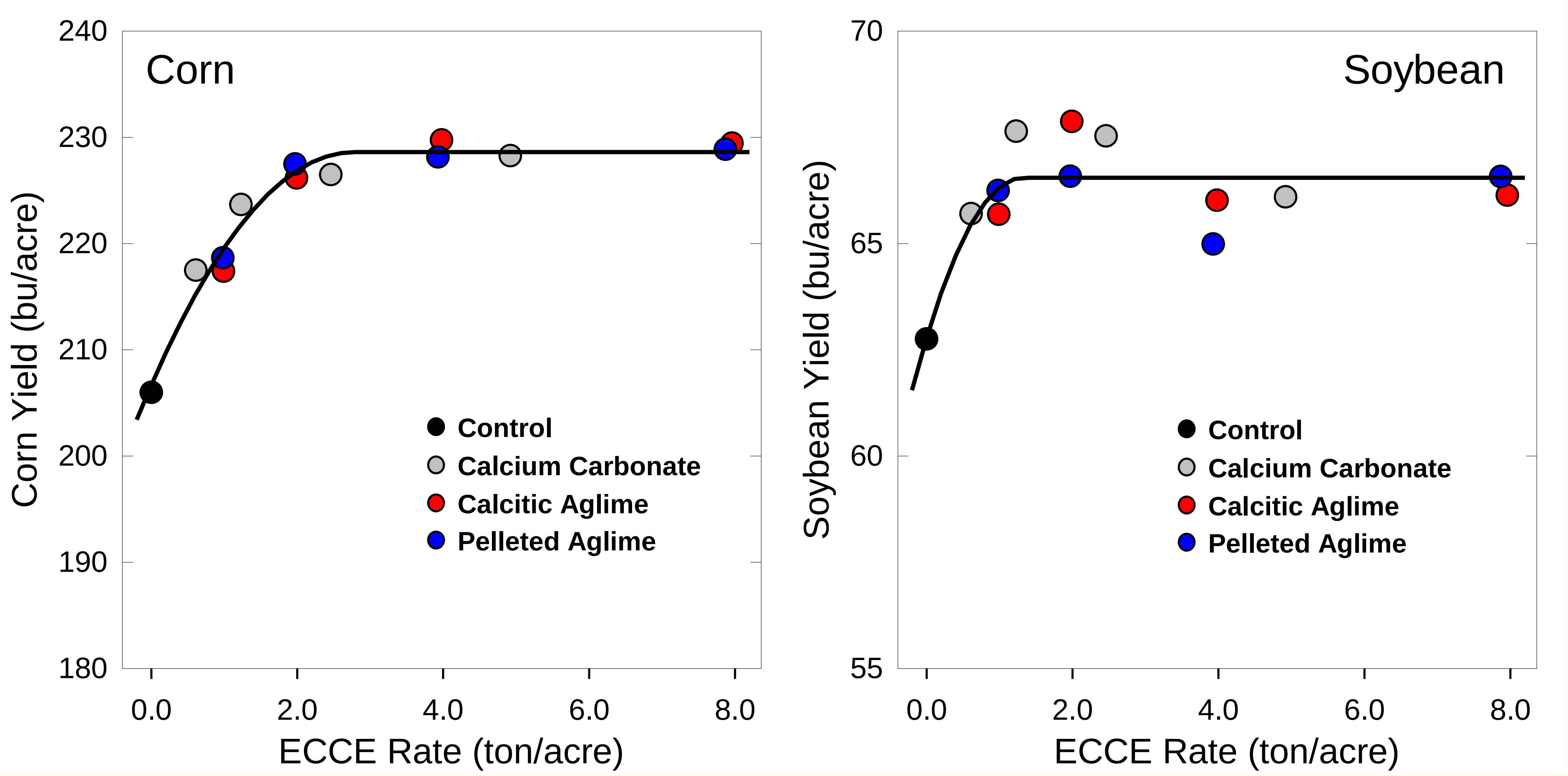
Pelleted Lime Research



Haq and Mallarino, ISU

Pelleted Lime Research

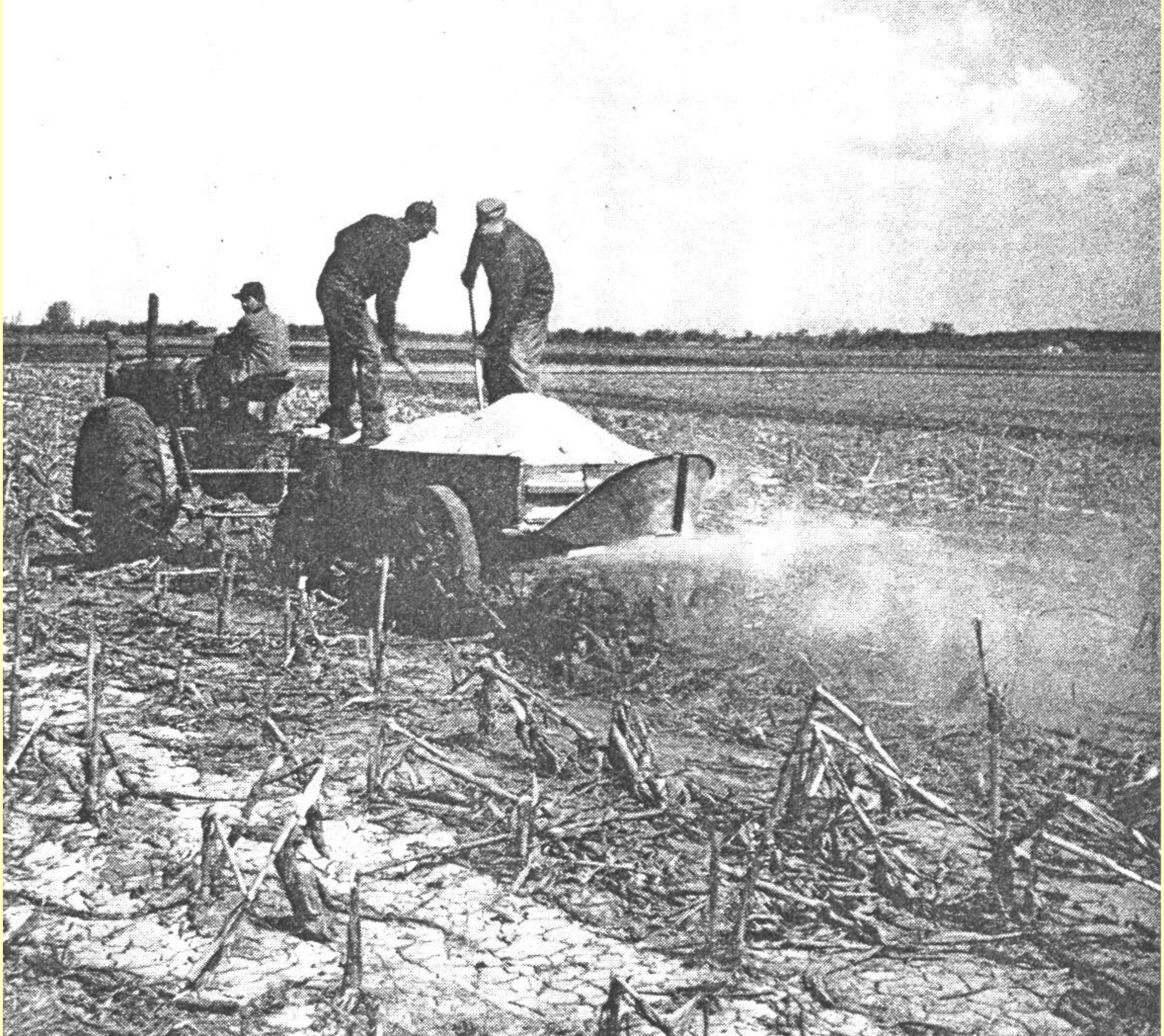
Averages of Responsive Fields, 2015-2016



Haq and Mallarino, ISU

Pelleted Lime Research Results

- Efficiency at increasing soil pH
  - High and similar for pure powdered calcium carbonate and pelleted time
  - Lower for calcitic aglime mainly the first year after application
  - Current ECCE slightly over-estimate short-term aglime efficiency; OK for pelleted
- But no yield difference between sources even for a first-year crop
- Low rates, small pH increase



Test Your Soil For Acidity

C.M. Linsley and F.C. Bauer

- University of Illinois Circular 346, August, 1929
- In a 40-acre field measure pH & carbonates
  - 23 surface samples (2 inch depth)
  - 5 subsurface (12 inch depth)
  - 5 subsoil (20 inch depth)
- Completed acidity map shows where and how much limestone is needed
- Good plan to test after six years

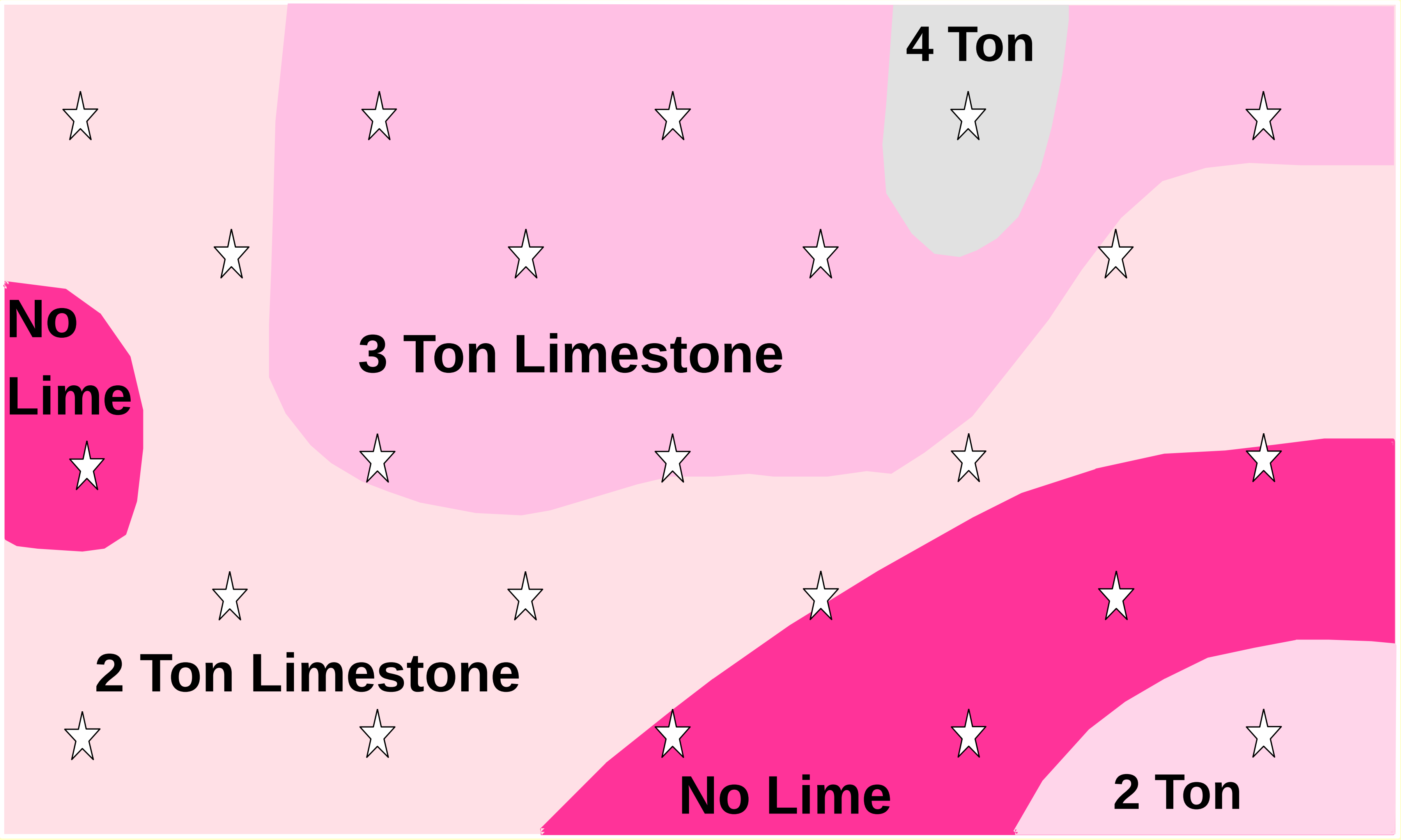
Test Your Soil For Acidity

C.M. Linsley and F.C. Bauer

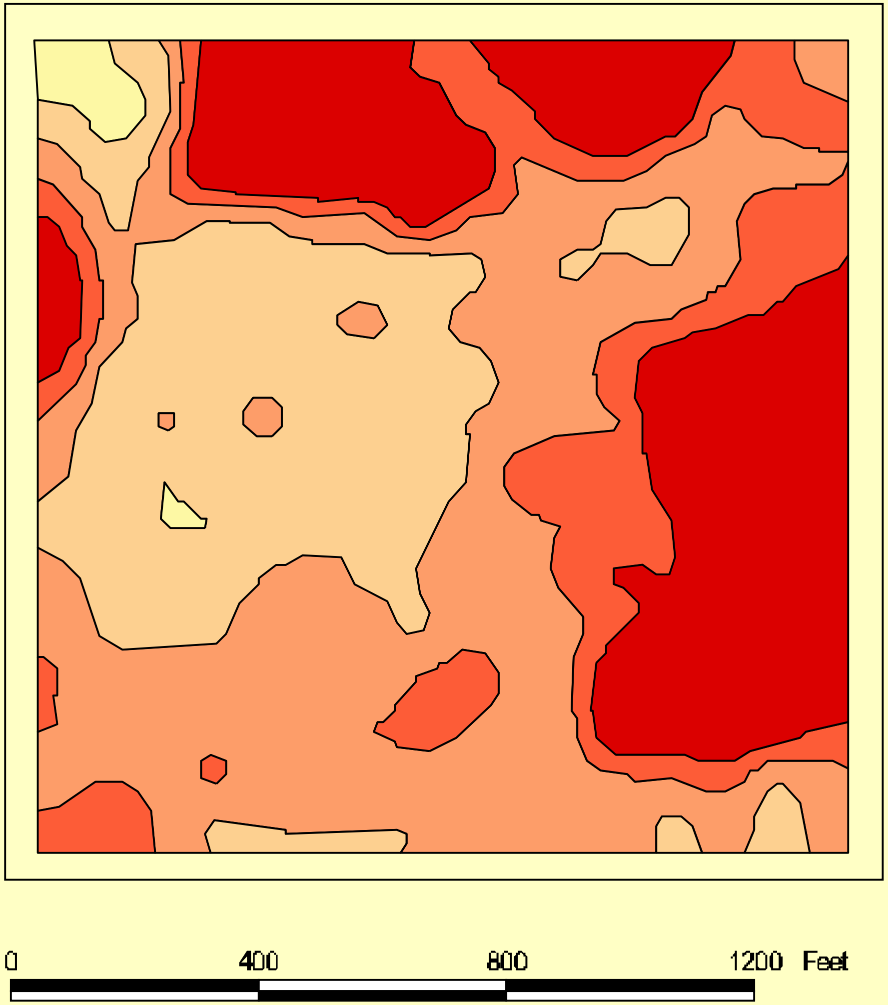
- 1929
  - Mapping native fertility patterns
- Today
  - Also mapping man's activities
    - More variable
    - Less tillage
    - Soil changes (erosion)
    - Need more samples?
    - Do as well as in 1929?

Test Your Soil For Acidity

Adapted from C.M. Linsley and F.C. Bauer



September 1991 Soil pH



Soil pH

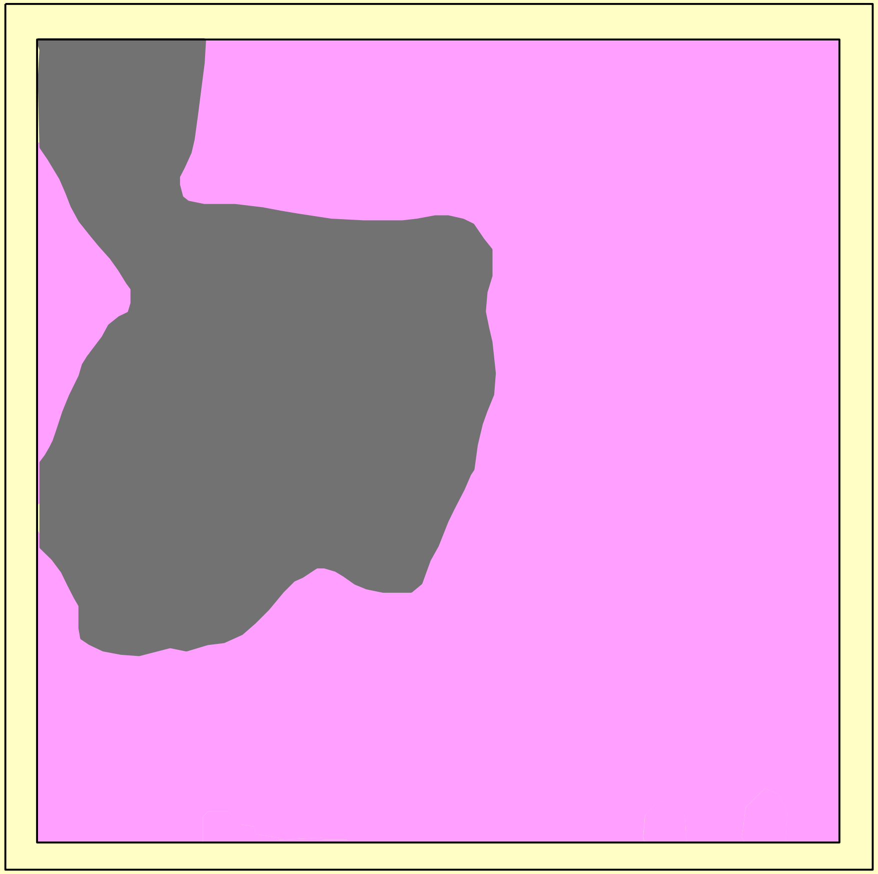
- < 5.5
- 5.5 - 6.0
- 6.0 - 6.5
- 6.5 - 7.0
- > 7.0

40 acres
16 x 16 grid
0.156 acres/sample

Mansfield Test Field

Data From:
T. Peck, Univ. of Illinois

Agricultural Limestone Application
4 Ton/acre -- October 1991



Lime Rate

4 ton/acre

0 ton/acre

40 acres
16 x 16 grid
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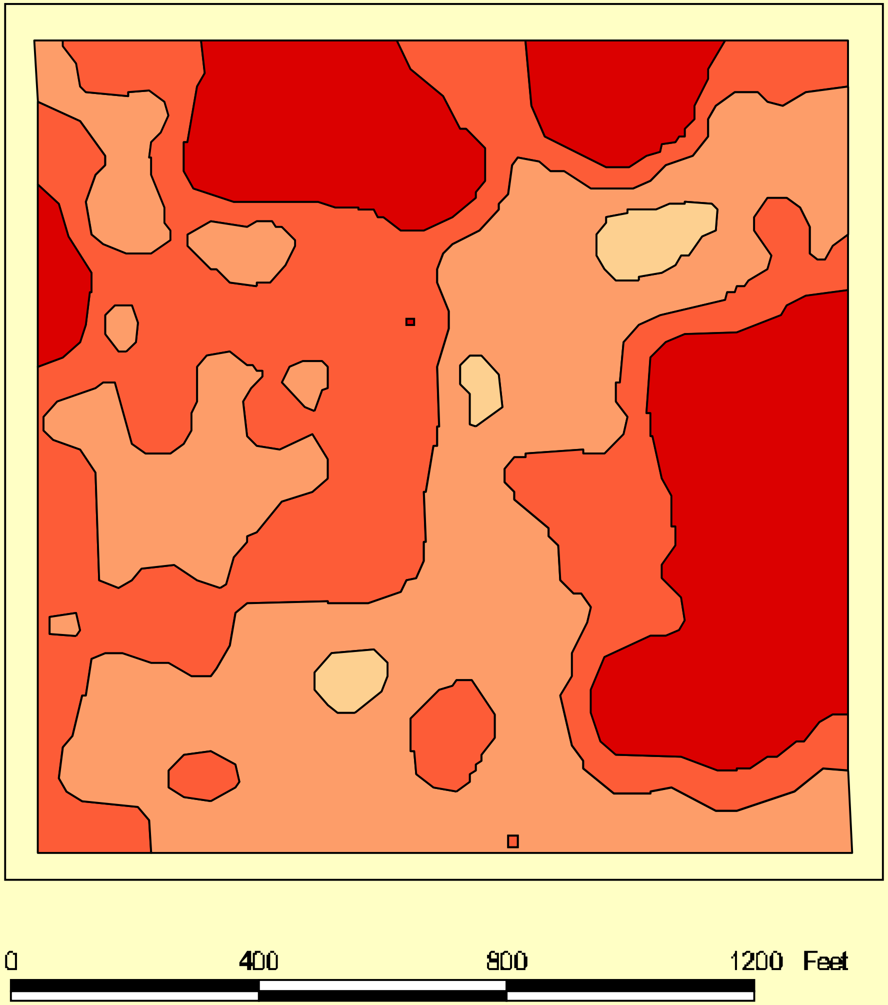

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Questions?