EFFECTS OF CA:MG RATIOS ON CROP YIELDS AND SOIL HEALTH

Conservation Tillage Conference, March 6, 2019

Steve Culman[1] and Will Osterholz[2]

[1] Assistant Professor of Soil Fertility
School of Environment and Natural Resources, culman.2@osu.edu

[2] USDA ARS Soil Drainage Research Unit, will.osterholz@usda.gov

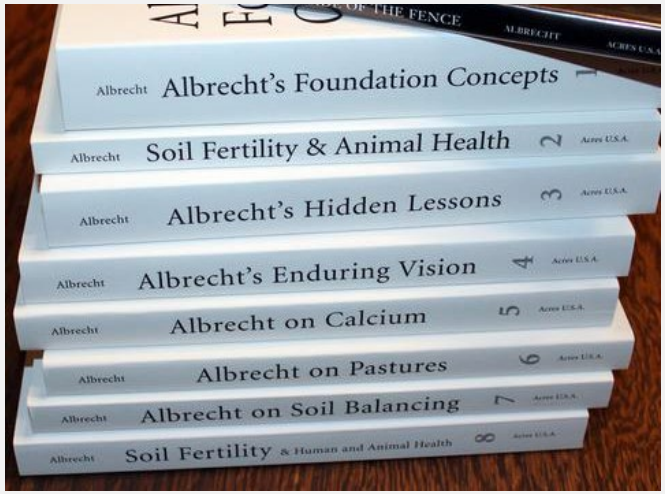
Ohio State University team: Doug Doohan, Doug Jackson-Smith, Matt Kleinhenz, Subbu Kumarappan, Vijay Chaganti, Will Osterholz, Caroline Brock, Cathy Herms, Cassie Brown

Soil Management Philosophies

- Build-Up and Maintenance
  - Build soils up to and maintain at a specific levels
- Sufficiency Level of Available Nutrients (SLAN)
  - Apply nutrients to a minimum level required by plants
- Base Cation Saturation Ratio (BCSR)
  - Focus placed on base saturation of Ca, Mg and K (sometimes ratios of Ca:Mg)
  - Ideal base saturation: 60-75% Ca, 10-20% Mg, 2-5% K

History of BCSR

- Loew 1892 – searched for ideal Ca:Mg
- Bear et al. 1945 – ideal soils 65% Ca, 10% Mg, 5% K
- Albrecht (and Graham) 1940-1977
  - Ideal base saturations 60-75% Ca, 10-20% Mg, 2-5% K
  - The Albrecht Papers
- Charles Walters 1970
  - ACRES U.S.A popularized BCSR



Albrecht's Work

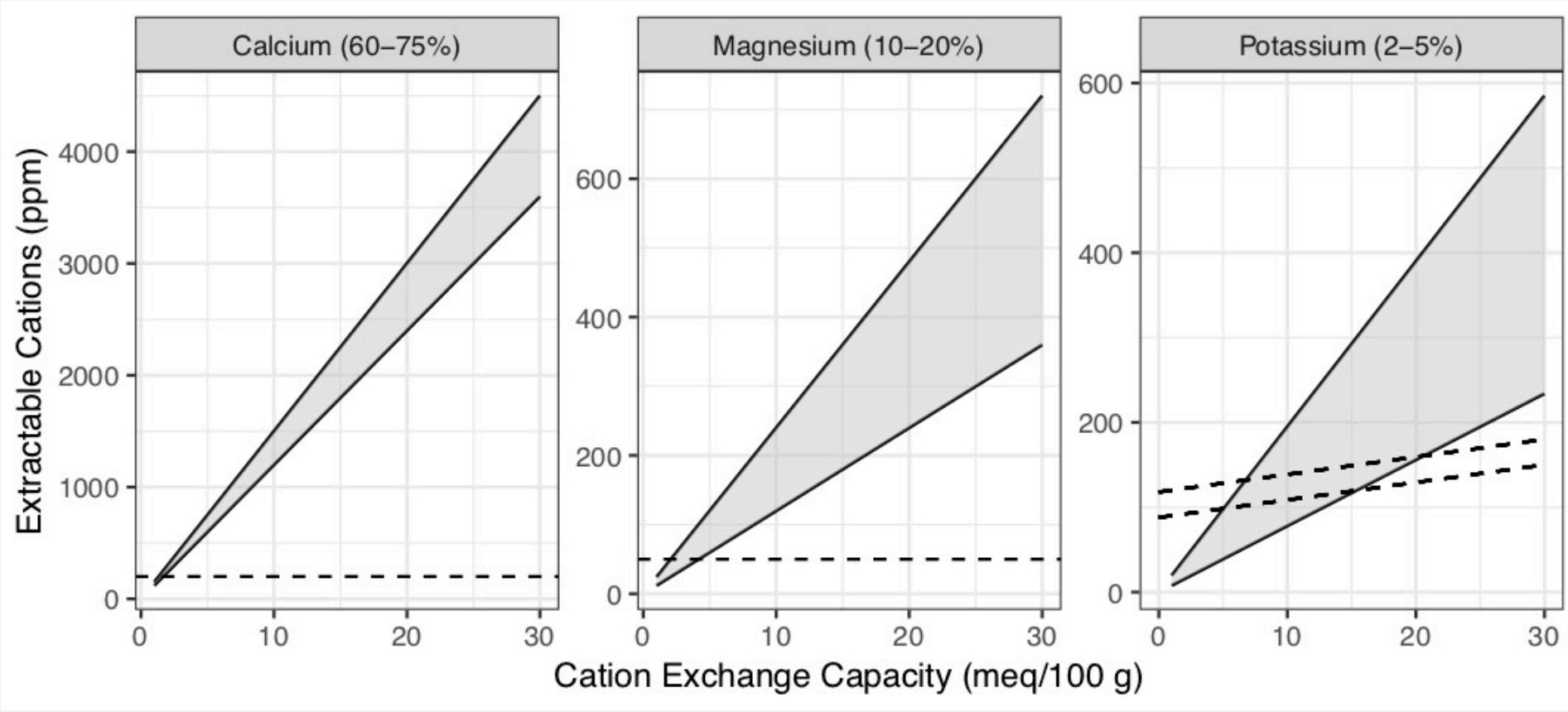
"Albrecht concluded that it is important to maintain a high Ca saturation percentage. Indeed, it was this observation that would eventually form the basis for much of Albrecht's concept of the "balanced soil." It would seem, however, that the design and interpretation of the experiments used to demonstrate the need for a high Ca saturation were often flawed"

Kopittke and Menzies, BCSR review, SSSAJ 2007

Albrecht did not control for pH changes when adding Ca

Soil Balancing vs. SLAN

(Ex. Tri-State Fertilizer Recs)



What are the economic implications?

Soil Fertility Specialists' – Soil Balancing Attitudes

Statement	Strongly Agree	Somewhat agree	Neither Disagree or agree	Somewhat disagree	Strongly Disagree
There is no scientific merit to this approach and this has been shown repeatedly	39%	39%	23%	0%	0%

Soil Fertility Specialists' – Soil Balancing Attitudes

Statement	Strongly Agree	Somewhat agree	Neither Disagree or agree	Somewhat disagree	Strongly Disagree
There is no scientific merit to this approach and this has been shown repeatedly	39%	39%	23%	0%	0%
I have not seen enough evidence to either endorse or discredit this approach	18%	16%	10%	20%	35%

Soil Fertility Specialists' – Soil Balancing Attitudes

Statement	Strongly Agree	Somewhat agree	Neither Disagree or agree	Somewhat disagree	Strongly Disagree
There is no scientific merit to this approach and this has been shown repeatedly	39%	39%	23%	0%	0%
I have not seen enough evidence to either endorse or discredit this approach	18%	16%	10%	20%	35%
It is possible that farmers do see benefits from this approach	2%	20%	22%	28%	28%

What does previous research on Soil Balancing show?

Historical Perspective of Soil Balancing Theory and Identifying Knowledge Gaps: A Review

Vijayasatya N. Chaganti* and
Steve W. Culman

Abstract

The common philosophies that contextualize soil test results and fertilizer recommendations are sufficiency level of available nutrients (SLAN), buildup and maintenance, and basic cation saturation ratio (BCSR). The BCSR approach postulates maintaining an ideal ratio of basic cation (Ca^{2+}, Mg^{2+}, and K^{+}) saturations on the soil exchange sites to maximize crop yields. The practice of adding amendments to alter the ratios of basic cation saturations in soils is called "soil balancing." Bear, Graham, and Albrecht promoted this concept, with each suggesting a desired saturation ratio of Ca:Mg:K for optimum crop yields. Several researchers have tried to validate this theory with both greenhouse and field experiments but could not conclude that an ideal cation saturation ratio existed and

15 peer-review studies (7 field, 8 greenhouse)

Chaganti and Culman, 2017, Crops, Forage and Turfgrass Management

Conclusions from previous research on BCSR and crop yield

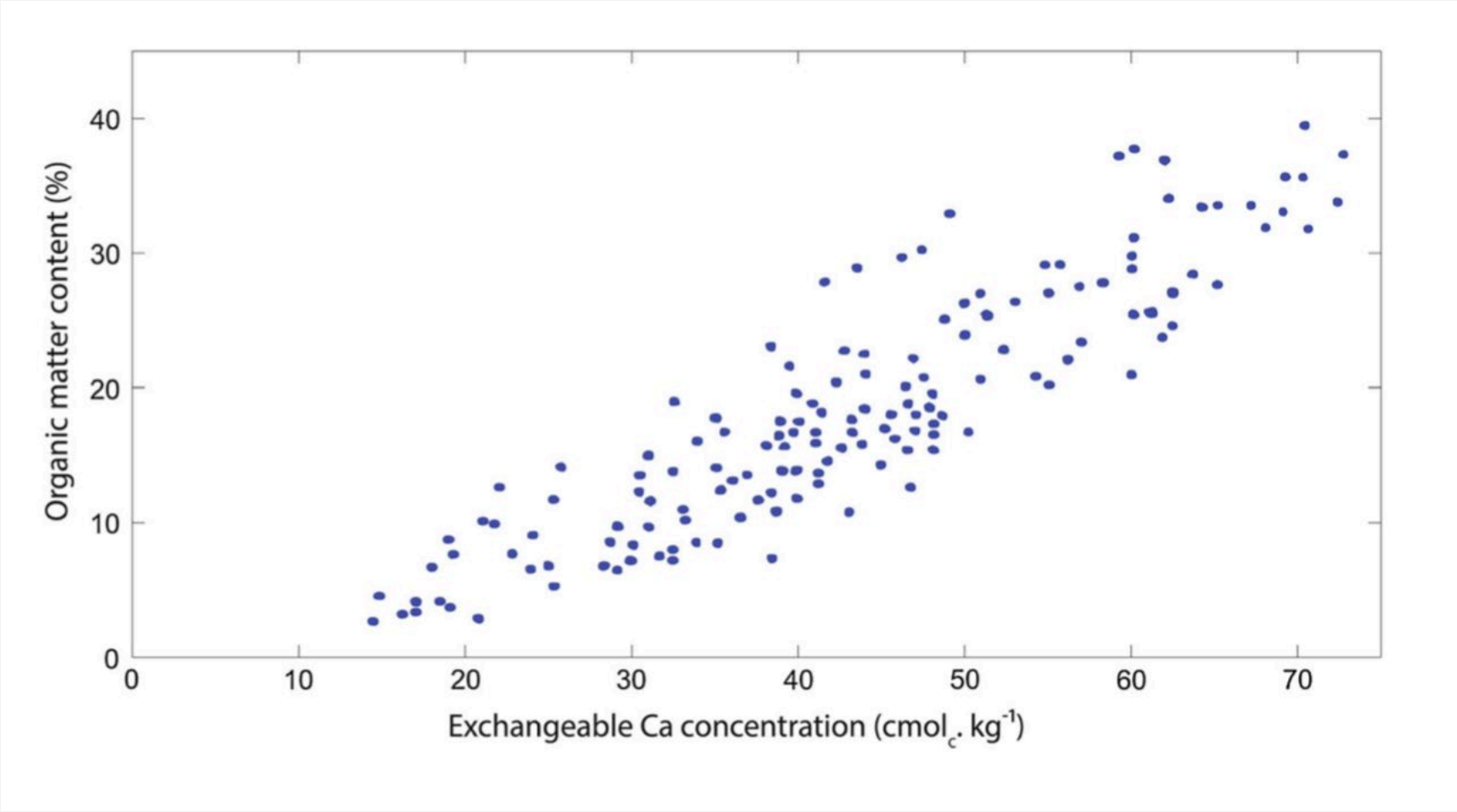
- There is no ideal ratio where crop yields are maximum. Yields were not affected across a wide range of ratios.
- Can result in excessive fertilizer applications when trying to maintain base cation ratios at specific levels/ranges (ideal levels).
- Buildup/Sufficiency level approach is more economical than BCSR
- Maintaining sufficient levels to meet crop needs is more important than to achieve a favorable cation ratio.

Why the disconnect??

Why does the agricultural community care about Ca:Mg ratios when no Land Grant Universities endorse??

Is it possible that soil Ca:Mg ratios do matter but were originally rooted in ~~bad~~ less than great science?

Soil Ca Saturation and Organic Matter



Rowley et al., 2018, Biogeochemistr

Increasing Ca:Mg Ratios in Practice

- Two products typically used:

- Hi-cal lime ($\underline{Ca}CO_3$)
  - Raises pH, effects on crop productivity well-documented

- Gypsum ($\underline{Ca}SO_4$)
  - Does not raise pH, crop effect inconsistent
  - Gypsum can be used as a soil amendment (physical structure)
  - Should farmers use gypsum for S nutrition or as a soil amendment?
    - S nutrition: <20-30 lb/ A
    - Amendment: 2000-4000 lb/A

Underlying Questions

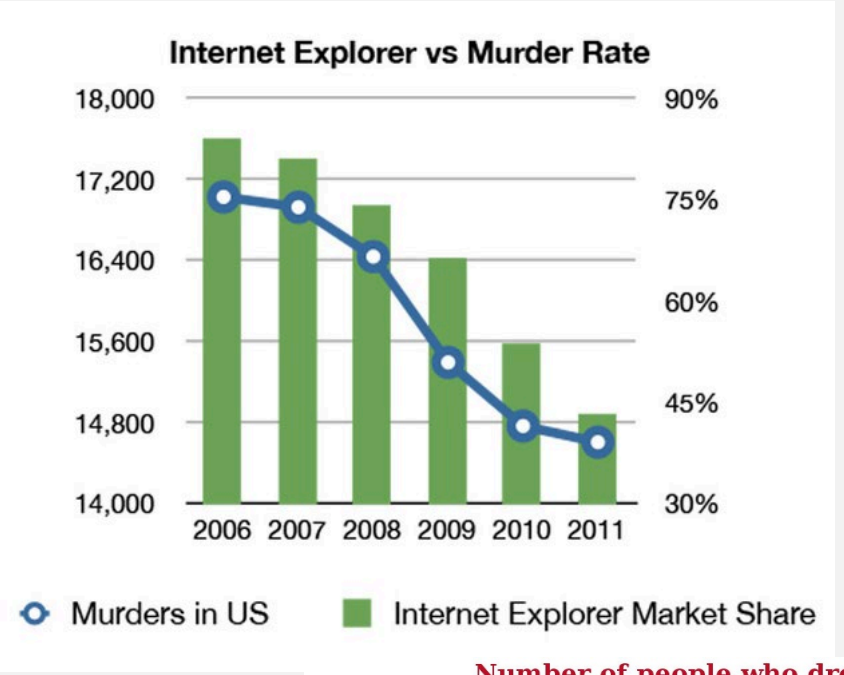
When we add lime ($CaCO_3$), we always

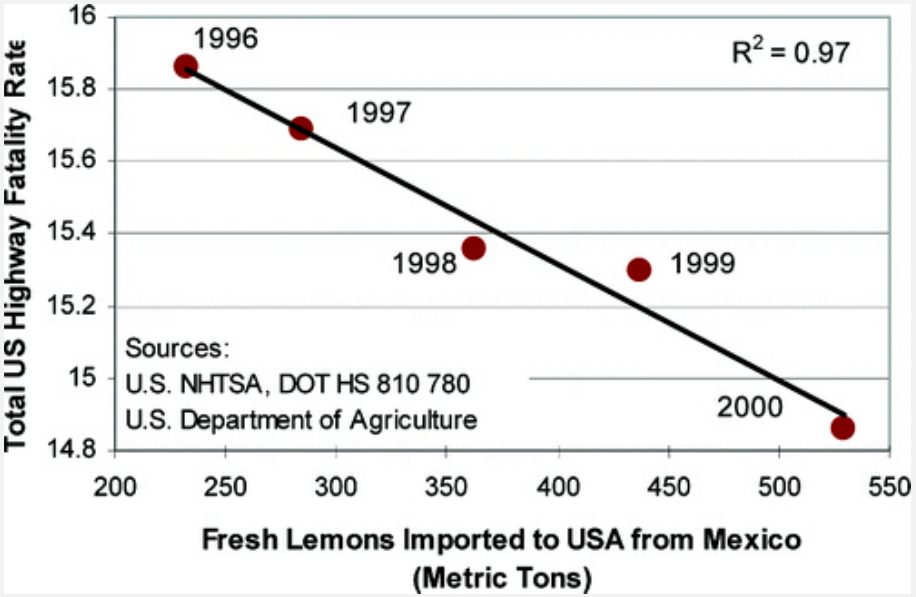
1) *Raise pH*
2) *Add calcium*

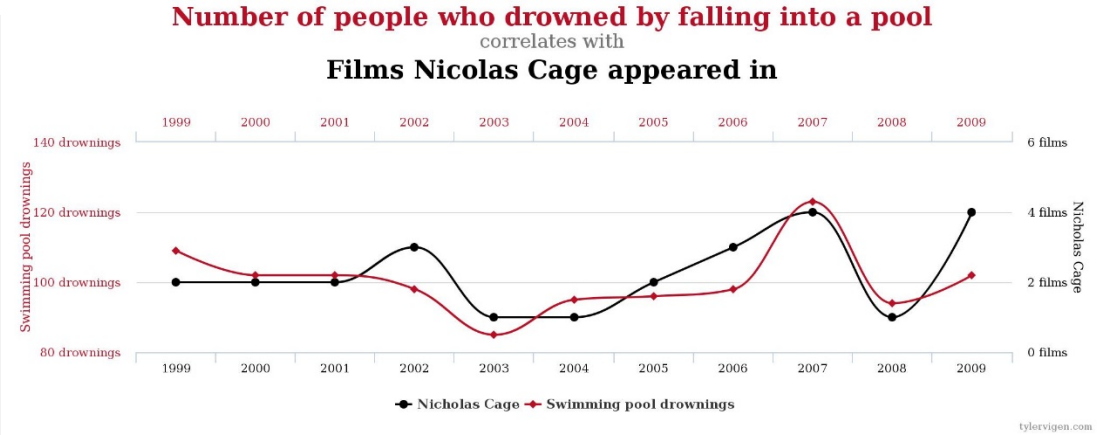
Are there additional benefits from lime not related to increasing pH? Is the Ca providing benefits? Can these effects be teased apart?

Are effects of gypsum ($CaSO_4$) a sulfur response or soil conditioning response?

Correlation vs. Causation







General Working Hypothesis

Applying lime to the soil…

- Increases nutrient availability and
- Increases soil biological activity
- Which improves crop growth

Applying gypsum to the soil…

- Increases soil aggregation and physical structure
- Which increases root growth, water/gas exchange, soil biological activity
- Which improves crop growth

General Working Hypothesis

Applying lime to the soil…

- Increases nutrient availability and
- Increases soil biological activity
- Which improves crop growth

Applying gypsum to the soil…

- Increases soil aggregation and physical structure
- Which increases root growth, water/gas exchange, soil biological activity
- Which improves crop growth

General Working Hypothesis

Applying lime to the soil…

- Increases nutrient availability and
- Increases soil biological activity
- Which improves crop growth

Established

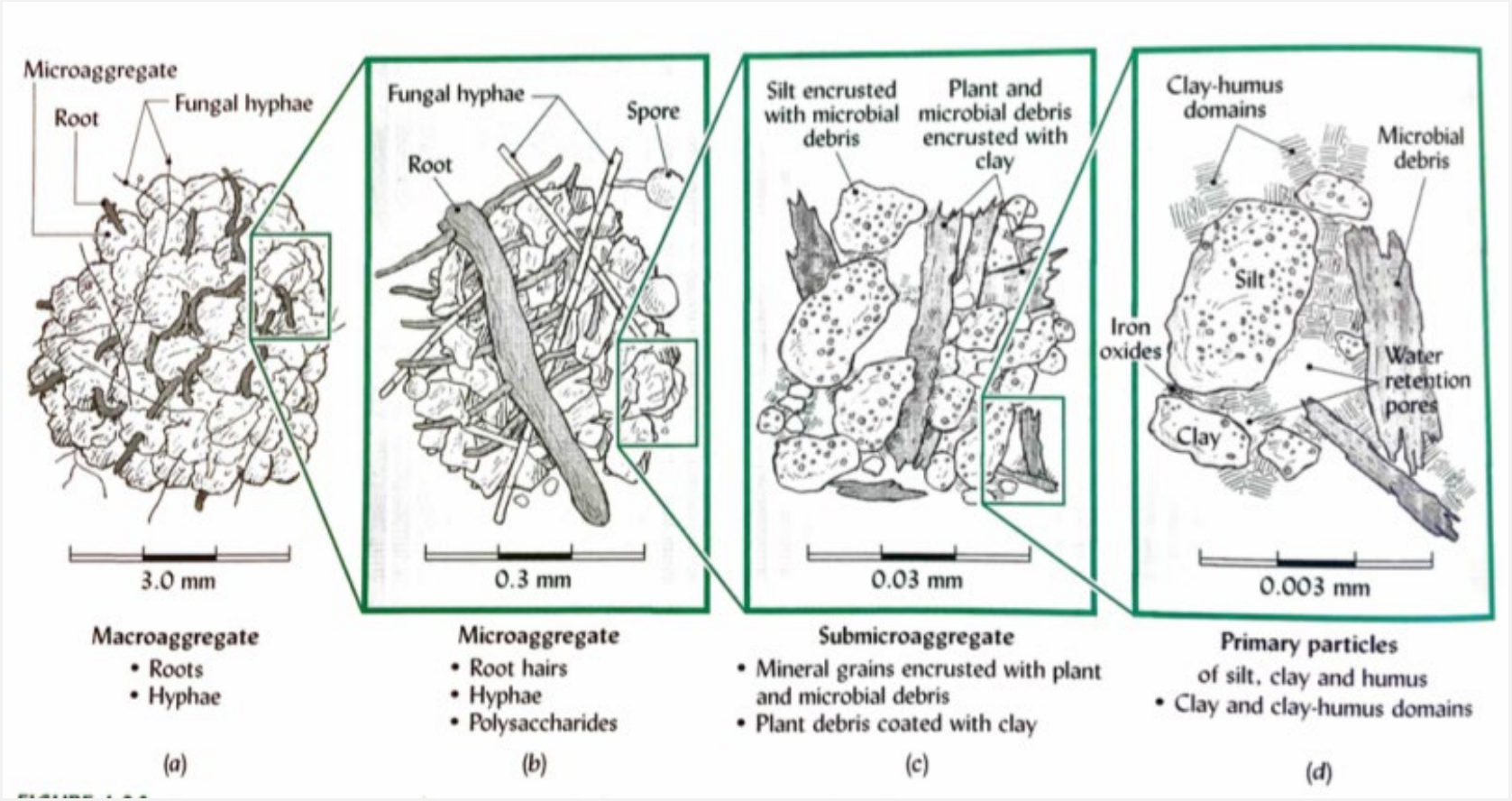
Applying gypsum to the soil…

- Increases soil aggregation and physical structure
- Which increases root growth, water/gas exchange, soil biological activity
- Which improves crop growth

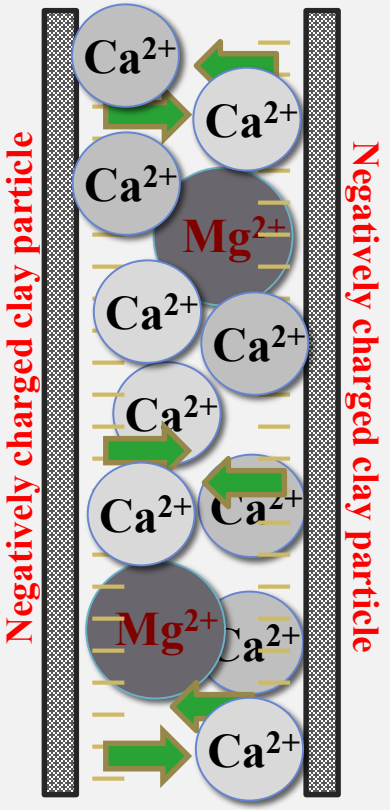
Theory

Aggregates are Key to Soil Physical Structure

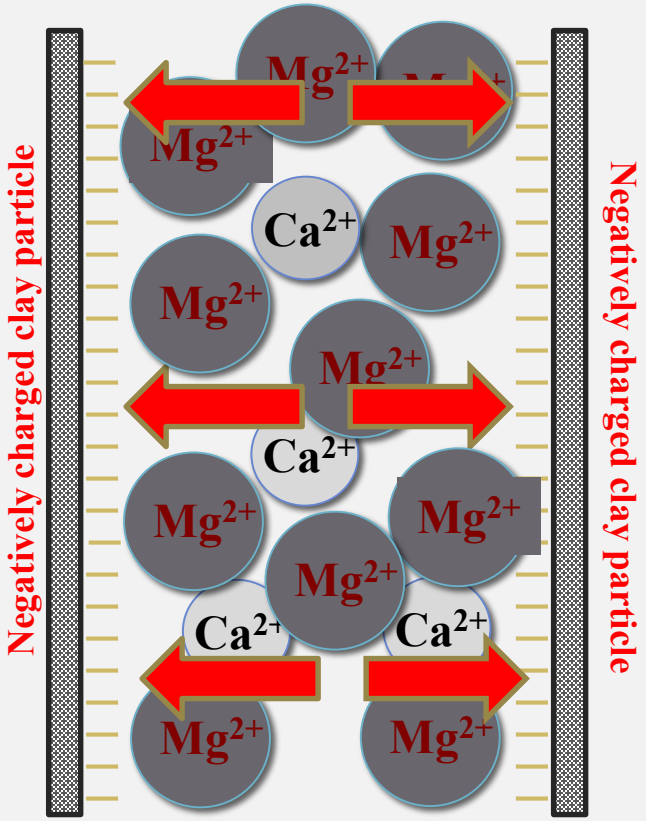
- **Soil aggregation:** Groups of soil particles that bind together to form an aggregate.



More calcium attracts clay particles together to form aggregates



More magnesium repels clay particles to disperse aggregates



Possible relationship between Ca and Mg in aggregate stability

Ca:Mg and Soil Hydrology

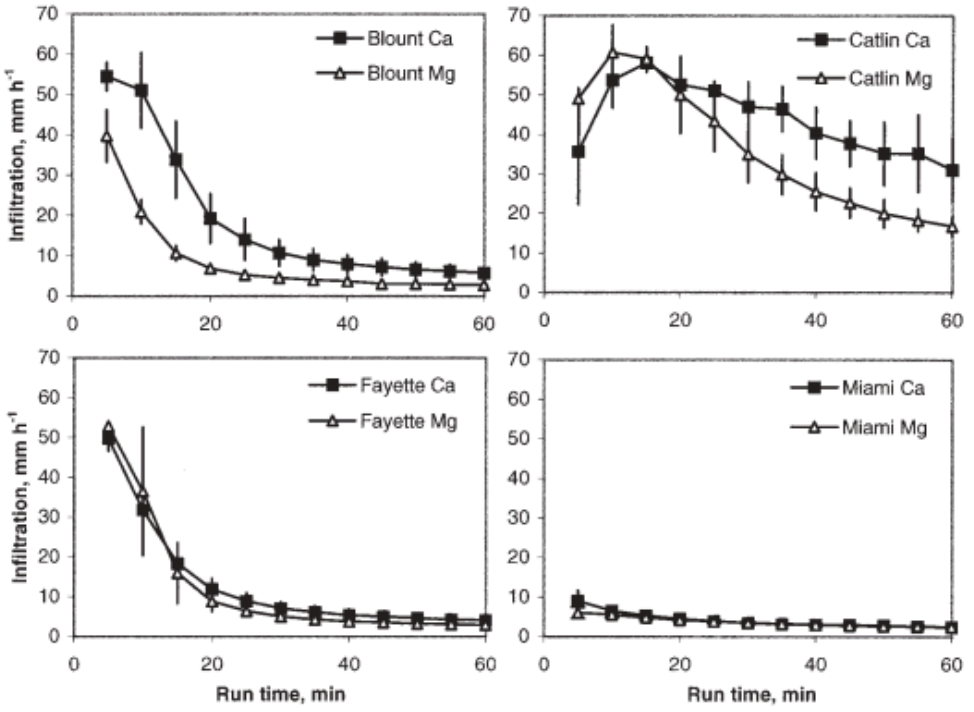


Fig. 3. Normalized infiltration rate (average of four replications) as a function of time for Ca- and Mg- saturated Blount, Catlin, Fayette, and Miami soils. Error bars equal one standard deviation.

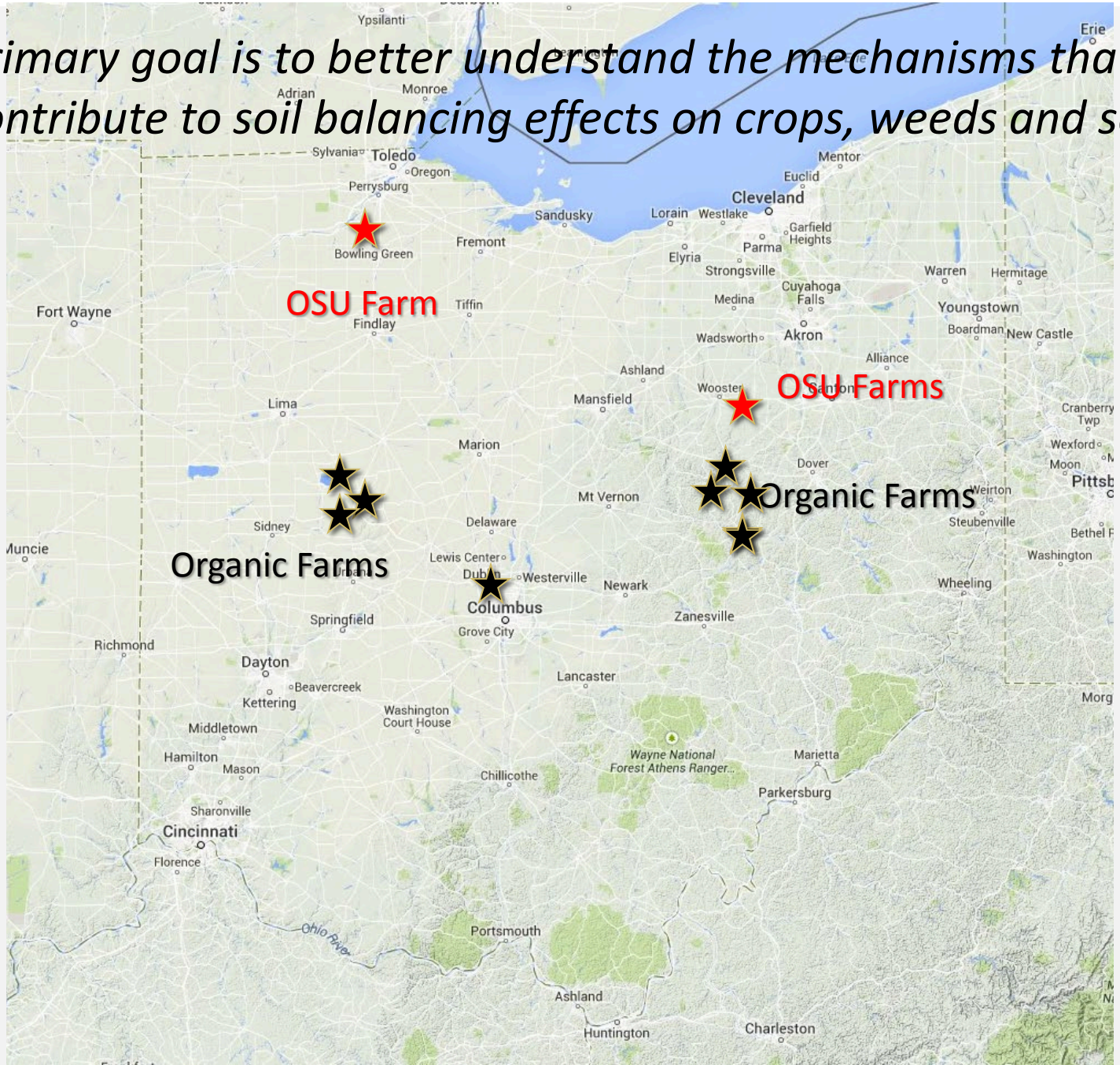
- Dontsova & Norton (2002) reported Mg Saturations >80% resulted in soil dispersion, reduced water infiltration and elevated soil losses.

- How realistic is 80% Mg saturation in field?

What about recent studies in Ohio?

USDA-NIFA Organic Program Funding

Primary goal is to better understand the mechanisms that contribute to soil balancing effects on crops, weeds and soils



Soil Balancing OSU Farm Experiment

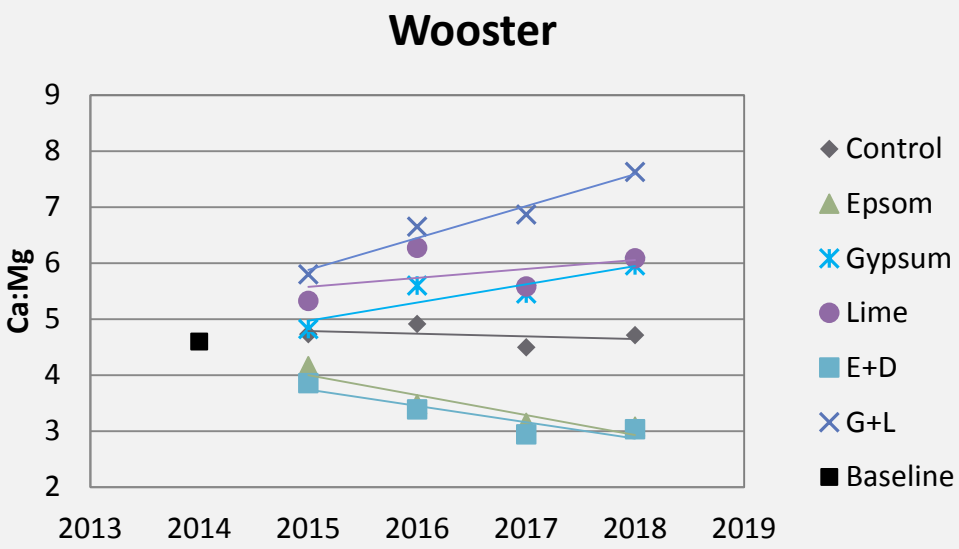
Location	Soil Series	Texture	CEC	Initial pH	Initial Ca:Mg
Wooster	Canfield	Silt Loam	6.3	5.8	4.6
Hirzel	Hoytville	Clay Loam	19	6.7	8.2

- Started in 2015
- Corn-soybean-small grain rotation, all crops present each year
- Organic management with compost applications
- Annual applications of soil amendments:
  - Gypsum
  - HiCal Lime
  - Dolomitic Lime
  - Epsom
  - Sufur

Measurements

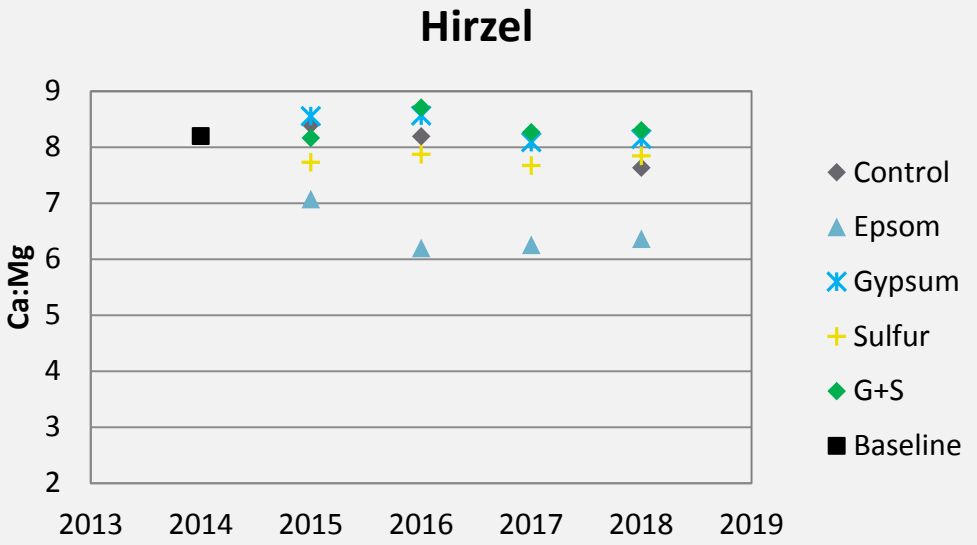
- Weeds
  - Weed emergence counts, weed community
- Crop
  - Tissue sampling (nutrient analysis at flowering)
  - Yields and grain nutrient analysis
- Soils
  - Standard nutrient analysis (chemistry)
  - Soil health testing (biology: Active C, Soil Protein, Respiration)
  - Soil physical structure (Aggregate Stability, penetration resistance, infiltration)

Soil Ca:Mg



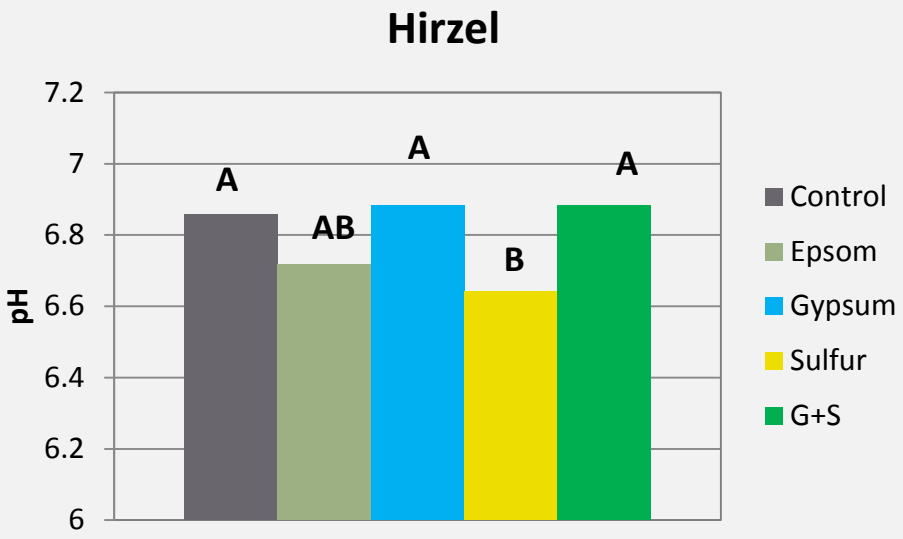
	Total application (lb/acre)
Epsom	6500
Gypsum	7000
HiCal Lime	8500
Epsom + Dolomitic Lime	6500+8000
Gypsum + HiCal Lime	6000+8000

	Total application (lb/acre)
Epsom	9000
Gypsum	4500
Sulfur	500
Gypsum + Sulfur	4500 + 500



Soil pH

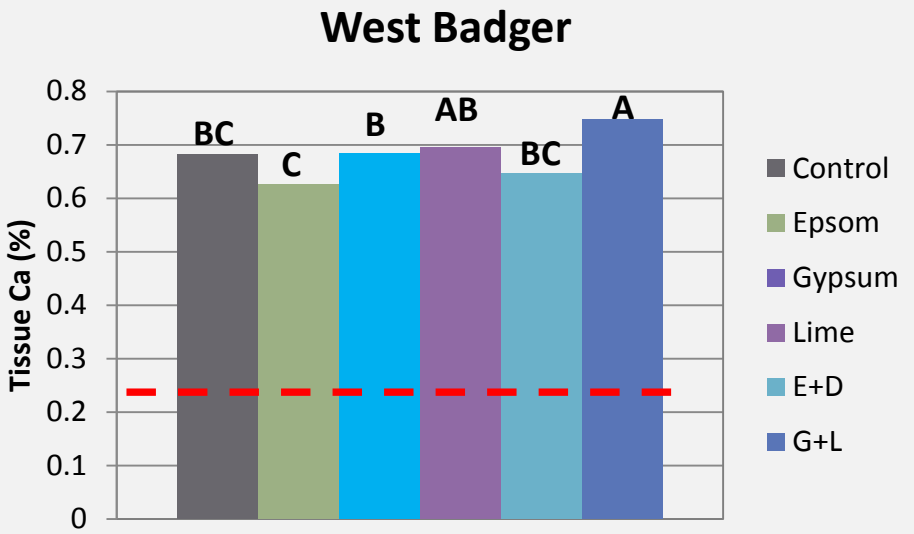

Wooster
7.2
7
6.8
6.6
6.4
6.2
6
pH
B
B
B
A
A
A
Control
Epsom
Gypsum
Lime
E+D
G+L

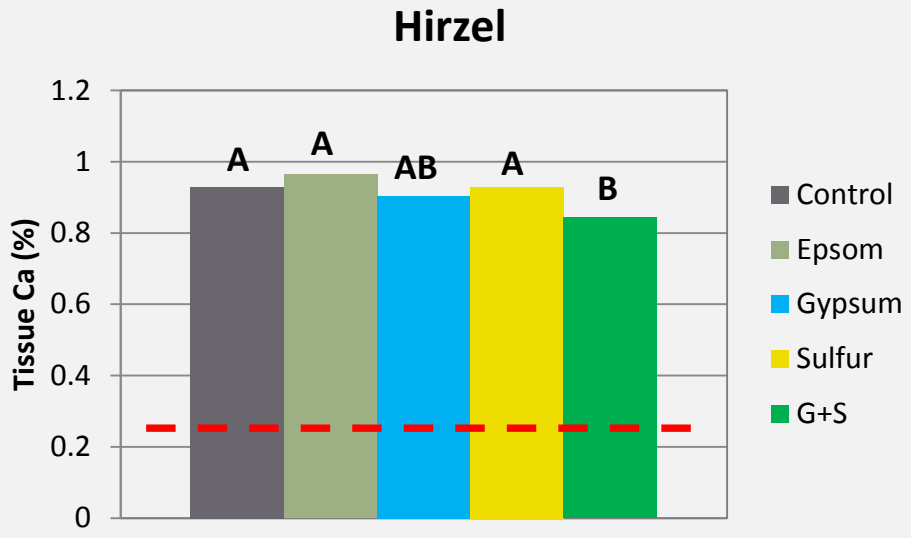

Hirzel
7.2
7
6.8
6.6
6.4
6.2
6
pH
A
AB
A
B
A
Control
Epsom
Gypsum
Sulfur
G+S

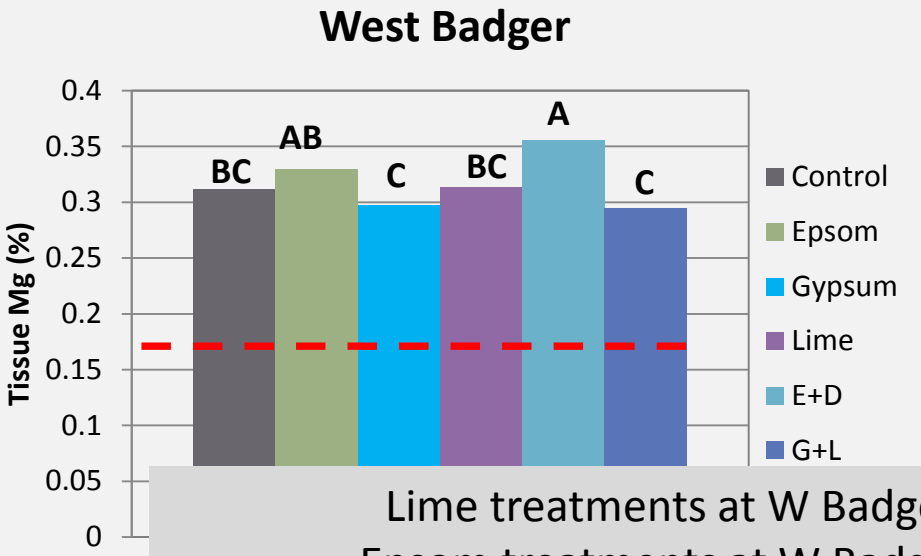
Overview of Findings (First 4 yrs)

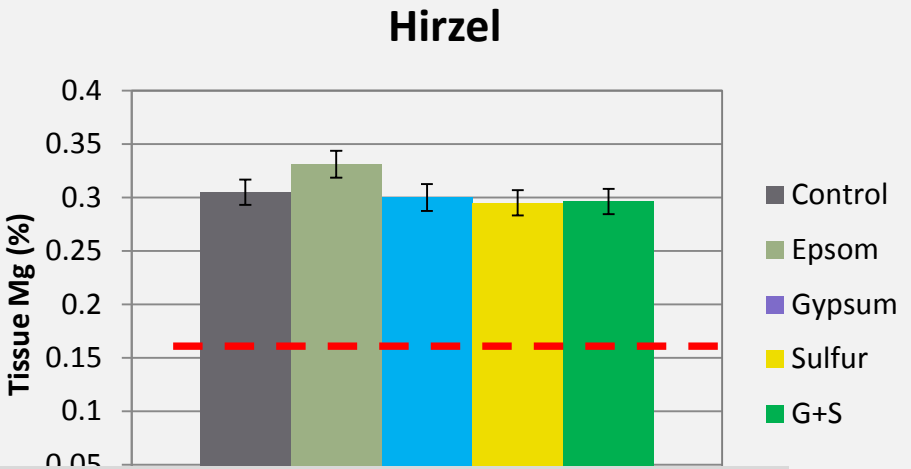
- No significant treatment effects for soil health indicators
  - POX-C, Respiration, Soil protein
- Crops (tissue, grain concentration) and soils
  - Most differences found in S and Ca concentrations
  - No other differences found in soil measures
- Grain yield response has been rare and not consistent among treatments/ sites

Tissue Ca and Mg concentrations





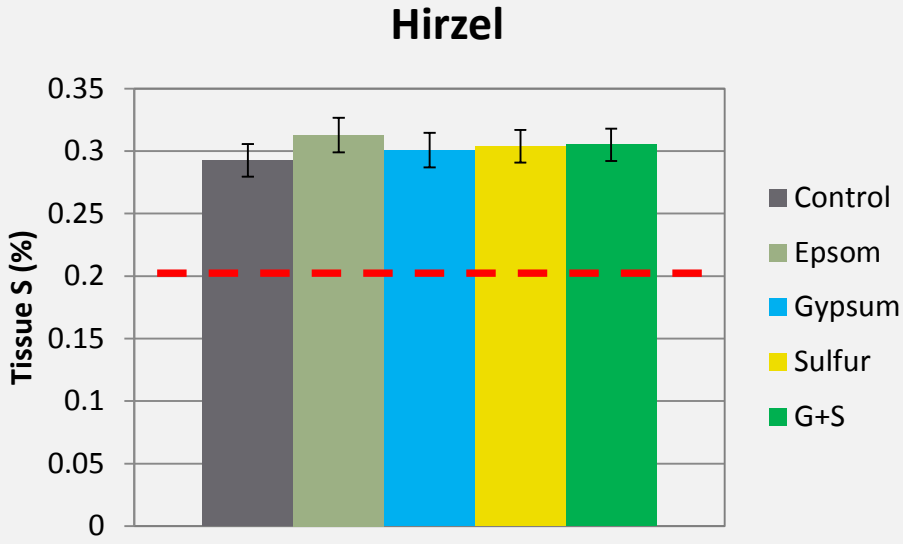




Lime treatments at W Badger resulted in higher tissue Ca
Epsom treatments at W Badger resulted in higher tissue Mg

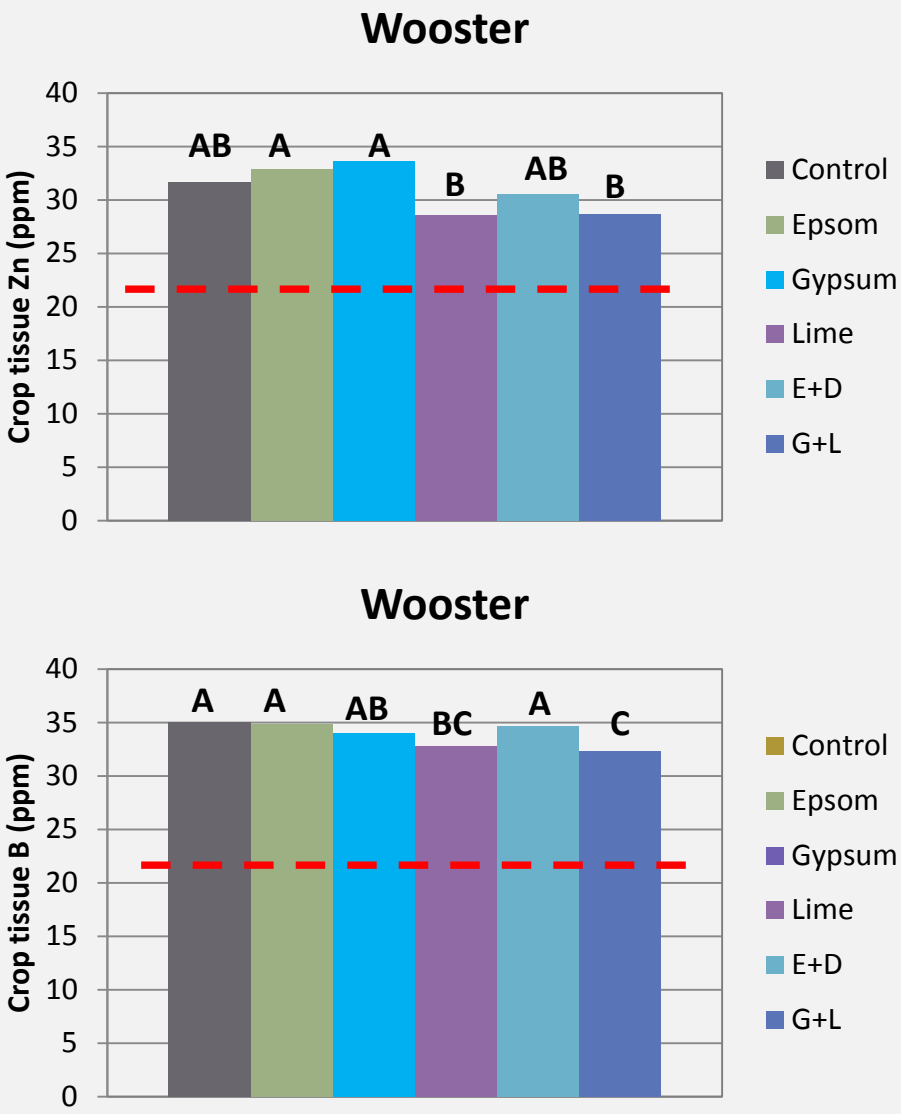
Tissue N, P, K, S concentrations

- Tissue N, P, and K: no treatments were different from control



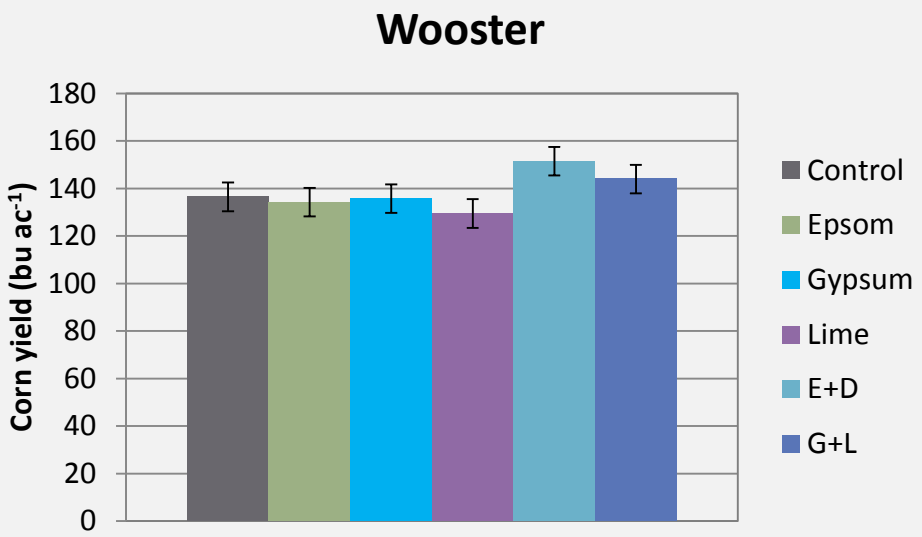
Epsom and Gypsum at W Badger both resulted in increased tissue S

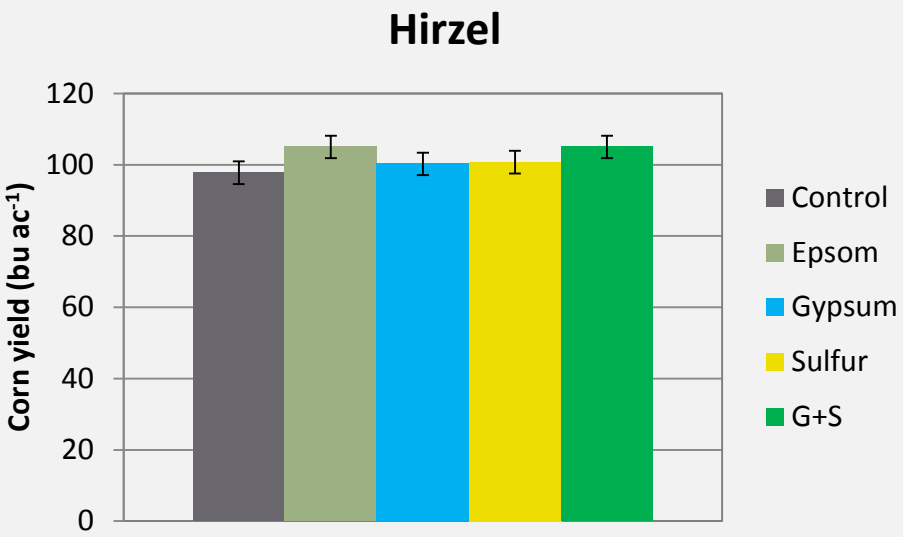
Tissue micronutrient concentrations

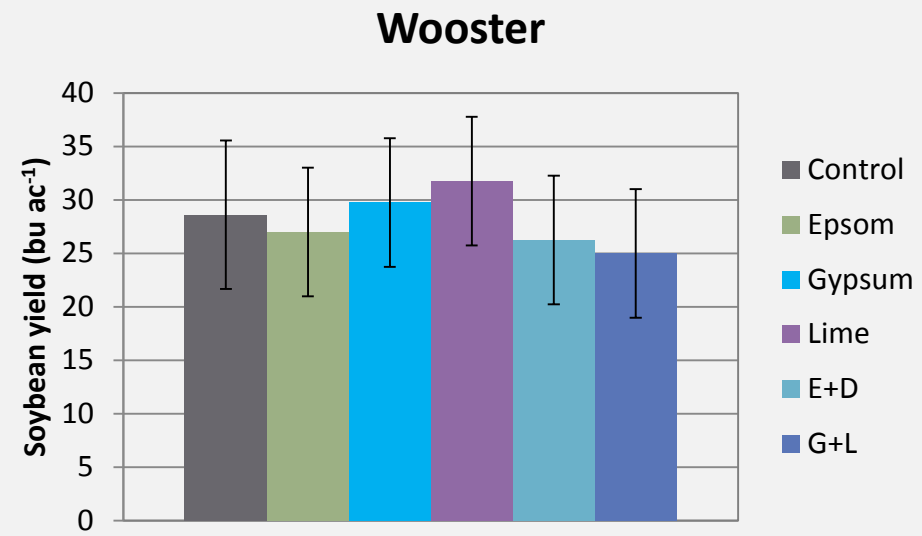


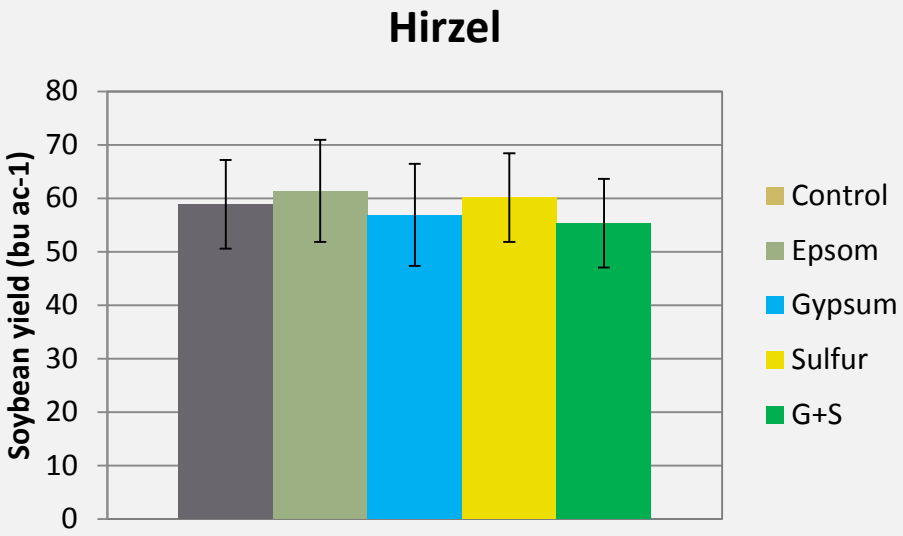
- Increased pH led to reduced tissue Zn and B
- No treatment differences at Hirzel

Grain Yields



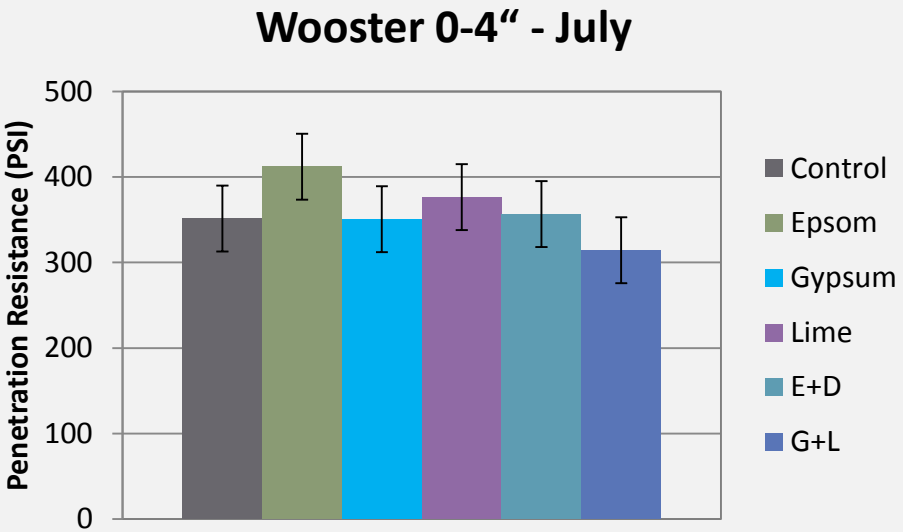


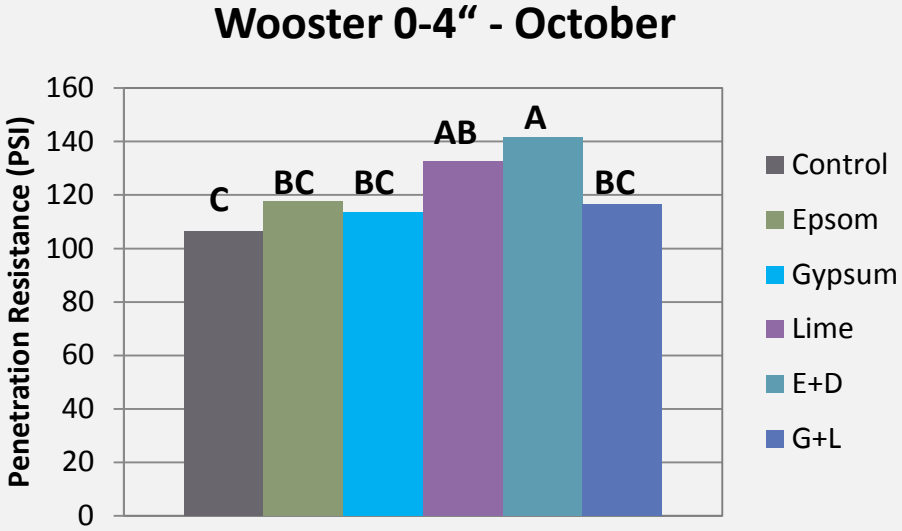


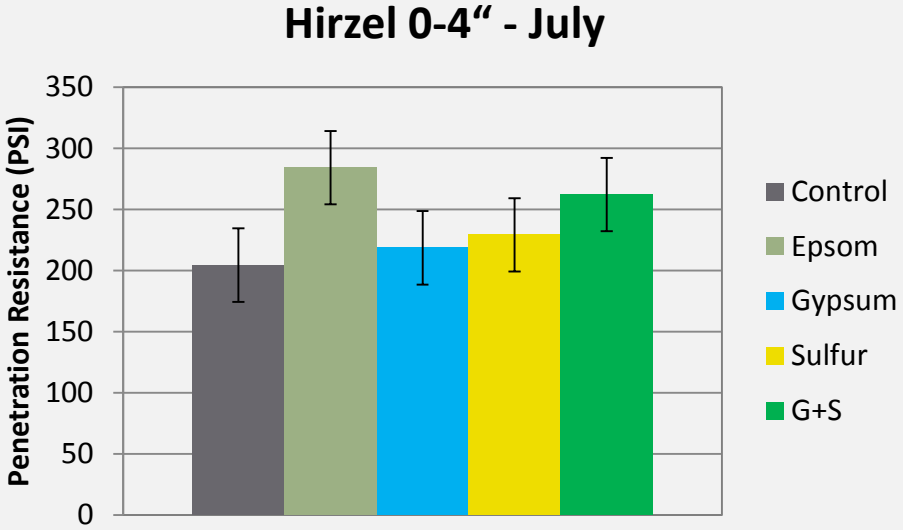


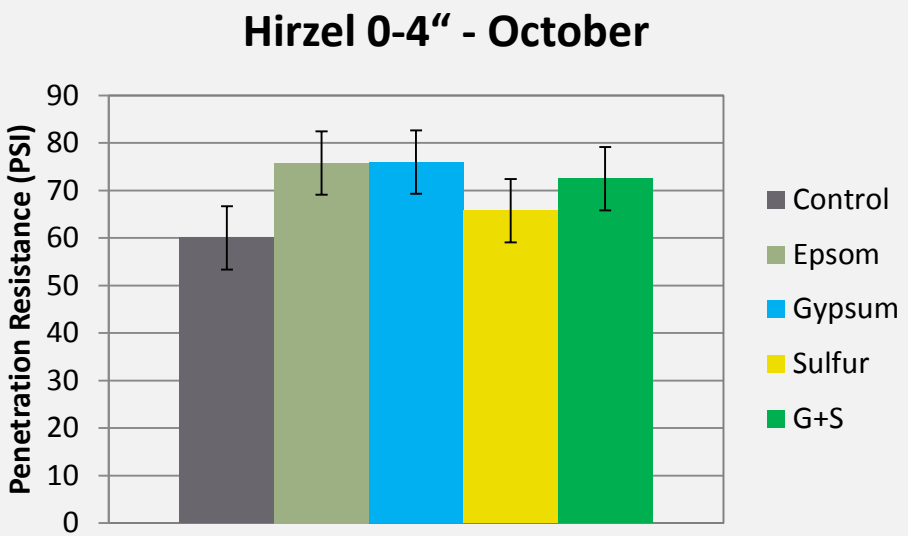
Soil Physical Properties

Soil penetration resistance

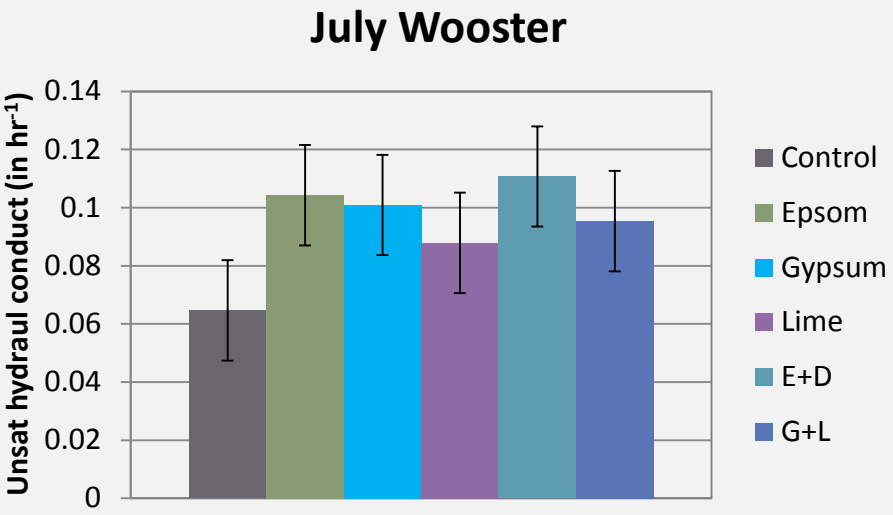


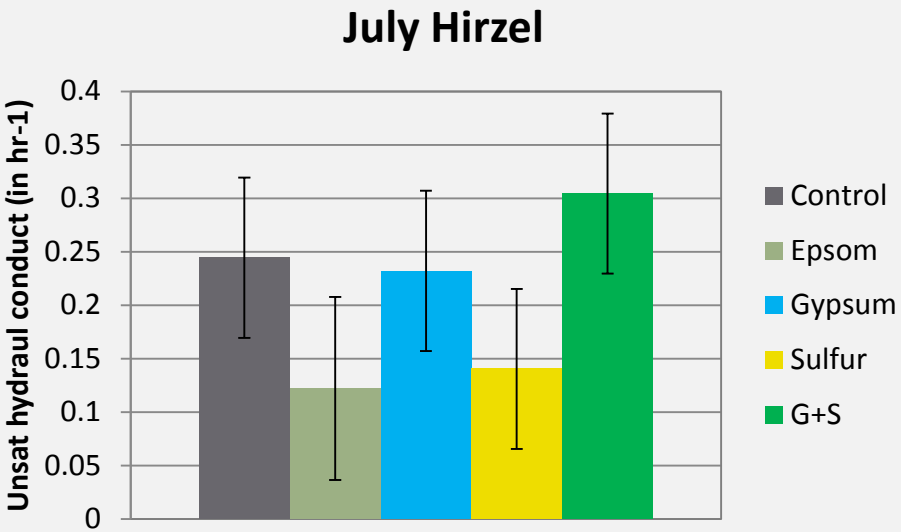


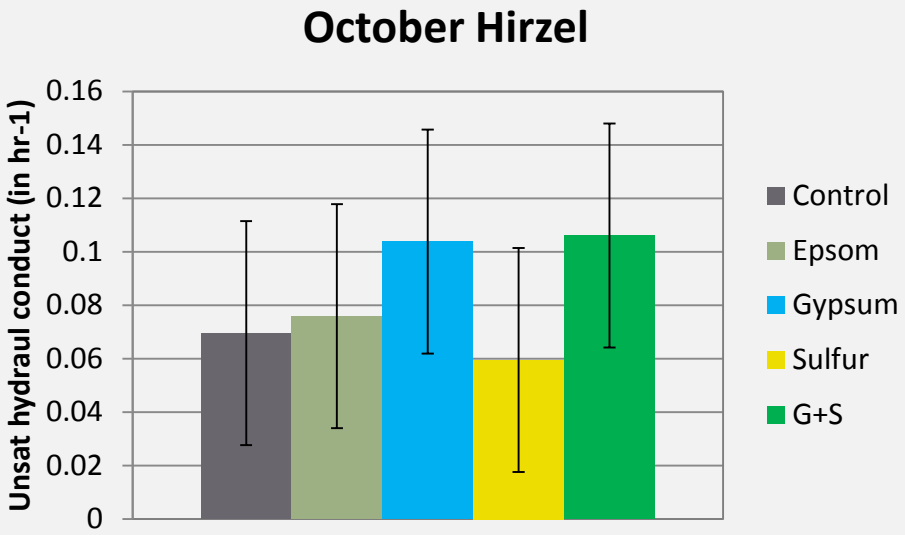




Water Infiltration







Other work

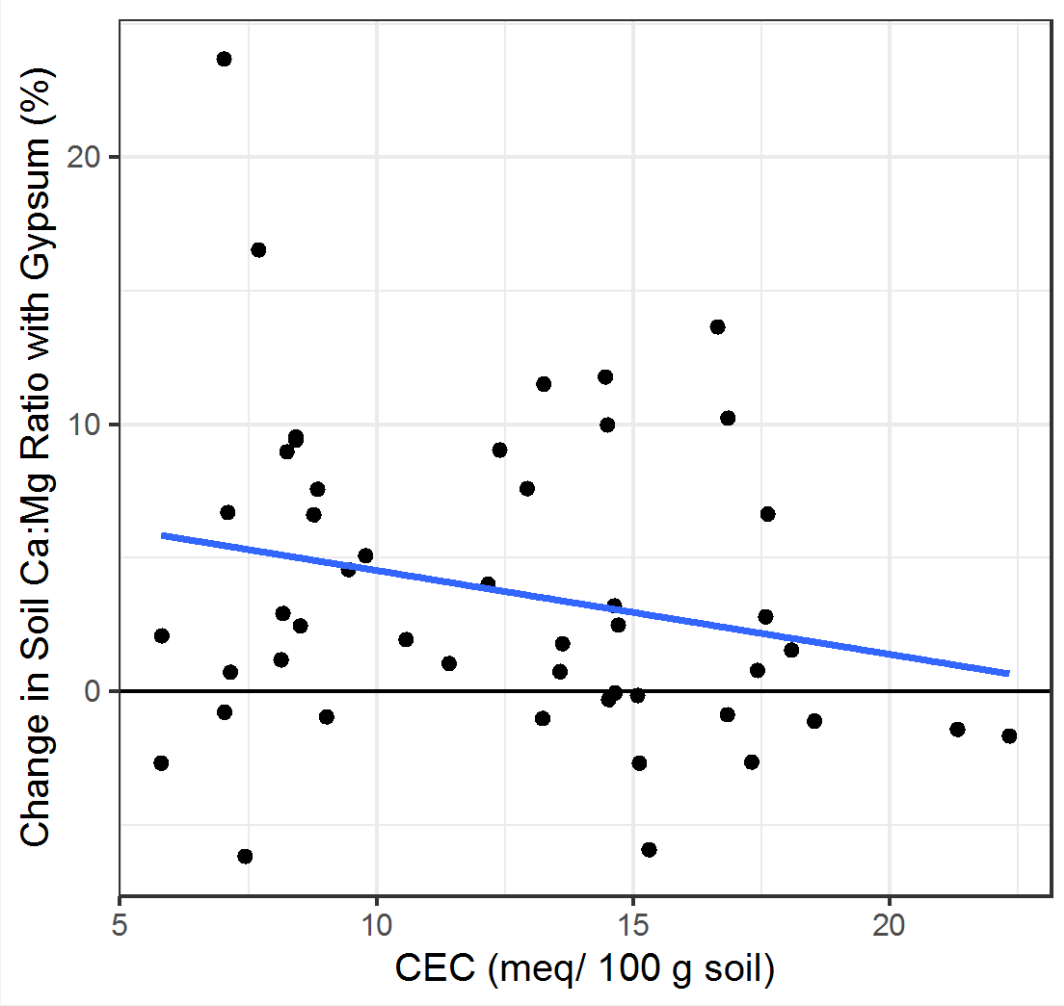
Conventional Corn

- 2 sites in Ohio, 4yrs
- Gypsum applied at
  - 3 rates (0, 1 ton/acre, 2 tons/acre)
  - 3 timings (every year, every other year, every four years)
- Only 1 year was there an increase in yield
  - Chaganti et al., Agronomy Journal, in press

On-farm work (corn, oat, forage)

- No significant yield increases with gypsum
- No consistent trends in soil health, some trends in penetration resistance

Return on Investment for Ca:Mg Ratios?



Conclusions

- Little evidence that managing Ca:Mg ratios increases crop yield or crop performance
- Expected changes seen with Ca and S concentrations with gypsum application
- No changes in soil biological measurements
- Some changes in soil physical properties – more time might be needed for consistent signals to emerge
- Few short-term benefits from S+ with gypsum; long-term soil conditioning benefits remain to be seen