PRESENTATION TO THE NATURE CONSERVANCY:

GYPSUM AS AN AGRICULTURAL SOIL AMENDMENT

JULY 2, 2015

GREENLEAF ADVISORS AND PARTNERS

Gypsum Webinar Agenda

- The State of the Science
  - Dr. Warren Dick, Professor, Environment and Natural Resources, The Ohio State University
- The State of the Practice
  - Ron Chamberlain, Agronomist, GYPSOIL/Beneficial Reuse Management
  - Joe Nester, Crop Consultant, NesterAg
- Policy Update and the Healthy Soils for Healthy Waters Initiative
  - John Andersen, President, Greenleaf Advisors
- Discussion

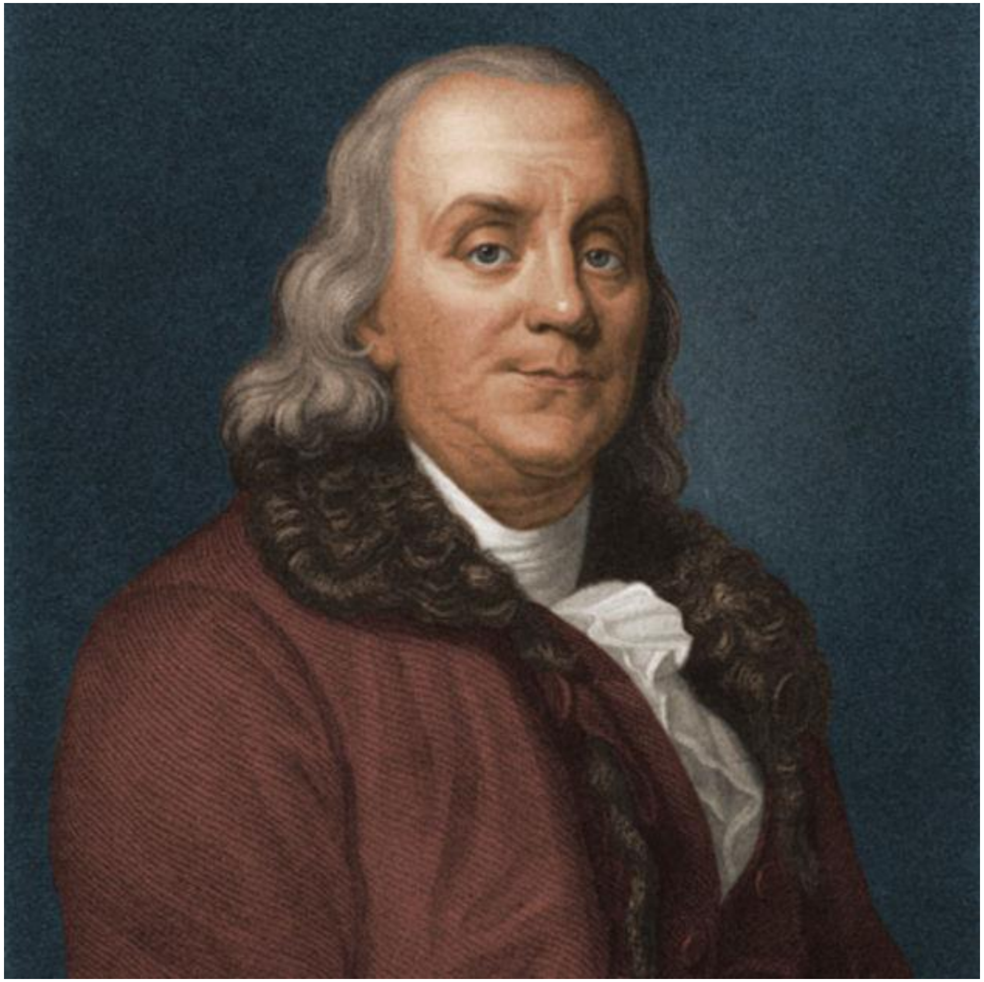
Gypsum as a Soil Amendment and Potential for Water Quality Benefits

Warren A. Dick
The Ohio State University
dick.5@osu.edu

What is Gypsum?

Gypsum is a very soft mineral composed of calcium sulfate dihydrate. The word gypsum is derived from a Greek word meaning "chalk" or "plaster". Gypsum is moderately water-soluble. The source of gypsum is both mined and synthetic.

Early History



Benjamin Franklin

“This hill has been land plastered”

Early History

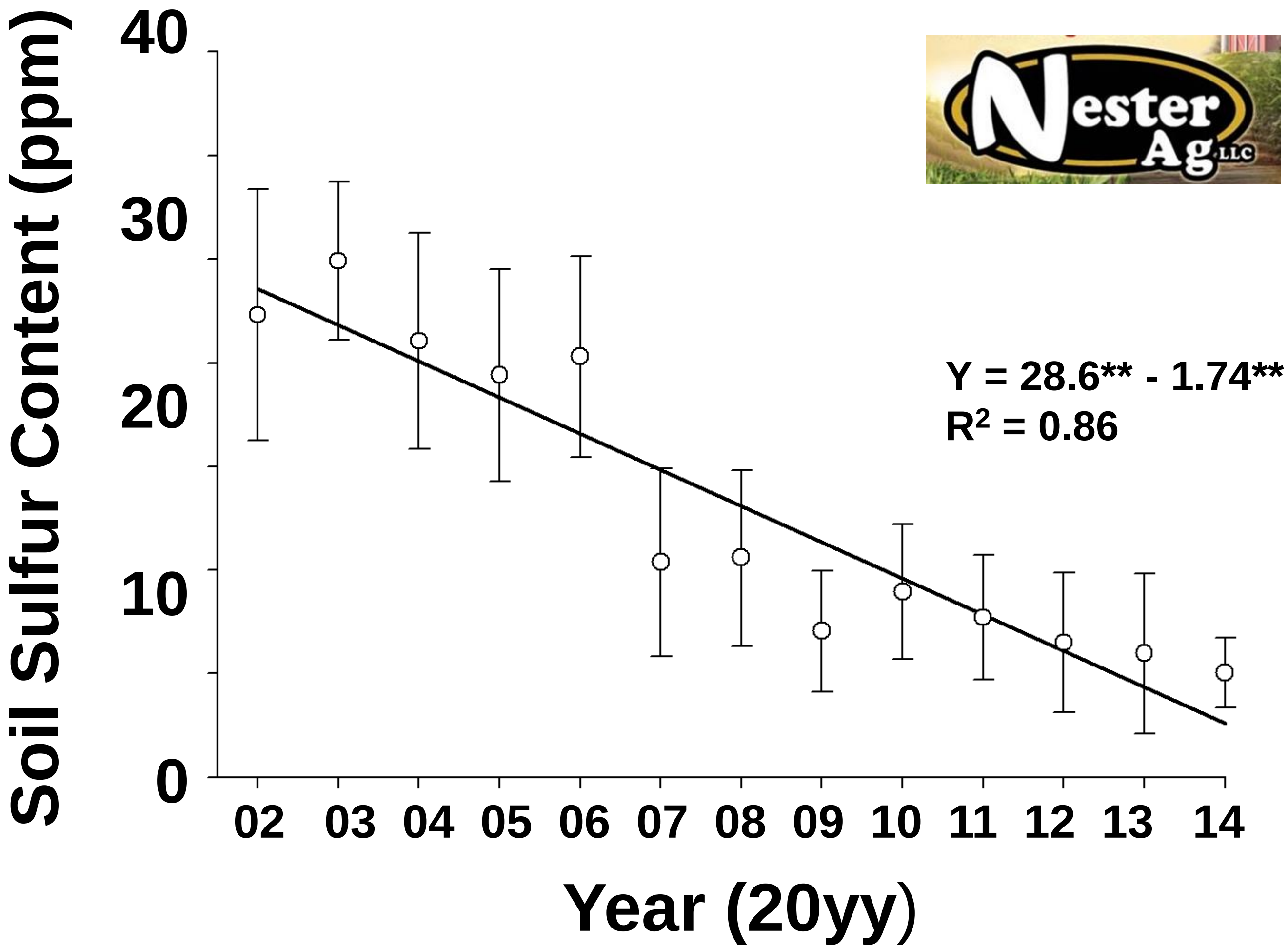
Doctor William Crocker was born in Medina County, OH on January 27, 1876. He received his A.B. degree in 1902 and an A.M degree in 1903 from the University of Illinois. From 1904 - 1906 he was a Fellow at the University of Chicago from which he obtained his PhD.

Summary of Gypsum Benefits in Agriculture

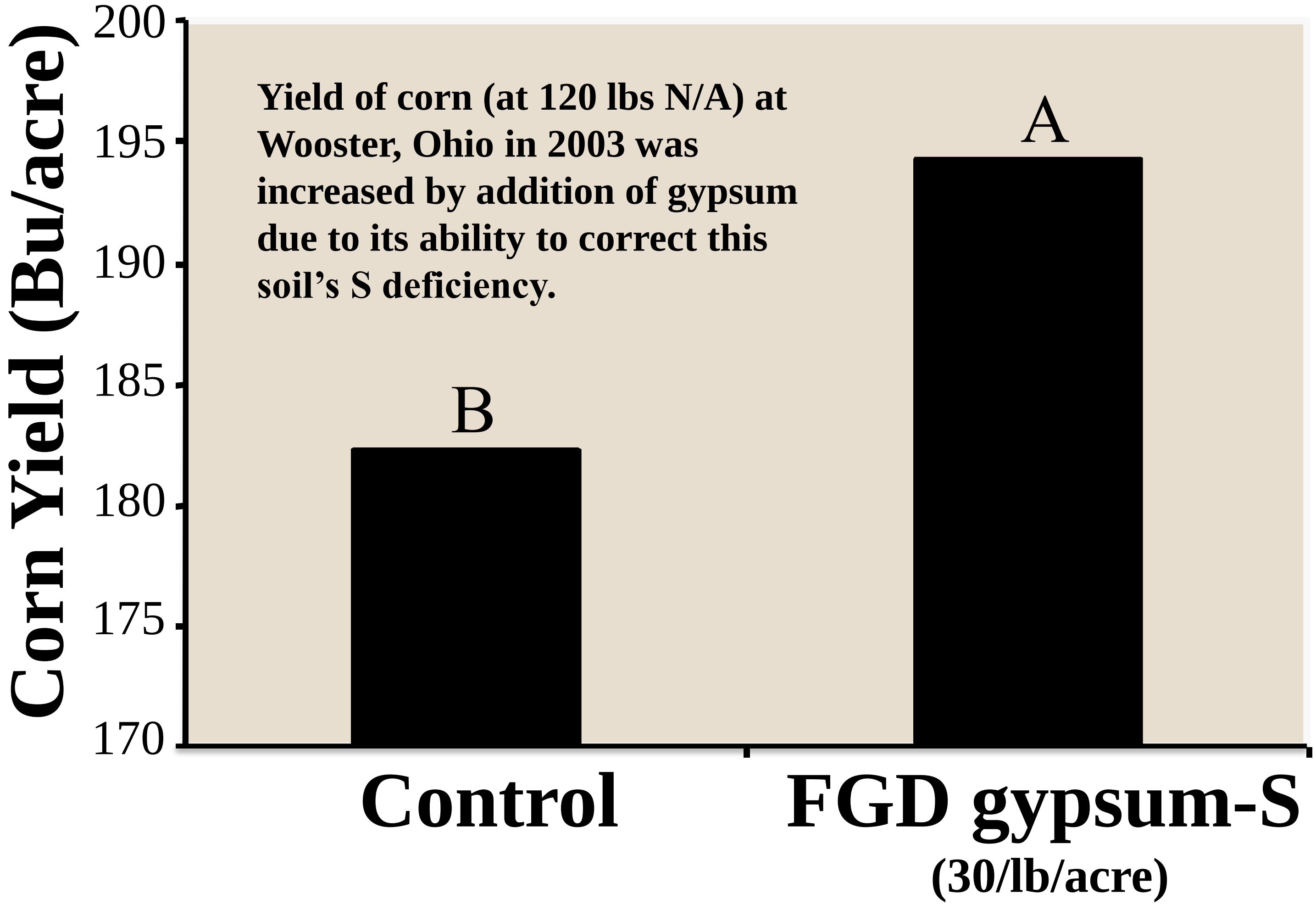
- ❑Ca and S source for plant nutrition
- ❑Source of S and exchangeable Ca to ameliorate subsoil acidity and Al^{3+} toxicity
- ❑Flocculate clays to improve soil structure and reclaim sodic and high magnesium soils
- ❑Ca-humate and $CaCO_3$ formation in soil
- ❑Apply with manure to enhance N use efficiency
- ❑Reduce phosphorus runoff from farm fields


Washington
Montana
North Dakota
Minnesota
Oregon
Idaho
South Dakota
Wyoming
Wisconsin
Michigan
Vermont
Maine
New Hampshire
New York
Massachusetts
Connecticut
Rhode Island
Nevada
Utah
Colorado
Nebraska
Iowa
Illinois
Indiana
Ohio
Pennsylvania
New Jersey
Delaware
Maryland
California
Kansas
Missouri
Kentucky
West Virginia
Virginia
Arizona
New Mexico
Oklahoma
Arkansas
Tennessee
North Carolina
South Carolina
Mississippi
Alabama
Georgia
Texas
Louisiana
Florida

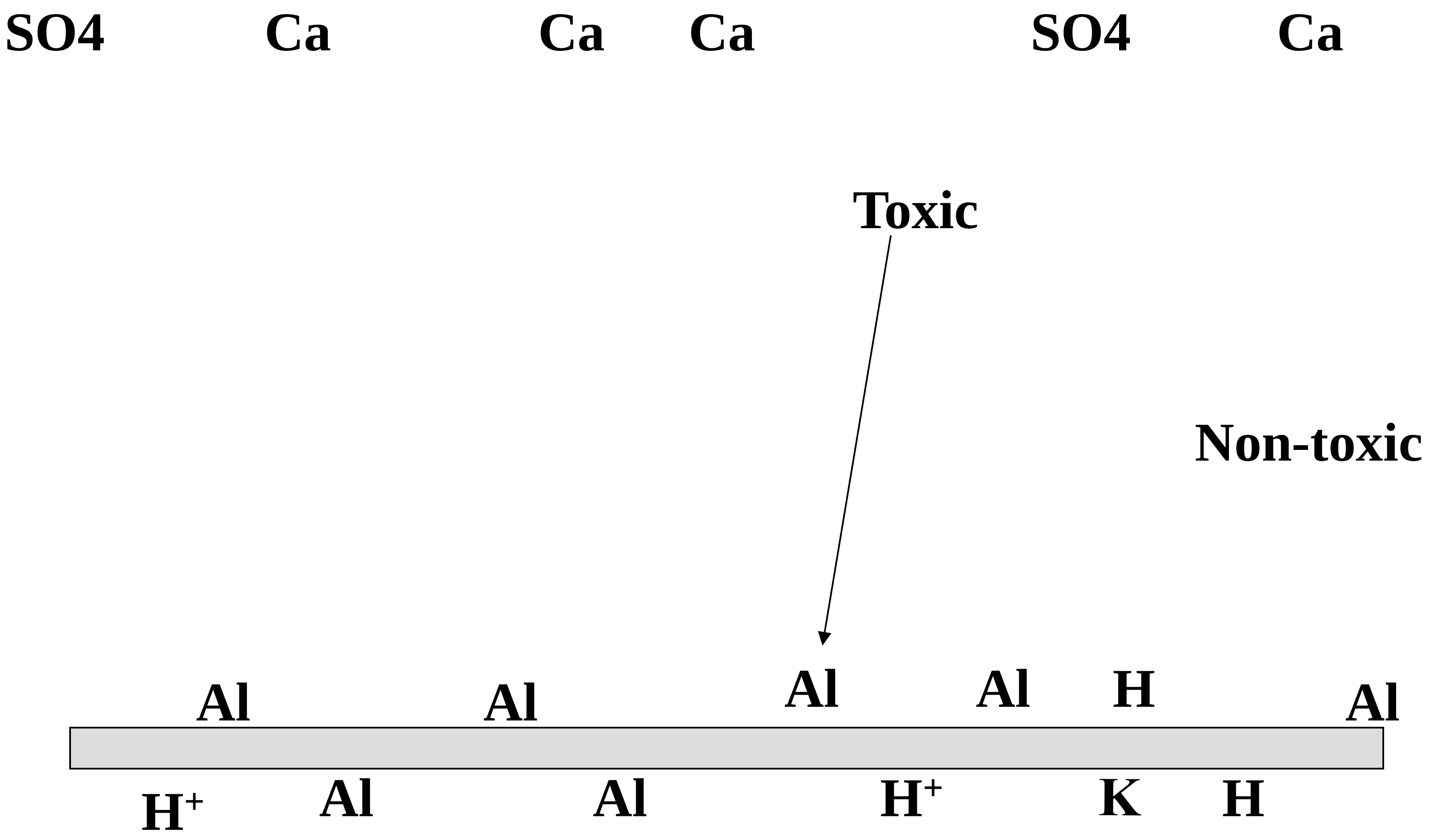
Soil Test Values - Sulfur



Corn Yields in 2003 (Wooster, Ohio)



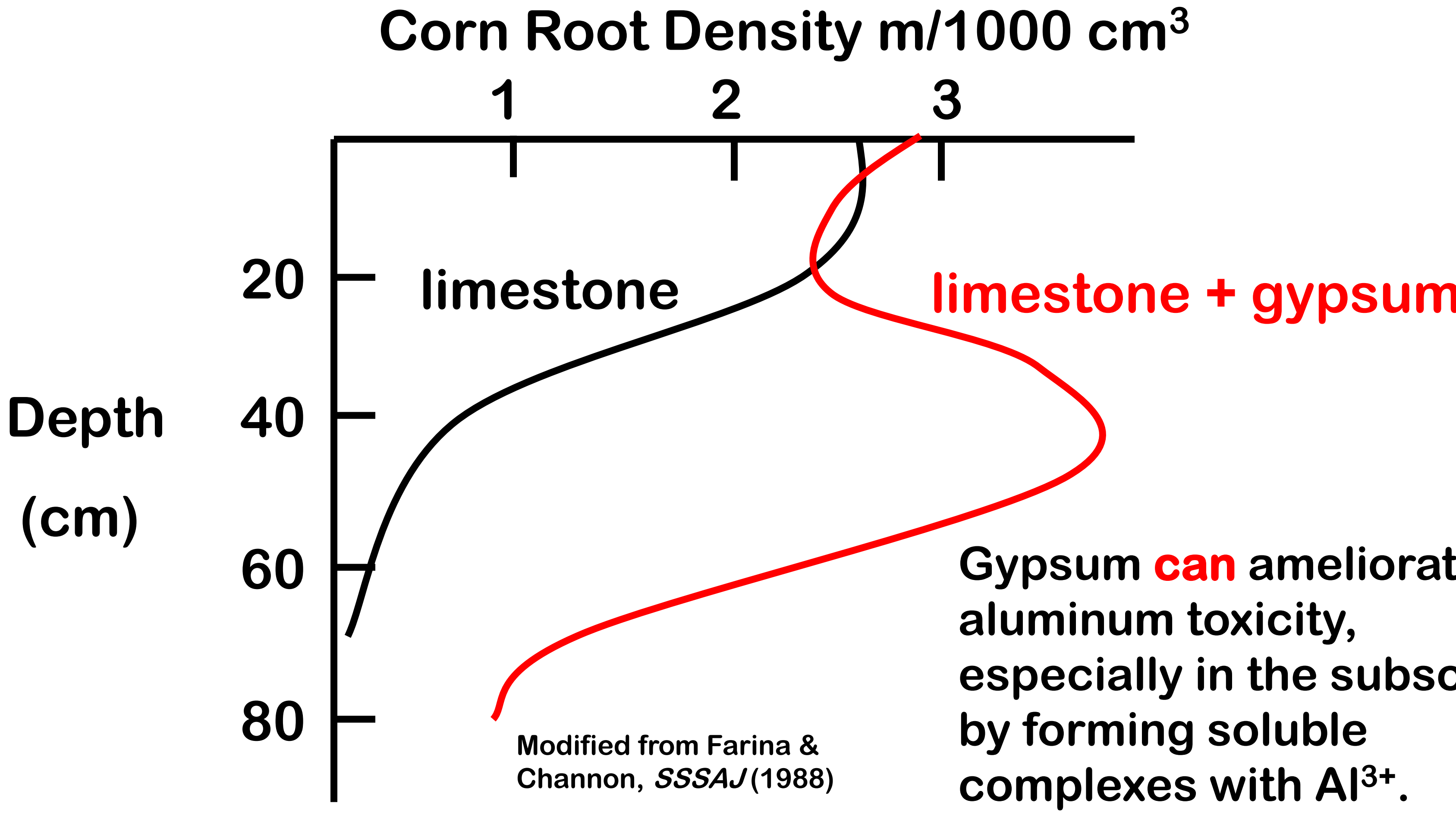
Gypsum applied to surface of soil with acidic subsoil



Clay platelet in subsoil

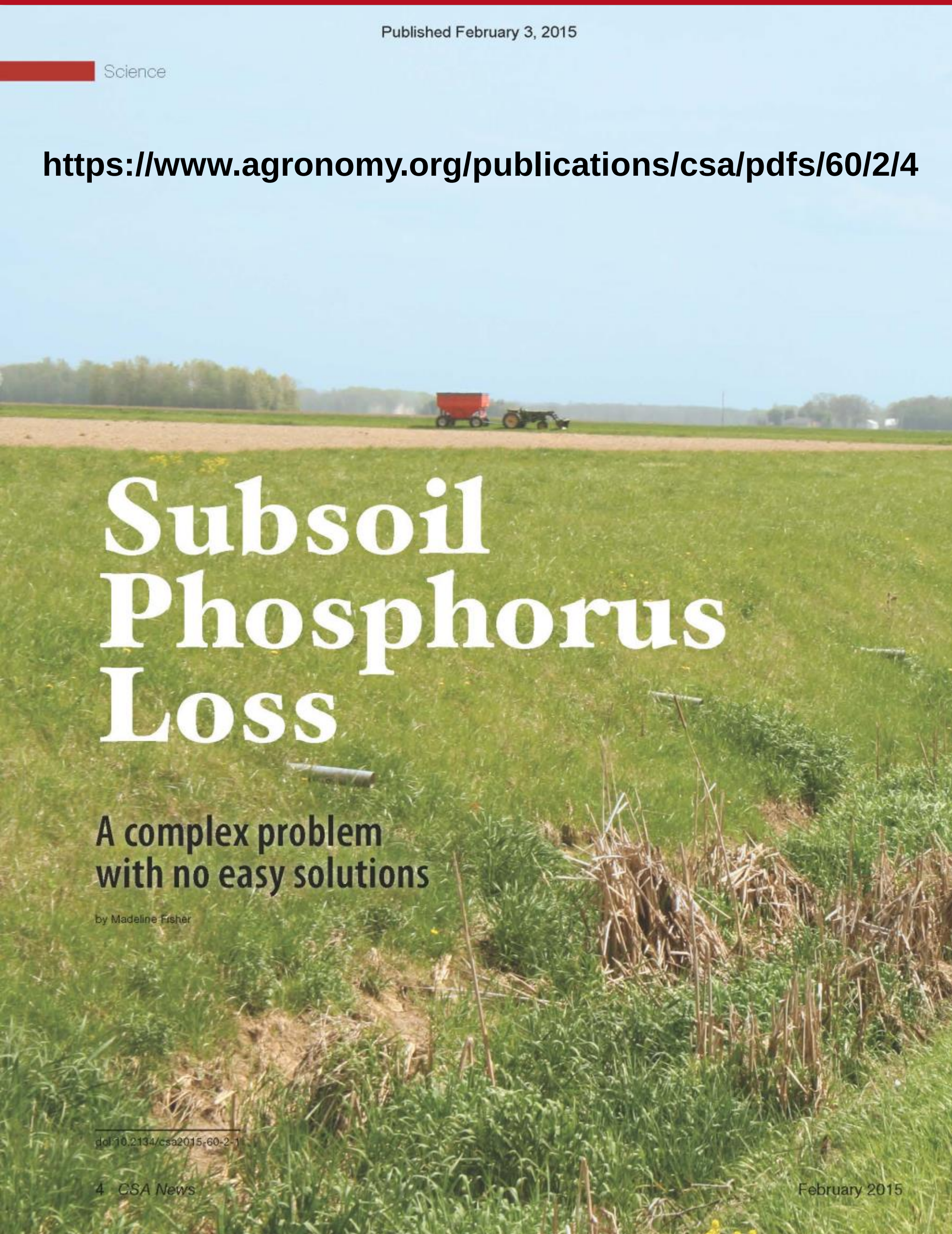
$$CaSO_4 + Al^{3+} \longrightarrow Al(SO_4)^{+} + Ca^{2+}$$

(toxic) (non-toxic)

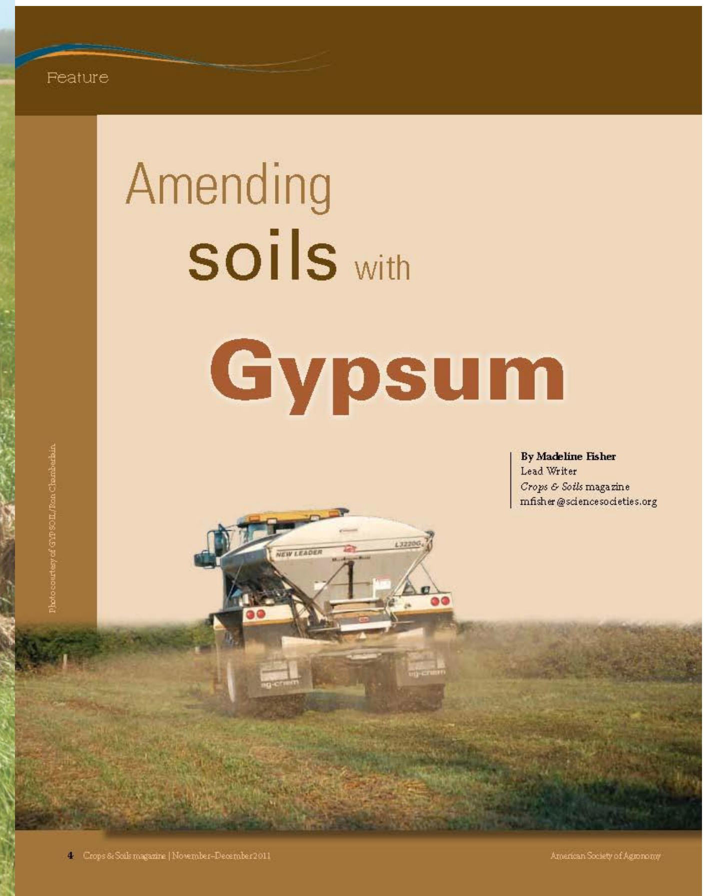


Modified from Farina & Channon, *SSSAJ* (1988)

Gypsum can ameliorate aluminum toxicity, especially in the subsoil, by forming soluble complexes with Al^{3+}.



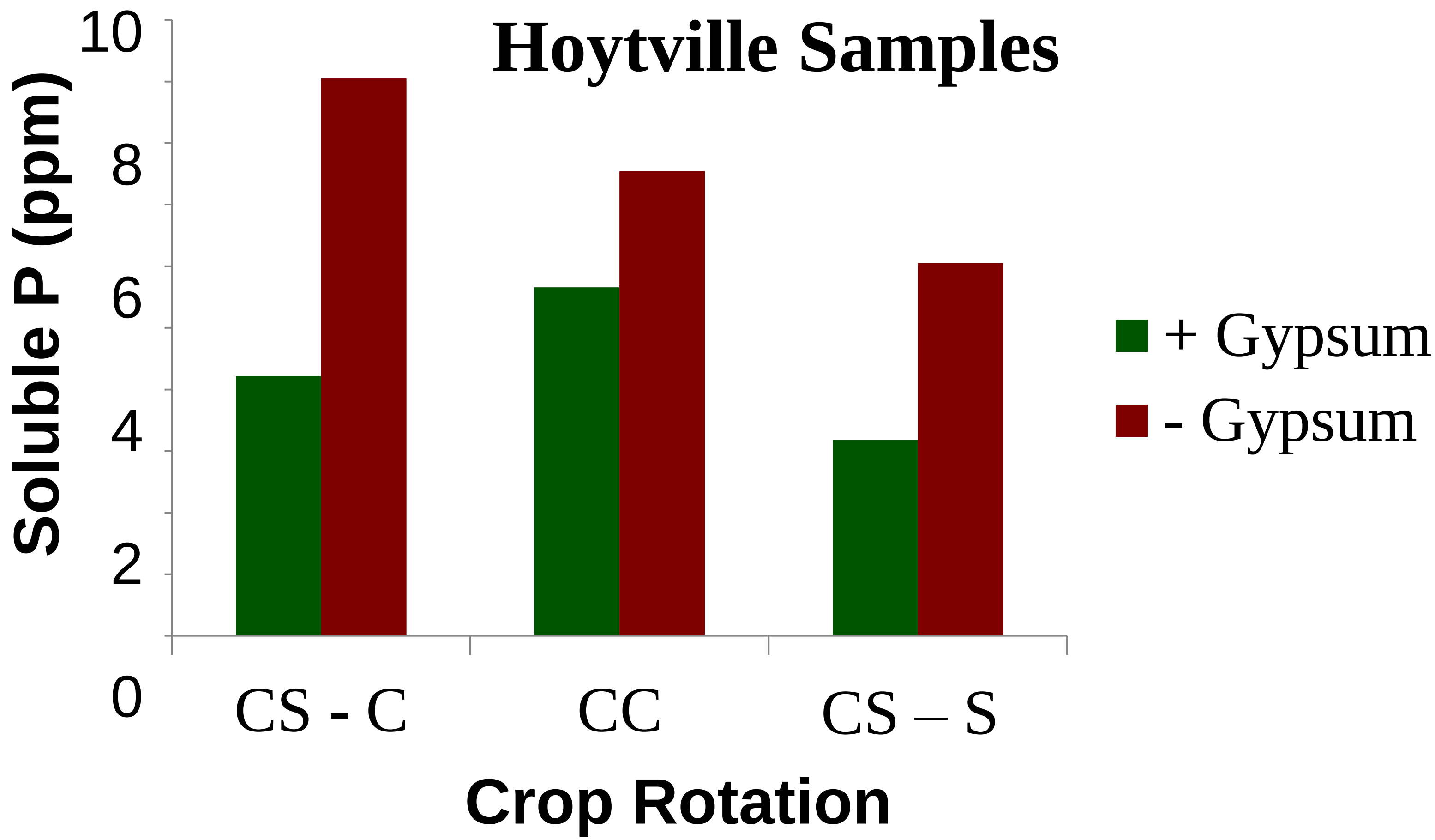
The article (left) is a good overview of the problem and the current level of scientific understanding of its cause.



Phosphorus and Soil Management

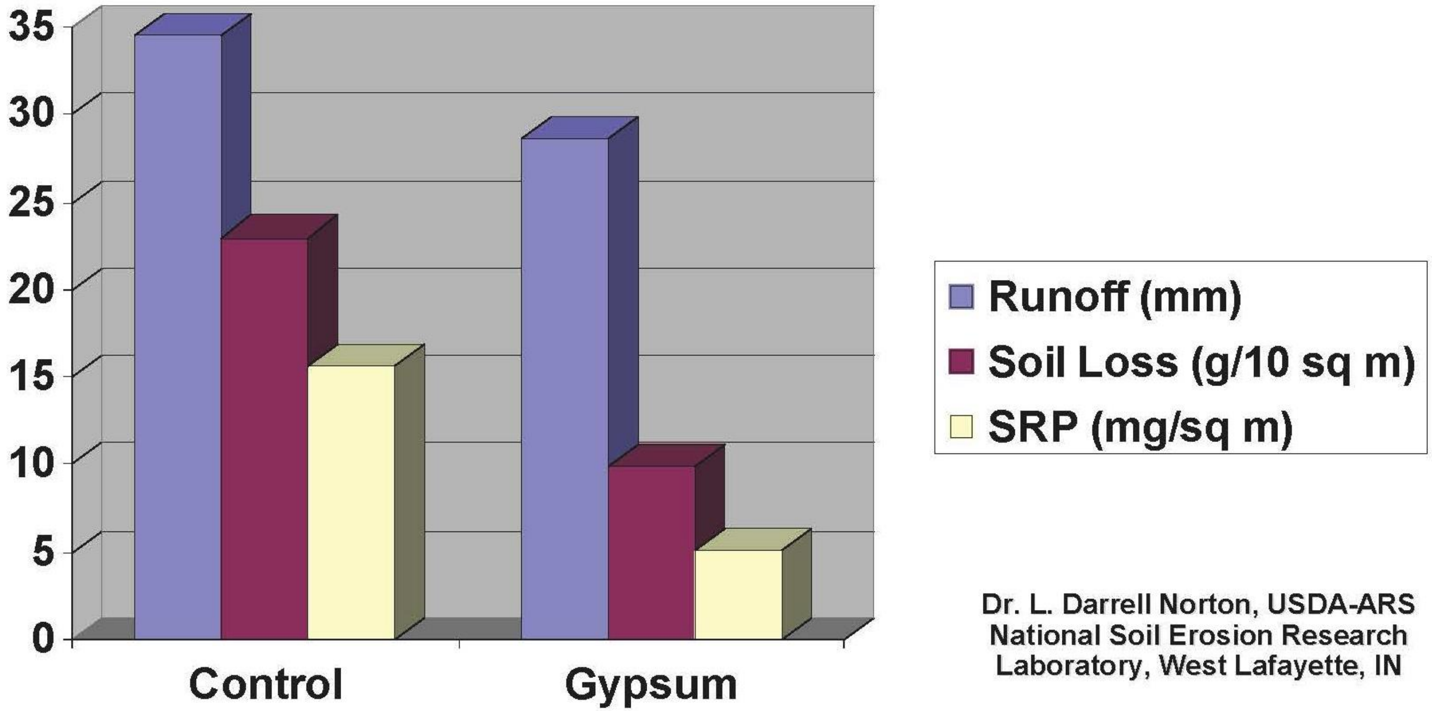
Site	Total P (0 - 12 in)	Soluble P (0 – 0.5 in)
Wooster	580 (PT) 609 (NT)	45 (PT) 160 (NT)
Hoytville	867 (PT) 868 (NT)	38 (PT) 282 (PT)

Water soluble P in 0.5 in soil layer (4 T/A gypsum, 1:3 w/v soil:water)



Water Quality Benefits

Effect of Gypsum on Water Runoff, Soil Erosion and Soluble Reactive Phosphorus (SRP)



Dr. L. Darrell Norton, USDA-ARS
National Soil Erosion Research
Laboratory, West Lafayette, IN

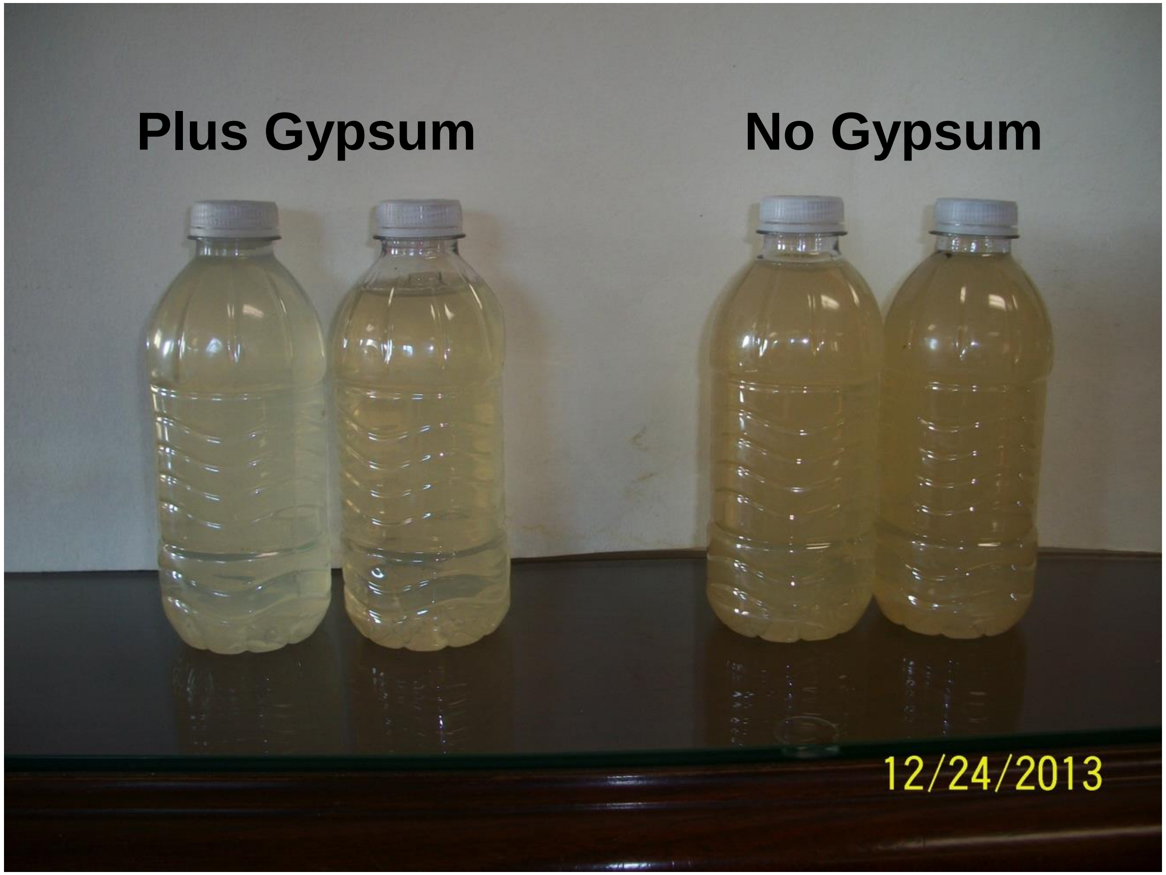
Tile Drain

Samples were collected from the Rolland Wolfrum Hale Farm (Hicksville, OH) on December 20, 2012.

Tile Drainage Samples (1)

Samples collected from the Ken Hahn Farm (Antwerp, OH) on January 6, 2013.

Tile Drainage Samples (2)



Rolland Wolfrum farm samples 20 months after gypsum application

Summary of Results (to Date)

1. **83 total sampling events (221 total samples) from May 2012 through June 2015.**

Through September 2014 Results Summarized are:

2. **Average reduction for all gypsum-treated areas combined was 39% with a range from 0 to 93%.**

3. **P reductions in tile drainage water persist at least 24 months after gypsum treatment but efficacy declines with time.**

Summary of Results (to Date)

4. **P concentrations in tile drain water for individual sampling events ranged from 0.010 to 0.111 mg L^{-1} (mean = 0.041) in gypsum-treated areas and from <0.01 to 0.429 mg L^{-1} (mean = 0.089) in areas without gypsum**

Effect of Gypsum on P in Surface and Tile Waters

(Kevin King USDA-ARS)

Mercer County very near to the Grand Lake St. Marys watershed

1. **This crop production field in Mercer County Ohio had very high soil test phosphorus levels (>400 ppm Mehlich 3 in the top 8 inches).**
2. **The typical crop production system is a corn-soybean rotation in a no-till system (Blount soil). The field is randomly tiled.**
3. **Surface and subsurface water quality data collection devices were installed in June 2011.**

Effect of Gypsum on P in Surface and Tile Waters

(Kevin King USDA-ARS)

Mercer County very near to the Grand Lake St. Marys watershed

4. **Data collection period spans June 2011 to October 2014.**
5. **On October 3 of 2013 a 1-ton/acre of gypsum was applied to treatment area.**
6. **There were 86 rainfall events (defined as 0.25 inches of rain in a 6 hour period separated by at least 6 hours) during the baseline period and 34 rainfall events during the treatment period. Not all events produced discharge.**

Effect of Gypsum on P in Surface and Tile Waters

(Kevin King USDA-ARS)

Mercer County very near to the Grand Lake St. Marys watershed

7. **There was a significant decrease in soluble P (DRP) concentrations in both surface runoff and tile discharge. This confirms previous findings.**
8. **In surface runoff, a decrease in soluble P loading occurred. In tile drainage there is no benefit for soluble P loading. The reductions in soluble P concentrations were negated by additional discharge volume, presumably due to increased aggregate stability and infiltration rates resulting from the gypsum.**

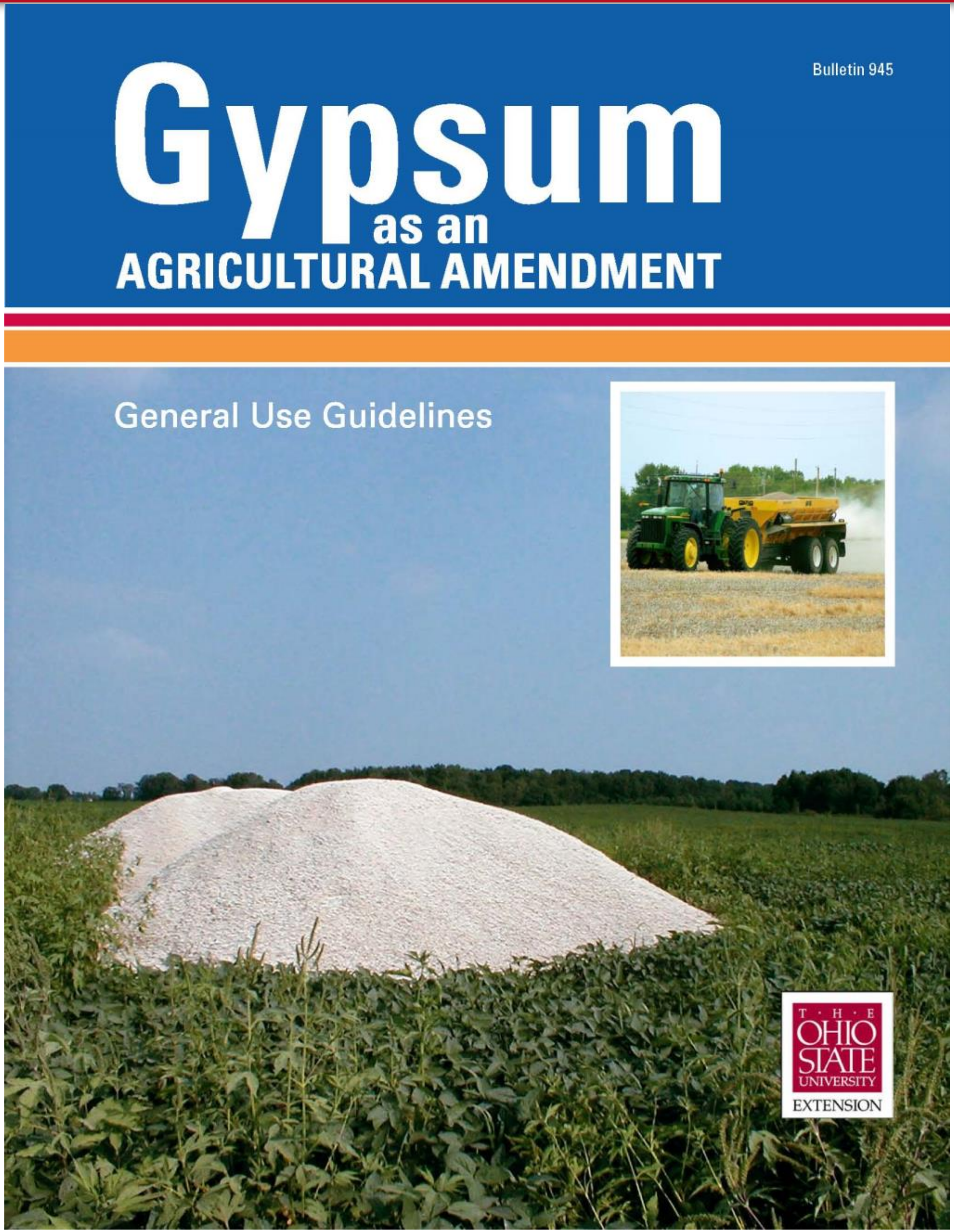
Effect of Gypsum on P in Surface and Tile Waters

(Kevin King USDA-ARS)

Mercer County very near to the Grand Lake St. Marys watershed

Overall Conclusion (to date)

For water quality, the benefit of gypsum was to decrease soluble P concentrations and loading in surface water runoff and also concentrations of soluble and total P in tile discharge. When considering P loadings as well as concentrations, the water quality benefits after one year of gypsum are minimal. Testing into a second or third year will be extremely important to determine the longer-term benefits of gypsum to affect water quality.



http://ohioline.osu.edu/b945/index.html

Increasing National Interest at the Scientific Level

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By-product Gypsum Uses in Agriculture

There is a paucity of information about beneficial uses of FGD gypsum on agricultural land. This community will provide a forum to share research ideas and results on FGD gypsum uses in agricultural systems.

The use of flue gas desulfurization (FGD) scrubbers to remove sulfur from the flue gas of coal-burning power plants for electricity production yields gypsum as a byproduct of the scrubber process. Presently, FGD gypsum is used primarily by the wallboard and cement industries. However, installation of FGD scrubbers is expected to increase significantly in response to new and existing air pollution regulations, with a concomitant increase in FGD gypsum. The current markets are not expected to be able to utilize all of the FGD gypsum produced. The beneficial uses of gypsum on agricultural land should provide an additional market for FGD gypsum, which would result in operation and maintenance cost savings and reduce on-site storage. Agricultural soils could potentially benefit from the addition of gypsum. For instance, gypsum can be used as a nutrient source for crops; a soil conditioner to improve soil physical properties, and water infiltration and storage; to remediate sodic soils, and to reduce nutrient and sediment movement to surface water, among other uses. However, most of the previous research on gypsum use has been on mined gypsum. There is a paucity of information about the use of FGD gypsum on agricultural land. Research is needed to access the environmental and plant productive effects of FGD gypsum application to soil.

Community Activities

- Sign-Up/Update Your Communities
- Update Your Member Information
- View ASA Communities List
- Section Information
- Annual Meetings Site
- Annual Meeting Proceedings
- Membership Directory (members only)

https://groups.yahoo.com/neo/groups/Gypsum/info (80 members)

View the By-product Gypsum Uses in Agriculture Community Leadership Roster

THANK YOU!

FGD Gypsum in Agriculture State of the Practice

GYPSOIL™ BRAND GYPSUM

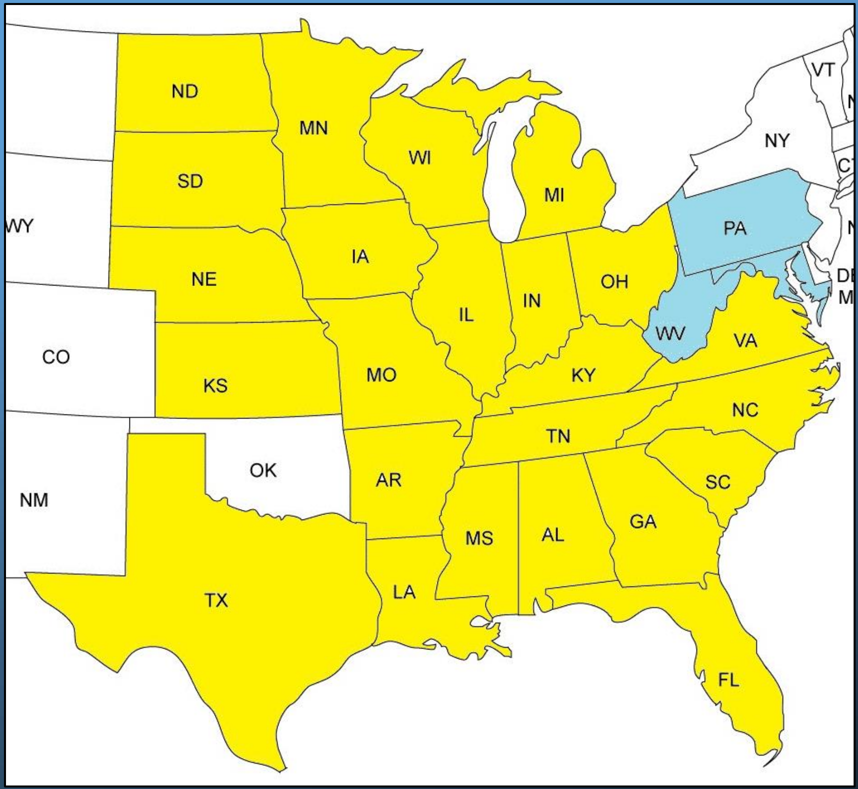
Beneficial Reuse Management

Ron Chamberlain

GYPSUM AG. MARKET GROWTH SINCE 2002

Gypsoil

- 2002:
  - Founded in Indiana
  - 1 State formally approved FGD gypsum for use in Agriculture
- 2009:
  - 3 States approved
- 2015:
  - 24 States approved
  - 4 more are currently reviewing

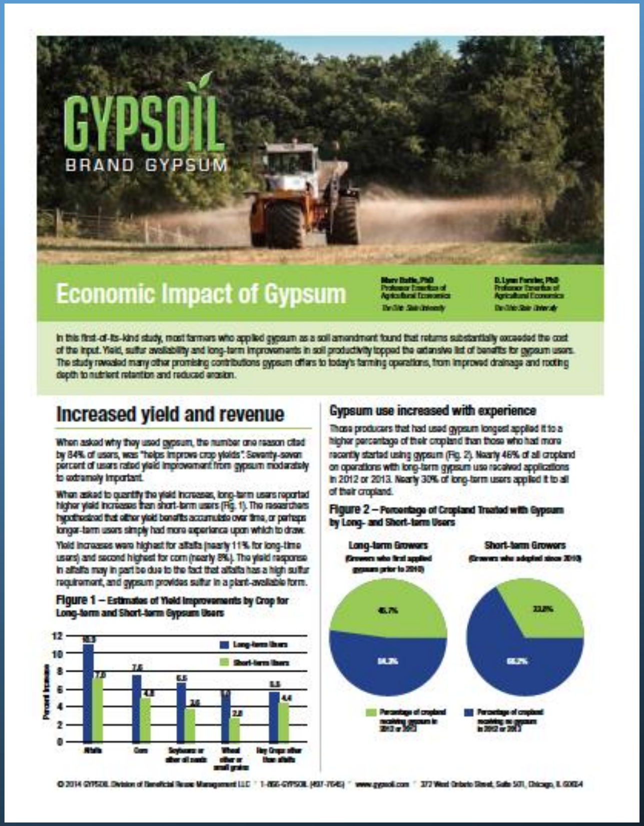


Permit Pending

Permit Approved

GROWER EXPERIENCES

- An economic impact study, including:
  - in-depth case studies,
  - a survey of 294 growers in 17 states, plus
  - an extensive review of peer-reviewed literature, revealed many new insights.


GYPSOIL
BRAND GYPSUM

Economic Impact of Gypsum

In this first-of-its-kind study, most farmers who applied gypsum as a soil amendment found that returns substantially exceeded the cost of the input. Yield, sulfur availability and long-term improvements in soil productivity topped the extensive list of benefits for gypsum users. The study revealed many other promising contributions gypsum offers to today's farming operations, from improved drainage and rooting depth to nutrient retention and reduced erosion.

Increased yield and revenue

When asked why they used gypsum, the number one reason cited by 84% of users, was "helps improve crop yields". Seventy-seven percent of users rated yield improvement from gypsum moderately to extremely important.

When asked to quantify the yield increases, long-term users reported higher yield increases than short-term users (Fig. 1). The researchers hypothesized that either yield benefits accumulate over time, or perhaps longer-term users simply had more experience upon which to draw.

Yield increases were highest for alfalfa (nearly 11% for long-time users) and second highest for corn (nearly 8%). The yield response in alfalfa may in part be due to the fact that alfalfa has a high sulfur requirement, and gypsum provides sulfur in a plant-available form.

Figure 1 – Estimates of Yield Improvements by Crop for Long-term and Short-term Gypsum Users

Gypsum use increased with experience

Those producers that had used gypsum longest applied it to a higher percentage of their cropland than those who had more recently started using gypsum (Fig. 2). Nearly 46% of all cropland on operations with long-term gypsum use received applications in 2012 or 2013. Nearly 30% of long-term users applied it to all of their cropland.

Figure 2 – Percentage of Cropland Treated with Gypsum by Long- and Short-term Users

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ECONOMIC IMPACT STUDY

- Researchers:
  - Marvin L. Batte
  - D. Lynn Forster
- Emeritus agricultural economics professors
- The Ohio State University

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HIGHLIGHTED SURVEY RESULTS

- Increases yield
- Reduces fertilizer requirements
- Soil productivity improvements
- Environmental benefits

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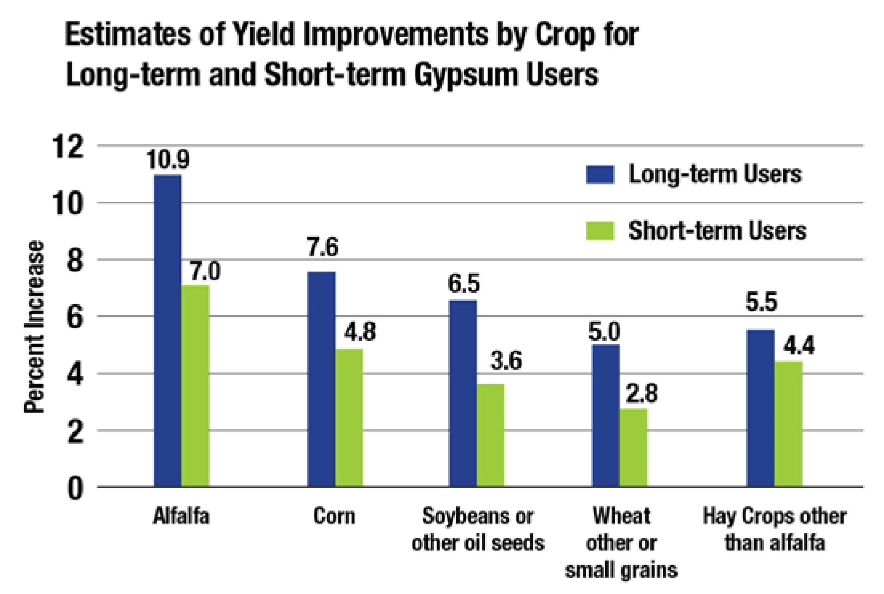
YIELD IMPROVEMENT

- Respondents report gypsum improves yield
- Long-term users realize more benefit
  - Alfalfa 11% ⇧
  - Corn 8% ⇧



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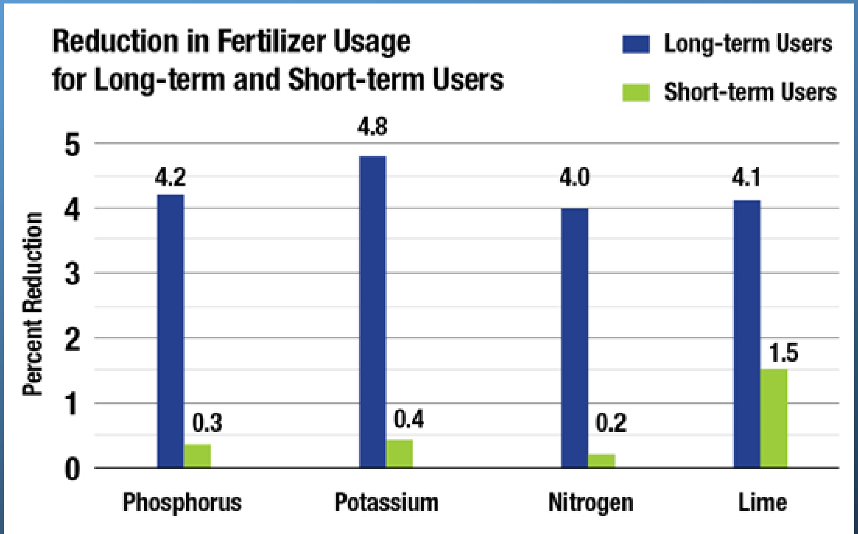
MORE EFFICIENT FERTILIZER USE

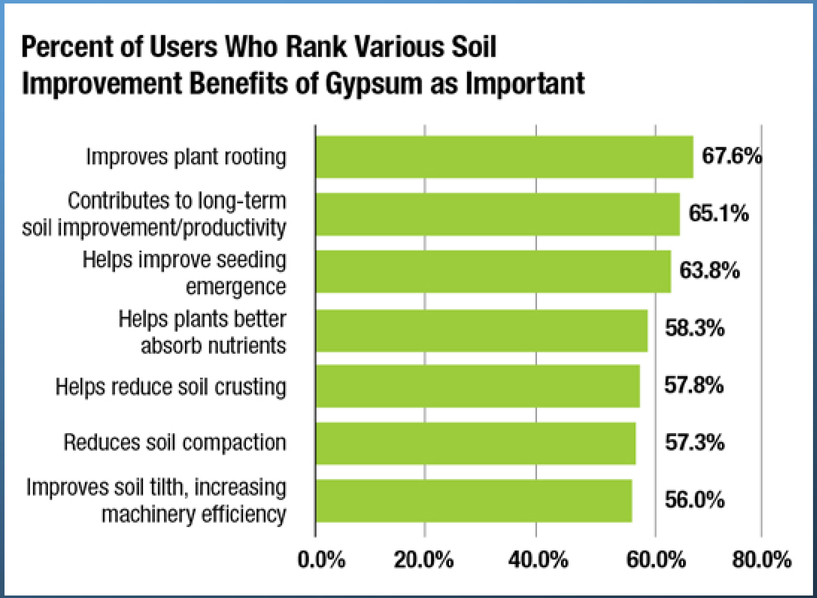
- Gypsum application can significantly reduce need for N, P, K
- Long-term users experience greater benefits
- ≥4% input reduction



GYPSOIL BRAND GYPSUM

SOIL IMPROVEMENT BENEFITS

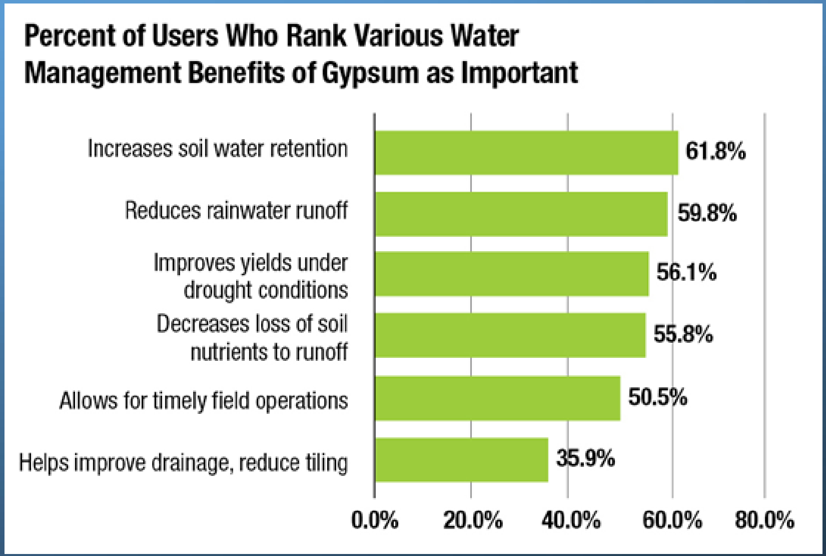
- Soil improvement benefits:
  - Improves rooting (68%)
  - Improves emergence (64%)
  - Reduces soil crusting and compaction (58%)



GYPSOIL™ BRAND GYPSUM

WATER MANAGEMENT BENEFITS

- Water management benefits:
  - Increases in soil water retention (62%)
  - Decreases rainwater runoff (60%)
  - Decreases loss of soil and nutrients to runoff (56%)



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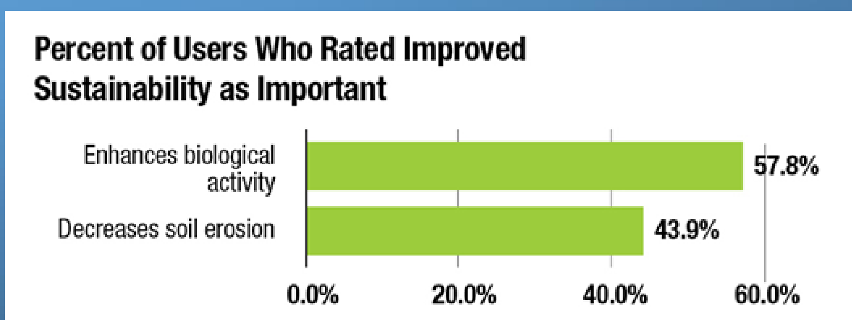
SUSTAINABILITY

- Gypsum enhances biological activity and decreases soil erosion



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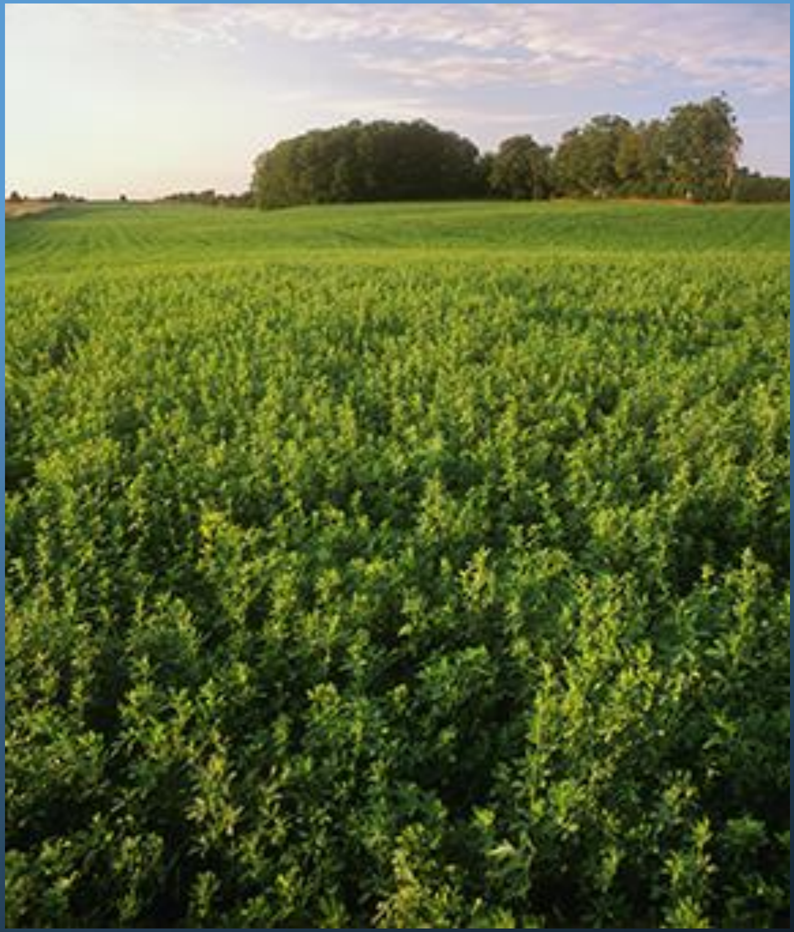
TOTAL RETURN PER DOLLAR INVESTED

- Combined average ROI is impressive*:

5.73:1 for alfalfa!

*Applied at average rates and typical costs.



GYPSOIL BRAND GYPSUM

TOTAL RETURN PER DOLLAR INVESTED

- Combined average ROI is impressive*:

2.27:1 for corn!

*Applied at average rates and typical costs.

GYPSOIL™ BRAND GYPSUM

SUMMARY

- There is clear evidence that benefits of gypsum use increase over time
  - Farmers who have used gypsum for 4 or more years gave higher ratings than recent adopters, and estimated their net benefits to be larger.

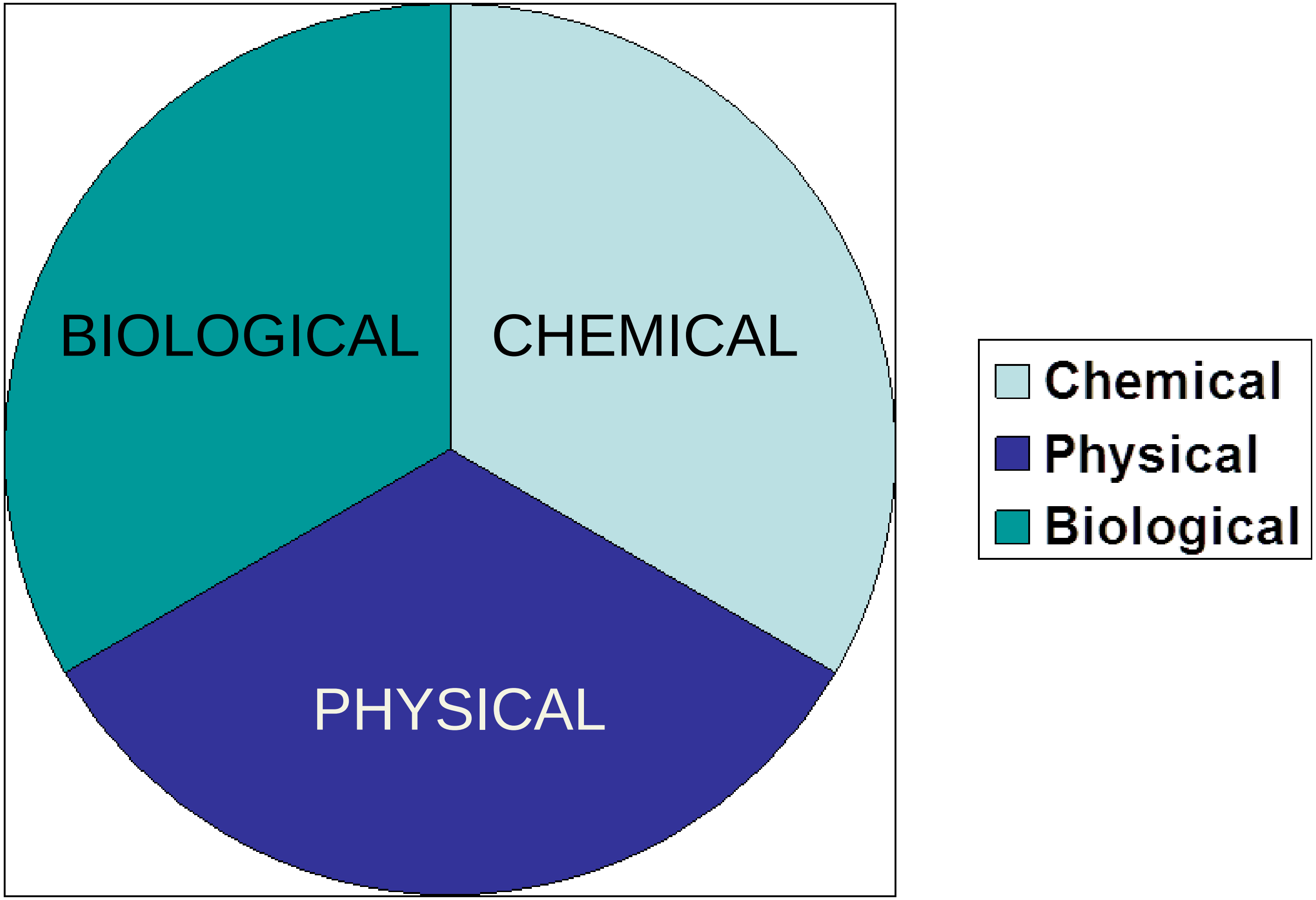
Practical Use of Gypsum for Crop Production

Joe Nester
Nester Ag, LLC
Bryan, OH

Gypsum: the State of the Practice

- Soil, water, and air affect yield
  - Managing soil structure and soil health along with nutrients is beneficial
  - Minimize stress to benefit crops
- Nutrient Management
  - A Soil with Good Structure, Ample Microbial Life, and a Decent Water Infiltration Rate Needs <u>Less Nutrients on Paper</u>

Water Infiltration and Air in the Soil



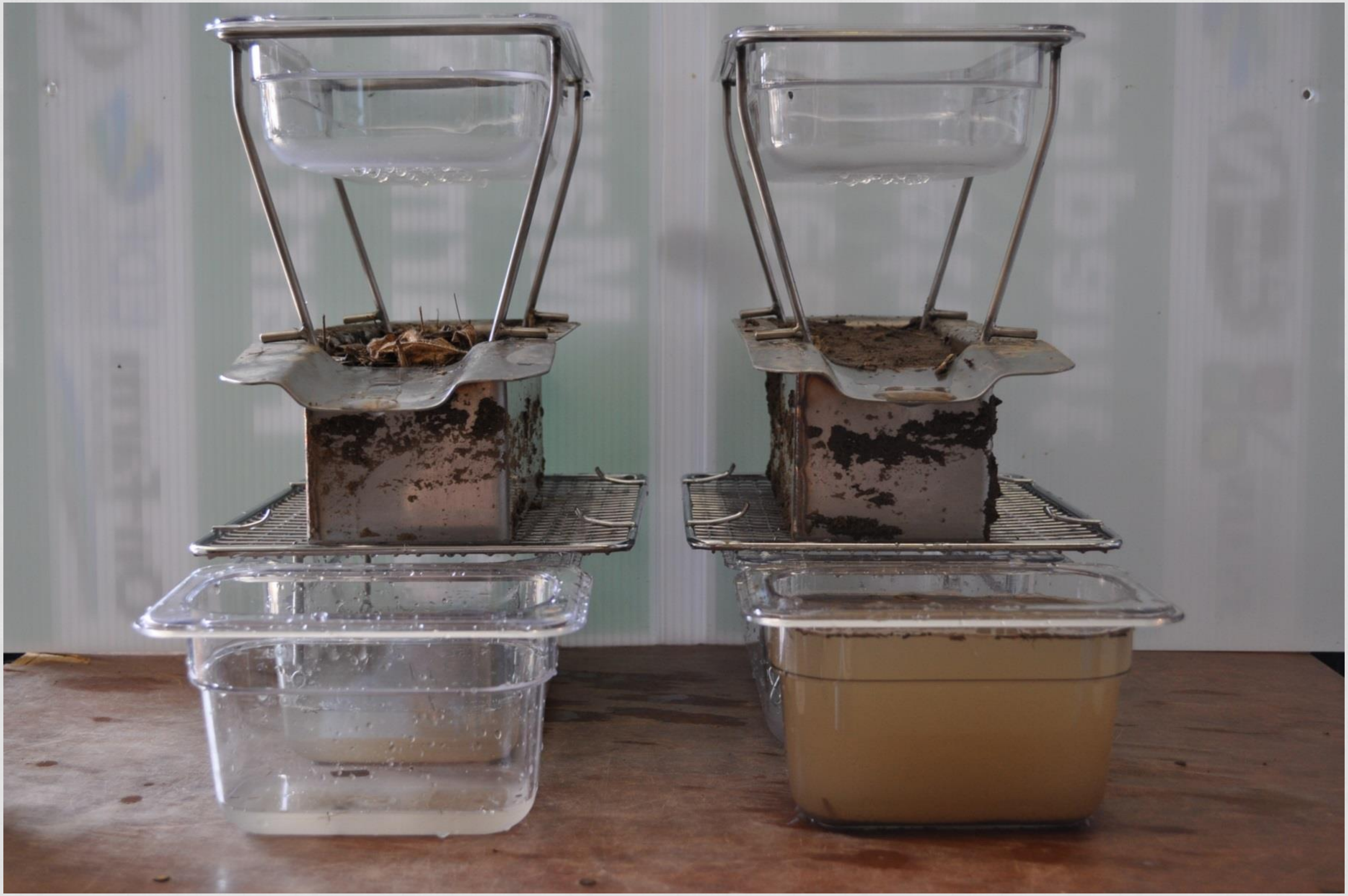
Soil Structure 101

- Build water stable aggregates
- Best agricultural soils contain 10-20% clay
- Calcium and magnesium react differently with clay
  - On Higher CEC Soils with Clay- Manage the Soil Structure Characteristics of Ca^{++} and Mg^{++}
  - Both can Purge H^{+} and correct pH
  - On Low CEC you MUST use SLAN
- Water Infiltration is the Key: Different Particle Size and Different Reaction With Clay

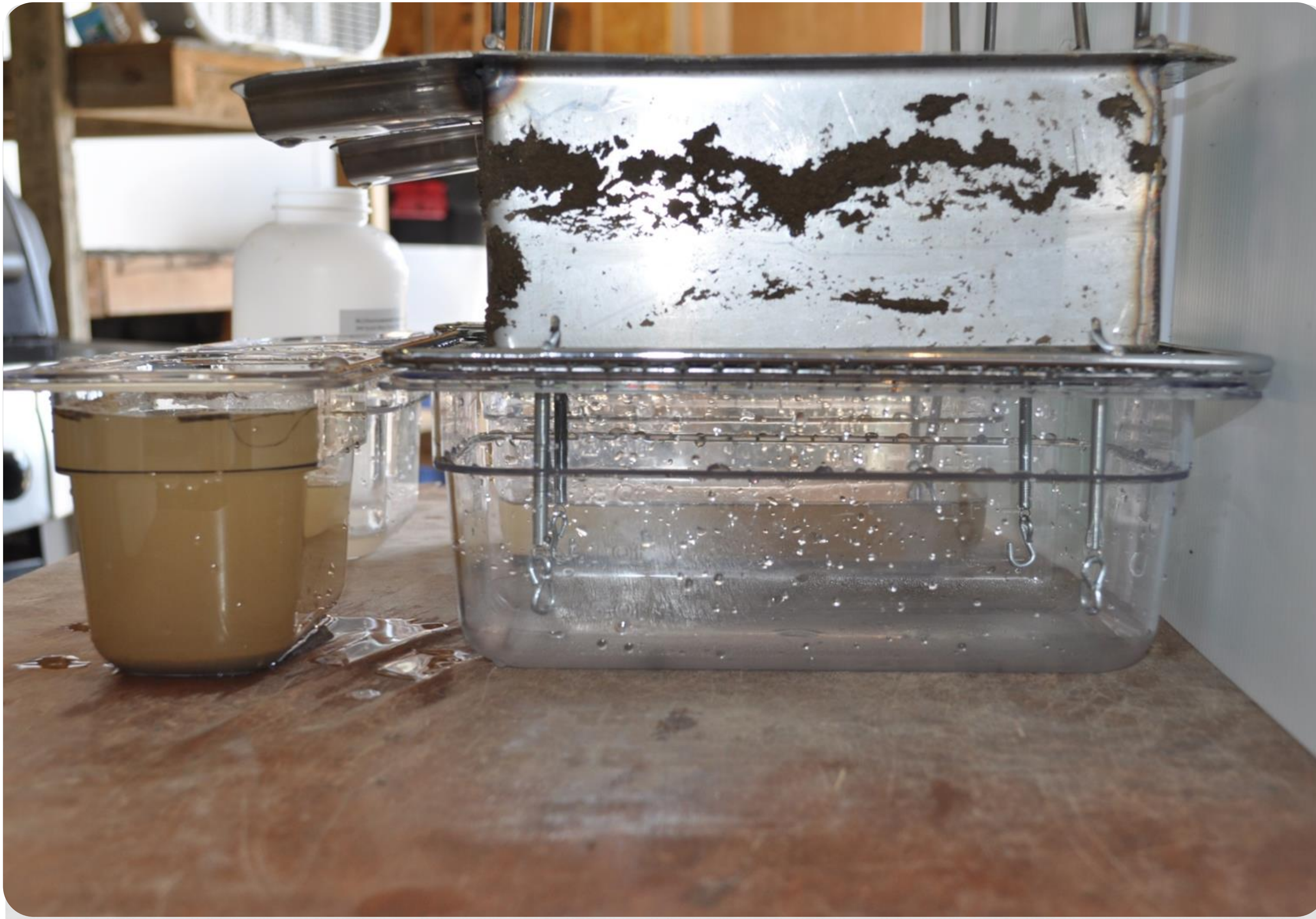
		Sulfur		
Grower	Date	with gypsum	without gypsum	% increase
A 13	12/23/13	200.37	66.57	201%
	12/23/13	200.85	66.42	202%
	12/24/13	234.33	83.10	182%
B 12	12/23/13	158.85	48.87	225%
	12/23/13	162.74	99.87	63%
	12/24/13	267.15	101.28	164%

		Magnesium		
Grower	Date	with gypsum	without gypsum	% increase
A13	12/23/13	23.02	12.03	91%
	12/23/13	23.21	11.89	95%
	12/24/13	27.13	13.97	94%
B12	12/23/13	23.31	12.10	93%
	12/23/13	24.23	11.79	106%
	12/24/13	35.15	17.28	103%
	12/24/13	35.66	17.54	103%

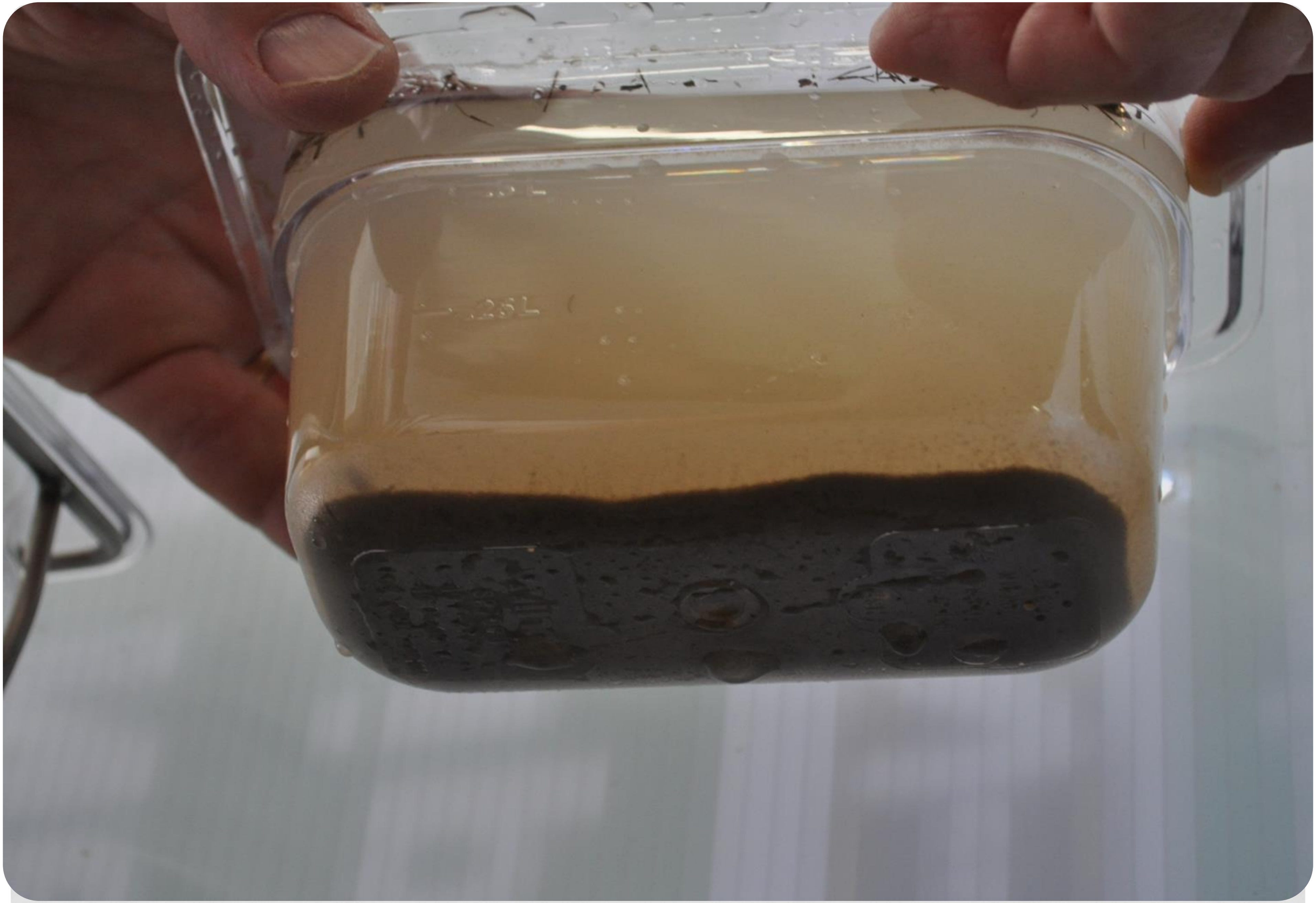
Gypsum vs. Control



Gypsum Treated Soil: most water infiltrated, very little runoff

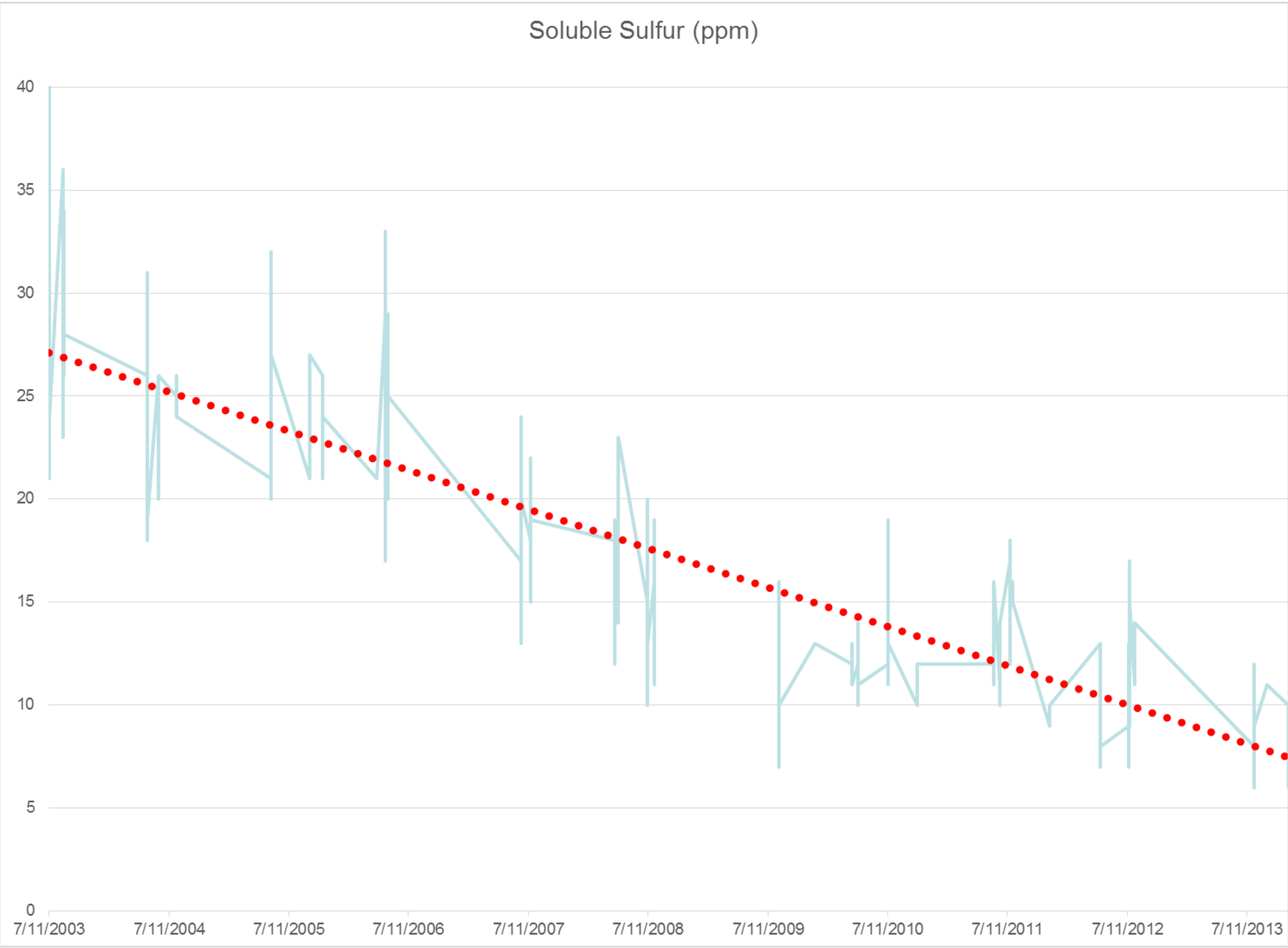


Control Soil: mostly runoff, very little infiltration



Control Soil: large amount of sediment in runoff

Gypsum Treated Soil: very little sediment in runoff water



Soluble Sulfur (ppm)
40
35
30
25
20
15
10
5
0
7/11/2003
7/11/2004
7/11/2005
7/11/2006
7/11/2007
7/11/2008
7/11/2009
7/11/2010
7/11/2011
7/11/2012
7/11/2013

Solubility Testing

- Used 4.2 pH vs 5.2 pH water
- Hoytville soils, moderate P levels
- >6X more soluble P @ 5.2 pH
- Operate Under This Assumption:
  - P is more soluble in (on) our soils than it used to be

POLICY UPDATE AND THE HEALTHY SOILS FOR HEALTHY WATERS INITIATIVE

JOHN ANDERSEN

Policy Update

- Ohio
  - NRCS 590 Standards incorporate gypsum in 2012
  - NRCS Conservation Practice Standard Code 801- March 2015
    - Amending Soil Properties with Gypsiferous Products
- Indiana
  - NRCS Conservation Practice Standard Code 801- Winter 2015
    - Amending Soil Properties with Gypsiferous Products
- Wisconsin
  - Standards under development
- National
  - NRCS Conservation Practice Standard Code 333

NRCS Conservation Practice Standard

- NRCS Conservation Practice Standard
  - Amending Soil Properties With Gypsum Products
  - Code 333 (Ac.)
- **DEFINITION**
- Using gypsum (calcium sulfate dihydrate) derived products to change the physical and/or chemical properties of soil.
- **PURPOSE**
- Improve soil health by improving physical/chemical properties and increasing infiltration of the soil.
- Improve surface water quality by reducing dissolved phosphorus concentrations in surface runoff and subsurface drainage.
- Improve soil health by ameliorating subsoil aluminum toxicity.
- Improve water quality by reducing the potential for pathogens and other contaminants transport from areas of manure and biosolids application.

Healthy Soils for Healthy Waters

- A multidisciplinary and whole-systems approach to managing agricultural lands for soil & water health.
- Symposia Series
  - September 2014 led by OSU at Farm Science Review
  - May 2015 led by OSU with Hypoxia Task Force & SERA-46
  - December 2015 led by University of Arkansas & Soil and Water Conservation Society, with HTF & SERA-46
- Presentations and case studies illustrate BMPs to reduce nutrient exports to water resources.

HSHW Steering Committee

- John Andersen, Greenleaf Advisors
- Larry Antosch, Ohio Farm Bureau Federation
- Larry Clemens, TNC - Indiana
- Mike Daniels, University of Arkansas
- Jim Gulliford, Soil and Water Conservation Society
- Eileen McLellan, Environmental Defense Fund
- Jim Moseley, AGree
- Joe Nester, Nester Ag
- Rebecca Power, University of Wisconsin Extension
- Randall Reeder, The Ohio State University
- Mark Smith, USDA, NRCS, Ohio
- Jennifer Tank, The University of Notre Dame
- Carrie Vollmer- Sanders, TNC
- Andy Ward, The Ohio State University
- Shannon Zezula, USDA, NRCS, Indiana

Discussion

- Q&A
- Opportunities for collaboration
  - HSHW and shared demonstration projects
  - NRCS Regional Conservation Partnership Program (RCPP)
  - Other

Contact Us

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  - Todd Main, tmain@greenleafadvisors.net
  - Katie DeMuro, kdemuro@greenleafadvisors.net
- Warren Dick, The Ohio State University, dick.5@osu.edu
- Ron Chamberlain, GYPSOIL, ron@gypsoil.com
- Joe Nester, NesterAg, nesterag@bright.net

Resources

- Greenleaf Advisors: http://greenleafadvisors.net/
  - Partner Resources: http://greenleafadvisors.net/servicessectors/land/greenleaf-partner-resources/
- Healthy Soils for Healthy Waters: http://symposium.greenleafadvisors.net/
  - Join the HSHW mailing list: http://eepurl.com/_MeRj
- GYPSOIL: http://www.gypsoil.com/
  - Research Library: http://www.gypsoil.com/research-library
- Gypsum as an Agricultural Amendment, Warren Dick: http://ohioline.osu.edu/b945/index.html
- Nester Ag: http://www.nesterag.com/