Midwest Soil Improvement Symposium:

Research and Practical Insights into Using Gypsum

Using Gypsum to Improve Crop Performance

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GYPSOIL™ BRAND GYPSUM

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Using Gypsum to Improve Crop Performance

Gypsum as a soil amendment and fertilizer for the production of commercial crops

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What is Gypsum?

Gypsum is a very soft mineral composed of calcium sulfate dihydrate, with the chemical formula $CaSO_4 \cdot 2H_2O$. The word gypsum is derived from a Greek word meaning "chalk" or "plaster". Because the gypsum from the quarries of the Montmartre district of Paris has long furnished burnt gypsum, this material has often been called plaster of Paris. Gypsum is moderately water-soluble. The source of gypsum is both mined and synthetic.

History of Gypsum in Agriculture

- Early Greek and Roman times
- Fertilizer value discovered in Europe in last half of 18th century
  - Germany (1768) – Reverend A. Meyer
  - France (date?) – Men working with alabaster (plaster of paris) noted better grass growth in areas they shook dust from clothing
- Extensive use in Europe in 18th century

Gypsum Benefits in Agriculture

Arthur Wallace (1994)

"Use of gypsum on soil where needed can make agriculture more sustainable"

Lists 30 benefits from use of gypsum but there is some overlap of functions

We have also conducted a review on this topic.

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
- Growth media component for mushroom production - approximately 60 kg/ton compost)
- Ca-humate and $CaCO_3$ formation in soil

Benefit #1

- **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

Relative Numbers of Atoms Required by Plants

Mo	1	P	60,000
Cu	100	Mg	80,000
Zn	300	Ca	125,000
Mn	1,000	K	250,000
B	2,000	N	1,000,000
Fe	2,000	O	30,000,000
Cl	3,000	C	35,000,000
S	30,000	H	60,000,000

Sulfur in Plant Physiology

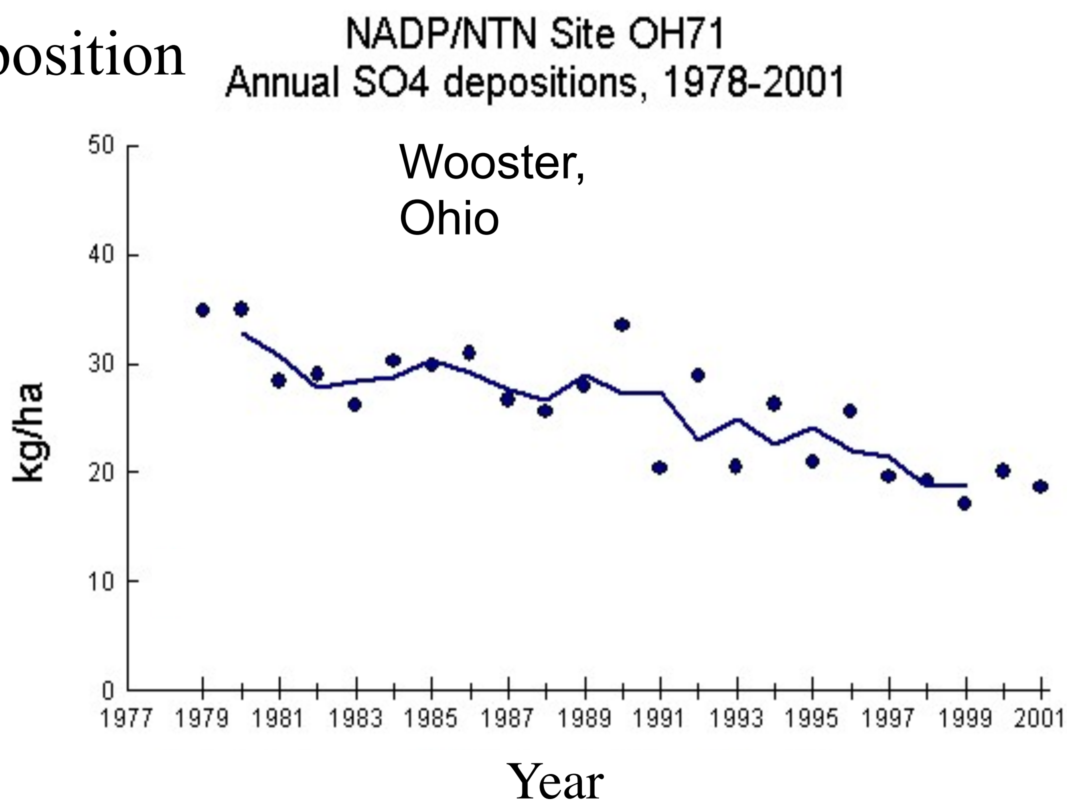
- Amino acids methionine and cysteine
  - Proteins
  - Precursors of other sulfur-containing compounds
- Sulfolipids (fatty compounds) in membranes, especially chloroplast membranes
- Nitrogen-fixing enzyme (nitrogenase)
  - 28 S atoms in active site

Causes of Sulfur Deficiencies in Crops

- Shift from low-analysis to high-analysis fertilizers
- High-yielding crop varieties use more S
- Reduced atmospheric S deposition
- Decreased use of S in pesticides
- Declining S reserves in soil due to loss of organic matter (erosion and tillage), leaching, and crop removal

Reduction in Atmospheric S Deposition

- Increasing in importance as cause for crop S deficiencies
- Loss of soil organic matter
- Reduced annual S deposition
  - 34 kg/ha in 1971
  - 19 kg/ha in 2002



Calcium in Plant Physiology

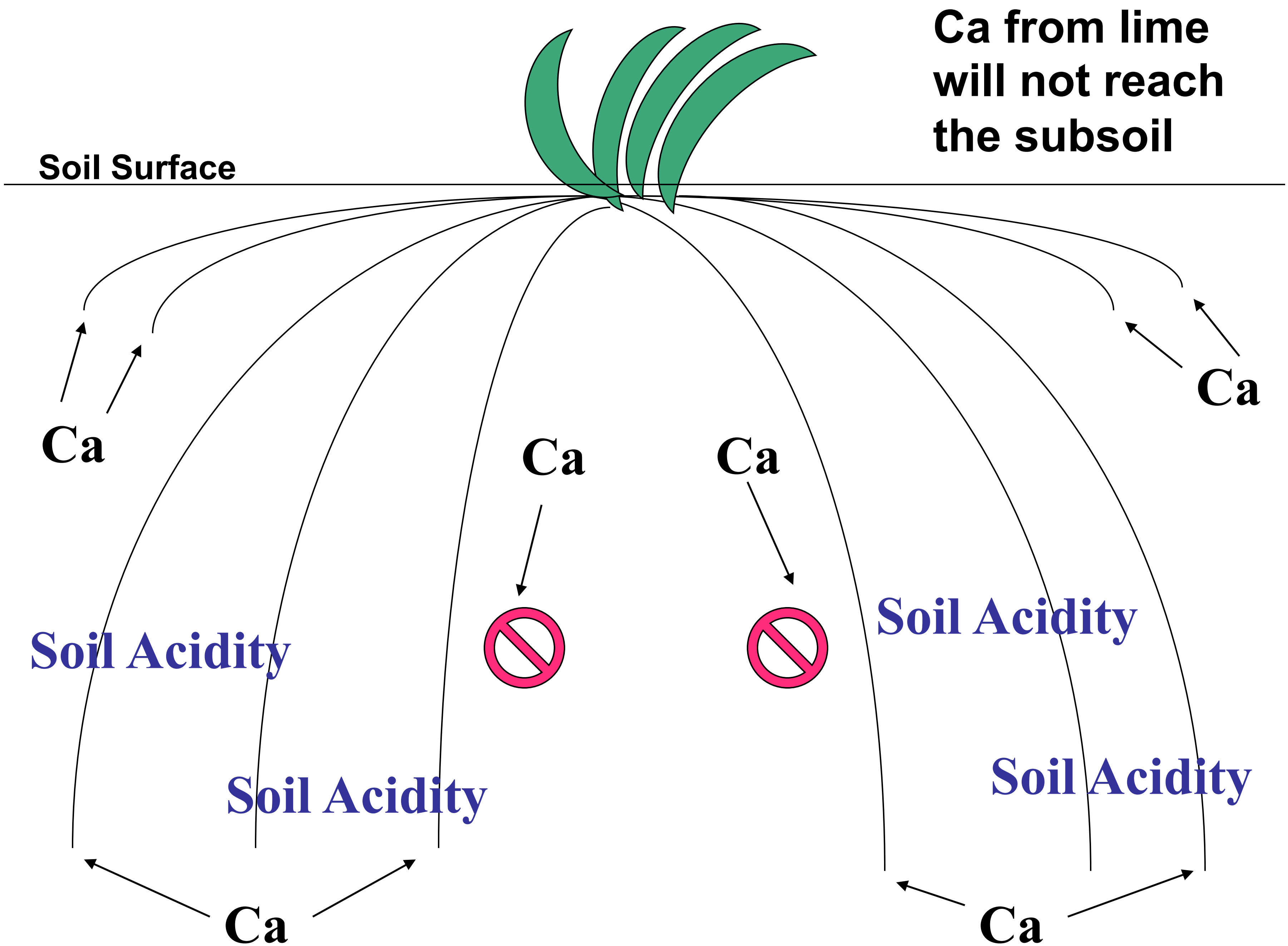
- Required for proper functioning of cell membranes and cell walls
- Needed in large amounts at tips of growing roots and shoots and in developing fruits
- Relatively little Ca is transported in phloem
  - Ca needed by root tips comes from soil solution

Benefit #2

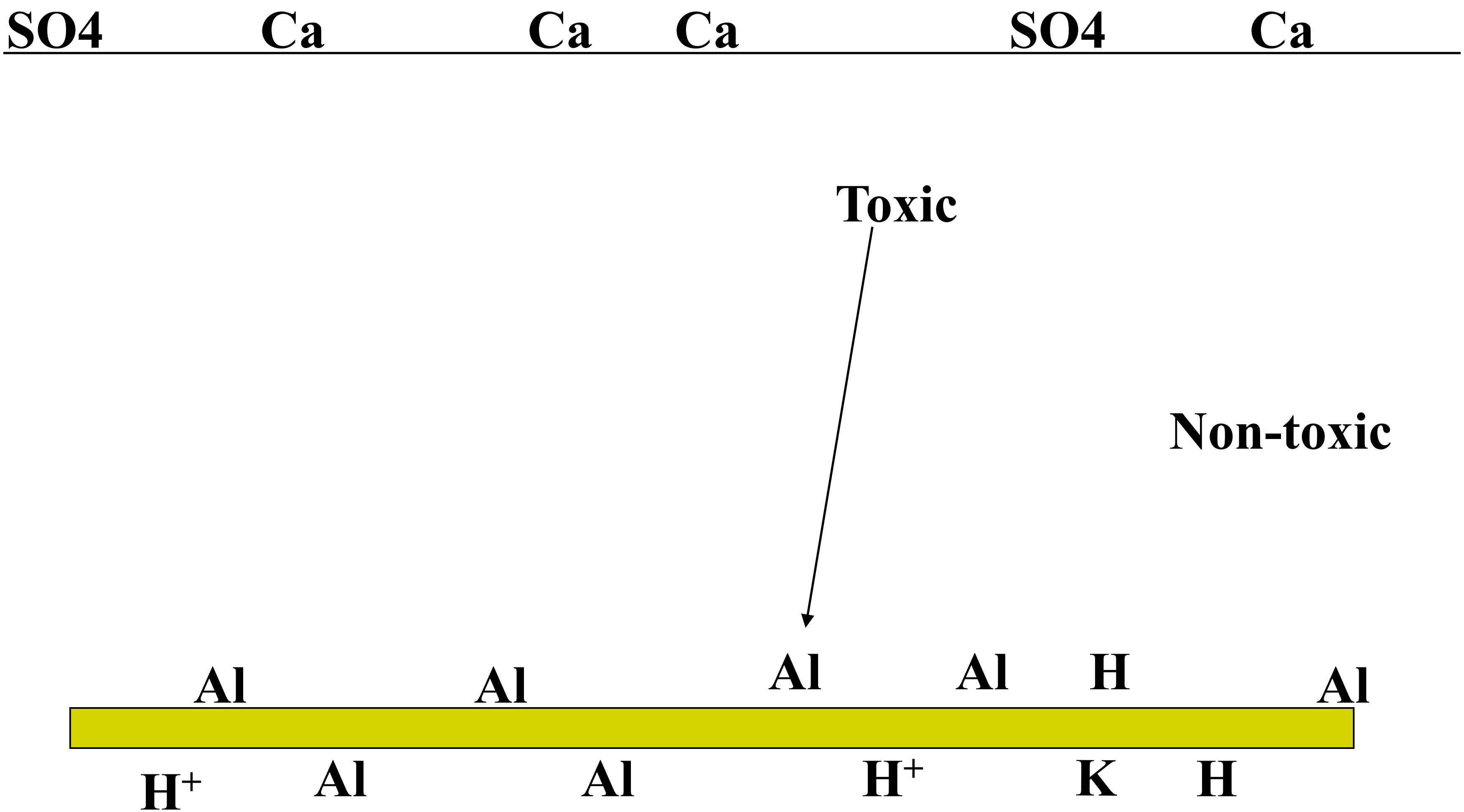
- Ca and S source for plant nutrition
- **Source of S and exchangeable Ca to ameliorate subsoil acidity and Al^{3+} toxicity**
- Flocculate clays to improve soil structure and reclaim sodic and high magnesium soils

Amelioration of Subsoil Acidity and Al^{3+} Toxicity

- Surface-applied gypsum leaches down to subsoil
- Ca^{2+} exchanges with Al^{3+}
- SO_4^{2-} complexes with Al^{3+} ion to form $AlSO_4^+$
- $AlSO_4^+$ is not toxic to plant roots
- Results in increased root growth in the subsoil

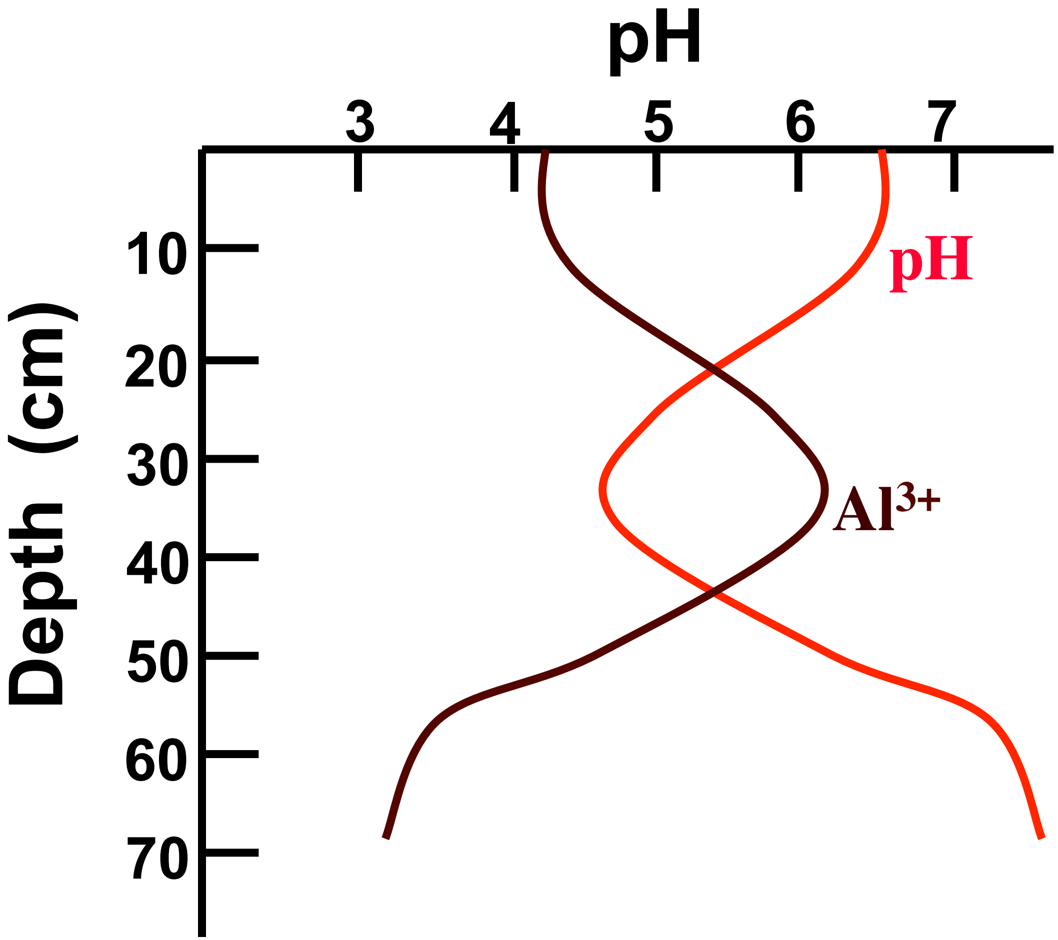

Ca from lime
will not reach
the subsoil
Soil Surface
Ca
Ca
Ca
Ca
Soil Acidity
Soil Acidity
Soil Acidity
Soil Acidity
Ca
Ca

Gypsum applied to surface of soil with acidic subsoil



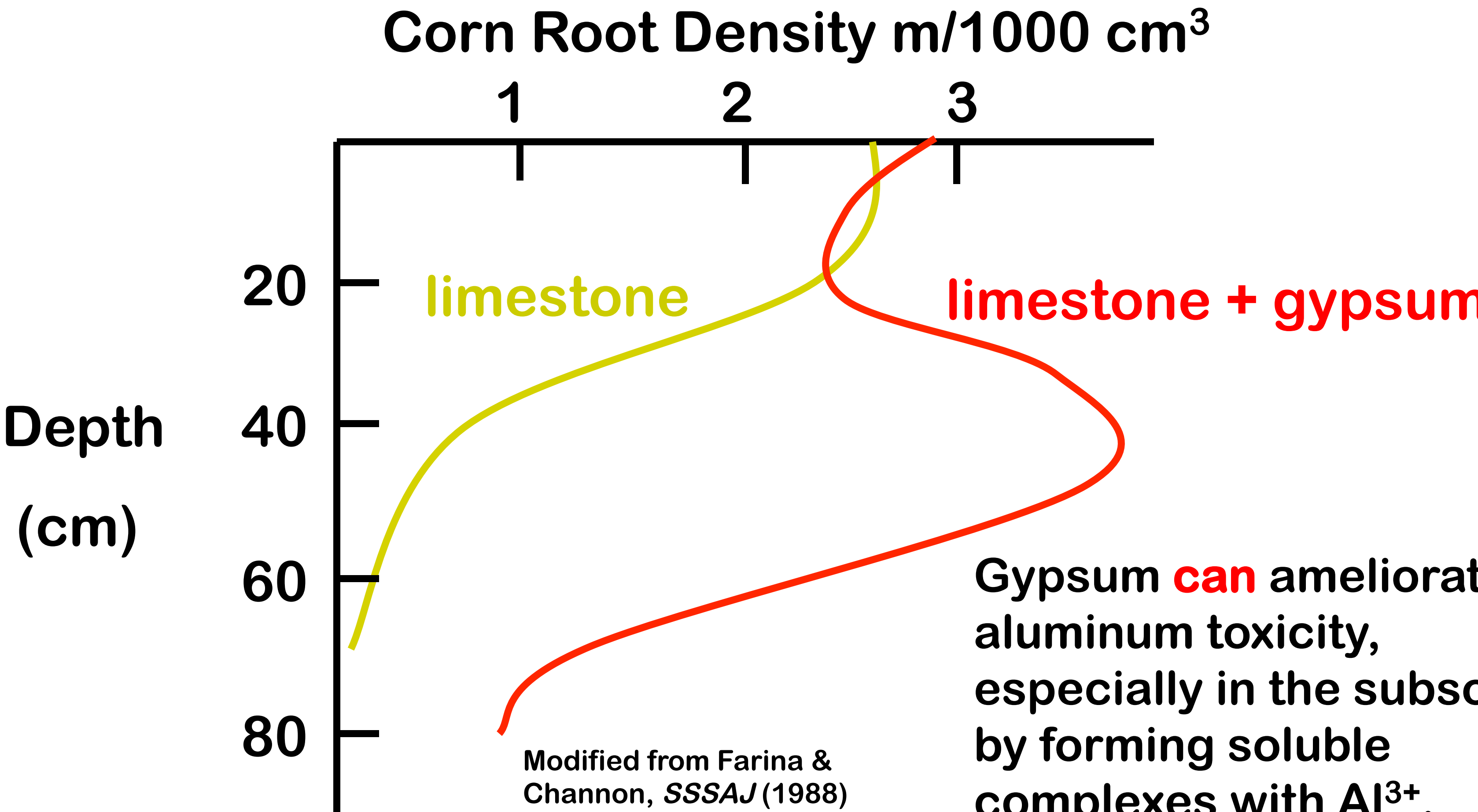
Clay platelet in subsoil

Typical pH profile for a Blount soil



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

(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+}.

Increased Root Growth into Subsoil

- Increased water absorption
- Increased recovery of N from subsoil
  - Demonstrated in Brazilian soils
  - Improved N-use efficiency, Ohio, USA

Benefit #3

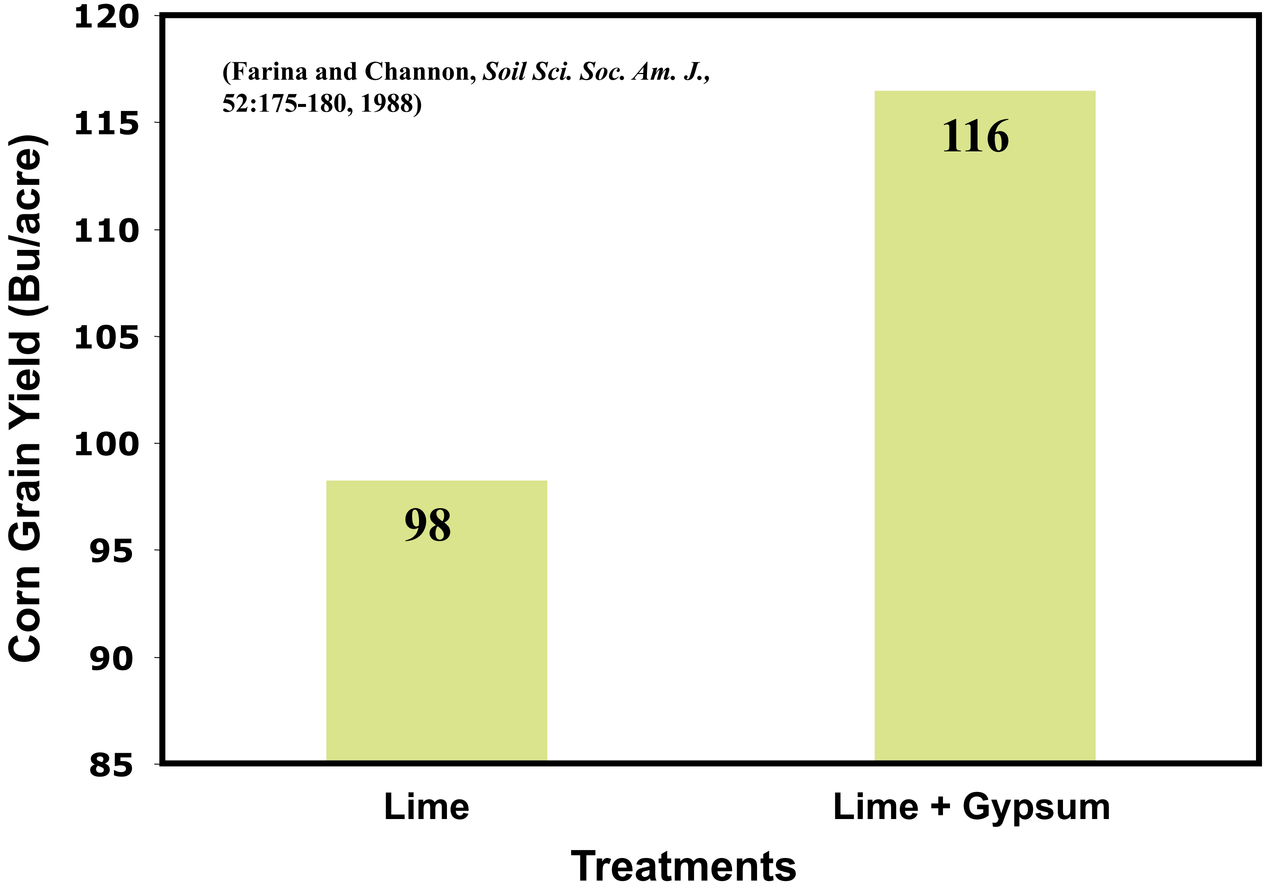
- Ca and S source for plant nutrition
- Source of S and exchangeable Ca to ameliorate subsoil acidity and Al^{3+} toxicity
- **Flocculate clays to improve soil structure and reclaim sodic and high magnesium soils**

Corn Production and Gypsum

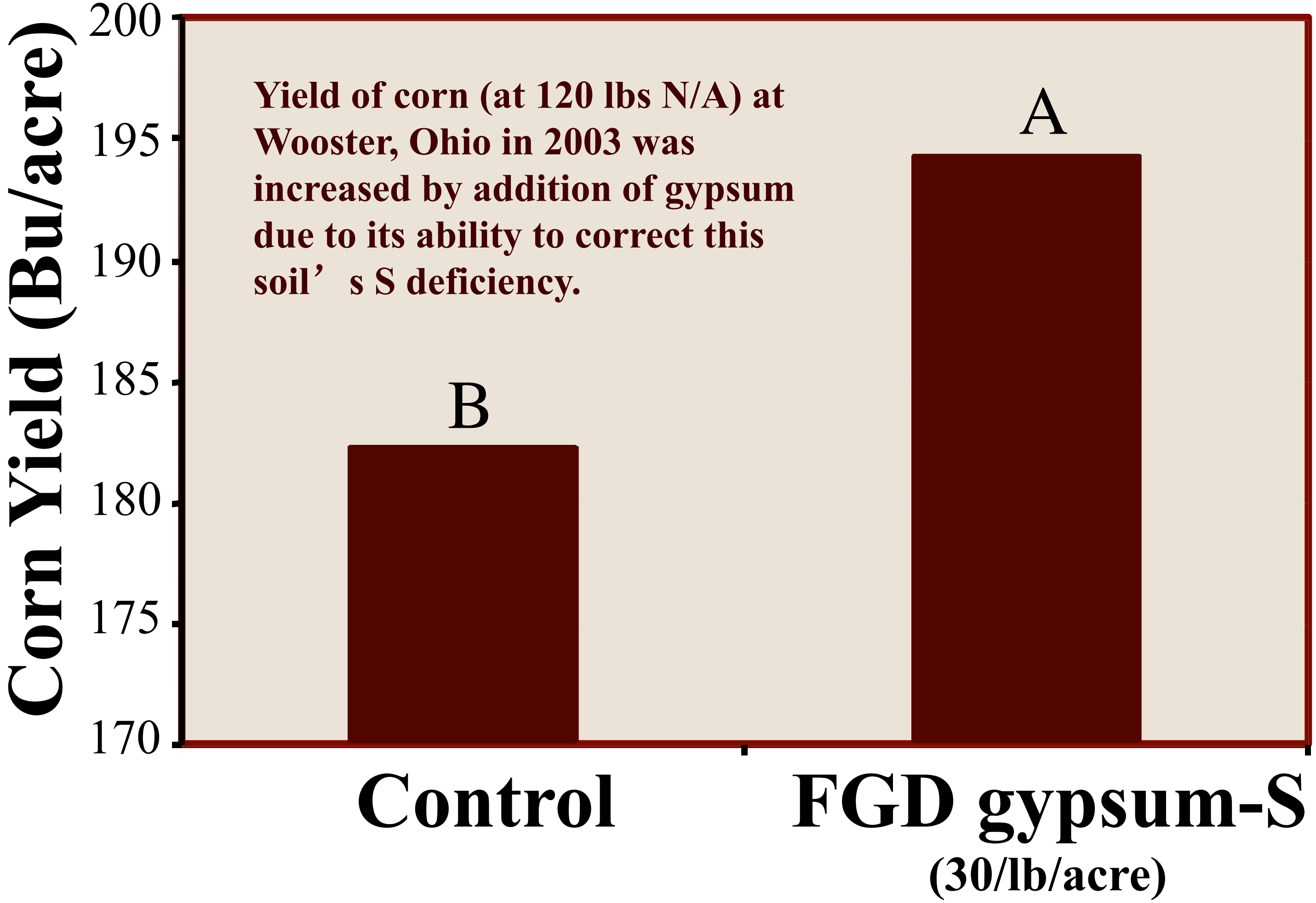
Gypsum and Sodic Soil Reclamation in China

Comparison of field with (background) and without (foreground) FGD by-product gypsum

Increased Root Growth into Subsoil



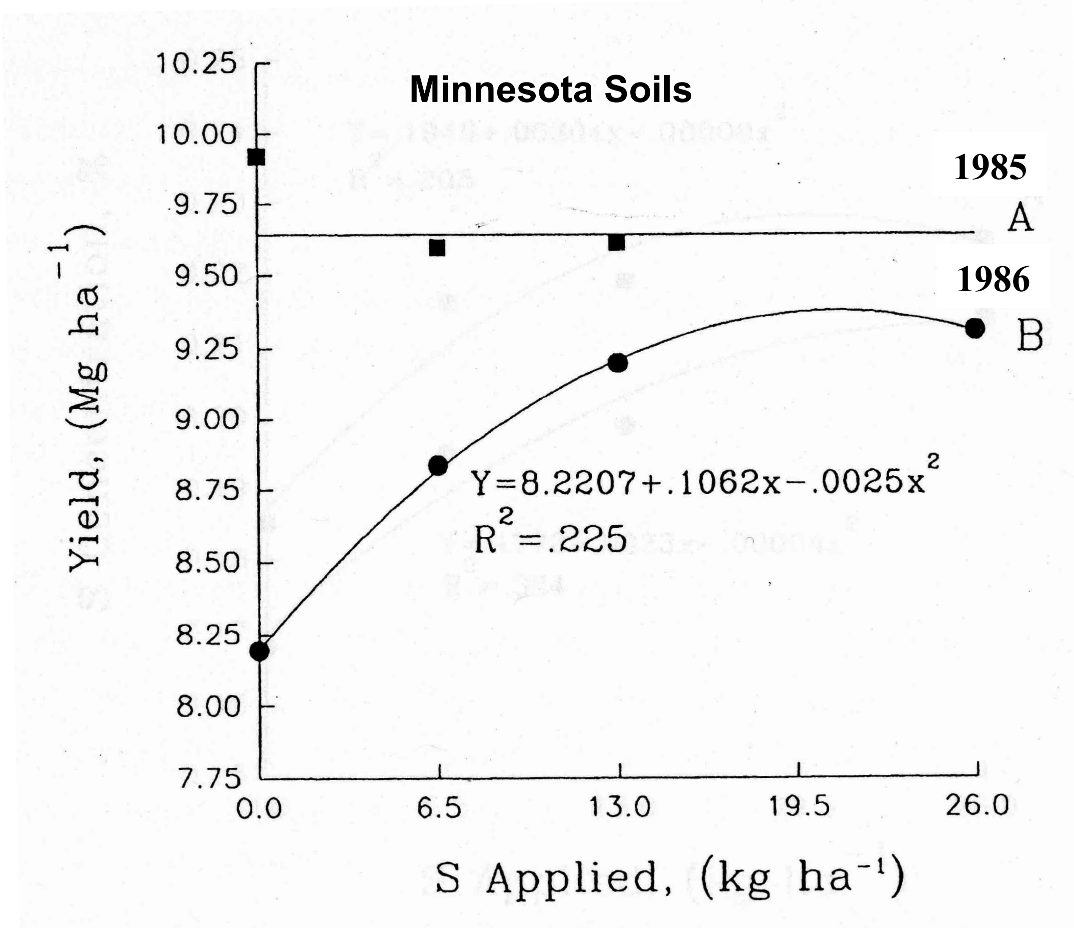
Corn Yields in 2003 (Wooster, Ohio)



Average Corn Yields from 2002 to 2005 (Ohio)

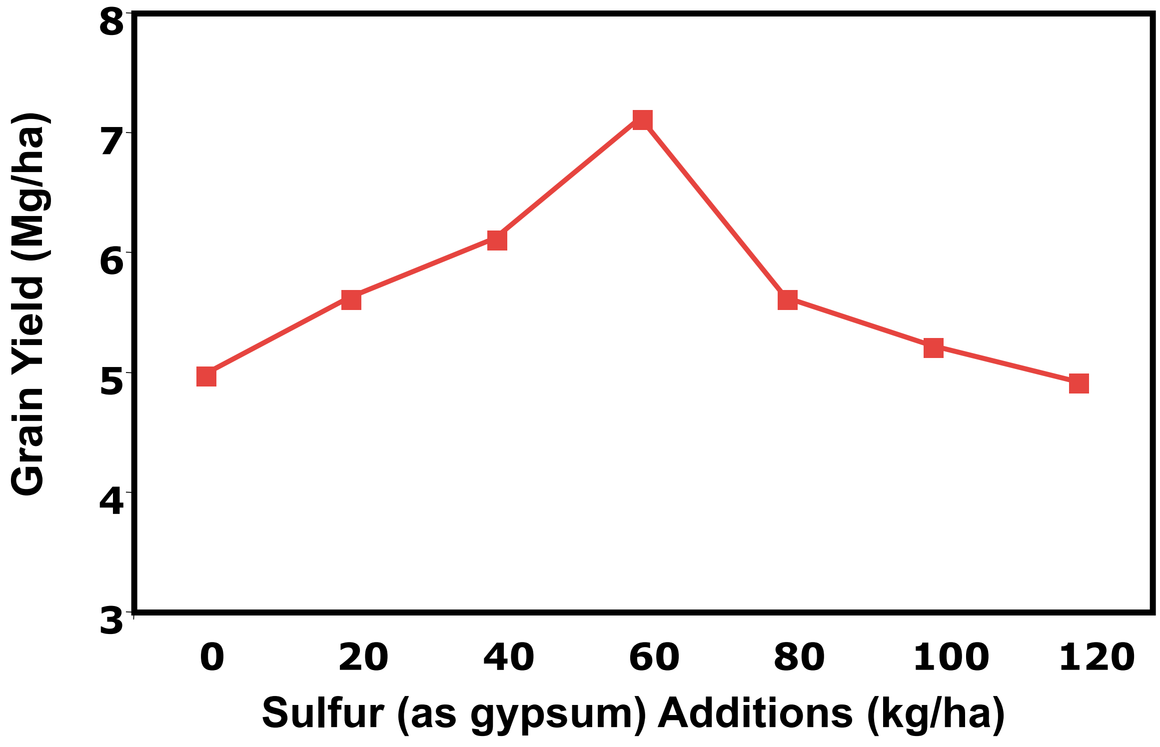
N Rate lbs/A	Corn Yield (dry weight) Bu/A	No S Bu/A	With S Bu/A	Increase by S %
0	116 d	110	121	10.0
60	148 c	140	156	11.4
90	154 bc	151	156	3.3
120	161 ab	155	166	7.1
150	162 ab	158	166	5.1
180	172 a	164	179	9.1
210	169 a	167	171	2.4
Means	155	149	159	6.7

Corn (Sulfur Nutrition)



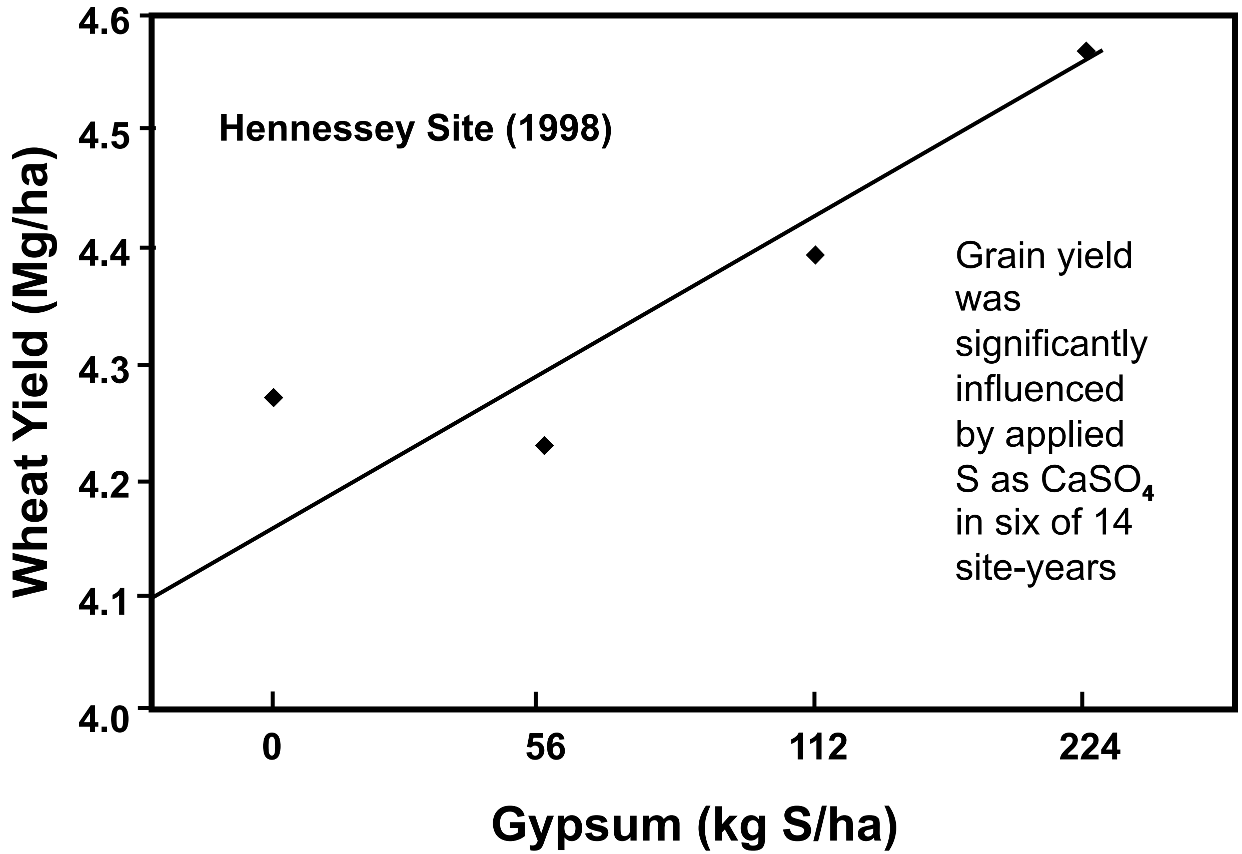
(Rehm, *Commun. Soil Sci. Plan Anal.*, 24:285-294, 1993)

Corn (Sulfur Nutrition)



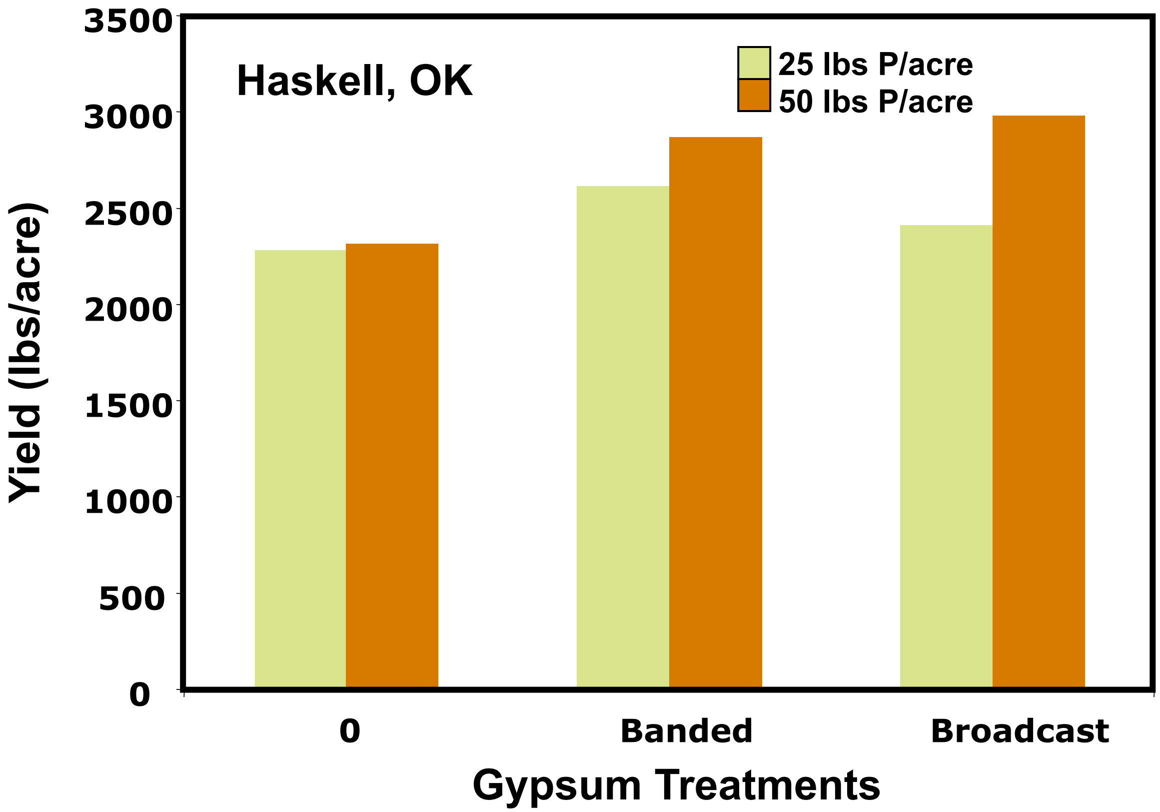
(Khan et al., *Commun. Soil Sci. Pl. Anal.*, 37: 41–51, 2006)

Wheat (Sulfur Nutrition)



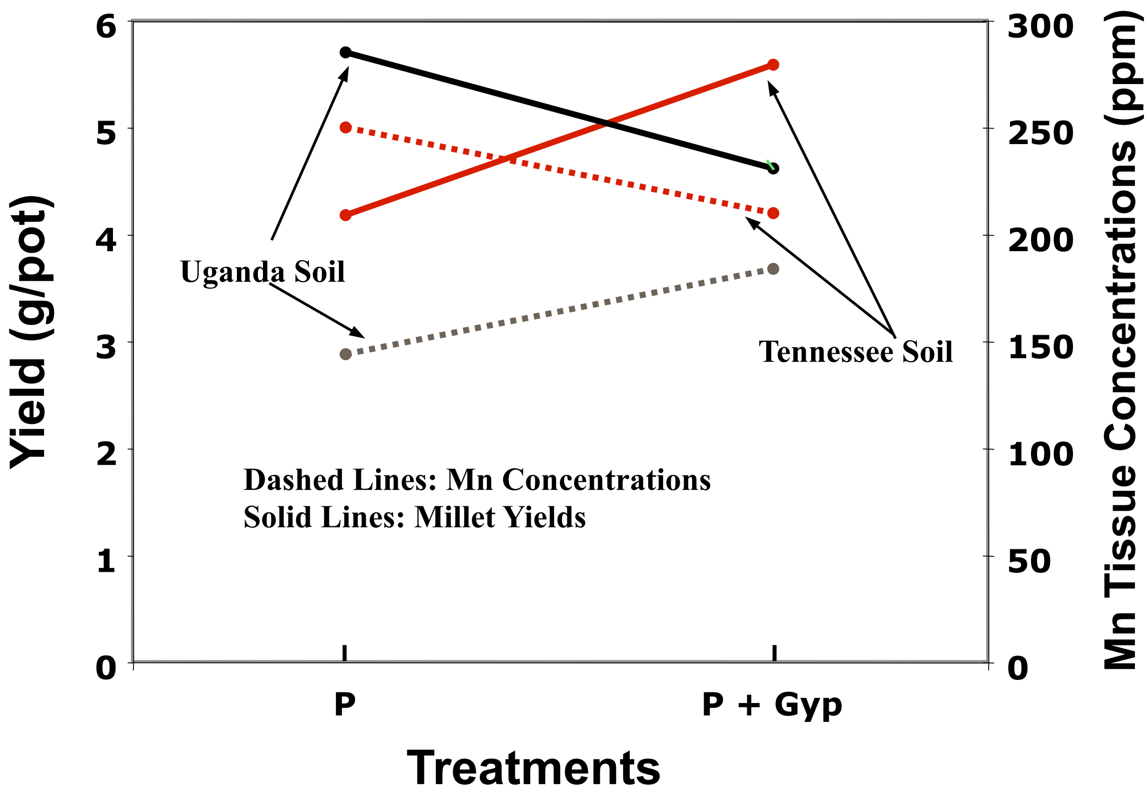
(Girma et al., *J. Plant Nutr.*, 28:1541–1555 (2005))

Wheat (Dual Banding)



(Phillips et al., *J. Plant Nutr.*, 23:251-261, 2000)

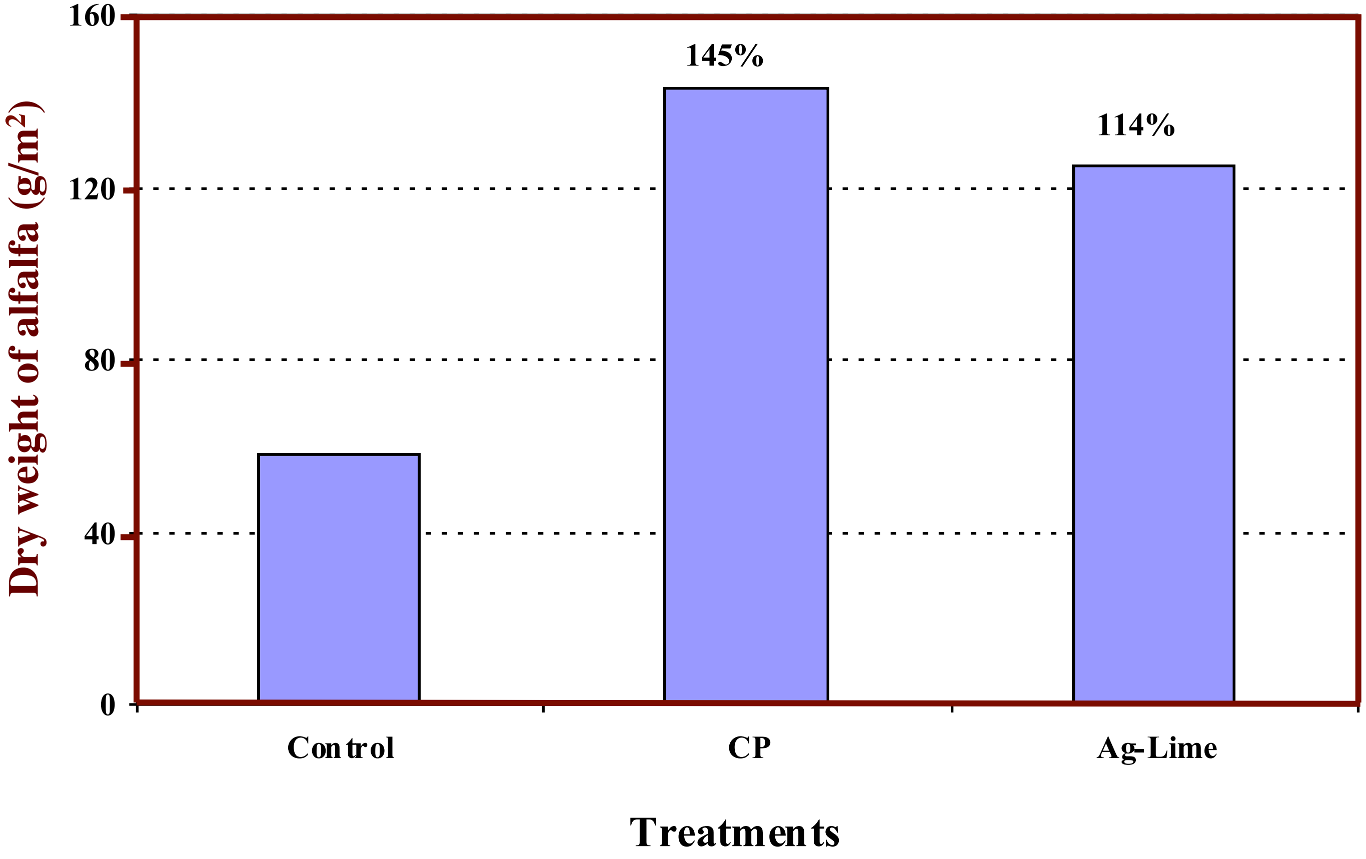
Millet (Surface Acidity and Plant Nutrition)



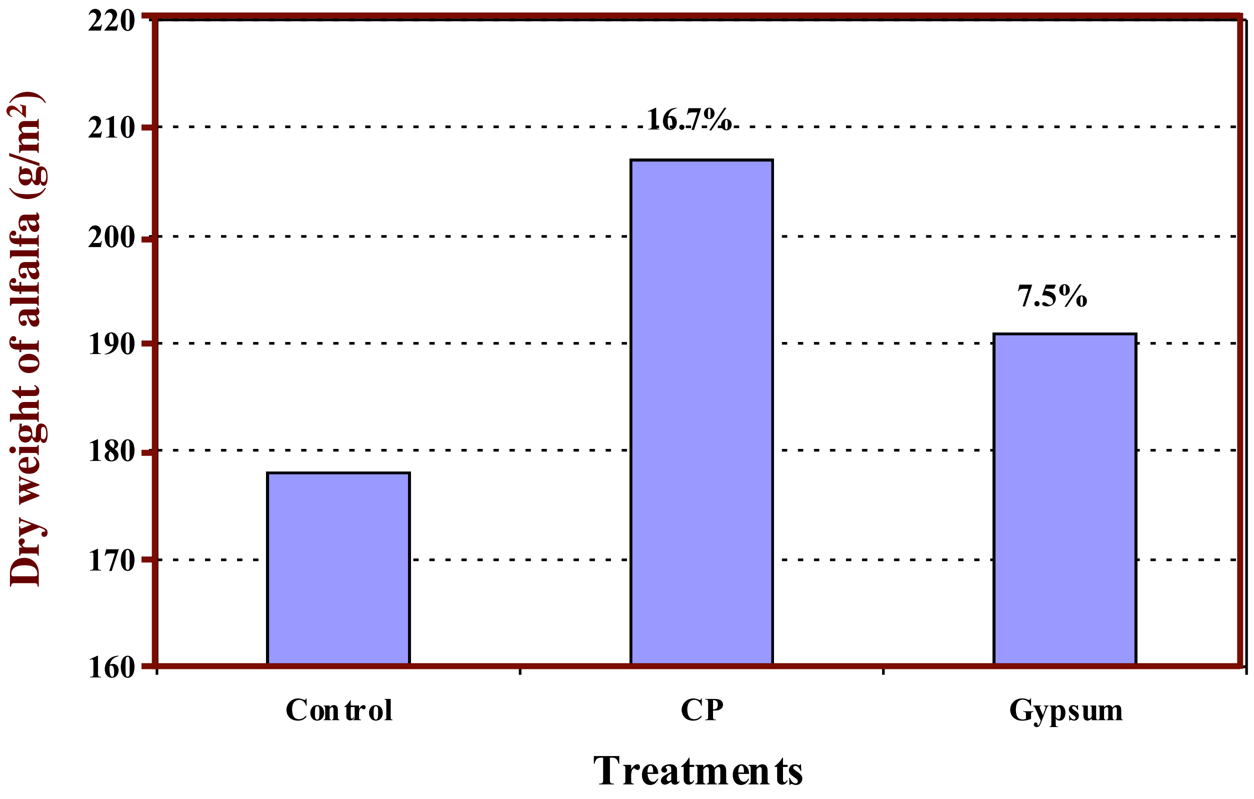
(McLean and Ssali, *Soil Sci.*, 123:155-164, 1977)

Forages Production and Gypsum

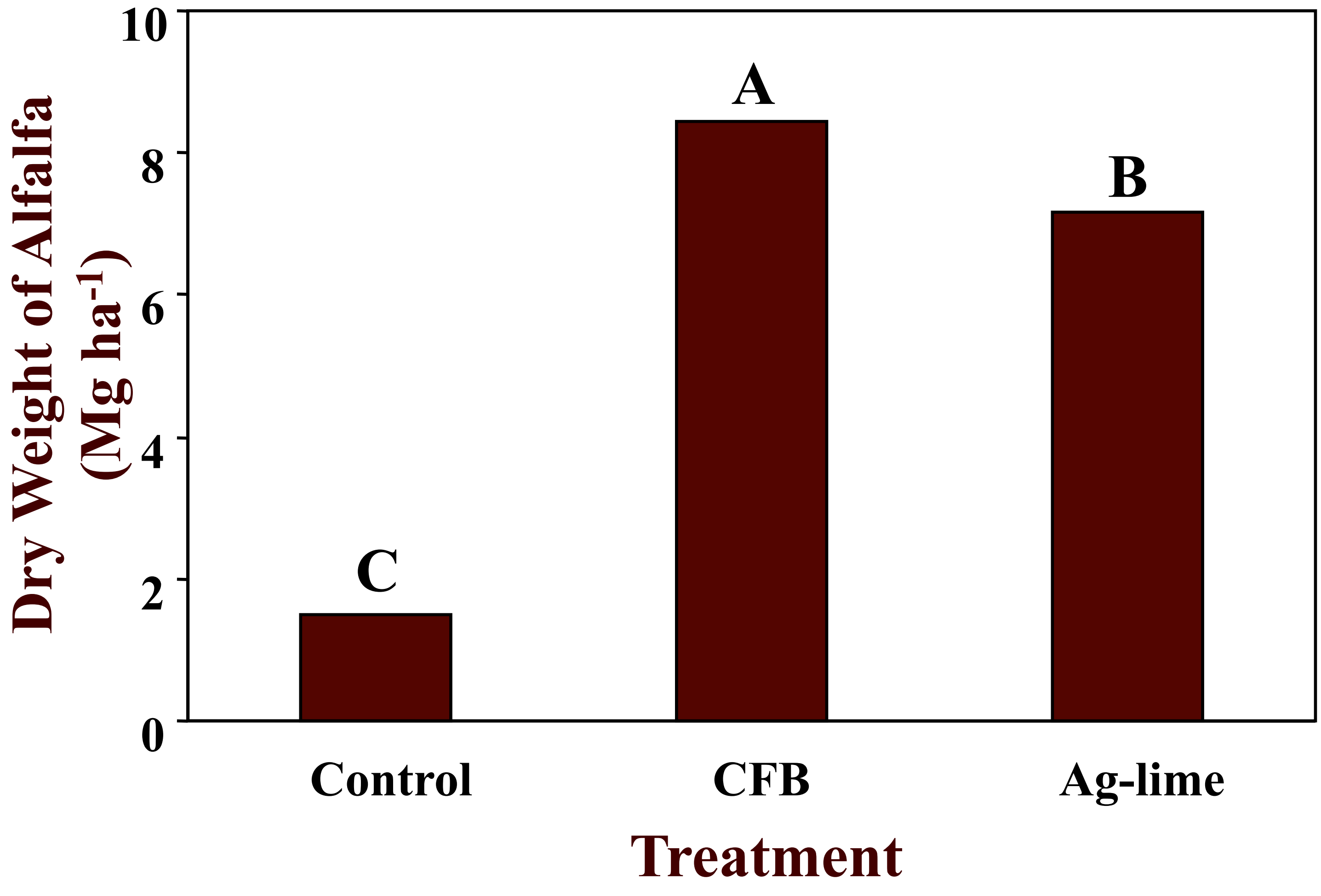
Effect coal product (CP) and ag-lime on alfalfa forage yield (dry weight of 2004 first harvest) on a newly established field



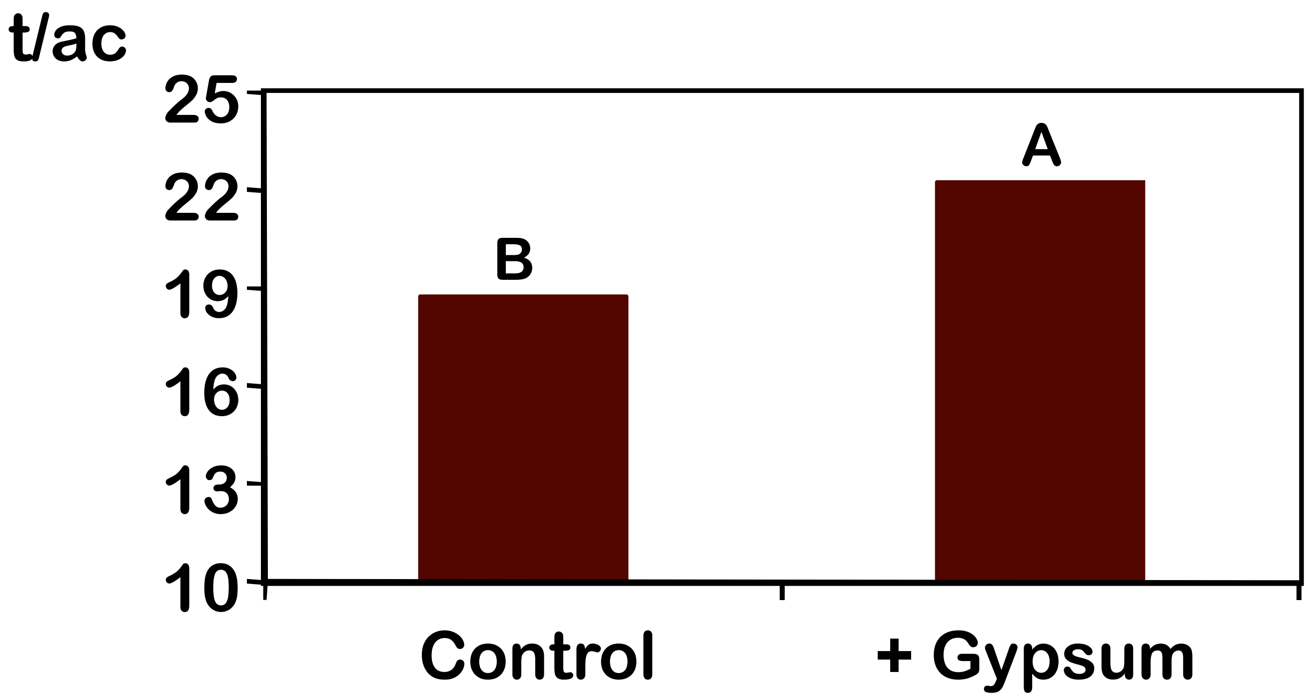
Effect of CP and gypsum as S sources on alfalfa forage yields (dry weight of 2004 first harvest) for an established field



Effect of CFB and ag-lime in farmer's field

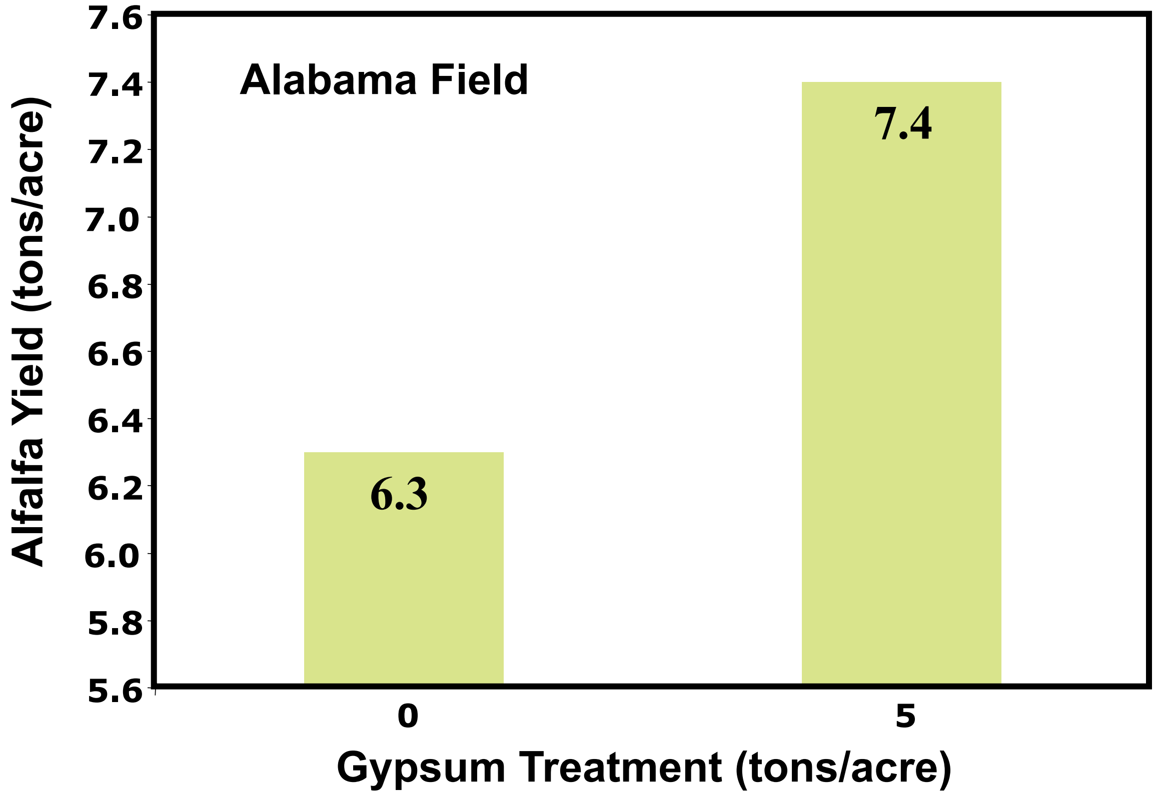


Effect of Gypsum on Cumulative Alfalfa Yields at Wooster, OH (2000 - 2002)



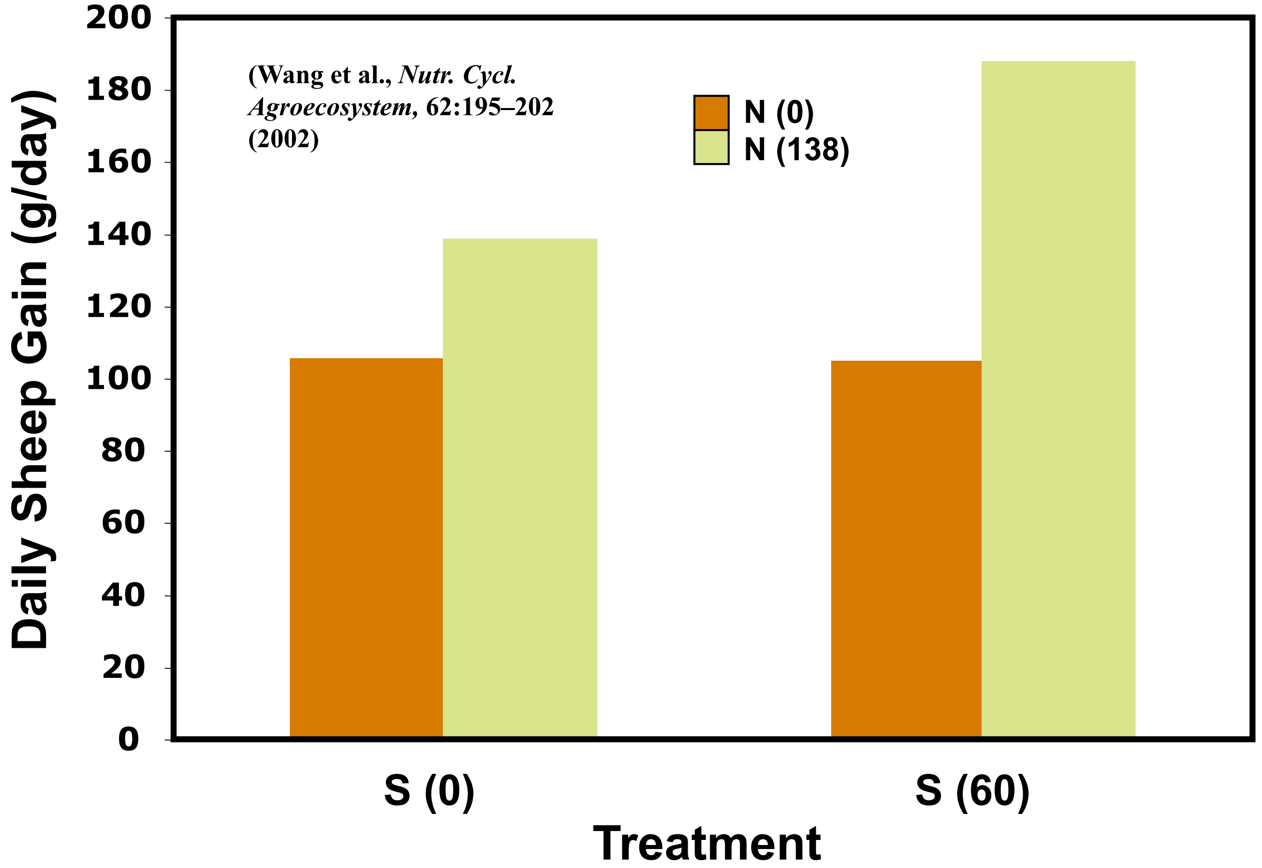
Different letters over each bar represent a significant difference at $p \leq 0.05$.

Alfalfa (Sulfur Nutrition)

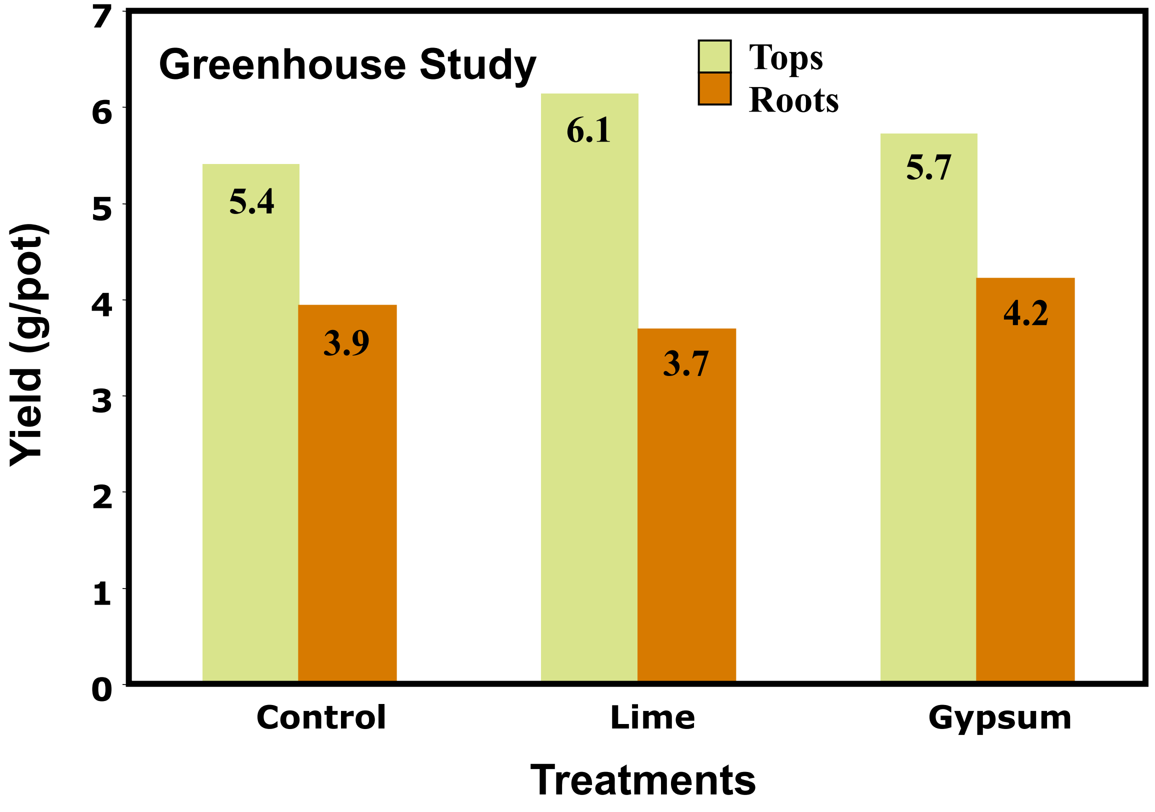


(Mitchell and Ball, *Alabama Agri. Exp. Station*, Spring, 1972)

Forage Quality and Fertilizer N Interaction

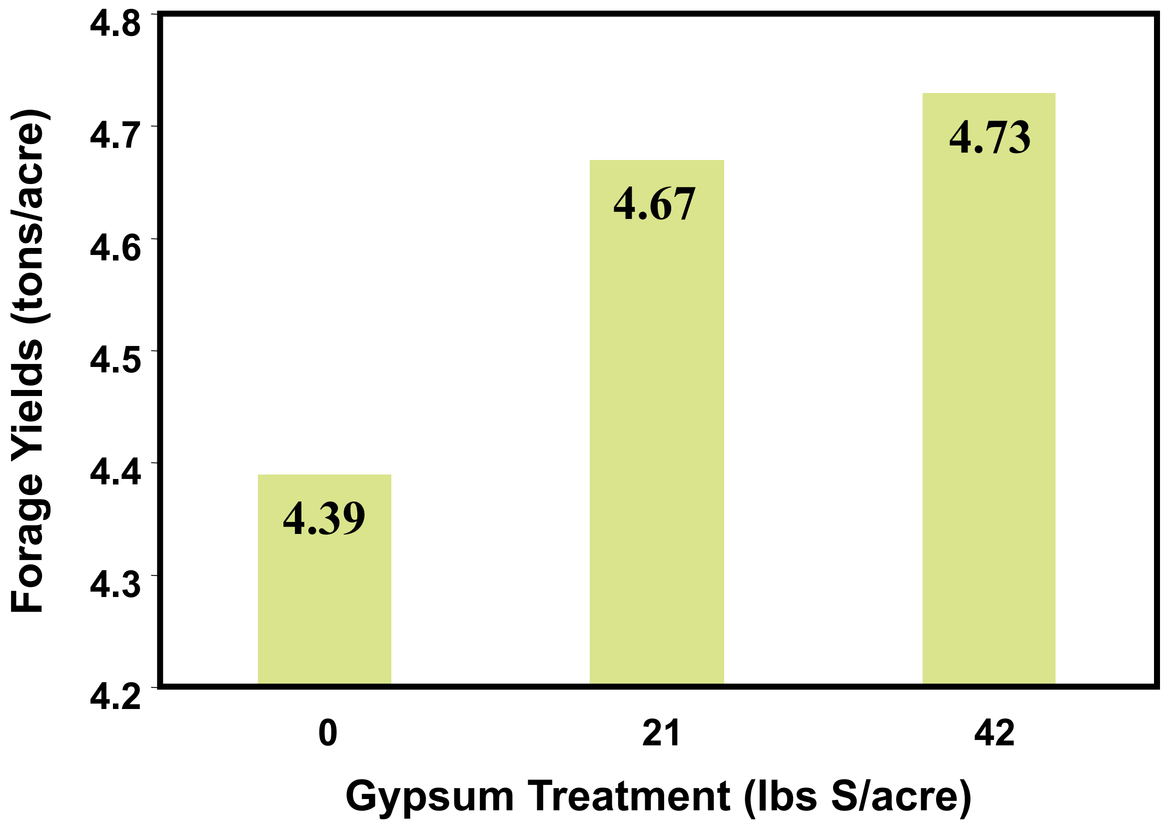


Forages (Subsoil Acidity)



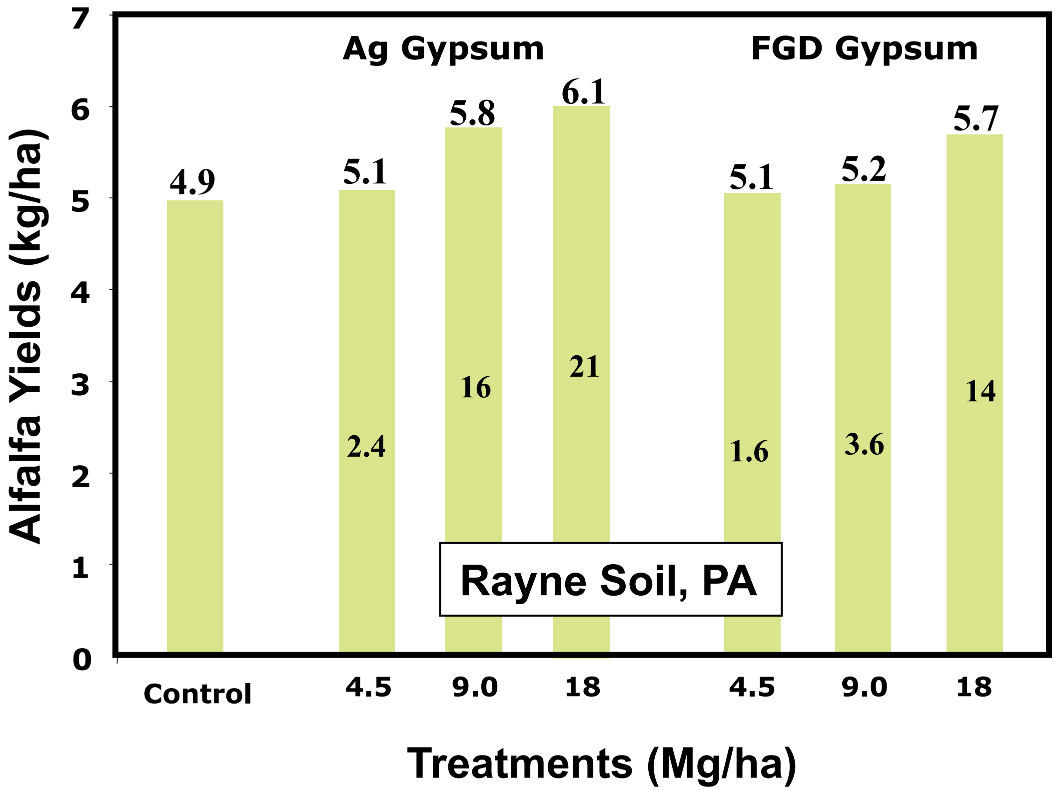
(Black and Cameron, *New Zealand J. Agric. Res.* 27:195-200, 1984)

Corn Silage (Sulfur Nutrition)



(Kless et al., *Grass and Forage Science*, 44:277-281, 1989)

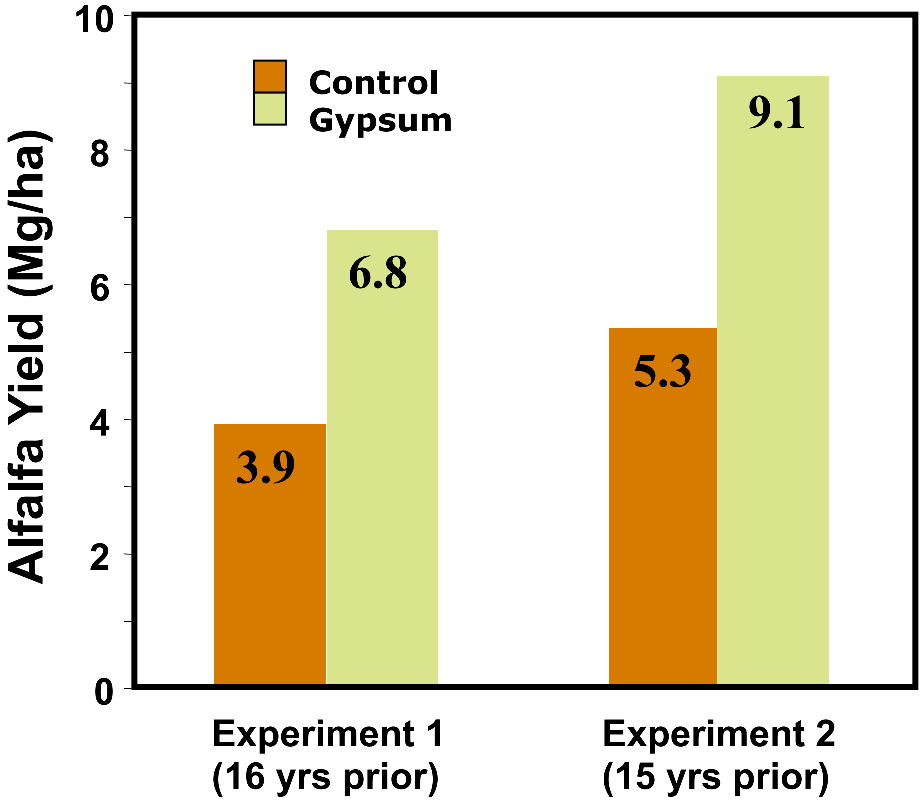
Forages (Comparison of Gypsum Sources)



Soluble Al content in the 45-60 cm soil layer was decreased 43% by treatment regardless of gypsum source.

Stout and Priddy, *Commun. Soil Sci. Plant Anal.*, 27:2419-2432, 1996)

Forages (Long-Term Effect)



Toma et al., *Soil Sci. Soc. Am. J.*, 39:891-895, 1999)

Forages (Subsoil Acidity)

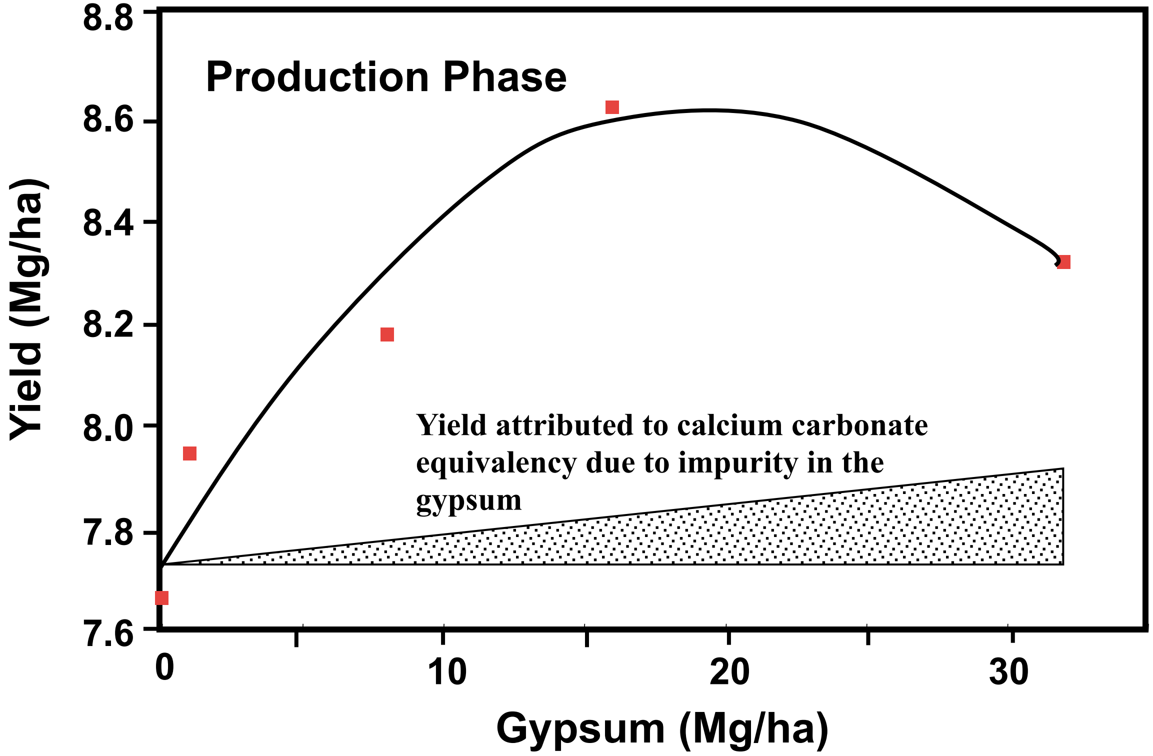
Achievements in management and utilization of southern grasslands

CARL S. HOVELAND

J. Range Manage. 53:17-22 January 2000

Grasslands in the humid southern USA are utilized primarily for grazing on improved pastures, most of which were developed since the 1930s and 1940s. Future areas of emphasis in improvement of these grasslands may include: (a) greater use of grazing-tolerant grasses and legumes; (b) stress-tolerant tall fescue with "friendly" non-toxic endophytes; (c) feed antidotes to the toxins of endophyte-infected tall fescue; (d) use of herbicide-and pest-resistant biotechnology genes in forage plants; **(e) use of gypsum to alleviate subsoil acidity and improve rooting depth of aluminum-sensitive forage cultivars;** (f) greater use of computers in information access and decision making by livestock producers; (g) greater use of forages for wildlife food; (h) breeding of pasture plants with greater winter productivity; (i) development of a perennial grass biomass energy industry for electrical generation and liquid fuel production.

Forages (Subsoil Acidity)



(Ritchey and Snuffer, *Agron. J.*, 94:830–839 (2002)

Conclusions

- The scientific literature contains numerous examples of corn grain yield and forage yield benefits associated with use of gypsum.
- Benefits for corn and forages seem to be mostly associated with increased sulfur nutrition and reduced subsoil acidity.
- Treating sodic soils with gypsum increases productivity of the soil for crop production.
- Benefits of gypsum use may persist for several years after application to soil.
- Inappropriate use of high rates of gypsum can decrease yield (due to nutrient imbalances).

Development of Network for FGD Gypsum Use in Agriculture

Workshop

Research and Demonstration of Agricultural Uses of Gypsum and Other FGD Materials

November 17-19, 2009
Indianapolis, IN

http://www.oardc.ohio-state.edu/agriculturalfgdnetwork

Workshop sponsored by:

Combustion ByProducts Recycling Consortium (CBRC)

Electric Power Research Institute (EPRI)

The Ohio State University

U.S. Department of Energy/National Energy Technology Laboratory

November 4 (afternoon), Pittsburgh, PA
https://www.acsmeetings.org/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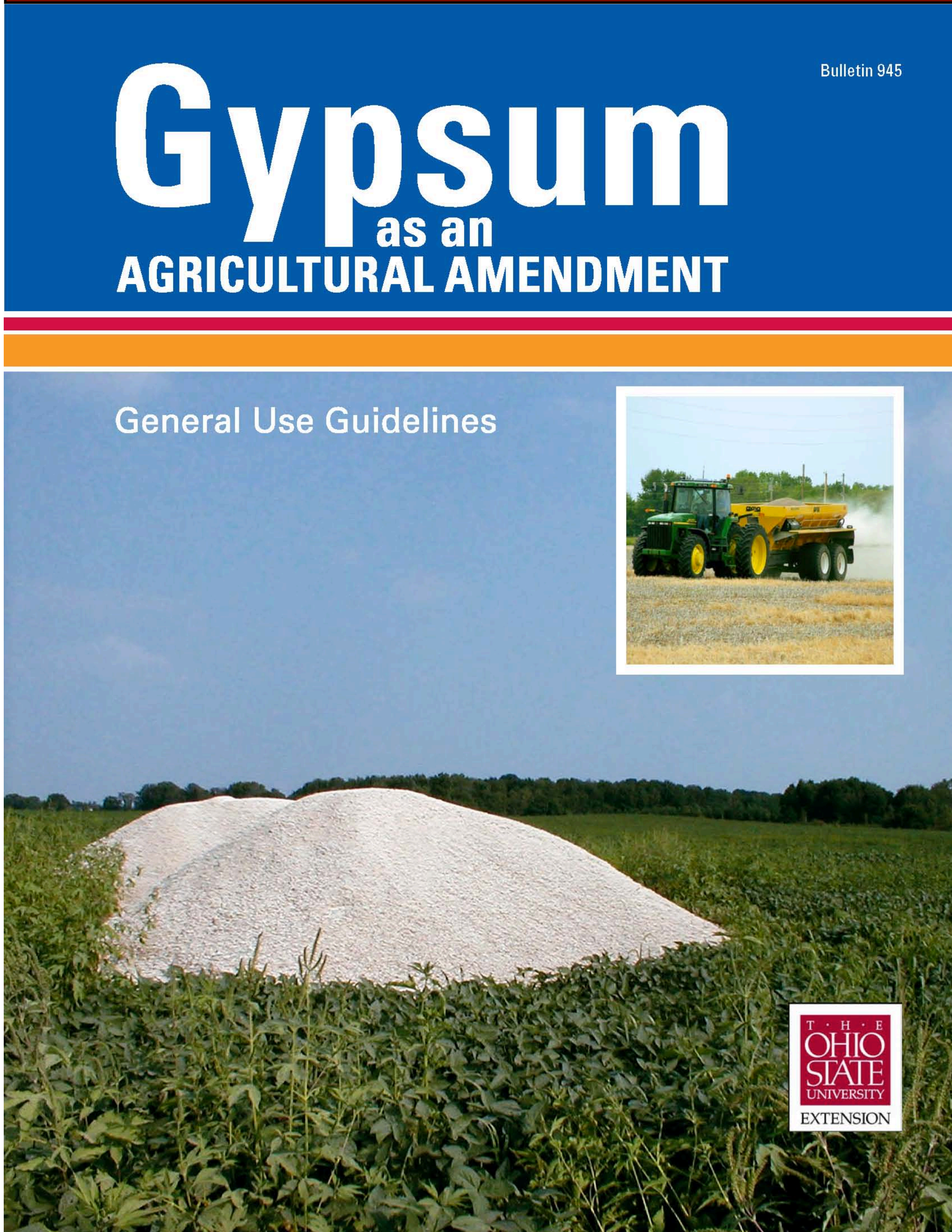

http://ohioline.osu.edu/b945/b945.pdf

Increasing National Interest at the Scientific Level

From: Ann Wolf <amw2@psu.edu>
Date: December 6, 2010 1:24:18 PM EST
To: sssa_s4s8@acs-net.soils.org
Subject: **2011 S8 Symposia Topics**

To: S4/S8 members (Soil Fertility and Plant Nutrition/Soil Management and Soil & Plant Analysis)

Thanks to all of you who provided input on symposia topics for the 2011 annual meeting. Based on the feedback provided, S8 will be sponsoring the two symposia listed below. Ann Wolf (S8 Division Chair)

NOTE: One related to sulfur is shown below.

Development of Soil-Test Based Recommendations: Historical Perspectives, Current Issues and Future Directions

Can Sulfur Still Be Ignored? Crop Responses, New Management Strategies, and Improved Methods for Assessing Sulfur Needs

Organizer: John Kovar (john.kovar@ars.usda.gov) ; Co-sponsored with the Canadian Soil Science Society

During the past ten years, sulfur deficiencies and crop responses to sulfur fertilizer have been reported with increasing frequency worldwide. This symposium will focus on crop species and soils most vulnerable to sulfur problems in today's high-yield production systems, new strategies for managing sulfur inputs, and recent improvements in assessing sulfur availability and crop sulfur status.

Increasing National Interest at the Scientific Level

Browse by Division of Interest

ASA Section: Environmental Quality

Oral Session Advances In Bioremediation and Ecosystem Restoration: I
Organizers: Bob Hubbard, Mimi Williams, Robert Hubbard and Mimi J. Williams

Poster Session Advances In Bioremediation and Ecosystem Restoration: II
Organizers: Robert Hubbard and Mimi Williams

Oral Session Advances In GIS Application: Environmental Monitoring/Assessment and Resource Management
Organizers: Cecil Dharmasri and Cecil Dharmasri

Oral Session Biochar: Environmental Uses
Organizers: James Ippolito, Kurt Spokas, James Ippolito and Kurt Spokas

Oral Session General Environmental Quality: I
Organizers:

Poster Session General Environmental Quality: II
Organizers:

Oral Session Gypsum Use - Agricultural Productivity: I
Organizers: Dexter Watts

Poster Session Gypsum Use - Agricultural Productivity: II
Organizers: Dexter Watts

Oral Session Gypsum Use - Soil and Water Quality: I
Organizers: Dexter Watts

Poster Session Gypsum Use - Soil and Water Quality: II
Organizers: Dexter Watts

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.

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

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)

Increasing National Interest at the Scientific Level

From: [redacted]
Date: August 2, 2011 4:09:27 PM EDT
To: Warren Dick <dick.5@osu.edu>
Subject: Re: Gypsum

Thanks for the information. I sent [redacted] an email to schedule a meeting with him.

Also, on our call for Thursday we would like to discuss how we figure how many tons per acre need to be applied. Our consulting company develops a lot of Nutrient Management Plans, we take the soil test with the manure analysis and establish the application rate through spreadsheets that we have developed. We would like to establish a similar process to show how many tons of gypsum should be applied to a cropfield, soil type, projected yield goal, gypsum analysis and soil test. We will have to document this type of information back to the regulatory authorities here in [redacted].

Let me know your thoughts. Thanks.

THANK YOU!