3rd Annual

Midwest Soil Improvement Symposium: 2013

Research and Practical Insights into Using Gypsum

March 7, 2013

Gypsum: Some Things Old and Some Things New

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THE OHIO STATE UNIVERSITY

GYPSOIL™ BRAND GYPSUM

CTIC CONSERVATION TECHNOLOGY INFORMATION CENTER

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

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.

Early History

History of the Use of Agricultural Gypsum. 1922. Gypsum Industries Association, Chicago, IL (p. 7-36)

I. The Early Use of Gypsum as a Fertilizer

II. Recent Studies on the Function and Quantity of Calcium and Sulphur in Crops and and the Supply of Sulphur in our Agricultural Soils.

III. Calcium in the Nutrition of Plants

Early History

History of the Use of Agricultural Gypsum. 1922. Gypsum Industries Association, Chicago, IL (p. 7-36)

IV. Gypsum as a Stimulant

V. Gypsum as Specific for Black Alkali

VI. Gypsum as a Preserver of Manure

VII. Effect of Gypsum on the Nitrogen Available for Crops

VIII. Gypsum Not a Substitute for Agricultural Lime

History of Gypsum in Agriculture

- Two names in gypsum research during the early days of the United States
  - Judge Richard Peters (Philadelphia)
  - John Binns (Loudon County, Virginia)
- Other important names are Benjamin Franklin, Robert R. Livingston and Edmund Ruffin

History of Gypsum in Agriculture

Gypsum as a Preserver of Nitrogen – In pioneering work by Heiden:

"Gypsum has great power in preserving the volatile nature of manure. It does this in large part by transforming the volatile ammonium carbonate into the non-volatile ammonium sulfate with the formation of calcium carbonate."

Further work on this topic was done by Ames and Richmond at The Ohio State Agricultural Experiment Station (Soil Science, 4:78-89, 1917). Using gypsum to preserve nitrogen for a 20 cow herd could provide $152 benefit in one year.

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.

Gypsum Sources

- Mined Gypsum
- FGD gypsum - 24% of total U.S. gypsum in 2005
- Phosphogypsum – phosphoric acid production
  - 4.5 tons gypsum for each ton of phosphoric acid produced
- Titanogypsum – TiO_2 production
- Citrogypsum – citric acid production
- Biotech gypsum

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

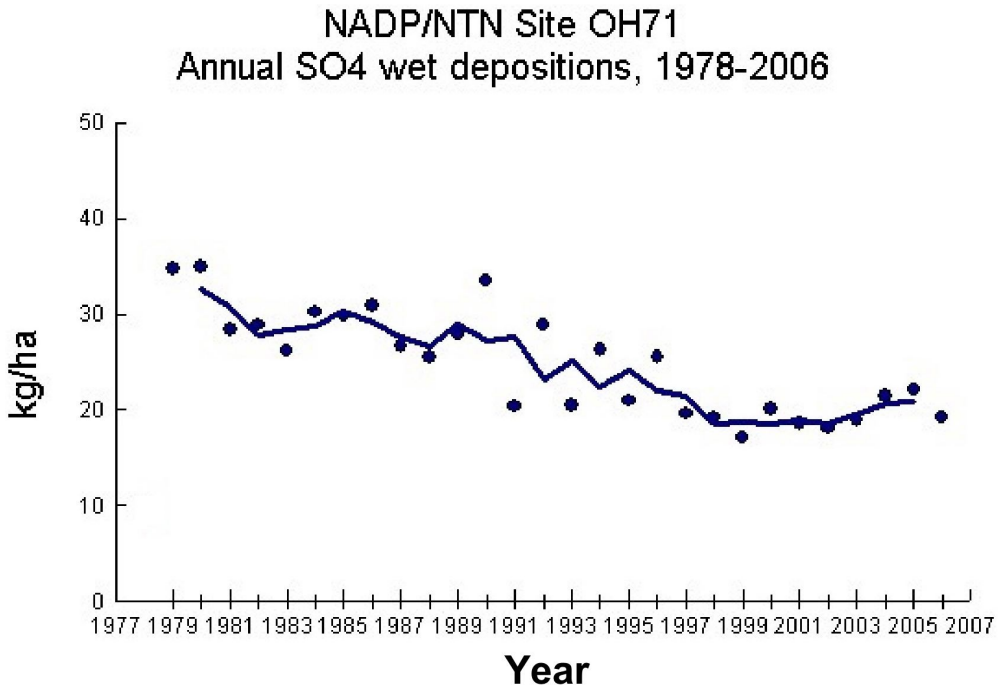
- Amino acids methionine and cysteine
  - Proteins
  - Precursors of other sulfur-containing compounds
- Sulfolipids (fatty compounds) in membranes, especially chloroplast membranes
- Nitrogen-fixing enzyme (nitrogenase)
  - 28 S atoms in active site

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 sulfate deposition
  - 34 kg/ha in 1971 (10 lb S/A)
  - 19 kg/ha from 2000 onward (5.7 lb S/A)

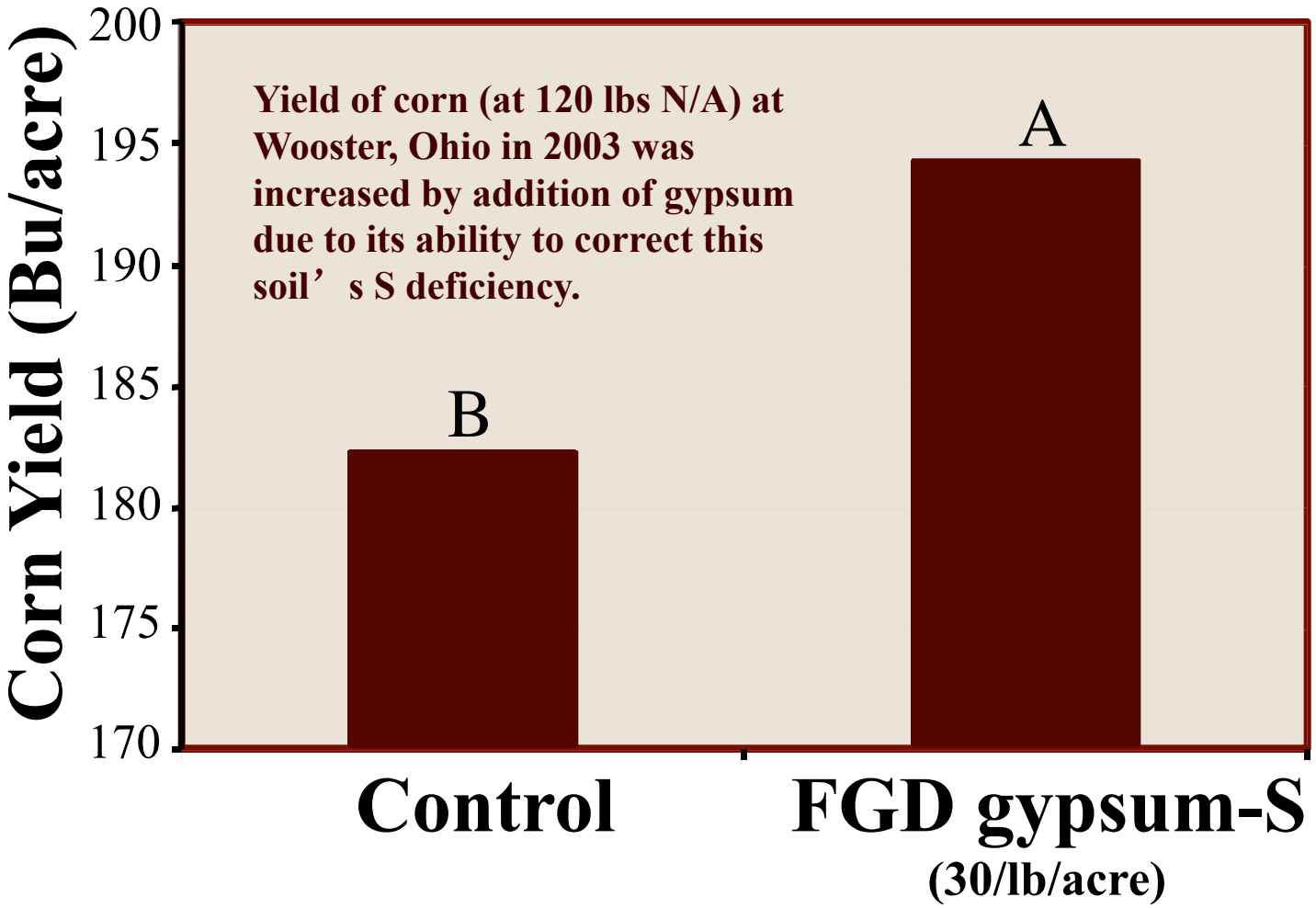


Calcium in Plant Physiology

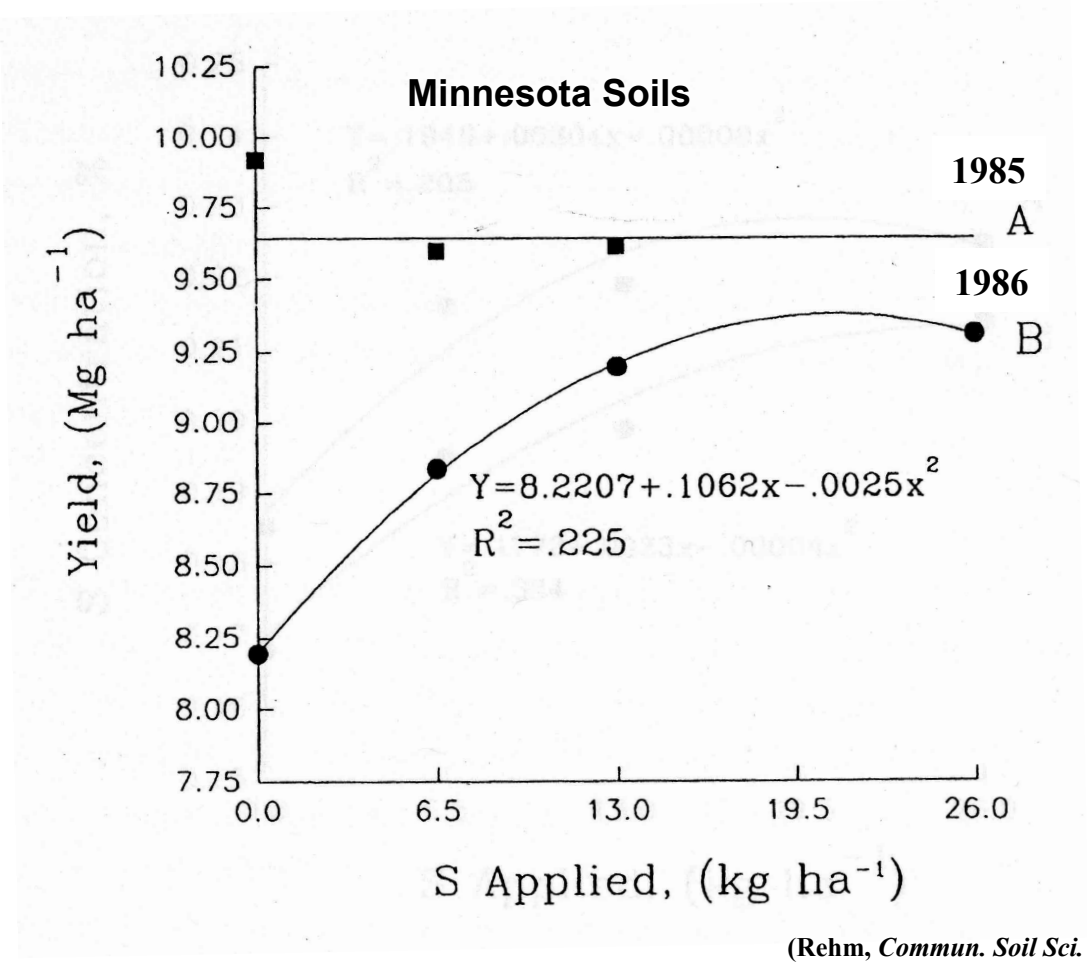
- Required for proper functioning of cell membranes and cell walls
- Needed in large amounts at tips of growing roots and shoots and in developing fruits
- Relatively little Ca is transported in phloem
  - Ca needed by root tips comes from soil solution

Corn Production and Gypsum

Corn Yields in 2003 (Wooster, Ohio)



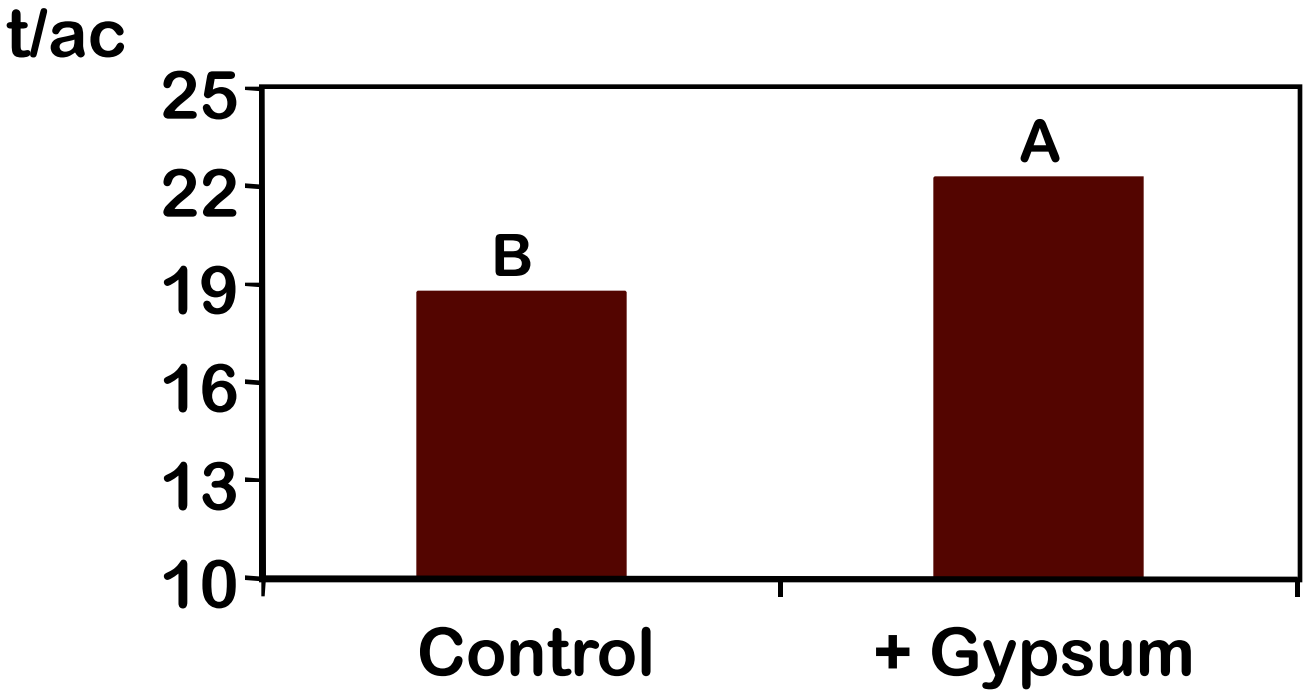
Corn (Sulfur Nutrition)



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

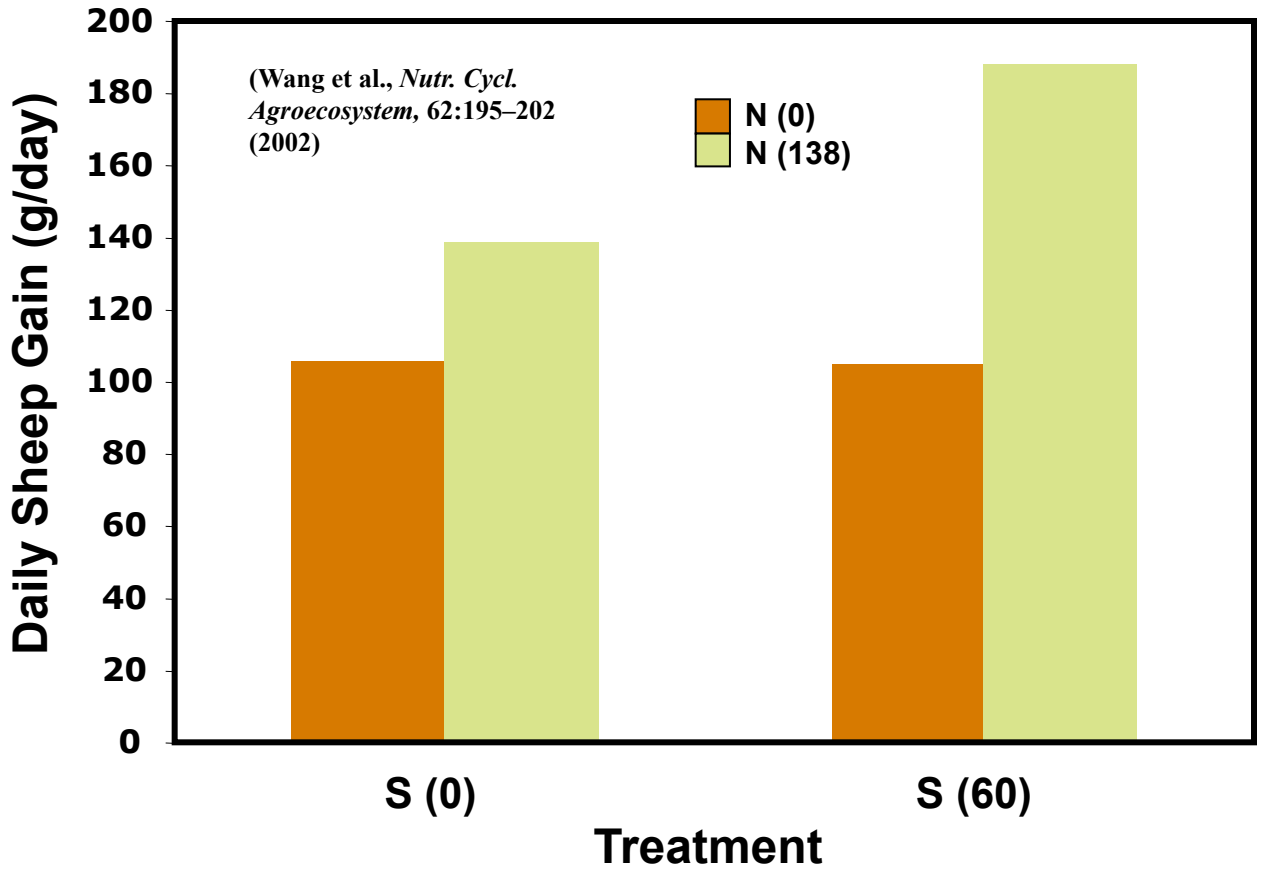
Forages Production and Gypsum

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



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

Forage Quality and Fertilizer N Interaction

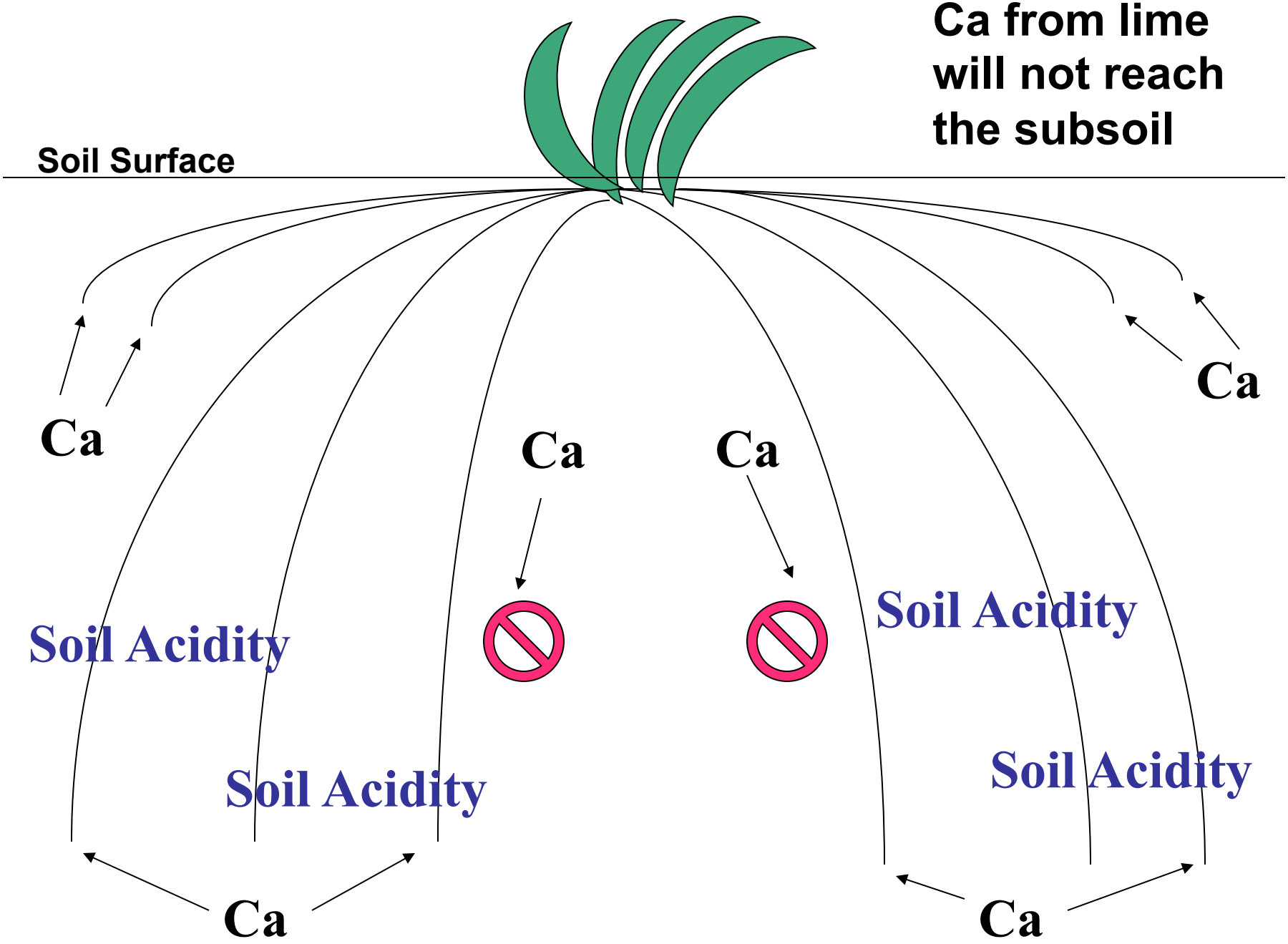


Benefit #2

- 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

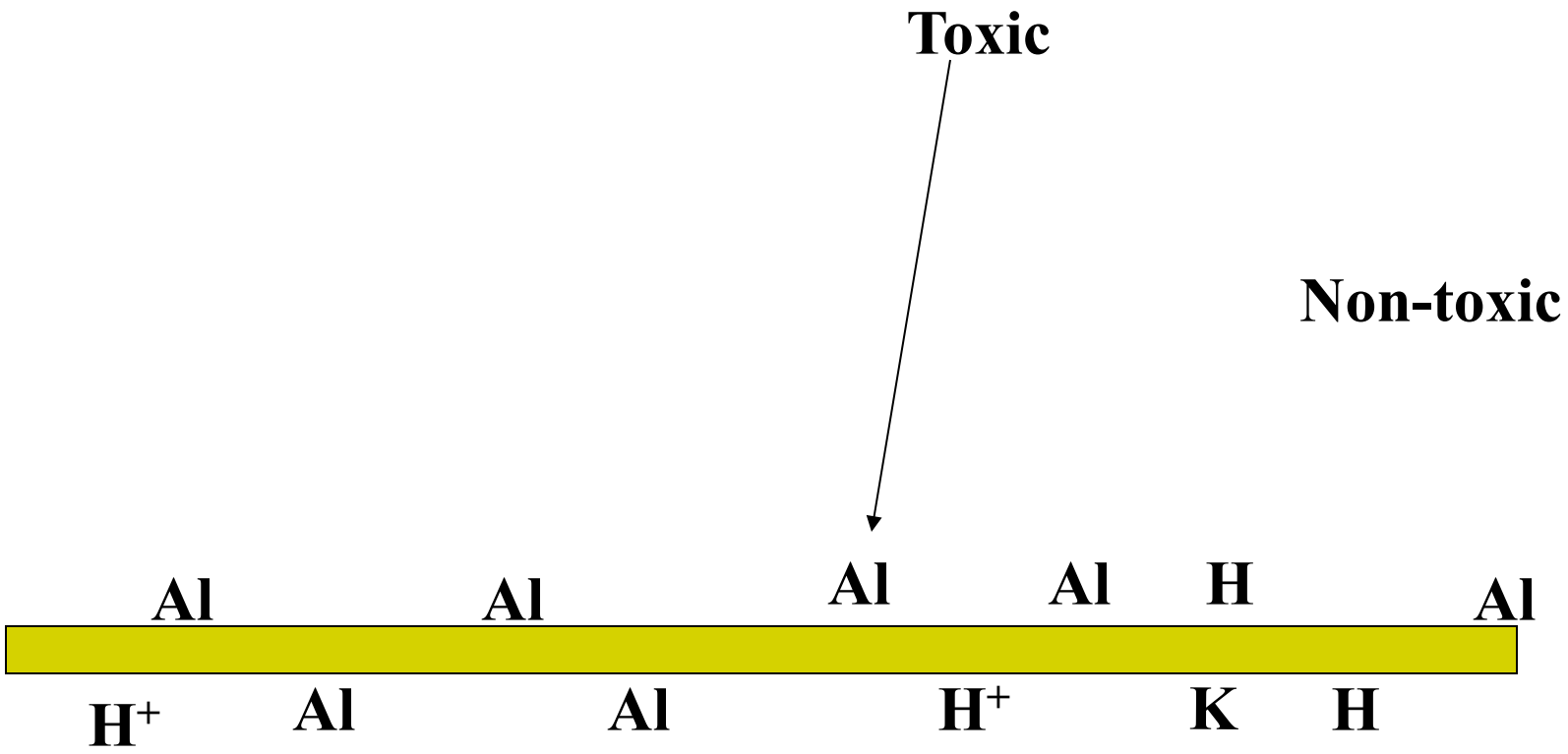
Amelioration of Subsoil Acidity and Al^{3+} Toxicity

- 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

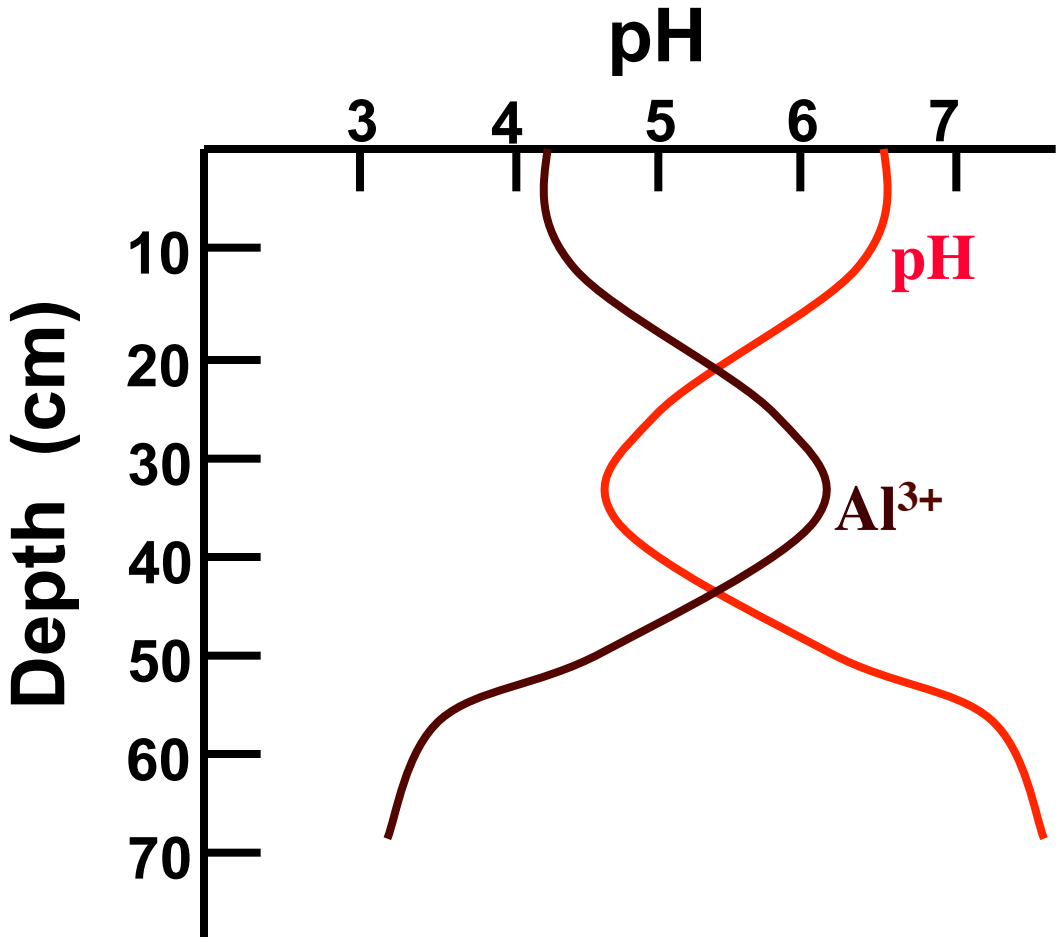
Gypsum applied to surface of soil with acidic subsoil

SO4 Ca Ca Ca SO4 Ca



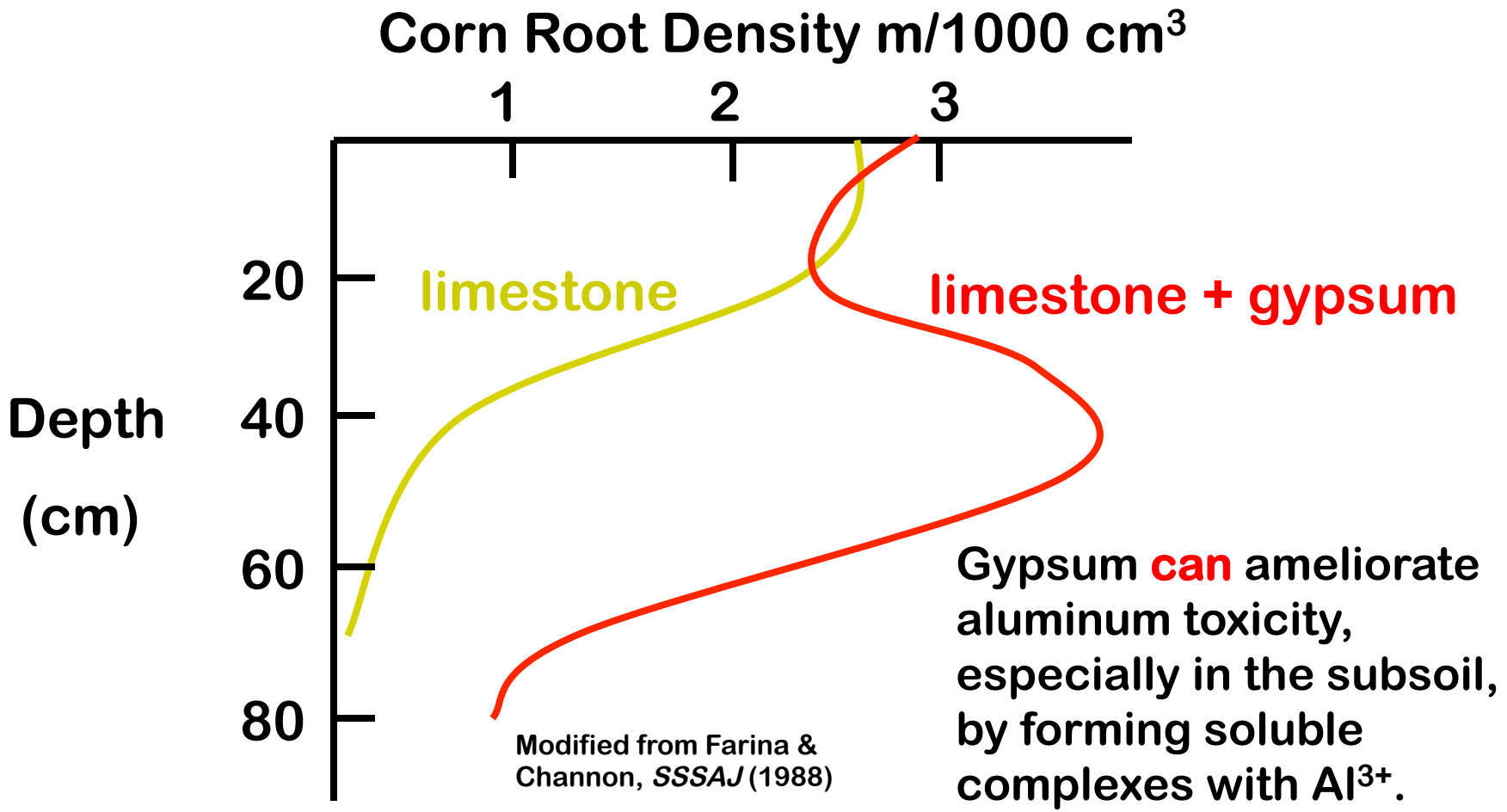
Clay platelet in subsoil

Typical pH profile for a Blount soil



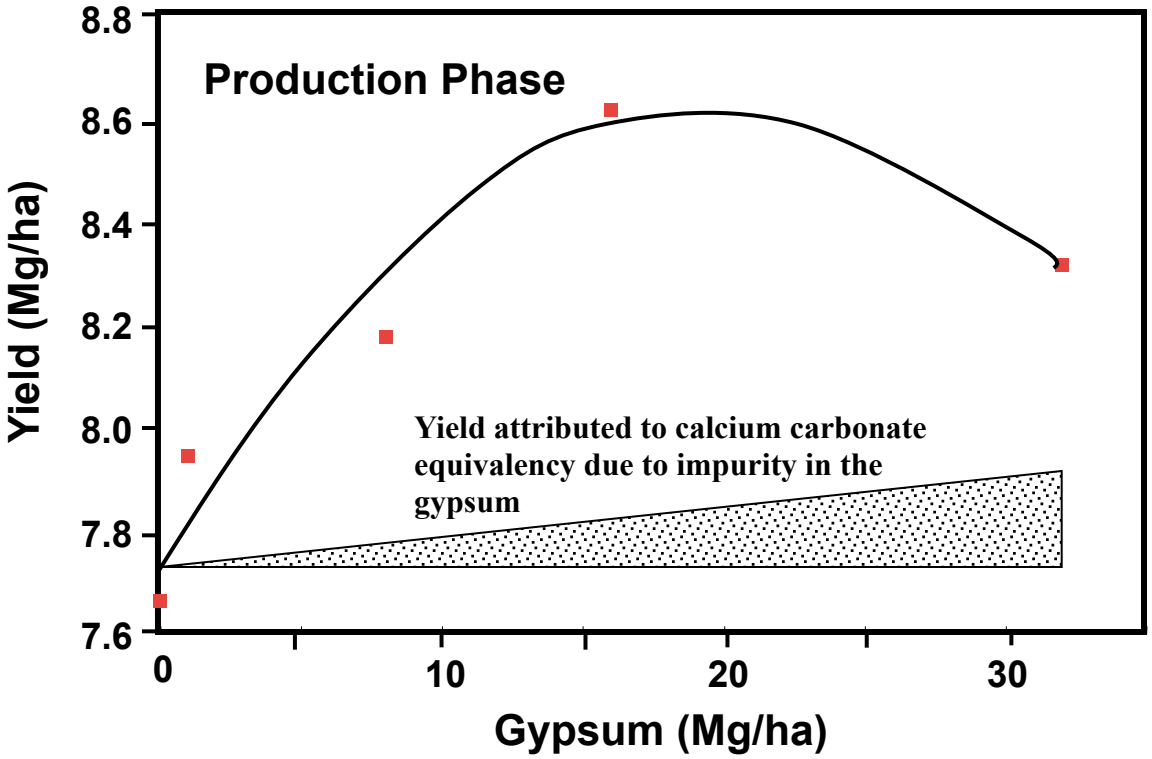
$$CaSO_4 + Al^{3+} \longrightarrow Al(SO_4)^{+} + Ca^{2+}$$

(toxic) (non-toxic)



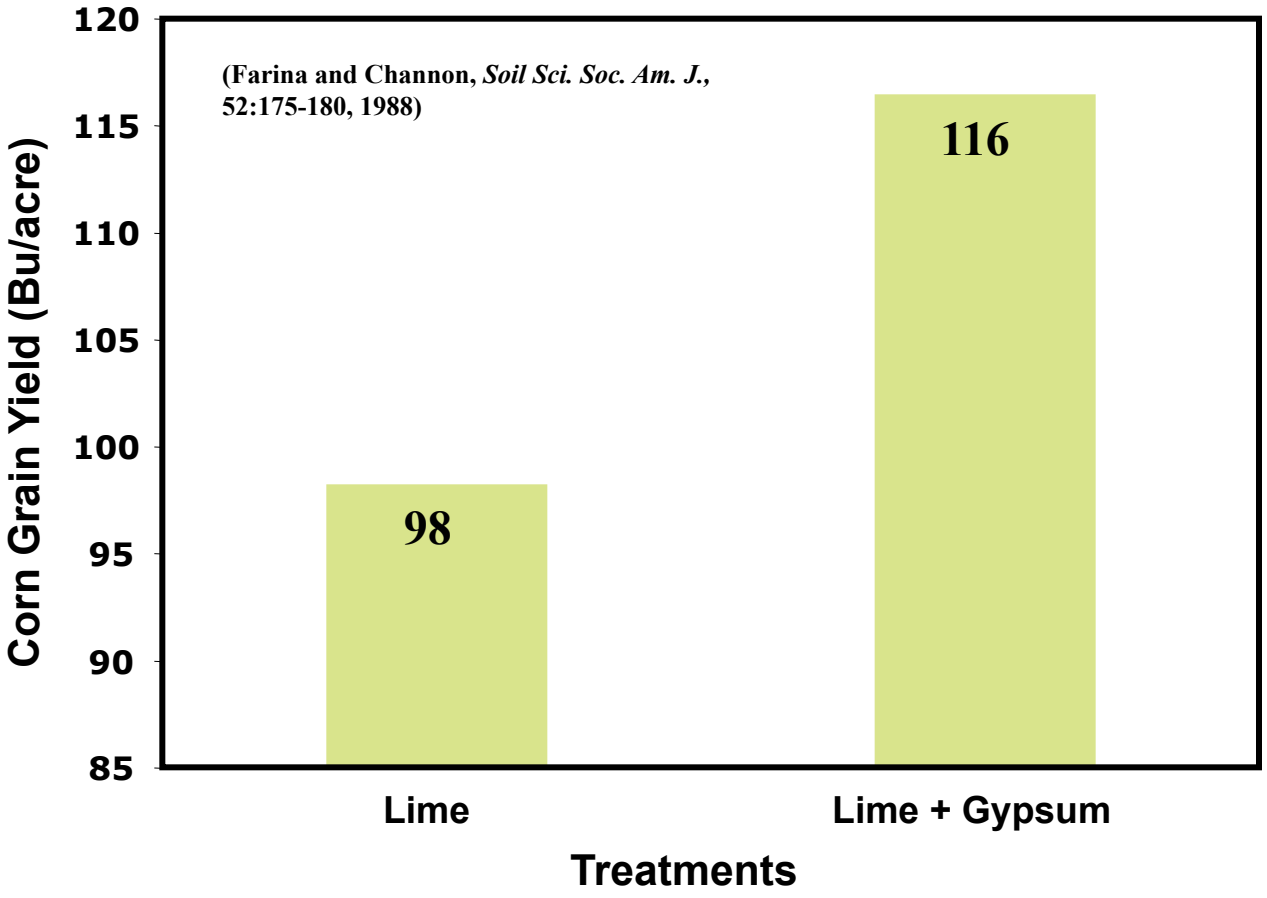
Gypsum **can** ameliorate aluminum toxicity, especially in the subsoil, by forming soluble complexes with Al^{3+}.

Forages (Subsoil Acidity)

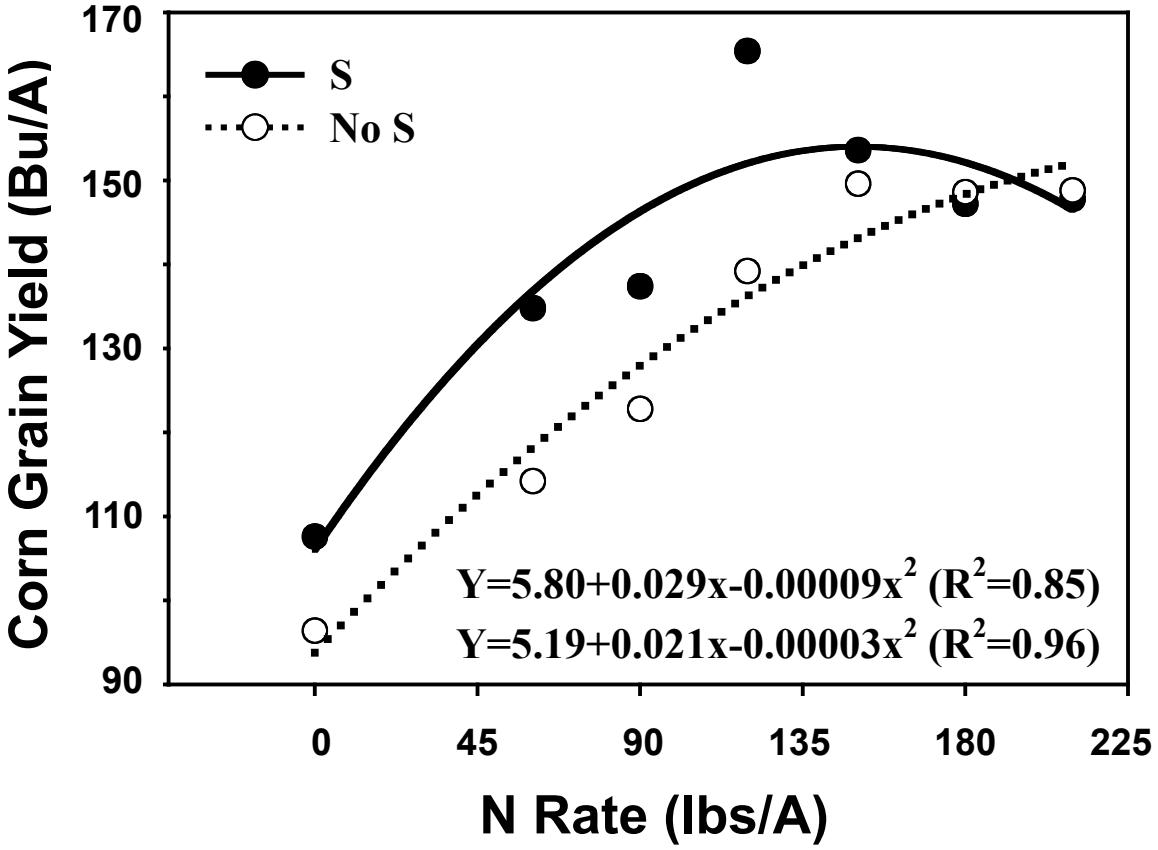


(Ritchey and Snuffer, *Agron. J.*, 94:830–839 (2002)

Increased Root Growth into Subsoil



Average Corn Yields from 2002 to 2005 (Ohio)



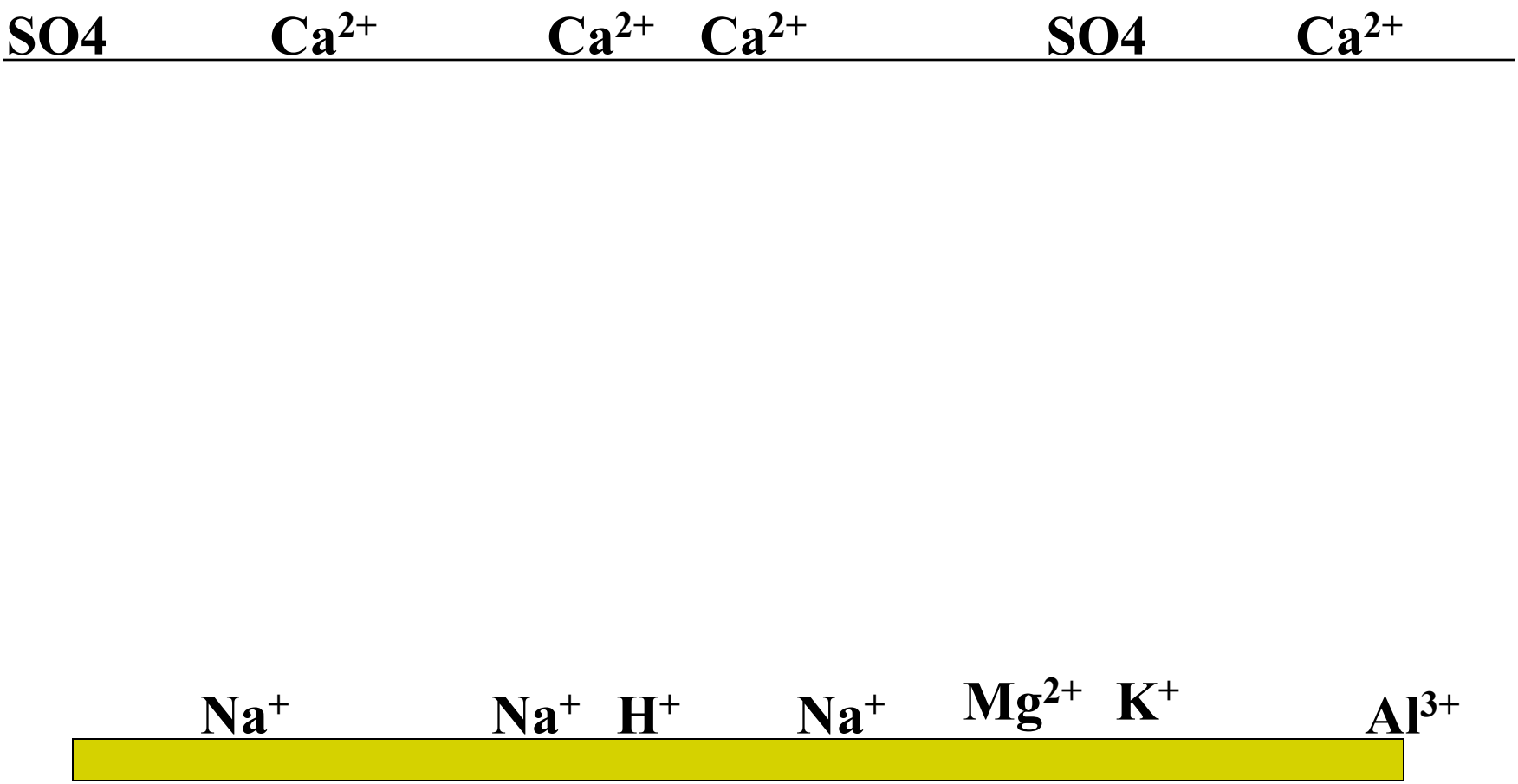
Increased Root Growth into Subsoil

- 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**

Gypsum applied to surface of sodic soil

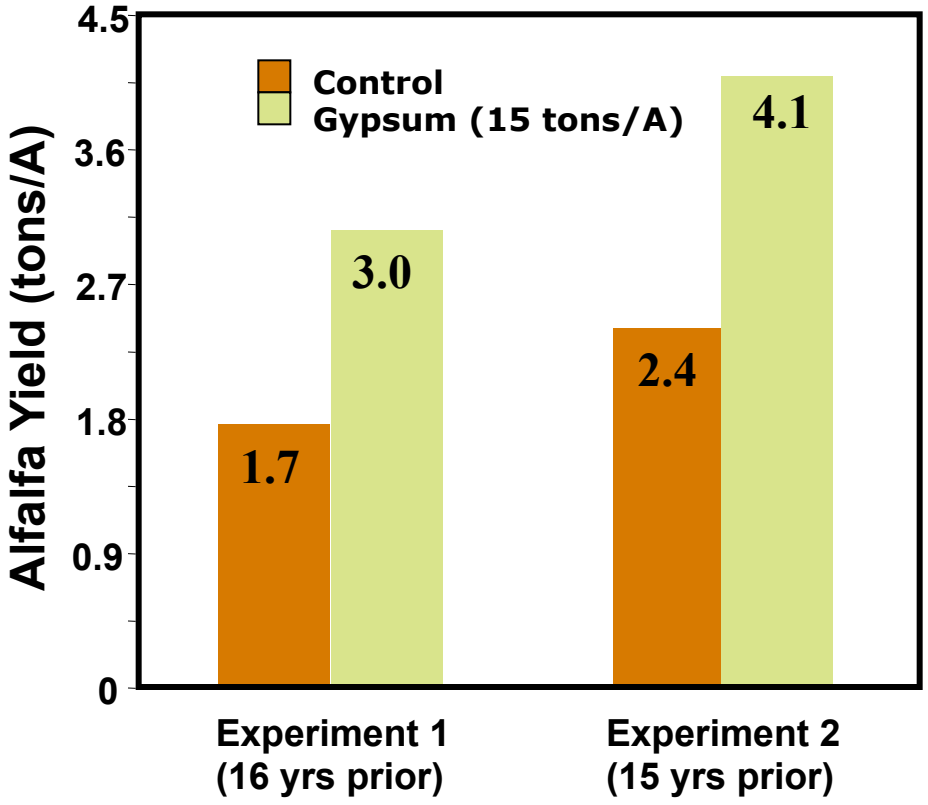


Clay platelet in sodic soil

Gypsum and Sodic Soil Reclamation in China

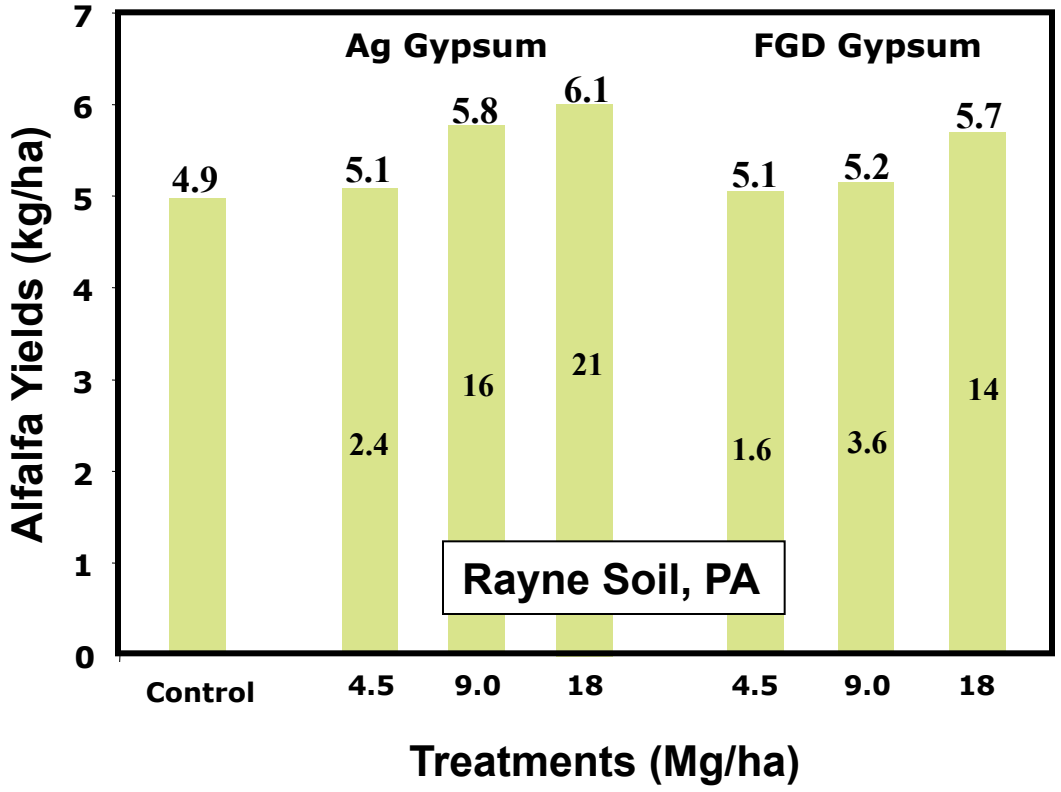
Comparison of field with (background) and without (foreground) FGD by-product gypsum

Forages (Long-Term Effect)



Toma et al., *Soil Sci. Soc. Am. J.*, 63:891-895, 1999)

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 (Gypsum from Wallboard)

- A study in Wisconsin using wallboard gypsum (16 tons/acre) showed a positive trend for increased yield of alfalfa at three of four locations (Wolkowski, Commun Soil Sci. Plant Anal., 31:187-199, 2000)

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)

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


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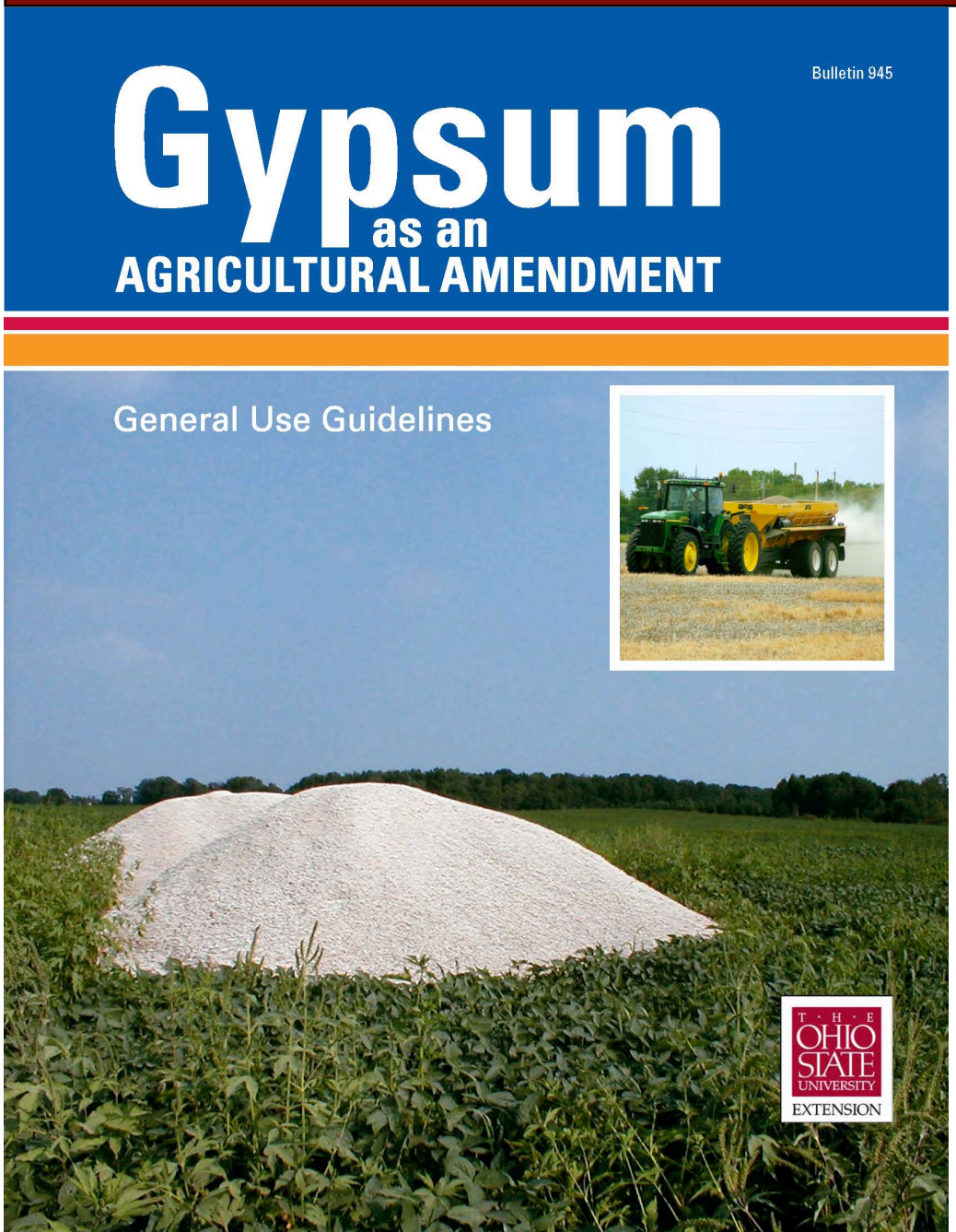

http://ohioline.osu.edu/b945/b945.pdf

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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

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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!