4th Annual
Midwest Soil Improvement Symposium:
2014
Research and Practical Insights into Using Gypsum

Gypsum Effects on Soil Particles and Physical Characteristics plus Potential Impact on the Environment

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National Soil Erosion Research Laboratory
(Retired)

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GYPSOIL | KARA

GYPSUM EFFECTS ON SOIL PARTICLES AND PHYSICAL CHARACTERISTICS PLUS POTENTIAL IMPACT ON THE ENVIRONMENT

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APOLLO 13 PHOTO-NASA

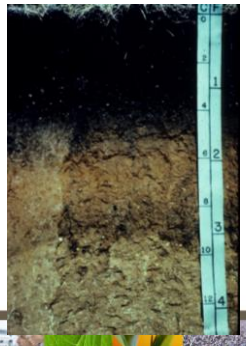
Air-water balance is the single most important factor limiting agricultural production in the U.S.

According to a study by Mittler (2006), the top two causes of economic loss to U.S. agriculture between 1980 and 2004 (major events of $1B loss or more) were:

1. Combined heat and drought stress ($130B)
2. Flooding and water-logging ($50B)

Courtesy of Dr. Jerry Bigham

QUALITY SOIL WITH HIGH PRODUCTIVITY

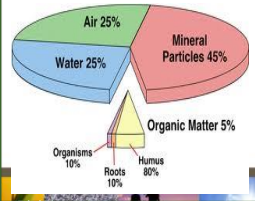


Soil Physical Properties

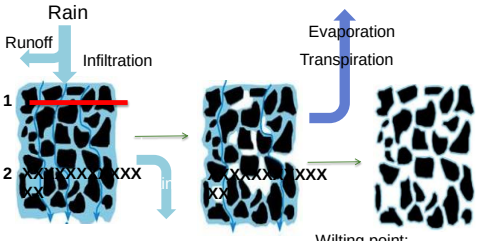
Some are invariant

Others are sensitive to

- Structure (Type, Size, Stability)
- Porosity (Amount, Size, Continuity)



Courtesy of Dr. Jerry Bigham



Saturated soil: All pores filled

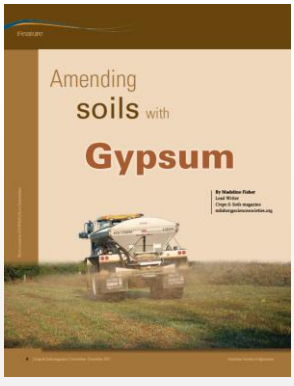
Field capacity: Abt ½ pores filled

Wilting point: Plants can't extract remaining water

The soil's available **water supplying capacity** is approximately the difference in water content between field capacity and the permanent wilting point.

Courtesy of Dr. Jerry Bigham

American Society of Agronomy Discovers Gypsum 2011



TOP TEN REASONS TO USE GYPSUM

from Wallace and Wallace, CSSPA. 1994

- Improve Soil Physical Properties in Relation to Water
- Improve Soil Chemical Properties
- Improve Soil Microbiological and Biogeochemical Environment
- Increase Plant Root Volume and Surface Area
- Provide a Soluble source of Ca for Plants
- Provide a Soluble source of S for Plants
- Prevent loss of Important Nutrients
- Make other Nutrients more Available
- Stabilize Organic Carbon in Soil
- Reduce Greenhouse Gas Emissions

SOURCES OF GYPSUM

CLEAN AIR ACT 1963

- 1970 EPA Created with enforcement mandate
- 1977 amended to require new coal-fired plants constructed install scrubbers to meet air quality standards (Older Gypsum mixed with Fly Ash)
- 1990 amended to require even older plants reduce air pollution (Modern FGD Gyspum of Wallboard Quality)
- 2000 EPA rule proposed to make CCP's toxic wastes – defeated
- 2010 EPA rule proposed to make CCP's toxic wastes - unknown

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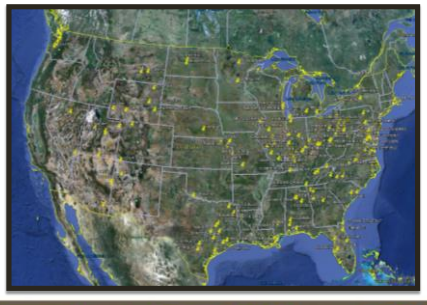
COAL FIRED POWER PLANTS WITH WET SCRUBBING



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SOLUBLE Ca ELECTROLYTE SOURCES

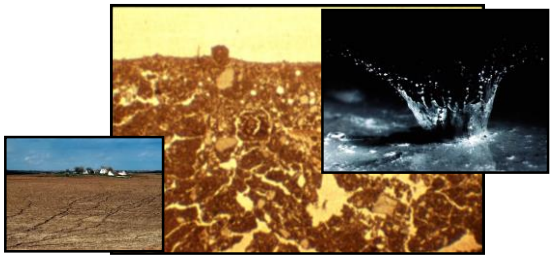
- Calcite ($CaCO_3$) 0.14 g/L
- Phosphogypsum (Gypsum + Phosphate)
- Gypsum ($CaSO_4 \cdot 2H_2O$) 2.41
- Anhydrite ($CaSO_4$) 2.09
- Calcium Chloride 745

RAINWATER IS NATURAL DISTILLED AND LOW IN ELECTROLYTES

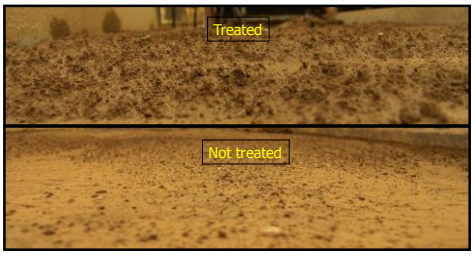
Demonstration of Electrolyte (Salt) Effect on Dispersion and Strength

Courtesy of Dr. Jerry Bigham

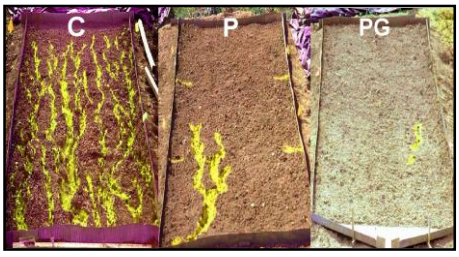
RAINDROP IMPACT AND DISPERSION LEADS TO SURFACE SEALING



AGGREGATE STABILIZATION



EFFECT OF GYPSUM AND PAM ON SOIL EROSION BY CONCENTRATED FLOW ON STEEP ROAD CONSTRUCTION SLOPES 2/1

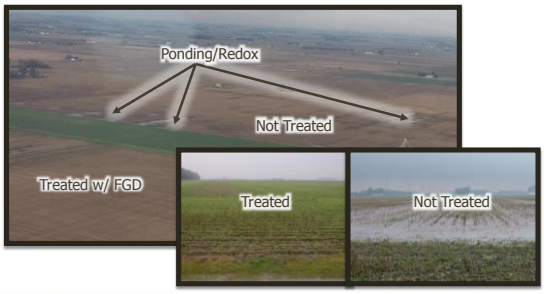


DETACHMENT BY FLOW REDUCED BY GYPSUM+PAM

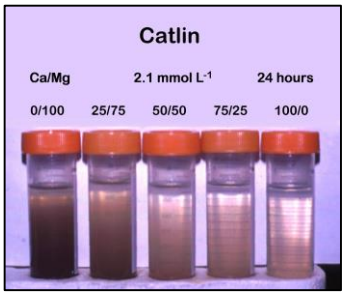
Treated vs Not treated

IMPROVES SOIL STRUCTURE

IMPROVED INFILTRATION/DRAINAGE BY AMENDING SOIL IN CONVOY OHIO



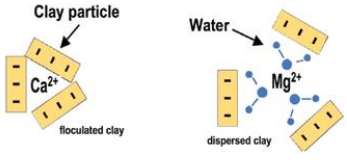
Ca EFFECT ON DISPERSION/ FLOCCULATION



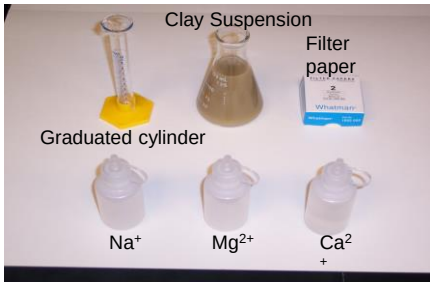
CLAY DISPERSION

- Soil is composed of Skeletal Grains of Sand and Silt plus plasmic materials (colloids) of Clay and Organic Matter
- Sand and silt give mass and bulk to the soil whereas Clay and Organic Matter give in chemical reactivity, water holding capacity and structure.
- Once these colloids disperse the soil structure is destroyed and water and oxygen have difficulty penetrating the soil if there is any appreciable amount of colloids (>3%).

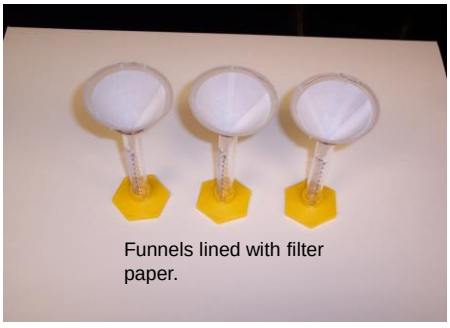
Soil dispersion is mainly caused by highly hydrated ions, such as Na^+ or Mg^{2+}, attracted to the surface of clay particles



Flocculation/Dispersion Demonstration



Courtesy of Dr. Jerry Bigham



Funnels lined with filter paper.

Clay suspension added to funnels. Time = 0 minutes.

Courtesy of Dr. Jerry Bigham

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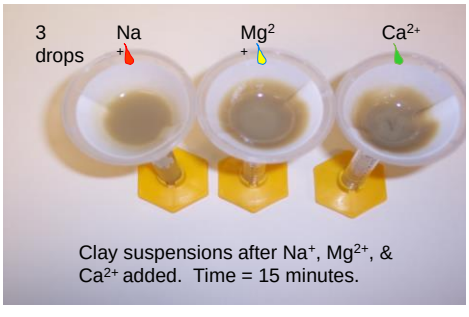
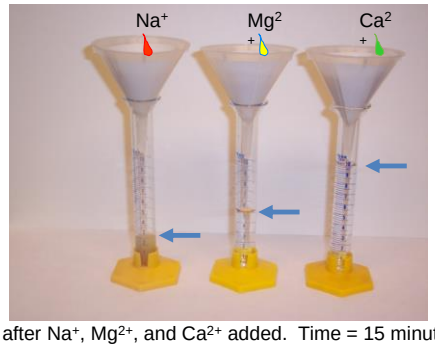


Clay suspensions after Na^+, Mg^{2+}, & Ca^{2+} added. Time = 15 minutes.

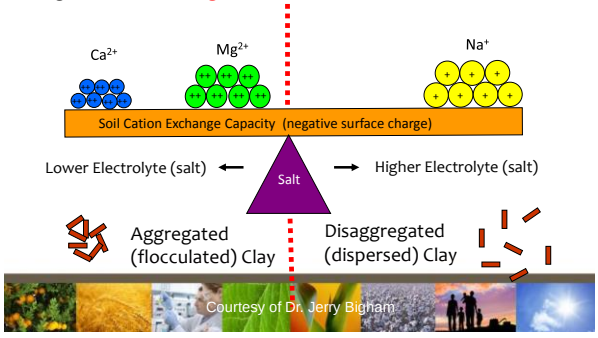


Filtrates after Na^+, Mg^{2+}, and Ca^{2+} added. Time = 15 minutes.

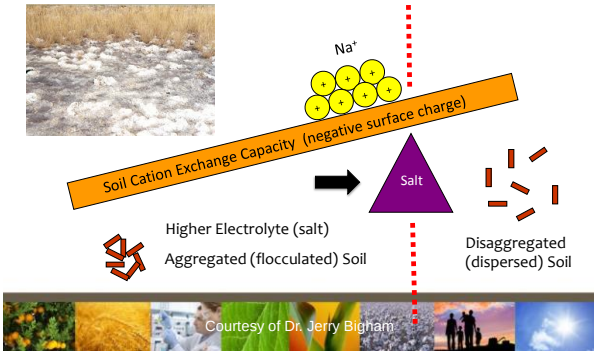
Courtesy of Dr. Jerry Bigham

Courtesy of Dr. Jerry Bigham

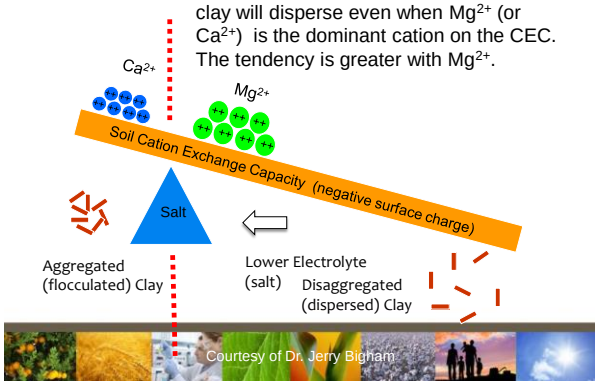
Clay dispersion depends on the balance between exch. Ca^{2+}, Mg^{2+} and Na^{+} as well as the amount of total electrolyte (salt) in the soil solution. Exchangeable Ca^{2+} is a good aggregating (flocculating) agent; Na^{+} is not; **Mg^{2+} is intermediate.**



If the electrolyte (salt) content of the soil solution is increased sufficiently, the soil clay will flocculate even when Na^{+} is the dominant cation on the CEC.



If the electrolyte (salt) content of the soil solution is decreased sufficiently, the soil clay will disperse even when Mg^{2+} (or Ca^{2+}) is the dominant cation on the CEC. The tendency is greater with Mg^{2+}.

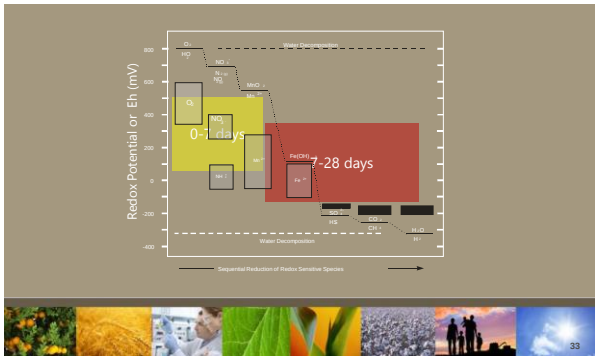


Sequence for microbially mediated reduction in the soil environment

Element	Oxidized	Reduced	Eh
Oxygen	O_2	H_2O	320 to 380
Nitrogen	NO_3^-	NO_2^-, NO, N_2O, N_2, NH_3	220 to 280
Manganese	MnO_2	Mn^{2+}	180 to 220
Iron	Fe_2O_3	Fe^{2+}	80 to 110
Sulfur	SO_4^{2-}	H_2S	-170 to -140
Carbon	CO_2	CH_4	-280 to -200

Data from Patrick and Jugsulinda. 1992. Soil Sci. Soc. Am. J. 56:1071-73.

REDUCTION SENSITIVE COMPOUNDS



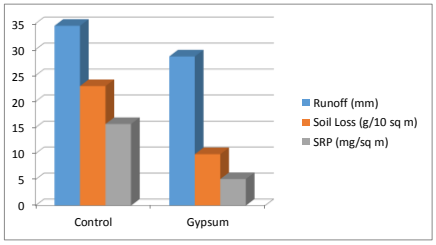
IMPROVED N USE EFFICIENCY

GLOBAL WARMING POTENTIAL GHGS FROM USEPA

Type of GHG	GWP
Carbon dioxide (CO_2)	1
Methane (CH_4)	21
Nitrous oxide (N_2O)	310
(HFC)-134a	1,300

POLLUTION ATTRIBUTED TO STRATIFICATION OF PHOSPHOROUS FROM REDUCED TILLAGE IN LAKE ERIE

EFFECT ON EROSION IN NO-TILL



REDUCED SEDIMENT AND P IN TILE FLOW FROM NORTHWEST OHIO WITH GYPSUM

Photo courtesy of Joe Nester

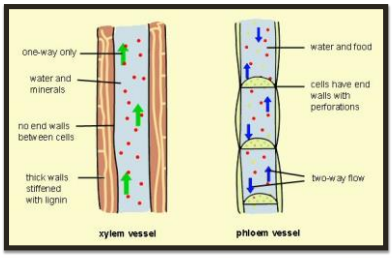
WATER STRESS REDUCED WITH GYPSUM AND PAM

MICRONUTRIENTS UPTAKE W/O & W GYPSUM

CALCIUM AS A FERTILIZER

- 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 shoot tips is transported in the transpiration stream of xylem
  - Ca needed by root tips comes from soil solution

PHLOEM VS XYLEM



ROOT MASS ENHANCED BY SOLUBLE CA

SULFUR AS A FERTILIZER

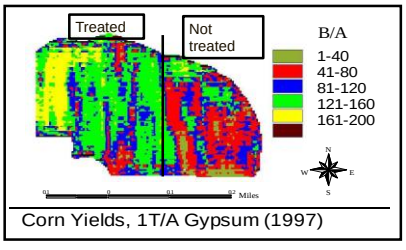
- Amino acids methionine and cysteine
  - Proteins
  - Precursors of other sulfur-containing compounds
- Sulfolipids (fatty compounds) in membranes, especially chloroplast membranes
- Nitrogen-fixing enzyme (nitrogenase)
  - 28 S atoms in two active sites

ROOT BIOMASS INCREASED

RANDOM CORN EARS AMENDED WITH GYPSUM ON LEFT AND CONTROL, COLORADO

RESULTS ON EAR SIZE 2008

YIELD MAP SHOWING EFFECT OF FGD-GYPSUM ON YIELD CARLISLE IN



REDUCTION OF AMMONIA VOLATILISATION FROM SWINE MANURE

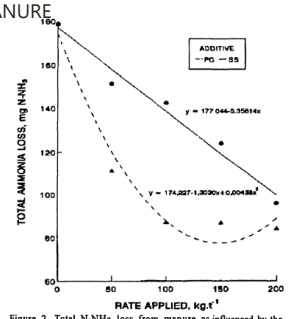


Figure 2. Total $N\text{-}NH_3$ loss from manure as influenced by the addition of different rates of phosphogypsum (PG) and simple superphosphate (SS)

FROM: L.L. Freitas dos, J.C. Kiehl; F.S. Pisani; J.E. Corrente. 2005. Controlling ammonia losses during manure composting with the addition of phosphogypsum and simple superphosphate. Sci. agric. (Piracicaba, Braz.) vol.62 no.2 Piracicaba

CONCLUSIONS

- Gypsum is a useful tool for soil, air and water environmental problems
- Gypsum improves infiltration and reduces erosion
- Gypsum improves soil drainage
- Gypsum can reduces loss of nitrogen gases from soil
- Gypsum can reduce soluble phosphate in surface runoff and tile flow
- Gypsum is a source of Ca and S for plants which can improve yield while conditioning the soil