

Midwest Soil Improvement Symposium:

... — 2012 — ...

Research and Practical Insights into Using Gypsum

The Effect of Gypsum on Soil Physical Properties

Dr. Jerry Bigham

Professor Emeritus,

*School of Environment and Natural Resources,
The Ohio State University*





The Effect of Gypsum on Soil Physical Properties

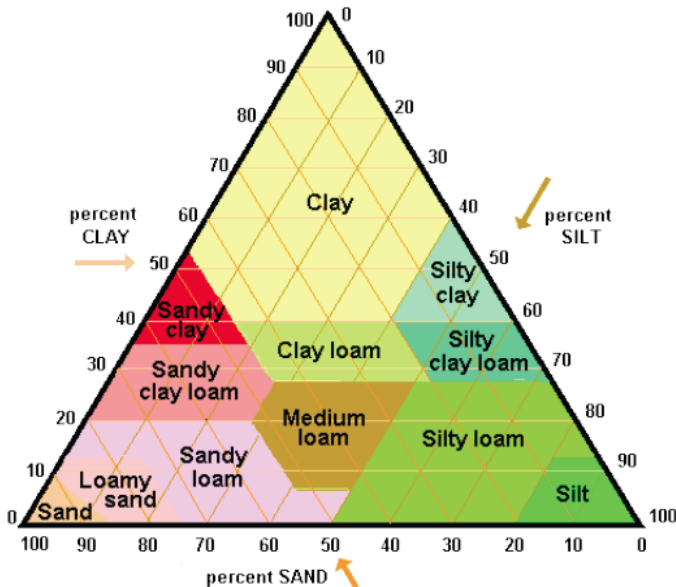
Midwest Soil Improvement Symposium
August 21, 2012; Acadia, IN

Jerry M. Bigham
Professor Emeritus
The Ohio State University
bigham.1@osu.edu

Soil Physical Properties

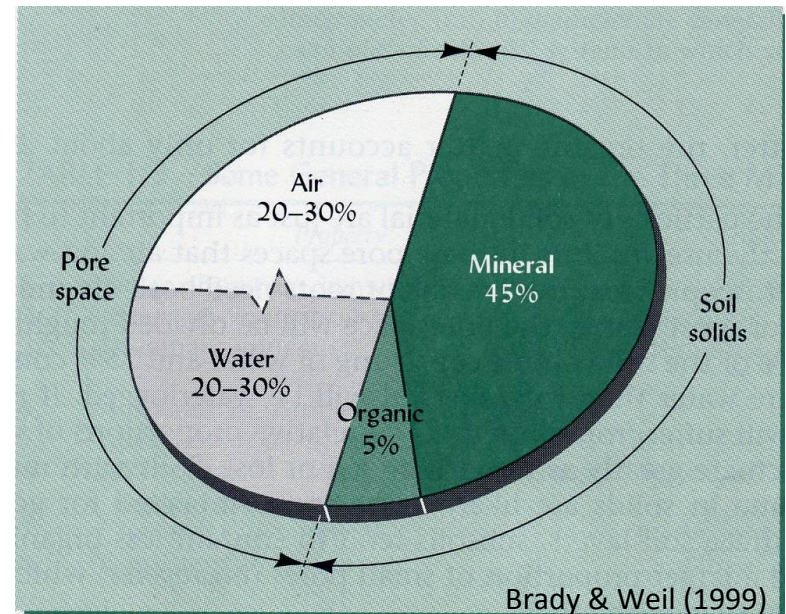
Some are almost invariant

- Particle Size Distribution (Texture)
- Mineralogy



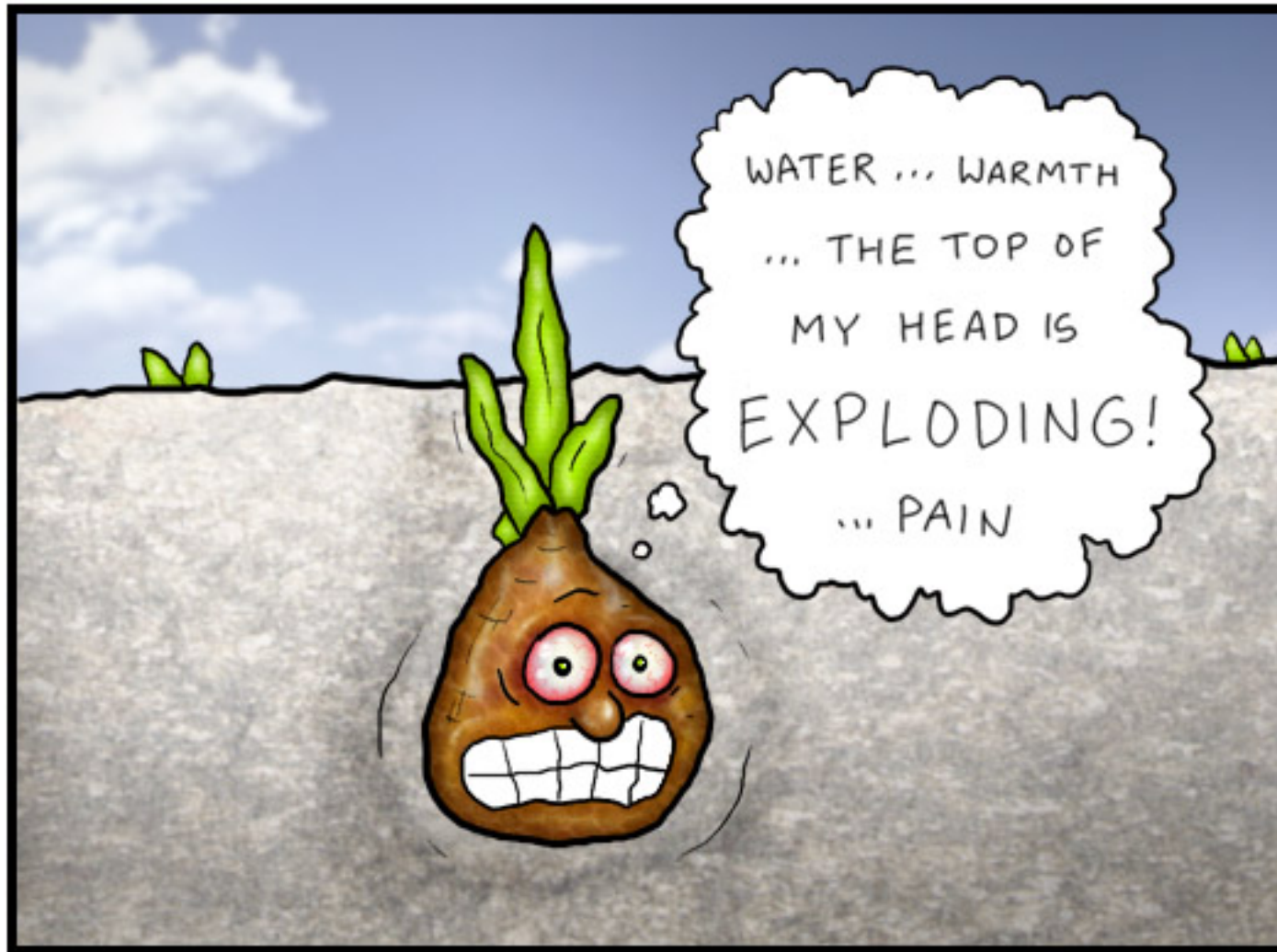
Others are sensitive to mgt.

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



DOCTOR FUN

11 May 2001



Copyright © 2001 David Farley, d-farley@ibiblio.org
<http://ibiblio.org/Dave/drfun.html>

This cartoon is made available on the Internet for personal viewing only. Opinions expressed herein are solely those of the author.

What springtime is really like for bulbs

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)



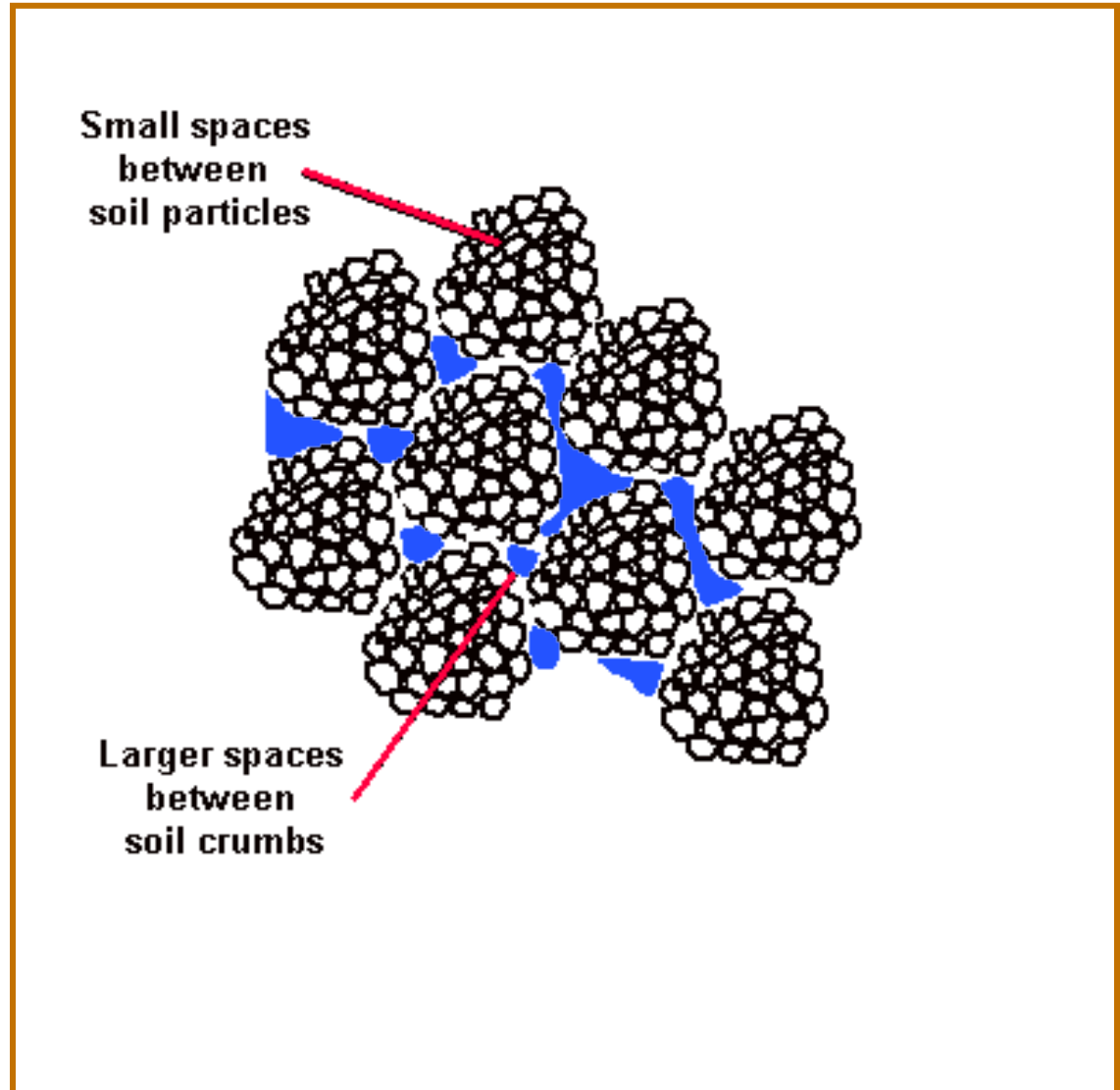


The ultimate goal of air & water management is to create an environment where the plant root system can reach its full genetic potential for respiration, nutrient uptake, and water transmission. Usually, this means exploiting the largest possible soil volume.

Photo courtesy of S.W. Buol

Several dynamic soil properties are impacted by the creation of water stable aggregates

- Infiltration
- Percolation (K_{sat})
- Available water
- Gas exchange



Aggregation and soil structure are enhanced by:

- root & faunal activity
- soil organic matter
- microbial exudates
- soluble calcium ions

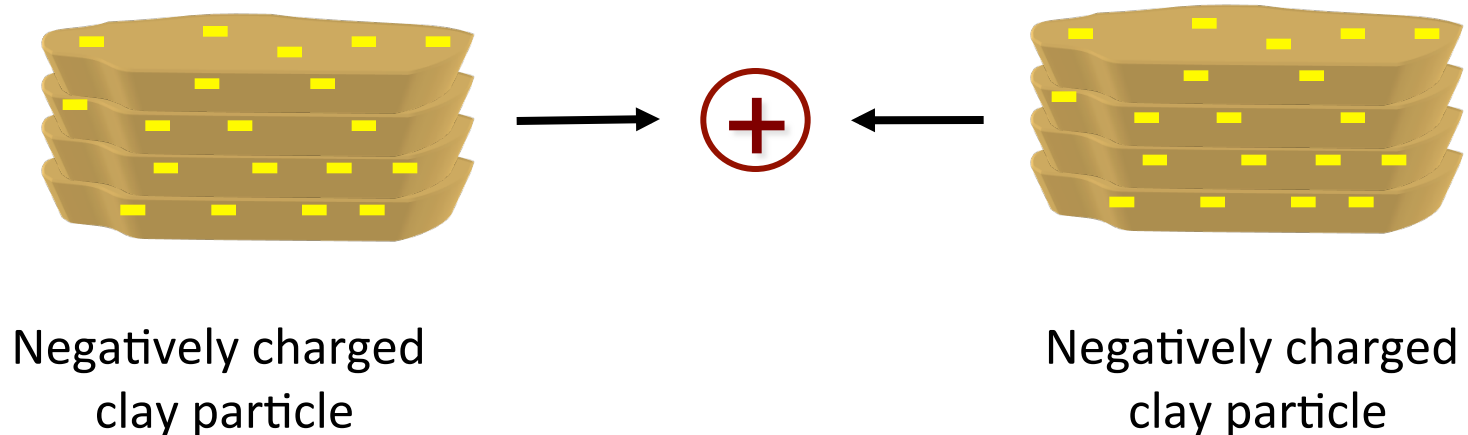


structureless

strong,
granular
structure

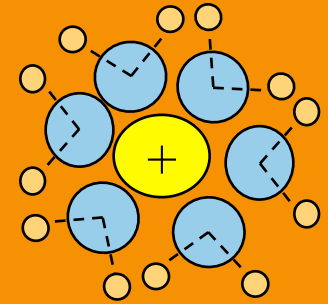
Calcium (Ca^{2+}) stabilizes decayed soil organic matter (humus) and is one of several cations (positively charged ions or molecules) that may occupy sites on the soil CEC. Others include ammonium (NH_4^+) sodium (Na^+), potassium (K^+), magnesium (Mg^{2+}), and aluminum (Al^{3+}).

These cations influence the tendency of soil colloids (clay particles) to separate (disperse) or aggregate (flocculate).



The tendency of a cation to serve as a dispersant or flocculant depends mostly on its charge and hydrated radius within the soil system.

Hydrated cation

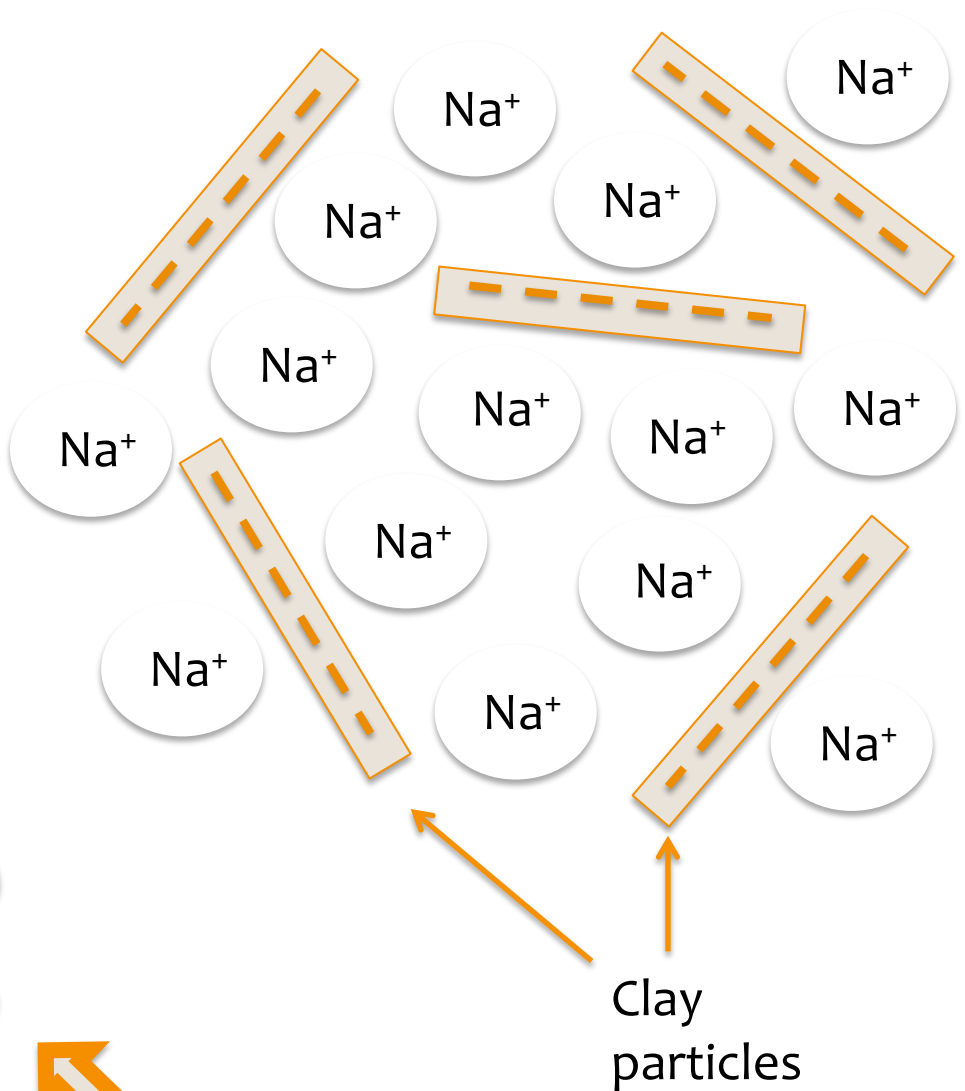
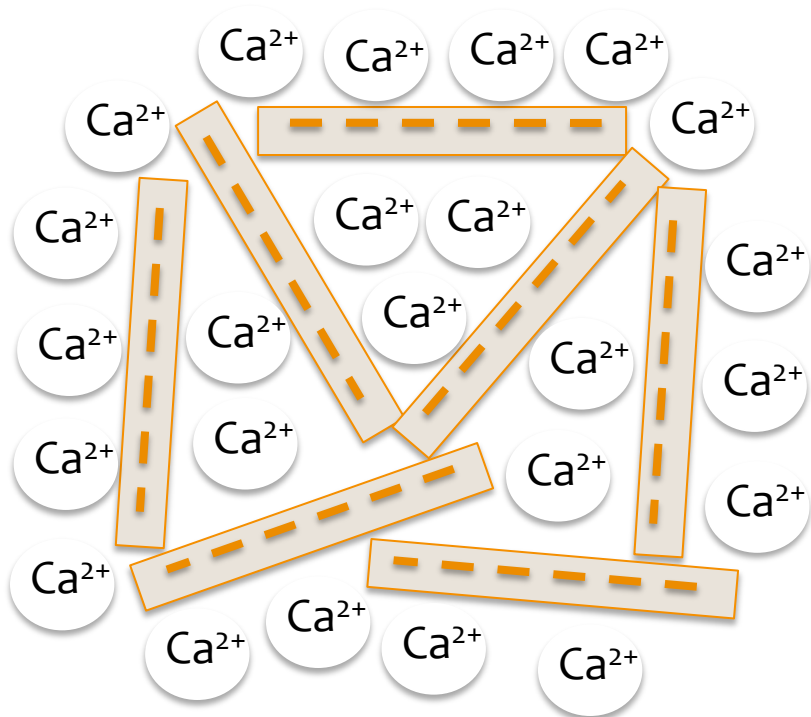


Cation	Charge per ion	Hydrated radius(\AA) per unit charge [*]	Relative flocculating power ^{**}
Sodium (Na)	1	3.6	1.0
Magnesium (Mg)	2	2.2	27.0
Calcium (Ca)	2	2.0	43.0

^{*}Conway (1981)

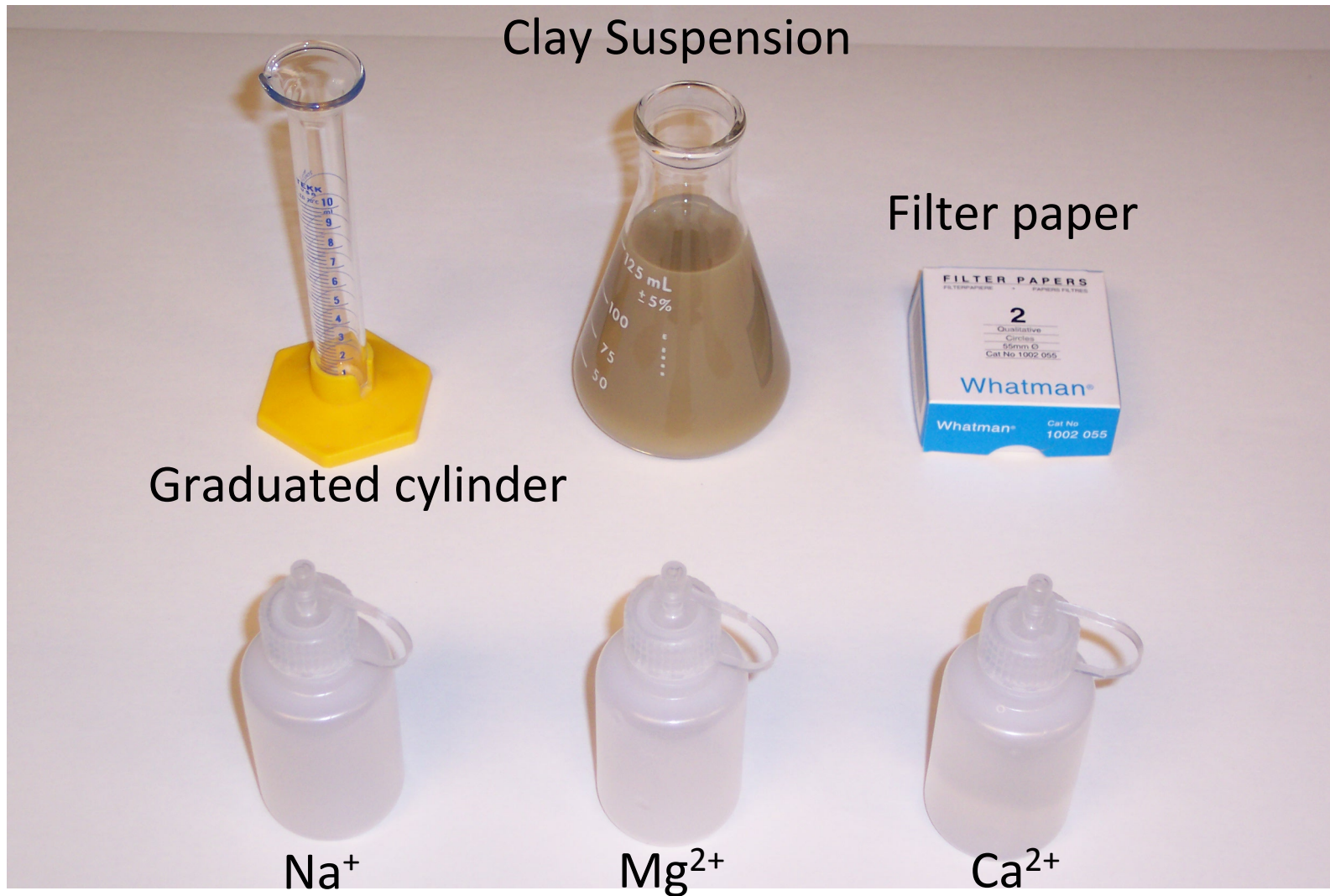
^{**}Rengasamy & Sumner (1998)

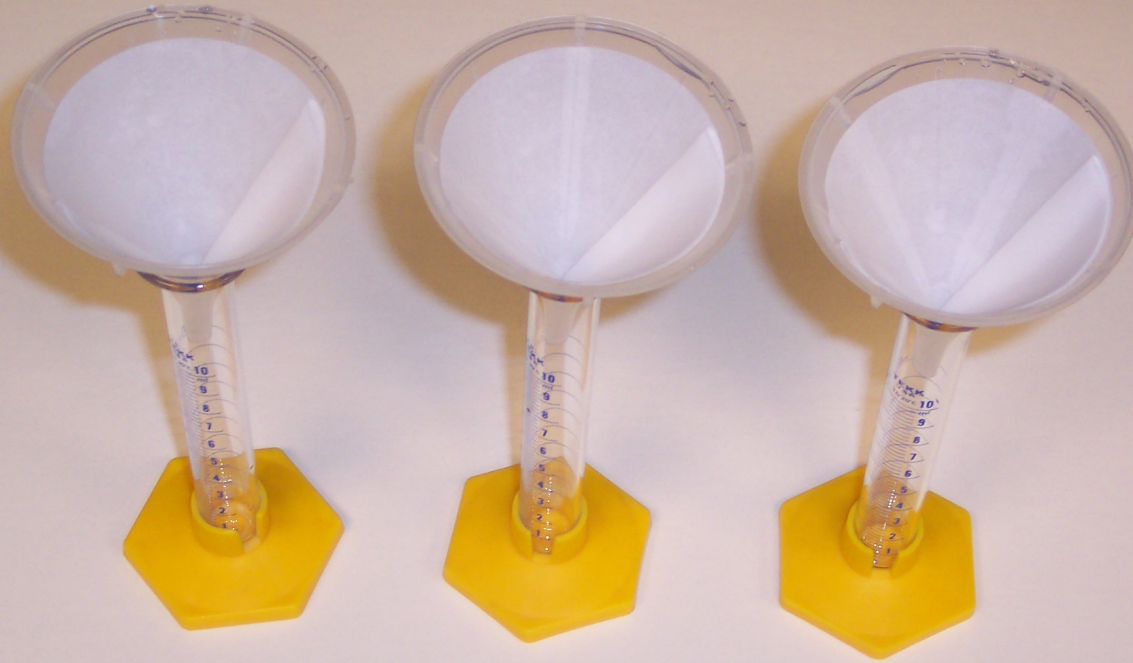
Dispersed Clay System



Flocculated Clay System

Flocculation/Dispersion Demonstration





Funnels lined with filter paper.



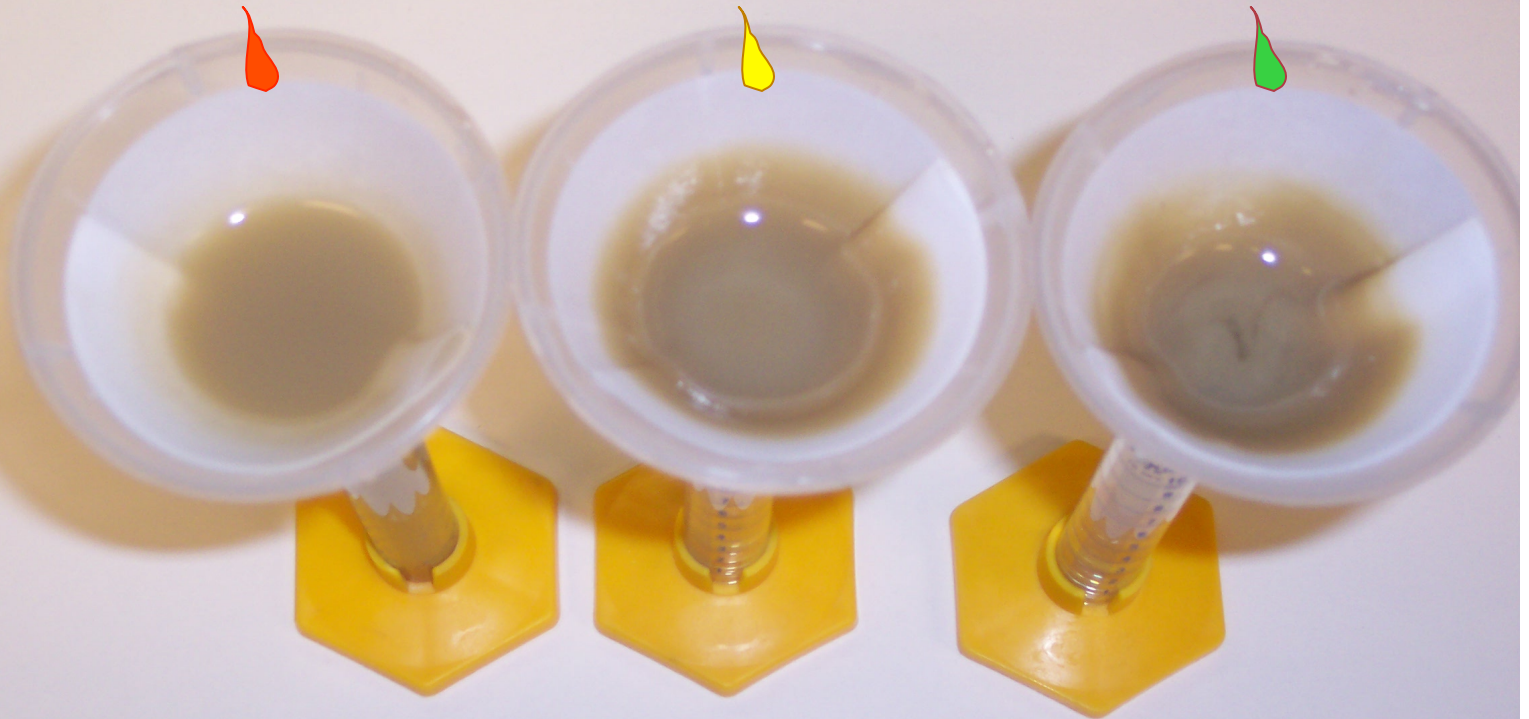
Clay suspension added to funnels.
Time = 0 minutes.

3 drops

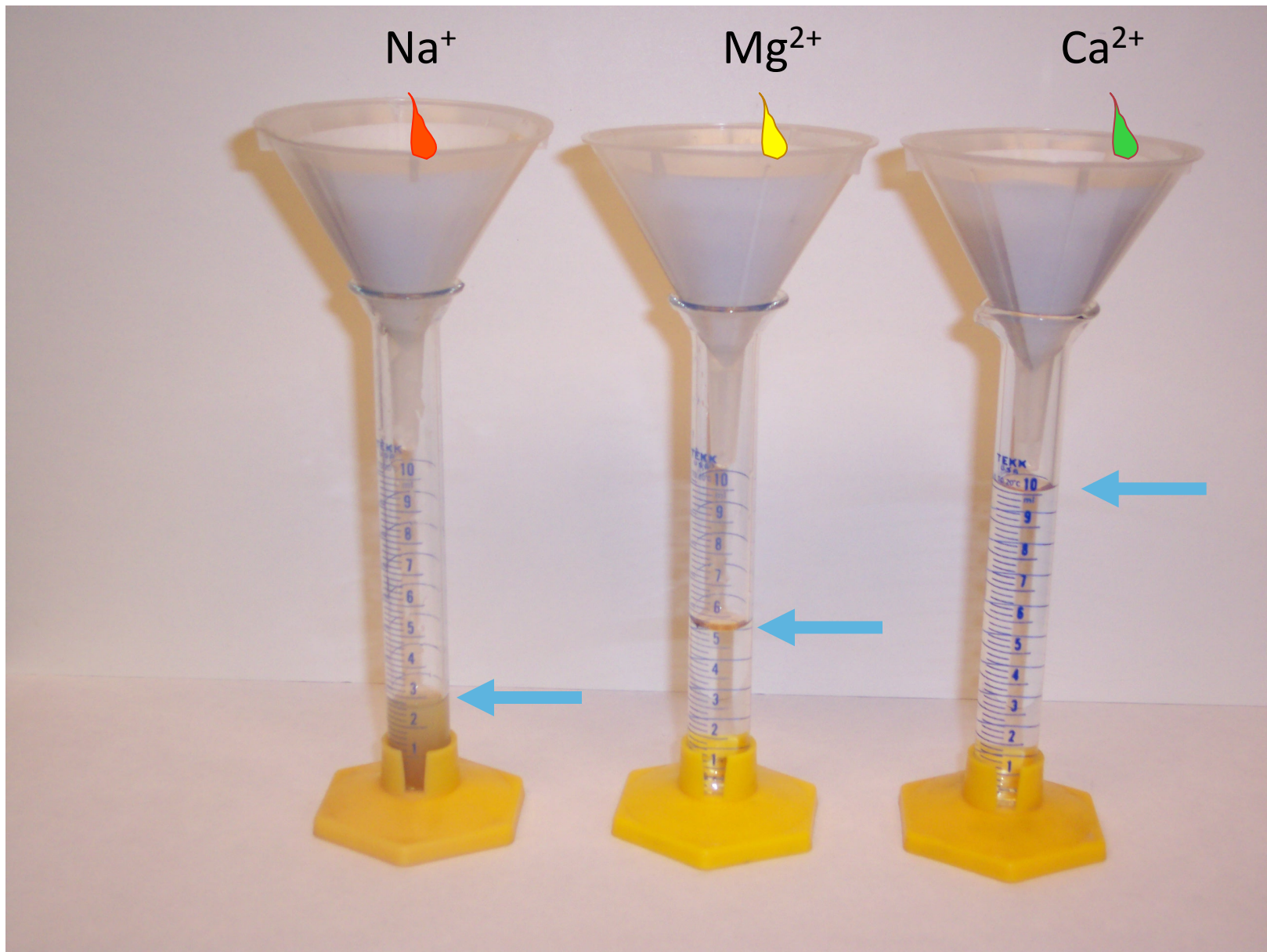
Na^+

Mg^{2+}

Ca^{2+}



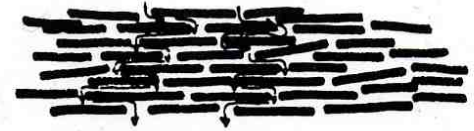
Clay suspensions after Na^+ , Mg^{2+} , & Ca^{2+} added.
Time = 15 minutes.



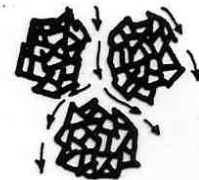
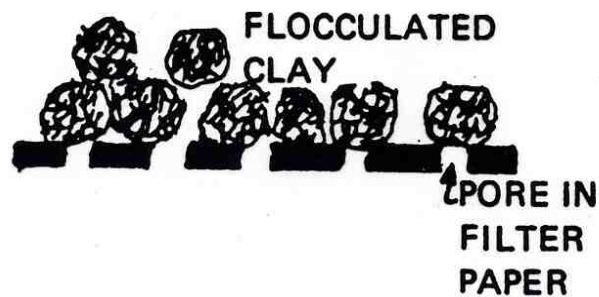
Filtrates after Na^+ , Mg^{2+} , and Ca^{2+} added. Time = 15 minutes.

What is
happening?

Na^+

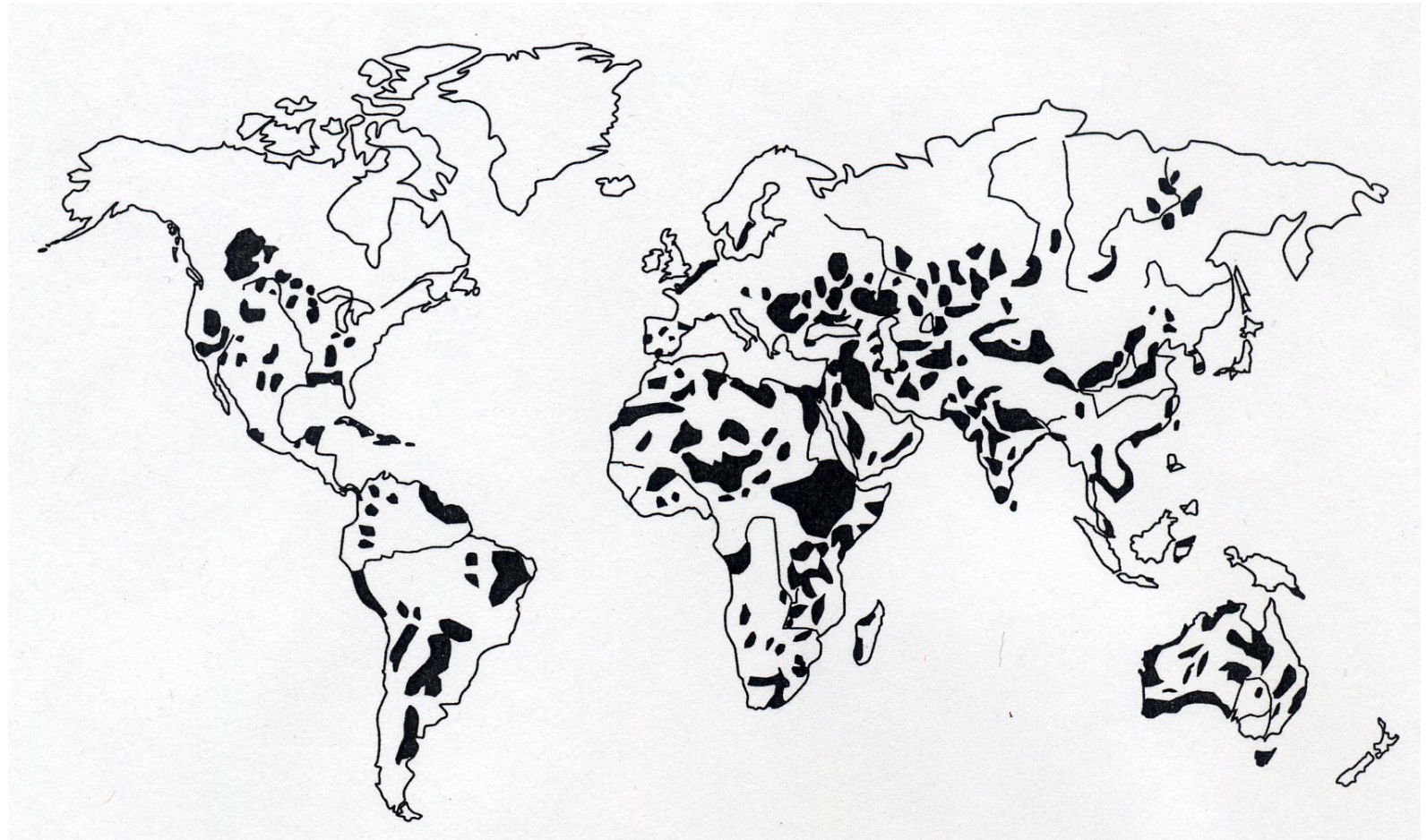


Ca^{2+}



Global Distribution of Na-affected Soils

(from Sparks, Environmental Soil Chemistry, 2nd Ed (2003))



Sodic (sodium affected) soils: have exchangeable $\text{Na} \geq 15\%$ of the CEC, and exchangeable $\text{Na} + \text{Mg}$ exceeds exchangeable Ca (USDA Hndbk 436, 1st ed, 1976).

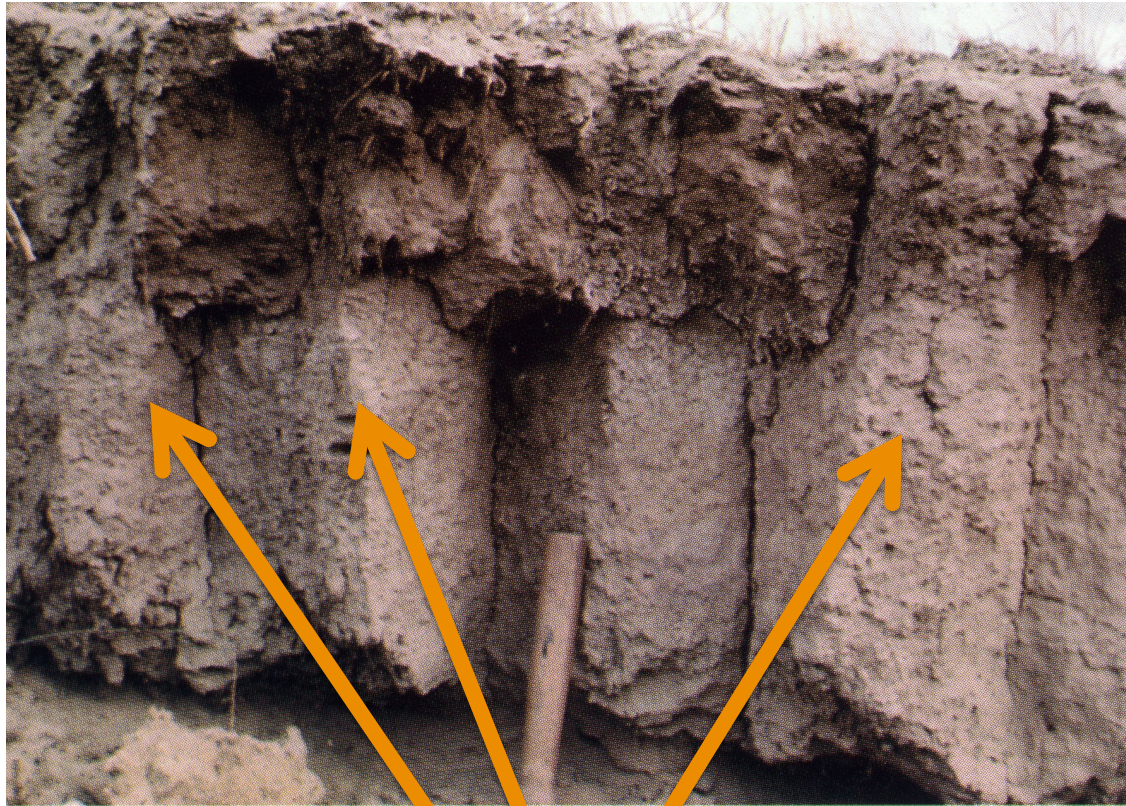


Photo courtesy of A.R. Southard

Note the large, internally massive prisms occurring in the subsoil.



Deep tillage in southern CA to improve permeability of a sodic (high sodium) soil.



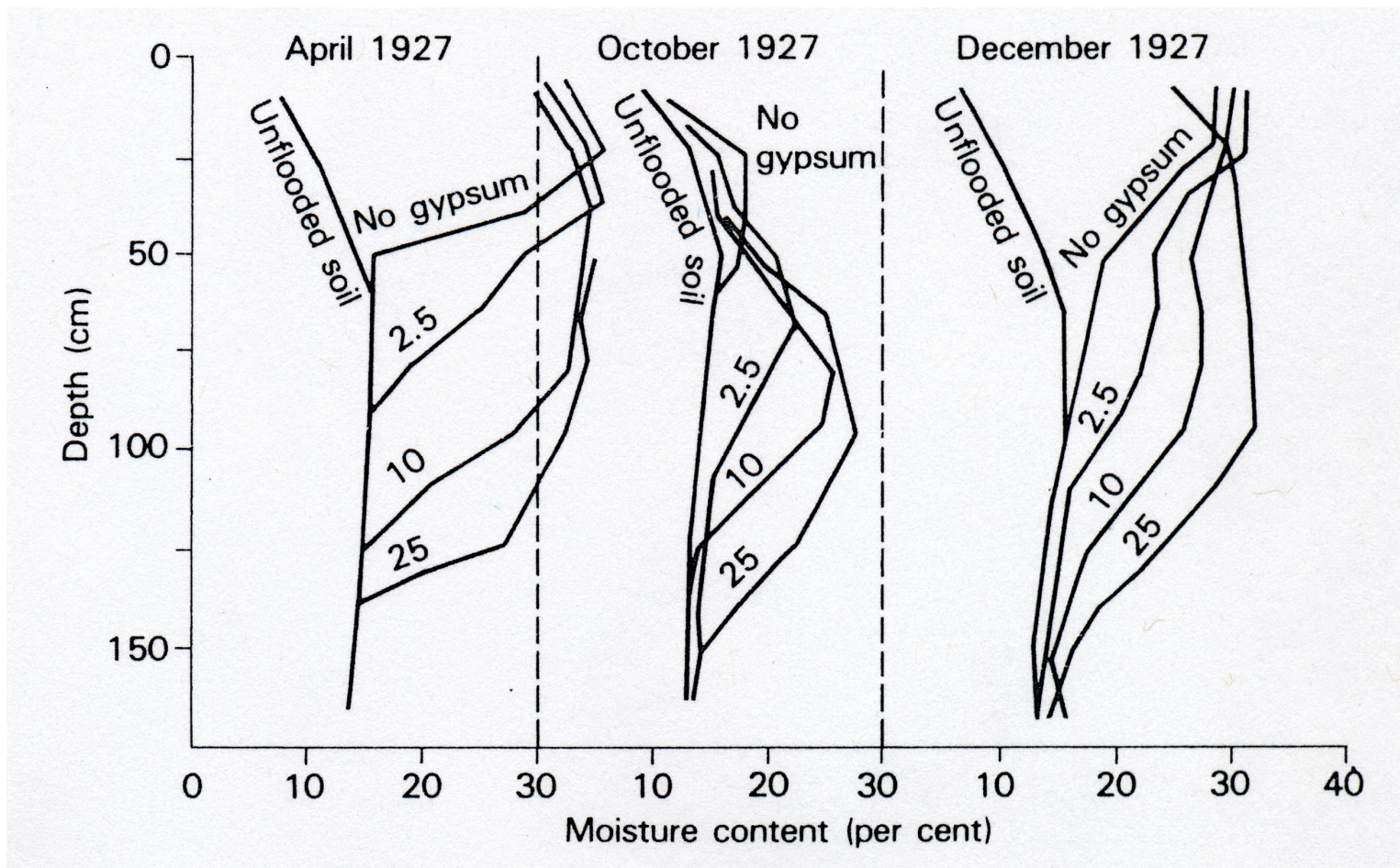
Photos courtesy of Blake Sanden

Gypsum as a Soil “Conditioner”

Gypsum has been used for many years to improve aggregation (structure) and inhibit or overcome dispersion in sodic (high sodium) soils. Soil dispersion contributes to:

- **surface sealing/crusting**
- **problems with seedling emergence**
- **runoff/erosion**
- **subsoil swelling with decreased water and root penetration**
- **poor air exchange**

Reclamation of an impermeable soil with 10% exchangeable Na using surface applied gypsum at rates of 2.5, 10, and 25 ton/ha

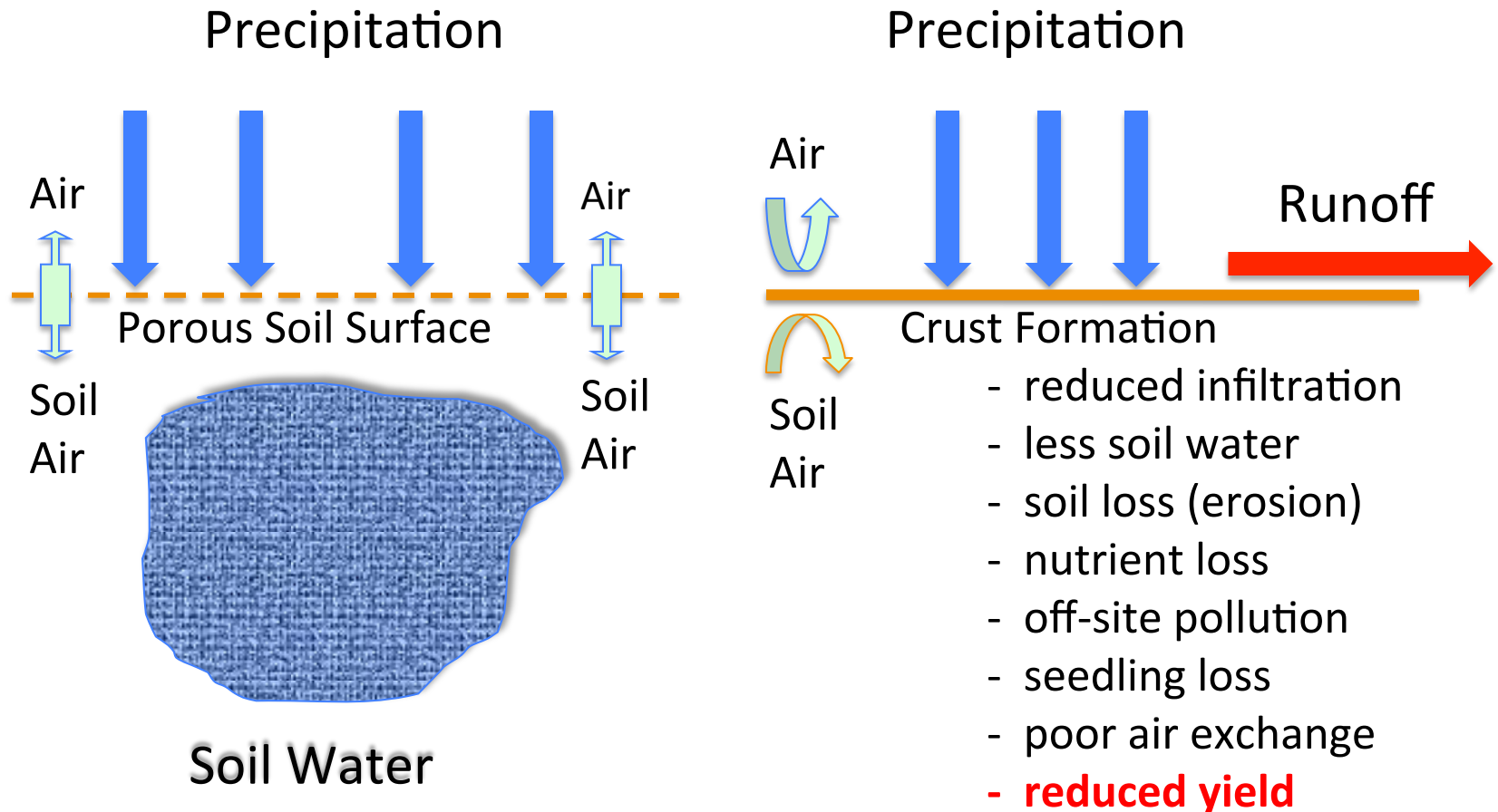


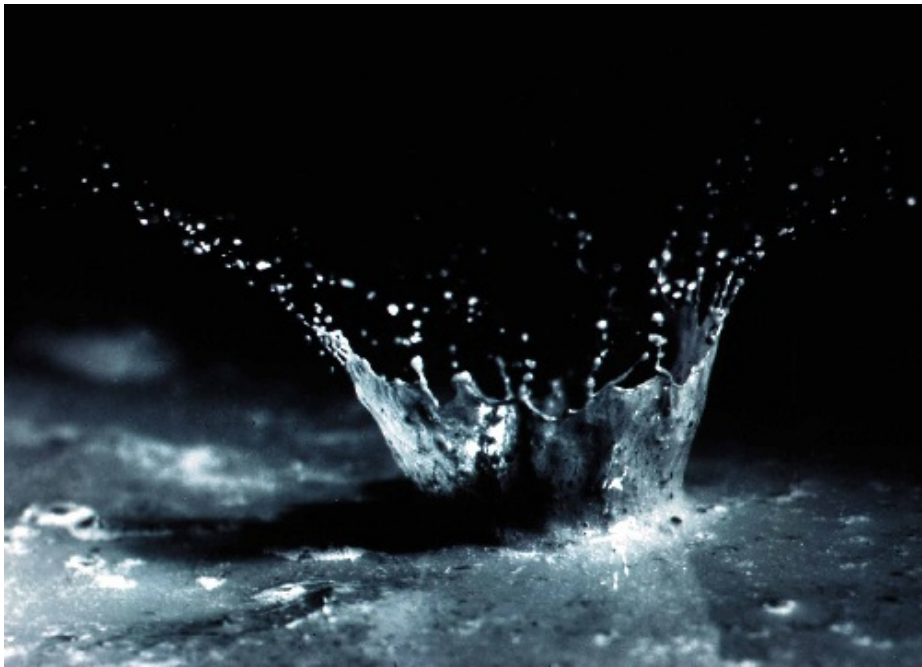
Source: Greene, H.J. J. Agric. Sci. 18:531 (1928)

What about non-sodic soils in the corn belt? Is there really a place for gypsum in a comprehensive management plan?



Clay dispersion and collapse of structure at the soil-air interface is a major contributor to surface sealing in **both** sodic and non-sodic soils.





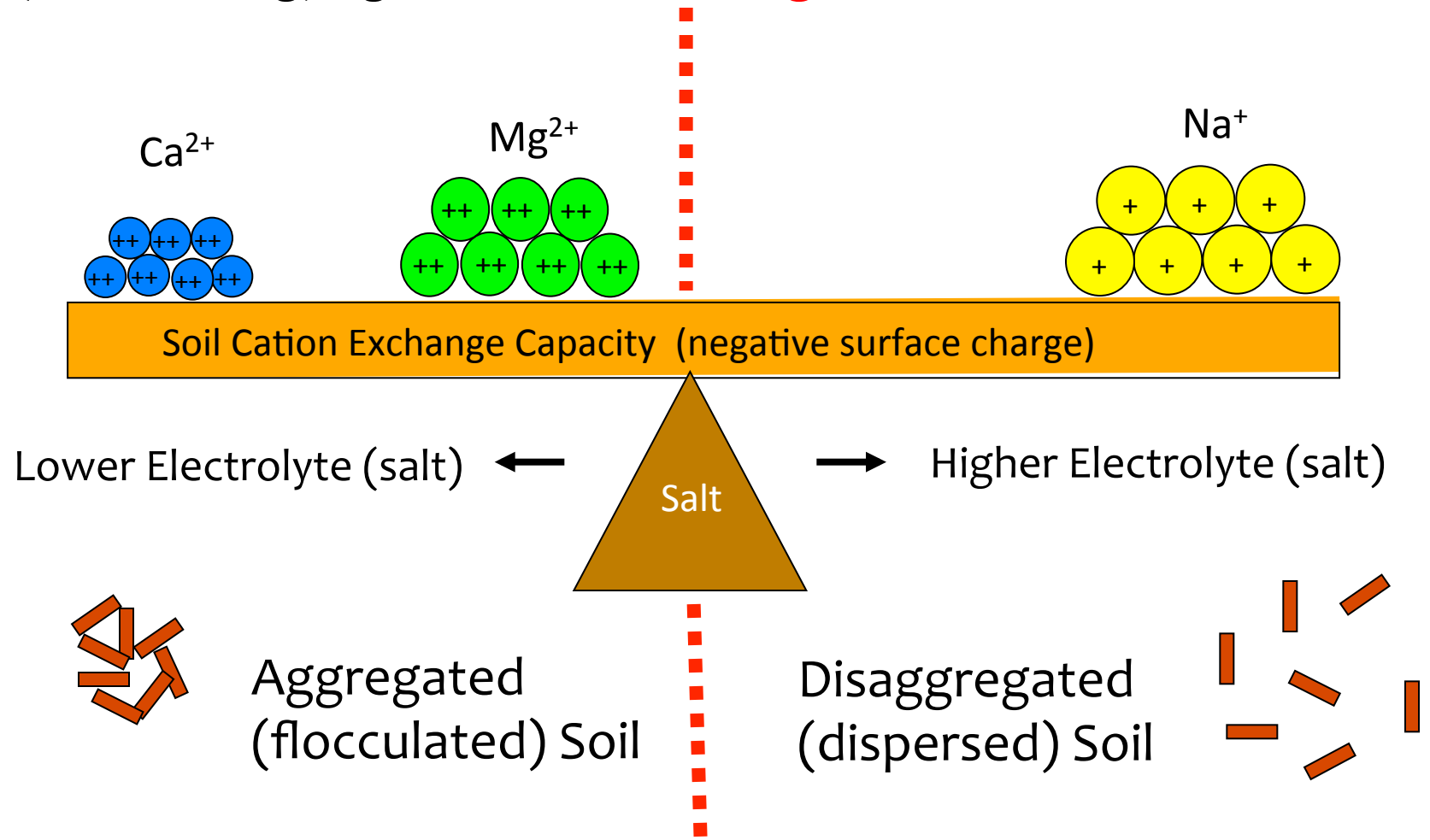
Natural rainwater is erosive, in part, because of its low electrolyte (salt) content.

Work at the NSEL (Norton et al.) has shown that soil and chemical loss due to crusting, poor infiltration of rainfall, and runoff can be reduced by managing the calcium (Ca) status of the topsoil.

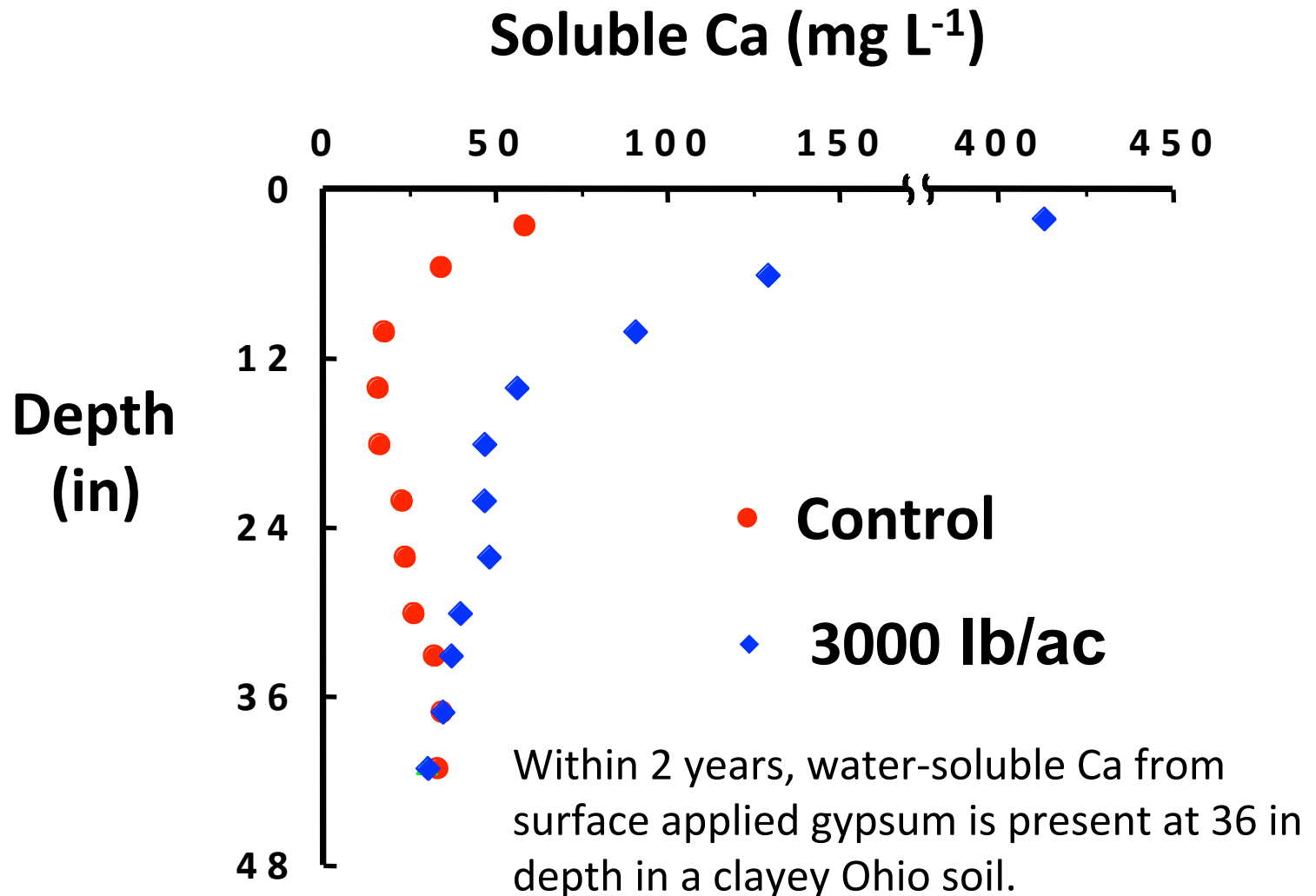
Traditional sources of Ca are:

<u>Compound</u>	<u>Solubility</u>
Limestone (CaCO_3)	0.014 g/L
Dolomite [$\text{CaMg}(\text{CO}_3)_2$]	0.32 g/L
Gypsum (CaSO_4)	2.41 g/L

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

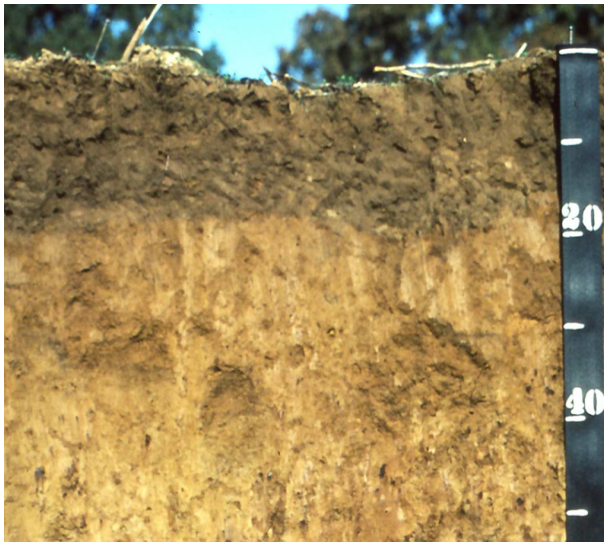


Because of its solubility, gypsum can also have a significant, positive impact on subsoil chemistry and structure, even under rainfed agriculture.



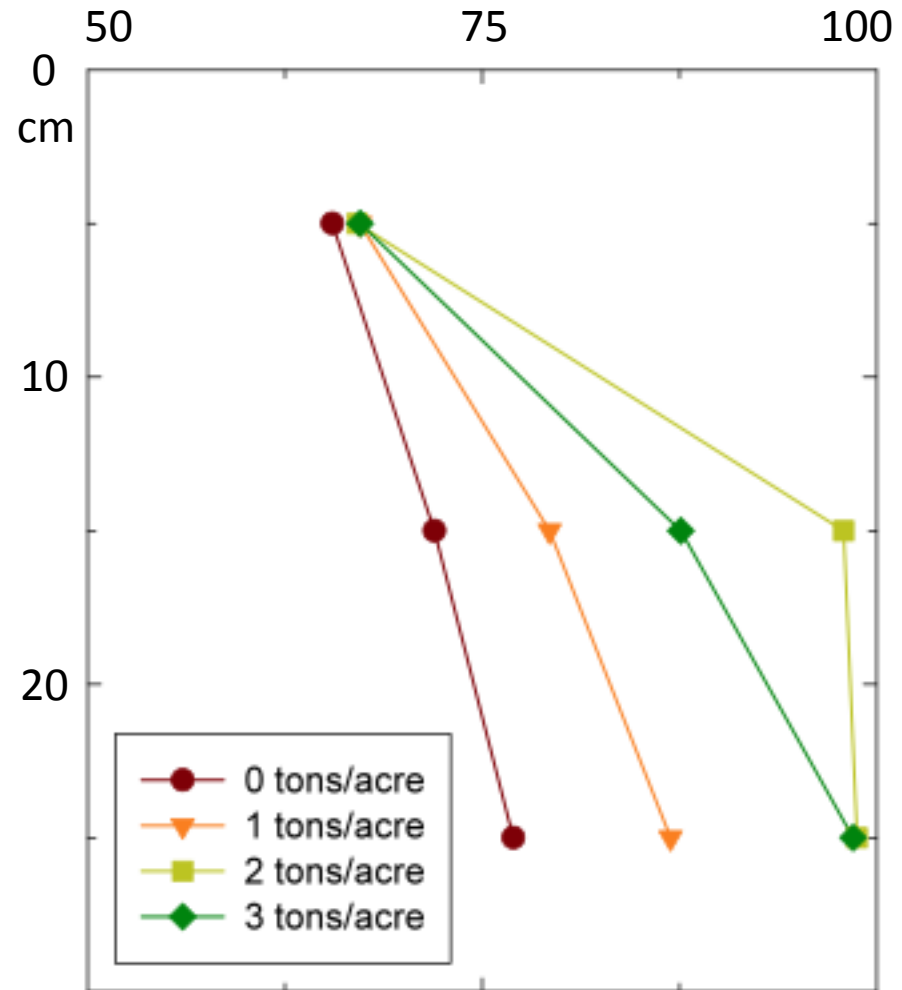
Effects of surface-applied gypsum on aggregation index (AI) in a silty, no-till cotton soil after three growing seasons.

$$AI = 100 (1 - WDC/100)$$



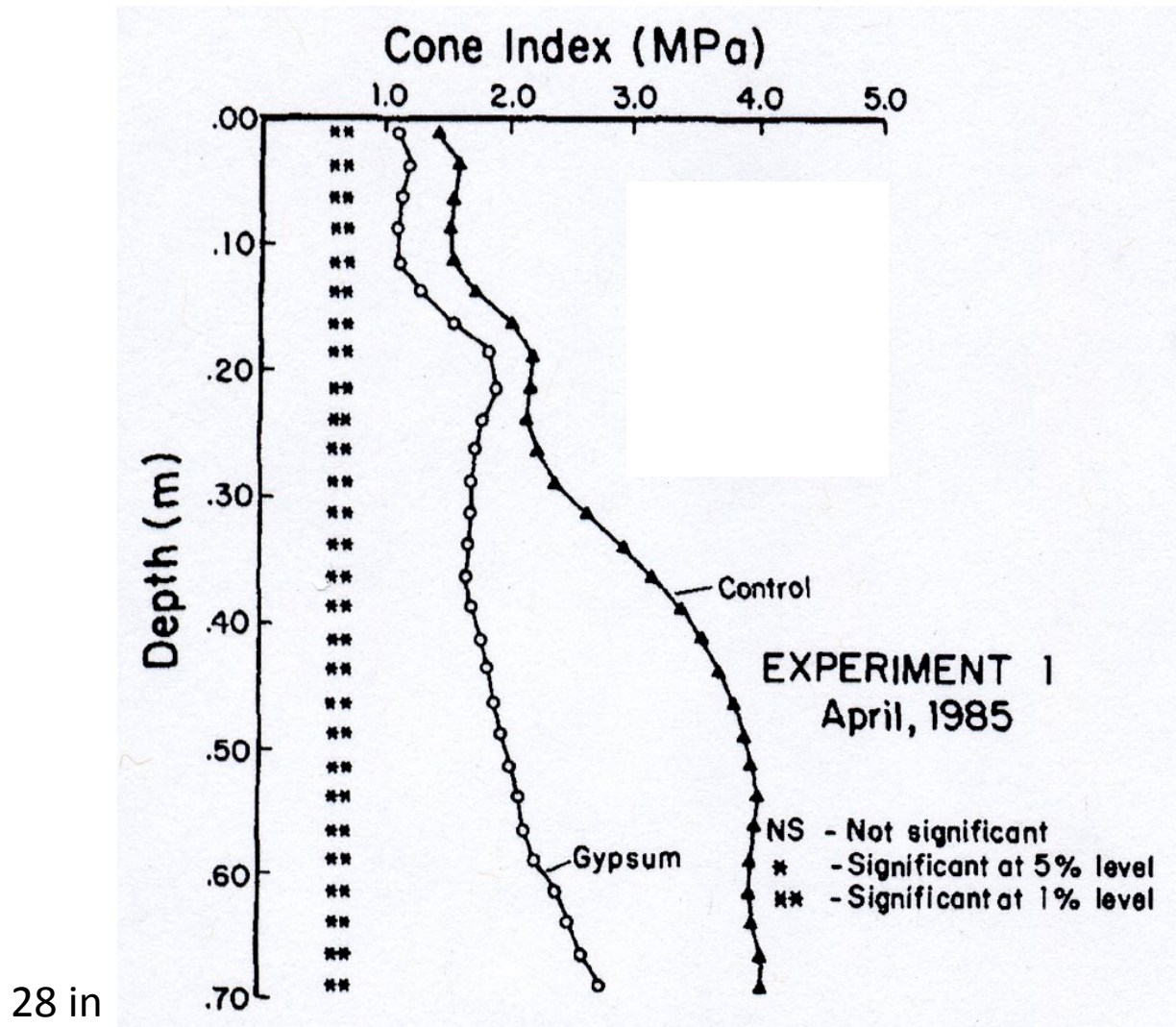
Grenada soil

Rhoton & McChesney (2011)



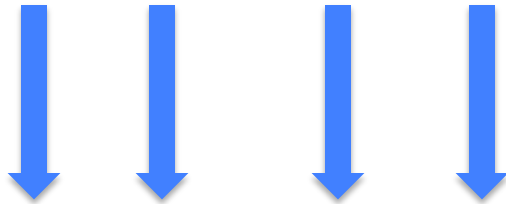
Depth

Mechanical impedance (root resistance) with depth, 3 yr after surface application of 3200 lb/ac gypsum on a clay soil

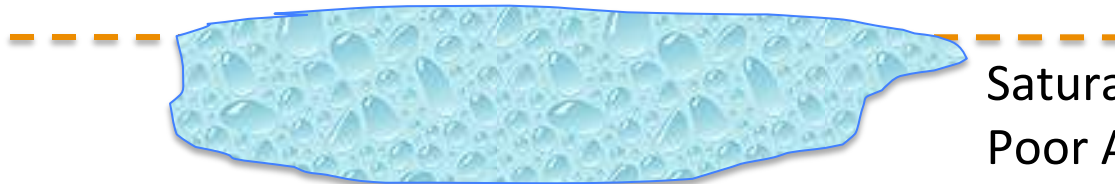


Radcliffe et al. (1986)

Rainfall or Irrigation



Ponding



Saturated Soil with
Poor Aeration

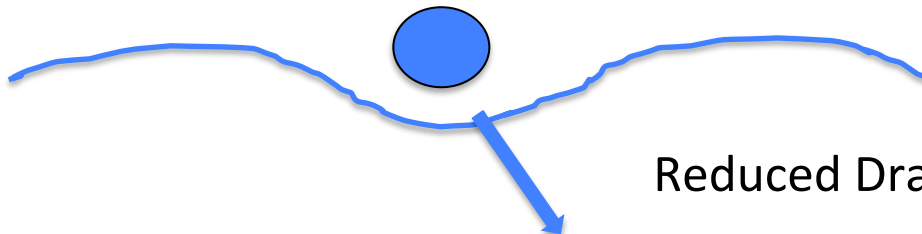
Limiting
Layer

XXXXXXXXXXXXXXXXXXXX



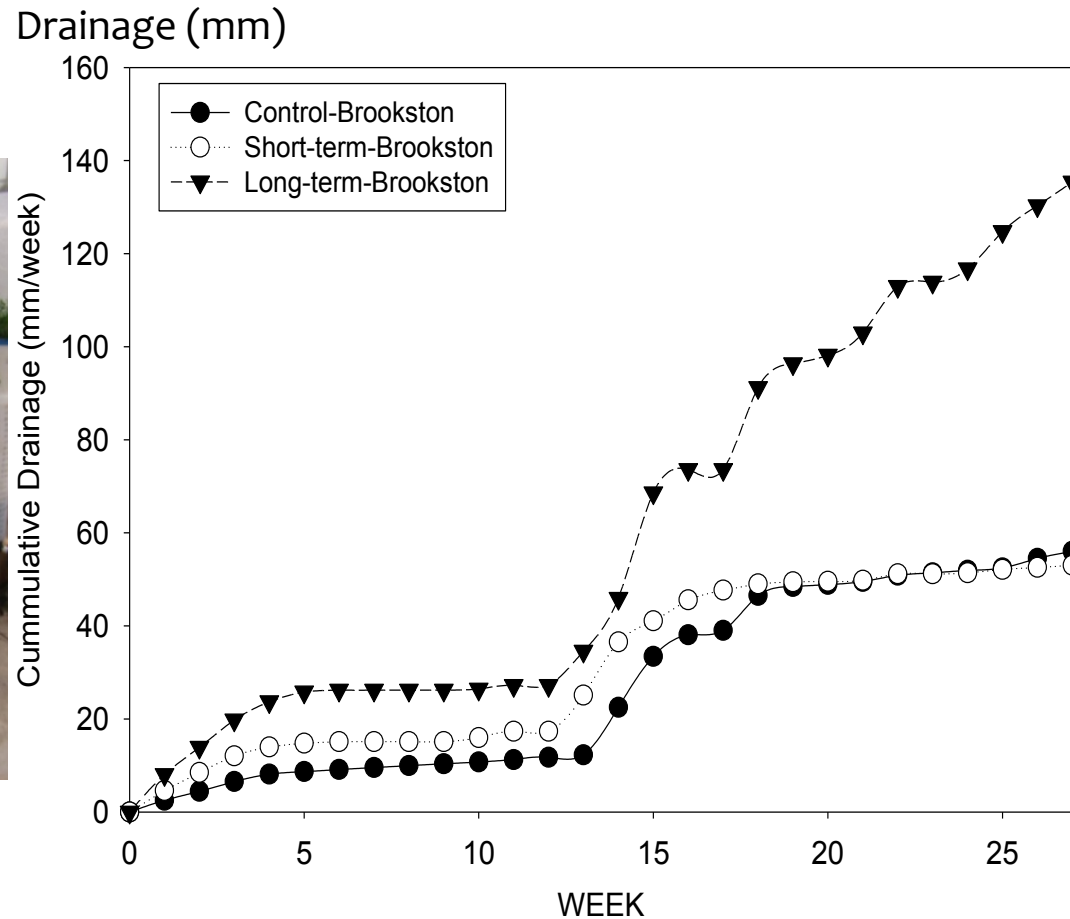
Reduced Percolation Rate

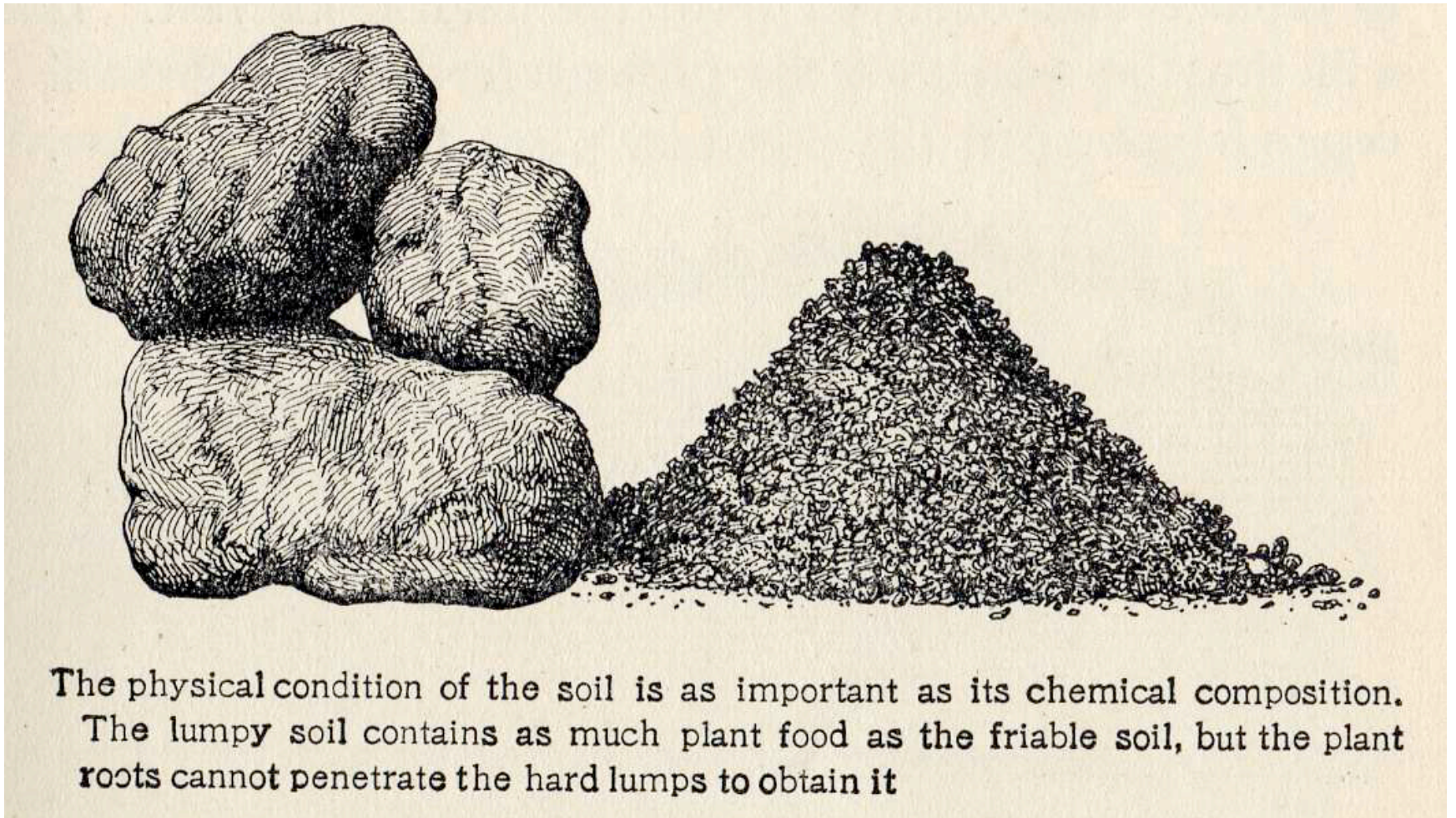
Water Table



Reduced Drainage Rate

Cumulative drainage over a 25 week period from intact cores (30.5 x 75 cm) of Brookston soil after 0, 4, and 12 yr of surface applied gypsum at a rate of 1,500 lb/yr (Tirado-Corbala, 2010).





Alfred Vivian. 1912. "*First Principles* of Soil Fertility"