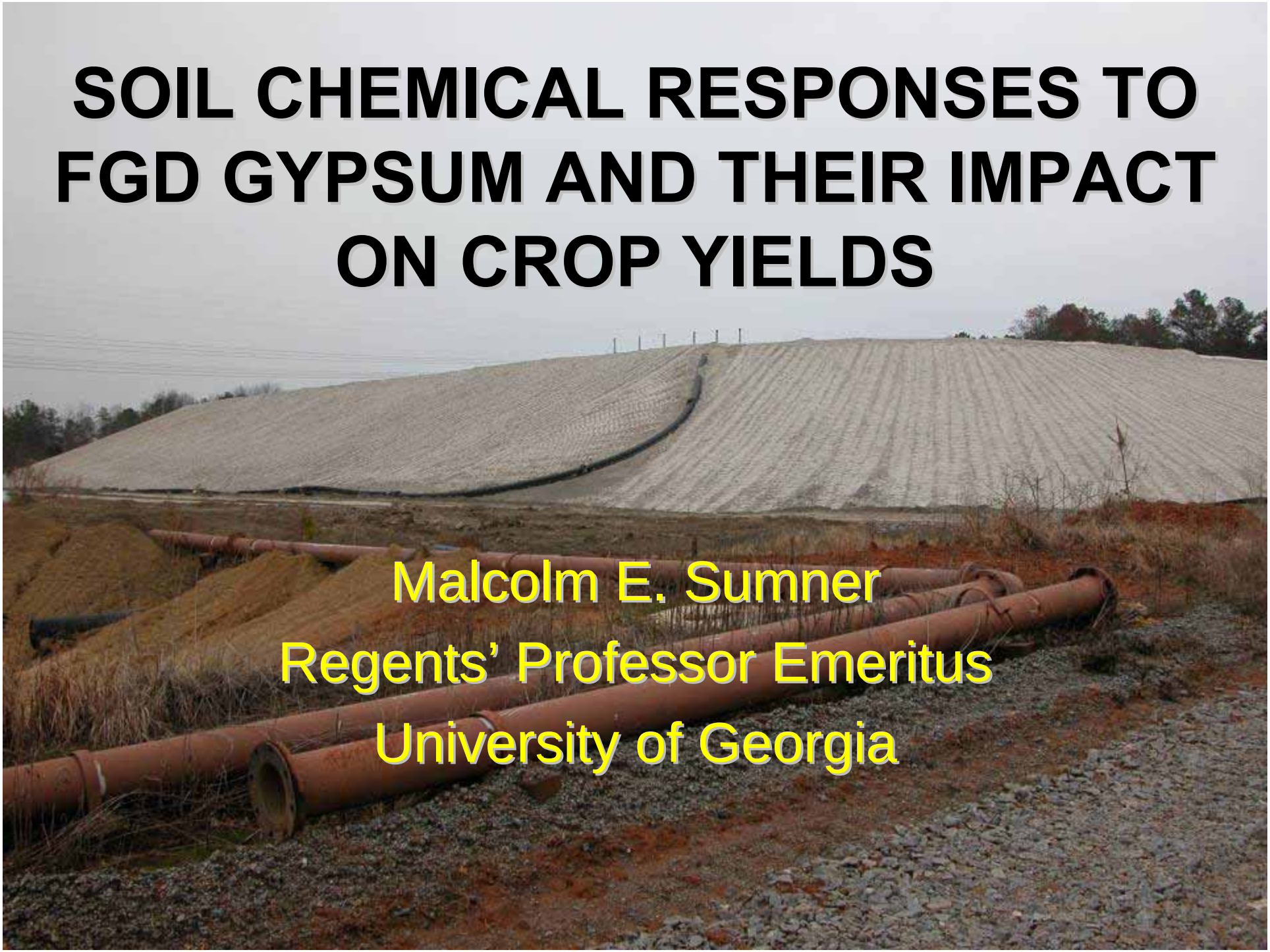
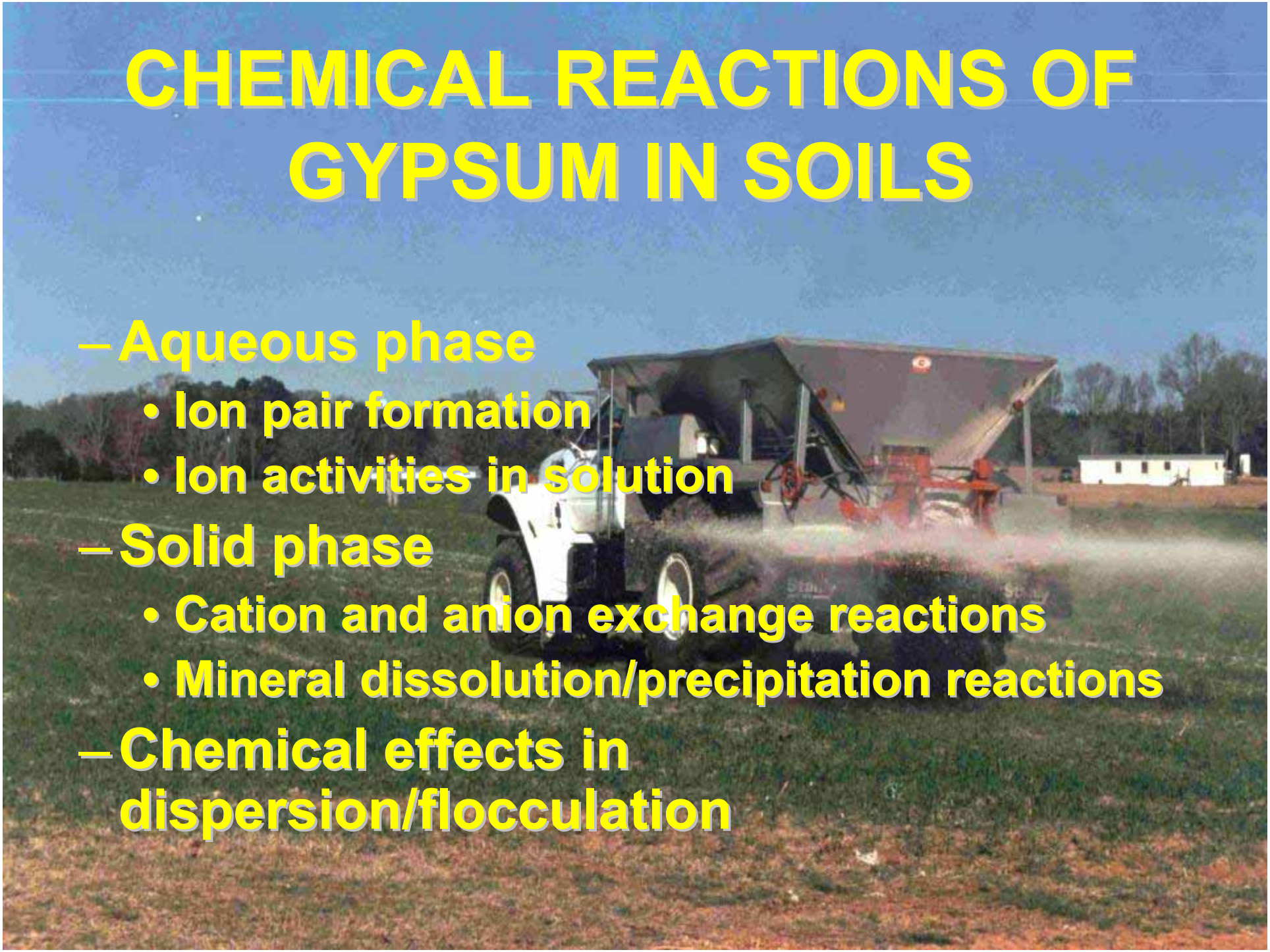
SOIL CHEMICAL RESPONSES TO FGD GYPSUM AND THEIR IMPACT ON CROP YIELDS

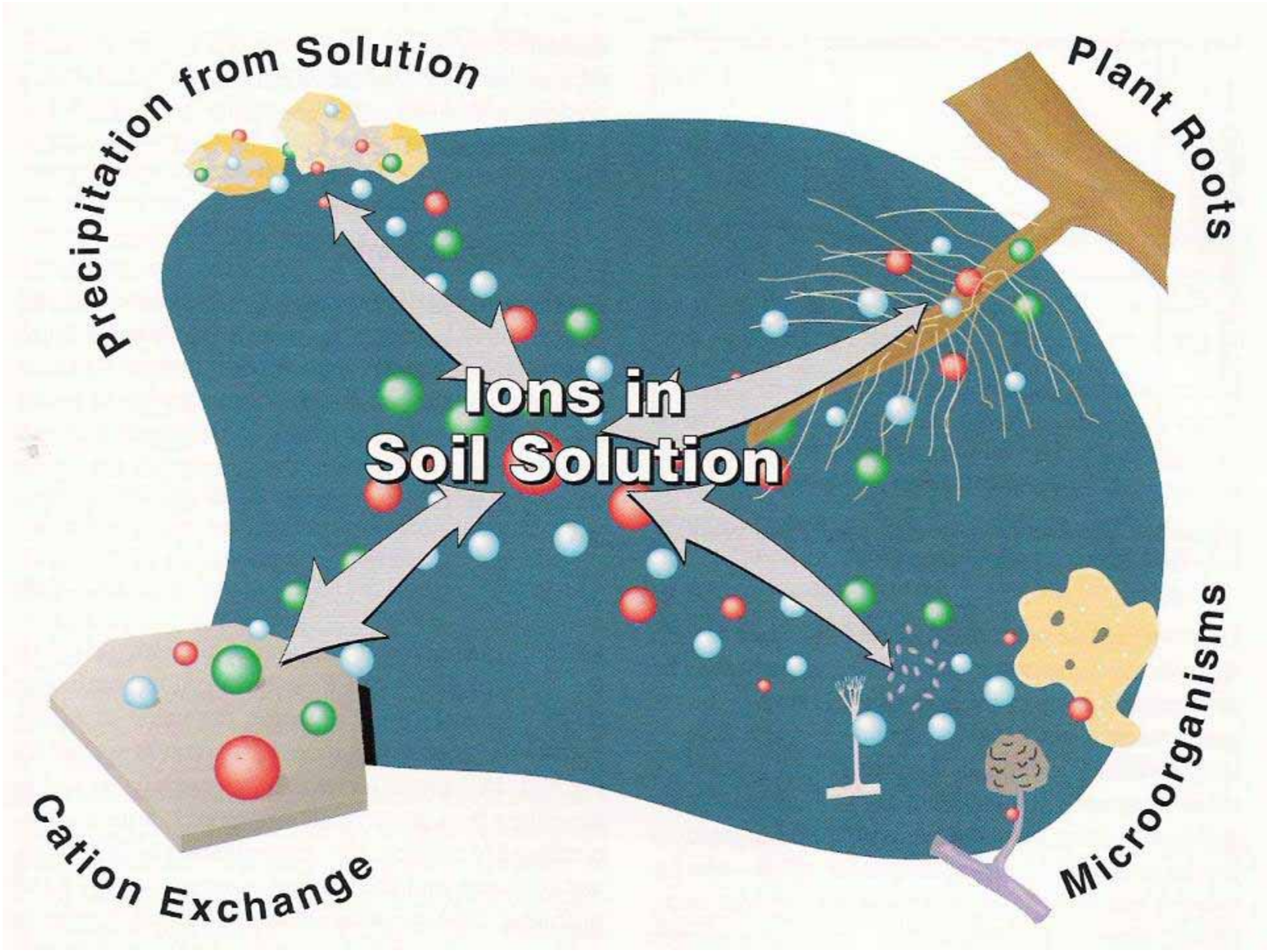


Malcolm E. Sumner
Regents' Professor Emeritus
University of Georgia

CHEMICAL REACTIONS OF GYPSUM IN SOILS



- Aqueous phase
  - Ion pair formation
  - Ion activities in solution
- Solid phase
  - Cation and anion exchange reactions
  - Mineral dissolution/precipitation reactions
- Chemical effects in dispersion/flocculation

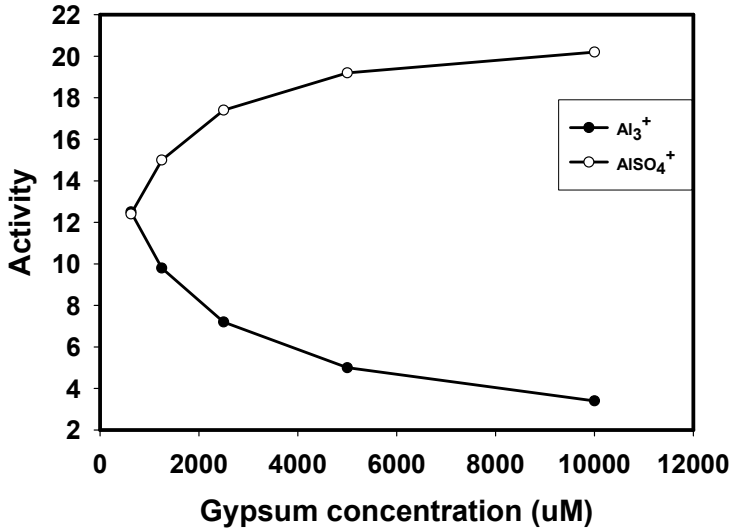

Precipitation from Solution
Plant Roots
Ions in
Soil Solution
Cation Exchange
Microorganisms

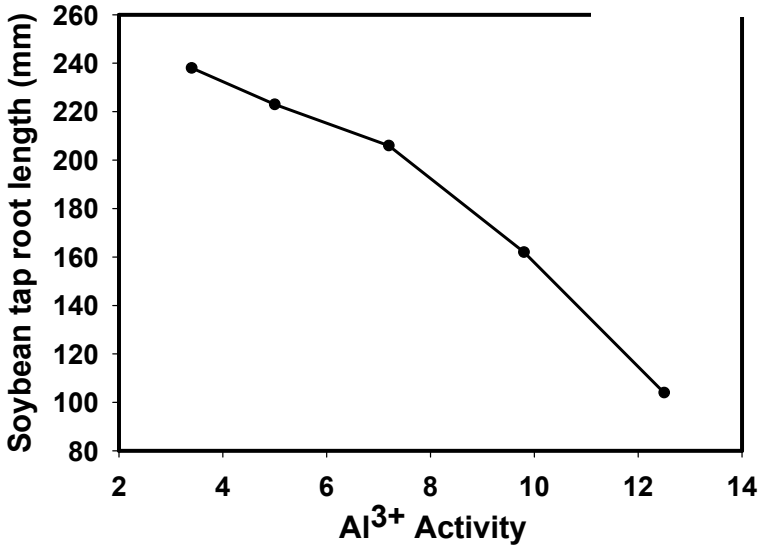
AQUEOUS PHASE REACTIONS

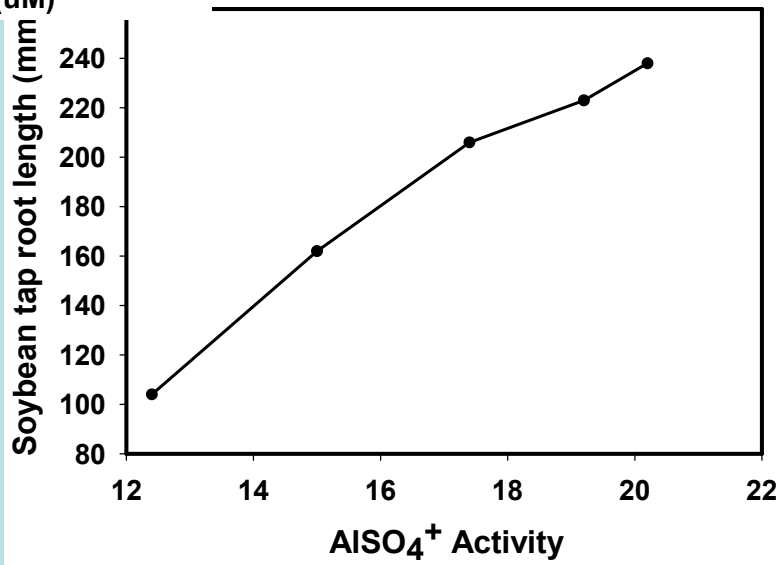
- **Ion pair formation**

$$Al^{3+}\ 3Cl^{-} + CaSO_4.2H_2O \longrightarrow Ca^{2+}\ 2Cl^{-} + AlSO_4^{+}\ Cl^{-}$$

Toxic aluminum — **Gypsum** — **Much less toxic**







Evidence for Ion Pair Detoxification

1 inch

SOLID PHASE REACTIONS

- **"Self-liming Effect" (Ligand exchange $OH \rightleftarrows 2SO_4$)**

$$[Fe,Al](OH)_2 + CaSO_4.2H_2O \rightarrow [Fe,Al]OHSO_4^- \tfrac{1}{2}Ca^{2+} + \tfrac{1}{2}Ca(OH)_2$$

Iron/aluminum hydroxide — Gypsum — New negative charge On surface — Hydrated lime

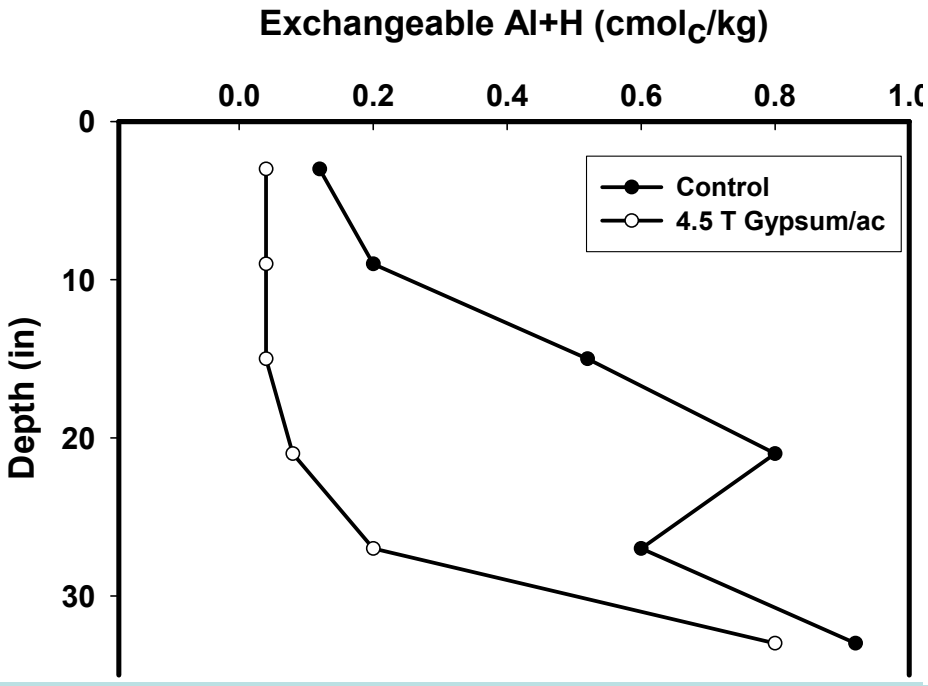
$$2Al^{3+} + 3Ca(OH)_2 \longrightarrow 2Al(OH)_3 + 3Ca^{2+}$$

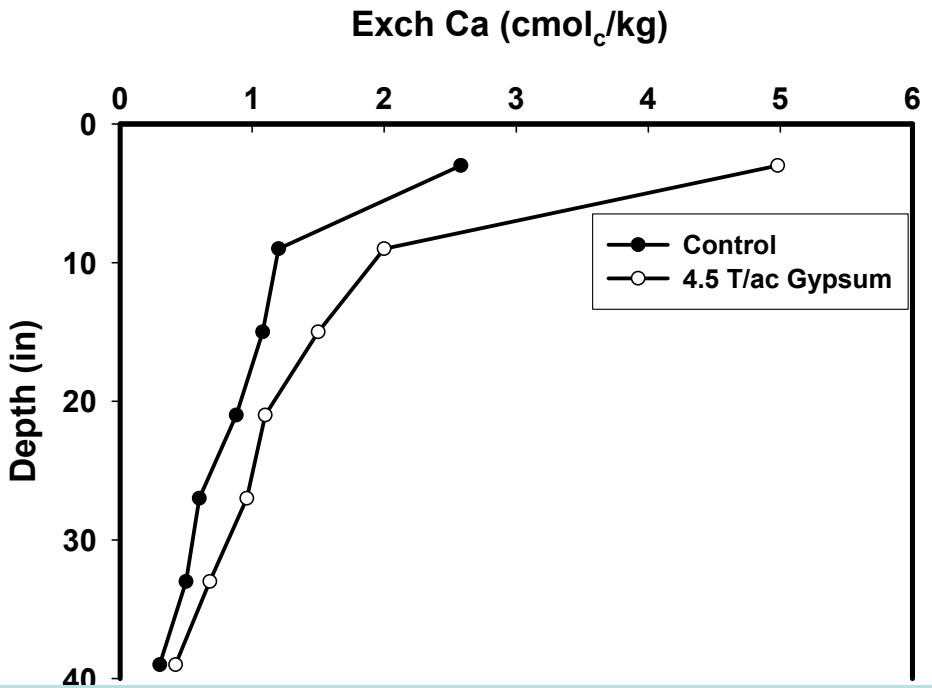
Toxic aluminum — Hydrated lime — Gibbsite insoluble

- **pH increases**
- **Negative charge increases**

(Reeve & Sumner, 1972)

EFFECT OF GYPSUM ON EXCHANGEABLE Al & Ca





Evidence for Self-Liming Effect

(Sumner, 1990)

I (mol/L)	pH		
	$CaSO_4$	$CaCl_2$	ΔpH
0.0300	4.54	4.20	+0.34
0.0140	4.72	4.44	+0.28
0.0028	4.95	4.74	+0.21
0.0014	5.08	4.91	+0.17
0.0007	5.19	5.06	+0.13

Gypsum Increases Negative Charge

(Sousa et al., 1986)

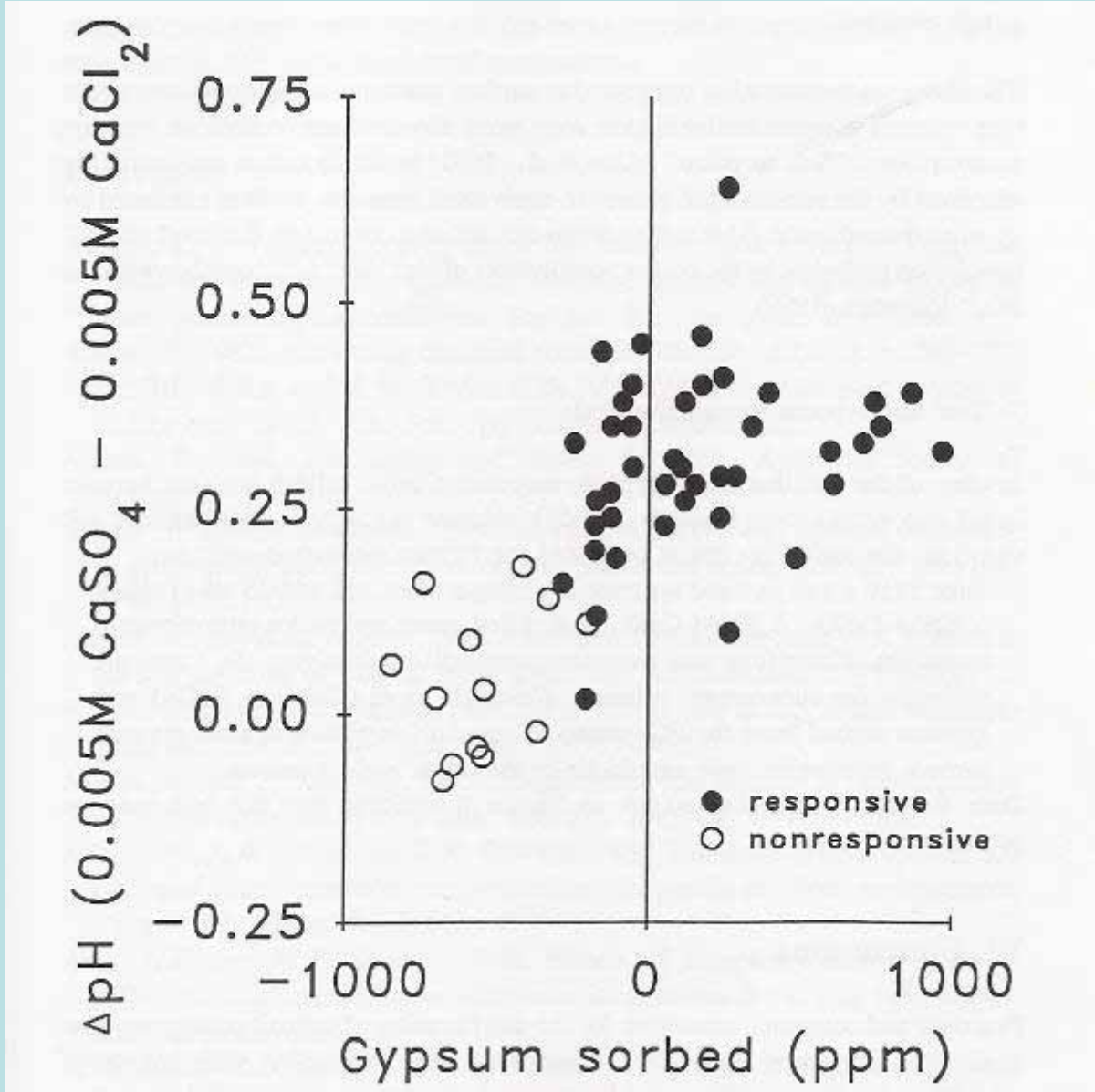
Depth (cm)	Negative charge ($cmol_c/kg$)	
	Control	Gypsum (6t/ha)
0-15	2.87	3.65
15-30	1.11	1.42
30-45	1.04	1.15
45-60	0.74	1.13
60-75	0.83	1.13
75-90	0.58	0.91
90-105	0.40	0.65

Responsive Soils Exhibit "Salt Sorption"

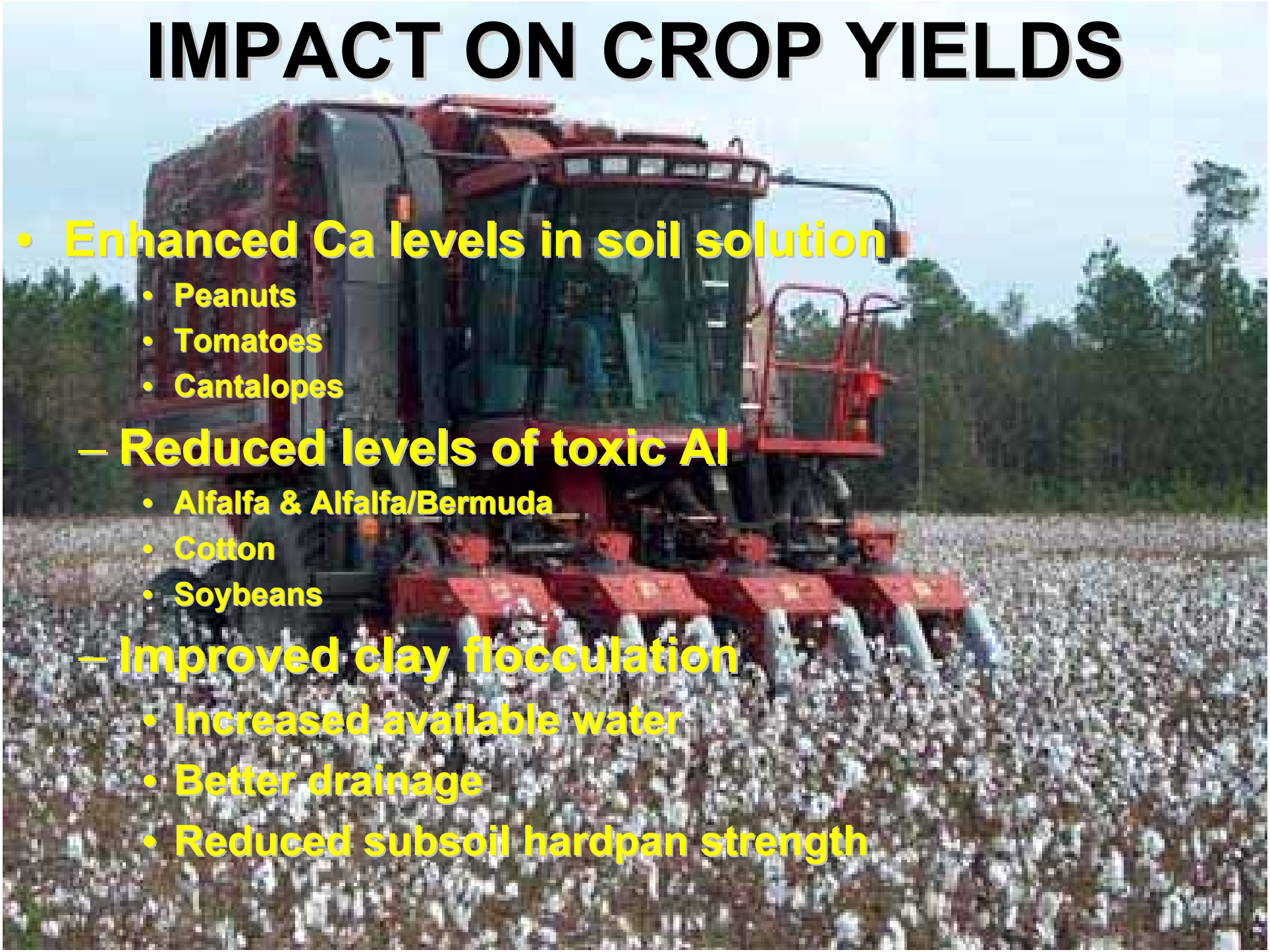
Treatment	EC	ΣCat_{sol}	ΣCat_{displ}	ΣAn_{sol}	ΣAn_{displ}
	µS/cm		$mmol_c/L \times 10$		
$CaSO_4$ soln	1830	23		23	
$CaSO_4$ + soil	35	2.7	1.2	3.0	1.0

Test for Gypsum Responsive Soils (Sumner, 1994)

- Measure pH in 0.005 M $CaSO_4$ and 0.005 M $CaCl_2$
- Calculate ΔpH ($CaSO_4$ – $CaCl_2$)
- Measure EC of 0.005 M $CaSO_4$ before and after addition of soil
- Calculate amount of gypsum adsorbed
- Plot ΔpH vs gypsum adsorbed


ΔpH (0.005M CaSO4 − 0.005M CaCl2)
0.75
0.50
0.25
0.00
−0.25
−1000
0
1000
Gypsum sorbed (ppm)
responsive
nonresponsive

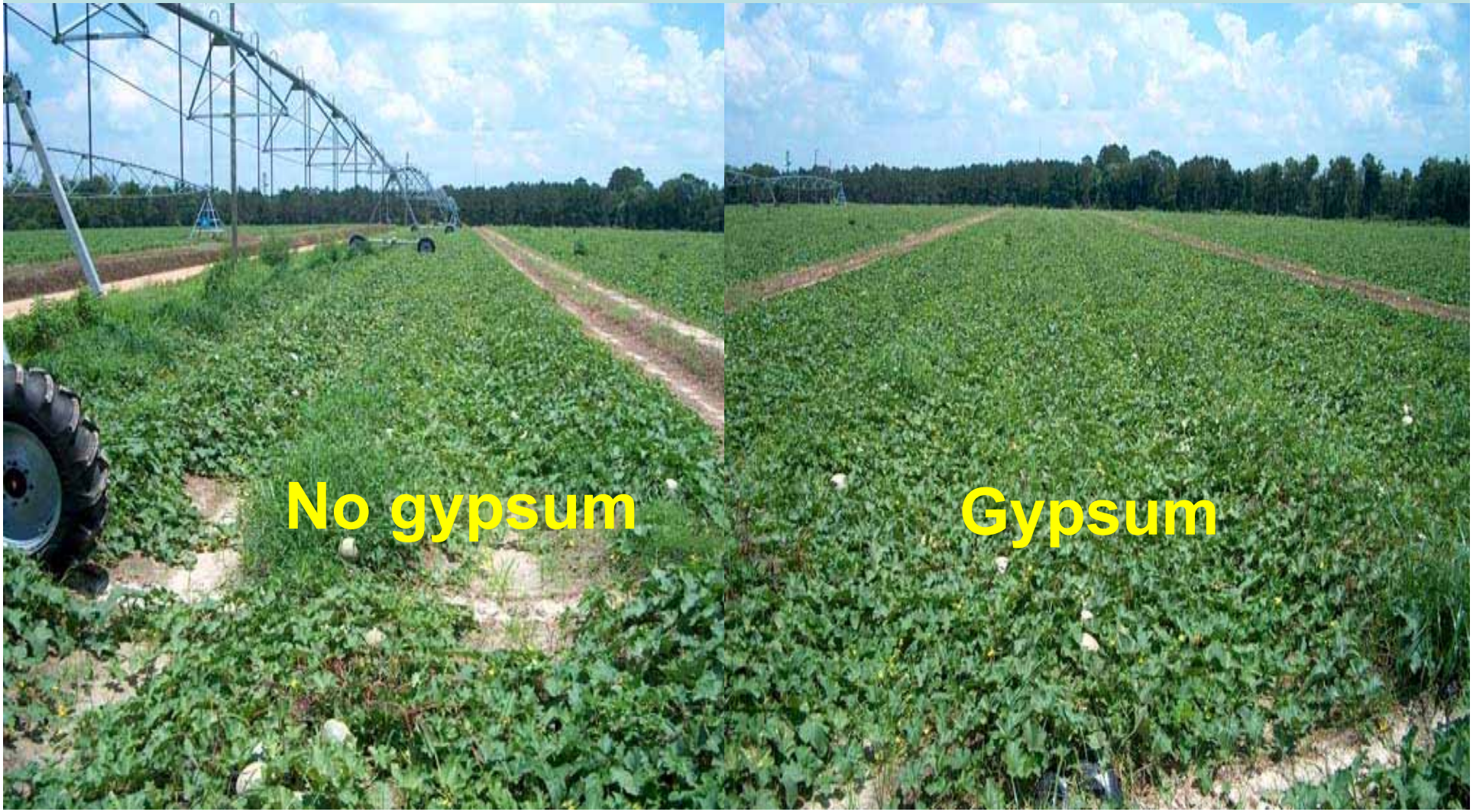
IMPACT ON CROP YIELDS



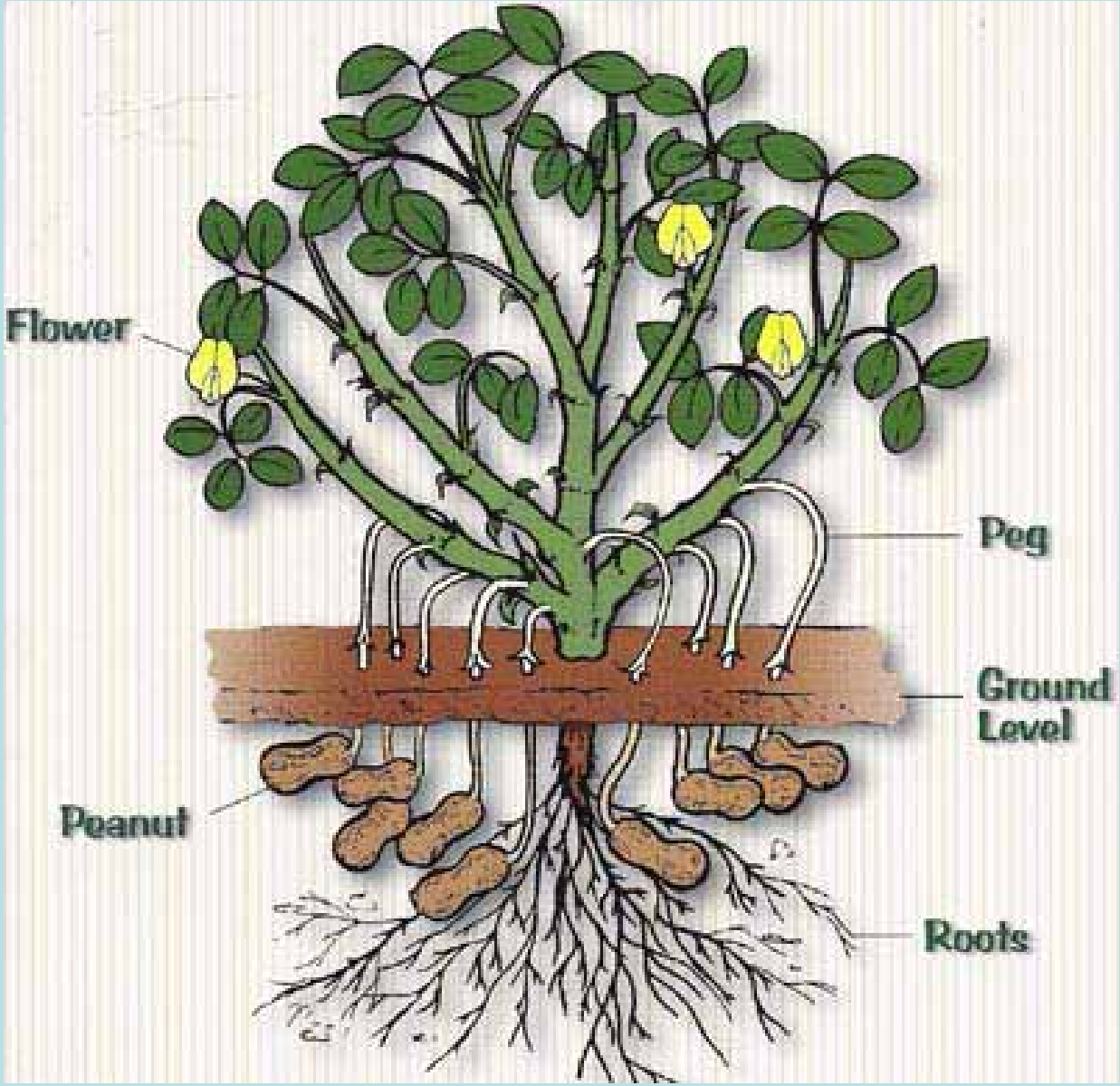
- Enhanced Ca levels in soil solution
  - Peanuts
  - Tomatoes
  - Cantalopes
- Reduced levels of toxic Al
  - Alfalfa & Alfalfa/Bermuda
  - Cotton
  - Soybeans
- Improved clay flocculation
  - Increased available water
  - Better drainage
  - Reduced subsoil hardpan strength

CROP RESPONSES TO GYPSUM

Enhanced Soluble Ca Levels in Soils



PEANUTS

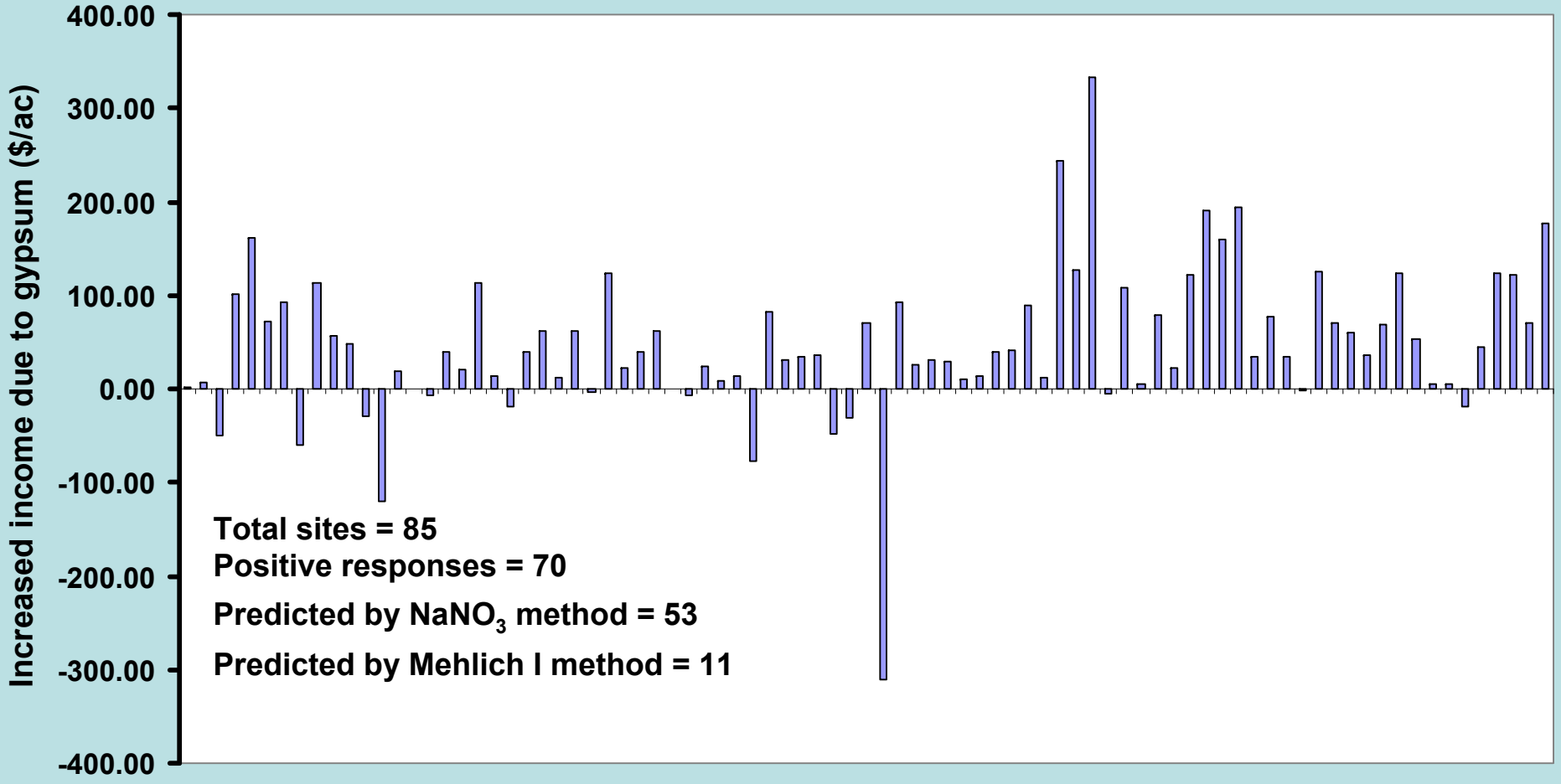


PEANUTS

Treatment	Yield	SMK*	Value	Seed Ca
	T/ac	%	$/ac	%
Control	2.1a	71a	375.12	0.049
0.5 T FGD gypsum/ac	2.6b	75b	481.96	0.059

* SMK = Sound mature kernels

Summary of Peanut Responses to Gypsum

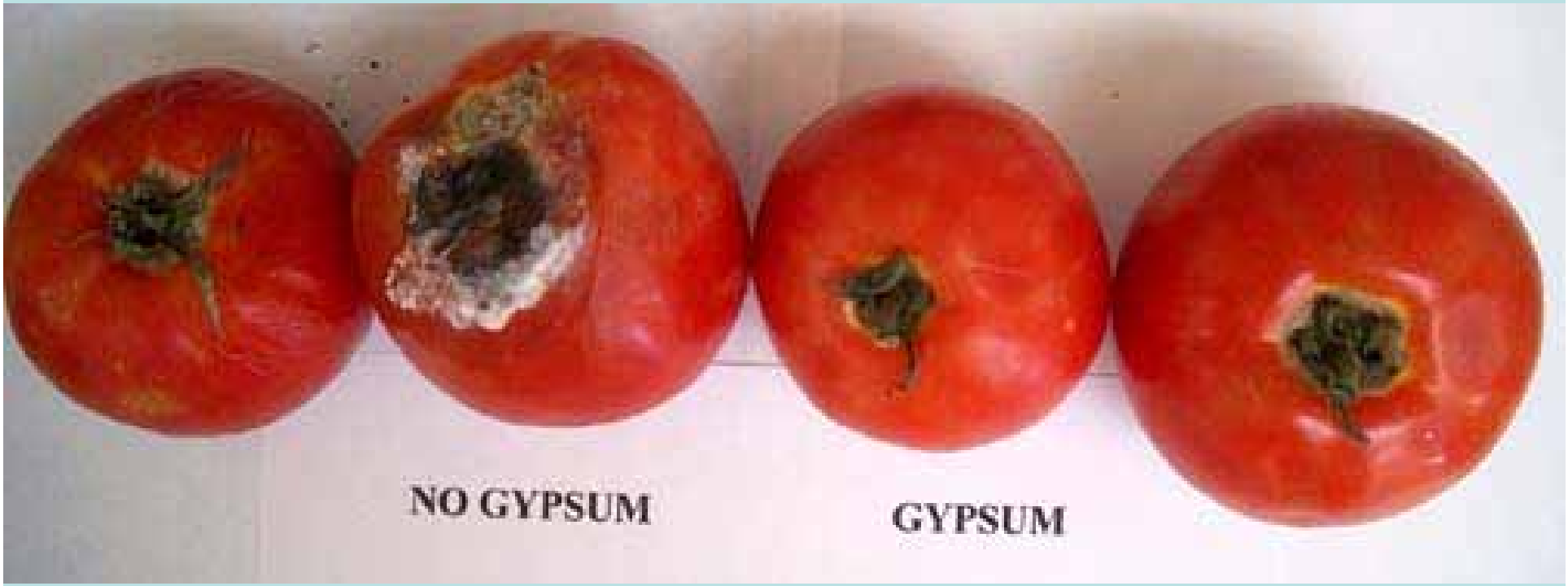


GYPSUM AND TOMATOES

Treatment	Yield	Skin Ca	Fruit rejection*
	T/ac	%	%
Control	26.5a	0.21a	95
5 T FGD gypsum/ha	37.5b	0.34b	15

* After storage for 4 weeks @ 4 ^{o}C

Effect of Storage at Room Temperature for 4 Weeks - 2006

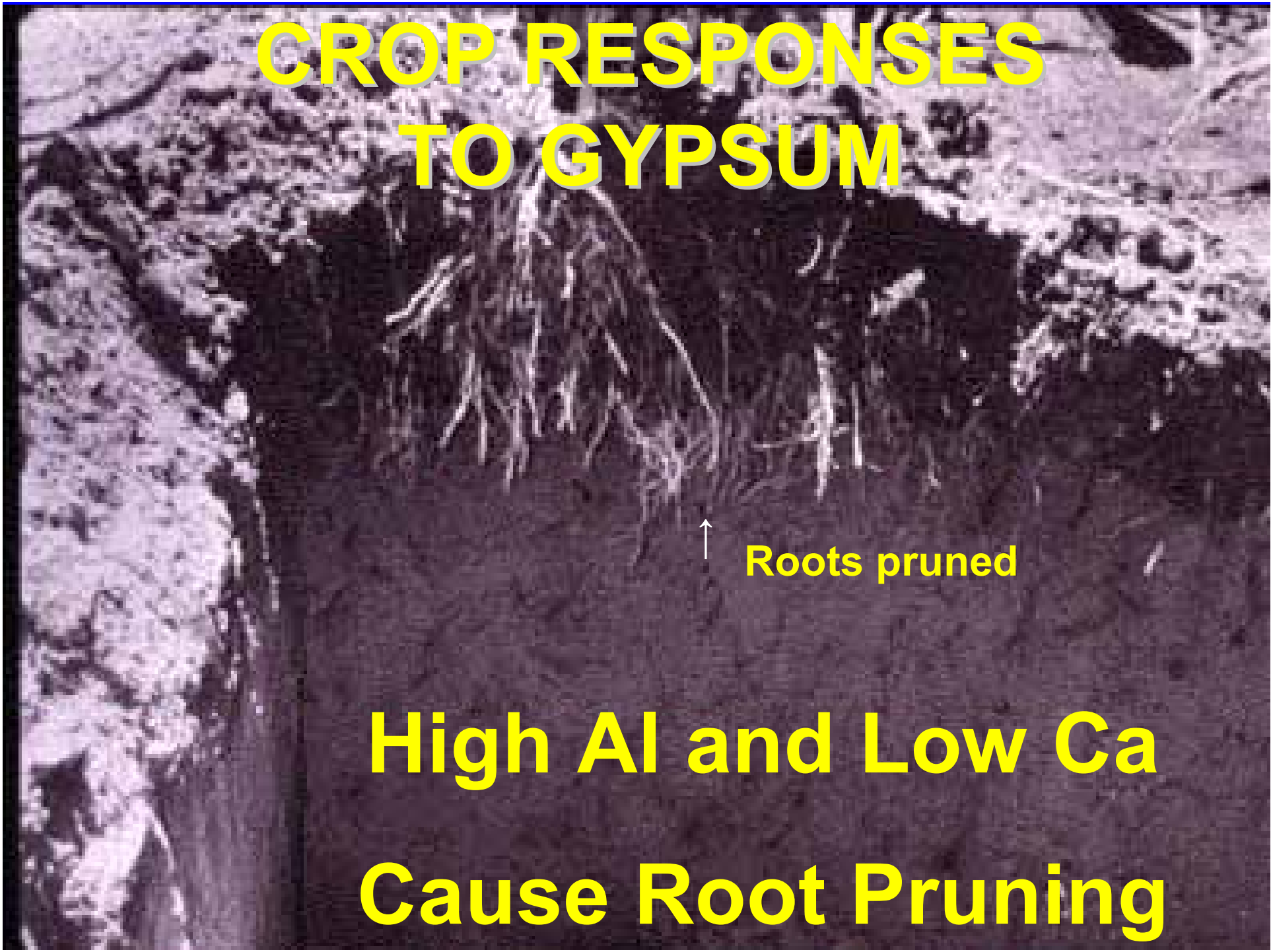


GYPSUM AND CANTALOUPES

Treatment	Yield	Wt/fruit	Skin Ca	Fruit rejection*
	T/ha	kg	%	%
Control	6.71a	2.12a	1.07a	89
1.25 T FGD gypsum/ha	10.17b	2.14a	1.24b	15

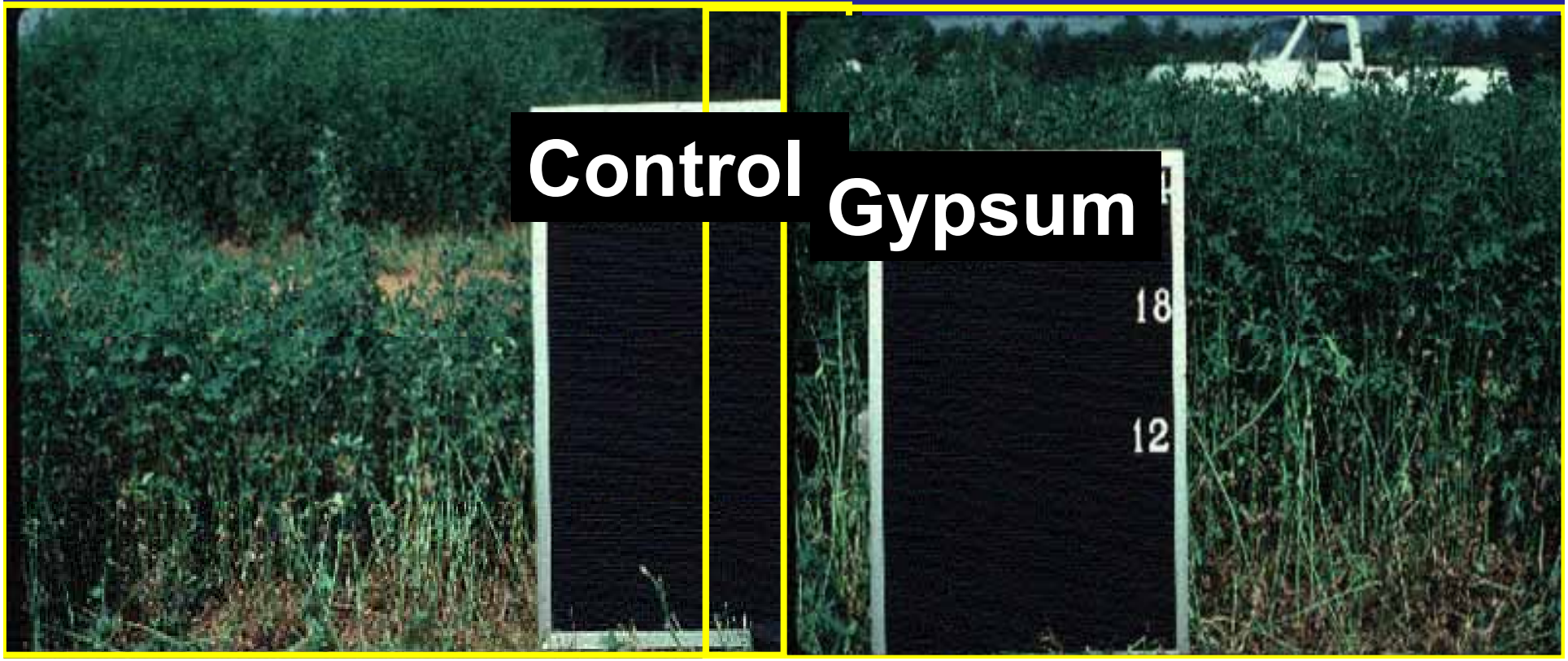
* After storage for 4 weeks @ 4 °C

Fruit Quality after 4 Weeks of Storage @ 40°F


CROP RESPONSES TO GYPSUM
Roots pruned
High Al and Low Ca Cause Root Pruning

CROP RESPONSES TO GYPSUM

Reduced Levels of Toxic Al
Increased levels of soluble Ca



Root Development

Control

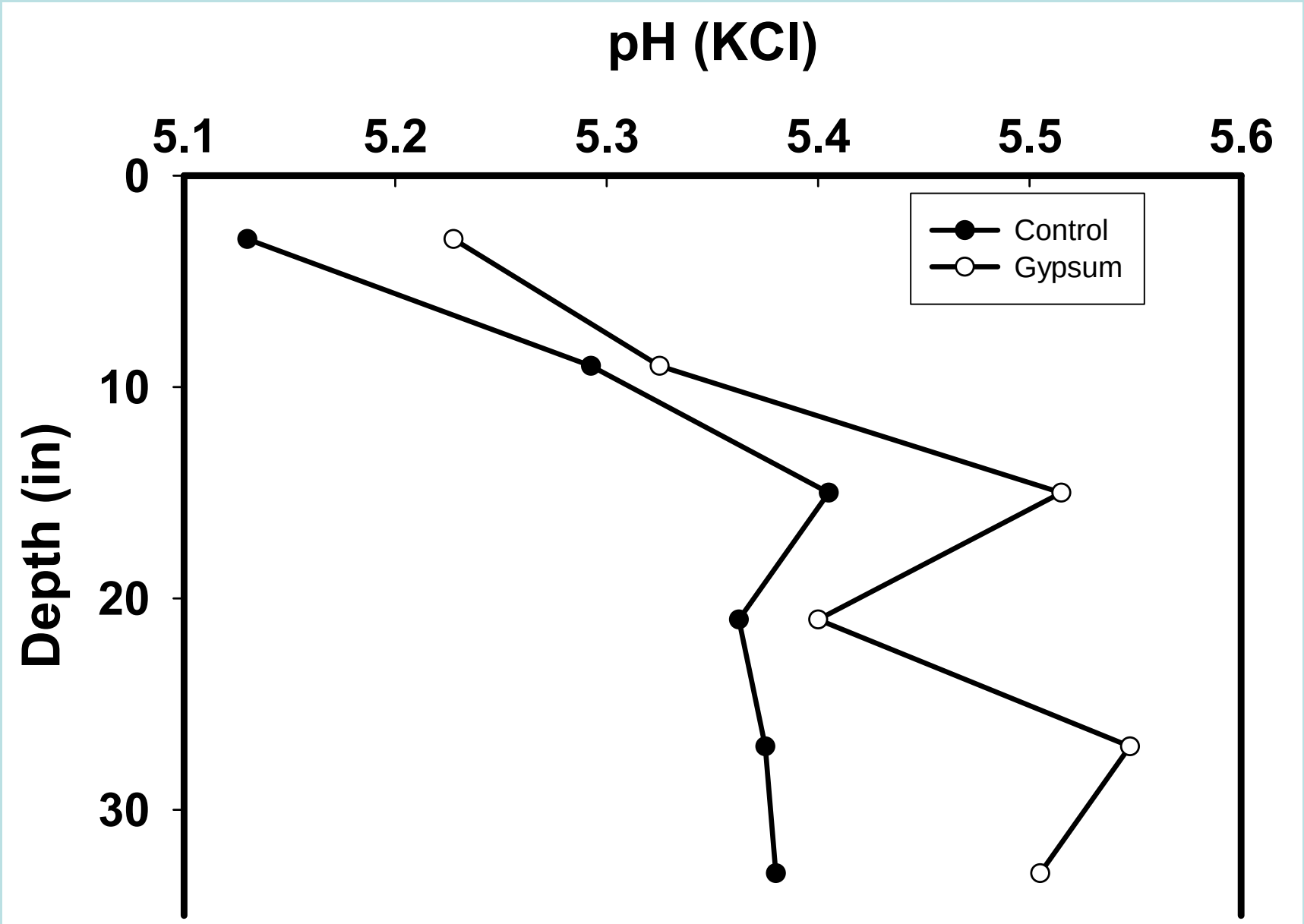
Gypsum

Alfafa

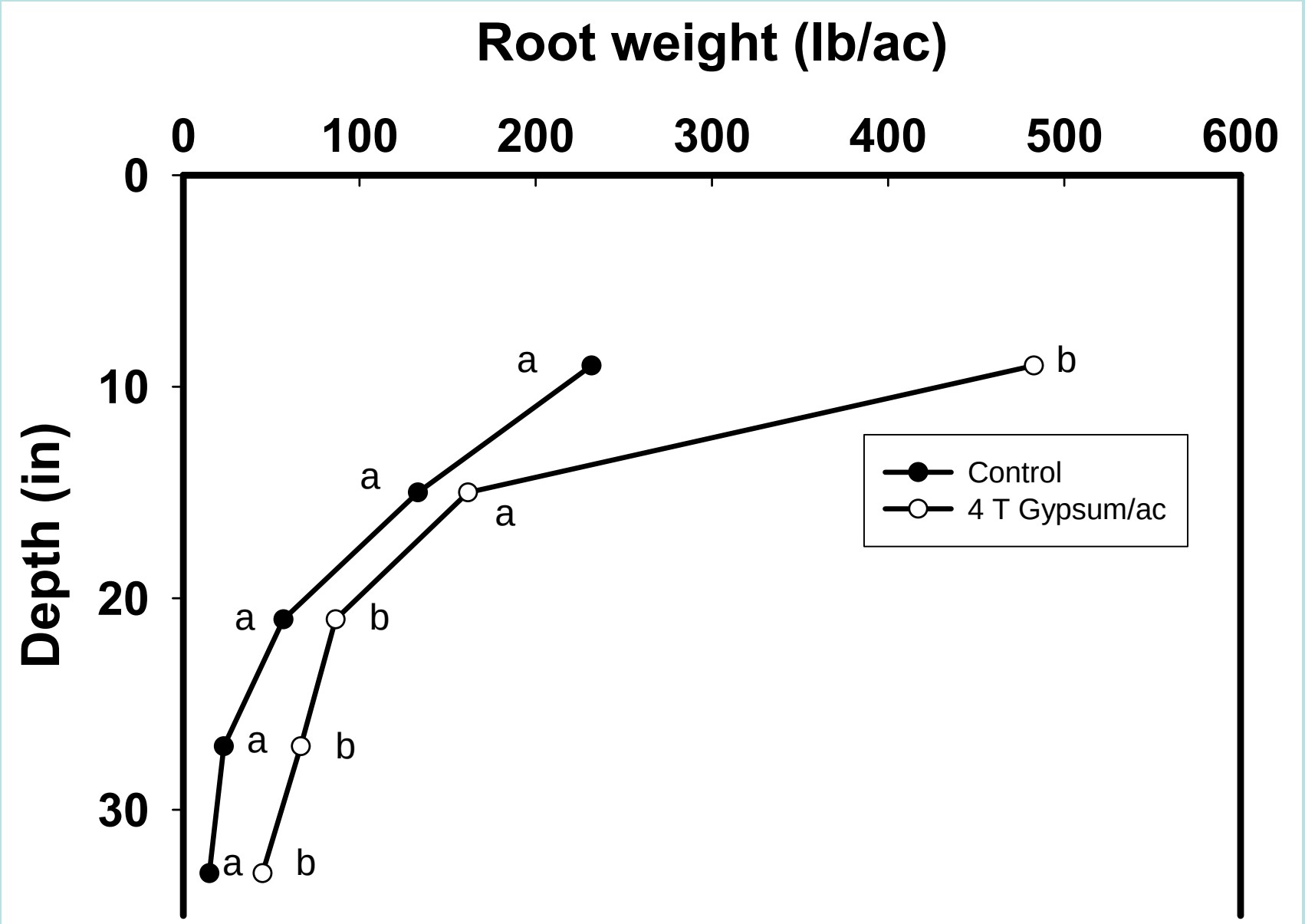
ALFALFA-BERMUDA

Treatment	Hay yield (lb/ac)				
	Cut 1	Cut 2	Cut 3	Cut 4	Total
Control	1.31	1.00	1.29	0.88	4.48
4.5 T Gypsum/ac	1.53	1.06	1.38	1.01	4.98

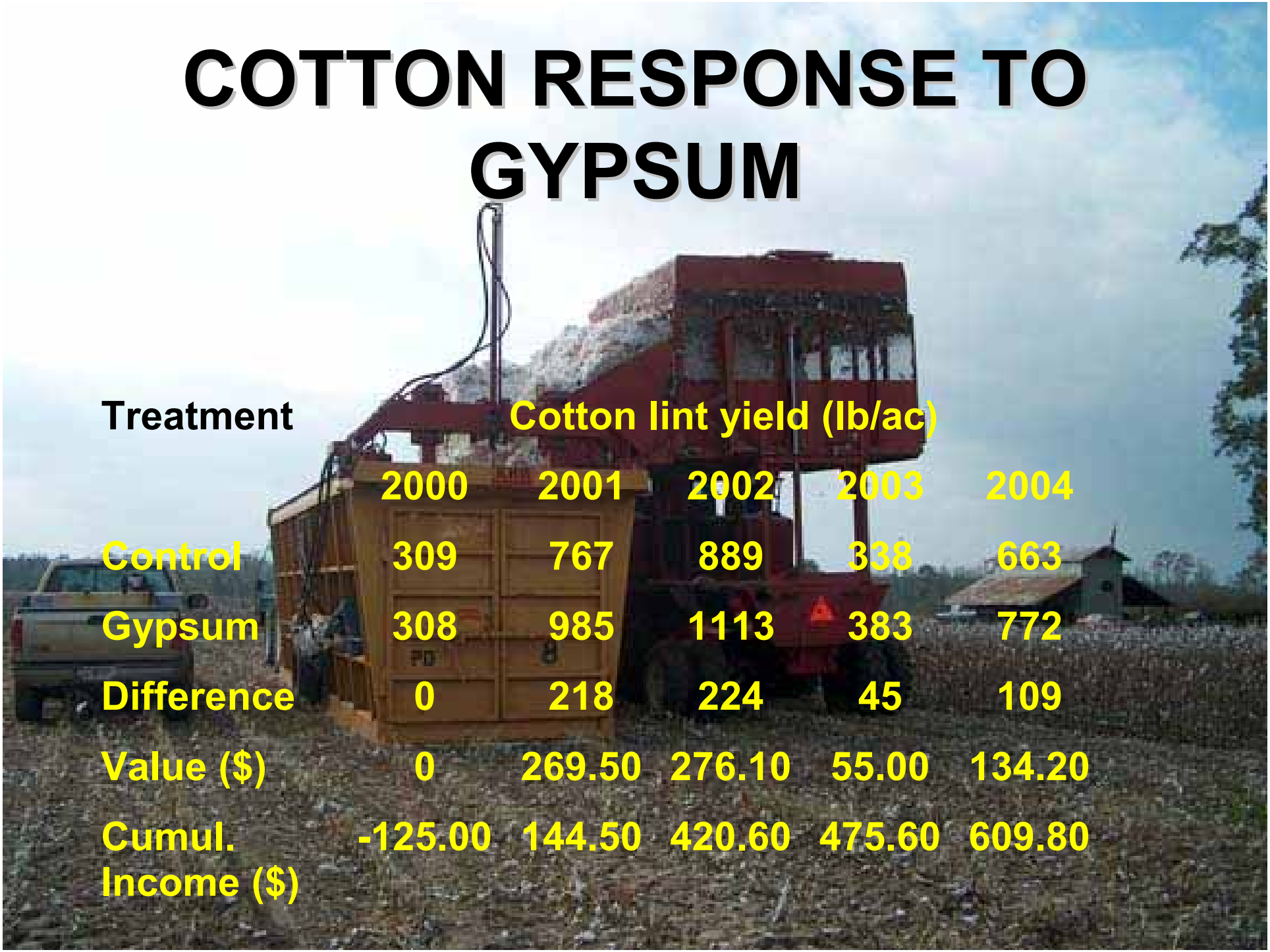
ALFALFA-BERMUDA



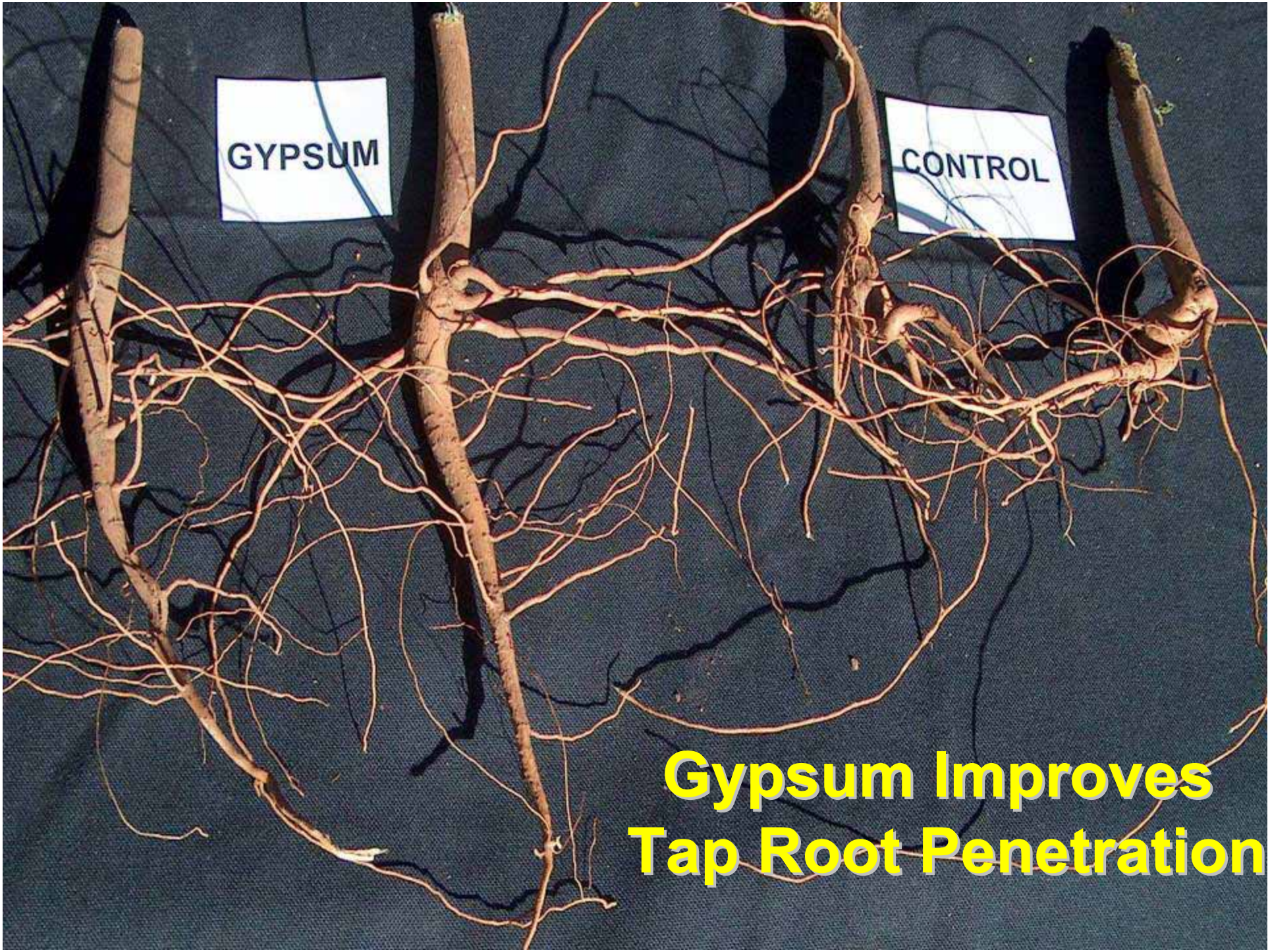
ALFALFA-BERMUDA



COTTON RESPONSE TO GYPSUM



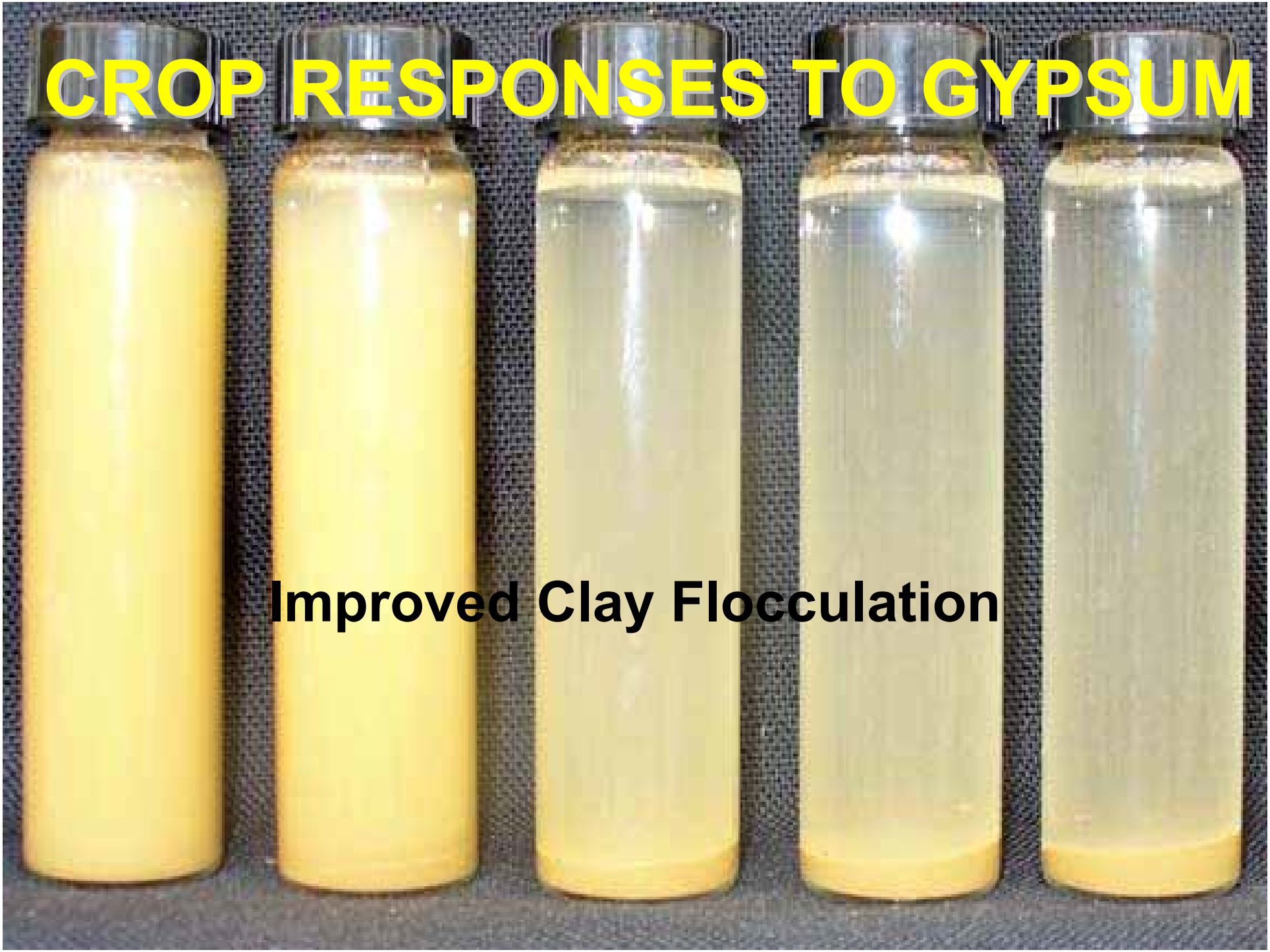
Treatment	Cotton lint yield (lb/ac)				
	2000	2001	2002	2003	2004
Control	309	767	889	338	663
Gypsum	308	985	1113	383	772
Difference	0	218	224	45	109
Value ($)	0	269.50	276.10	55.00	134.20
Cumul. Income ($)	-125.00	144.50	420.60	475.60	609.80


GYPSUM
CONTROL
Gypsum Improves
Tap Root Penetration

SOYBEANS

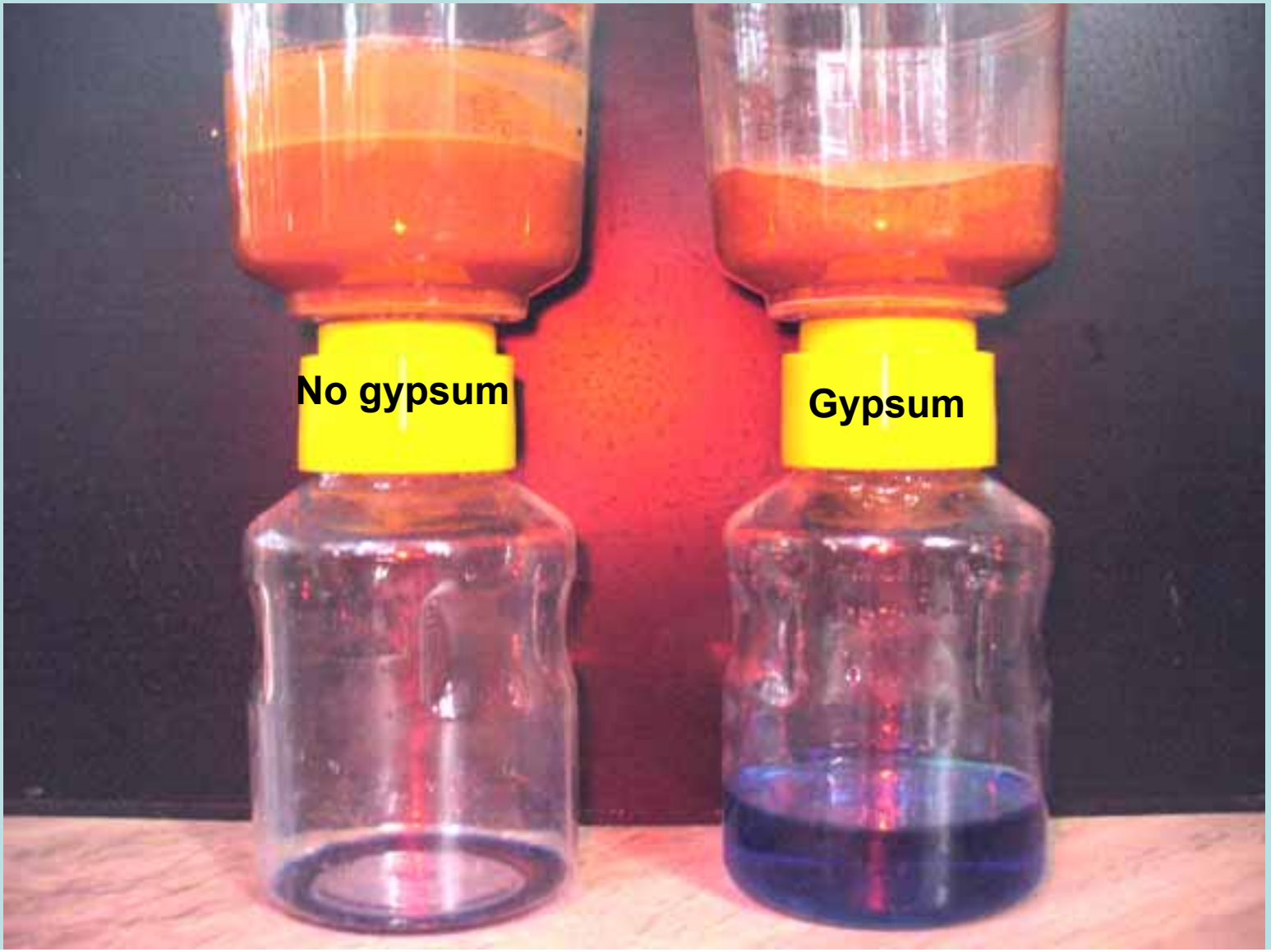
Soybeans

CROP RESPONSES TO GYPSUM

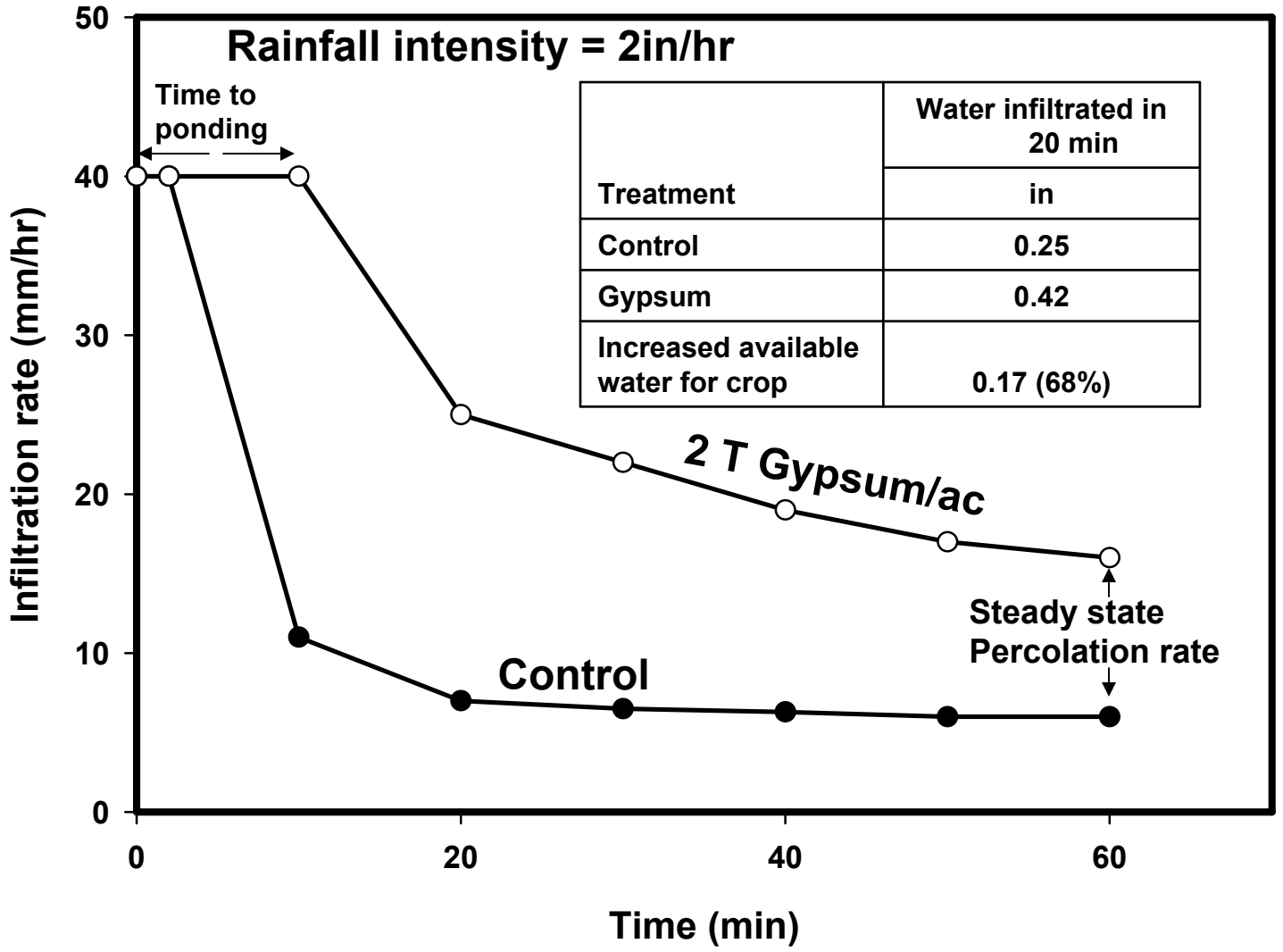


Improved Clay Flocculation

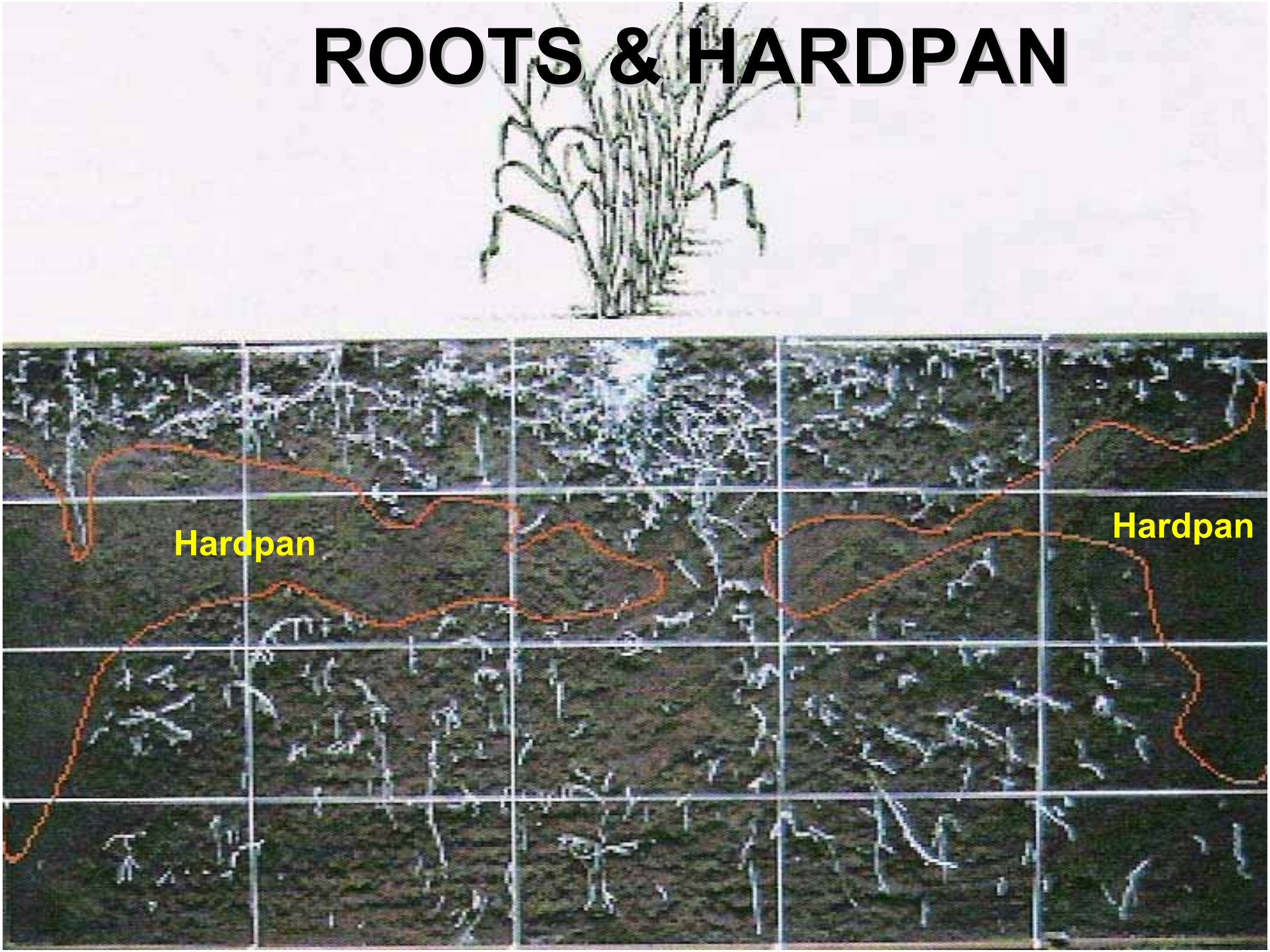
GYPSUM IMPROVES PERCOLATION



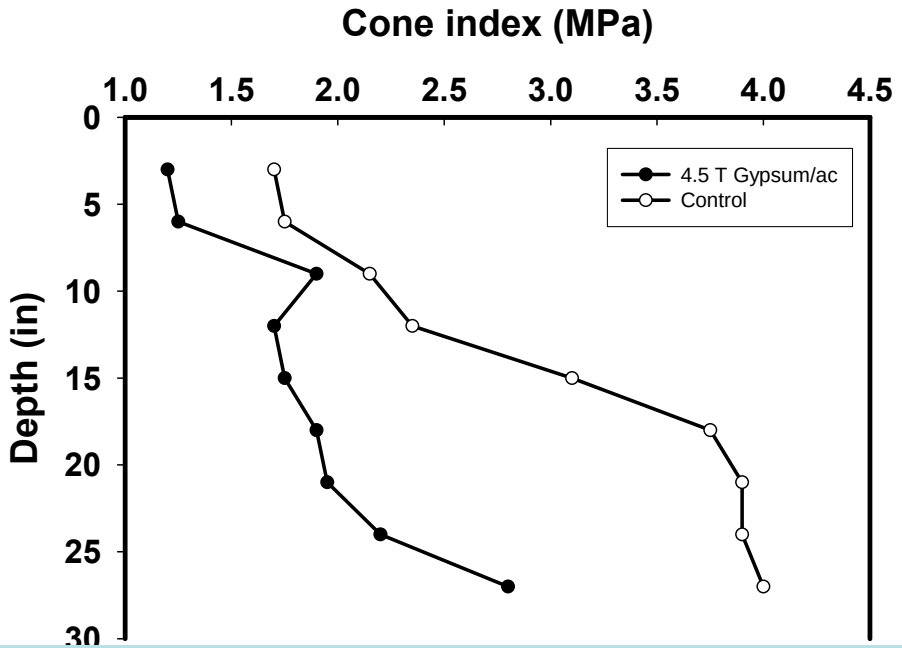
GYPSUM INCREASES INFILTRATION & PERCOLATION RATES IN CLAY SOIL

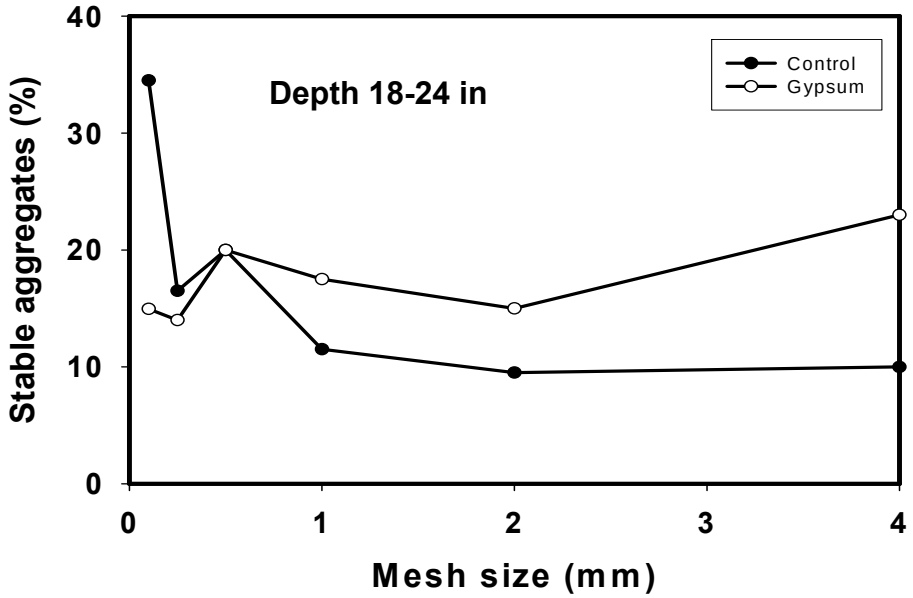


ROOTS & HARDPAN



GYPSUM SOFTENS SUBSOIL HARDPANS & IMPROVES AGGREGATION





CONCLUSIONS

- Gypsum
  - Supplies essential elements (Ca & S) to crops
  - Reduces levels of toxic Al in subsoils
  - Promotes clay flocculation
  - Softens subsoil hardpans
  - Improves aggregation
- Result
  - Crop yields and quality improved

Thank you for your attention

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