WCMC 2015

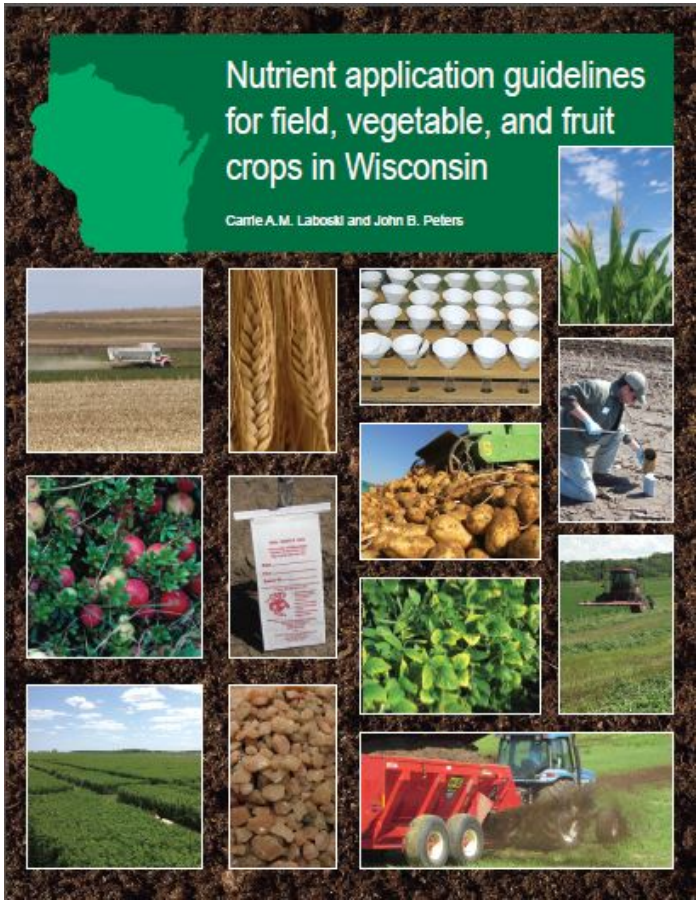
The Base Cation Saturation Ratio – BCSR

Adam P. Gaspar[1] & Carrie A.M. Laboski[2]
University of Wisconsin-Madison
[1]Dept. of Agronomy
[2]Dept. of Soil Science

UW Extension
University of Wisconsin-Extension

Overview

- What is the Base Cation Saturation Ratio (BCSR)?
- Where did this idea originate?
- Theory?? behind the BCSR.
- Why it is **NOT** a recommended method across the Midwest.



UW Extension
University of Wisconsin-Extension

Soil Fert. Recommendations

- Three philosophies driving Soil Fertility Recs.

1. Build and Maintain (WI, IL, IA, IN, MI)
2. Sufficiency (MN & SD)
3. Base Cation Saturation Ratio (.....)
    - Not recommended any where.

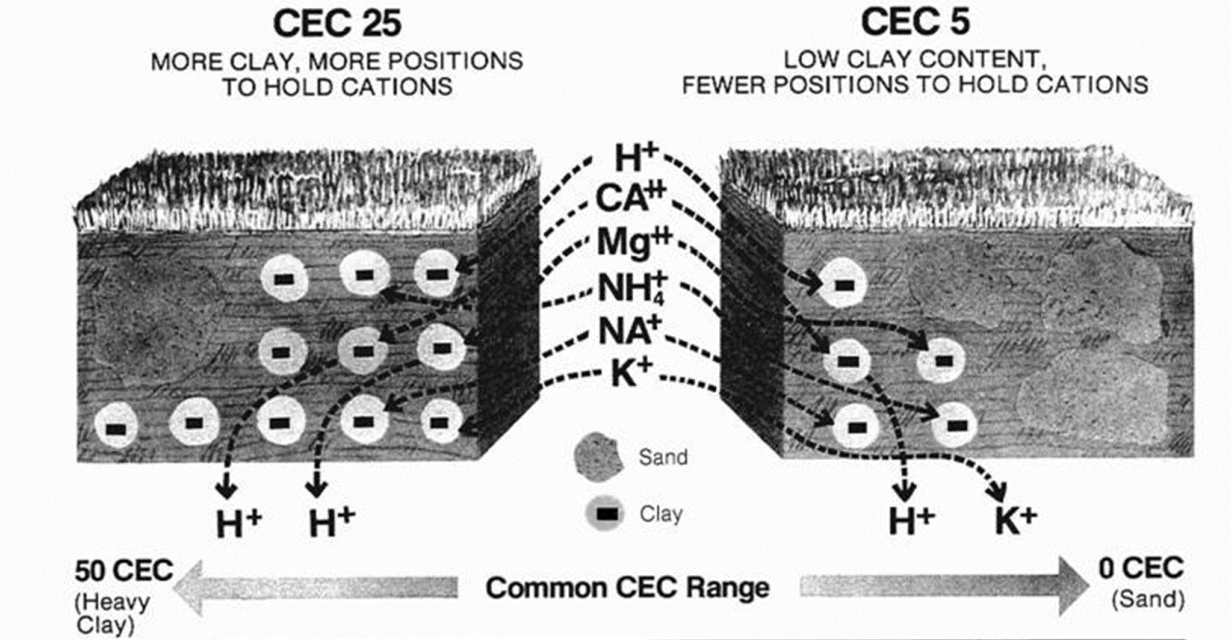
Cation Exchange Capacity – CEC

- CEC is the total amount of cations held to soil components that can be exchanged with cations in soil solution.

- Factors affecting CEC:
  1) Amount of Clay (soil texture)
  2) Type of Clay
  3) Amount of Organic Matter (OM)

$Ca^{2+} + NH_4^+ + Mg^{2+} + K^+ + Na^+ + H^+ = \text{Total soil CEC}$

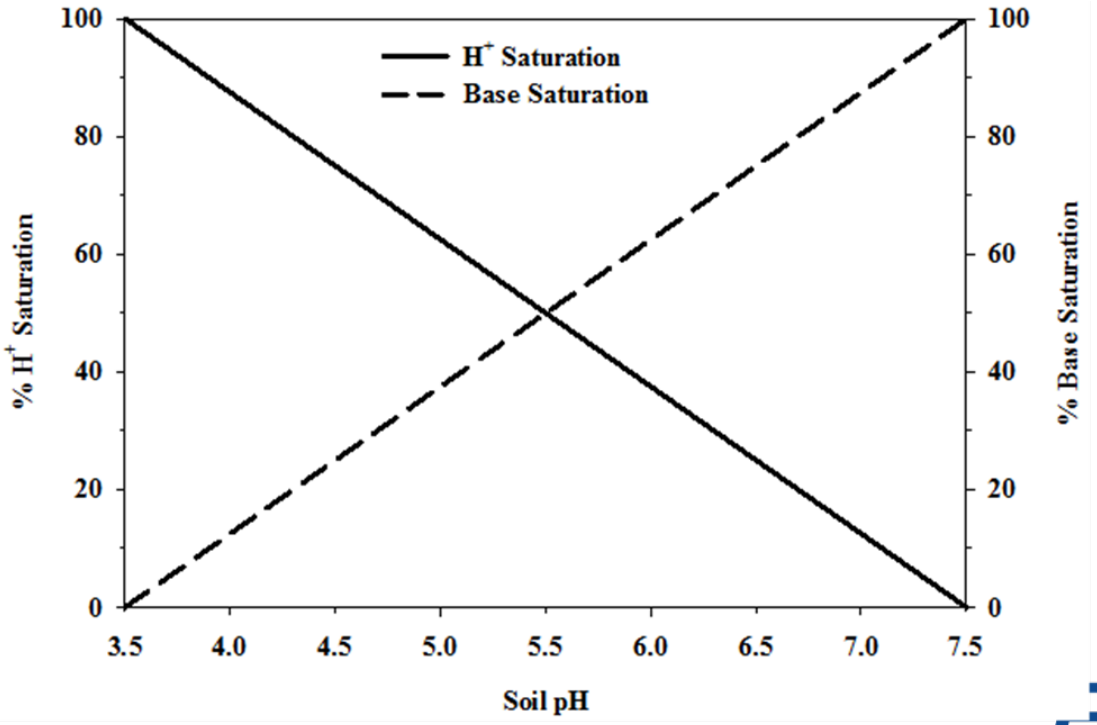
- meq./100g soil
- $cmol_c$/kg soil



**From Spectrum Analytics Inc.*

Base Saturation

- *Ca2+ + Mg2+ + K+ + Na+ + etc./***Soil total CEC** *= Base Saturation* (%)
- ***Base cations***(%) + ***H↑+*** (%) = **100%** ***of the CEC***



The Proposed "Ideal" Ratio

- Base Cation Saturation Ratio (BCSR)
- Theory that there is a specific Base Saturation or BCSR that a soil must hold for optimal plant growth and nutrient availability
- Proposed **Base Saturation** should be 65% Ca^{2+}, 10% Mg^{2+}, and 5% K^{+} (Bear et al., 1945)
  - Remaining 20% a combination of H^{+}, Na^{+} and NH_4^{+}
- Resulting "ideal" **ratio**'s are:
  - Ca:Mg 6.5:1
  - Ca:K 13:1
  - Mg:K 2:1
  - Ca:Mg:K 13:2:1

UW Extension
University of Wisconsin-Extension

Origin and History

- Idea originated in 1901 and gained steam in the 40's and 50's (Bear, Hunter, Prince, and Albrecht)
- Much of the early work supporting the BCSR was conducted in New Jersey and Missouri.
  - Developed in the lab and NOT tested in the field.
- Has since been a heavily **disproven** theory to increase crop yields in WI, the Midwest, and globally.
- While there is no "ideal" BCSR or base saturation, some still promote this concept.

Origin and History

- After the “ideal” ratio was established some researchers altered this to encompass “ideal” ranges:

Table 1. Previously reported base saturations and subsequent base cation saturation ratios for an “ideal soil”.

Nutrient	Bear et al. (1945)	Graham (1959)	Baker & Amacher (1981)
		Base Saturations (%)	
Ca	65	65 – 85	60 – 80
Mg	10	6 – 12	10 – 20
K	5	2 – 5	2 – 5
		Base Cation Saturation Ratios	
Ca:Mg	6.5:1	5.4:1 – 14.1:1	3.0:1 – 8.0:1
Ca:K	13:1	13.0:1 – 42.5:1	12.0:1 – 40.0:1
Mg:K	2:1	1.2:1 – 6.0:1	2.0:1 – 10.0:1

*Bear et al. (1945) is considered the “ideal ratio”

Flaws in BCSR Theory

- It solely focuses on maintaining a specific ratio between Ca^{2+}, Mg^{2+}, and K^{+}, (13:2:1)

- This can lead to expensive, inconsistent fertilizer recommendations regardless of actual Ca, Mg, and K soil tests levels

- In many cases this can result in **excessive fertilizer applications** or **nutrient deficiencies** even though the "ideal" ratio is being held.

Example #1 – CEC

Table 2. Comparison of two soils with the same base saturations but different CEC and thei approximate levels of Calcium, Magnesium, and Potassium in the soil at the "ideal" ratio.

		CEC = 40 meq./100g	CEC = 5 meq./100g
Nutrient	**Base saturation**	**Estimated soil test level**	
	%	ppm	ppm
Ca	65	5,200	650
Mg	10	480	60
K	5	780	98
Na+H+etc.	20		

- What if the first soils Ca:Mg ratio was initially 5.5:1???
- The soil test level would be 4,400 ppm Ca which equates to ~8,800 lbs/a Ca in this soil
  - BCSR recommendation would be **3.6 tons/a** of gypsum at a cost of **~$144/a.**

Example #2 – Base Sat.

Table 4. Comparison of two soils with the same CEC and "ideal" ratio of 13:2:1 of Ca:Mg:K but different percent base saturations and their approximate levels of Calcium, Magnesium, and Potassium.

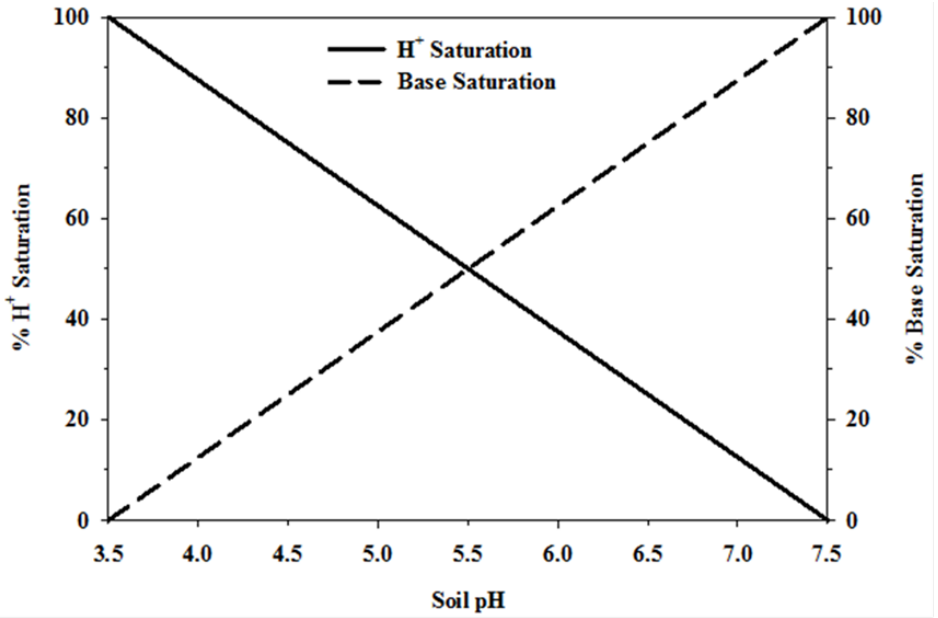
Nutrient	Base saturation	Estimated soil test level	Base saturation	Estimated soil test level
	Soil #1		*Soil #2*	
	%	ppm	%	ppm
Ca	65	650	32.5	325
Mg	10	60	5	30
K	5	98	2.5	49
Na+H+etc.	20	--	60	--

*Both soils are at the "ideal" ratio

- Optimum soil test category:
  - **Ca:** 401-600
  - **Mg:** 51-250
  - **K:** 66-90
- Soil #2 would test in the low and almost very low categories for all nutrients

Soil #2 a pH Challenge

Soil #2	
Nutrient	Base saturation
	%
Ca	32.5
Mg	5
K	2.5
Na+H+etc.	60



- Soil #2 would likely have a extremely low soil pH and require a lime application.
- A lime application would actually move the cation ratios away from the “ideal” ratio.
- But at the same time actually improve crop production because of a more favorable pH

Ca:Mg Ratios in WI

- The Ca:Mg ratio varies substantially across the state

Table 5. Ca:Mg ratio for various soil types throughout WI.

Soil	Ca:Mg Ratio	Soil	Ca:Mg Ratio	Soil	Ca:Mg Ratio
Antigo	4.0:1	Kewaunee	3.1:1	Pella	3.9:1
Almena	3.2:1	Marathon	7.7:1	Plainfield	6.1:1
Boone	1.0:1	Morley	4.0:1	Plano	3.3:1
Dubuque	4.0:1	Norden	8.1:1	Poygan	4.3:1
Gale	4.3:1	Onaway	6.7:1	Withe	3.5:1
Freer	3.7:1	Ontonagon	4.0:1		

*From Schulte and Kelling (1985)

- Will also vary considerable across a given field because the estimated CEC is based upon soil test results

Ca:Mg Ratios in WI

- It seems that crop production on 4 common WI soil does not heavily affect the Ca:Mg ratio.

Table 6. Effect of crop production on the Ca:Mg ratio in four WI soils.

	Ca:Mg Ratio	
Soil	**Non-Cropped**	**Cropped**
Plainfield sand	7.9:1 (850/108)†	8.7:1 (590/68)
Boone loamy sand	1.5:1 (75/50)	1.0:1 (50:50)
Gale silt loam	2.6:1 (540/206)	4.3:1 (2,040/472)
Ontonagon silt loam	3.9:1 (1930/140)	4.2:1 (2,660/634)

*From Schulte and Kelling (1985)

†Actual pounds of exchangeable Ca/exchangeable Mg.

BCSR and Crop Production

- After Bear and his colleagues (1949) there have been **NO** published studies reporting any affect of the BCSR on crop yields

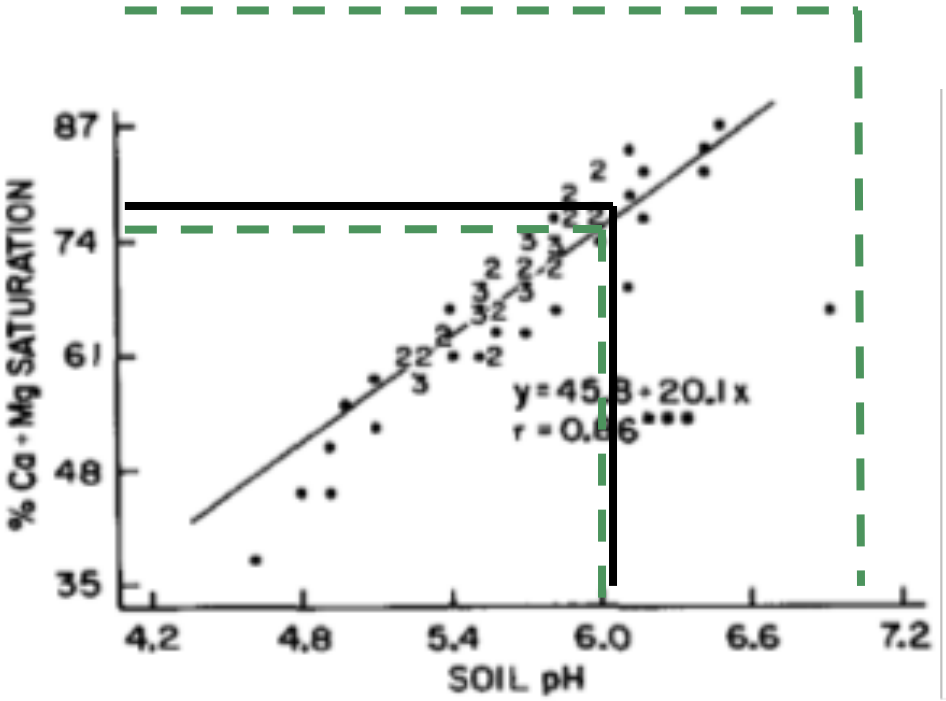


Figure 3. Soil pH - Ca+Mg relationship.

- Was soil pH the underlying factor for the "ideal" ratio and range???

BCSR and Crop Production

- 4 years of corn and soybean rotation studied in Ohio

Table 7. Range of BCSR's for the five highest and lowest yields for corn and soybeans.

		Ranges in BCSR			
Ratio	**Yield Level**	**Corn (1975)**	**Corn (1976)**	**Soybean (1977)**	**Soybean (1978)**
Ca:Mg	Highest Five	5.7 – 26.8	5.7 – 14.3	5.7 – 14.0	5.7 – 26.8
Ca:Mg	Lowest Five	5.8 – 21.5	5.0 – 16.1	2.3 – 16.1	6.8 – 21.5
Mg:K	Highest Five	0.6 – 3.0	1.3 – 3.1	1.0 – 3.0	1.1 – 3.1
Mg:K	Lowest Five	1.1 – 2.1	0.7 – 2.1	0.7 – 3.6	0.7 – 2.1

*Data from McLean et al., (1983) and table adapted from Rehm (1994).

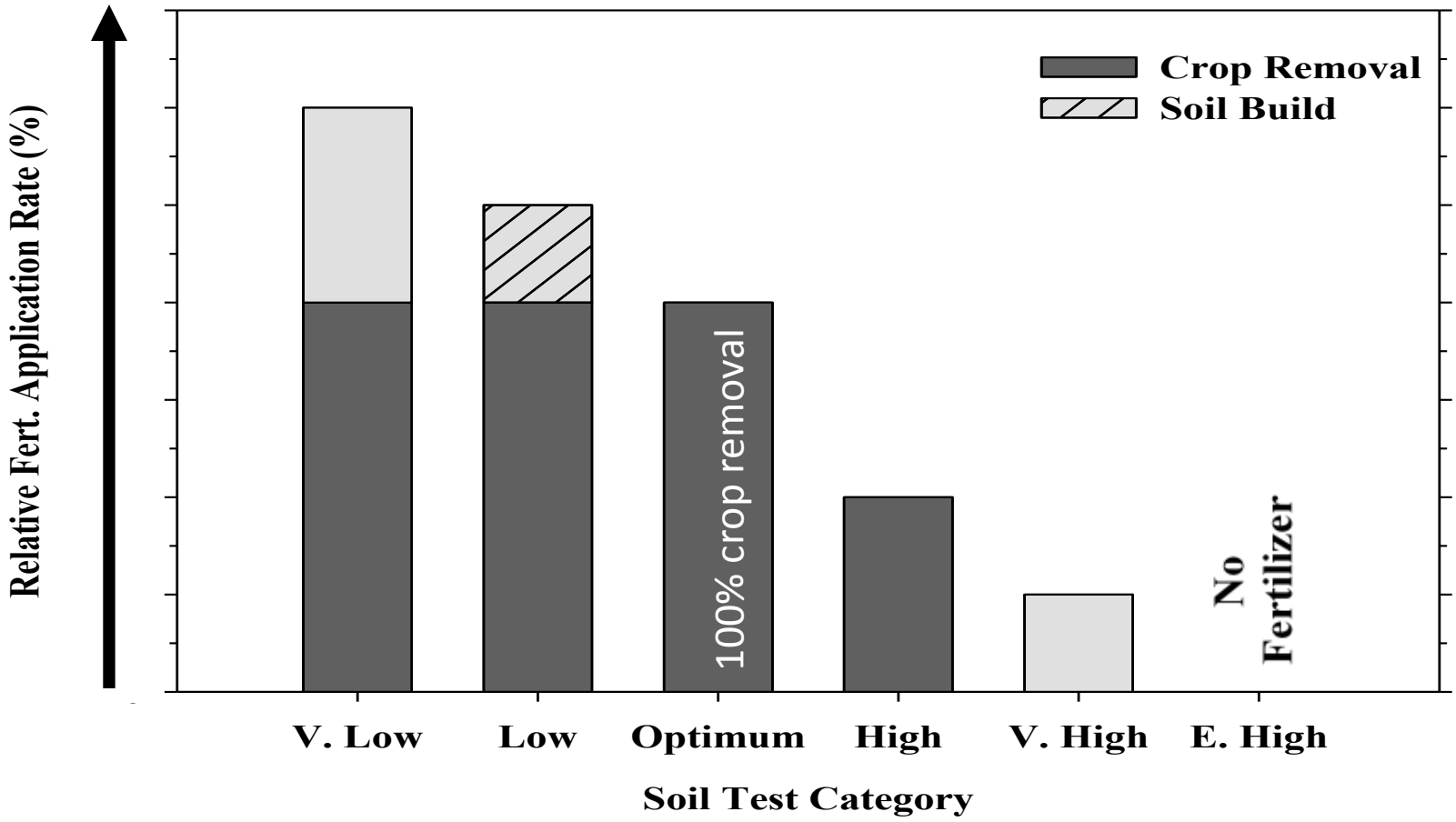
- A wide range of ratio's produced the highest and lowest yields every year regardless of crop
  - NO EFFECT ON YIELD

BCSR and Plant Uptake

- There have been some reports of an altered **BCSR effecting plant tissue concentrations.**
- Simson et al. (1979) showed that increasing Ca saturation past critical soil test levels increased Ca concentration in corn and alfalfa
- Rehm & Sorenson (1985) showed increasing Mg saturation past critical soil test levels increased Mg concentration in corn.
  - Increasing K saturation past critical soil test levels actually decreased Mg concentration though.
- **↑ Plant concentration ≠ increased yield**
- **Yields were never increased by altering the BCSR**

Build and Maintain

- Philosophy behind UW and many other recommendations



Conclusions

- The BCSR is NOT recommended by Land Grant Universities
- The BCSR can result in **excessive fertilizer applications** or **nutrient deficiencies** when trying to hold cation ratios at specific levels or ranges.
- There is NO connection between the BCSR and Yield
  - Most likely pH was the factor driving early results
- Liming practices should be followed appropriately without worrying about the BCSR
- Growers should follow a build and maintain approach for economically sustainable fertilizer recommendations

Questions or Thoughts?