Soil Ca:Mg ratios: myth, hoax or legitimacy

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ALTA

AGRICULTURAL LABORATORY TESTING ASSOCIATION

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History

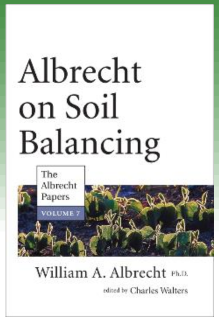
The concept of soil cation ratio fertility emerged In the 1920s and 1930s based on alfalfa and forage research in New Jersey. Researchers associated a link between soil quality to animal and human health, and suggested *ideal* soil saturations were 65-70% Ca, 10-20% Mg and 2-5% K.

Work of Albrecht (and Graham), University of Missouri 1950-1970 concluded it was important to maintain high Ca saturation, that later formed the basis for Albrecht's concept of a *"balance soil"* (Kopittke and Menzies, 2007).

While Albrecht, a highly respected soil scientist, he discounted soil pH, stating that *"plants are not sensitive to, or limited by, a particular pH value of the soil."* [1]

William Albert Albrecht, granduate of the University of iIllinois, trained in soil microbilology. (September 12, 1888 – May 19, 1974)

continued



Albrecht believed that the benefit of liming soil stems from the additional calcium available to the plant, not the increase in pH. He promoted the concept of base cation saturation ratios (BCSR) where soil pH is not controlled.

Subsequent recommend BSCR ratios were reported by Bear et al, (1945) Graham (1959) and Baker and Amacher (1981).

It's been noted, *"balanced soil"* saturations that were developed, corresponded to soil pH values slightly above 6.0, optimum for growth for many crops.

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

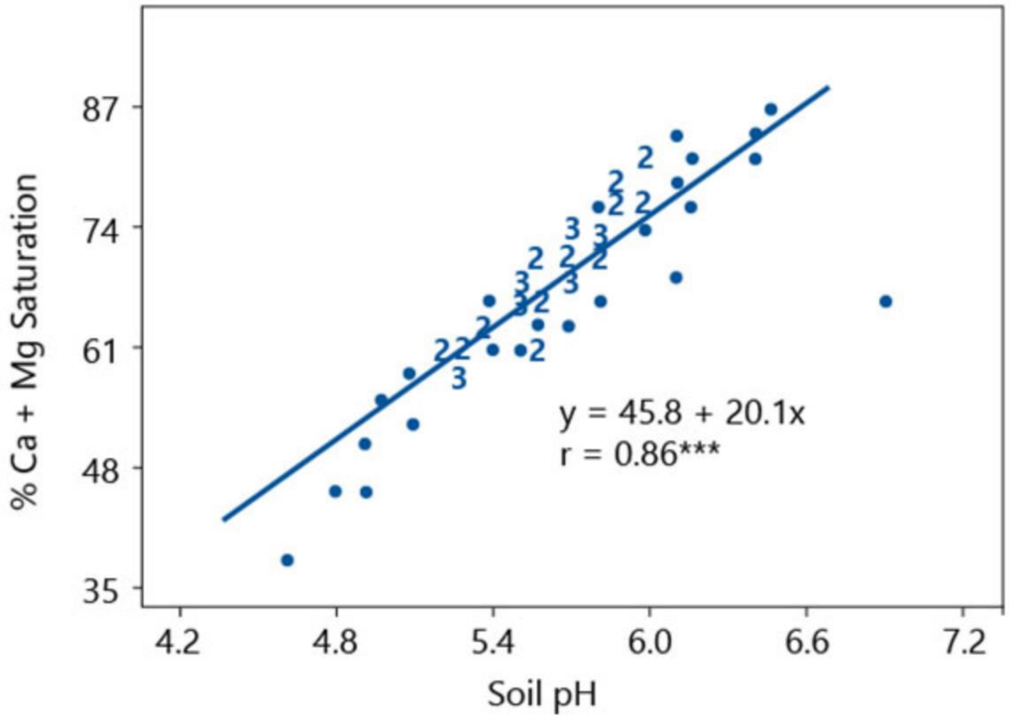
www.pioneer.com/us/agronomy/Base-Saturation-Cation-Exchange-Capacity.html

Ca and Mg Ratios

Liebhardt (1981), observed a direct relationship between soil $pH_{(1:1)}$ and the sum of exchangeable Ca+Mg for soils in Delaware.

However, his research identified no relationship between BCSR ratios and grain yield. Further, there was a wide range of ratios that corresponded to the highest and lowest grain yields each year.

Schulte and Kelling (1985) in Wisconsin varied soil Ca:Mg ratios between 2 to 8 and found no effect on alfalfa forage yield, but noted high additions of Ca on sandy soils, induced Mg deficiency.



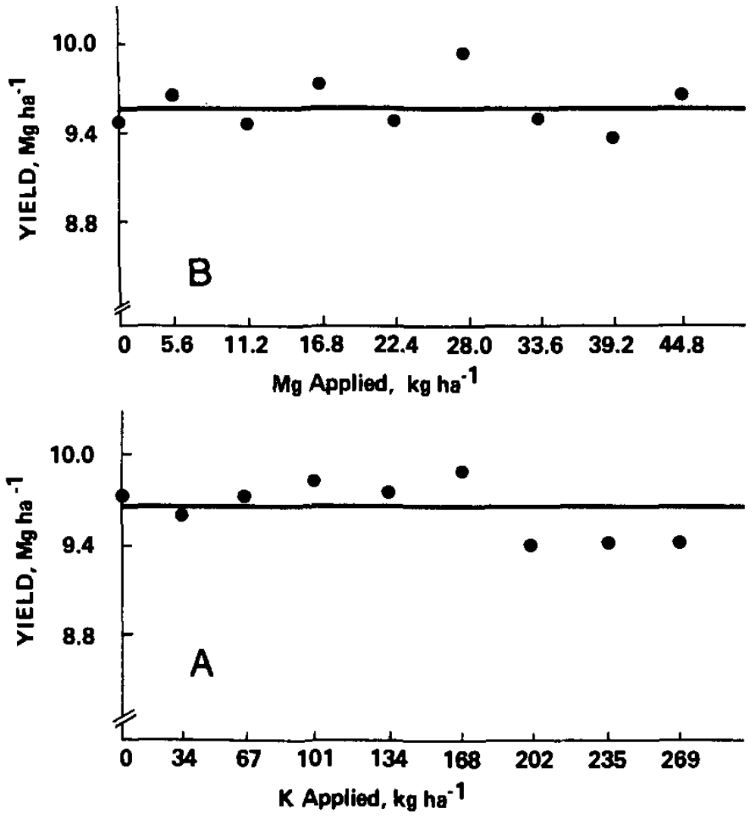
Liebhardt, W.C. 1981. The basic cation saturation concept and lime and potassium recommendations on Delaware Coastal Plain soils. Soil Sci. Soc. Am. J. 45:544-549.

Ca and Mg Ratios

Rehm and Sorensen (1985), studied Mg and K applied to corn on an irrigated loamy sand soil in Nebraska.

Altering a soil with a BCSR of 10.3:2.5:1.0 by additions of Mg and K up had no effect on grain yield. The only observed effect was changes in relative plant tissue concentrations in Ca, Mg and K.

Rehm (1994), concluded a sufficiency supply approach, based on cation supply and not ratios, directs a producer to fertilize a crop to maximize profitability.



Rehm, G.W. and R.C. Sorensen. 1985. Effects of potassium and magnesium applied for corn grown on an irrigated sandy soil. Soil Sci. Soc. Amer. J. 49:1446-1450.

Soil cations: ratios vs concentration

The cation ratio concept fails to address differences in soil cation concentrations associated with soil texture. The soils listed at right have nearly identical pH, Ca saturation of CEC and optimum Ca:Mg ratios, based on Albrecht and Graham recommendations.

However, these soils vary greatly in texture, CEC and exchangeable cations. Based on a sufficiency supply approach, SRS-1610 is potentially deficient in K and Mg whereas SRS-1502 is not.

Analysis	SRS-1610	SRS-1502
pH $_{1:1\ H_2O}$	6.17	6.23
Ca:Mg ratio	8.3	8.7
Texture (USDA)	Sandy loam	Loam

CEC (cmol/kg)	4.5	21.1
Ca Exch (ppm)	670	3260
Mg Exch (ppm)	87	326
Ca sat. CEC (%)	74.2	77.3
K Exch (ppm)	95	203

[1] Soils selected from ALP program databased 2005-2024, consensus median values reported. Note CEC based on cation displacement.

Soil cations ratios - continuted

The cation ratio concept was developed in the eastern US and fails to account for alkaline soils containing carbonates or dissolved salts.

The soils listed at right are alkaline with similar CEC values. Soils vary in soluble salts. Because of carbonates and soluble salts these soils would have Ca:Mg ratios far outside the ideal ratios noted by Albrecht and Graham.

For alkaline soils containing carbonates and gypsum, Mehlich 3 would inflate the amount of extractable Ca, not associated with CEC.

Analysis	SRS-1311	SRS-1508
pH $_{1:1\ H2O}$	7.86	8.10
EC $_{1:1}$ (dS/m)	0.49	2.00
Texture (USDA)	Loam	Sandy loam

CEC (cmol/kg)	17.4	20.6
Ca $_{Exch}$ (ppm)	3990	4495
Mg $_{Exch}$ (ppm)	209	358
Ca:Mg ratio (cmol)	20.6	13.5
Ca sat. CEC (%)	125	138

[1] Selected soils from ALP program databased 2005-2024, consensus median values reported. Note CEC based on cation displacement.

Ca and Mg ratios

A historical review was published by Chaganti and Culman (2017), summarizing 7 decades of cation saturation research, and finding little evidence for “ideal” BSCR ratios associated with improved crop yields.

Despite 15 peer review studies (field and greenhouse) the Albrecht theory of cation ratios, there remains interest amongst some consultants and farmers in the Ag industry.

Historical Perspective of Soil Balancing Theory and Identifying Knowledge Gaps: A Review

Vijayasatya N. Chaganti* and Steve W. Culman

Abstract

The common philosophies that contextualize soil test results and fertilizer recommendations are sufficiency level of available nutrients (SLAN), buildup and maintenance, and basic cation saturation ratio (BCSR). The BCSR approach postulates maintaining an ideal ratio of basic cation (Ca^{2+}, Mg^{2+}, and K^{+}) saturations on the soil exchange sites to maximize crop yields. The practice of adding amendments to alter the ratios of basic cation saturations in soils is called “soil balancing.” Bear, Graham, and Albrecht promoted this concept, with each suggesting a desired saturation ratio of Ca:Mg:K for optimum crop yields. Several researchers have tried to validate this theory with both greenhouse and field experiments but could not conclude that an ideal cation saturation ratio existed and

Reviews

ACCEPTED

Core Ideas

- A soil with an ideal basic cation saturation ratio (BCSR) is said to maximize crop yields.
- Previous studies concluded higher crop yields are possible over a wide range of ratios.
- Scientific community generally disregards BCSR theory.
- Soil balancing effects on weeds, soils, and crop quality are critical knowledge gaps.

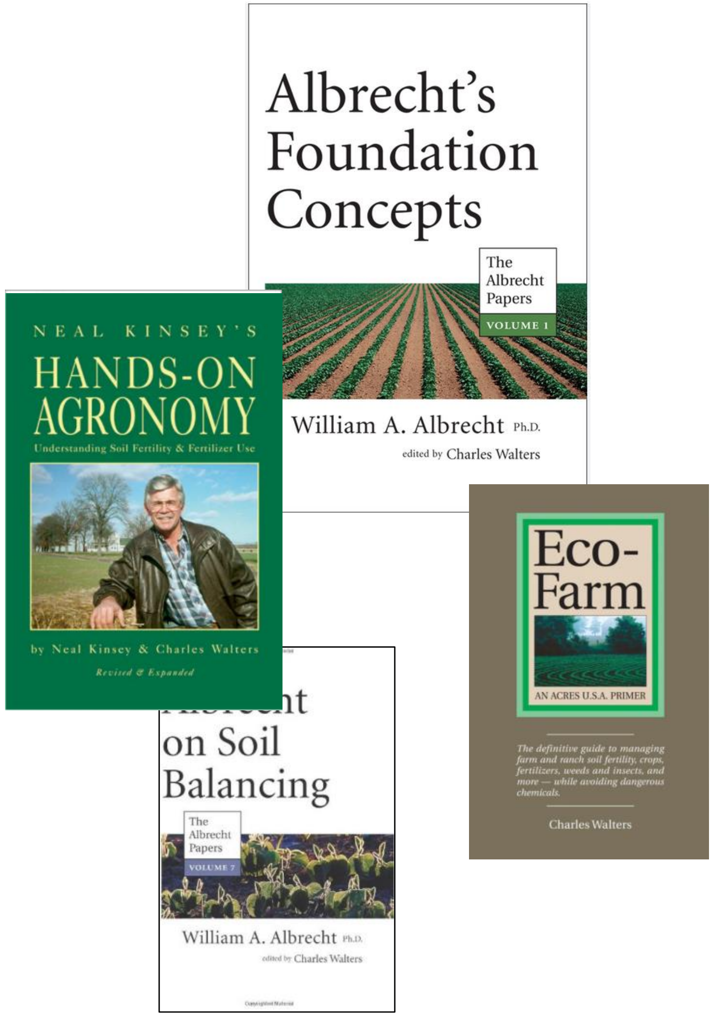
Chaganti, V.N. and S.W. Culman, 2017, Historical Perspective of Soil Balancing Theory and Identifying Knowledge Gaps: A Review. *CFTM.*

Why does interest persist

The Albrecht approach to soil nutrient management has continued by consultants that focus on specialty crops, organic producers and producers with limited knowledge seeking alternate management.

Through books, workshops, you-tube videos and anecdotal personal accounts, the Albrecht philosophy of a *“balance soil”* has continued in various forms.

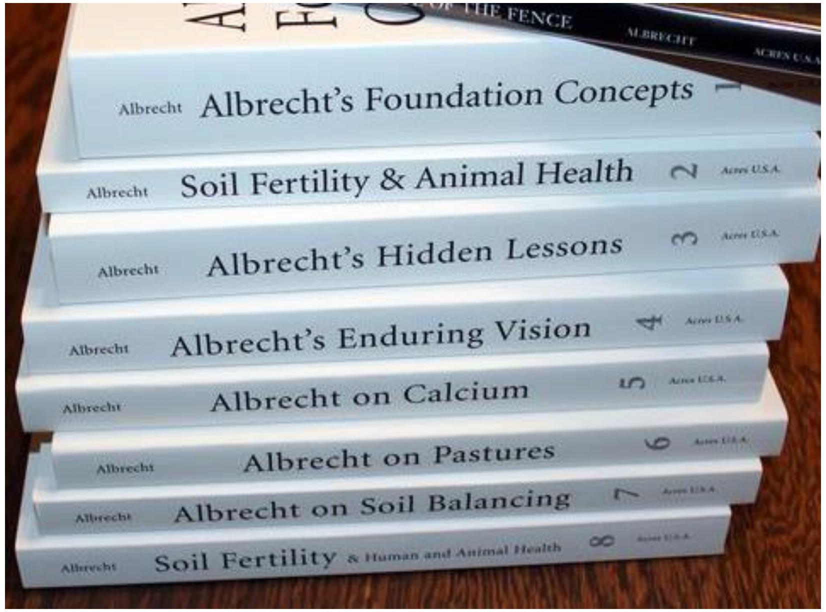
> **“The dogma of a philosophy is that once the prophet dies all that follow must except his teachings as true.” - anonymous**



BCSR overview

Adapted from: *Adam Gaspar, Pioneer Research Scientist. 2019. Base Saturation and Cation Exchange Capacity, Crop Insights, Pioneer.*

The use of BCSR can lead to expensive, non-consistent recommendations. The conclusion of multiple university studies was that no "ideal" ratio or range of ratios existed to improve crop production. It is advised nutrients should be held in sufficient but not excessive levels of a specific ratio.



www.pioneer.com/us/agronomy/Base-Saturation-Cation-Exchange-Capacity.html

Soil analysis terminology

Ca $_{Exch}$: soil exchangeable Ca measured by NH_4oAc or Mehlich 3.

Mg $_{Exch}$: soil exchangeable Ca measured by NH_4oAc or Mehlich 3.

Ca:Mg $_{Exch}$: ratio of exchangeable Ca:Mg

CEC_{SUM} : CEC measured by summation of exchangeable cations and H^+

CEC_{DIS} : CEC as measured by cation displacement, pH 7.0

Ca base saturation: percentage Ca of sum of bases

EC $_{SPE}$: electrical conductivity of saturated paste extract

Ca $_{SPE}$: soluble Ca, as measured by saturated paste extraction.

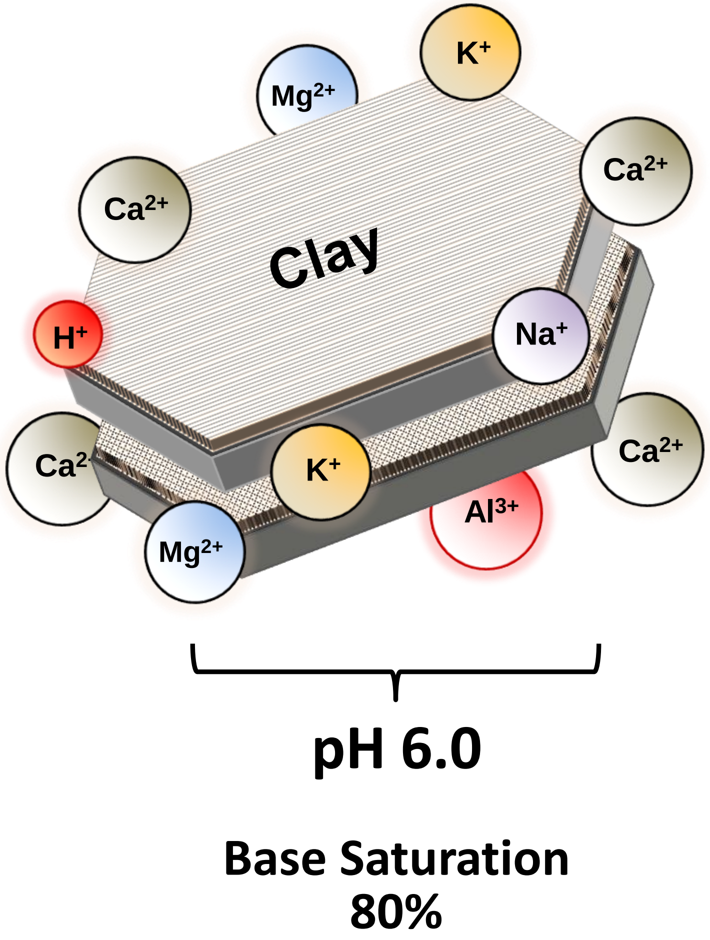
Mg $_{SPE}$: soluble Mg, as measured by saturated paste extraction.

Ca:Mg $_{SPE}$: ratio of Ca:Mg in saturated paste extract.

Soil exchangeable cations

Ca, Mg, K and Na comprise the dominate base cations of the cation exchange capacity (CEC) of soils, with Ca $^{+2}$ as the dominate ion of typical Midwest Ag soils. Divalent cations, dominated by exchangeable Ca, bind soil particles into aggregates which facilitate soil water infiltration and internal drainage of soil water movement.

Elevated Na concentrations will disperse soil clay resulting in a loss of soil aggregation and reduced water infiltration. Sodium absorption ratios (SAR) in the soil solution phase > 13 are considered sodic. Similar issues have been noted by high Mg.



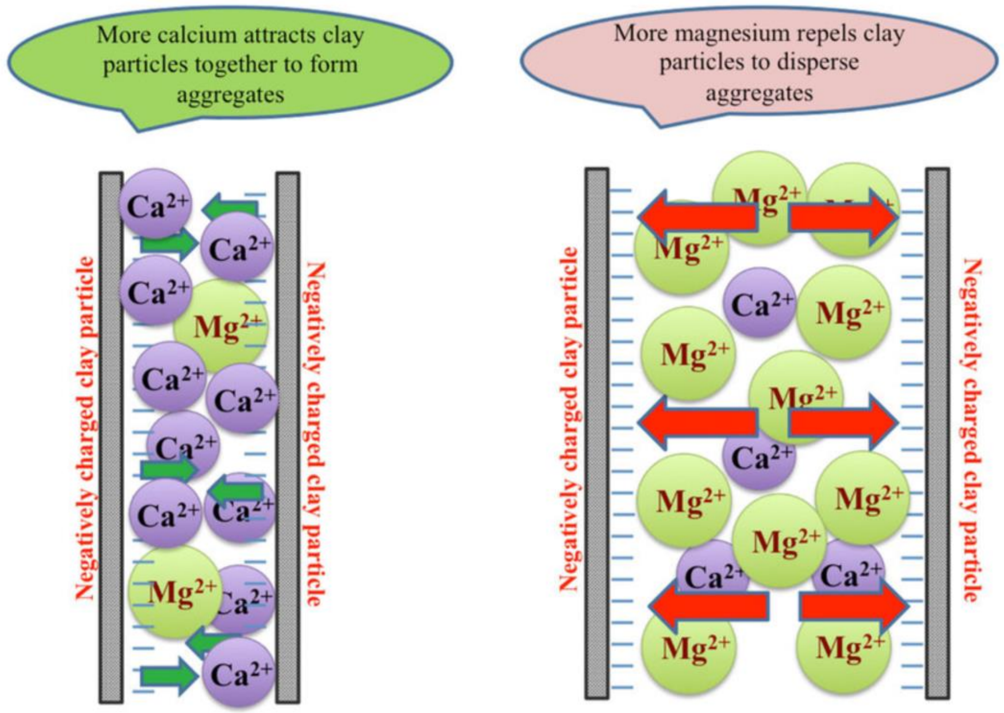
Adapted from www.agric.wa.gov.au/soil-acidity

Clay, Ca and Mg

Calcium is generally more effective than Mg in binding soil clays and is the preferred cation due to its smaller hydrated radius than Mg (Rao and Mathew, 1995).

Higher soil Mg saturations generally, increase surface sealing, aggregate destruction and decreased water infiltration, on Midwestern soils under simulated rainfall conditions. (Dontsova and Norton, 2002).

Potential Relationship between Ca and Mg in aggregate stability



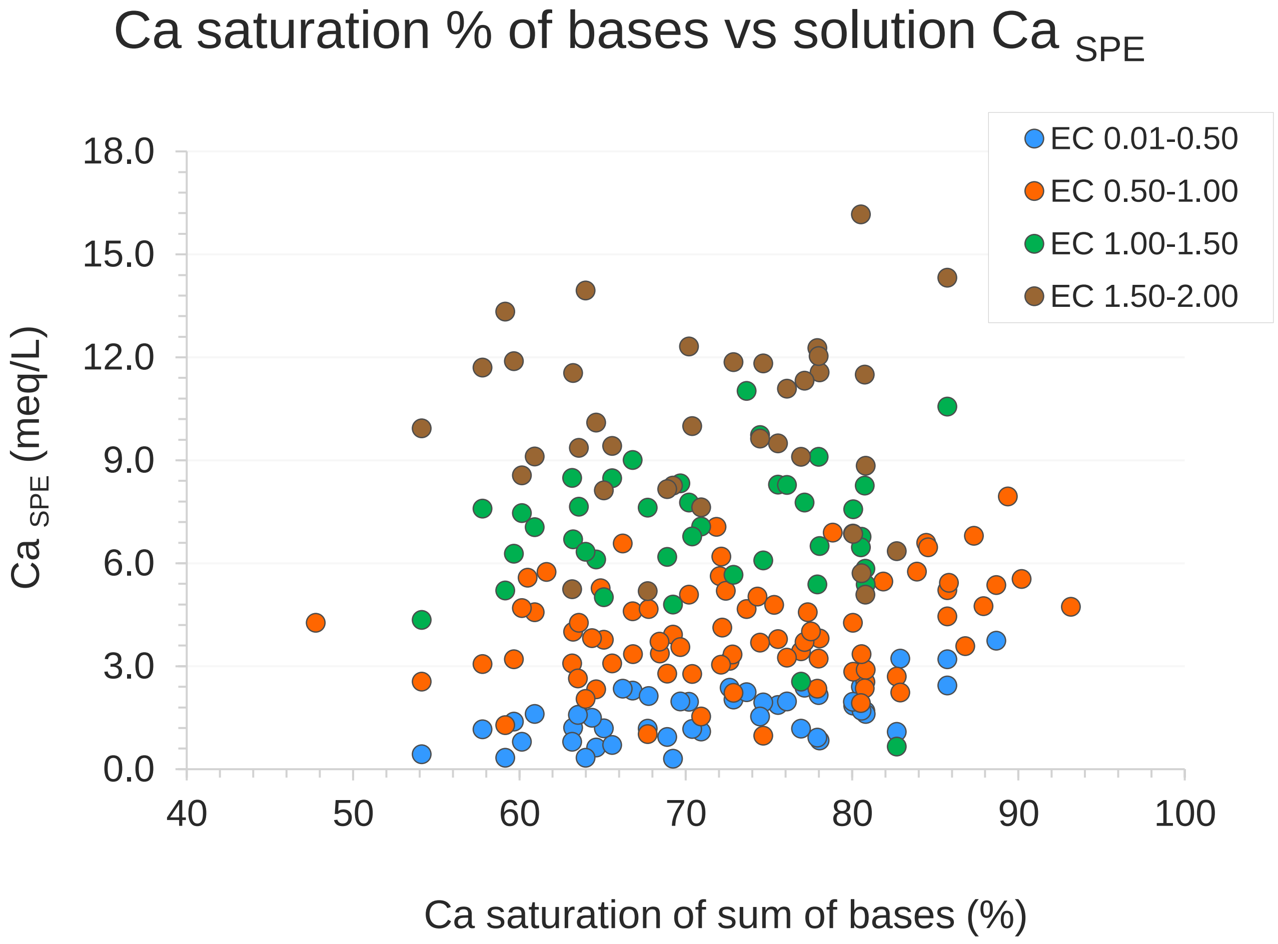
https://www.researchgate.net/figure/Possible-effects-of-Ca-2-and-Mg-2-cations-on-soil-aggregation_fig3_318581460

Soil solution cations

Soil solution Ca and Mg concentrations are not indicative of the Ca and Mg of exchangeable fraction.

At right a figure of soil Ca saturation of bases vs soil solution Ca, based saturated paste extract (Ca_{SPE}) across 207 soils EC < 2.0 dS/m and CEC 1.8 – 62.4 cmol/kg.

Ca concentrations are a function of soil solution dissolved salts (EC), pH and mineralogy.



Soil solution cations - continued

Soils at right have similar CEC values, identical Ca_{Exch} and Ca base saturations, but large differences in Mg_{Exch}.

Sat paste extract (SPE) results show low concentrations for Ca resulting in a low $Ca:Mg_{SPE}$ ratio 1.5.

Despite Ca base saturation of 78% for SRS-2115, low Ca_{SPE} combined with a low EC, is likely to impact aggregate stability and soil water movement.

Analysis	**SRS-2115**	**SRS-1308**
$pH_{1:1\ H2O}$	5.84	6.85
CEC (cmol/kg)	12.7	10.9
Ca_{Exch} (cmol/kg)	7.5	7.6
Mg_{Exch} (cmol/kg)	1.9	0.45
$Ca:Mg_{Exch}$ ratio	3.9	17.1
Ca sat. CEC_{sum} (%)	78	82

EC_{SPE} (dS/m)	0.28	0.48
Ca_{SPE} (meq/L	1.2	3.2
Mg_{SPE} (meq/L)	0.77	0.63
$Ca:Mg_{SPE}$ ratio	1.5	5.1

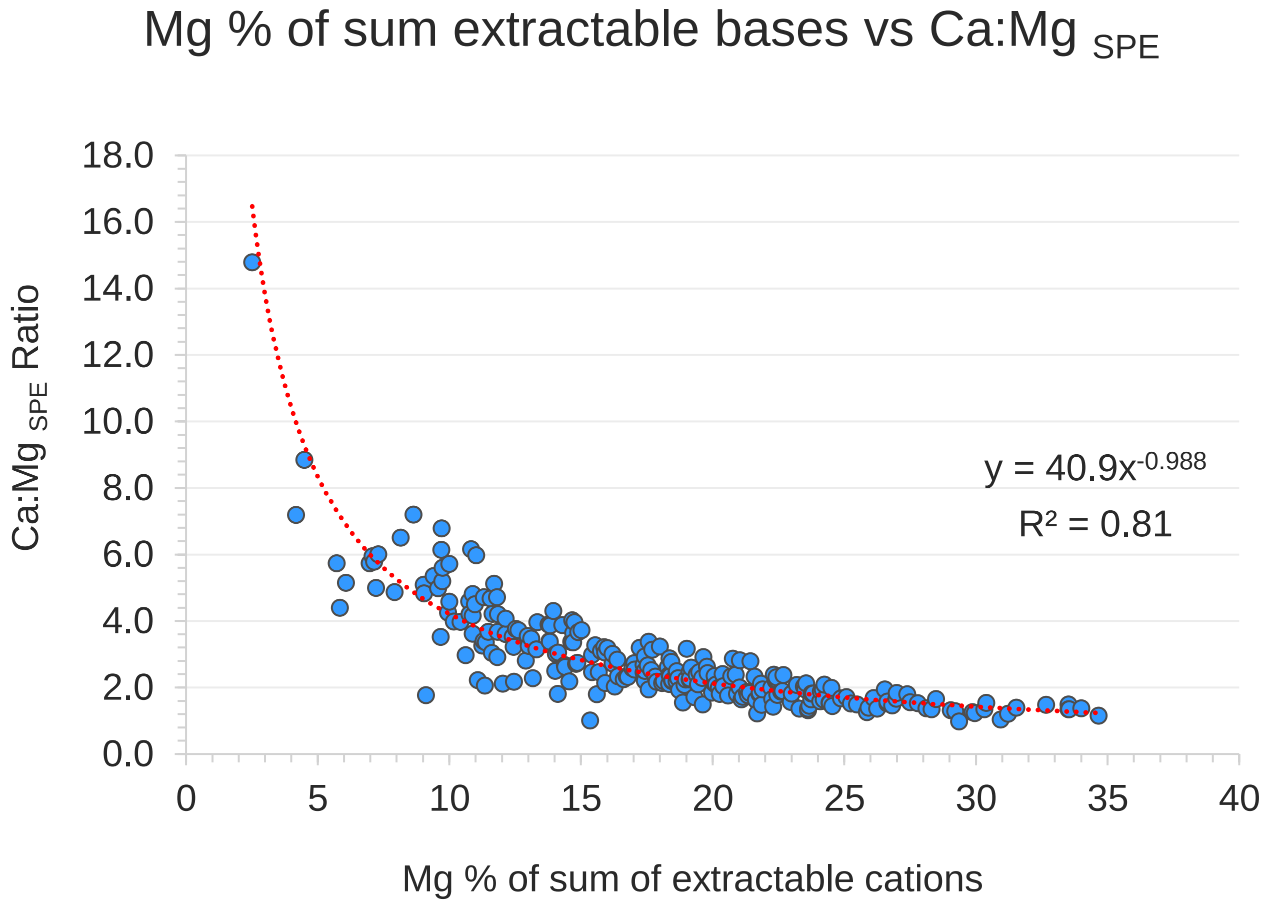
[1] Soils selected from ALP program databased 2005-2024, consensus median values reported. Cation extractions based on NH4oAC.

Soil solution Ca:Mg ratios

Soil solution Ca:Mg ratios are highly correlated with the Mg percentage of the sum of extractable bases.

At right a figure of soil Mg as percent of bases vs Ca:Mg ratio for 262 soils compromising 11 soil textures, pH 3.9 - 8.6, and CEC 1.8 – 62.4 cmol/kg. Similar to relationship of exchangeable Na percentage (ESP) and Ca:Mg.

As the percentage of Mg increases above 25% the Ca:Mg $_{SPE}$ ratio approaches 1.0, reducing soil aggregate stability.

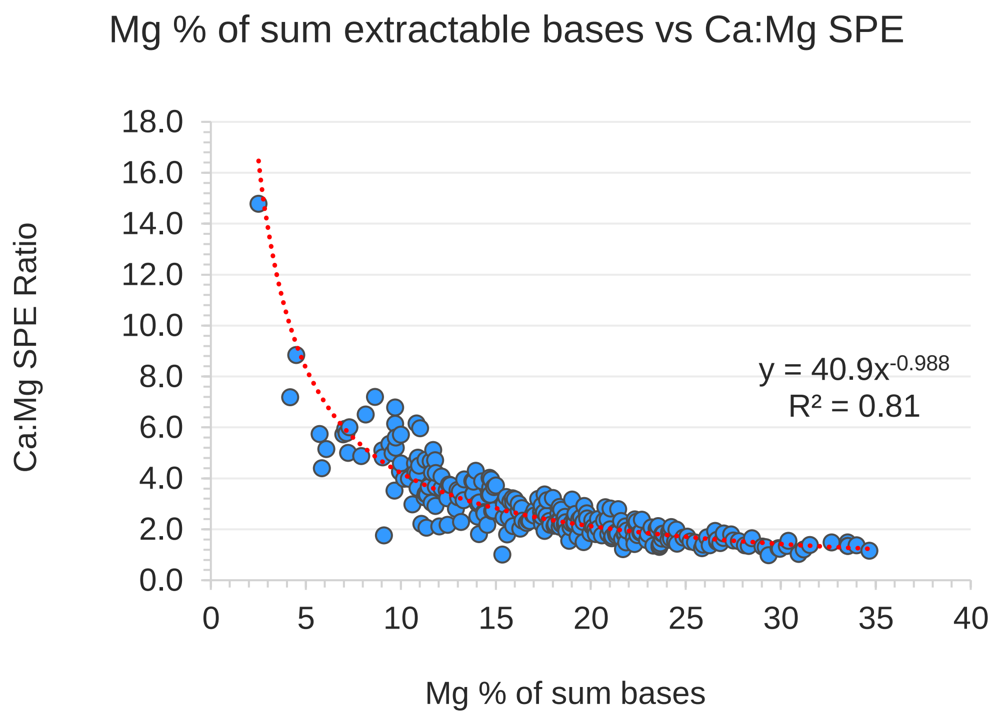


[1] Soils selected from ALP program databased 2005-2024, consensus median values reported. Cation extractions based on NH4oAC.

Soil solution cations

Low Ca:Mg $_{SPE}$ ratios and high Mg cation base saturation both result in aggregate deflocculation and indicate poor soil structure in clay-dominant soils.

Soils with a high concentrations soluble salts tend to maintain structure. Adding fresh water to high Mg base saturated soils will cause dispersion and loss of aggregation.



Three experiences

The three following examples assess soil calcium and magnesium, ratios based on CEC and soil solution concentrations.

- UC Davis Sustainable Ag Research
- Vineyard soil analysis and management
- Crop consulting Illinois

SAFS Project research, Ca and Mg

UC Davis Sustainable Agricultural Farming Systems (SAFS) project 1992-2007. Four crop species in rotation and 3 irrigated management systems: conventional, low input and organic.

Corn yield averages indicated superior yields of organic over conventional systems. Ca:Mg $_{Exch}$ ratios were identical, whereas Sat. paste extract Ca:Mg $_{SPE}$ were substantial different.

Field observations indicated limited irrigation water movement beyond 8” in all conventional treatments. Observation was noted over 5 yrs.

Parameters	Conventional	Organic
Grain yield (bu/ac)	183 [a]	227 [b]
EC (dS/m)	0.43 [a]	0.80 [b]
Ca:Mg $_{Exch}$ ratio	2.6 [a]	2.7 [a]

Ca $_{SPE}$ (meq/l)	0.82 [a]	3.1 [b]
Mg $_{SPE}$ (meq/l)	2.7 [a]	2.5 [a]
Ca:Mg $_{SPE}$ ratio	0.30 [a]	1.2 [b]

Miller and Friedman, 1997. SAFS Year report Volume 1. UC Davis, SAFS Project.
Measurement values followed by the same letter are nonsignificant, 0.05.

Grapes: Napa, California

Paul Anamosa, PhD soil scientist Napa, CA, is a vineyard consultant in the north coast of California.

His services focus on land evaluations for vineyards, problem investigations and on-farm research. His focus is evaluating soil chemical properties and structure for vineyard production.

Paul's extensive background in soil morphology and vineyard management has proven invaluable to vineyard growers in the costal range.

https://vineyardsoil.com

Grapes: Napa, California

Two vineyard soils from Northern, CA. Gold Ridge site, Mg $_{Exch}$ comprises has 39.1% of the bases cations, resulting Ca:Mg $_{SPE}$ of the saturated extract of 0.87. Conversely the Hill Rd site, a clay loam has lower Mg resulting in a higher Ca:Mg $_{SPE}$.

Coastal soils of northern California typically have serpentine parent materials with low pH and elevated Mg. The Hill Rd site represents an alluvial valley soil with lower Mg.

Analysis	Gold Ridge	Hill Rd.
pH $_{1:1\ H2O}$	4.8	7.4
$EC_{1:1}$ (dS/m)	0.22	0.42
Ca $_{Exch}$ (cmol/kg)	4.4	19.2
Mg $_{Exch}$ (cmol/kg)	4.7	3.3
Ca:Mg $_{Exch}$ ratio	0.93	5.8
Sum Cations (cmol/kg)	12.2	23.1
Mg Saturation (%)	39.1	25.1
Ca $_{SPE}$ (meq/l)	0.72	2.7
Mg $_{SPE}$ (meq/l)	0.83	0.8
Ca:Mg $_{SPE}$ ratio	0.87	3.4

https://vineyardsoil.com/

Grapes: Napa, California

A potential vineyard site was excavation near Sebastopol, CA, lab analysis results listed at right. Site indicated a strongly acid soil with increasing Mg saturation with soil depth and decreases in $Ca:Mg_{SPE}$.

The soil profile indicated a shift in soil structure from weak coarse blocky at the surface to a massive structure with little aggregation.

Recommendations, 2 tons/ac lime and 24 tons/ac of gypsum applied as two split treatments over consecutive years, to raise soil Ca_{Exch} to 60% of the CEC.

Analysis	**Soil Depth**		
	0-13”	**13-28”**	**28-43”**
$pH_{1:1\ H2O}$	4.6	4.3	4.2
CEC (cmol/kg)	9.4	10.8	17.5
Mg Sat. (%)	29	37	43
Ca_{SPE} (meq/l)	0.32	0.30	0.18
Mg_{SPE} (meq/l)	0.21	0.42	0.74
$Ca:Mg_{SPE}$ ratio	1.5	0.7	0.2

https://vineyardsoil.com/

Clay county Illinois

Elevated soil Mg issues have been noted by Parker Timmons, Elemental Ag, Centralia, Illinois.

Soils at right show nearly identical pH, and EC, but wide ranges in exchangeable Ca and Mg. Although the two samples have similar Ca_{SPE}, elevated Mg_{SPE} results in a $Ca{:}Mg_{SPE}$ ratio for soil A.

The low SPE ratio for soil A and low soluble salts reduces aggregate stability and limits water movement. Soil analysis used in VRT gypsum applications.

Analysis	Soil A	Soil B
$pH_{1:1\ H2O}$	6.93	6.23
$EC_{1:1}$ (dS/m)	0.32	0.29
Ca_{Exch} (cmol/kg)	21.5	8.0
Mg_{Exch} (cmol/kg)	8.6	0.80
Ca:Mg ratio (Exch)	2.5	10.0

Ca_{SPE} (meq/L	3.91	3.32
Mg_{SPE} (meq/L)	2.41	0.73
$Ca{:}Mg_{SPE}$ ratio	1.6	4.5

[1] Soil analysis JM Lord Laboratories, Fresno, CA. Cation extractions based on NH4oAC.

Summary

https://umaine.edu/mafes/wp-content/uploads/sites/98/2015/03/compost.jpg

The Albrecht concept of the “ideal” BCSR for crop fertility has largely been found to be with out merit. Whereas, the sufficiency supply approach, based on cation supply and not ratios, has proven effective.

However, the concept of soil cation ratios is still relevant, but from the perspective, aggregate stability, soil profile structure and soil water internal drainage.

Assessment of soil Mg cation base saturation, saturated paste Ca:Mg ratios and soil salts provides insight on management using gypsum.

Summary (Cont)

The assessment of Mg base saturation[1] as it relates to Ca:Mg $_{SPE}$ is show at right. Based on the ALP database, soils with >25% Mg base saturation have a 65% probability of a Ca:Mg $_{SPE}$ ratio < 1.5.

Based on Vineyard Technologies consulting, soils with Mg base saturations > 25% and Ca:Mg $_{SPE}$ < 1.2 require gypsum to reduce soil Mg and improve water infiltration and internal drainage.

[1] Base saturation determination by NH_4oAC extraction (1:10), analysis of Ca, Mg, K and Na cation bases. Ca:Mg $_{SPE}$ determined from saturated paste extract, or 1:1 water extract.

Mg percent of bases	Ca:Mg $_{SPE}$
	Mean
10	5.0 ± 0.4
15	3.1 ± 0.4
20	2.2 ± 0.2
25	1.4 ± 0.3
30	1.2 ± 0.1
35	1.0 ± 0.2

Classification ranges derived from ALP data 2005-2024.

Special thanks

Steve Culman, Washington State University

Paul Anamosa, Vineyard Technologies, Napa, CA

Parker Timmons, Elementa Ag, Centralia, IL

Recommended Sources

Adam Gaspar, www.pioneer.com/us/agronomy/Base-Saturation-Cation-Exchange-Capacity.html

Culman: https://www.youtube.com/watch?v=2_NVgbUXJYo

Chaganti, V.N. and S.W. Culman, 2017, Historical Perspective of Soil Balancing Theory and Identifying Knowledge Gaps: A Review. *CFTM.*

Rehm, G.W. and R.C. Sorensen. 1985. Effects of potassium and magnesium applied for corn grown on an irrigated sandy soil. Soil Sci. Soc. Amer. J. 49:1446-1450.

Thank you for your time and interest in Ca and Mg ratios

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Robert.Miller@cts-interlab.com
Txt: 970-217-2572

ALTA-SPAC Webinar

When: August 27 2024, 10:00 am CDT

“Strategies for collecting representative soil samples for lab analysis”

ALP Soil Carbon program

Soil Carbon program cost $600/yr. Three proficiency cycles (April, July, Nov), four soils per cycle, five required test parameters, each measured in triplicate. A sample instruction sheet will accompany each set of proficiency samples.

To enroll in the Soil Carbon program, forward an email to Robert.Miller@CTS-Interlab.com with you interest in the program. Collaborative testing Services will contact you with enrollment and payment details.

Agricultural Laboratory Proficiency Program

Summary

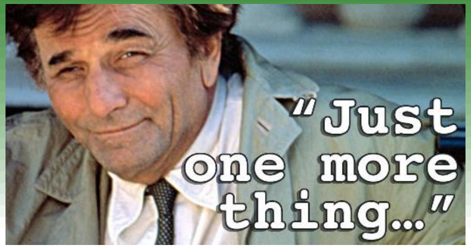
The Albrecht concept of the "ideal" BCSR for crop fertility has largely been found to be with out merit. Whereas, the sufficiency supply approach, based on cation supply and not ratios, has proven effective.

Questions

The dogma of philosophy is that once the prophet dies all that follow must except his teachings as true.

But as with many philosophies even if its effective 1% of the time, there will those that see it as a success, despite peer reviewed science.

Additional notes



- ✓ A protocol on soil carbon sampling is needed. USDA is working on establishing sampling SOP. Industry input, both samplers and laboratories, is needed.

- ✓ An official document of soil carbon sample preparation, similar to that developed in Australia, is needed to standardize sample prep and ID methods.

- ✓ ALTA (Agricultural Laboratory Testing Association) is developing a Soil Carbon Testing Certification program. Specific requirements suggestions are welcome.

- ✓ An ALTA Webinar is planned with Graham Lancaster, lab manager EAL Southern Cross University on lab soil carbon testing later this year.

EAL Environmental Analysis Laboratory

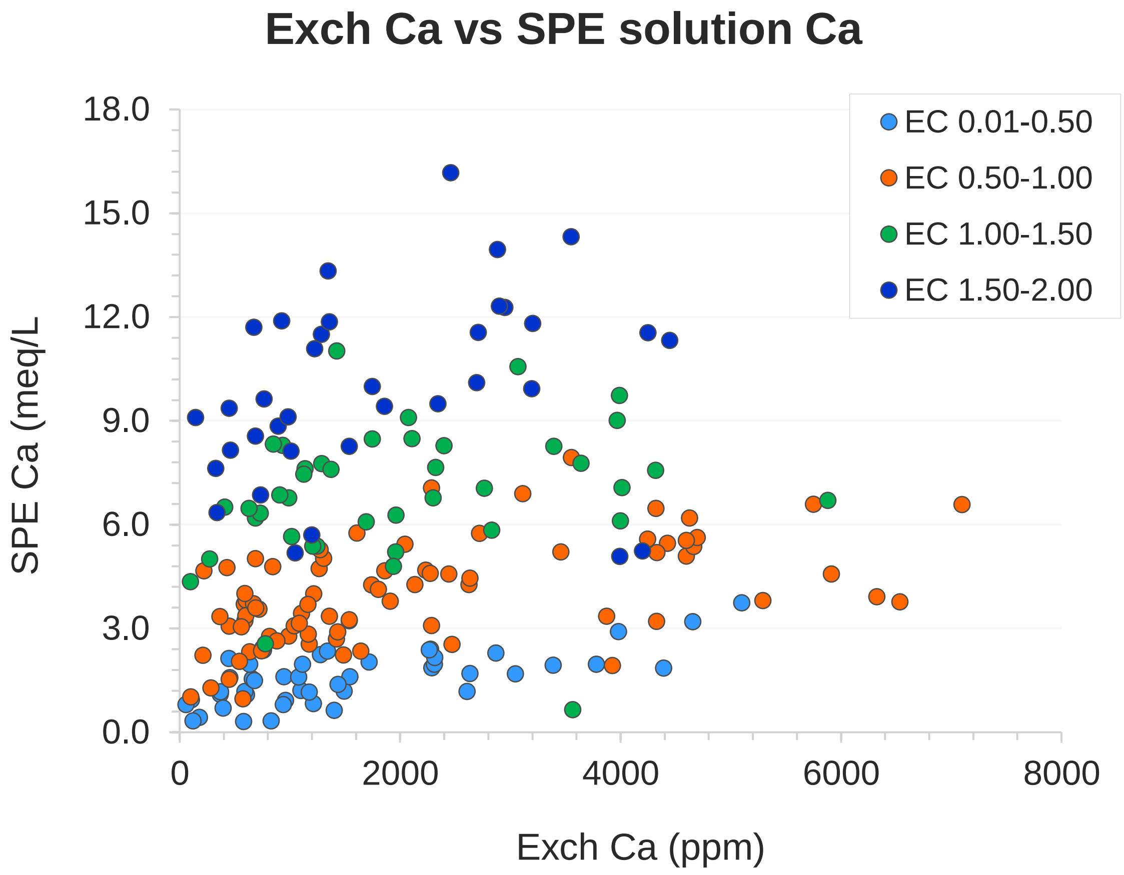
The concept of soil cation ratio is still relevant, but from a different perspective, management of soil structure and water movement.

Soil solution cations

Soil solution Ca and Mg concentrations are not indicative of the exchangeable Ca and Mg.

At right a figure of Exch Ca vs soil solution Ca, based saturated paste extract (SPE). Across 206 soils representing 9 soil textures, EC 0.01 - 2.00 dS/m and CEC 1.8 – 62.4 cmol/kg, there is no relationship between solution and Exch Ca.

Soil solution Ca concentrations are a function of soil solution dissolved salts (EC), mineralogy, pH and biochemistry.



[1] Soils selected from ALP program databased 2005-2024, consensus median values reported.

Soil carbon PT samples

- ALP soil inventory. SOC values range 0.24 – 27.9%.
- To ensure soil homogeneity and integrity, PT soils milled to minus 0.18 mm, double sieved and homogenized.
- Proficiency soils pre-conditioned at 20% relative humidity for 48 hours prior to packaging and distributed in vapor barrier enclosures for proficiency distribution.
- Four PT soils submitted each PT cycle submitted as two blind pairs.

Soil carbon proficiency reports

- ✓ PT reports will provide statistical summaries for each soil and test parameter: number of results, mean 95% confidence limits, intra-lab precision and laboratory bias, each proficiency cycle.

- ✓ Supplemental statistical analysis using Youden pair analysis as developed by AOAC for assessing method performance. A year end report will be developed utilizing meta data for primary soil carbon parameters.

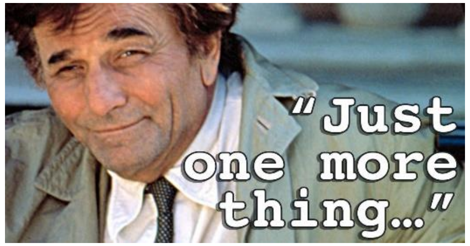
- ✓ For 2024 the ALP soil carbon program is provisional. In September a participant assessment review of the soil carbon PT program will be conduct to address issues and changes.

ALTA

- ✓ A protocol on soil carbon sampling is needed. USDA (person) is working on establishing SOP for sampling. Industry input, both samplers and laboratories is needed.

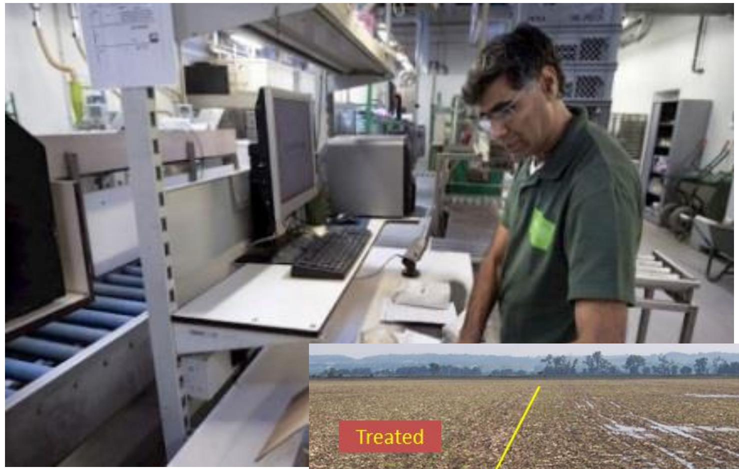
- ✓ An official soil carbon sample preparation document, similar to that developed by Phil Mulvey, in AU is needed to standardize sample prep. Test methods are a separate activity.

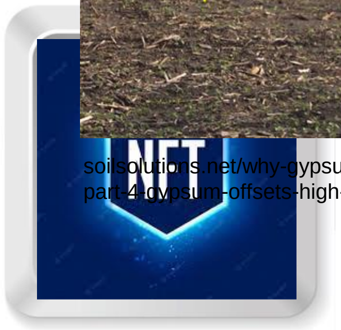
- ✓ ALTA (Agricultural Laboratory Testing Association) will develop Soil Carbon Testing Certification program. Specific requirements are ongoing and suggestions/opinions are welcome.



Questions

Calcium facilitates the formation of more stable soil aggregates due to its higher flocculating power than Mg (Rengasamy and Sumner, 1998).





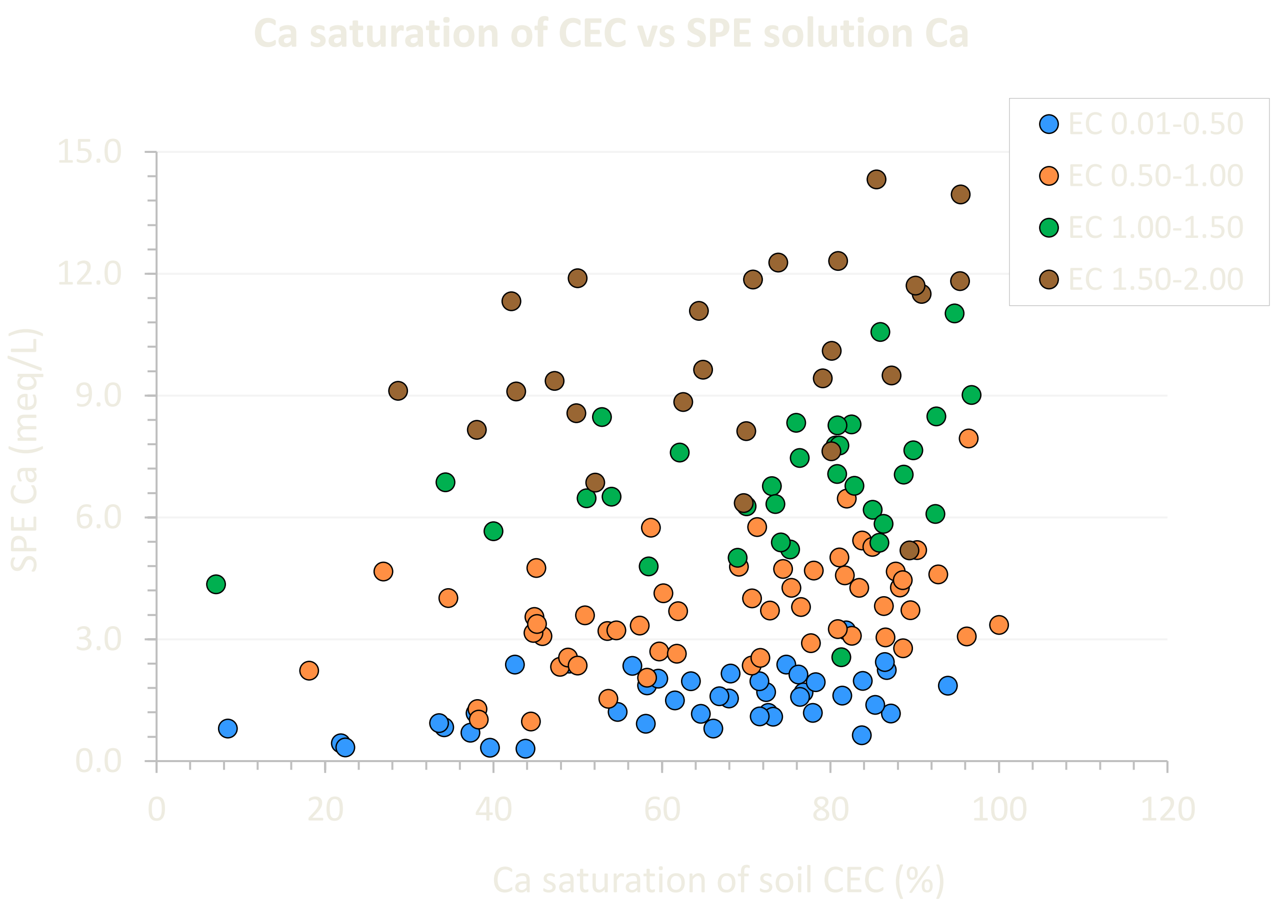
soilsolutions.net/why-gypsum-works-in-your-soils-part-4-gypsum-offsets-high-magnesium-in-soils/

Soil solution cations

Soil solution Ca and Mg concentrations are not indicative of the Ca and Mg on CEC sites.

At right a figure of soil Ca saturation of CEC vs soil solution Ca_{SPE}, based saturated paste extract (SPE) across 128 soils with pH < 7.2, EC < 2.0 dS/m and CEC 1.8 – 62.4 cmol/kg.

Ca concentrations are a function of soil solution dissolved salts (EC), pH and mineralogy.



Overview

SOM and SOC

Field soil sampling for SOC and BD

Sample preparation

TC, OC and IC

Carbon analysis instrumentation

Measurement uncertainty

Carbon sequestration measurements

✓ program fo cALTA-SAC will be developing in the 3rd Qtr of 2024 for certification of soil carbon testing labs.