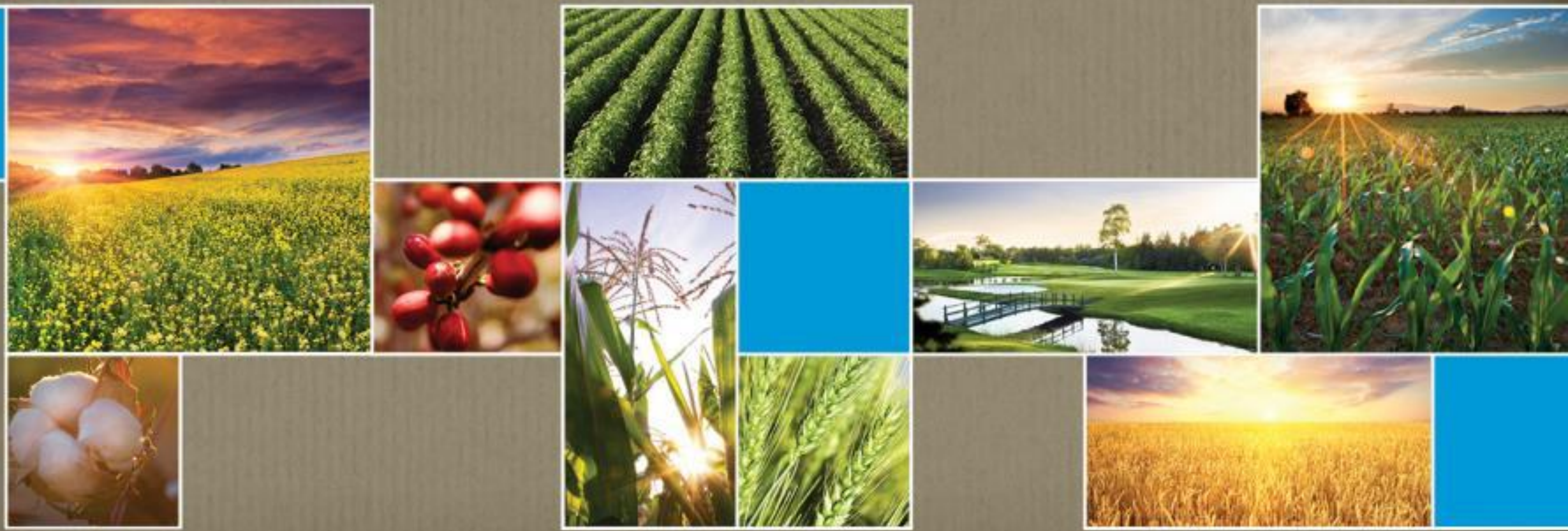
KOCH AGRONOMIC SERVICES, LLC

Diagnosing and Correcting P & K Deficiency



THE POWER TO MAKE THINGS GROW

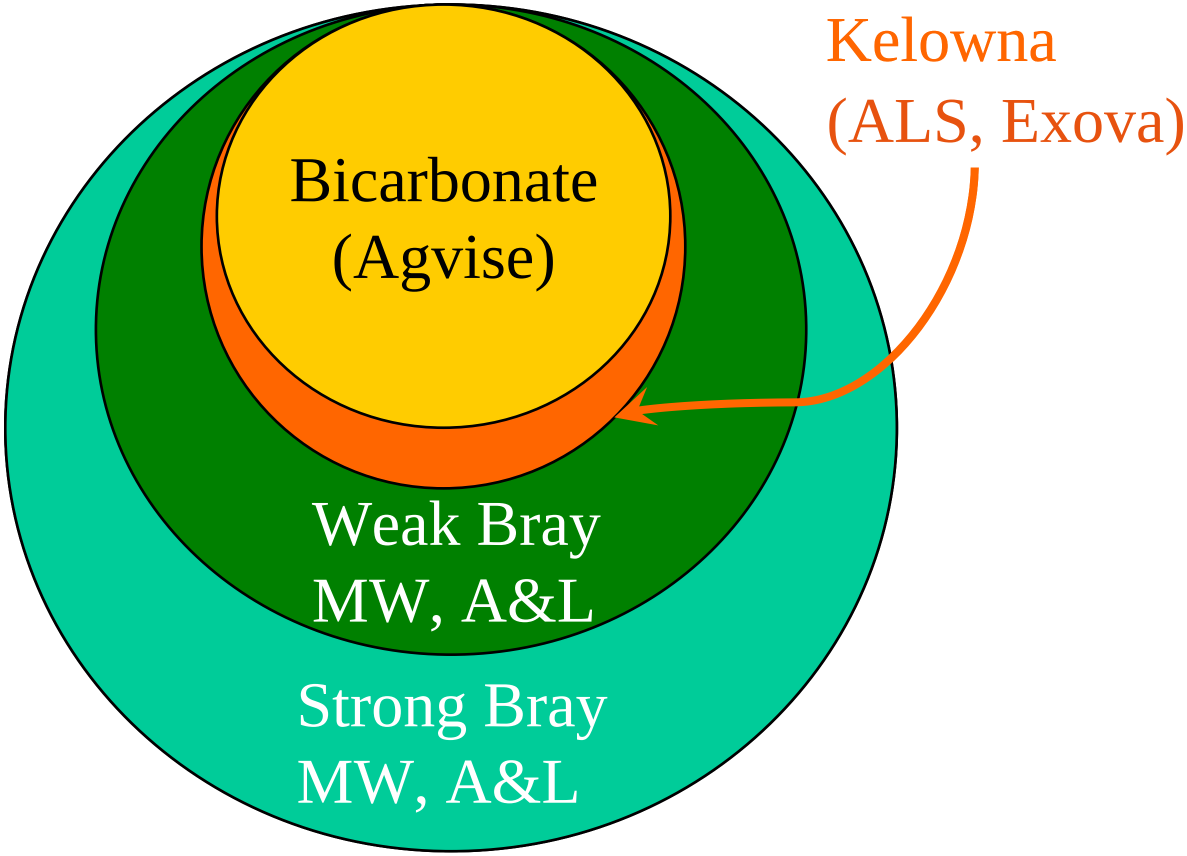
Four Steps

- Sampling
- Extraction and chemical analysis
- Correlation and interpretation
- Fertilizer recommendation

Different Methodology - Which one is the best?

- Two criteria
  - Compatibility of chemistry or methodology
  - CALIBRATION WITH LOCAL FIELD RESEARCH DATA

Methodology for Phosphorus



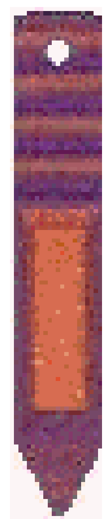
Methodology for Potassium

- Ammonium acetate (original)
- Bicarbonate, Kelowna extract
- Similar results

CALIBRATION WITH LOCAL **FIELD** RESEARCH DATA

Remember no matter what one uses, **the test is done ahead of the growing season**! Therefore, **ALL** methods, whether chemicals, membranes, resin or even plants grown in pots, **SIMULATE PLANT ROOTS** and **HAVE NO VALUE UNLESS THEY ARE CORRELATED WITH CROP YIELDS**.

or



or

?

Soil tests that have been calibrated in field studies for western Canadian soils

- N Water (bicarbonate, Kelowna modifications)
- P Olsen (bicarbonate), Kelowna modifications,Miller Axhley
- K NH_4OAC (ammonium acetate), Olsen, Kelowna modifications
- S 0.01M $CaCl_2$
- Cu, Zn DTPA
- B Hot water extractable

Soil tests that have NOT been calibrated in field studies for western Canadian soils

- N Mineralization indices, e.g., amino sugars, phosphate borate
- P Bray (weak and strong), Mehlich extractants
- K based on %K saturation, K/Ca
- Cu, Zn HCl extraction
- Mn All extractants
- B Sorbitol
- Cl Cl electrode, chromatography, $AgNO_3$, water mercury (II) thiocyanate
- Ca All extractants
- All Exchange membranes and resins

Manitoba P Response Data

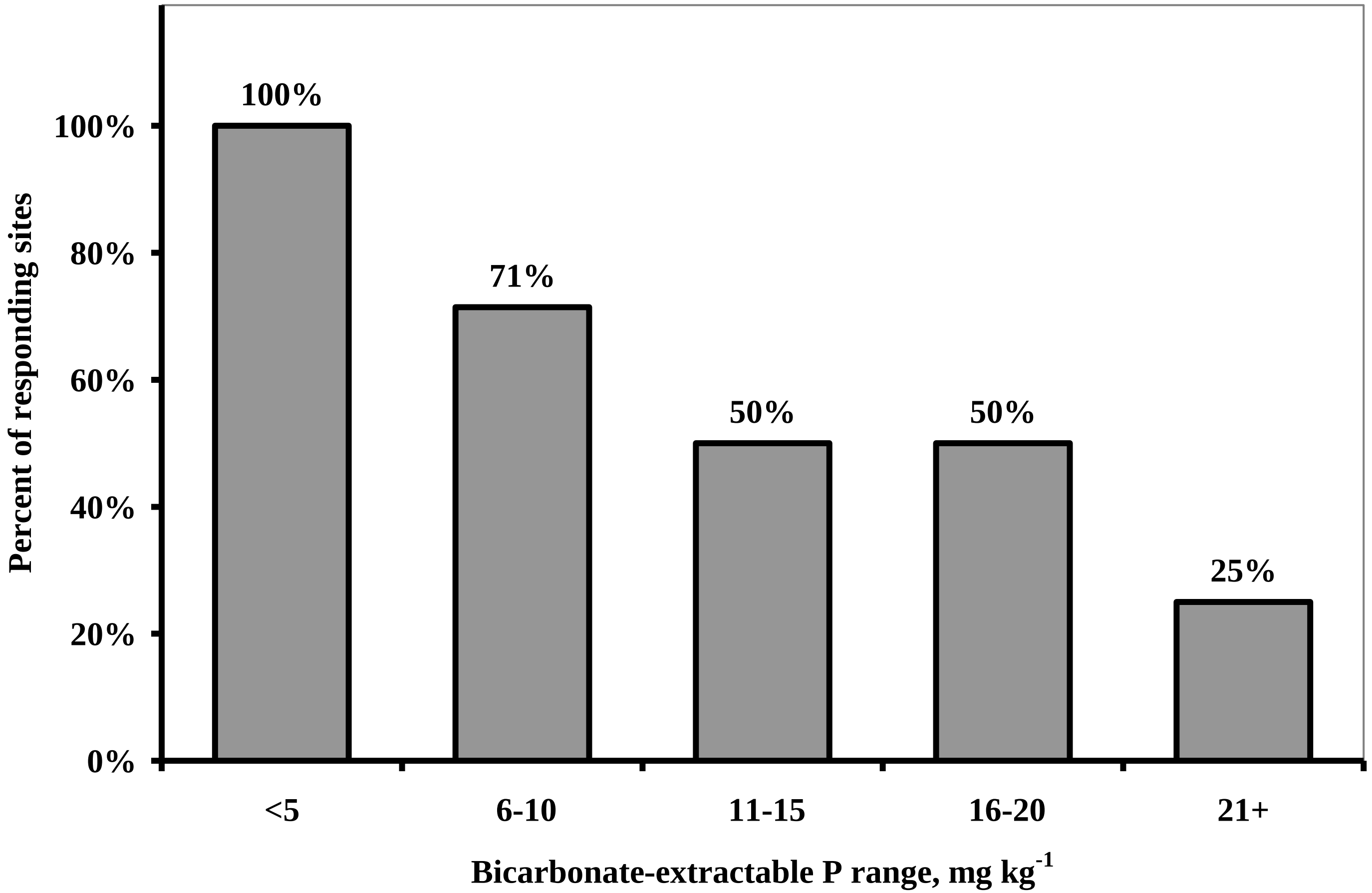
Available P (lbs/A)	Number of Experiments	% Responding to Fertilizer P
0-10	15	100
10-24	50	62
24-36	16	56
>36	14	29
	95	63

Hedlin, 1962

What are the best uses for soil test P information?

- Estimating average probabilities of crop response
- Examining changes in levels over time
- Estimating average relative yield response
- Estimating a specific probability of response for a given site and year
- Estimating a specific relative yield response at a given site and year

Wheat Experiments - Response to P*



*Karamanos et al. 2010, Can. J. Plant Sci., 90:265-277.

Types of Responses to KCl (0-0-60)

- ✓ **responses to K on low soils**
- ✓ **responses to K on high soils**
- ✓ **responses to chloride**

Types of Responses to KCl (0-0-60)

- ✓ responses to K on low soils
- ✓ responses to K on high soils
- ✓ responses to chloride

General Soil Test K criteria*

Soil Test K (0-6" depth)			General Potassium Recommendations to correct deficiency** lb K_2O/acre
Rating	**ppm**	**lb/acre**	
Very deficient	0-25	0-50	130-180
"	26-50	51-100	90-150
"	51-75	101-150	50-100
Moderately deficient	76-100	151-200	10-70
	101-125	201-250	10-50
Critical level	**125**	**250**	**0-20**
High Potassium levels (Marginal to Adequate)	**126+**	**251+**	0

** cereals and oilseeds

***Sources: Malhi et al. (1993); McKenzie (2001); Saskatchewan Agriculture and Food (2000).**

Soil Test Calibration of K*

Potassium Category (lb K acre)	Average K Response (%)	Number of Sites Responding (%)
less than 50	1000	100
51-100	240	75
101-150	50	66
151-200	30	24
201-250	30	18
more than 250	10	3

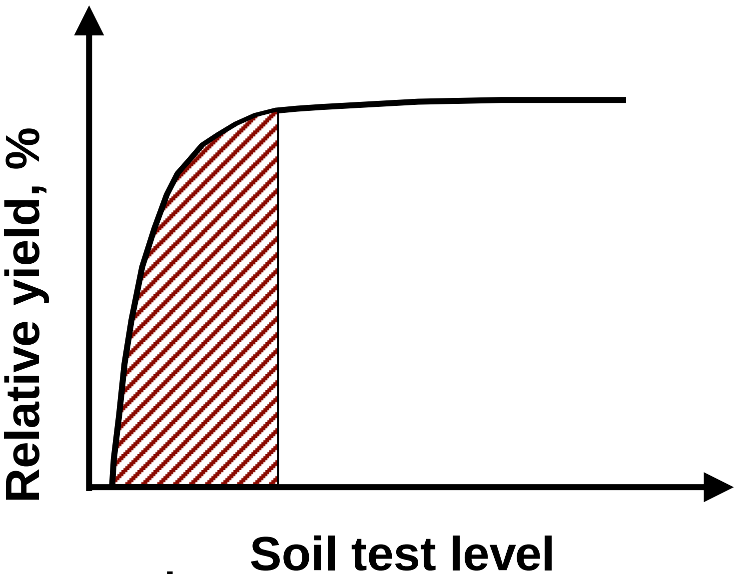
*Agriculture and Agri-Food Canada, Lacombe Research Station, and Alberta Agriculture and Rural Development data

Types of Responses to KCl (0-0-60)

- ✓ responses to K on low soils
- ✓ responses to K on high soils
- ✓ responses to chloride

Sufficiency Approach to Fertilization

- Apply nutrient to maximize net returns to fertilization in the year of application
  - Strategy: fertilize only when there is a good chance that a profitable yield response will be realized
  - Soil test levels kept in lower, responsive ranges

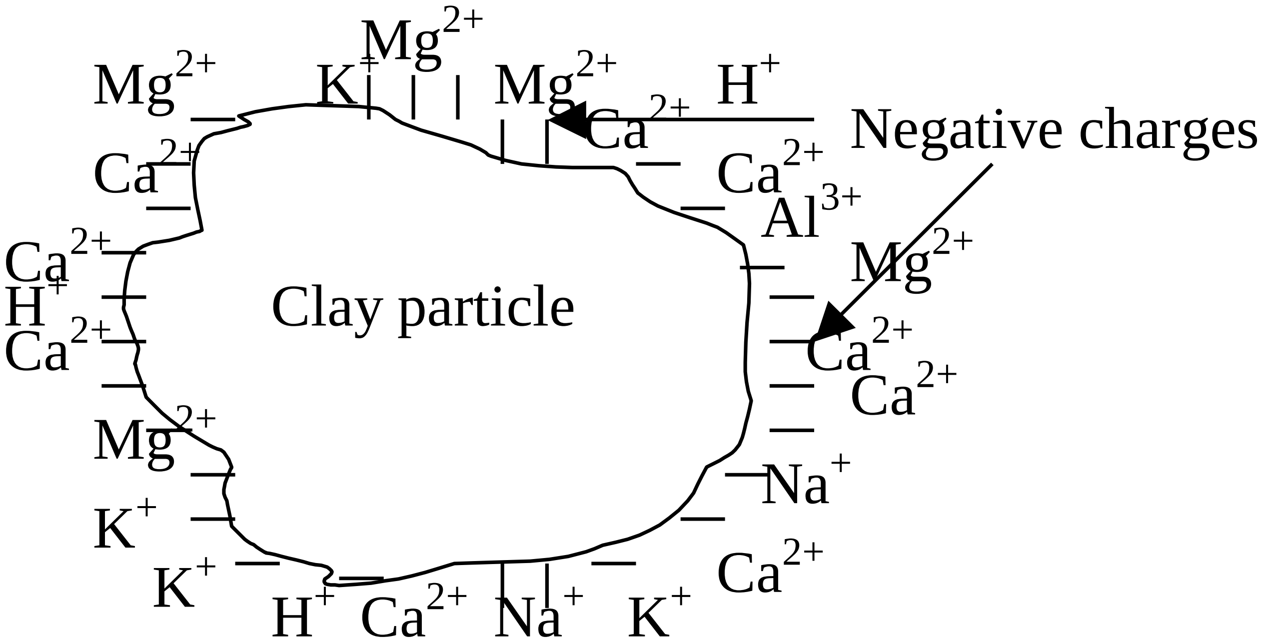


Sufficiency vs. BCSR

- the main objective when using the sufficiency level concept is to fertilize according to the plant's needs
- the BCSR aims to fertilize according to the soil's needs

Base Saturation

- The term base saturation is used to characterize how completely occupied are the adsorbing (surface held) sites of soil mineral and organic particles with basic cations. The basic cations commonly found in the soil are calcium (Ca), magnesium (Mg), potassium (K) and sodium (Na) and acidic cations are aluminum (Al) and hydrogen (H).



Base Saturation

- So, base saturation describes how completely the soil particle surface is filled with the basic cations (Ca, Mg, K, Na). When all the soil particle exchange sites are occupied with bases we have 100% saturation. This happens when the soil pH is above 7 (alkaline). However at lower pH values, some H and Al find their way onto the surface of the soil mineral and organic particles and that drops the base saturation to less than 100.

Base Saturation

- So, base saturation is:

$$\%BS = \frac{Ca+Mg+Na+K}{Ca+Mg+Na+K+H+Al} \times 100$$

Base saturation has been used as a tool to make decisions on whether a soil should be limed or not, along with a number of other tools. It is not a soil testing index and does not necessarily imply nutrient fertility of a soil.

The Base Cation Saturation Ratio Concept

- According to the BCSR concept, maximum plant growth will be achieved only when the soil's exchangeable Ca, Mg, and K concentrations are approximately **65% Ca, 10% Mg, and 5% K** (termed the ideal soil).
- This "ideal soil" was originally proposed by Firman Bear and coworkers in New Jersey during the 1940s as a method of reducing luxury K uptake by alfalfa
- "the absolute amounts of available Ca, K, and Mg are not so important as their relative values" (Bear et al., 1951).

KOCH
KOCH AGRONOMIC SERVICES, LLC

The BCSR Concept

- The early concern of researchers was with the luxury consumption of K by alfalfa - that is, if K is present in very high levels, alfalfa will continue to take up much more K than it needs, and, to a certain extent, it does so at the expense of Ca and Mg.
- When looking with the hindsight provided by more than a half century of soil research after the work of Bear and Albrecht, **the experiments carried out in New Jersey and Missouri were neither well designed nor well interpreted by today's standards**.

The BCSR Concept

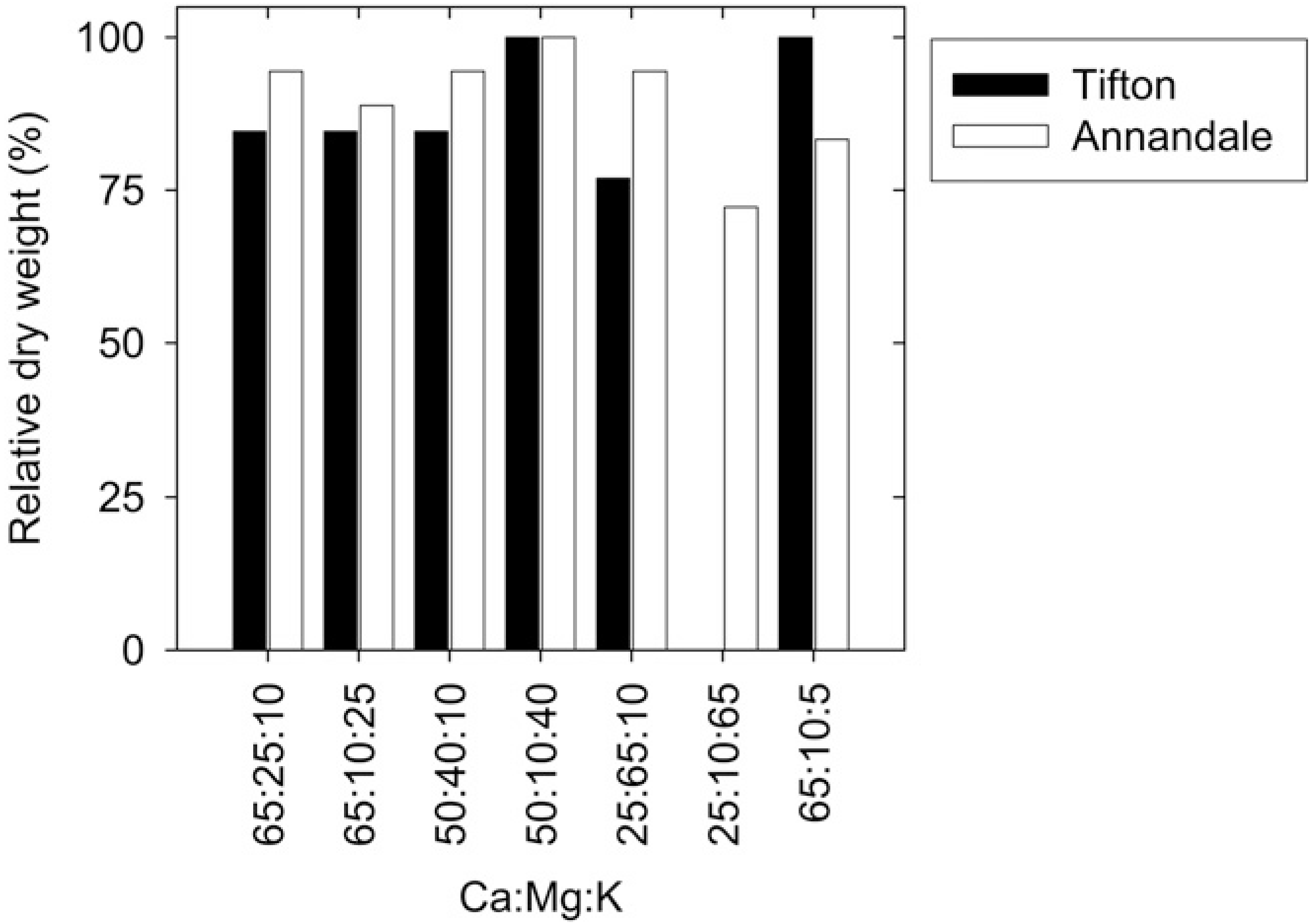
- Bear et al. (1945) tentatively stated that their evidence indicated that, "for the ideal soil,… 65% of the exchange complex should be occupied by Ca, 10% by Mg, 5% by K, and 20% by H."
- So, an "ideal" soil suggests a Ca/Mg ratio of 6.5:1, a Ca/K ratio of 13:1, a Ca/H ratio of 3.25:1, and a Mg/K ratio of 2:1 (all ratios are presented on a charge [equivalent] basis).
- **It is unclear, however, how these values for the ideal soil were established**.

The BCSR Concept

- In 1959 Graham stated that “the balance soil scientists recommend… is 75% Ca, 10% Mg and from 2.5 to 5% K.” In addition, he also suggested that the range could be from 65 to 85% for Ca, 6 to 12% for Mg, and 2 to 5% for K.
- **Again it is unclear, however, how these “new” values for the ideal soil were established**.
- Many of the original experiments were flawed and results often confounded by a decrease in acidity or other ions, e.g., Ba toxicity.
- **Benefits were from change in pH NOT cation ratios!**

The BCSR Concept

- First cracks in the concept appeared with the research by Giddens and Toth (1951), who carried out an experiment with four soils that were saturated at seven Ca/Mg/K ratios (with one being “ideal”), and compared plant growth between treatments.
- They concluded that provided Ca was the dominant cation, no specific cation ratio produced the best yield.



Data are sorted in order of decreasing Ca saturation. The columns at the far right of the graph (65:10:5) would reflect the “ideal soil” as proposed by Bear et al. (1945). Giddens and Toth (1951) did not present statistical differences.*

***Source: Kopittke and Menzies , 2007**

The BCSR Concept

- In addition to the lack of modern research indicating that it actually helps to use the BCSR system to make recommendations, and the problems that can arise when it (in contrast to the sufficiency system) is used, its use perpetuates a basic misunderstanding of what CEC and base saturation are all about.
- Than there is another issue: **The system is based on a faulty understanding of CEC and soil acids, as well as a misuse of the greatly misunderstood term percent base saturation.**

The BCSR Concept

- Once soils are much above pH 5.5 (and almost all agricultural soils are above this pH, making them moderately acid to neutral to alkaline), the entire CEC is occupied by Ca, Mg, and K (as well as some Na and ammonium). There are essentially no truly exchangeable acids (hydrogen or aluminum) in these soils. This means that the actual CEC of the soils in this normal pH range is just the sum of the exchangeable bases. **The CEC is therefore 100% saturated with bases when the pH is over 5.5 because there are no exchangeable acids.**

The BCSR Concept

- Even when the ratios of the nutrients are within the recommended crop guidelines, there may be such a low CEC (such as in a sandy soil that is very low in organic matter) that the amounts present are insufficient for crops.
- If the soil has a CEC of only 2 meq/100 g of soil, for example, it can have a “perfect” balance of Ca (70%), Mg (12.5%), and K (3.5%) but contain only 560 pounds Ca, 60 pounds of Mg, and 53 pounds of K per acre to a depth of 6 inches.
- Thus, while these elements are in a supposedly good ratio to one another, there isn’t enough of any of them.
- **The main problem with this soil is a low CEC**; the remedy is to add a lot of organic matter over a period of years, and, if the pH is low, it should be limed.

The BCSR Concept

- The opposite situation also needs attention. When there is a high CEC and satisfactory pH for the crops being grown, even though there is plenty of a particular nutrient, the cation ratio system may call for adding more.
- This can be a problem with soils that are naturally moderately high in magnesium, because the recommendations may call for high amounts of calcium and potassium to be added when none are really needed—wasting the farmer's time and money.

The BCSR Concept

- The cation ratio system can be used to reduce the chance of nutrient deficiencies, if interpreted with care and common sense—not ignoring the total amounts present and paying attention to the implications of a soil's pH. Using this system, however, **will usually mean applying more nutrients than suggested by the sufficiency system**—with a low probability of actually getting a higher yield or better crop quality.

Example from Manitoba CanoLAB

The BCSR Concept

Ca:Mg ratio	Ca	Mg	Yield
	---- % -----		ton/acre
Theresa silt loam:			
2.28	34	35	3.31
3.4	45	22	3.31
4.06	46	19	3.4
4.76	49	17	3.4
5.25	52	16	3.5
8.44	62	12	3.22
Plainfield loamy sand			
2.64	32	20	4.14
2.92	35	20	4.28
3.48	38	18	4.35
4.81	43	15	4.12
7.58	65	13	4.3
8.13	68	15	4.35

Simpson et al. 1979. Comm. Soil Sci. plant Anal. 10:153-162

Major disadvantage

- Although cations in the soil are in an ideal/optimum ratio, nutrient deficiencies may still exist.

Sufficiency Philosophy

Rate	Time	Advantages	Disadvantages
Most economic rate of fertilizer. Yield response in the year of application pays for cost of fertilizer.	Short term e.g. leased land, limited cash flow.	Low risk of over-fertilization	Hinges on knowing critical soil test value, so more calibration data are required. Precise critical value depends on the season, soil, and crop. Annual fertilization is needed unless the soil test is high.

Built and Maintenance Philosophy

Rate	Time	Advantages	Disadvantages
• At low soil test: apply>crop removal; build to > critical level. • At medium to high: apply crop removal; maintain levels in adequate (to meet crop needs) range. • At very high: no fertilizer, soil allowed to draw down.	Medium to long-term	Fertilizer not needed any given year; flexible; less calibration data needed.	Risk of over application; soils where freshly applied fertilizer is more available than residual.

BCSR Philosophy

Rate	Time	Advantages	Disadvantages
Range of ratios 65-85% calcium (Ca), 6-12% magnesium (Mg), 2-5% K	Medium to long term	Supporting data from subtropical weathered (old) soils. Excessive amounts of one nutrient can induce deficiencies of another.	• In temperate (young) soils, favourable ratios do not exist. • In high pH soils, CEC, Ca and Mg are overestimated when acidic extractants are used to determine exchangeable cations. This alters the ratio and can trigger unnecessary applications. • Only applies to cations. • No economic analysis goes into the recommendations.

McLean et al. 1983. Agron. J. 75: 635-639.

Earlier growth chamber study showed that no best ratio existed for either millet or alfalfa*.

A field study was carried out that involved:

- an acid silt loam soil, which had been adjusted to three pH (Ca), three Mg, and two K levels, in all combinations.
- A crop rotation of: corn, corn, soybeans, wheat, alfalfa, and alfalfa.

*Eckert and McLean, 1981, Agron. J. 73: 795-799.

McLean et al. 1983. Agron. J. 75: 635-639.

The treatment variables

- for pH were: 5.0, 6.0, and 6.5;
- for percent Mg saturation of soil CEC were: 4, 6, and 10; and
- for percent K saturation of CEC were 2.4 and 4.3.

- Both yields and crop compositions were measured.
- The treatment variables resulted in an average soil Ca/Mg ratio range of 2.3 to 26.8 and an average soil Mg/K ratio range of 0.6 to 3.6.

McLean et al. 1983. Agron. J. 75: 635-639.

The main conclusions were:

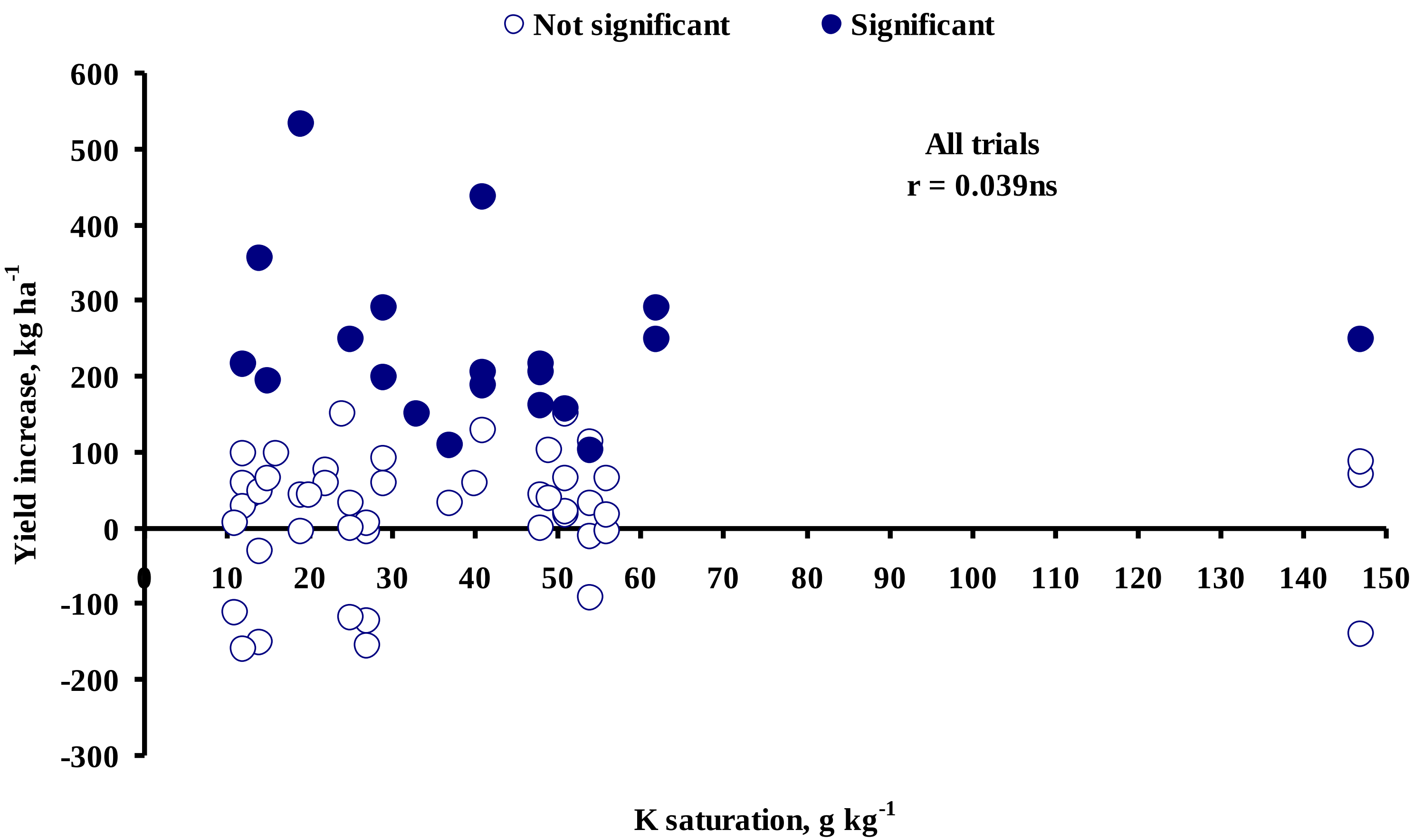
- Direct correlation or association of crop yields with basic cation saturation ratios (BCSR) were quite low.
- the treatments producing the five highest yields for each crop gave rather wide ranges in both Ca/Mg and Mg/K ratios which were to a large extent also common to those ratios associated with the five lowest yielding treatments.
- Found no evidence to support the validity of the BCSR concept as a basis for providing maximum crop yield conditions.

McLean et al. 1983. Agron. J. 75: 635-639.

The main conclusions were:

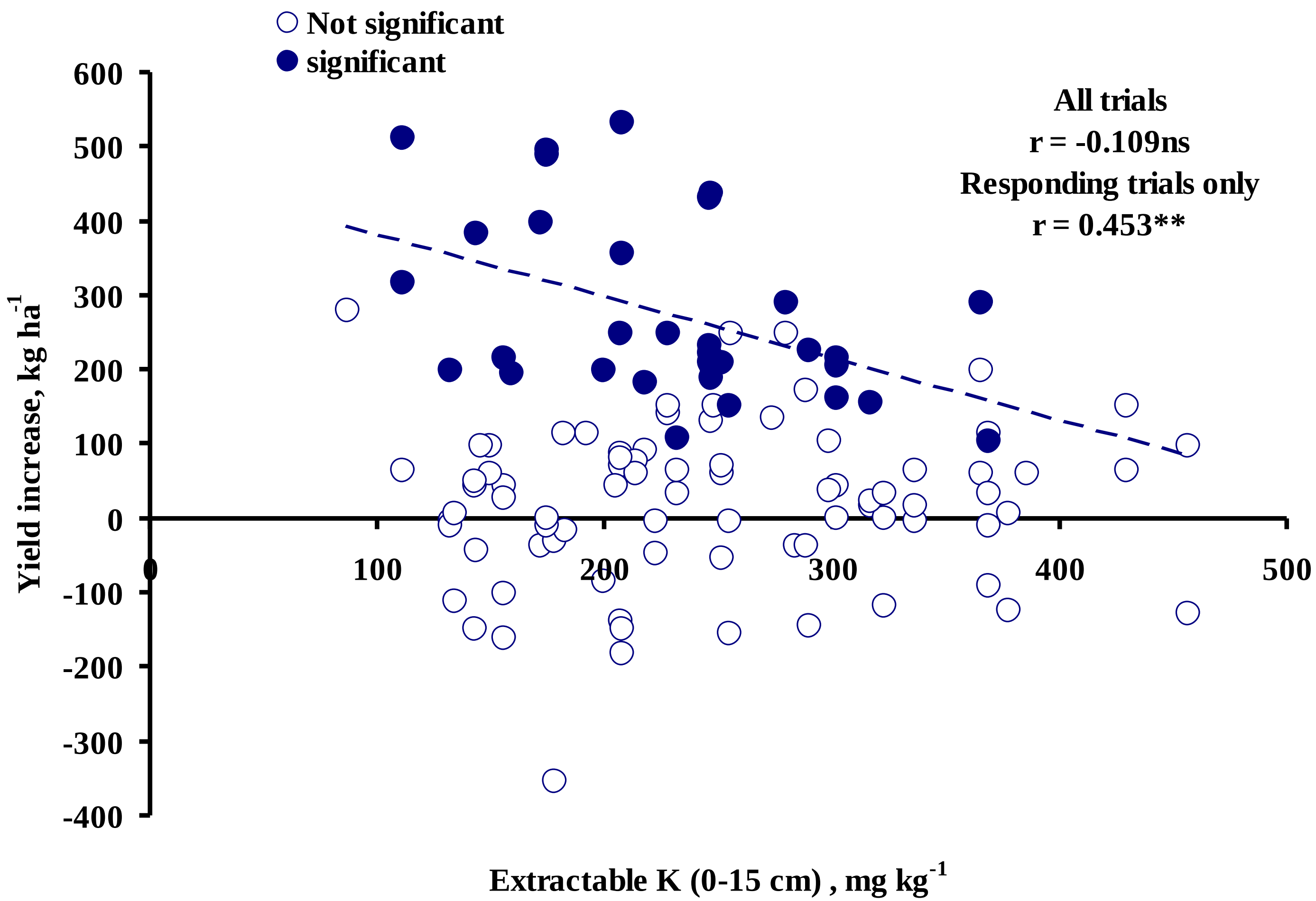
- Sufficiency concept still worked the best.
- The results strongly suggest that for maximum crop yields, emphasis should be placed on providing sufficient, but non-excessive levels of each basic cation rather than attempting to attain a favorable BCSR **which evidently does not exist**.

Response of barley to K application on high K soils*



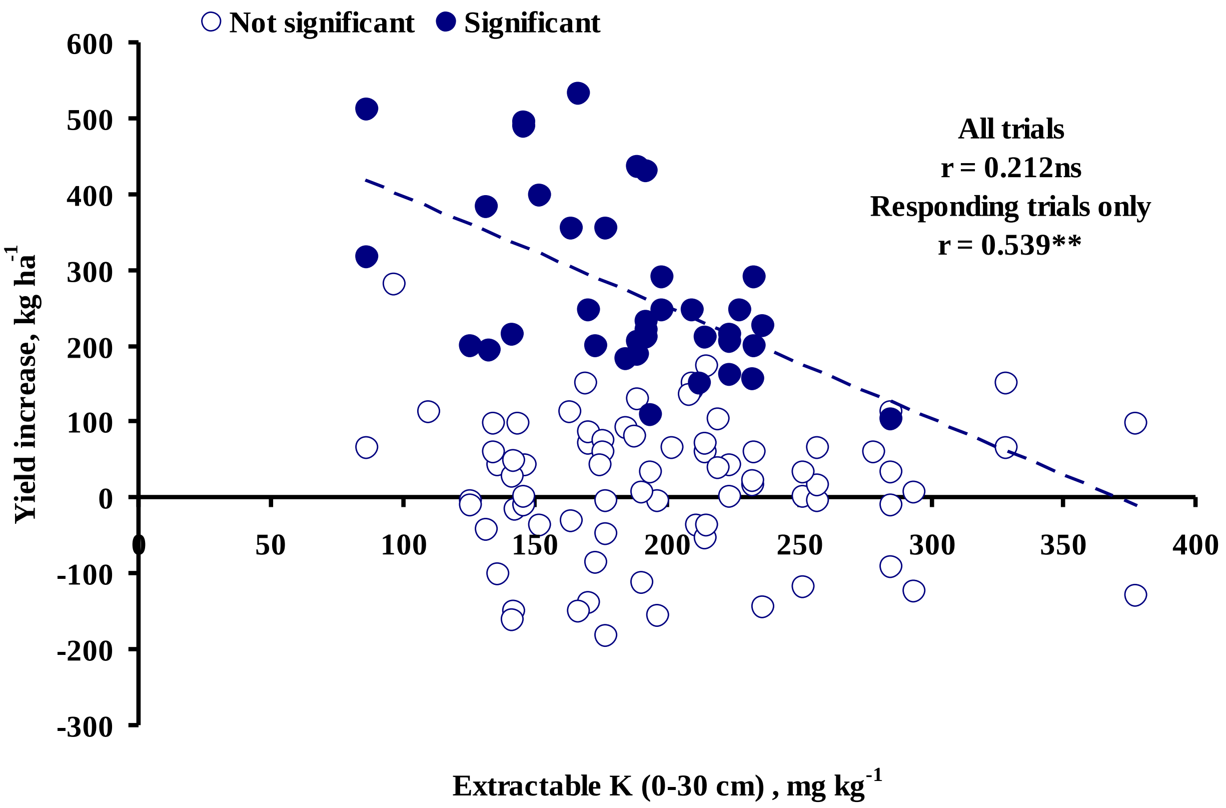
*adapted from Karamanos et al. 2003

Response of barley to K application on high K soils*



*adapted from Karamanos et al. 2003

Response of barley to K application on high K soils*



*adapted from Karamanos et al. 2003

Plant Root Simulator (PRS) Probes

- The PRS probes provide an assessment of nutrient supply rates by absorbing anions (-) or cations (+) on a membrane buried in moist soil.
- Continuous absorption over a burial period, trying to be similar to a plant root - *dynamic ion flux*.
- Caution: membranes get saturated.

Imbalance between K and Mg in grass tissue can lead to grass tetany in cattle



The data and material contained herein are provided for informational purposes only. No warranty, express or implied, is made including, but not limited to, implied warranties of merchantability and fitness for a particular purpose, which are specifically excluded. Results may vary based on a number of factors, including environmental conditions. Before use, consult the product packaging and labeling for information regarding the product's characteristics, uses, safety, efficacy, hazards and health effects.

Neither the individual researcher referred to, nor their respective universities, endorse the products mentioned herein.

THANK YOU

KOCH
KOCH AGRONOMIC SERVICES, LLC