The Advisability of Using Cation Balance as a Basis for Fertilizer Recommendations

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BCSR Concept Implications:

* Only considers base cations (Ca, Mg, and K) and soil acidity

* For optimum growth
  - Need best total base saturation
  - Need ideal ratio of cations

Base Cation Saturation Ratio (BCSR) Approach:

* First proposed by Loew, 1892

  "The balance of cations, especially that of calcium and magnesium, appears to substantially influence crop growth…"

* Theoretical basis

  - Bonding energies differ between cations
  - Level of one cation influences uptake of others
  - Both capacity (total exchangeable) and intensity (activity) affect availability
  - Filling pH dependent change sites increases availability

“Ideal” BCSR soil proposed by Bear et al (1945)

% saturation	ratios
65% Ca	Ca:Mg = 6.5:1
10% Mg	Ca:K = 13:1
5% K	Ca:H = 3.25:1
20% H	Mg:K = 2:1

Based on one NJ soil for alfalfa

BCSR contributing research

* Bear and Toth (1948) used 20 important NJ ag soils; concluded that “ideal” ratios were correct.

* Graham (1959) suggested ratios more broad in MO

65 – 85% Ca
6 – 12% Mg
2 – 5% K

Often forgotten observations by Bear and coworkers:

1. 10% Mg saturation may be minimum rather than optimum
2. Use least expensive cation (Ca) to avoid luxury K uptake
3. Liming above 80% BCS resulted in micronutrient (especially Mn) deficiencies
4. Soluble Mg needed on some soils

Treatments resulting in highest yield or tissue Ca level on 20 NJ soils

Cation	Alfalfa Yield	Alfalfa Ca
	--- % exchange site saturation ---	
Ca	15	22
Mg	11	16
K	2.2	1.6
H	67	59

Ca:Mg 1.4:1; Ca:K 6.8:1 – 13.7:1
Bear and Toth (1948)

W.A. Albrecht and students; Several papers from 1937-1947

- No alfalfa nodules at pH 5.5 unless added Ca
- Adding Ca increased number more than raising pH
- Limed and fertilized gave better bones
- Hay yields increased when Ca variable
    - Artificial media
    - Few or no statistics

Soils where BCSR may work:

* Highly weathered, low pH soils
* Low to moderate CEC
* Medium to coarse texture
* Large rates of nutrients/lime required
* Addition of Mg required to avoid grass tetany

Private soil testing labs sought distinction:

* In 1960's private soil testing labs expanded rapidly

* Survey in early 1970's showed 11 of 12 university labs in NC region used sufficiency level concept for recommendations

* 87% of private labs used BCSR
  - concept attractive
  - private vs university distinction
  - generally recommended more nutrients
  - tested soils for more nutrients

Field evaluation of BCSR vs sufficiency level (McLean et al, 1983)

* Silt loam very low in basic cations

* CEC = 14.2 mg/100g

* pH = 4.1

* Treatments
    - Ca from calcitic lime (5.0, 6.0, 6.5)
    - Mg = 4, 6, 10% of CEC
    - K = 2.4, 4.3 % of CEC
* Created soil ratio ranges
    - Ca:Mg 2.3 – 26.8
    - Mg:K 0.6 = 3.6

Ranges in BCSR for the 5 highest and 5 lowest yielding treatments

Nutrient Ratio	Crop	Highest 5	Lowest 5
Ca:Mg	Corn	5.7 – 36.8	5.6 – 21.5
	Soybean	5.7 – 14.9	2.3 – 16.1
	Wheat	5.7 – 14.0	6.8 – 21.5
	Alfalfa	6.8 – 26.8	5.7 – 21.5
Mg:K	Corn	0.6 – 3.0	1.1 – 2.2
	Soybean	1.0 – 3.0	0.7 – 3.6
	Wheat	1.1 – 3.1	0.7 – 2.1
	Alfalfa	0.6 – 2.1	1.0 – 3.0

McLean et al, 1983

Recent Wisconsin experiments

- 3 locations (River Falls, Pine Bluff, Marshfield)
- Added gypsum, Epsom salts, dolomitic lime, calcitic lime or pelletized calcitic lime to achieve various soil pH and Ca:Mg ratios
- At Marshfield and River Falls superimposed annual gypsum and Epsom salts treatments
- Grew corn followed by alfalfa

Measured:

- Yields
- Forage quality
- Earthworms
- Alfalfa stand (weediness)
- Compaction

Relationship between selected soil test parameters and various experimental measures at Marshfield, 1993

Soil test parameter	Alfalfa yield	Alfalfa Stand	Weeds	Alfalfa quality			Earthworms
				CP	ADF	NDF	
pH	**	NS	NS	*	NS	NS	NS
OM	**(-)	**(-)	*	*(-)	NS	NS	*
Exch Ca	NS	NS	NS	NS	NS	NS	NS
Exch Mg	NS	NS	NS	NS	NS	NS	NS
Exch K	**	**(-)	NS	NS	NS	NS	NS
Exch Ca+Mg+K	NS	NS	NS	NS	NS	NS	NS
Ca:Mg	NS	NS	NS	NS	NS	NS	NS

Schulte et al, 1995

Conclusions:

- Alfalfa yield related to exchangeable K and soil pH, not Ca:Mg
- Neither Ca or Mg additions affected weeds
- Earthworms related to organic matter, not Ca:Mg
- Alfalfa quality related to pH and stand, not Ca:Mg
- No justification to use calcitic over dolomitic lime or adding extra Ca

Why no response to Ca:Mg imbalance

- Ca and Mg levels are relatively high in soil solution compared to plant uptake
- Plant K uptake is 2 – 4 times that of Ca and Mg
- Ca and Mg are supplied to roots by mass flow

The bottom line:

1. "Basic cation ratios per se seem unimportant to the well-being of the crop. Indeed, it appears that instead we should concentrate on sufficiency levels of each basic cation."

   E.O. McLean, 1982

2. Emphasis should be placed on providing sufficient, but non-excessive levels of each basic cation rather than attempting to adjust to a favorable BCSR which evidently does not exist.

   McLean et al., 1983

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