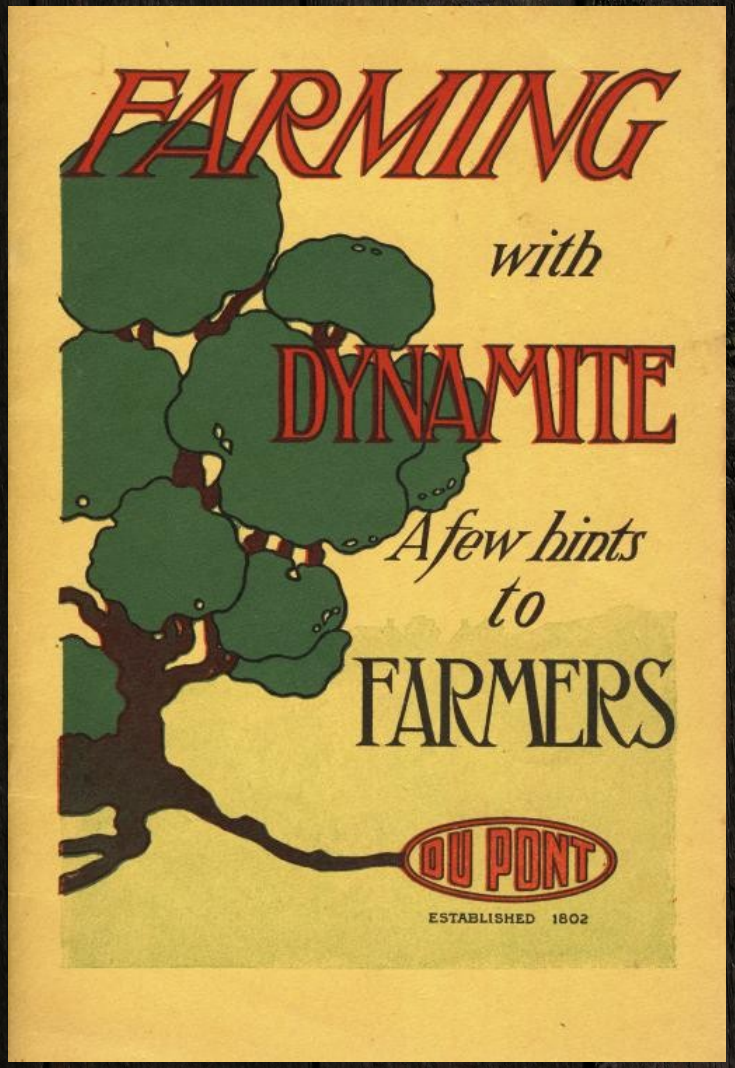
“Agriculture should be advanced by scientific knowledge.”

5ST 8-13-96



Do I advocate:

- Hydroponics ? no
- Biodynamics ? no
- Aquaculture ? no
- Permaculture ? no
- “Back to Eden” ? no

Building a ”soil bank” of nutrition for <u>you</u> and your crops starts with establishing the right mineral environment for highly active microbiology. Fungi, bacteria, algae and enzymes are the biological catalysts for the mineral nutrients that your plants (and you) need.

Building this bank is a process that involves evaluating your soil analysis in two steps. This presentation will guide you through the first step.

Major Soil Orders of the United States

Minnora, West Virginia

What is soil?

Minerals	50%
Air	23-25%
Water	23-25%
Organic Matter	3-5%

Three primary soil chemical classes:

Acid soils
- pH below 7
- free hydrogen H^+ in Base Saturation
- 70% of world's arable land

Calcareous soils
- alkaline pH - 7.1 to 8.3
- contain Calcium and Magnesium carbonates
- often contain phosphates
- can be very fertile

Sodic soils
- highly alkaline – pH above 8
- excessive free sodium Na^+ (above 15% in Base Saturation)
- very poorly drained, poor water penetration
- found in arid and semi-arid regions

First Step: A Soil Analysis

- Use a reputable, privately run soil laboratory
- Be certain that they include a "Base Saturation" component
- Extraction Methods:

  Bray (for Calcareous soils with pH >7.3)

  Ammonium Acetate or Morgan (low acid extraction)

  Mehlich I

  *Mehlich III (for acidic to pH <7.3 soils)

  Olsen (for very high pH >8 and Sodic soils)

I like the "S3M" package from A&L Eastern Laboratories in Richmond, VA

http://al-labs-eastern.com/agricultural.html

Other laboratories listed here:

http://www.bereagardens.org/soil.html

pH scale (potential Hydrogen)

---------- | ----------

0 — 7 — 14

H^+ — Neutral — OH^-

(Hydrogen ions) — (Hydroxyl ions)

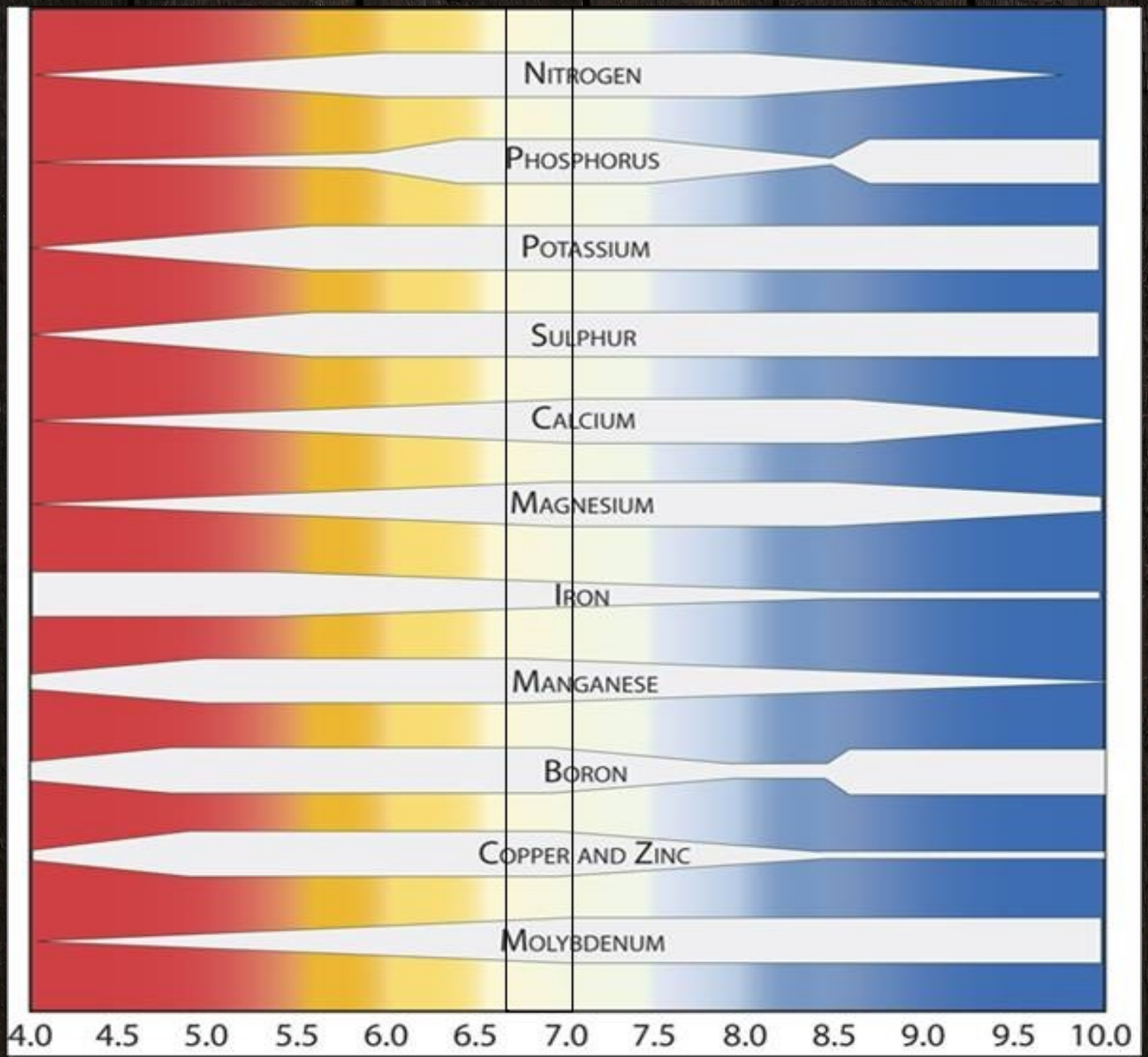
H^+ in base Saturation — Na^+ in Base Saturation

Limestone raises pH ----> — 6.5 to 7 optimum range — <---- Sulfur lowers ph

Calcitic limestone
Hydrated limestone
Dolomite limestone

Elemental Sulfur

Nutrient availability changes according to pH



17 Essential Plant Nutrients:

Carbon, Hydrogen, Oxygen

(Environmental Nutrients)

Nitrogen, Phosphorous, Potassium

(Primary Nutrients)

Calcium, Magnesium, Sulfur

(Secondary Nutrients)

Boron, Copper, Iron, Zinc, Molybdenum, Manganese, Chlorine, Nickel

(Trace Nutrients)

*16 Additional Elements Required for Human Health

*Aluminum**
*Arsenic**
Boron
*Bromine**
*Cadmium**
Calcium
Carbon
Chlorine
*Chromium**
*Cobalt**
Copper
*Fluorine**
*Germanium**
Hydrogen
*Iodine**
Magnesium
Manganese
Molybdenum
Nickel
Nitrogen
Oxygen
Phosphorous
Potassium
*Rubidium**
*Selenium**
*Silicon**
*Sodium**
Sulfur
*Tin**
*Tungsten**
*Vanadium**
Zinc

Plants *mine* the soil for minerals

Only a few of these are replaced through fertilization of crops

- Typically only Nitrogen, Phosphorous, Potassium are applied
- Occasionally Sulfur or Calcium are added
- Rarely some trace elements added through foliar applications
- Soil deficiencies are very rarely corrected
- The other 16 elements required for human nutrition are ignored as considerations in agriculture

Dr. William A. Albrecht, University of Missouri

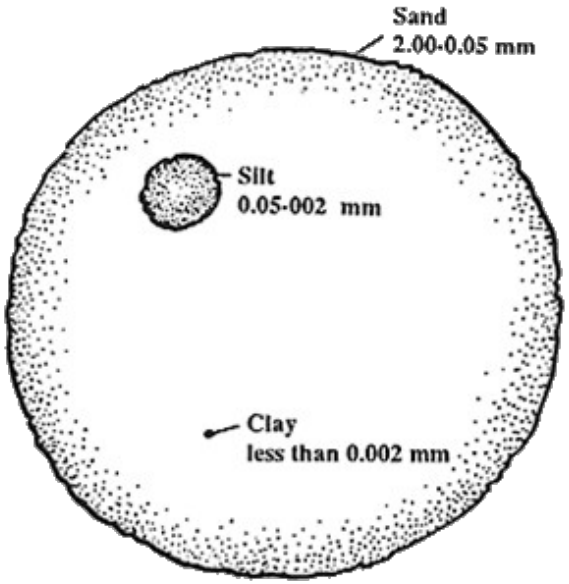
- Correlated soil chemistry (health) with human health
- Developed understanding of Base Saturation of the Cation Exchange Capacity in soils
- Emphasized the role of calcium in ratios with magnesium and potassium to promote optimum health

"NPK formulas, (nitrogen, phosphorus, potassium) as legislated and enforced by State Departments of Agriculture, mean malnutrition, attack by insects, bacteria and fungi, weed takeover, crop loss in dry weather, and general loss of mental acuity in the population, leading to degenerative metabolic disease and early death."

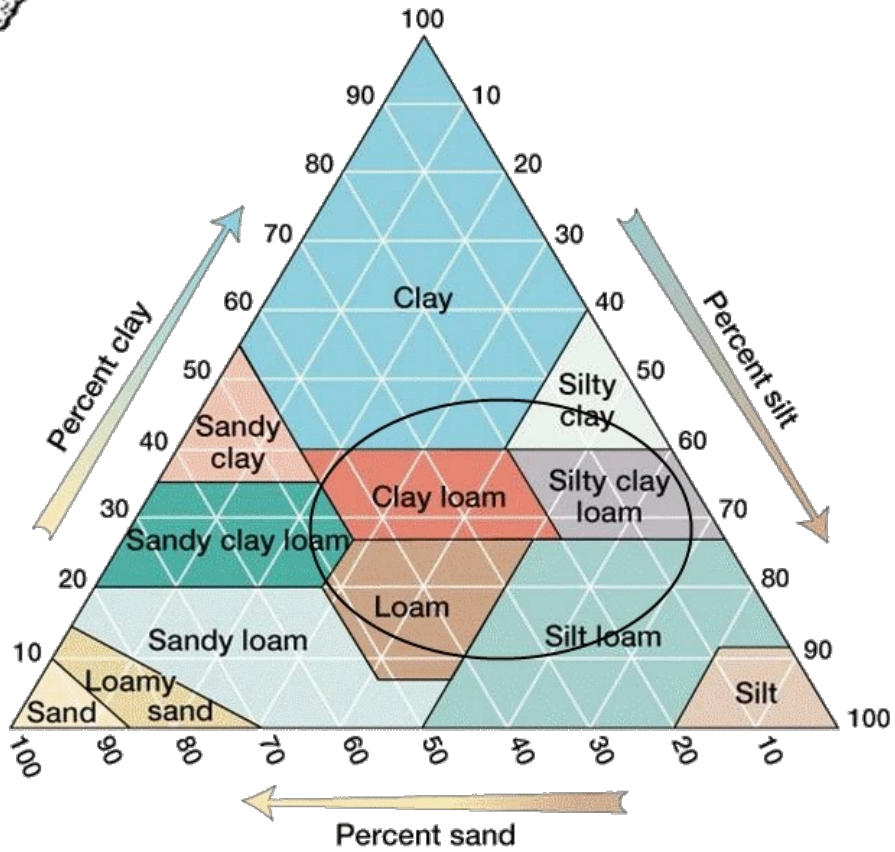
William A. Albrecht

Soil texture: a reference to the size of soil particles

- Sand
- Silt
- Clay



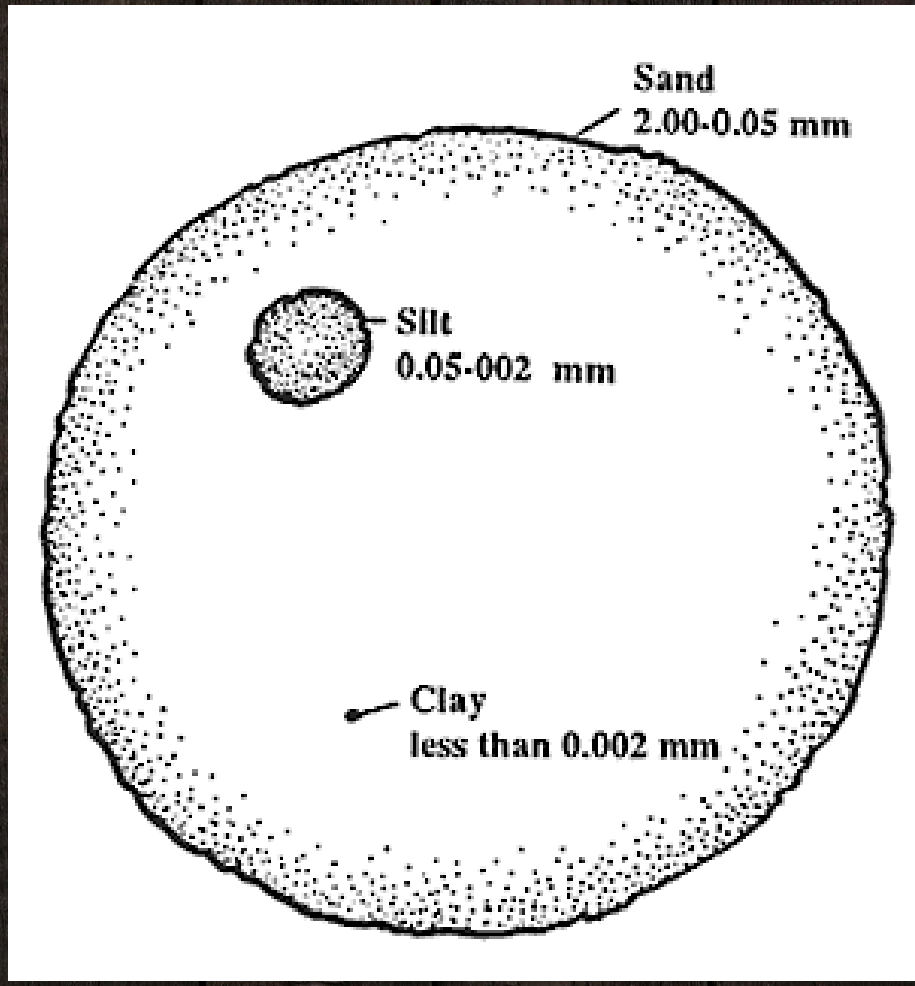
- Texture indicates potential capacity to hold water and nutrients
- Gives an indication of friability



Soil particles have a slight <u>negative electrical charge</u>

<u>Size</u> of soil particles determines how much negative charge in a given quantity or volume of soil

Sand - very low
Silt - low
Clay - high



Cation Exchange Capacity (CEC)

Measurement of a soil's ability to hold cation (positively charged ion) nutrients in the soil

Cations are positively charged ions $^{+}$

Ca^{++}	Calcium
Mg^{++}	Magnesium
K^{+}	Potassium
H^{+}	Hydrogen
Na^{+}	Sodium

Anions are negatively charged ions $^{-}$

Example of a soil analysis report

Page 1 of 1

Report Number: 10-103-0558

Account Number: 00879

www.allabs.com

A&L Eastern Laboratories, Inc.

7621 Whitepine Road Richmond, Virginia 23237 (804) 743-9401 Fax (804) 271-6446

Send To: ROBERT GREGORY
97 MILO RD
ORMA WV 25268

Grower: BEREA GARDENS

Submitted By: BOB GREGORY
Farm ID:

SOIL ANALYSIS REPORT

Analytical Method(s):
Mehlich 3

Date Received: 04/13/2010 **Date Of Analysis:** 04/14/2010 **Date Of Report:** 04/15/2010

Sample ID / Field ID	Lab Number	Organic Matter			Phosphorus				Potassium		Magnesium		Calcium		Sodium		pH		Acidity	C.E.C
		%	Rate	ENR lbs/A	Mehlich 3 ppm	Mehlich 3 Rate	Reserve ppm	Reserve Rate	K ppm	K Rate	Mg ppm	Mg Rate	Ca ppm	Ca Rate	Na ppm	Na Rate	Soil pH	Buffer Index	H meq/100g	meq/100g
F1	05346	1.7	L	68	37	M			131	M	199	M	1097	L			5.2	6.54	3.9	11.4

Sample ID / Field ID	Percent Base Saturation					Nitrate		Sulfur		Zinc		Manganese		Iron		Copper		Boron		Soluble Salts		Chloride		Aluminum
	K %	Mg %	Ca %	Na %	H %	NO_3N ppm	NO_3N Rate	S ppm	S Rate	Zn ppm	Zn Rate	Mn ppm	Mn Rate	Fe ppm	Fe Rate	Cu ppm	Cu Rate	B ppm	B Rate	SS ms/cm	SS Rate	Cl ppm	Cl Rate	Al ppm
F1	2.9	14.5	48.1		34.0			19	M	1.7	L	29	H	121	VH	2.1	H	0.4	L					

Values on this report represent the plant available nutrients in the soil. Rating after each value: VL (Very Low), L (Low), M (Medium), H (High), VH (Very High). ENR - Estimated Nitrogen Release. C.E.C. - Cation Exchange Capacity.

Explanation of symbols: % (percent), ppm (parts per million), lbs/A (pounds per acre), ms/cm (milli-mhos per centimeter), meq/100g (milli-equivalent per 100 grams). Conversions: ppm x 2 = lbs/A, Soluble Salts ms/cm x 640 = ppm.

This report applies to sample(s) tested. Samples are retained a maximum of thirty days after testing.

Analysis prepared by: A&L Eastern Laboratories, Inc.

by: Pauric McGroary

Pauric McGroary

SOIL ANALYSIS REPORT

Analytical Method(s): Mehlich 3

Date Received: 04/13/2010 Date Of Analysis: 04/14/2010 Date Of Report: 04/15/2010

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Analysis prepared by: A&L Eastern Laboratories, Inc.

by: Pauric McGroary

Pauric McGroary

The “Base Saturation” refers to the quantity of cations adsorbed by the soil particles and held by the soil’s negative charge.

The “Percent Base Saturation” tells us how much of each cation element is presently attached in the soil complex.

Desired levels of elements in the Base Saturation

Calcium > 68%

Magnesium 17 to 20%

Potassium 3 to 5%

Cation Exchange Capacity (CEC)

Measurement of a soil's ability to hold cation (positively charged ion) nutrients in the soil

Cations are positively charged ions $^{+}$

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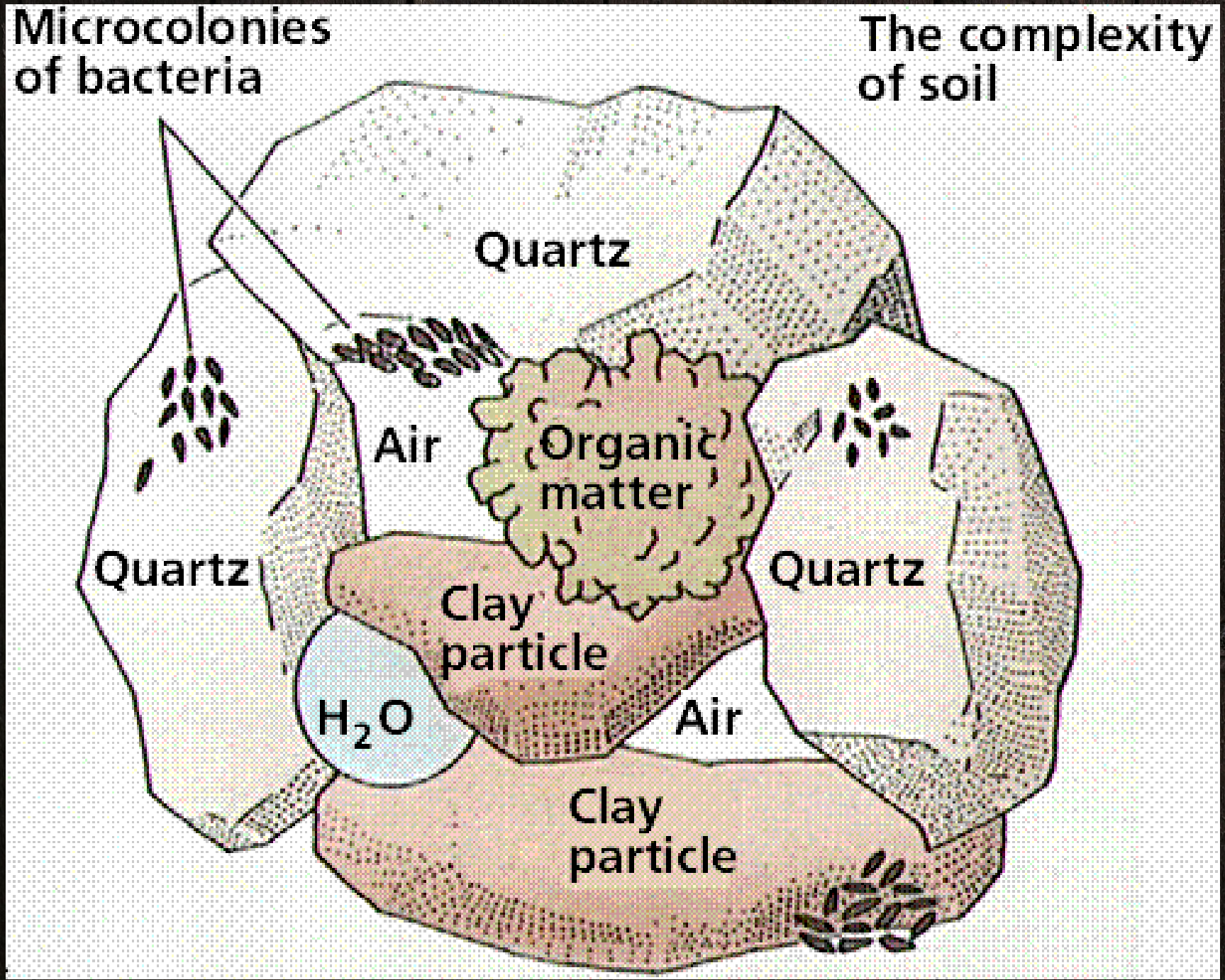
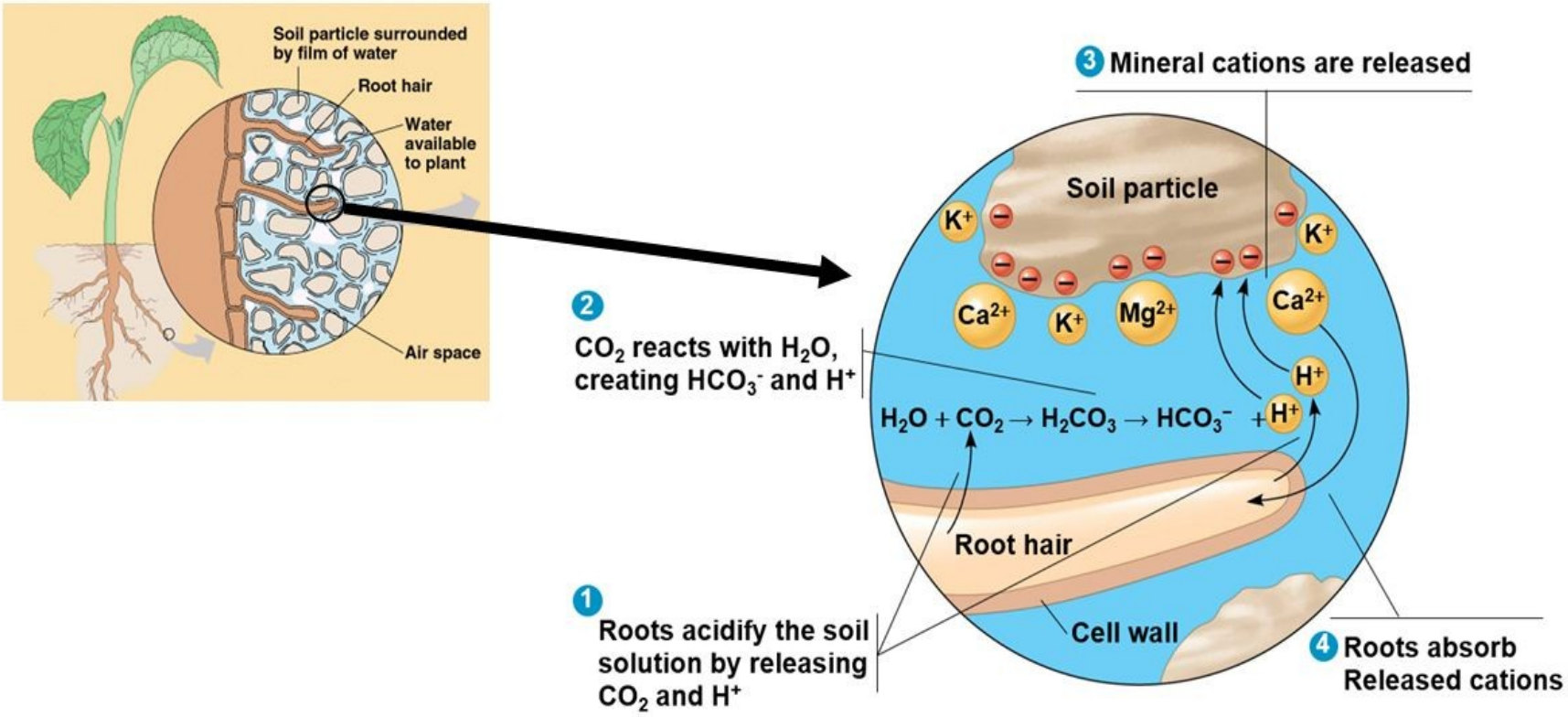

Microcolonies of bacteria
The complexity of soil
Quartz
Air
Organic matter
Quartz
Quartz
Clay particle
H_2O
Air
Clay particle

Cation Exchange in the Soil



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Analysis prepared by: A&L Eastern Laboratories, Inc.

by: Pauric McGroary

Pauric McGroary

*Tons per acre limestone = .5 (CEC x H%)

**(modifies the "plow layer" or top 6 2/3" of soil)*

SOIL ANALYSIS REPORT

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Analysis prepared by: A&L Eastern Laboratories, Inc.

by: Pauric McGroary

Pauric McGroary

Example:

Tons per acre limestone = .5 (11.4 x .34) = 1.938 tons per acre

(to modify the top 12" of soil multiply this result by 1.8)

1.938 X 1.8 = 3.48 tons of limestone per acre

SOIL ANALYSIS REPORT

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Analysis prepared by: A&L Eastern Laboratories, Inc.

by: Pauric McGroary

Pauric McGroary

Types of Limestone:

Limestone (calcitic) $CaCO^3$ 40% Ca

Hydrated Lime $Ca(OH)^2$ 54% Ca

Dolomite *$CaCO^3$ $MgCO^3$* *21% Ca + 12% Mg**

*Ratio of Calcium to Magnesium varies with brands

Always READ THE LABEL

SOIL ANALYSIS REPORT

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Analysis prepared by: A&L Eastern Laboratories, Inc.

by: Pauric McGroary

Pauric McGroary

We have now displaced the Hydrogen in the Base Saturation and that 34% is now occupied by Calcium and Magnesium. The Hydrogen is now 0% and the pH is neutral (7)

Since we used Dolomite with roughly a 2:1 ratio of Calcium to Magnesium, we have increased the Calcium level by about 22.5% and the Magnesium level by about 11.5%

Our Calcium level has moved from 48.1% to 70.6%
The Magnesium level has moved from 14.5% to 26%

Dolomite *$CaCO^3$ $MgCO^3$* *21% Ca + 12% Mg (2:1 ratio of Ca to Mg)*

SOIL ANALYSIS REPORT

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Analysis prepared by: A&L Eastern Laboratories, Inc.

by: Pauric McGroary

Pauric McGroary

Our Calcium level has moved from 48.1% to 70.6%
The Magnesium level has moved from 14.5% to 26%

To avoid raising the Magnesium level too high I can use a combination of limestone types. By solving for how much Magnesium to apply using Dolomite and then adding Calcitic limestone, I can achieve a better Magnesium to Calcium ratio.

SOIL ANALYSIS REPORT

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Analysis prepared by: A&L Eastern Laboratories, Inc.

by: Pauric McGroary

Pauric McGroary

To solve for a Magnesium level of 20% I use this equation to tell me how many <u>pounds</u> of Magnesium per acre to apply:

240 X CEC (.20 – Mg%)

240 X 11.4 (.20 - .145) or 240 X 11.4 X .055 = <u>150.48 Pounds of Magnesium</u>

The Dolomite I have contains 12% Magnesium, so to determine how much to apply I divide the amount I need by the 12%:

150.48 / .12 = 1,254 pounds of Dolomite per acre to raise my Mg level to 20%

Again, for a depth of 12” multiply the result by 1.8 (1,254 X 1.8 = 2,257 lbs. Dolomite per acre)

SOIL ANALYSIS REPORT

Analytical Method(s): Mehlich 3

Date Received: 04/13/2010 Date Of Analysis: 04/14/2010 Date Of Report: 04/15/2010

Sample ID / Field ID	Lab Number	Organic Matter %	Organic Matter Rate	Organic Matter ENR lbs/A	Phosphorus Mehlich 3 ppm	Phosphorus Mehlich 3 Rate	Phosphorus Reserve ppm	Phosphorus Reserve Rate	Potassium K ppm	Potassium K Rate	Magnesium Mg ppm	Magnesium Mg Rate	Calcium Ca ppm	Calcium Ca Rate	Sodium Na ppm	Sodium Na Rate	pH Soil pH	pH Buffer Index	Acidity H meq/100g	C.E.C meq/100g
F1	05346	1.7	L	68	37	M			131	M	199	M	1097	L			5.2	6.54	3.9	11.4

Sample ID / Field ID	Percent Base Saturation K %	Mg %	Ca %	Na %	H %	Nitrate NO_3N ppm	Nitrate Rate	Sulfur S ppm	Sulfur Rate	Zinc Zn ppm	Zinc Rate	Manganese Mn ppm	Manganese Rate	Iron Fe ppm	Iron Rate	Copper Cu ppm	Copper Rate	Boron B ppm	Boron Rate	Soluble Salts SS ms/cm	Soluble Salts Rate	Chloride Cl ppm	Chloride Rate	Aluminum Al ppm
F1	2.9	14.5	48.1		34.0			19	M	1.7	L	29	H	121	VH	2.1	H	0.4	L					
	5	*20*	*>68*		*0*																			

Values on this report represent the plant available nutrients in the soil. Rating after each value: VL (Very Low), L (Low), M (Medium), H (High), VH (Very High). ENR - Estimated Nitrogen Release. C.E.C. - Cation Exchange Capacity.

Explanation of symbols: % (percent), ppm (parts per million), lbs/A (pounds per acre), ms/cm (milli-mhos per centimeter), meq/100g (milli-equivalent per 100 grams). Conversions: ppm x 2 = lbs/A, Soluble Salts ms/cm x 640 = ppm.

This report applies to sample(s) tested. Samples are retained a maximum of thirty days after testing.

Analysis prepared by: A&L Eastern Laboratories, Inc.

by: Pauric McGroary

Pauric McGroary

We determined that I need 3.48 tons of limestone per acre, so:

3.48 X 2,000 = 6,960 pounds of limestone per acre is required

6,960 – 2,257 = 4,703

6,960 = total limestone needed

2,257 = dolomite used to meet the Mg requirement

4,703 = the balance of limestone from a Calcitic source

SOIL ANALYSIS REPORT

Analytical Method(s): Mehlich 3

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This report applies to sample(s) tested. Samples are retained a maximum of thirty days after testing.

Analysis prepared by: A&L Eastern Laboratories, Inc.

by: Pauric McGroary

Pauric McGroary

Calcium level is now 76%

Magnesium level is now 20%

These now total 96%, leaving me room to raise my Potassium level to 4%

	Optimum K% Desired		
CEC	3%	4%	5%
	Pounds of K_20 (Potash) per acre		
5	142	189	237
10	284	378	473
15	426	568	710
20	568	757	946
30	852	1135	1419
40	1135	1514	1892

For a CEC above 30 it is more economical to use this equation:

K (critical level) = 110 + 2.5 X CEC

Optimum K% Desired

CEC	3%	4%	5%
	Pounds of K_20 (Potash) per acre		
5	142	189	237
10	284	378	473
15	426	568	710
20	568	757	946
30	852	1135	1419
40	1135	1514	1892

x x

CEC = 11.4 K level is 2.9%

I have around 312 and want 430

I need to add 118 pounds of K_2O (potash) per acre

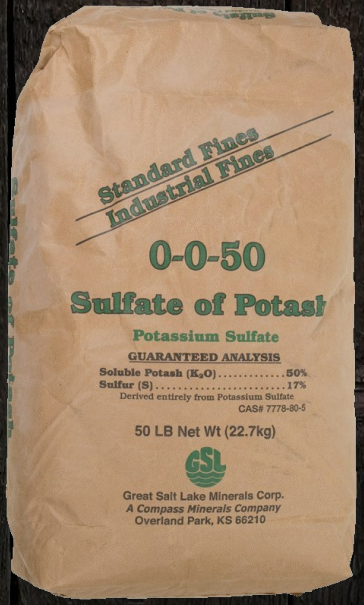
Potassium Sources

Potassium Sulfate	0-0-50	(50% potash)
Greensand	0-0-3	(3% potash)

I need to add 118 pounds of potash

118/.50 = 236 pounds of Potassium Sulfate per acre

118/.03 = 3,933 pounds of Greensand per acre



To quote J. I. Rodale, from Organic Gardening magazine,

"we organic gardeners have let our enthusiasm run away with us. We have said that the nitrogen which is in organic matter is different (and thus somehow better) from nitrogen in a commercial fertilizer. But this is not so." And "actually there is no difference between the nitrogen in a chemical fertilizer and the nitrogen in a leaf."

Calcareous Soils

Can be high in Calcium^{++} and/or Magnesium^{++}

Albrecht's principles still apply

3-5%K 17-20%Mg >68%Ca

Calcium source:	Gypsum (calcium sulfate)	23% Ca
Magnesium source:	Epsom Salt (magnesium sulfate)	9% or 20% Mg
Potassium source:	Potassium Sulfate	0-0-50

These are neutral salts that do not change the pH

Physical properties of soils with Mg levels in excess of 20% will benefit from additional Calcium and organic matter. 1,000 to 2,000 pounds of Gypsum per acre is a good starting point to help with issues of crusting and water penetration

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Magnesium source:	Epsom Salt (magnesium sulfate)	9% or 20% Mg
Potassium source:	Potassium Sulfate	0-0-50

These are neutral salts that do not significantly change the pH

To adjust pH

Sulfur:	Elemental Sulfur	>99% S

Sulfur rates to adjust soil pH

Desired change in pH	CEC 5 *	CEC 10 *	CEC 20 *
8.5 to 6.5	370	730	1460
8.0 to 6.5	340	670	1340
7.5 to 6.5	300	600	1200
7.0 to 6.5	180	360	720

(* pounds of sulfur per acre)

Calcareous Soils

Physical properties of soils with Mg levels in excess of 20% will benefit from additional Calcium and organic matter.

Addition of sulfur to a calcareous soil forms calcium sulfate which will aid in water penetration and soften the soil by clumping or “floculating” soil particles.

Calcareous Soils

Adjusting Magnesium

240 X CEC (.20 – Mg%) = Pounds of elemental Magnesium per acre

This is for the Plow Layer of 6 2/3”

To adjust an acre foot, multiply the result by 1.8

Use Epsom Salt (Magnesium Sulfate)

Adjusting Potassium

Use the chart we showed previously for Acid Soils

Sodic Soils

- High pH – often above 8 (fizz test)
- Sodium (Na) above 15% in Base Saturation
- Poor water penetration/poor drainage/crusting
- Use Olsen analysis method

Adjust pH with Sulfur using the previous chart

Addition of sulfur to a Sodic soil also forms calcium sulfate which will aid in water penetration and soften the soil by clumping or “floculating” soil particles.

Sodic Soils

When soils are high in sodium, the goal is to replace the sodium with calcium and then leach the sodium out. There are two possible approaches for doing this:

1.) Dissolve the limestone (calcium carbonate) or gypsum (calcium sulfate) already present in the soil.

OR

2.) Add calcium to the soil.

If free lime is present in the soil, it can be dissolved by applying sulfur. Sulfur products reduce the pH which dissolves the lime, thus freeing up the calcium. This works well when the Base Saturation of Calcium is higher than 78%.

If free lime or gypsum is not present in adequate amounts as determined by a soil test, then add calcium.

Example gypsum requirement calculation:

If soil has a CEC of 18 and Sodium at 19%, and you desire a level of approximately 10% following treatment

19% – desired 10% = 9% exchangeable Na must be replaced with calcium (Ca) to achieve the desired level.

0.09 X 18 = 1.62 meq Na/100 g soil that must be replaced.

*1.7 tons Gypsum X 1.62 meq Na = 2.75 tons of gypsum.

2.75 tons of pure gypsum per acre would be required to reclaim the top 12 inches of this soil. Be sure to adjust this calculation for lower grades of gypsum and different soil depths.

*As a general rule of thumb, 1.7 tons of gypsum is required per meq of sodium.