Putting Principals into Practice
2nd Soil & Nutrition Conference

IMPROVING NUTRIENT CIRCULATION WITHIN FARM ECOSYTEMS

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FIRST CHURCHES, NORTHAMPTON, MA
JANUARY 31 – FEB 2

Approaching Agriculture - Our Philosophy

Brix Bounty Farm
Growing Food with Respect for the Earth & Future Generations

Minerals & Biological Activity - Keys to Healthy Crops

1) By addressing mineral deficiencies in our soils,
2) Increasing biological activities to ensure these minerals are available and biologically complexed,
3) And ensuring adequate moisture and air in our soils…

We can grow healthy crops

Yields and Farm Viability ($) are
Connected with Soil Health and Fertility Investments

Brix Bounty Farm

Growing Food with Respect for the Earth & Future Generations.

Caring, Honoring, & Dignifying our Biological Systems

Nourishing Food Tastes Good

Building Fires with Fertility

Growing a Foundation for Health Since 2008

Every Day… Solar Array

Commercial Agriculture & Natural Systems

- Monocropping, Tillage, & Heavy Harvests (crop removal)
- Diversity, Natural Cycling, & Sustainable Yields
  - *A World in One Cubic Foot* by David Littschwager
- Intensive Agriculture - Foundation for Complex Societies
- Constricted by Labor, Money, Time…

  Harmonizing within paradigm of "monocropping"

Increasing Circulation of Minerals in Soils & Plants

- Application of minerals, Increase Availability –
  - Either to address deficiency or "jumpstart" biological system
  - Stimulation of biology to increase nutrient availability
- Crop uptake, root exudates, & residue sequestration
- Mineralization of residues "release" nutrients
- Nutrients available for uptake by biological community:
  - microbes, bacteria & fungal community, etc….

And ultimately - root systems of following crops…

Evolution of Agricultural Practices

- "Best Management Practices" change over time
- Often guided by realities of commercial production
- New information, new knowledge, new systems
- Currently we are amidst a "constant" evolution of best practices… an agricultural renaissance?

  Questions, Observations, Answers, Questions (repeat)

Soil Testing & Soil Analysis

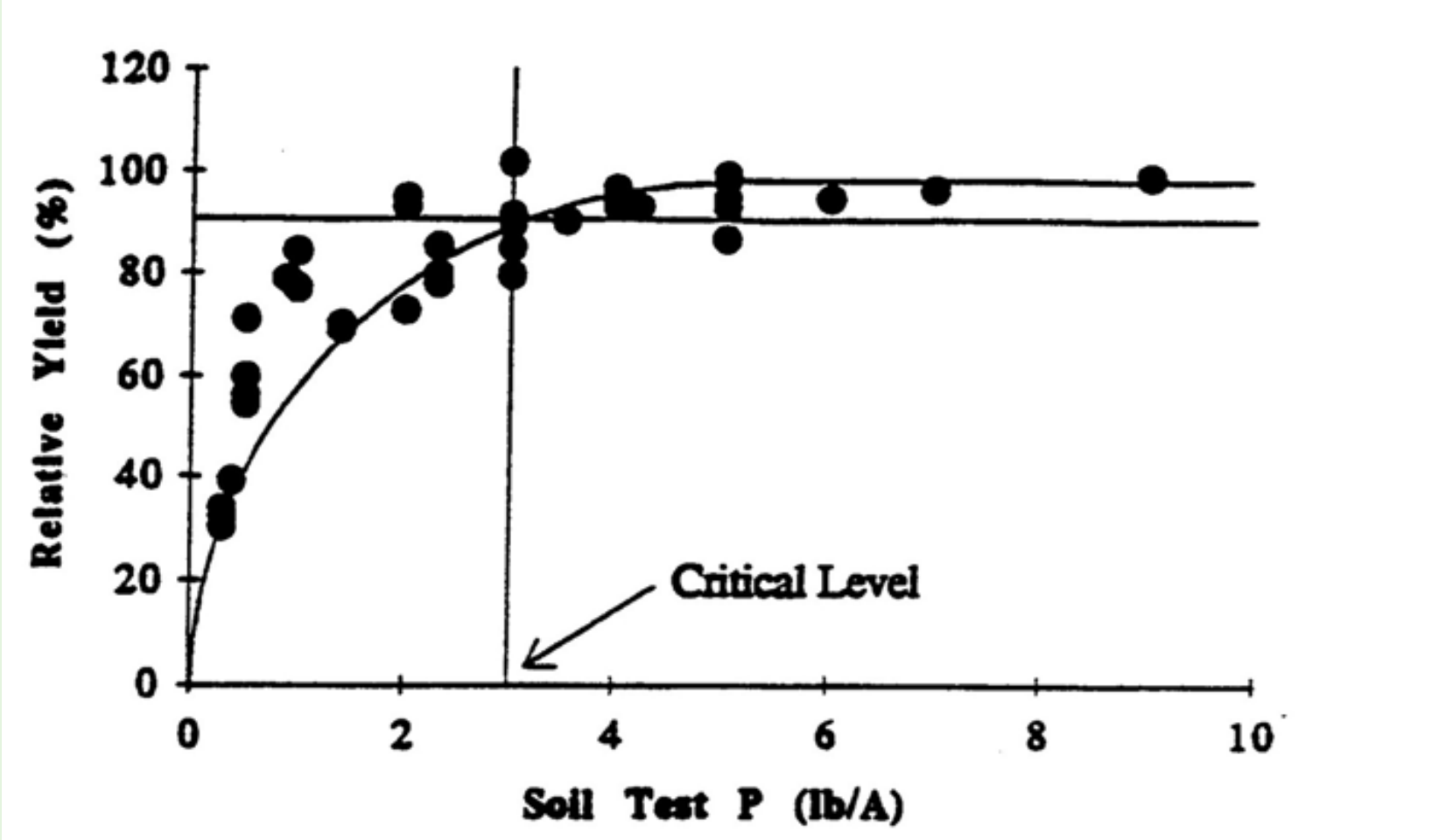
- Soil Testing can be an important tool in determining fertility needs and making sound amendment choices.
- **It is only one of the "tools" used to make fertility decisions…**
- Strong Acid, Weak Acid and Saturated Paste Analysis
- Field Sampling Depth – 6'' if tilled, 4'' if pasture/hay.
- Soil pH: As pH goes down, soil becomes more acidic. More H^+ ions in the soil; replacing Ca, Mg, K, etc. which are "cation" nutrients the plant needs. It's important to look at calcium and magnesium levels before using lime to amend the soil; otherwise may end up with Mg excess.

Selecting a Soil Lab

- Logan Labs (Ohio) – http://www.loganlabs.com/ (Albrecht)
  - Mehlich-3 Extraction – Strong Acid & ICP Spectrometry
    - Mehlich 3 extractant (Mehlich, 1984) is a combination of acids (acetic [HOAc] and nitric [HNO3]), salts (ammonium fluoride [NH4F] and ammonium nitrate [NH4NO3]), and the chelating agent ethylenediaminetetraacetic acid (EDTA). (from NRCS article – reference on next page)
    - ICP = Inductively Coupled Plasma Spectrometry
  - Saturated Paste Analysis

- University of Massachusetts Soil & Plant Tissue Testing Laboratory -http://www.umass.edu/soiltest/
  - Modified Morgan Extraction (ammonium acetate) – weak acid
  - Note – Regarding trace minerals… UMass rarely offers trace mineral rec's

From: Beegle, Chapter 14 - Interpreting Soil Test Results, *Recommended Soil Testing Procedures for the Northeastern United States*
Figure 14-2. Relative yield vs. soil test phosphorus showing response curve and Cate-Nelson graphical separation of the data into responsive and non-responsive populations. (Adapted from data of Greweling and Peech, 1960). (http://extension.udel.edu/lawngarden/files/2012/10/CHAP14.pdf, accessed 1/25/13)



Considering Different Soil Testing Procedures

- Aqua Regia Digest – Recommended by Hugh Lovel ("complete" analysis)
  - "Aqua regia digestion, which uses concentrated nitric (HNO3) and hydrochloric (HCl) acids"
- Recommended Soil Testing Procedures for the Northeastern United States
  - 3rd edition, Revised July 1, 2011
  - http://extension.udel.edu/lawngarden/lawn-garden/soil-health-composting/recommended-soil-testing-procedures-for-the-northeastern-united-states/
- Phosphorous Soil Testing Methods
  - Http://nmsp.cals.cornell.edu/publications/factsheets/factsheet15.pdf
- Selection of an Appropriate Phosphorous Test for Soils (NRCS)
  - ftp://ftp-fc.sc.egov.usda.gov/NSSC/Analytical_Soils/phosphor.pdf

Additional Soil Labs…

- A&L Eastern Labs - http://al-labs-eastern.com/agricultural.html
- Cornell Soil Health Testing - http://soilhealth.cals.cornell.edu/
- EarthFort (Soil Food Web Analysis) - http://www.earthfort.com/
- International Ag Labs - http://www.aglabs.com/
  - Morgan Extract – Weak Acid (see Carey Reams)
- Kinsey's Agricultural Services - http://www.kinseyag.com/ (Albrecht)
- Spectrum Analytic - http://www.spectrumanalytic.com/
- Woods End Laboratory (Solvita CO_2 Test) - http://woodsend.org/

Tests From One Lab Do Not Directly Translate to Another Lab

Soil, Plant, & Tissue Testing Resources

- Agro-One (NY State) - http://www.dairyone.com/AgroOne/
  - Modified Morgan & Mehlich-3 analysis available…
- University of Conn - http://soiltest.uconn.edu/
- LaMotte Company - http://www.lamotte.com/
  - LaMotte Testing Kit Supplies
- Linus Pauling Institute – Micronutrient Research for Optimum Health
  - Tissue Analysis (currently used by BFA) - http://lpi.oregonstate.edu/
- Pike Agri-Lab Supplies, Inc – http://www.pikeagri.com/

Real Time Soil/Crop Analysis

Reminder – Soil Testing is done in a laboratory
Relatively "small" sample of soil…

Farmers Footsteps as Fertility
Question – Observations – Answers – Questions
Knowledge Loop

- Reading the Soil, Reading the Plants, & Reading the Field
- Soil Conductivity – EC or ERGS
- Brix Levels of Sap, Fruit, etc.
- pH and Conductivity of Sap, Nitrate & Potassium Meters
- Tissue Analysis

3 “Programs” for Soil Testing

- Typical Backyard Vegetable Garden ($50-$80 - including postage)
  - Umass Soil Test (including determination of heavy metals) $15
  - Logan Labs – AEA Base + (includes cobalt, molybdenum, Se, & silicon) $25
  - (Optional) – Logan Labs Paste Test (during growing season) - $25
- Commercial Vegetable Production – 3-4 fields in production ($350)
  - Logan AEA Base + Test - $25x4 = $100
  - Logan Paste Test - $25x4 = $100
  - Additional High Tunnel Testing - $50-$100
- High Value Vegetable Production - ($850)
  - 2x Mehlich-3 Soil Tests per year – 6 field sections ($300)
  - 2x Paste Tests per year – 6 field sections ($300)
  - Tissue Analysis for 6 crops ($150)

Financials of Fertility Budgets ($)

Example: 4 acres in production, at $25K per acre

Gross Income = $100,000

- Typical - 5-15% of gross spent on fertility (not including labor)
  - Some as low as 3%...
- If $5,000 total fertility budget - $350 for soil testing is 7% of fertility budget, .35% of gross income (less than 1%)
- If $10,000 total fertility budget - $850 for soil testing is 10.63% of fertility budget, .85% of gross income (less than 1%)

Generally speaking, larger farms will have lower % of gross spent on fertility and soil testing… until scaled up to cash crops – where labor costs are lower and fertility costs become a greater portion of gross.

Fertility Expenses (organic mixed vegetables)

$500 - $2,000 per acre

- Soil Testing - $ Potting Soil - $ Equipment - $

- Soil Amendments (Fall Application) - $200-$600 per acre
  - Lime, Gypsum, Rock Phosphate, Mineral Balancers, Traces, Manure, Compost, etc.
- Crop Fertilizers - $150-$300-$450
  - Pre-Plant or Top-dress – "Starter"
- Sidedress, Foliar, Fertigation/Drench Inputs - $60-$120 +
- Cover Crop Seed - $100-$150-$200 per acre

What are the potential savings? Reduced costs for pesticides & fungicides…

Improved Yields = Increased Gross Farm Income

Vegetable Crop Income – Can We Afford Fertility?

- Imagine… 1 acre of Carrots (43,650 sq. ft)
- ~40 – 1000 sq ft beds (200' x 5') w/ 3 rows per bed
- "low yields" of 1# per row foot - marketable roots
- =600 row feet per bed = 600# of carrots per bed
- =24,000 # carrots per acre
- Wholesale at .50 per lb. = **$12,000**
- 1.5# per row foot – marketable roots = 900# per bed
- 36,000# carrots per acre, @.50 = **$18,000**
- Wholesale @.60 = **$21,600**

Soil Health & Human Health

Can we afford to not focus on fertility?

ERoEI – Energy Returned on Energy Invested

Energy Invested on Small Farms Includes: Human Labor

Energy Costs

Transportation Costs

Water & Resource Limitations

“Health Care” Costs – Future Expenses

Soil Testing Reference Terms

Acre Furrowslice = ~Top 6'' of soil

Average weight of an acre furrowslice is 2 million lbs.

2,000,000 pounds

- Pounds per Acre = lbs/acre or ppa or #/acre
- Parts Per Million = ppm

- lbs/acre to ppm - divide lbs/acre by 2 to get ppm
  - e.g. 2,400 lbs/acre calcium = 1.200 ppm

- ppm to lb/acre – multiply ppm times 2
  - e.g. 120 PPM magnesium = 240 lbs/acre

Cation and Total Cation Exchange Capacity

CEC and TCEC

- Cation (definition) – nutrients with a positive charge
- Soil: Air, Water, Mineral (Sand, Silt, Clay) & OM
- Soil Colloids – Adsorption onto negative charges

- Clay
- Humus & Organic Matter (OM)

- “Light” or Low CEC Soils <10 TEC
- “Heavy” or High CEC Soils >10 TEC

milliequivalents (mEq) – 1 mg / 100 g

Acre furrow slice = volume of 1 acre, 6'' deep

- 1.0 mEq of Calcium = 400 pounds of Ca in an acre furrow slice
- 1.0 mEq of Magnesium = 240 pounds of Mg in an acre furrow slice
- 1.0 mEq of Potassium = 780 pounds of K in an acre furrow slice
- 1.0 mEq of Sodium =460 pounds of Na in an acre furrow slice

- 1.0 mEq of Hydrogen = 20 pounds of H in an acre furrow slice

- Math: Soil with TEC of 10 mEq – 4000 lbs. of Ca would fully saturate the exchange sites in that soil. If we target 68% of our sites with Ca then 4000*.68 = 2,270 lbs. would be target Ca level

Minerals for the soil, plant, animal, and human

- CALCIUM (Ca^{++})
- Magnesium (Mg^{++})
- Potassium (K^{+})
- Nitrogen (N) – NH_4^{+} and NO_3^{-}
- Phosphorous (P)
- Sulfur (S)
- Carbon (C) and Hydrogen (H)
- Sodium (Na)
- Trace Minerals: Boron (B), Copper (Cu), Iron (Fe), Manganese (Mn), Zinc (Zn)…Cobalt(Co), Iodine (I) Molybdenum(Mo), Nickel (Ni), Selenium (Se), Silica (S)…

Nutrient Uptake by Plants

- Direct Root Intercept
- Mass Flow
- Diffusion
- & Complex Compounds (*Paradigm Shift*)
- Nutrient Translocation - Xylem vs. Phloem

Nitrogen – Nitrate NO_3^- or Ammonium NH_4^+

- Nitrogen
- Animal Health
- Human Health

Target Level

not typically tested with mineral soil test

Reams (IAL): 40# Nitrate
40# Ammonium

- Too much Nitrogen > insect infestations – free amino acids

Nitrogen Availability

- Availability - through mass flow
- Soil N levels are constantly changing
- Too much available N will reduce n fixation by microbes
- PSNT – Pre-Sidedress Nitrate Test – often used in conventional systems…
- Nitrogen Assimilation – Enzymes
  - Nitrate Reductase Enzyme (Mo)
  - Urease Enzyme (protein, Ni) – Urea > Carbon Dioxide and Ammonia

Nitrogen – in Soils & Plants

- Functions
- Essential constituent in Amino Acids > Proteins
- Growth Mineral

Addressing Nitrogen Deficiencies

- Application Rates and Notes:

- Biological N Fixation – Rhizobia, Azotobacter, etc.
- Cover Crops

- Protein & Seed Meals
  - Alfalfa Meal, Linseed Meal, Soybean Meal
  - Blood Meal, Feather Meal, Fish Meal,
  - Chilean Nitrate – Natural Nitrate of Soda

- Note: Re – manure & composts

Costs & Benefits of Nitrogen

- Alfalfa Meal (2.6-0-2.3) $30 per 50#, $23 per # of N
- Blood Meal (12-0-0) $80 per 50#, $13 per # of N
- Soybean Meal (7-0.5-2.3) $35 per 50#, $10 per # of N
- Blended Fertilizer – 5-4-3
  - $10 = $4 per # of N
  - $20= $8 per # of N
- Fish Fertilizer – Liquid @ $6 per gal, $18.75 per # of N

- Soil Application of 200# 5-4-3 starter = $40-80 per acre
- Soil Application of 800# 5-4-3 starter = $160-320 per acre

Practically Speaking - Nitrogen

- Cool spring soils – N from biological activity may not be adequate for rapid growth… spring supplementation
- Consider adding N when digesting high lignin crop residue…
- Azotobacter – N fixation (including phylloplane)
- Natural Nitrogen flushes may create excesses (rain after drought)

Phosphorous – Anion **P** Major Nutrient

- Phosphorous
- Animal Health
- Human Health

Target Level
(Mehlich-3)
Phosphorous
75 PPM - 150PPM

- Phosphate (as reported on fertilizer labels) is P_2O_5 = Therefore, if soil reports report Phosphate levels you need to convert to Phosphorous
- Phosphate x .43 = Phosphorous, Phosphorous x 2.3 = Phosphate
- Fertilizers are usually reported as Phosphate levels
  - 5-4-3 = Phosphate level is 4% therefore actual P is ~1.7%

Phosphorous Availability

- Availability – very little of the P in soils is actually "available" at any given moment.
- Biology will greatly impact availability
  - Mycorhizzal
  - Biological Metabolites
  - P solubilizing bacteria
- Nutrient tie-up's … Fe (in the plant), Zn, etc.
- Mobility – doesn't leach – but will "run off…

Phosphorous – in Soils & Plants

- Functions
- Energy Production in Plants - Respiration
- Photosynthesis
- Cellular enzymes
- Seed & Fruit Production

Addressing Phosphorous Deficiencies

- Bone Char/Bone Meal 0-16-0 (~32% total phosphate, ~33% Ca)
- Compost
- Guano
- Manure
- MAP (not allowed under NOP rules, 11-52-0 (23% P))
- Rock Phosphates (~27% phosphate, ~1.5% avail. ~12%P)
- **Soft Rock Phosphate** (20% phosphate, 3% avail. Phosphate, ~9%P) $12.50 per 50# = <$3 per lb. actual P

Costs & Benefits of Phosphorous

- 1000# soft rock phosphate application = $250 per acre
  - ~30# available phosphate, ~200# total phosphate
  - **~13# actual available P, 90# total Phosphorous**
- 200# bone char (0-16-0) ~$20 per bag = $80 per acre
  - ~32# available phosphate, 64# total phosphate
  - ~14# actual available P, 28# total Phosphorous
  - Sodium content ~6%
- 600# bone char (0-16-0) = $240 per acre
  - ~96# available phosphate, 192# total phosphate
  - ~42# actual available P, 84# total Phosphorous

Practically Speaking - Phosphorous

- Phosphorous in the spring– consider supplementing in cool soils (while root systems are colonizing soils)
- Soluble P in the root zone will reduce mycorrhizzal activity… preference to not add too much soluble P!
- Increasing P availability by blending p inputs with compost/biology
- Carey Reams: Phosphorous of supreme importance…

Sulfur – Anion **S** "Minor" Nutrient

- Sulfur
- Animal Health
- Human health

Target Level
(Mehlich-3)
50-75 PPM

Solomon – ½ Mg level in acidic soils

- Reduction in atmospheric deposition with clean air act…
- Availability – depends on soil levels

Sulfur Availability

- Availability
- Mobility – will leach readily through soils, Sulfates take with them cations…
- Low OM soils – less Sulfur…
- Sulfate forms are readily available
- Elemental Sulfur – Requires microbes to mobilize

Sulfur – in Soils & Plants

- Functions
- Structural Part of Protein
- Catalyst in Chlorophyll Production
- Flavor Builder

Addressing Sulfur Deficiencies

- ***Calcium Sulfate (17% Sulfur) - $12 per bag**
  - $1.40 per # of actual S (plus additional Ca)
- Potassium Sulfate (17% Sulfur) - ~$35 per bag
  - ~$4 per # of actual S (plus additional K)
- ***Sul-Po-Mag (22% Sulfur) = $20-40 per bag**
  - $1.80 - $3.60 per # of actual S (plus additional K and Mg)
- ***Elemental Sulfur – 90%S – (look for OG) $25 per 50#**
  - $.56 per # of actual S

Costs & Benefits of Sulfur

- Sulfur Test Shows 46 PPM and we target 75 PPM
- Sulfur Test Shows 21 PPM and we target 50 PPM

- Deficit in each situation is 29 PPM or 58 lbs per acre
  - Credit from other sulfate applications…
    - 200# K-Mag will provide 44# S in sulfate form. $80-100
    - Likely other minor amounts from trace cation application
    - & blended fertilizers…?
  - Remaining deficit is 14 lbs.
    - Consider 50# application of Elemental Sulfur (45#S) which will release over time… $25-30…
  - If budget were limiting factor, 10-20# elemental sulfur annually $5-10

Practically Speaking - Sulfur

- Sulfur deficiencies in the Northeast
- Maintenance applications of sulfur, especially on low OM soils.
- Don’t rely solely on elemental Sulfur for S release
- Increase OM and circulation to improve S retention…

Calcium – Cation Ca^{++} Major Nutrient

- Calcium
- Animal Health
- Human Health

Target Level
(Mehlich-3)
SLAN:
1200 -2000+ lbs/acre
Solomon – 1,900 lb/acre

Base Saturation :
65-70%

- Mobility – will leach - rainfall (especially with nitrate or chlorides)

Calcium Availability

- Availability

- **Critical Information**
- Calcium is available to be picked up at the root tip.
- Mostly accessed through mass flow – “flow” i.e. water in soils drawn through plants.
- Low soil moisture and/or high humidity (low transpiration) will reduce Ca uptake.
- Boron synergy…

Calcium – in Soils & Plants

- Functions
- Role in nutrient uptake from roots
- Role in cell wall and membranes formation
- Calcium/Magnesium ratios in soil impact aeration

Addressing Calcium Deficiencies

- Application Rates and Notes:

- Gypsum – calcium sulfate (23% Ca, 17% S)
  - 200# per acre "fertilizer application" - $50 per acre
  - 500# per acre addressing Mg excess…

- Hi-Cal Limestone – (~35-40% Ca)
  - 1,000# - 4,000# per acre depending on soil test - $100+ per acre
  - dolomitic lime (~20% Ca, 12% Mg - usually not recommended)

- Rock Phosphates – i.e. soft rock phosphate (~20% Ca)
  - 200# - 2,000# per acre depending on soil test… $50 - $500 per acre

- Micronized Calcium Sources - ~$10 per acre

Costs & Benefits of Calcium

- Amending Soils
- Higher TEC will require greater amounts of Ca to "balance soils" but will also store larger reserves…
- Low TEC soils may have to apply Ca regularly
- Fertilizer applications $10-100 per acre annually.

Practically Speaking - Calcium

- Which type of lime to apply…
- Gypsum – increase available Ca independent of pH
- Calcium – Saturation in Solution (vs. K, Mg, Na)
- Calciums – Reams
  - "Biology Trumps Solubility" in Dec. 2012 Acres USA by Lawrence Mayhew
- Patterns… Setting growth patterns with Calcium

Magnesium – Cation Mg^{++} Major Nutrient

- Magnesium
- Animal Health
- Human Health

Target Level
(Mehlich-3)
SLAN:
200+ lbs/acre

Base Saturation:
10-15%

- Magnesium is mobile in plants, xylem & phloem
- Higher Mg reduces N “efficiency” (Kinsey)

Magnesium Availability

- Availability – through mass flow
- Mobility – Magnesium will leach – i.e. with sulfur
- Excessive Ca or K may limit Mg availability in solution.

Magnesium – in Soils & Plants

- Functions

- "Central" to chlorophyll molecule
- Key to phosphorous utilization
- Protein synthesis
- Plant oil & fat production – immune system

- Impact soil structure

Addressing Magnesium Deficiencies

- Application Rates and Notes:
- Dolomitic Lime –(~21% Ca, 12% Mg)
  - Beware of over-application
  - & “hardness” – impacting 1st year availability
- Sul-po-mag (0-0-22, 11% Mg, ~20% S)
- Magnesium Sulfate (13% Mg, 16% S)

Costs & Benefits of Magnesium

- Dolomitic Lime
  - for amending soil Mg levels (initially on acid soils)
  - Best to split with Hi-Cal (to not overdo Mg levels)
- Sul-Po-Mag for annual fertilizer applications/maintenance levels…
  - 100# per acre ($20-40 per bag) = $40-80 per acre
  - 200# per acre ($20-40 per bag) =$80-160 per acre
- Magnesium Sulfate – Epsom Salts
  - 100# per acre ($30 per bag) = $60 per acre
  - Foliar applications – 10-15# per acre (100 gal water) = $6-10

Practically Speaking - Magnesium

- Mg will impact Nitrogen “efficiency”
- Excessive nitrates may be reduced with Mg application
- Lighter, sandy soils – target higher Mg –(15-18% TEC)
- Spinach example of high Mg demand crop
- Capturing Energy through Photosynthesis
  - Increasing the Net

Potassium – Cation K^+ Major Nutrient

- Potassium – Kalium
  - Potashen (old dutch word)

Animal Health

Human Health

Target Level
(Mehlich-3)
SLAN:
200 lb/acre
Base Saturation: 2-5%

Solomon:
Lower K% at higher CEC
255 lb/acre min.

Potassium is listed as K_20 Equivalent (often referred to as Potash) on fertilizer bags. K_20 Potash is 83% elemental K.

Potassium Availability

- Building K – K tough to “build up” when pH is above 6.5 (unless using manures/compost) b/c fewer exchange sites open for adsorption [Kinsey].

- K enters the roots primarily through diffusion.

Potassium – in Soils & Plants

- Functions
- Carbohydrate production, transport, & storage
- Regulating water – guard cells – stomata “poor man’s irrigation”
- K “builds” bulk & size

Addressing Potassium Deficiencies

- Application Rates and Notes:
- Sulfate of Potash or Potassium Sulfate, Sul-Po-Mag
- Compost, Rock Dusts, & Zeolites

- Greensand ~7% Potash, ~6% elemental K
  - Slow long-term K release, less than half available.
  - Use of greensand for soil building properties (clay)
  - 500# per acre (50# bag = ~$20) = $200 per acre
  - 500# applications would add 30# K per acre (not all available)
  - ~$6.67 per lb. of elemental K (& Ca, Mg, Fe and other traces).

Costs & Benefits of Potassium

- Sul-Po-Mag ~22% potash, ~18% elemental K
  - 200# per acre (50# bag = $20-30) = $80-$120 per acre
  - 400# per acre = $160-$240 per acre
  - $2.22 per lb. actual K (at $20 per bag) & (also Mg & S)
- Potassium Sulfate 50% potash, 42% K
  - Typically broadcast 50-200#/acre in blend…
  - 50# per acre = $33 $1.57 per lb. actual K (& also S)

Practically Speaking - Potassium

- Be aware of K sinks (fruits, tubers, & roots) these crops often have a high demand for Potassium.
  - Beets
  - Potatoes
  - Tomatoes
- Woody plants have a high demand of K.
- Dry Period, Clay Soils, & Potassium
- If you are adding significant amounts of Sulfate of Potash to amend the soil, we often include a bit of gypsum & sul-po-mag or epsom salts to ensure soil solution doesn't become overly saturated with K.

Sodium – Cation Na^+ Minor Nutrient

- Function
  - Regulate cellular fluid/osmotic pressure
- Availability

Target Level
(Mehlich-3)
SLAN:
20-40 lbs/acre
Base Saturation: .5-2%

- Mobility – very mobile… usually leaches unless poor drainage or limited rainfall
- Application Rates and Notes:
  - Check Irrigation Water Quality
  - Sea-Minerals – Sea Salts or Sea Water
- Economics

Chlorine - Anion Cl^- Trace Mineral

- Chlorine

Target Level
(Mehlich-3)

Minerals – Quantities

Classification "doesn't" denote level of importance

- Major Nutrients
- Minor Nutrients
- Trace Minerals

Enhancing Mineral Availability

- Biology
- Priming the Pump
- Biodynamic Preparations
- Capturing Mineral Nutrition through the Air

Increasing Circulation on Minerals in Soils & Plants

- Application of minerals –
  - either to address deficiency or “jumpstart” biological system
  - Or stimulation of biology to increase nutrient availability
- Crop uptake, root exudates, & residue sequestration
- Mineralization of residues “release” nutrients
- Nutrients available for uptake by biological community:
  - microbes, bacteria & fungal community, etc….

And ultimately - root systems of following crops…

Assessing Mineral Deficiencies

- Crop Symptoms
- Tissue Analysis
- Indicator Species
- Paste Analysis
- Strong-Acid Test
- Aqua Regia Digest

Boron – Anion **B** Trace Mineral

- Mined in CA., Turkey, S. America
- Animal Health
- Human Health – bone health…Ca
- Sap Pressure
- Nutrient Transport
- Mobility within plants varies by crop, many crops Boron mobility is limited in the phloem

Target Level
(Mehlich-3)
1-3 PPM
Solomon:
1/1000th Ca level (Astera)

Boron Availability

- Highly Leachable as Borate (H_4BO_4) – affinity for N
- Lower pH = Higher Availability
- Dependent on Organic Matter (ability to hold anions)
- Low Moisture Limits B Availability (mass flow)
- High Calcium Levels Need Higher Boron Levels
- Impacted by Calcium and Silica levels

Boron – in Soils & Plants

- Cell Wall Structure
  - Bonding of Polysaccharides (molecular staple)
- Cell Division (all new growth)
  - Root Tips, New Leaves, & Bud Development, etc.
- Sugar Transport & Nutrient Translocation
  - Increased rate of transport from mature leaves > new growth
- Transporter of Potassium to Guard Cells (Stomata)
  - Water balance, transpiration > mass flow (nutrient uptake)

Addressing Boron Deficiencies

- Need to Show “Nutrient Deficiency” for Applications
- Split Applications is Recommended
- Careful, Careful, Careful
- Dry – Borax (~10%B) or Solubor DF (18% B)
  - Solubor costs $1.40 per lb. (2013 price) ~$7.00 per lb. actual B
- Foliar - Solubor (21% B) - Important to “stabilize” w/carbon

Costs & Benefits of Boron

- Soil Test - .3 PPM – Target is 1 PPM (low CEC, low CA)
- Soil Test - .8 PPM – Target is 1.5 PPM
- Soil Test – 1.3 PPM – Target is 2 PPM (high CA & potato)

- Deficit is .7PPM or 1.4#
- Apply Solubor (21%B) – 7# Solubor per acre
- One option – Backpack Application – 3 x 4 gal. per acre
- Applied in late spring before planting (or late fall/winter)
  - Solubor, liquid humate or fulvic acid (or compost tea), equiseteum
    (at brix bounty – also bit of molasses, fish (if fall or spring), & calcium)
- $9.80 for Boron per acre + labor and other materials…

Practically Speaking - Boron

- Calcium, Silica, & Boron
- Fall Application (Lovel) to allow for fungal incorporation
- “Chelate” with humic substance to prevent leaching at time of application
- Larger Plant – generally a greater need for sap pressure...
  - i.e. a tomato at full-size vs. lettuce

Copper – Cation **Cu** Trace Mineral

- Copper
- Copper Sulfate – Bluestone
  - Cu $S0_4$ 5 H_20 (penta-hydrate)
- Animal Health
- Human Health

Target Level
(Mehlich-3)
2-6 PPM
Solomon:
½ target Zn level

Copper Availability

- Availability
  - Copper will “lock-up” with OM reducing availability in solution.
  - Deficiency more common in high OM (peat & muck soils).
  - Copper becomes less available as the pH rises.
- Mobility
  - Copper is not very mobile in soils
  - Copper isn’t very mobile in plants, “need constant supply”

Copper – in Soils & Plants

- Function
  - Chlorophyll Production
  - Nitrogen Utilization and Protein Syntheis
  - Lignin Formation – cell wall strength
  - carbohydrate mobility into grain (starch formation)
  - Seed production & formation (U of MN, Copper for Crop Prod.)
  - "…Stronger cell walls, higher polymers and proteins are formed and consequently, they are more resistant to fungal attack (*Australian Soil Fertility Manual*, 3rd ed.)."
  - "…Bark and cuticle can grow and stretch… improved sap flow" (Beddoe, p.62)

Addressing Copper Deficiencies

- Broadcast Copper Sulfate (25% Cu), **Max 10 lbs. Copper Sulfate per acre/per year (Bionutrient Food Association)**
  - **28# CuS absolute maximum recommended – "harsh" on soil life.**
- Foliar .1 - .25 # Copper (.4 - 1# Copper Sulfate) per acre
  - Solomon 1 tsp/gal maximum… Reams ½ tsp per gallon foliar spray.
- Reams – Increasing copper availability with Sul-Po-Mag application late summer (mid-July 'til mid-September)

Costs & Benefits of Copper

- Once soil copper levels are raised, they often stay adequate for long periods.
- Copper Sulfate (25% Cu, 12.5% S)
  - 50# bag = ~$100 or $2 per lb. of Copper Sulfate
  - = ~$8.00 per lb. actual Copper
- Soil Application: 10# CuS per acre = $20.00
  - Soil applications positively impacts future seasons
- Foliar Application: 1# CuS per acre = $2.00

Practically Speaking - Copper

- Buffering/Chelating Copper Applications
  - Including raising pH (calcium) of foliar sprays, avoid dry/hot days
- For small grains – foliar early in stages of growth
  - At tillering or <6th leaf for wheat
  - Pollen fertility > number of grains in each head
- Copper affects flavor…

Iron - Cation **Fe** Trace Mineral

- Iron
- Animal Health
- Human Health

Target Level
(Mehlich-3)
150 PPM

Solomon:
50-75PPM

- Target soil Iron levels above Mn…
- Iron doesn't translocate well in leaves…

Iron Availability

- Availability
- Lots of Iron in most soils… but available Fe may be low…
- Decreases as soil pH goes up…
  - "Overly"-Aerated soils reduce availability

- Impacted by pH, lower availability as pH rises

- Calcium
- Phopshorous - In the plants
- Manganese in the soils

- Bacteria

Iron – in Soils & Plants

- Functions
- Assist in the function of enzymes in chlorophyll production.
- Leaf Thickness
- Increase Capture of Solar Energy

Addressing Iron Deficiencies

- Application Rates and Notes
- Greensand (9% Fe)
  - 500# per acre application would apply 45# of Iron – slow release
- Iron Sulfate – (30% Fe, 18% S)
  - 100# per acre soil application, mixed with Sulfur to increase avail.
  - At high pH will “tie-up” and availability will remain low…
- Foliar applications – Iron Sulfate
  - ~1-2# actual Fe per acre – 3# Iron Sulfate per acre
  - 5# Iron Sulfate per 100 gallons (tree application)
- Molasses

Costs & Benefits of Iron

- Iron Sulfate
  - 100# per acre broadcast = $50 per acre
- Foliar spray of Iron Sulfate
  - 3# per acre = $1.50 per acre
- Common to apply Iron consistently in the turf industry.

Practically Speaking - Iron

- Foliar application will help to determine if Fe deficiency is problem.
- Symptoms often appear on new growth…
- Iron & Bacteria…

Manganese – Cation **Mn** Trace Mineral

- Manganese

- Animal Health
- Human Health

- Mn travels freely in xylem,
- Phloem transport is “limited”

- Manganese is considered immobile within plants. Leaf Mn isn’t considered mobile (however stem & root Mn can be mobilized).

Target Level
(Mehlich-3)
80-90 PPM
Solomon:
27.5 ppm – 50 ppm

Manganese Availability

- Iron & Manganese
- pH: Mn availability decreases as the pH rises
- Aerated soils reduce Mn availability
- Use of acid forming fertilizers increases availability
- Manganese & Glyphosate (Huber Research)

- Saturated Soils possible to leach Manganese
  - University of Wisc. – Soil & Applied Manganese (http://www.soils.wisc.edu/extension/pubs/A2526.pdf)

Manganese – in Soils & Plants

- Functions
  - Catalyst in photosynthetic process
  - Chlorophyll synthesis
  - Activates Fat Forming Enzymes
  - Important Reproductive Energy
- Important in Seed & Nut Production
- Reams – Reproductive Energy

Addressing Manganese Deficiencies

- Application Rates and Notes:
- Use of Acid Forming Fertilizers
- Broadcast up to 20# Manganese Sulfate per acre
  - We have seen recommendations as high as 200# MnS per acre! EXPENSIVE.
- Foliar 3# Manganese Sulfate per acre or…
  - Foliar 1# Mn Sulfate – more dilute, easier to put into solution… may still yield results…
- Application Rates and Notes
  - Manganese Sulfate - **Max 20 lbs. Manganese Sulfate per acre/per year**
  - Foliar Applications – often recommended for financial reason and availability

Costs & Benefits of Manganese

- Manganese Sulfate (32% Mn, 19% S)
  - 50# bag = $65.00 or $1.15 per lb Manganese Sulfate
  - = ~$3.50 per lb actual Manganese
- Soil Application: 20# MnS per acre = $22
- Foliar Application: 1-2# actual Mn per acre (usually 1# per application, 20-30 gallons water min.)… if foliar application of MnS at 3# MnS per acre = ~$3.50

Practically Speaking - Manganese

- Acid forming starter fertilizer – conventional approach on many soils…
- Foliar applications are often most economical…
- Reams - Reproductive Energy

Zinc **Ca^{++}** Major Nutrient

- Zinc impacts Leaf Size
- Animal Health
- Human Health

Target Level
(Mehlich-3)

4-8 PPM

Solomon:
1/10th Soil P level (Astera)

- Important to have Zinc available in early stages of growth.

Zinc Availability

- Availability:
- Zinc becomes less available as pH rises
- High P reduces Zn in plants
- Less available in cool, wet spring soils

Zinc – in Soils & Plants

- Functions (http://www.spectrumanalytic.com/support/library/ff/Zn_Basics.htm)
  - Production of Auxin (growth hormone)
  - Protein Synthesis
  - Starch Formation
  - Root Development
  - Chlorophyll Formation

Addressing Zinc Deficiencies

- Application Rates and Notes:
- Often applied in starter fertilizers
- Soil Application: 10# Zinc Sulfate per acre per year max
  - Others: Maximum 40# Zinc Sulfate per acre (WA State)
- Foliar Application: .3 # to 1.5# actual Zn per acre
  - 1# to 4.5# Zinc Sulfate

Costs & Benefits of Zinc

- Zinc Sulfate (35% Zn, 17% S)
  - 50# bag = $45.00 or $.90 per lb Zinc Sulfate
  - = ~$3 per lb actual Zinc
- Soil Application: 10#/acre = $9.00
- If target 8PPM zinc and current test is 2PPM
  - = 6PPM deficit = 12 lbs. acre deficit of Zinc
  - 10#/acre will apply ~3.5 lbs. or 1.75PPM actual Zinc
  - Factoring crop uptake, biology, etc - usually 3-4 years to correct deficiency
- Foliar Application: 1.5#/acre = $1.35

Practically Speaking - Zinc

- Zinc – early application (if not in starter)
- Consider soil P levels when applying Zinc
- pH impacts availability
- Target soil application + foliar for high value crops…

Cobalt – Cation Co Trace Mineral

- Cobalt:
- Target – 2 PPM

- Broad spectrum traces – kelp, etc…
- Cobalt Sulfate (27% Cobalt)
- Cobalt Sulfate $10-$15 per lb.
  - ~$40-60 per lb. of actual Cobalt

- Application Rates:

Molybdenum – Anion Mo Trace Mineral

- Molybdenum
- Target – 1 PPM

- Broad spectrum traces – kelp, etc…
- Sodium Molybdate (39% Mo)
- Sodium Molybdate $50 per lb.
  - ~$125 per lb. of actual Molybdenum

- Application Rates:
  - 2 oz/acre foliar = $4-8
  - 6-10 oz/acre broadcast - $18-30

Selenium – Anion Se Trace Mineral

- Selenium
- Target – .5 PPM

- Sodium Selenite –
- Sodium Selenate (41% Se)
  - NDSC (offered in the past) – 6% Se

- Sodium Selenate $75 + per lb.
  - ~$180 per lb. of actual Selenium

- Application Rates: 5-10 g. Sodium Selenate/Acre = $2 - $12

Silicon

- Silicon
- Target –50-100 PPM

- Diatamaceous Earth
- Equiseteum
- Soft Rock Phosphate
- Potassium Silicate

Nickel – Cation Ni Trace Mineral

- Nickel – N metabolism and biological fixation
- Higher pH reduces availability
- Cu & Zn may “compete” with Ni for uptake

- Readily translocated within plants
  - Symptoms show up on older leaves first…

- Broad Spectrum Traces…
- Nickel Sulfate
- Nickel Nutrition in Plants (Liu, June 2011, Univ. of Florida)
  - http://edis.ifas.ufl.edu/hs1191

Chromium, Iodine, Vanadium, etc.

- Chromium
- Iodine
- Vanadium
- …

Available Nutrients for Plant Health

Paradigm Shift

Simple Ion Uptake > Complex Compounds

- Total Nutrients – Aqua Regia Digest
- Mehlich-3 Available Nutrients (“Bank” or “Pantry”)
- Weak Acid or Saturated Paste (“Cash” or “Dinner Table”)

- Balance
- Mineral & Nutrient Interaction – in Soils & Plants

Saturated Paste Analysis – Logan Labs Target

	BFA Targets	McKibben Targets
pH		6.2-6.5
Phosphorous	.5ppm	.3-.6 ppm
Sulfur	5ppm	1-3 ppm, 5-6ppm
Calcium	30-50ppm, 60%	30-40 ppm 60%
Magnesium	6-10ppm, 18-20%	6-8 ppm 20%
Potassium	15-25ppm, 15%	12-15 ppm, 12-15%
Sodium	5ppm, <5%	<6 ppm
Chlorides	25-50ppm	<60 ppm
Bicarbonate	50-100ppm	<90 ppm

Saturated Paste Analysis – Target's Continued

	BFA Targets	McKibben Target
• Boron -	.1 ppm	.05-.1 ppm
• Iron -	.3 ppm	.5-1.5 ppm
• Manganese -	.15 ppm	.07-.15 ppm
• Copper -	.05 ppm	.05-.08 ppm
• Zinc -	.1 ppm	.07-.15 ppm

- Soluble Salts - 300-750 <1,000 ppm
- *Traces - + or - .02 ppm variability from target is okay.*

Tissue Test - Targets

Biodynamic Preparations – Rudolf Steiner

- bd 500 – horn manure – earthly formative forces (lime)
- bd 501 – horn silica – cosmic formative forces
- bd 502 – Yarrow: Sulfur & Potassium, Traces
- bd 503 – Chamomile: Calcium, K, Sulfur, & Nitrogen
- bd 504 – Stinging Nettle, S, K, Calcium, & Iron
- bd 505 – Oak Bark - Calcium
- bd 506 – Dandelion – Silicon and Potasium
- bd 507 – Valerian - Phosphorous
- bd 508 – Equiseteum - Silicon

Cho Global Natural Farming – “DIY”

Cho Han-kyu, Cho Ju-Young - http://www.janonglove.com/

- Indigenous Microorganisms (IMO)
- Oriental Herbal Nutrient (OHN)
- Fermented Plant Juice (FPJ)
- Fish Amino Acid (FAA)
- Lactic Acid Bacteria (LAB)
- Water-soluble Calcium Phosphate (WCP)
- Water-soluble Phosphoric Acid (WPA)
- Water-Soluble Potassium (WP)

Patterns for Healthy Growth

- Nutrition within the Seed
- Germination Environment
- Balanced Nutrition
- Natural Systems… Seeds

Seed Starting

- Potting Soil – Greenhouse Media
- Irrigation Water Quality
- Light
- Temperature – Air & Soil (and Water)
- Air flow

Flat Sizes

- Consider the impact of root spacing upon plant growth
- Trial different flat sizes > yield and crop performance
- Example: Winter Squash typically grown in 50's
  - Trial 50's vs. 24's
  - 24's produced stockier transplants
- Scaling the propagation greenhouse to meet your needs

Leverage Points

- Setting out plants at “optimum” age – root vs. top growth
- Handling costs – movement of flats, plants, transplanting
  - Opportunity to take advantage of this “handling” cost

PATTERN POINT

- Encourage healthy root establishment & growth

Plant/Transplant Drench

- Garden Scale –
  - Root Soak & Watering In…
- Small Commercial Scale –
  - Root Soak,
  - Watering In (?),
  - Fertigation
- Large Commercial Scale –
  - Water Wheel Transplanter – “Watering In”
  - Carousel Transplanters lack this leverage point…

Plant/Transplant Solution

- Calcium
- Phosphorous
- Biologicals – Compost Tea, Inoculants, etc.
- Sugars (to feed biology) – molasses
- Enzymes, Bio-Stimulants – liquid seaweed,

Plant – TP Drench (Soak) at Brix Bounty 2012

Add the following w/~15-30 gal water into "drench trough"

- Foundation – 6 oz. (Ca, P, Traces) could use soft rock slurry+
- Liquid Kelp – 2 Tbsp. (microbial food & root stimulant)
- Sea Crop – 3 oz. (microbial food, trace minerals)
- Microbial Inoculant – ½ tsp. "Complete"
- Liquid Fish – 6 oz. Organic Gem
- Pepzyme – ½ tsp. (enzymatic stimulant
- Equiseteum Extraction (silica) – 3-6 oz.
- Molasses – 2 Tbsp (bit of sugar and Fe for microbes)
- Compost Tea – ~16-32 oz. (home grown microbes)

If prepared for each 1000 sq ft bed ~$80 per acre, ~$2 per bed

Practically Speaking -

Considerations for Crops

Fruits, Leaves, Perennials, & Roots

Fruit Crops

Leaf Crops

Root Crops

Seed Crops

Perennial Plantings

Considering Crop Families

Alliums

- Sulfur Demands
- Nitrogen – Avoid in “late” stages of growth

Brassicas

- Non-mycorrhizal
- Bacterial
- Sulfur
- Boron

Chenopods

- Boron
- Beets – Potassium

Cucurbits

- P
- Silica
- Potassium (fruiting crops)

Grasses

- Phosphorous

Legumes

- Calcium
- Cobalt
- Molybdenum

Nightshades

- Boron
- Potatoes – Potassium
- Tomatoes - Potassium

Umbelliferae

- Carrots & K
- Celery – N, K, Boron

Carrying a Burden of Responsibility

A New Social Contract for Farmers (and Gardeners)

- Responsible Stewardship of Resources
  - Fossil Fuels
  - Minerals
  - Water

Interconnected Ecosystems

- Addressing Human Health & “Disease” Care Costs

Thank You

Handouts & Presentation
Available at www.brixbounty.com

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