Biological Soil Amendment Practices in Sustainable Agriculture

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Background to this PowerPoint Presentation

Presented at the South Central Soil Summit at Univ of Houston, December 2017. This was the second regional FSMA soil summit for stakeholders (FDA, State Departments of Agriculture, Farmers, NGOs) to address Subpart F of the Food Safety Modernization Act (FSMA). The first FSMA soil summit was in New England.

Subpart F of FSMA addresses Biological Soil Amendments of Animal Origin (BSAAO). The Final Rule of FSMA lays out restrictions for BSAAOs with regards to Animal Manures, Composts (Processes to Further Reduce Pathogens via biothermic kill temperatures), Agricultural Teas (e.g., Compost Teas), and Organic Fertilizers derived from Animal Meals and Fish (e.g., Blood Meal, Bone Meal, Fish Meal, Fish Hydrolysate, Fish Emulsion)

The author speaks from 30 years of experience teaching farm-scale composting, compost quality, compost teas & extracts, soil microbiology, soil foodweb, soil testing, and technical advisement to farmers and Extension Agents.

He served on the NOSB Compost Tea Task Force in 2003-2004. He was formerly a soil and crop consultant in Texas, familiar with organic and sustainable farming systems that use Biological Soil Amendments, and invited to speak at the South Central Soil Summit.
Downsides of Conventional Agriculture

- Hypoxia — Dead Gulf Zone
- Endocrine Disruption
- Monarch Butterfly & Soil Biology
The Future of Agriculture is Regenerative:

Sustainable (e.g., USDA-SARE, USDA-NRCS)
Organic (e.g., USDA-NOP)
Eco-agriculture (e.g., Acres USA, Albrecht-Reams)
Permaculture (e.g., ecological design)
Bio-dynamic (e.g., Steiner, Pfeiffer)
Korean Natural Farming (Asia and Hawaii)
Zero Budget Natural Farming (India)
Integrated Crop-Livestock and Holistic Grazing

Three Common Themes:
1. Agro-ecosystems that mimic nature
2. Organic and Biological soil amendments
3. Healthy consortia of beneficial microorganisms
Geological Clock: Chronology of Life on Earth
Adapted from David C. Johnson, NMSU
- Forest and Prairie ecosystems are complex assemblages of above-ground plant species and below-ground soil foodweb species
- Soil micro-organisms include MicroFlora (Bacteria, Actinomycetes, Fungi, Algae), MicroFaunal Grazers (Protozoas, Nematodes) and MesoFauna (Springtails, Mites)
- Soil macro-organisms include Earthworms, Centipedes, Isopods, Ants, Spiders
- Plant growth and productivity is driven by soil foodweb processes interacting with soil and rock mineral substrates
- F:B ratio (Fungal-to-Bacterial) is greater in forests and prairies vs cropland
Bio-Spheres of Plant-Microbe Interaction

Rhizosphere

Phyllosphere

Nature Reviews Microbiology, 2013

ETH Zurich, 2009
Liquid Carbon Pathway

Root Excretions (photosynthates)
- Sugars
- Amino acids
- Organic acids
- Fatty acids
- Nucleic acids
- Inorganics
- Enzymes
- Vitamins
- Growth Factors
- Sloughed-off cells

Dakora and Phillips (2002); Hirsch, Miller, Dennis (2013)

Photosynthates Feed & Stimulate Rhizospheric Microorganisms

30% to 60% of photosynthetically-generated plant compounds are excreted into the rhizosphere. Symbiotic and mutualistic plant-microbe association and communication systems; microbes perform multiple functions and are integral to plant health, build soil structure, and increase soil carbon levels.
Soil microorganisms live in association with plant roots and excrete nutrients & sticky substances

Rhizobacteria occur in high numbers and perform multiple functions (nutrient availability, nitrogen fixation, biocontrol, soil glues). Endo-mycorrhizae live symbiotically with 90% of vascular land plants. They live inside plant cells (arbuscules), send fungal hyphae several centimeters into surrounding soil, increase the plant surface rooting area, enmeshing soil particles, and exude a soil glue called glomalin.

Alfalfa root with bacterial rhizosphere: Jennifer Fox

VAM mycorrhizal fungi on plant root: Paula Flynn
Well-aggregated soils (“good crumb structure” or “black cottage cheese”) result from the action of plant roots, soil microbes, and soil organic matter (with clay, Ca and Fe). These water-stable aggregates allow rainfall to infiltrate while maintaining crumb structure. In contrast, dispersible soils easily lose their structure with rainfall and subsequently puddle, resulting in water runoff and erosion.
Five Foundational Principles for Agro-Ecosystems (next 5 slides)

1. Principle of Microbial Abundance and Diversity (MAD) -- aka Microbial Density and Diversity (MDD)

2. Principle of SOM Functioning (Soil Organic Matter)

3. Principle of SFW Functioning (Soil Foodweb) or SMC Functioning (Soil Microbial Community)

4. Principle of Biological Control Mechanisms

5. Principle of Microbially Enhanced Nutrient Delivery (MEND)
   Practical application of MAD, thereby reducing purchased fertilizer inputs by 25% to 75%
Microbial Abundance & Diversity (MAD)

The population **Abundance** and complex **Diversity** of soil micro-organisms drives soil **Functions**

- Soil Structure
- Soil Moisture
- Soil Fertility
- Disease Suppression
- Soil Organic Matter
SOM Functioning (Soil Organic Matter)

Biological
- Carbon is a source of energy which provides food and habitat for soil microorganisms
- Slow-release of nutrients (N,P,S, micros) for crop growth
- Suppression of soil-borne diseases

Physical
- Modifies soil color, texture, structure, & moisture-holding capacity
- Improves soil tilth, aggregation, porosity, and infiltration

Chemical
- Buffers soil pH, increases CEC, chelation of nutrients
- Cementing of soil particles, formation of clay-humus
SFW / SMC Functioning *

Rhizosphere (root) and phyllosphere (leaf)
Plant-growth promoting rhizobacteria
Symbiotic & saprophytic fungi

Bacterial and fungal decomposers
Nitrogen fixation
Carbon fixation
Transformation and availability of N, P, S
P-solubilizing bacteria
Biological control of diseases and insects
Fungal-generated organic acids
Plant growth-promoting substances
Soil enzymes
Slimes, glues, & cements

* SFW (Soil Foodweb) or SMC (Soil Microbial Community)
Biocontrol Mechanisms: Antagonism, Competition, Competitive Exclusion, Parasitism, Induced Resistance, Lytic Enzymes

In healthy soils fed with organic amendments, beneficial microorganisms suppress, control, and keep pathogenic microorganisms in check.
Microbially Enhanced Nutrient Delivery

The Microbe Bridge
The higher the number and diversity of micro-organisms living on the leaf, the more efficient the utilisation of foliar nutrients.

The MEND™ Concept
Building beneficials in the soil and on the leaf with MEND™ Compost Tea can increase nutrient uptake, protect against pathogens and stimulate plant growth.

Field Applications:
Microbe-Mineral Liquid Product Blends and On-Farm Microbial Brews Used in Fertigation & Foliar Applications

RESULT: Reduce fertilizer inputs 25% to 75% via MEND
Vegetable Production Systems that Use Organic and Biological Soil Amendments

The research farm I manage – UK-HRF (University of Kentucky, Horticulture Research Farm), located in Lexington, KY – is a 100-acre university research farm which has a 30-acre Organic Farming Unit. UK-HRF thereby offers both CONV and ORG research plots, but in addition we have a working organic farm through UK-CSA with 225 members that produces on ~10 acres. UK-CSA is tied to a 4-year degree program in Sustainable Agriculture which requires a Summer Internship with ~10-20 students each year.

The following slides provide a summary of organic vegetable production systems (e.g., UK-HRF / UK-CSA plus farms in Texas as examples) that regularly employ Organic and Biological Soil Amendments.

It is important to understand that sustainable and organic farmers utilize both BSAAO (Biological Soil Amendments of Animal Origin) and BSA-NAO (Biological Soil Amendments – NOT of Animal Origin).

Observe how many different ways sustainable and organic farmers use BSAs at every point of influence during the crop production cycle:

- Transplant production potting mix
- Transplant production liquid feed
- Pre-plant crop soil fertility
- Sidedress fertility on bare ground
- Fetigation sidedress on plastic mulch
- Foliar Applications for Bio-Stimulation & Fertility
- Foliar Applications integrated with Pest Control
- Cover Crop establishment
- Cover Crop decomposition
- Ancillary on-farm and purchased BSAs
UK Horticulture Research Farm

Organic Farming Unit

UK-CSA

Conventional Field Plots, Orchards, Vineyards

Greenhouses

Organic UK-CSA
UK Horticulture Research Farm
Organic Cropping Systems Team

Dr. Mark Williams, Professor
Dr. Krista Jacobsen, Assoc Professor
Neil Wilson, Research Technician
Grant Clouser, Greenhouse Manager
Ben Abell, Former CSA Manager
Tiffany Thompson, Former CSA Manager
Kristi Durbin, CSA Manager
Steve Diver, Farm Superintendent
Plasticulture Production – 8 beds per plot on 6’ centers
Plasticulture Production – 6 beds per plot on 8’ centers
Bare Ground Production

- 50’x 300’ plots
- 10 beds/plot
- 52” wheel centers
- 32” bed top
- 4” bed height
- Double rows 16” apart
Widespread Use of Cover Crop Systems

- Living mulch
- Cover crop strip
- Undersown
- Winter-killed
Access to Aerobic Thermophilic Compost and Dairy Manure Bedding (aka “Raw Manure” per USDA-NOP)
Soil preparation is a multi-step process: Flail Mowing cover crops, Spreading Compost, Incorporating Compost and Organic Fertilizer, Bed Formation with Buried Drip Tape, Transplanting Seedlings. Planting usually occurs 1-3 weeks after compost application but might take place within days in the busy Spring. Manure-based compost (BSAAO) meets USDA-NOP for pathogen-kill time & temperature.
Fall-Applied Raw Manure with Cover Crops

Early Fall: mid-Aug to mid-Sept
Oats - Peas

Late Fall: mid-Sept to Nov 1
Rye - Vetch - Clover

Early Spring Vegetable Crops
Planted March 15 – April 15

Late Spring Vegetable Crops
Planted May 7 – June 15

Sequence Meets USDA-NOP for 90 / 120 Days Before Harvest
Quality Organic Transplant Production
Organic crop inputs for production under USDA-NOP are carefully scrutinized for allowed ingredients and manufacturing processes. The three main organic labeling and database sources include OMRI, WSDA, and CDFA. How will FSMA regulations effect product evaluation and labeling?
RTU Commercial Organic Potting Mixes
Peat-Lite and Peat-Compost
Commercial Organic Liquid Fertilizers
Fish Hydrolysate, Plant Extracts, Fermentations, Biodigestates

Begin supplemental liquid organic fertilization at first true leaves
As a general guideline, begin 2-3 weeks after sowing
Commercial Organic Liquid Fertilizers
Cross-Over with Organic Hydroponics & Fertigation

OMRI Products List by Category

- Aquatic Plant Products, nonsynthetic
- Aquatic Plant Products, synthetically extracted
- Compost Tea, from manure feedstock**
- Compost Tea, without manure feedstock
- Fermentation Products
- Fish Products, liquid stabilized
- Plant Extracts
- Seaweed & Seaweed Products
- Yucca

Organic Materials Review Institute (OMRI) lists over 5,000 products which have been scrutinized and approved for use in organic crop and livestock production. The above OMRI categories overlap as sources of liquid fertilizers and bio-stimulants in greenhouse, nursery, vegetable, and fruit production (drench, fertigation, foliar).
## Common Organic Potting Mix Ingredients

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Typical Rate / yd³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sphagnum Peat Moss</td>
<td>75%</td>
</tr>
<tr>
<td>Vermiculite</td>
<td>25%</td>
</tr>
<tr>
<td><strong>Manure-Based Compost</strong></td>
<td>10-30%</td>
</tr>
<tr>
<td><strong>Vermicompost</strong></td>
<td>5-15%</td>
</tr>
<tr>
<td>Dolomitic Limestone</td>
<td>5-10 lbs</td>
</tr>
<tr>
<td>Greensand</td>
<td>5 lbs</td>
</tr>
<tr>
<td>Rock Phosphate</td>
<td>5 lbs</td>
</tr>
<tr>
<td><strong>Bone Meal</strong></td>
<td>5 lbs</td>
</tr>
<tr>
<td><strong>Blood Meal</strong></td>
<td>5 lbs</td>
</tr>
</tbody>
</table>
10–2–8
All Season Fertilizer
Fine & Coarse Grades

Net Wt. 50 Lbs.

SGN: Super Fine 90-100 • Fine 130-140 • Coarse 220-230

GUARANTEED ANALYSIS

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Nitrogen (N)</td>
<td>10.0%</td>
</tr>
<tr>
<td>0.25% Ammoniacal Nitrogen</td>
<td></td>
</tr>
<tr>
<td>9.00% Water Insoluble Nitrogen*</td>
<td></td>
</tr>
<tr>
<td>0.75% Other Water Soluble Nitrogen</td>
<td></td>
</tr>
<tr>
<td>Available Phosphate (P₂O₅)</td>
<td>2.0%</td>
</tr>
<tr>
<td>Soluble Potash (K₂O)</td>
<td>8.0%</td>
</tr>
<tr>
<td>Calcium (Ca)</td>
<td>1.8%</td>
</tr>
<tr>
<td>Sulfur (S)</td>
<td>3.0%</td>
</tr>
<tr>
<td>3.00% Combined Sulfur (S)</td>
<td></td>
</tr>
</tbody>
</table>

Source of Nutrients:

Hydrolyzed feather meal, meat and bone meal, blood meal and sulfate of potash.

*This product contains 9.0% slow release nitrogen from hydrolyzed feather meal and meat meal.
HyR BRIX® Vegetable Fertilizer 4-7-9
Guaranteed Analysis

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Nitrogen (N)</td>
<td>4%</td>
</tr>
<tr>
<td>4.0% Ammoniacal Nitrogen</td>
<td></td>
</tr>
<tr>
<td>Available Phosphate (P₂O₅)</td>
<td>7%</td>
</tr>
<tr>
<td>Total Phosphate (P₂O₅)</td>
<td>10%*</td>
</tr>
<tr>
<td>Soluble Potash (K₂O)</td>
<td>9%</td>
</tr>
<tr>
<td>Calcium (Ca)</td>
<td>9.75%</td>
</tr>
<tr>
<td>Magnesium (Mg)</td>
<td>1.24%</td>
</tr>
<tr>
<td>Sulfur (S)</td>
<td>10.40%</td>
</tr>
<tr>
<td>Boron (B)</td>
<td>0.122%</td>
</tr>
<tr>
<td>Copper (Cu)</td>
<td>0.0606%</td>
</tr>
<tr>
<td>Iron (Fe)</td>
<td>0.465%</td>
</tr>
<tr>
<td>Molybdenum (Mo)</td>
<td>0.00069%</td>
</tr>
<tr>
<td>Nickel (Ni)</td>
<td>0.00358%</td>
</tr>
<tr>
<td>Sodium (Na)</td>
<td>1.63%</td>
</tr>
<tr>
<td>Zinc (Zn)</td>
<td>0.1735%</td>
</tr>
</tbody>
</table>


*3.00% slowly available phosphate from rock phosphate.

Also Contains Non-Plant Food Ingredients:
- Worm Castings ........................................... 1%
- Humic Acid (derived from Leonardite) ........... 1%
- Total Other Ingredients ............................... 98%
Pre-Plant Bed Application of Compost Blended with Organic Fertilizer + Minerals + Trace Elements on 200-acre Organic Farm

Modern organic farming is an advanced growing system with a sophisticated blend of scientific and practitioner-based technology. At this 200-acre organic CSA, soil tests guide the nutrient management plan while crop fertility and biology inputs meet USDA-NOP guidelines. Compost serves multiple functions, including a substrate to mix and evenly spread minerals, organic fertilizers, and trace elements.
Sidedressing with nitrogen fertilizer is a common technique in vegetable production (both CONV and ORG) to provide a supplemental boost of energy about a third of the way into the crop cycle and to split fertilizer application with Pre-plant. This first example shows sidedress equipment and application on bare ground production, which is followed by a light cultivation or irrigation for incorporation & microbial activation.
This second example shows sidedress equipment and application in combination with plasticulture production. Injection of liquid fertilizers, bio-stimulants, and microbial inoculants into drip irrigation lines is known as fertigation. Fertigation is repeated more often and is a major tool for nutrient management and crop health in commercial organic, eco-agriculture, and conventional vegetable production.
“Agricultural Tea” Substrates (FSMA)

**Synergism:**
- Soluble Nutrients
- Microorganisms
- Humic acids
- Hormones
- Enzymes
- Microbial metabolites

**Humus Substrate options include BSAAOIs and BSA-NAOIs**

**Worm Compost**

**Aerobic Compost**
Aqueous Extracted Microbiology

Bacteria
Protozoas
Fungi
Nematodes
**“Agricultural Teas” (FSMA)**

<table>
<thead>
<tr>
<th>Aerated Compost Teas (ACT)</th>
<th>Liquid Compost Extract (LCE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compost, Vermicompost, Peat-Humus Substrates</td>
<td>Compost, Vermicompost, Peat-Humus Substrates</td>
</tr>
<tr>
<td>Agitate &amp; Dislodge Beneficial Microbiology</td>
<td>Agitate &amp; Dislodge Beneficial Microbiology</td>
</tr>
<tr>
<td>Aerate for 24 to 36 hours</td>
<td>No Further Aeration</td>
</tr>
<tr>
<td>Microbial Food Sources (Additives)</td>
<td>No Further Additives</td>
</tr>
<tr>
<td>Goal: Extract &amp; Proliferate Microbiology</td>
<td>Goal: RTU Compost Extract</td>
</tr>
<tr>
<td>Actively Metabolizing</td>
<td>Some Active, Mostly Dormant</td>
</tr>
<tr>
<td>Homemade and Commercial Brewers</td>
<td>Mostly Commercial Extractors</td>
</tr>
</tbody>
</table>

Both BSAAO and BSA-NAO Substrates are Commonly Used

Compost Teas and Compost Extracts are a popular way to make low-cost microbial amendments in sustainable and organic farming. Liquid Compost Extracts are more widely used in broad-scale farming and commercial landscaping. For example, the commercially-manufactured compost extractors featured in the next 4 slides are in common use by farmers, ranchers, and landscapers in Texas.
GEOTEA – Dual Compost Tea Brewer / Extractor
MBS TE-250 and TE-500 Compost Extractors
Hronek Flow-Thru Compost Extractor
Bio-Sprayer Technology

Jackto Backpack Sprayer

Sustainable Growth Texas, LLC

Liquid Biological Amendment Technology

Bio-Augmentation and Bio-Stimulation on Farms, Ranches, Landscapes

Bio-Sprayer Technology includes equipment to spray agricultural teas & bioferments (aka Liquid Biological Amendments).
Humus Management Practices with Bio-Sprays

Darren Doherty (Australia)
Keyline Chisel Plow with Bioferment Spray to augment soil carbon processes

Gerald Wiebe, Manitoba (Canada)
Compost extract with microbial food additives to enhance microbial digestion and humification of crop residues

Farmers make their own Compost Teas, Compost Extracts, Bioferments, and Microbial Inoculants – mixed with Microbial Food Additives – to “add” soil biology and to “stimulate” soil biology to gain a system effect: Improved Microbial Digestion of Crop Residues and Green Manures, Improved Soil Fertility, Improved Soil Structure, Improved SOM, Improved SFW Functioning, Improved Biocontrol.
Integrated Crop-Livestock for Soil Health

Basic Reasons for Crop Rotation
- Alternate vegetable families for disease control
- Alternate N-fixing legumes with heavy-feeding crops
- Alternate with cover crops

“Soil-Building” Crop Rotations Include:
- 5-year and 7-year crop rotations that integrate crop-livestock with sod-forming forages composed of grasses & legumes
- 2-3 years of a green fallow – grazed for income – to rebuild soil structure, fungal biomass, and natural SOM Functioning and SFW Functioning
- A balance of “soil depleting” and “soil building” crops & forages

Short and long-term crop rotations advocated by pre-1960s land-grant universities and USDA-SCS were based on sod-forming grasses and legumes that promoted SOM with soil aggregation. The obvious farm enterprise to make this economically profitable was green cover crop fallows and pasture fallows combined with livestock grazing. Now USDA-NRCS promotes integrated crop-livestock for soil health.
Biodynamic Farming (BD) is the oldest alternative farming system, based on the work of Rudolf Steiner (scholar) and Ehrenfried Pfeiffer (soil microbiologist). BD pays special attention to soil humus and food quality. The BD Preparations consist of fermented plant, mineral, and animal manures which are used to stimulate soil and plant processes.

Pfeiffer Field & Garden Spray, Josephine Porter Institute, 50 species of SOM digesting & humifying microbes

Horn Manure Preparation
BD 500

BD 500 and CPP are biodynamic preparations derived from raw manure, placed in the soil, that undergo microbial transformation and humus stabilization (but not thermophilic kill temperatures) and contain a consortia of beneficial microorganisms.

Barrel Compost (BC) or Cow Patty Pit (CPP)
Korean Natural Farming (KNF) teaches farmers to make their own extracts and microbial inoculants from on-farm biomass resources. These KNF recipes contain synergistic soil and crop health promoting Bioavailable Nutrients, Bioactive Substances, and Beneficial Microorganisms.
Natural Farming in India — Vedic Krishi

Amrit Pani (ghee, honey, Vitex & Neem leaves, cow urine)
Beejamrit (cow dung, cow urine, cow milk, limestone, water)
Dasagavya (Panchagavya with plant extracts)
Jivamrit (cow dung, cow urine, jaggary, pulse flour, soil, water)
Kunapajola (fish, sesame oil cake, rice husk, cow urine)
Matka Khad (cow dung, cow urine, jaggary, earthen pitcher)
Pachagavya (cow dung, cow urine, cow’s milk, curd, ghee)
Sanjibani (cow dung, cow urine, water)
Vermiwash (earthen pitcher, worm compost, earthworms, water)

Vedic Krishi is the 1,000 year-old agriculture knowledge of India. Modern farmers and NGOs have adapted and modified these ancient recipes to make on-farm extracts and microbial inoculants from local biomass resources.
References: Organic Amendments & Biological Control Mechanisms


References: Microbial Assessment of Prairie Ecosystems & Organic Farming Systems

Prairie Ecosystems:


Organic Farming Systems:


References: Microbial Assessment of Biodynamic Preparations


References: Microbial Assessment of Natural Farming Recipes


Thank You!

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