Dynamics and Functionalities of O.A. on Fertilizer, Water-use Efficiency and Soil Health

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Future of Crop Production

1. By 2050 the world population will double
2. Crop production will need to double
3. Soil organic matter has declined drastically all around the world
4. We need to become smarter at maximising our resources
5. Water quantity and quality are declining
6. Soils are becoming salt affected and diseased
7. Cost of production is increasing
8. **We have to create an innovative soil and plant nutrient balance**
Humic Substances aren’t the only universal depot of carbon and energy but possess a big biological potential that makes them an analog of ATP for biosphere.

Chuko, 2008
Humic Acids are “super-mixtures” Understanding the chemistry is very complex.
Functional Groups in Humates

- Carboxyl: -CO2H
- Phenol: -OHp
- Hydroxyl: -OHa
- Ketone: -C=O
- Ester: O=C-O-R
- Ether: -C-O-C-
- Amine: -NH2, -NH, -N
Reality check???

What percentage of harvested crops, fruits, vegetables etc... are made of C - H - O ?
Plant Composition

Content %

C, H, & O = 96.6%
Mir’s Theory:
Farming is transforming sunlight into crop yield

- Photosynthesis:
capture C energy = Make it

- Translocation:
move C energy = Move it

- Respiration:
re-manufacture C energy = Use it (yield)
The 5-R’s of Nutrient Stewardship

1. Right Fertilizer
2. Right Rate
3. Right Time
4. Right Place

5. Right Humate
Organic Acids Influences Plant Growth and Soil Health

**Culture Conditions**
- Soil fertility
- HS placement

**Humic Substance**
- Source
- Concentration
- Size (molecular wt.)

**Plant**
- Species
- Age

*Enhanced adsorption of macro- and micro-nutrients (e.g. NO$_3^-$)*
*Seed Germination*
*Shoot Development*
*Root Initiation and Development*

*Enhanced Metabolic Activity*
*Seedling growth*

**Culture Conditions**
- Soil fertility
- HS placement
Interactions of soil minerals, humic and microbes

Physical: organo-mineral complexes and water infiltration

Chemical: soil solution chemistry, complexation-chelation and buffering

Biological: microbial activation, soil foodweb

Plant Stimulant Properties: Humin chemistry/C27 Algal & C29 plant sterols
HUMIN AND ITS FUNCTIONALITY

Theoretically, humin is the non-soluble fraction of soil humus which breaks down slowly by soil microbial activity, and affects the soil by regulating its water holding capacity, ion exchange rate, EC, pH and soil crumple (micro aggregates).
Biomarkers

• Gas chromatography-mass spectrometric analysis of the humin pyrolysate revealed the occurrence of hopanoid and steroid biomarkers.

• Biomarkers have been widely used to assess the biological sources of dead matter. These are pristene, sterenes, and hopenes in the humin pyrolysate.
Pristene Biomarker

- Pristene is most likely derived from the phytol side chain of chlorophyll.
- Pristene is thus a marker of photosynthetic activity.
- Precursors of sterenes include C27 algal and C29 plant sterols.
Soil Particles & HS in Perspective

<table>
<thead>
<tr>
<th>Particle type</th>
<th>Diameter (mm)</th>
<th>Number of Particles/g</th>
<th>Surface Area Sq.cm/g</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very course sand</td>
<td>2.00-1.00</td>
<td>90</td>
<td>11</td>
</tr>
<tr>
<td>Course sand</td>
<td>1.00-0.50</td>
<td>720</td>
<td>23</td>
</tr>
<tr>
<td>Medium sand</td>
<td>0.50-0.25</td>
<td>5,700</td>
<td>45</td>
</tr>
<tr>
<td>Fine sand</td>
<td>0.25-0.10</td>
<td>46,000</td>
<td>91</td>
</tr>
<tr>
<td>Very fine sand</td>
<td>0.10-0.05</td>
<td>722,000</td>
<td>227</td>
</tr>
<tr>
<td>Silt</td>
<td>0.05-0.002</td>
<td>5,780,000</td>
<td>454</td>
</tr>
<tr>
<td>Clay</td>
<td>&lt;0.002</td>
<td>90,300,000,000</td>
<td>8,000,000</td>
</tr>
</tbody>
</table>

Relative comparison .005 mm = 5,000 nanometers
Particle size dynamics of H.S. and how they create organo-mineral complexes.

Transmission electron micrograph of a 0.01% (w/v) HA solution. The scale: 0.4 cm = 1 μm. HAs and FAs form flat elongated multi-branched filaments of 20 to 100 nm in width. Smallest particles are spheroids of 9-12 nm in diameter.
Humics create excellent environment for microbes

Soil microbes inhabiting the surface of clay-humus crumb, glowing under UV light, stained with acridine orange, as seen under a high-resolution Leitz microscope.

Source: Siegfried Luebke's CMC Group Laboratory; Peuerbach, Austria.
These physical bondings will create good aggregate
How H.S. helps Soil Micro-pores

- Roots, water, and nutrients reside in micro pore space
- Oxygen resides in macro pore space

1 cm is 10,000,000 n.m.
Humics and Soil Interactions

Cation bridging
(Fotyma, Mercik 1992)

H-bonding
(Fotyma, Mercik 1992)

Bond by hydrous oxides
(Fotyma, Mercik 1992)
Nutrient Exchange

Clay CEC 20 to 40  ------  Organic Acids CEC 250 to 500

Fixed
Slowly
Available

Exchangeable
More
Available

Water Soluble
Readily
Available

Clay Particle

Organic Acid
Effect of Humic Substances on Plant Metabolism

Nutrient Acquisition - NO$_3^-$

IAA

Humic Acid

LMWHS acts at transcriptional level to induce production of Mha2-mRNA

Mha2 gene codes for pmH$^+$-ATPase on Zea mays.

Citric Acid

Citrate anion channel

Nucleus

Cytoplasm

Plasmalemma

Root Epidermal Cell

1. LMWHS acts at transcriptional level to induce production of Mha2-mRNA

2. More Mha2-mRNA is produced

3. More pmH$^+$-ATPase is produced

4. More H$^+$-ATPase activity = more of a gradient to support more NO$_3^-$ influx and citrate efflux.

(after Quaggiotti et al. 2004)
Variations in soil fertility & how O.A. helps to buffer
What do you think the yield variation will be?

Yield variation 38t/ha – 108t/ha
Harvested 10 days earlier
O.A./pH influence on Nutrient Availability
Effects of Humic Acid Rate on Potato Yield at Three Sites

\[ Y = 343.4 + 12.01X - 0.746X^2 \]

\[ R^2 = 0.92 \quad *** \]

Yield (T/ha)

Humic acid (L.ha⁻¹)
2014 Field Potato Research

• Variety: Norkotah
• Soil Texture: Sandy Loam
• Ph 7.9
• Organic matter 1.4%
• Plot design: randomized plots
• Four replications of each treatment:
  1. Control: farmers usual fertility application
  2. 1X = 37.39 Liters/ha
  3. 2X = 74.78 Liters/ha
  4. 3X = 112.17 Liters/ha

Hand-harvested and graded on Aug. 5, 2014
Effects of Different Rates of Humic Acids on Potato Total Yield, 2014
Comparisons of Control, 1X, 2X & 3X
Sugarbeet Harvest Raw Data

- **Row 1X**: 220.5 lbs.
- **Row 2X**: 301.5 lbs.
- **Row 3X**: 197 lbs.
- **Row Control**: 242.5 lbs.

Between 2X & Control there is 19.6% difference in yield.

Statistical analysis will be run at a later date.
POTATOES ARE WATER SENSITIVE
Influence of HS on Water-Use Efficiency

Wetting Patterns after 6 hours for 10-20 cm emitter depths
Humics Influence on Water Sequestration

Watermark studies in three years showed an average of 11.2% water sequestration.
Disease Resistance

Sufficient Quantities of all Essential Nutrients Must be Delivered to the Plants

Problem: Availability

O.A. = solubility/availability
Most Important Nutrients for Disease Resistance

K, Ca, Cu, Zn, B, Mn, S, Si, Cl
Importance of Humic Substances in Soil Nutrient Management

Based on scientific research, Humic Substances help to solubilize macro-micro nutrients, chelate, complex, buffer, and make them more available to plants.

Soil Society of America
Humics/Elements Interactions = Better Nutrient Balance

Mulder’s chart Interaction of Elements

Synergize
Increase availability to plant

Antagonize
Decrease availability to plant
### General Concept for Macro & Micro-Nutrient Ratios

<table>
<thead>
<tr>
<th>Ratios</th>
<th>Ideal</th>
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<tbody>
<tr>
<td>N:S</td>
<td>5-10:1</td>
</tr>
<tr>
<td>Ca:Mg</td>
<td>6-20:1</td>
</tr>
<tr>
<td>Ca:K pH&gt;7</td>
<td>15:1</td>
</tr>
<tr>
<td>Ca:K pH&lt;7</td>
<td>10:1</td>
</tr>
<tr>
<td>Ca:P ph&gt;7</td>
<td>100:1</td>
</tr>
<tr>
<td>Ca:P ph&lt;7</td>
<td>40:1</td>
</tr>
<tr>
<td>P:Zn</td>
<td>15:1</td>
</tr>
<tr>
<td>P:Mn</td>
<td>4:1</td>
</tr>
<tr>
<td>P:Cu</td>
<td>25:1</td>
</tr>
<tr>
<td>Zn:Cu</td>
<td>2:1</td>
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<tr>
<td>Mn:Zn</td>
<td>3:1</td>
</tr>
<tr>
<td>Mn:Cu</td>
<td>5:1</td>
</tr>
<tr>
<td>Mn:Cu</td>
<td>5:1</td>
</tr>
<tr>
<td>K:B</td>
<td>200:1</td>
</tr>
<tr>
<td>Mg:K</td>
<td>2:1</td>
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Quantitative Field Observations
O.A. and Stubble Digestion
(Nitrogen Mineralization)
# L.H. and Stubble Digestion

Nitrogen Mineralization in Sugarbeets

<table>
<thead>
<tr>
<th>Site</th>
<th>Depth</th>
<th>Initial N Level</th>
<th>June</th>
<th>July</th>
<th>Aug</th>
<th>Sept</th>
<th>Oct</th>
<th>Soil N Supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>G.V.</td>
<td>0-12</td>
<td>98.42</td>
<td>174.0</td>
<td>185.4</td>
<td>241.3</td>
<td>217.4</td>
<td>256.5</td>
<td>354.92</td>
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<tr>
<td></td>
<td>12-24</td>
<td>78.66</td>
<td>98.8</td>
<td>100.7</td>
<td>118.8</td>
<td>150.9</td>
<td>119.3</td>
<td>197.98</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>177.08</td>
<td>272.8</td>
<td>286.1</td>
<td>359.48</td>
<td>368.3</td>
<td>375.82</td>
<td>552.90</td>
</tr>
</tbody>
</table>
Watermark Sensor locations for O.A. Research

Alfalfa
Shale Oak, CA Project

O.A. transformed very high salt, high H2S and poor canopy into productive vineyard
Shale Oak Trials: Good Yield Potential
Organic Acids
Enhance Vigor and Stand
Humics Influence
Vigorous Healthy Roots
O.A. Influence on N.M. & Soil Health

very compacted soil to healthy soil
Effect of H.S. on Plant Growth

Corn at 6-8th vegetative leaf stage
Effect of H.S. on Plant Growth:
Plant Physiology and Morphology

Alfalfa-not treated

Alfalfa-treated with OA @ 2 g/acre
Q.A./balanced nutrients = uniformity and quality
O.A. Enhances Quality
Studies suggest that humics (synergize) increase availability of macro-micro nutrients to the plants.
Summary of Research Findings

1. SOLUBILIZATION OF MICRONUTRIENTS (e.g. Fe, Zn, Mn) & SOME MACRONUTRIENTS (e.g. K, Ca, P)

2. Buffers salts, reducing burning

3. Forms a bond with fertilizer preventing “Tie-up”

4. Increase crop production by 10-40%

5. Enhance plant nutrient translocation

6. Accelerate the ripening period 5-10 days
Summary of Research Findings

7. Enhance soil & plant health
8. Increase water sequestration by 11%
9. Decrease the content of nitrates and other harmful substances in fruit & improves nutritional quality
10. Increased plant’s resistance to disease, frost damage and drought
THANK YOU