Growing Happy Blueberries in Healthy Soil

Kerry Clark (clarkk@missouri.edu)
University of Missouri Bradford Research Center

http://fc05.deviantart.net/fs71/i/2009/345/6/6/Blueberry_Madness_Emotions_by_dragorien.jpg
What is the one thing that everyone knows blueberries need for good growth?

Acid pH

Why?
pH is the negative log of hydrogen activity in soil

\[
\begin{align*}
\text{pH} = 7 &= 1 \times 10^{-7} \ H^+ = .0000001 \\
\text{pH} = 6 &= 1 \times 10^{-6} \ H^+ = .000001 \\
\text{pH} = 5 &= 1 \times 10^{-5} \ H^+ = .00001 \\
\text{pH} = 4 &= 1 \times 10^{-4} \ H^+ = .0001
\end{align*}
\]
Why would blueberries need hydrogen atoms?

They don’t – they need lots of iron, which is only available to them at low pH.

They also prefer NH$_4^+$ to NO$_3^-$. NH$_4^+$ is dominant at acid pH.
• pH measures the acidity or alkalinity of the soil

• pH can have a profound affect on crop growth because it controls nutrient availability by altering chemical form of essential elements

• pH can also affect biological activity
Plants can take up iron as Fe$^{2+}$ and Fe$^{3+}$ but Fe$^{2+}$ is the most soluble and the easiest for plants to take up.

Whether or not iron is Fe$^{2+}$ or Fe$^{3+}$ in the soil depends on the pH and the soil water relations.

Iron is more likely to exist as Fe$^{2+}$ in acid, when pH is 5.5-8, iron is most likely to be Fe$^{3+}$.
Iron is needed for the production of chlorophyll, which drives photosynthesis, which produces sugars for plant energy.

Any reduction in chlorophyll during the growing season reduces plant growth, vigor, and tolerance to stress conditions.
It is important to monitor and keep a record of soil pH on a yearly basis and take corrective actions if necessary.

• Locate new blueberry plantings on soil that is near or within the correct pH range of 4.3-5

• Adjust soil pH before planting with lime (if too acidic) or sulfur (if too basic)-based on soil test results
• Sulfur at 1 ton/A would be needed to lower a pH 6 clay loam soil to 4.5
• Although this rate is fine before planting, once blueberries have been planted, use no more than 200 to 400 lb/A at any one time
• Changes in soil pH will be slow and may take up to a year for results to show in soil tests

\[
\begin{align*}
2S + 3O_2 + 2H_2O & \rightarrow 2H_2SO_4 \\
\text{sulfur} & \quad \text{oxygen} \quad \text{water} & \quad \text{bacteria} \quad \text{sulfuric acid}
\end{align*}
\]

\[
\begin{align*}
Al_2(SO_4)_3 + 6H_2O & \rightarrow 2Al(OH)_3 + H_2SO_4 \\
\text{aluminum sulfate} & \quad \text{water} & \quad \text{gibbsite (solid)} & \quad \text{sulfuric acid}
\end{align*}
\]

Aluminum sulfate acidifies but can also lead to Al toxicity
Don’t over apply elemental sulfur or you may get pH seriously out of whack.

Table 1. Acidifying effect of some common fertilizers and soil amendments.

<table>
<thead>
<tr>
<th>Material</th>
<th>Pure CaCO₃ needed to neutralize acidity in 100 pounds of material (pounds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ammonium nitrate</td>
<td>60</td>
</tr>
<tr>
<td>ammonium sulfate</td>
<td>110</td>
</tr>
<tr>
<td>32% liquid nitrogen</td>
<td>55</td>
</tr>
<tr>
<td>urea</td>
<td>81</td>
</tr>
<tr>
<td>sulfur-coated urea</td>
<td>118</td>
</tr>
<tr>
<td>diammonium phosphate</td>
<td>70</td>
</tr>
<tr>
<td>flowers of sulfur (elemental S)</td>
<td>312</td>
</tr>
<tr>
<td>aluminum sulfate</td>
<td>45</td>
</tr>
</tbody>
</table>
• Use ammonium sulfate as a nitrogen source especially if soil pH is on the high side.
• Can also use sulfur coated urea
• Repeated use can lower soil pH below the optimum range.
• Increase soil organic matter to reduce free soil aluminum under low soil pH.

\[
2\text{NH}_4^+ + 3\text{O}_2 \xrightarrow{\text{bacteria}} 2\text{NO}_2^- + 2\text{H}_2\text{O} + 4\text{H}^+
\]

ammonium + oxygen \hspace{2cm} nitrile + water + acid
Salt pH vs water pH

- Water pH is more variable than salt pH because salts affect pH and are in greater or lower concentrations depending on the year and the season.

- Salt pH is more stable because the salt concentration stays the same no matter when you test. The lab uses a known quantity of salt in the test.

- Salt pH = water pH - 0.5

- Blueberries prefer a salt pH of 4.3-5

- That translates to a water pH of 4.8-5.5

- Many University labs use salt pH and many commercial labs use water pH
Advice for Blueberry Growers

Fool around with Mother Nature as little as possible

The best crops are those that fit their natural surroundings

Re-create the natural environment to have the healthiest, most productive crops

Add diversity and organic matter to have productive soils
Soil health has three main components:

- Sustained biological productivity
- Environmental quality
- Plant and animal health
Soil is a living, breathing body that can attain a state of health, or its opposite—degradation

• Soil health is the integration of biological with chemical and physical measures of soil quality that affect farmers' profits and the environment.

• This definition reflects the living and dynamic nature of soil
A master variable in plant productivity is the presence of organic matter in the soil. Organic matter also acidifies soil by feeding microorganisms, which release CO$_2$. CO$_2$ reacts with H$_2$O to form carbonic acid and hydrogen. Microorganisms also release organic acids when they break down organic matter and plant residues.
What is Soil Organic Matter?

- SOM is derived from
  - Plant residue (both litter and roots)
  - Animal remains and excreta
  - Living soil microbes (microbial biomass)
- Over time fresh organic material is transformed into soil organic matter
All organic matter in soil is not equal

Scientists describe 3 pools of soil organic matter

**really is a continuum of decomposition**

**Active SOM**
- Recently deposited organic material
- Rapid decomposition
- 10 – 20% of SOM
- 1 – 2 yrs
- C/N ratio 15 – 30

**Slow SOM**
- Intermediate age organic material
- Slow decomposition
- 10 – 20% of SOM
- 15 – 100 yrs
- C/N ratio 10 – 25

**Passive SOM**
- Very stable organic material
- Extremely slow decomposition
- 60 – 80% of SOM
- 500 – 5000 yrs
- C/N ratio 7 – 10
SOM
Improves Soil Biological Properties

• Greater abundance, diversity, and activity of soil microbes

• Increased nutrient cycling

• Increased access to water and nutrients

• Soil organisms improve aggregation
Fungi

- General *saprophytic* fungi (i.e., decomposers)
- Produce *glomalin* – glue in aggregation
- Nutrient cycling! Especially hard to decompose SOM
Fungi and Soil Structure

- Fungal hyphae (threads) help hold soil granules together
- Fungal exudates (e.g. glomalin) help cement soil particles

**Active Fungi Present**
- Soil structure is maintained

**Fungi absent**
- Soil structure is not maintained
Mycorrhizal Fungi and Nutrient Acquisition

• A symbiotic relationship between a soil fungus and plant root
• Unlike rhizobia and their legume partners, mycorrhizal associations are common and relatively nonselective
• Although parasitic and neutral relations exist, most of these associations are beneficial both to the host plant and the colonizing fungi
• Mycorrhiza assist plants in obtaining water, phosphorus and other micronutrients (e.g., Zn and Cu) from the soil and in return receive sustenance (carbon) from the plant.
Mycorrhiza

Bacteria bridge short distances, but fungi can work over long distances to explore and to transport nutrients thanks to their fine hyphal system.

Thus, mycorrhizas (symbioses between roots and fungi) have been very successful in evolution.

Photo: David Read
SOM Improves Soil Physical Properties

• Increased aggregate stability
• Increased water infiltration
• Reduced runoff
• Increased water holding capacity
• Decreased erosion
• Improves aeration and macroporosity
Soil Structure

• Arrangement of soil solids and voids
• Soil structure influences water infiltration and retention, erosion, crusting, nutrient recycling, root infiltration and crop yield
• Expressed as degree of aggregate stability

• Aggregation is controlled by SOC, microorganisms, ionic bridging, clay
Aggregate Stability

Fungal-produced glomalin helps bind aggregates

http://ed.fnal.gov/trc_new/pandp/soil_research/soil_aggregates.html

Wright, et al., 1999
Improving soil structure is about providing pores that can fill with and retain soil moisture

Good structure allows for:
• water films for microbial movement and feeding
• good plant root growth and seedling emergence
• allows a wet field to drain
• Increased water holding capacity of soil
• cycling and storing nutrients
PRACTICES THAT DESTROY STRUCTURE

• Tillage
• Disturbance that exposes soil to the adverse effects of higher than normal soil drying and erosion
• Conventional tillage and soil disturbance that accelerates organic matter decomposition
• Residue harvest, burning or other removal methods that prevent accumulation of soil organic matter
• Equipment or livestock traffic on wet soils
What is the Problem with Tillage?

• Causes increased susceptibility to water and wind erosion
• Can compact soil below the depth of tillage
• Accelerates decomposition of soil organic matter and release of CO$_2$
• Damages fungal hyphae and earthworms
• Increases net nitrate production and leaching
• Can destroy macropores and lead to surface crusting, decreased water infiltration
ONLY PORES CONNECTED TO SURFACE INCREASE FLOW RATE
Soil Engineers: Earthworms
Subsoil macropores - Model of earthworm burrow systems

75 ind/m²
- 30% endogeic (⌀ 2-3 mm)
- 70% anecic (⌀ 6 mm)
- ⌀ core 212 cm

SOM Improves Soil Chemical Properties

- Increases CEC to store and supply plant nutrients: 20 – 70% of CEC in soils is due to organic matter
- pH buffering so the soil resists changes in pH
- Reduces aluminum, iron, and manganese toxicity in acidic soil
- Adsorbs pesticides and other chemicals
Cation Exchange Capacity

- Maximum quantity of total cations, of any class, that a soil is capable of holding, at a given pH value, available for exchange with the soil solution.
- Used as a measure of fertility, nutrient retention capacity, and the capacity to protect groundwater from cation contamination.
- Soil particles have negative charge, so they can hold on to positively charged ions (NH$_4^+$, Ca$_2^+$, Mg$_3^+$, K$^+$, Na$^+$, Fe$_2^+$, etc)
- Weathered clay particles have more charge than sands and silts. Extremely weathered clays can lose their negative charge
- Organic matter has the greatest amount of cation exchange capacity in soil
Having soil that is high in organic matter will give your soil a greater ability to provide essential nutrients to plants.

<table>
<thead>
<tr>
<th>Soil texture</th>
<th>CEC (meq/100g soil)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sands (light-colored)</td>
<td>3 to 5</td>
</tr>
<tr>
<td>Sands (dark-colored)</td>
<td>10 to 20</td>
</tr>
<tr>
<td>Loams</td>
<td>10 to 15</td>
</tr>
<tr>
<td>Silt loams</td>
<td>15 to 25</td>
</tr>
<tr>
<td>Clay and clay loams</td>
<td>20 to 50</td>
</tr>
<tr>
<td>Organic soils</td>
<td>50 to 100</td>
</tr>
</tbody>
</table>
Plant Essential Elements
Carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, boron, chlorine, iron, manganese, zinc, copper, molybdenum, and nickel

Carbon- makes up 58% of soil organic matter
• Comes from atmospheric carbon dioxide.
• During the photosynthesis process, carbon dioxide is changed into organic carbon and gives plants their structure.
• After the water is removed plants are 45% carbon, 45% oxygen and the rest hydrogen and all the other essential and non-essential elements
When plant tissue dies, plant carbon is stored in the soil as soil organic carbon (animals, insects and microbes also contain carbon)

Once in the soil, it becomes very useful to us. It feeds the soil microbes that transform organic compounds into inorganic plant usable forms

Forms soil organic matter, which gives soil many of its life-giving characteristics
Carbon fuels the soil microbes that help make phosphorus, sulfur and organic nitrogen available for plants to take up.
95% of the nitrogen in the soil is organic nitrogen and is contained in soil organic matter.

About 2-3% of this is mineralized and made available to plants each year.
Soil organic matter: the nitrogen gorilla

Slide taken from 2013 MU Crop Management Conference presentation by Dr. Peter Scharf.
If we use practices that build organic matter, we will help allow the soil to function to its fullest capabilities and maximum productivity.

Grow high residue crops in your alleys - Annual ryegrass - very large root system.
Soil temp on soil with residue cover: 88°F

August 10, 2011
Air temp this afternoon was about 85°F

Soil temp on soil with residue cover and under sunflower canopy: 78°F

Soil temp on bare soil: 98°F
When soil temp reaches... 

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Moisture Usage</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>140°F</td>
<td>100% moisture lost</td>
<td>Soil bacteria die</td>
</tr>
<tr>
<td>130°F</td>
<td>15% moisture used for growth</td>
<td>100% moisture lost through evaporation &amp; transpiration</td>
</tr>
<tr>
<td>100°F</td>
<td>85% moisture lost</td>
<td>15% moisture is used for growth</td>
</tr>
<tr>
<td>70°F</td>
<td>100% moisture lost</td>
<td>100% moisture is used for growth</td>
</tr>
</tbody>
</table>

J.J. McEntre, USDA SCS, Kerrville, TX, 1956
University of Missouri
Soil Health Lab

- SMAF SQI
- Active Carbon
- pH
- Aggregate Stability
- Available P
- Mineralizable N
- PLFA
- Total Carbon
- Infiltration

http://engineering.missouri.edu/soil/soil-health-lab/
Soil quality assessments require measuring the current state of an indicator and comparing the results to known or desired values (Karlen et al., 1997)
Basic Soil Health Package $30

**Potentially Mineralizable Nitrogen**
Reduce nitrogen expenditures — take credit for nitrogen released by soil during growing season.

**Active Carbon**
Estimate activity of soil organic matter and soil microorganisms

**Aggregate Stability**
Evaluate soil structure and water relationships

**pH (salt and water)**
Optimize pH and crop suitability; maximize nutrient availability.
Expanded Soil Health Package (includes basic package) $65

- Total Nitrogen
- Total Organic Carbon
  - Add total Nitrogen and Carbon to the analyses to put perspective on PMN and active carbon

- Effective Cation Exchange Capacity
  - Measure ECEC, capacity of soil to hold cations (calcium, magnesium, potassium, sodium, hydrogen and aluminum) at the current soil pH. Most CEC measurements are made with pH adjusted to 7. ECEC estimates more closely current soil conditions allowing future improvements to be measured.

- Effective Base Saturation
  - Measure effective base saturation, the proportion of ECEC held by the basic cations of calcium, magnesium, potassium and sodium. Hydrogen and aluminum are acidic cations.

- Plant Available Phosphorus
  - Measure phosphorus available for plant uptake
Add any of these analyses to either of the above packages

• Analyze Phospholipid Fatty Acid content of your soil to estimate the biomass and groups of microbes present in the soil. $39

• Measure soil bulk density to determine if compaction is limiting crop root growth, water infiltration, and water holding capacity. $5

• Classify your soil by texture. $30
PLFA Sub-categories at Bradford

Biomass (mg/g)

Cropping System

- Soybean
- Switchgrass
- NT Corn
- Hedgerow/fescue
- Fescue field

- Rhizobia
- Arbuscular Mycorrhizal
- Saprophytes
• Do soil health testing every three to five years

• Use it to monitor management changes

• Continue soil fertility testing and/or do tissue testing to see if your plants are taking up the nutrients they need
• Improving your soil health will improve your productivity

• Surround your blueberries with diverse, deep rooting plants
  Blue Grama  Annual ryegrass
  Sideoats Grama
  Buffalo Grass

• Keep your farm and your blueberry patch full of diversity for better insect and disease control and improved soil health