Advanced pH management

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Outline

1. pH solubility curves, and what they can teach us about pH management

2. The “life cycle” of pH as a young plant crop develops

Before we get too far…

- pH management is not that complex
- Maintain pH around 5.6-6.4, and you will be fine.
- But this is an advanced session, and we will discuss subtleties for nutrition nerds. No apologies (sorry).

1. pH and solubility

pH affects
- Nutrient solubility
- Uptake by Plant
- Plant health
too much → toxicity
too little → deficiency
- But – it all depends…

pH solubility curve: Did you know…

- Based on one mix (peat/bark/sand/vermiculite) and one fertilizer containing STEM (sulfate micronutrients) and dolomitic lime?
- Why do different nutrients have the reported shape in the curve?
- Thanks to QAL, Panama City FL, for analysis

Nitrate is not affected by pH

100% nitrate-N fertilizer, no plants

Ammonium tends to be nitrified (turned into nitrate) by bacteria at high pH

Phosphorus reacts with calcium at high pH

Potassium is not affected by pH, but coconut coir can contribute K

- Much of the acidity of ammonium can result from microbes
- Ammonium toxicity with high NH₄ fertilizer, low pH, cool & wet
- Low P can be an issue at high pH
- Media components can sometimes add nutrients
Increasing Calcium at high pH is because of the lime source, not solubility.

- Raising pH per se will not increase calcium availability
- Adding calcitic limestone, calcium nitrate, or gypsum increases Ca

Magnesium has the same trend as Calcium.

- Raising pH per se will not increase magnesium availability
- Adding dolomitic limestone, mag nitrate, or mag sulfate increases Mg

Substrate components can affect pH response

<table>
<thead>
<tr>
<th>Substrate-pH</th>
<th>4.3</th>
<th>4.7</th>
<th>4.8</th>
<th>5.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>70 Peat/30 perlite</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>70 Peat/15 perlite/15 vermiculite</td>
<td></td>
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</tbody>
</table>

Adding vermiculite reduced iron/manganese toxicity at low pH

Iron deficiency at high pH is the most common pH issue

Iron chelate form is very important

- All iron forms effective at low pH; pH management is cheapest option
- Using iron-EDDHA is very effective at high pH; insurance

At low pH, there are various iron sources

- Iron in the pre-plant and post-plant fertilizer
- Iron in the lime (up to 0.3%)
- Iron in the irrigation water (up to 1 ppm)
- Iron in the peat
  - 0.3 ppm in water extraction
  - up to 45 ppm in DTPA extraction

At low pH (5.1) all iron forms soluble

- Iron-EDDHA
- Iron-EDTA
- Iron sulfate

Turning to micronutrients...

At low pH and high micronutrient fertilizer levels, iron/manganese toxicity is likely in iron-efficient crops.

Optimum pH range depends on the crop AND your fertilizer regime

- If you run high fertilizer, optimum pH is higher. Lean means lower pH.

Iron in the pre-plant and post-plant fertilizer

Iron in the lime (up to 0.3%)

Iron in the irrigation water (up to 1 ppm)

Iron in the peat

0.3 ppm in water extraction
up to 45 ppm in DTPA extraction

Iron-EDDHA

Iron-EDTA

Iron sulfate
At high pH (7.0) iron form matters

- 0.25 0.5 1 2 ppm

Iron-EDDHA
Iron-EDTA
Iron sulfate

At high pH, increasing micronutrient level can lead to improved growth and appearance

- ppm iron 0.5ppm 1ppm 2ppm (pH 7.0)

• Consider having a separate injector for micronutrients v NPK
• Control growth with N or P, maintain color with magnesium and micros.

At high pH, funky things happen with micronutrient reactions. For example, zinc.

- It is not always just low iron that is an issue at high pH

Usually an iron drench at high pH is most effective

- ppm iron 20 40 80

Effect of pH on boron solubility

- Don't ignore pH management and just add more iron

Increasing iron at high pH can reduce other nutrient levels

- 0.0 0.1 0.2 0.3 0.4 0.5 0.6 ppm Boron

2. The pH life cycle

- Increasing plant and fertilizer effects

Many factors affect substrate-pH

- Nitrate NO₃⁻ Fertilizer Ammonium NH₄⁺
- Lime Alkalinity Species Substrate Acid
- Petunia Geranium
- BASIC Factors (Raise pH) pH balance ACID Factors (Lower pH)
An example pH management experiment

- 29 substrates
- "Neutral" fertilizer (17-4-17, 25% NH₄-N)
- "Acid" fertilizer (19-5-19, 50% NH₄-N)
- 100 ppm N from stick onwards
- Petunia & Osteos
- 40 ppm alkalinity water

pH management during MIST

<table>
<thead>
<tr>
<th>Substrate-pH</th>
<th>Days (t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial pH of the substrate components</td>
<td>3 - 7</td>
</tr>
<tr>
<td>Equilibrium pH</td>
<td>6 - 8</td>
</tr>
</tbody>
</table>

LIME: How does lime react?

- Equilibrium pH depends on: lime acid neutralizing value, lime rate (lb/yd³ or kg/m³), substrate pH and buffering

LIME: Increasing lime rate increases pH to a maximum level

<table>
<thead>
<tr>
<th>Substrate-pH after 14 days</th>
<th>Lime rate (lb/yd³ peat)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 - 8</td>
<td>0 - 30</td>
</tr>
</tbody>
</table>

LIME: Not all lime reacts. What is left is residual lime.

<table>
<thead>
<tr>
<th>Applied lime rate (lb/yd³)</th>
<th>Residual lime</th>
<th>Reactive lime</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>5.4</td>
<td>10.8</td>
</tr>
<tr>
<td>5.4</td>
<td>10.8</td>
<td>16.2</td>
</tr>
<tr>
<td>10.8</td>
<td>16.2</td>
<td>21.6</td>
</tr>
<tr>
<td>16.2</td>
<td>21.6</td>
<td>27.0</td>
</tr>
<tr>
<td>21.6</td>
<td>27.0</td>
<td></td>
</tr>
</tbody>
</table>

pH management during FINISHING

Base: nitrate

- Nitrate

NO₃⁻ → H⁺ or HCO₃⁻ → OH⁻

pH↑

Acid: ammonium

NO₃⁻ → 2H⁺ + NH₄⁺ → H⁺

pH↓

Mist phase | Finishing phase
---|---
Lime reaction | Lime residual
Substrate pH & cation exchange capacity (CEC) | Alkalinity
Electrical conductivity (EC) | Nitrogen form & concentration
Water quality | Plant Species

Major pH factors during propagation
LIME: Residual lime buffers pH drop later in the crop

Impatiens
Acid (high ammonium) fertilizer

LIME: Chemistry

<table>
<thead>
<tr>
<th>Lime chemistry</th>
<th>Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrated (Ca(OH)₂)</td>
<td>Very fast reacting/no residual. Short term crops such as plugs.</td>
</tr>
<tr>
<td>Calcitic carbonate (CaCO₃)</td>
<td>Fast acting if fine particles. Otherwise slow. Supplies Ca.</td>
</tr>
<tr>
<td>Dolomitic carbonate (CaMg(CO₃)₂)</td>
<td>Fast acting if fine particles. Otherwise slow. Supplies Ca, Mg.</td>
</tr>
</tbody>
</table>

LIME: Particle size

<table>
<thead>
<tr>
<th>Lime particle size</th>
<th>Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fine calcitic or dolomitic carbonate lime</td>
<td>Fast reacting/Low residual. Short to medium term crops such as plugs.</td>
</tr>
<tr>
<td>Calcitic carbonate (CaCO₃)</td>
<td>Mainly provides initial pH correction.</td>
</tr>
<tr>
<td>Dolomitic carbonate (CaMg(CO₃)₂)</td>
<td>Slow reacting/Provides residual buffering. Medium to long term crops such as nursery.</td>
</tr>
</tbody>
</table>

Testing Lime Rates and Reactivity

- Do a wet out test with each new batch of peat or if you change your lime source
  - Measure substrate-pH at 0, 1, 2, 4, 8 weeks depending on crop length
  - Plant a crop and track over time, or make up a small batch and keep moist in an open bag or pot
- For short term crops (less than 3 months) pH should reach the target level within 1 week of planting

SUBSTRATE: Components vary in their lime requirement

<table>
<thead>
<tr>
<th>Component</th>
<th>Typical pH range</th>
<th>Lime requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vermiculite</td>
<td>7.5 to 9</td>
<td>None</td>
</tr>
<tr>
<td>Compost</td>
<td>6 to 8</td>
<td>Little to none</td>
</tr>
<tr>
<td>Perlite, pumice, volcanic rock, sand</td>
<td>6.5 to 7.5</td>
<td>None</td>
</tr>
<tr>
<td>Coconut fiber (coir)</td>
<td>5.5 to 6.5</td>
<td>None</td>
</tr>
<tr>
<td>Bark</td>
<td>4.5 to 6</td>
<td>Moderate</td>
</tr>
<tr>
<td>Peat</td>
<td>3 to 5</td>
<td>High</td>
</tr>
</tbody>
</table>

SUBSTRATE: Different peat sources vary in lime requirement

- Blond peat: Slightly decomposed
- Brown peat: Well decomposed
- Humus: Highly decomposed
  - Typically higher lime requirement

SUBSTRATE: Interactions with lime

- Acidic components such as peat (pH 3 to 4) need to be neutralized by lime
- Neutral components such as perlite and coconut coir (pH 6 to 7) do not need lime
- Substrates with acidic components (and more lime) tend to have more buffering

Your substrate choice affects liming

Example: a 70% peat/30% perlite substrate
- Is acidic, and is neutralized by lime
- Not all the lime reacts, which provides buffering
- Lime also provides Ca and Mg
- Perlite is inert

Example: a 100% Coconut coir substrate
- Near neutral, so no lime needed
- Very little buffering to pH change
- Check salts (Na, K, Cl). May need leaching.
- Best as an amendment mixed with other components
EC EFFECTS: High pH and low salts are common at the end of the mist phase.

Why? Because pH increases as EC decreases with leaching.

Leaching with clear water washes out salts and raises pH.

EC: Pre-plant salts (especially Calcium) drop pH.

<table>
<thead>
<tr>
<th>Cation</th>
<th>Substrate-pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control (water)</td>
<td>5.8</td>
</tr>
<tr>
<td>Ammonium</td>
<td>5.5a</td>
</tr>
<tr>
<td>Potassium</td>
<td>5.5a</td>
</tr>
<tr>
<td>Magnesium</td>
<td>5.5a</td>
</tr>
<tr>
<td>Calcium</td>
<td>5.2b</td>
</tr>
</tbody>
</table>

Adding fertilizer will drop pH.

EC EFFECTS: What should you do about this high pH/low EC issue?

- Avoid excess leaching
- Fertilizer at end of mist phase

WATER QUALITY: pH effects under mist.

Which solution will lead to the lowest substrate-pH under MIST with DI water?

- Water pH in pure water has little direct effect on substrate-pH.

Which solution will lead to the lowest substrate-pH under MIST with well water?

- Increasing EC decreases substrate-pH (CEC effect)
Which solution will lead to the lowest substrate-pH under MIST with well water?

- Increasing water alkalinity increases substrate-pH

Finishing stage (Rooted plants)

Increasing plant and fertilizer effects

Major pH factors during propagation

<table>
<thead>
<tr>
<th>Mist phase</th>
<th>Finishing phase</th>
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<tbody>
<tr>
<td>Lime reaction</td>
<td>Lime residual</td>
</tr>
<tr>
<td>Substrate pH &amp; cation exchange capacity (CEC)</td>
<td>Alkalinity</td>
</tr>
<tr>
<td>Electrical conductivity (EC)</td>
<td>Nitrogen form &amp; concentration</td>
</tr>
<tr>
<td>Water quality</td>
<td>Plant Species</td>
</tr>
</tbody>
</table>

Testing species/fertilizer pH effects

- Species
  - Geraniums
  - Impatiens
  - Petunia
- 70%:30% peat:perlite media
- Hydrated lime (no residual)
- DI water (no alkalinity)
- 4-in-diameter azalea pots with saucers
- 18 commercial fertilizers

Acidic fertilizers do drop substrate-pH

Iron-efficient

- Geranium (Pelargonium x hortorum)
- Marigold (Tagetes)

Remember why fertilizers are potentially acidic or basic

- Cations are positively charged and acidic (NH₄⁺, K⁺, Ca²⁺)
- Anions are negatively charged and basic (NO₃⁻, SO₄²⁻, OH⁻)

But species vary with the same fertilizer

- Prone to Fe/Mn toxicity below pH 6.0
- Recommended pH 6.0-6.6
Iron-inefficient

- Calibrachoa
- Petunia

- Prone to Fe deficiency above pH 6.4
- Recommended pH 5.4-6.2

Why do plant species push pH up or down?

We have run experiments with both hydroponics and growing media

- Do iron-efficient geraniums take up mostly acidic cations?
- Do iron-inefficient petunias take up mostly basic anions?

Yes. The cation/anion ratio of species matches pH effect. They are programmed to get into trouble.

As Ammonium concentration increases, so does cation/anion uptake. And therefore, pH drops.

We can use this knowledge to improve pH management

- Uptake of cations such as NH$_4^+$ is acidic
- Uptake of anions such as NO$_3^-$ is basic
- Nitrogen is most important
- Geranium is acidic. Impatiens is intermediate. Petunia is basic.
- We can match nitrogen form & concentration to the crop species and water alkalinity to avoid pH drift

In conclusion

- pH management is not that complex
- Maintain pH around 5.6-6.4, and you will be fine.
- Understanding how factors interact will improve your pH management strategy

Fertilizer pH app available at BackPocketGrower.com