Managing water and oxygen for optimum rooting

Oxygen supply to roots

• Oxygen supply to roots is essential for root growth and plant health
• Root zone low oxygen (hypoxia) occurs at \(< 3 \text{ mg/L}\)
  – Decrease metabolism and nutrient uptake
  – Root death
  – Wilting
• Low oxygen and high substrate moisture increases the risk of root pathogens

Overwatering leads to disease

Root rot in *Ipomoea* (sweet potato)

Pythium spores

Dr. Rob Wick
University of Massachusetts

Overwatering delays rooting

Scaevola

• A saturated substrate delays root growth after callus

Oxygen in air and water

• Oxygen \((O_2)\) is a gas present in the atmosphere at 271 mg/L at 1 atm & 25°C
• Dissolved oxygen (DO) is 8.3 mg/L at saturation at 1 atm & 25°C
• DO is less soluble at high temperature
• Oxygen diffuses 10,000 times more quickly through air than water
When does it make sense to oxygenate?

**Oxygen injecting technology**

6-7 mg/L

25 - 33 mg/L

www.Mazzei.net, Technical bulletin No. 7

When does it make sense to oxygenate?

**Ponds**

Water quality issues: iron, manganese, hydrogen sulfide

When does it make sense to oxygenate?

**Hydroponics**

Completely water-logged conditions

Lei et al. (2015)

When does it make sense to oxygenate?

Water treatment

<table>
<thead>
<tr>
<th></th>
<th>Corn ear weight (g/pot)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aerated</td>
<td>34 grams</td>
</tr>
<tr>
<td>Non-aerated</td>
<td>17 grams</td>
</tr>
</tbody>
</table>

Lei et al. (2015)

Water-filled container

Pot filled with vermiculite

Corn plant
Oxygen injecting technology

Data collection: DO in solution

- Optical oxygen sensor (Neofox, Ocean Optics)
- Senses oxygen pressure
- Multi-point factory calibrated
- Temperature probe

We can super-saturate water, and DO levels stay very high for several hours at 75°F

<table>
<thead>
<tr>
<th>Water Type</th>
<th>Water Movement</th>
<th>Initial Time</th>
<th>Final Time 4.5 hr.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxygenated</td>
<td>Non-stirred</td>
<td>28.3 mg/L</td>
<td>26.5 mg/L</td>
</tr>
<tr>
<td>Oxygenated</td>
<td>Stirred (100 gal / hr)</td>
<td>26.8 mg/L</td>
<td>16.9 mg/L (37% decrease)</td>
</tr>
</tbody>
</table>

DO was measured at different points in greenhouse irrigation

- Source tank
- Bench no nozzle
- Bench nozzle

Does oxygenation benefit plant propagation under mist?

There were no differences in plant growth with oxygenated compared to tap water for lobelia and calibrachoa
Oxygen off-gassed when super-saturated water passed through a mist nozzle

![Graph showing dissolved oxygen concentration (mg/L) for different conditions.](image)

DO measured in irrigation water at a commercial operation was 98% of saturation after passing through a nozzle

<table>
<thead>
<tr>
<th></th>
<th>Before Nozzle</th>
<th>After Nozzle</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Before Nozzle</strong></td>
<td>7.0 mg/L (74%)</td>
<td>8.6 mg/L (98%)</td>
</tr>
</tbody>
</table>

Key findings

- Oxygenated water held in unpressurized containers remained super-saturated after a few hours
- There were no differences observed in root and plant growth for oxygenated water compared with ambient tap water during the propagation trial
- Water that passed through fine mist nozzles were brought to 100% DO saturation for oxygenated and tap water

What happens when we irrigate plants with oxygenated vs. ambient water without using a fine breaker

<table>
<thead>
<tr>
<th>Level</th>
<th>Water Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Tap</td>
<td>6.0 mg/L DO at 26°C</td>
</tr>
<tr>
<td>2</td>
<td>Oxygenated</td>
<td>27.7 mg/L DO at 26°C</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Level</th>
<th>Irrigation Delivery Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Top watered</td>
</tr>
<tr>
<td>2</td>
<td>Subirrigated</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Level</th>
<th>Plant Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><em>Calibrachoa x hybrid</em> ‘Aloha Kona Dark Red’</td>
</tr>
<tr>
<td>2</td>
<td>Lobelia erinus ‘Bella Aqua’</td>
</tr>
<tr>
<td>3</td>
<td><em>Pelargonium x hortorum</em> ‘Patriot Red’</td>
</tr>
</tbody>
</table>

Plants were irrigated when the average of 6 pots dried to 45% of container capacity

- Randomized complete block design with four blocks and two replicate pots per block for each treatment combination

There was an increase in root length and root dry mass for top watering compared to subirrigation for calibrachoa but no effect of oxygenation

![Image showing plants with and without oxygenation.](image)
Geraniums grew healthy and vigorous, and there were no treatment effects observed.

How does subirrigation with oxygenated or ambient water and different substrate moisture levels affect the growth of geranium?

<table>
<thead>
<tr>
<th>Water Type</th>
<th>Description</th>
<th>Substrate Moisture Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tap</td>
<td>6.0 mg/L DO at 26°C</td>
<td>High (80% of CC)</td>
</tr>
<tr>
<td>Oxygenated</td>
<td>27.7 mg/L DO at 26°C</td>
<td>Medium (45% of CC)</td>
</tr>
</tbody>
</table>

There was a slight increase in root length and root dry mass for high moisture compared to medium moisture level for geranium.

Can you increase DO the growing substrate by irrigating with oxygenated water compared to ambient water?

<table>
<thead>
<tr>
<th>Water Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tap</td>
<td>7 mg/L DO at 24°C</td>
</tr>
<tr>
<td>Oxygenated</td>
<td>29 mg/L DO at 24°C</td>
</tr>
</tbody>
</table>

Measuring dissolved oxygen in substrate

- Sub-irrigated & drained to container capacity
- Measured at 2 and 4-cm depth in substrate
  - Used a tooth pick to indent the substrate
  - Inserted the oxygen sensor
    - Equilibrated for 40 to 120 sec
    - Recorded temperature and DO

When a lot of oxygenated water was applied to pots the substrate-DO increased compared to ambient water.
Conclusions

- Continued growth of transplants
  - Irrigating with oxygenated water did not benefit plant growth of three bedding plants compared to tap water
  - Treatment effects on plant growth were observed for calibrachoa, lobelia, and sub-group of geranium with medium and high substrate moisture level
  - High porosity in peat-based substrate provided adequate oxygen to roots by air-filled pores (19% at container capacity for 4-in pots)

- Hypoxic growing conditions were not observed and therefore oxygenated water did not enhance or negatively affect plant growth
- Adding oxygenated water to an already saturated container substrate is not a recommended approach to irrigation management
- In container substrate, the supply of water and oxygen must be adequate to support plant growth demands
  - Substrate with porosity
  - Irrigation management by not overwatering

1 to 5 moisture scale

Manage water with the moisture scale

There isn’t much oxygen in water

Irrigation management
Water management is air management

Continue to study root environment on root growth and architecture

Continue to study root environment on root growth and architecture

How does container size and shape affect root growth?

Acknowledgements

- Dr. Paul Fisher
- Dr. Freyre’s Lab
- FNGLA Endowed Research Fund
- FRA