Potential Benefits of Using Hydrogen Peroxide in Crop Production Systems

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Why Hydrogen Peroxide ($\text{H}_2\text{O}_2$)?

Crop stress
- Crop plants subject to various stresses in their life cycle
- Crops develop stress tolerance or lose yield
- Most stresses are related to oxidative stress

$\text{H}_2\text{O}_2$
- Low concentration – a signaling compound
- High concentration – toxic causing cell death

In this presentation
- Can exogenous $\text{H}_2\text{O}_2$ reduce chilling injury?
Why Chilling Injury?

Greenhouse vegetables – chilling sensitive
- Tomatoes
- Cucumbers
- Sweet peppers

Chilling sensitivity – storage temperature of higher than 10°C is recommended

Consequence of chilling injury (< 10°C)
- Decay
Chilling Injury – symptoms and causes

Symptoms of chilling injury

– Pitting
– Decay
– Other (e.g. reduced radicle elongation)

Symptoms – most obvious after returning to room temperature

Causes – reactive oxygen species (ROS)
Objectives – H₂O₂ to Reduce Chilling Injury

Chilling stress
- Experimental plant – sweet potato
- Greenhouse crop – sweet pepper

Sweet potato – leaves and shoots (during production)
- Chilling injury < 10°C

Sweet peppers – colored fruits (during storage)
- Chilling injury < 7°C
- Decay, high CO₂, high C₂H₄
- *Alternaria* rot (< 7°C)
- *Botrytis* decay (< 4.5°C)

**Sweet potato and sweet peppers – used in our study**
Sweet Potato – Leaf (Injury index of 0 to 5 after 3 days at 2.5°C followed by 3 days at room temperature)

<table>
<thead>
<tr>
<th></th>
<th>Non-chilled</th>
<th>Chilled</th>
</tr>
</thead>
<tbody>
<tr>
<td>H₂O₂ 0 mM</td>
<td>0.12</td>
<td>2.25</td>
</tr>
<tr>
<td>H₂O₂ 15 mM</td>
<td>0</td>
<td>0.38</td>
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</tbody>
</table>
Sweet Potato – Leaf (Chilled)
Sweet Potato – Shoot Tip (3-day chill at 2.5°C followed by 2 or 7 days at 20°C)

150 mM H₂O₂ + 16h photoperiod
Increased antioxidant capacity (ORAC) of chilled shoot tips
2 days after chilling

150 mM H₂O₂ + 16h photoperiod
Reduced injury index of chilled shoot tips
7 days after chilling
Sweet Potato – Shoot Tip (3-day chill at 2.5°C followed by 2 or 7 days at 20°C)

Negative correlation between antioxidant capacity (ORAC) and chilling injury

Increase of ORAC preceded the reduction of injury index

![Graph showing the negative correlation between ORAC and injury index. The equation is: y = -63.42x + 550.17, R² = 0.9572.]

Fig. 2C - ORAC measured 2 days after chill negatively correlated with injury index observed 7 days after chill
Sweet Pepper - Commercial Harvests

Increase in Decay Index after Storage - Commercial Harvests

Storage Temperature (C)

Increase in Decay Index (31d-28d)

Forever
Striker

<table>
<thead>
<tr>
<th>Temperature (C)</th>
<th>Forever</th>
<th>Striker</th>
</tr>
</thead>
<tbody>
<tr>
<td>1C</td>
<td>2.5</td>
<td>3.0</td>
</tr>
<tr>
<td>2.5C</td>
<td>2.5</td>
<td>3.5</td>
</tr>
<tr>
<td>5C</td>
<td>1.0</td>
<td>1.5</td>
</tr>
<tr>
<td>7.5C</td>
<td>0.5</td>
<td>1.0</td>
</tr>
<tr>
<td>10C</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>12.5C</td>
<td>1.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>
Effects of pulsed 500 ppm H$_2$O$_2$ (ca. 14.7 mM) on decay of stored sweet peppers

H$_2$O$_2$ decreased the decay of stored sweet peppers

At 2.5° or 5°C, chilling injury occurred
Sweet Pepper – Fruit (decay index after 4-week storage plus 3 days at room temperature)

<table>
<thead>
<tr>
<th>Weeks after pulse H₂O₂ application</th>
<th>2.5°C</th>
<th>5.0°C</th>
<th>7.5°C</th>
<th>10.0°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Week 1</td>
<td>4.6</td>
<td>6.9</td>
<td>13.6</td>
<td>21.8</td>
</tr>
<tr>
<td>Week 2</td>
<td>6.0</td>
<td>8.5</td>
<td>15.3</td>
<td>17.7</td>
</tr>
<tr>
<td>Week 3</td>
<td>7.5</td>
<td>12.7</td>
<td>17.4</td>
<td>19.9</td>
</tr>
</tbody>
</table>
H$_2$O$_2$ – Induced Chilling Tolerance

Survival rate: after a 36h, 4°C chilling stress
- 8°C pre-treated seedlings – 97%
- H$_2$O$_2$ pre-treated seedling – 71%
- Control (25°C) – 33%

Chilling of mung bean seedlings induces symptoms of oxidative stress. Both acclimation at 8°C and H$_2$O$_2$ pre-treatment stimulate protective mechanisms that alleviate chilling stress. Glutathione is an essential, but not the only, protective compound.

H$_2$O$_2$ – Induced Salt Tolerance

Barley: 5 – 25 mM H$_2$O$_2$ induced maximal accumulation of osmoprotectant (e.g. glycinebetaine)

Rice: 10 µM H$_2$O$_2$ enhanced salt tolerance in rice seedlings

Tomato: 50 mM H$_2$O$_2$ increased sugar content in tomato fruit by 1.5 fold

Conclusion – Our Study Indicates

Sweet Potato – $H_2O_2$ increased chilling tolerance of excised leaves (15 mM $H_2O_2$) and shoot tips (150 mM $H_2O_2$)

Sweet Pepper – pulsed 500 ppm $H_2O_2$ (14.7 mM) application in greenhouse decreased storage decay at 2.5 or 5°C

Beneficial effects of $H_2O_2$ appear to vary with environments under which crop plants are grown

Careful experiments are necessary to define parameters of practical uses of $H_2O_2$ in crop production systems
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