Modifying High Tunnels for Improved Performance

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Background

High Tunnels are being studied and used for

• Season extension of berry crops
  • Advance the spring crop
  • Extend the fall crop
• Environmental protection
  • Freezes, frosts, rains
• Pest exclusion
The Need for High Tunnel Modifications/Additions

• More heating in early spring and late fall to extend harvest
• More protection in early spring and late fall to protect flowers/fruit
• Less heat in the summer months
• Cooling options for late summer months
Sub-studies for Potential Tunnel Modifications/Additions to Extend, Protect Crops

1. **Tunnels in Tunnels (TnT)**
   - Build temporary TnT in order to provide additional environmental modification of the tunnel system in spring and fall to provide more heat

2. **Summer Shading**
   - Apply shade over plant canopies to reduce heat stress and potentially delay flowering in primocane fruiting blackberry and raspberry

3. **Overhead Mist Systems (not being presented)**
   - Install overhead mist lines as an add-on to existing irrigation line to help cool during severe heat
Spring Frosts by Region

☑ One single layer of poly provides one hardiness zone of protection
Sub-study 1. Tunnels in Tunnels (TnT)

Research and Objectives

• Spring Production Systems – Floricane berries
  1. Increase heat unit accumulation to advance the crop
  2. Provide increased frost/freeze protection during freezing events during early season bloom – protecting flowers

• Fall Production Systems – Primocane berries
  1. Increase heat unit accumulation to maintain flowering longer through the season
  2. Increase heat unit accumulation to sustain fruit maturation
  3. Provide increased frost/freeze protection during freezing events during fruit ripening – protecting fruit
Effect of TnT on Spring ‘Natchez’ Blackberry Yield

- **2013**
  - Cumulative Yield: 3,766 lbs/A
  - Cumulative Yield: 15,549 lbs/A
  - Cumulative Yield: 19,363 lbs/A

- **2014**
  - Cumulative Yield: 10,030 lbs/A
  - Cumulative Yield: 22,897 lbs/A
  - Cumulative Yield: 28,334 lbs/A

Dates:
- 6/13, 6/18, 6/23, 7/3, 7/8, 7/13, 7/18, 7/23, 7/28
- 5/26, 6/5, 6/15, 6/25, 7/5, 7/15, 7/25, 8/4
Effect of TnT on Spring ‘Natchez’ Blackberry Quality

**Berry Weight (g)**

- **FD 2013**
- **HT 2013**
- **TNT 2013**
- **FD 2014**
- **HT 2014**
- **TNT 2014**

**Marketable Yield (%)**

- **FD 2013**
- **HT 2013**
- **TNT 2013**
- **FD 2014**
- **HT 2014**
- **TNT 2014**

**Soluble Solids**

- **FD 2013**
- **HT 2013**
- **TNT 2013**
- **FD 2014**
- **HT 2014**
- **TNT 2014**

N=3
Effect of TnT on Fall ‘Prime-Ark 45’ Blackberry Yield

- **2013**
  - TNT: ~12,308 lbs/A
  - HT: ~11,889 lbs/A
  - FD: ~7,090 lbs/A

- **2014**
  - TNT: ~7,446 lbs/A
  - HT: ~7,030 lbs/A
  - FD: ~4,672 lbs/A

*lbs/A calculated at 8 ft row spacing
Effect of TnT on Fall ‘Prime-Ark 45’ Blackberry Quality

**Berry Weight (g)**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>2013</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>FD</td>
<td>6.0</td>
<td>5.0</td>
</tr>
<tr>
<td>HT</td>
<td>7.0</td>
<td>6.0</td>
</tr>
<tr>
<td>TNT</td>
<td>8.0</td>
<td>7.0</td>
</tr>
</tbody>
</table>

**Marketable Yield (%)**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>2013</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>FD</td>
<td>35%</td>
<td>40%</td>
</tr>
<tr>
<td>HT</td>
<td>40%</td>
<td>45%</td>
</tr>
<tr>
<td>TNT</td>
<td>45%</td>
<td>50%</td>
</tr>
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</table>

**Soluble Solids**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>2013</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>FD</td>
<td>9.0</td>
<td>9.5</td>
</tr>
<tr>
<td>HT</td>
<td>8.5</td>
<td>8.0</td>
</tr>
<tr>
<td>TNT</td>
<td>8.0</td>
<td>8.5</td>
</tr>
</tbody>
</table>
TnT Study Seasonal Summary

**Spring**
- TnT has potential to increase yields 1-2 weeks earlier than HT, 2-3 weeks earlier than field
- Growers may want to consider having a combination of both TnT and HT when considering windows of production in spring
- Both TnT and HT protect the crop during poor weather conditions such as wet springs, late frosts
- TnT can limit pollination
- HT significantly increased berry weight across two growing seasons, TnT increased for one
- TnT and HT both significantly increased marketable yield percentage compared to field both seasons
- Field showed significantly greater sugar content in both seasons

**Fall**
- TnT and HT significantly increased yield by ~40% for an extended fall season
- TnT and HT significantly increased yields on average 30-40% for a short fall season (early frost)
- TnT and HT showed increased berry weight although variable between seasons
- HT significantly increased sugar content for both growing seasons, TnT showed greater than field in one season
TnT Schematic
Methanol chafing dish burners 1/50sqft Burn 6-7 hrs
Effect of high tunnel and tunnel in tunnel (TnT) on **daily average temperature** over a 1 month period October-November, 2013.
Effect of high tunnel and tunnel in tunnel on daily low temperature over a 1 month period October-November, 2013.
Effect of high tunnel and tunnel in tunnel on ambient temperature difference over a 1 month period October-November, 2013.
Effect of high tunnel and tunnel in tunnel on **temperatures** over a 1 month period October-November, 2013.

<table>
<thead>
<tr>
<th>Trt</th>
<th>Avg. Temp (°C)</th>
<th>Avg. Minimum Temp (°C)</th>
<th>Ambient Temp Difference (°C)</th>
<th>Freeze Exposure (hrs/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>Mean</td>
<td>N</td>
<td>Mean</td>
</tr>
<tr>
<td>TnT</td>
<td>96</td>
<td>14.3 a</td>
<td>96</td>
<td>6a</td>
</tr>
<tr>
<td>HT</td>
<td>96</td>
<td>12.1 b</td>
<td>96</td>
<td>4.3 b</td>
</tr>
<tr>
<td>Field</td>
<td>96</td>
<td>10.6 c</td>
<td>96</td>
<td>4.2 b</td>
</tr>
<tr>
<td>Prob &gt; F</td>
<td>&lt;0.0001</td>
<td>0.035</td>
<td>0.0004</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

Z Mean separation using LSD for comparisons and means followed by different letters are significantly different, \( \alpha=0.05 \).
Effect of high tunnel and tunnel in tunnel on temperature with supplemental heating over a 48 hour period November 12-13, 2013.
Effect of high tunnel and tunnel in tunnel on ambient temperature difference with supplemental heating over a 48 hour period November 12-13, 2013.
Table 3. Effect of high tunnel and tunnel in tunnel on temperatures with supplemental heating over a 48 hour period November 12-13, 2013.

<table>
<thead>
<tr>
<th>Trt</th>
<th>Avg. Temp (°C) N Mean</th>
<th>Avg. Minimum Temp (°C) N Mean</th>
<th>Ambient Temp Difference (°C) N Mean</th>
<th>Freeze Exposure (hrs) N Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>TnT</td>
<td>6 15.1 a</td>
<td>6 1.3 a</td>
<td>6 7.1 a</td>
<td>6 0.5 b</td>
</tr>
<tr>
<td>HT</td>
<td>6 9.8 b</td>
<td>6 -3.1 b</td>
<td>6 2.8 b</td>
<td>6 4.3 a</td>
</tr>
<tr>
<td>Field</td>
<td>6 4.4 c</td>
<td>6 -5.8 b</td>
<td>6 0 c</td>
<td>6 7.7 b</td>
</tr>
</tbody>
</table>

Prob > F <0.0001 0.0009 <0.0001 0.003

Mean separation using LSD for comparisons and means followed by different letters are significantly different, α=0.05.
Effect of high tunnel and tunnel in tunnel on temperature **with no supplemental heating** over a 48 hour period November 23-24, 2013.
Effect of high tunnel and tunnel in tunnel on ambient temperature difference with no supplemental heating over a 48 hour period November 23-24, 2013.

![Graph showing temperature difference over time with high tunnel, tunnel in tunnel, and field data. The graph highlights daytime periods with a temperature difference between 0 and 20 degrees Celsius.]
Table 4. Effect of high tunnel and tunnel in tunnel on temperatures with no supplemental heating over a 48 hour period November 23-24, 2013.

<table>
<thead>
<tr>
<th>Trt</th>
<th>N</th>
<th>Avg. Temp (°C)</th>
<th>Avg. Minimum Temp (°C)</th>
<th>Ambient Difference Temp (°C)</th>
<th>Freeze Exposure (hrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TnT</td>
<td>6</td>
<td>5.1 a²</td>
<td>-1.6 a</td>
<td>3.4 a</td>
<td>6</td>
</tr>
<tr>
<td>HT</td>
<td>6</td>
<td>2.5 ab</td>
<td>-4 ab</td>
<td>1.1 b</td>
<td>7</td>
</tr>
<tr>
<td>Field</td>
<td>6</td>
<td>-0.3 b</td>
<td>-5.1 b</td>
<td>0 c</td>
<td>14</td>
</tr>
</tbody>
</table>

Prob > F | 0.007 | 0.03 | <0.0001 | ns

² Mean separation using LSD for comparisons and means followed by different letters are significantly different, α=0.05.
TnT Study Summary

- Tunnels provide increased daily heat accumulation
- Tunnels provide minimal heat conservation during a frost
- Tunnels with supplemental heat had some temperature increase
- TnT provide increased daily heat accumulation over tunnels
- TnT provide increased heat conservation during a frost
- TnT with supplemental heat had significant temperature increase
Sub-study 2. High Tunnel Shading of Brambles

Research Objectives

• Focus: Fall high tunnel study
• Place shade structures over plant canopies of both blackberry and raspberry ~July 1 for 30 days to reduce heat stress and delay flowering
• Delaying flowering and reducing heat stress may have potential to increase marketable yields
Effects of Shade on ‘Prime-Ark 45’ Blackberry Yield

2013

Cumulative Yield (g per 10ft plots)

Date

No Shade
Shade

N=3

2014

Cumulative Yield (g per 10ft plots)

Date

No Shade
Shade

N=3

*lbs/A calculated at 8 ft row spacing

= ~6,809 lbs/A

= ~4,360 lbs/A

= ~7,588 lbs/A

= ~5,604 lbs/A
Effects of Shade on ‘Prime-Ark 45’ Blackberry Quality

**Berry Weight (g)**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>2013</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>NoShade</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>Shade</td>
<td>8</td>
<td>7</td>
</tr>
</tbody>
</table>

**Marketable Yield (%)**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>2013</th>
<th>2013</th>
<th>2014</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>NoShade</td>
<td>30</td>
<td>40</td>
<td>50</td>
<td>60</td>
</tr>
<tr>
<td>Shade</td>
<td>25</td>
<td>35</td>
<td>45</td>
<td>55</td>
</tr>
</tbody>
</table>

**Soluble Solids (brix)**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>2013</th>
<th>2013</th>
<th>2014</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>NoShade</td>
<td>9</td>
<td>8</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>Shade</td>
<td>10</td>
<td>9</td>
<td>8</td>
<td>7</td>
</tr>
</tbody>
</table>
Effects of Shade on Raspberry Yield

Cumulative Yield (g per 10ft plots)

Date

2013

N=3

*lbs/A calculated at 8 ft row spacing

No Shade

Shade

N=3

= ~2,471 lbs/A

= ~1,787 lbs/A
Effects of Shade on ‘Nantahala’ Raspberry Quality

### Berry Weight (g)

- **NoShade**: N=3
- **Shade**: N=3

### Marketable Yield (%)

- **NoShade**: N=3
- **Shade**: N=3

### Soluble Solids

- **NoShade**: N=3
- **Shade**: N=3
HT Shade Study Summary and Conclusions for Blackberry

- Shading ~1 month before fruiting showed no effect on reducing heat during flowering
- Shade significantly reduced flowering (not pollination)
- Shade significantly increased cumulative yield on average 30-40% over two growing seasons
- Shade increased berry weight in blackberry but could be contributed to lower yields (further statistical analysis needed)
- Shade significantly increased marketable yield percentage in one growing season but not enough to justify cost and labor of shading
- Shade had no effect on sugar content
HT Shade Study Summary for Raspberry

• Shading ~1 month prior to expected yields significantly increased yield in ‘Nantahala’ raspberry by ~30% for one growing season
• Additional season of data needed to conclude effect on yield
• Shade reduced overall raspberry quality by significantly reducing berry size and marketable yield percentage
• Shade did not have any effect on sugar content of raspberry
• Reducing the amount of shade may have potential to increase fruit quality
What have we learned?

- TnT can be a good tool for growers for enhancing and protecting seasonal bramble yields
- Growers should consider TnT as a tool for increasing early spring yields
- TnT has potential to be a good tool in the fall for protecting and extending harvest but will vary by year
- TnT is not outperforming HT in fall production
- HT can serve as a form of crop insurance for growers during seasonal occurrence of bad weather (wet springs, late frosts)
- Shading mid-late summer for fall primocane producing blackberry is NOT recommended
- Shading mid-late summer for fall raspberry production should be considered and additional seasons of data needed to confirm
Thank you!

Questions?