Winter Production of Leafy Greens in the Southwestern USA Using Hoop Houses

Hoop houses at the Sustainable Agriculture Science Center, Alcalde NM

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http://aces.nmsu.edu/academics/aeab/hoop-house-project.html
The 2008 Farm Bill launched the Seasonal High Tunnel Initiative to help farmers extend their growing season\(^1\)

USDA Environmental Quality Incentives Program (EQIP) has funded dozens of high tunnels in Colorado and New Mexico

Research and literature on the use of these structures for winter production the high elevation, arid climates of the southwest (CO, AZ, NM) is limited\(^2\)

Most research in the U.S.A. on crop production in high tunnels has been in the northeastern and mid-Atlantic states including Pennsylvania\(^3\) and New Jersey\(^4\)

Study Objectives

- To evaluate the effects of planting date in **low cost** hoop houses for **winter production**:
  - Hypothesis: The crops planted earlier will produce a higher yield than the crops planted later.

- To evaluate the effects of hoop house heat-retaining capacity on crop yield for **winter production**:
  - Hypothesis: The crops grown in the highest heat retaining model of hoop house (double layer of plastic insulation and water barrels) will produce the highest yield.
Materials & Methods

Construction of hoop houses at Leyendecker Plant Science Research Center in Sept 2009
Hoop House Defined

Definition: **A high tunnel or hoop house** is defined as a plastic covered, passively heated, walk-in, semi-permanent structure\(^1\)

Hoop House Models

- **SL (Single Layer)**=Heavyweight woven plastic (SOLAROOF 172, J&M Industries; Ponchatoula, LA) covered the SL model
- **DL (Double Layer)**=DL models were covered with a lightweight woven plastic (SOLAROOF 140), followed by a second layer of heavyweight plastic (SOLAROOF 172) inflated with a fan
- **DL+B (Double Layer with Barrels)**=DL+B models had the double layer of plastic plus sixteen 208 liter (55 gallon) water barrels aligned on the north interior wall

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Passive Heating & Insulation Layer

- Double layer of plastic with air inflation system and electric blower fan
- 10.2cm (4 in) air space in between plastic layers
Sixteen 208 liter (55 gallon) barrels painted black with spray paint and filled with water
Barrels were aligned on the north side of the house to minimize shading of the crop in the hoop house from the low southern sun in the winter
Three or more gallons of water per square foot of south facing glazing

1. FarmTek. 2012. PolyMax Water Wall Bags. Dyersville, IA. 
http://www.farmtek.com/farm/supplies/ProductDisplay?catalogId=10052&storeId=10001&langId=-1&division=FarmTek&productId=109786
Experimental Plots

Emmanuel Hecher Collecting Plot Data, January 2011
Experimental Design

- Three models of house at two experiment stations:
  - Three models of house (SL, DL, DL+B) were replicated twice and constructed in a randomized complete block design
  - Sustainable Ag Science Center in Alcalde, NM and Leyendecker Plant Science Research Center in Las Cruces, NM

- Six replications of four treatments:
  - Planting date (October and November)
  - Crop (lettuce and spinach)
Hoop House Locations

Hesperus, CO
Elevation: 7,500ft
Avg Low in Jan: 8°F

Durango, CO
Elevation: 6,500ft
Avg Low in Jan: 10°F

Tsaile, AZ
Elevation: 6,500ft
Avg Low in Jan: 17°F

Window Rock, AZ
Elevation: 7,000ft
Avg Low in Jan: 14°F

Alcalde, NM
Elevation: 5,500ft
Avg Low in Jan: 15°F

Tijeras, NM
Elevation: 6,000ft
Avg Low in Jan: 15°F

Las Cruces, NM
Elevation: 4,000ft
Avg Low in Jan: 23°F

WeatherReports.com
Hardiness zones: NM and CO

Southwestern U.S.
Timeline and Locations

Timeline:
- Three winter seasons (Oct-March) from fall 2009-spring 2012

Locations:
- Leyendecker Plant Science Research Center in Las Cruces, NM (southern NM)
- Sustainable Ag Science Center at Alcalde, NM (northern NM)

<table>
<thead>
<tr>
<th>Location</th>
<th>Avg Maximum Temp in Jan</th>
<th>Avg Minimum Temp in Jan</th>
<th>Elevation</th>
<th>Growing Season</th>
</tr>
</thead>
<tbody>
<tr>
<td>Southern NM</td>
<td>59° F (14.6° C)</td>
<td>28° F (-2.1° C)</td>
<td>4,000 ft</td>
<td>~220 days</td>
</tr>
<tr>
<td>Northern NM</td>
<td>48° F (8.8° C)</td>
<td>15° F (-7.5° C)</td>
<td>5,500 ft</td>
<td>~150 days</td>
</tr>
</tbody>
</table>


Dimensions and Orientation

4.5 ft

3.5 ft

16 ft

32 ft

NORTH
Temperature Probes

Data loggers recorded temperature every 30 minutes, 24 hours a day. There were 6 probes per house (3 in. deep in the soil and 12 in. above soil surface for air temp).
Data Collection

- Fresh weight, dry weight, plant height, stand count
- Temperature data in different models of hoop house
- Photosynthetically active radiation (PAR) on the winter solstice every year
- Soil tested each year before first planting
- Irrigation water testing
Row Cover as Additional Insulation

- Row cover (Agribon AG-19, J&M Industries) was used to cover the lettuce and spinach in all houses for additional cold protection.
- A 2-year study in southern New Mexico demonstrated that row cover increased lettuce yield by 23% in the fall and 70% in the spring. Row cover increased spinach yield by 68% in the fall and 66% in the spring.
- Row cover typically raises temperatures several degrees, effectively lengthening the growing season.

• ‘Flashy Trout’s Back’ lettuce is a high yielding cultivar for fall production in Las Cruces, NM$^{1,2}$
• ‘Bloomsdale’ spinach was popular in a local CSA and also yields in Las Cruces$^1$
• Multiple harvests off one planting, efficient space use
• Time to harvest is 35-50 days for spinach and 42-56 days for lettuce$^3$
• Lettuce and spinach have relatively high resistance to frost and light freezes$^4$

Air Temperature Extremes in 3 Models of Straight Framed Hoop House
Alcalde, NM

Degrees F

SL
DL
DL+B

Air Temp Thresholds

Date

11/14/06 11/11/06 11/18/06 11/25/06 12/2/06 12/9/06 12/16/06 12/23/06 12/30/06 1/6/07 1/13/07 1/20/07 1/27/07 2/3/07 2/10/07 2/17/07 2/24/07 3/3/07 3/10/07 3/17/07
Air Temperature Extremes in 3 Models of Straight Framed Hoop House
Las Cruces, NM 2011

[Graph showing temperature extremes across dates for SL, DL, DL+B models.]

Air Temp Thresholds
Soil Temperature Data (Nov-Feb)

Soil Temp Inside of and Outside of Single Layer Hoop House
Alcalde, NM 2011

Graph showing data on soil temperature inside and outside a single layer hoop house in Alcalde, NM for the year 2011. The graph includes lines for maximum and minimum inside soil temperatures, maximum and minimum outside soil temperatures, and maximum and minimum optimum soil temperatures. The dates range from November 14, 2006, to February 3, 2007.
Soil Temperature Data (Nov-Feb)

Soil Temp Inside of and Outside of Single Layer Hoop House
Las Cruces, NM 2011
Row Cover

Air Temp Under Row Cover and Not Under Row Cover in Single Layer Hoop House
Alcalde, NM

[Graph showing air temperature trends under and without row cover in a single layer hoop house with dates and temperature values.]
Row Cover

Soil Temp Under Row Cover and Not Under Row Cover in a Single Layer Hoop House
Alcalde, NM 2011

Graph showing soil temperature data from 11/4/06 to 2/3/07, with different lines representing maximum and minimum soil temperatures under and not under row cover, and the max and min optimum soil temperatures.
February 3, 2011: Brrr!

Temperature outside: -26°F
Temperature inside: -4°F
Temperature inside, under row cover: +15°F
Total temperature difference: 41°F!
February 3, 2011: Brrr!

Outside temperature: -6°F
Single layer (SL): 5°F
Double layer (DL): 10°F
Double layer plus barrel (DL+B): 18°F
Total temperature difference: 22°F!
Harvest Results

Collecting harvest data at Leyendecker Plant Science Research Center in January, 2011
Total season long crop yields from ‘Bloomsdale’ spinach planted in October and in November in three different models of hoop house (SL, DL, DL+B) in Las Cruces, NM. Yields are combined 180 feet of row for each crop.
Total season long crop yields from ‘Trout’s Back’ lettuce planted in October and in November in three different models of hoop house (SL, DL, DL+B) in Las Cruces, NM. Yields are combined 180 feet of row for each crop.
## Economics: yields

Table 1. Yields of winter leafy greens in three high tunnel designs in two New Mexico locations, three planting dates, and three seasons (2009–12).

<table>
<thead>
<tr>
<th>Design</th>
<th>Planting mo.</th>
<th>Crop</th>
<th>Las Cruces, S2</th>
<th>Alcalde, S1</th>
<th>Alcalde, S2</th>
<th>Alcalde, S3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mean yield (lb/tunnel)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SL</td>
<td>October</td>
<td>Lettuce</td>
<td>51.7</td>
<td>N/P*</td>
<td>36.1</td>
<td>60.9</td>
</tr>
<tr>
<td>SL</td>
<td>November</td>
<td>Lettuce</td>
<td>39.4</td>
<td>8.9</td>
<td>38.3</td>
<td>42.2</td>
</tr>
<tr>
<td>SL</td>
<td>December</td>
<td>Lettuce</td>
<td>N/P</td>
<td>7.1</td>
<td>N/P</td>
<td>N/P</td>
</tr>
<tr>
<td>SL</td>
<td>October</td>
<td>Spinach</td>
<td>47.6</td>
<td>N/P</td>
<td>28.5</td>
<td>49.7</td>
</tr>
<tr>
<td>SL</td>
<td>November</td>
<td>Spinach</td>
<td>47.5</td>
<td>6.6</td>
<td>14.4</td>
<td>37.0</td>
</tr>
<tr>
<td>SL</td>
<td>December</td>
<td>Spinach</td>
<td>N/P</td>
<td>6.4</td>
<td>N/P</td>
<td>N/P</td>
</tr>
<tr>
<td>DL</td>
<td>October</td>
<td>Lettuce</td>
<td>52.4</td>
<td>N/P</td>
<td>37.3</td>
<td>90.8</td>
</tr>
<tr>
<td>DL</td>
<td>November</td>
<td>Lettuce</td>
<td>55.5</td>
<td>11.1</td>
<td>18.5</td>
<td>76.7</td>
</tr>
<tr>
<td>DL</td>
<td>December</td>
<td>Lettuce</td>
<td>N/P</td>
<td>10.1</td>
<td>N/P</td>
<td>N/P</td>
</tr>
<tr>
<td>DL</td>
<td>October</td>
<td>Spinach</td>
<td>47.4</td>
<td>N/P</td>
<td>36.8</td>
<td>67.3</td>
</tr>
<tr>
<td>DL</td>
<td>November</td>
<td>Spinach</td>
<td>48.3</td>
<td>12.7</td>
<td>24.5</td>
<td>52.2</td>
</tr>
<tr>
<td>DL</td>
<td>December</td>
<td>Spinach</td>
<td>N/P</td>
<td>10.5</td>
<td>N/P</td>
<td>N/P</td>
</tr>
<tr>
<td>DL+B</td>
<td>October</td>
<td>Lettuce</td>
<td>42.3</td>
<td>N/P</td>
<td>38.7</td>
<td>68.2</td>
</tr>
<tr>
<td>DL+B</td>
<td>November</td>
<td>Lettuce</td>
<td>13.2</td>
<td>14.8</td>
<td>45.9</td>
<td>48.0</td>
</tr>
<tr>
<td>DL+B</td>
<td>December</td>
<td>Lettuce</td>
<td>N/P</td>
<td>7.8</td>
<td>N/P</td>
<td>N/P</td>
</tr>
<tr>
<td>DL+B</td>
<td>October</td>
<td>Spinach</td>
<td>31.7</td>
<td>N/P</td>
<td>23.8</td>
<td>40.0</td>
</tr>
<tr>
<td>DL+B</td>
<td>November</td>
<td>Spinach</td>
<td>38.0</td>
<td>13.5</td>
<td>12.4</td>
<td>39.2</td>
</tr>
<tr>
<td>DL+B</td>
<td>December</td>
<td>Spinach</td>
<td>N/P</td>
<td>9.0</td>
<td>N/P</td>
<td>N/P</td>
</tr>
</tbody>
</table>

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*SL = single layer of plastic, DL = double layer, DL+B = double layer plus barrels.

*S1 = season 1 (2009–10), S2 = season 2 (2010–11), S3 = season 3 (2011–12).

*High tunnels were 16 × 32 ft (4.9 × 9.8 m) outside dimensions; 1 lb/512-ft^2 (47.6 m^2) tunnel = 85.0781 lb/acre = 95.3599 kg·ha⁻¹.

*Not planted in seasons 2 or 3.

From: Hecher et al., 2014 (HortTechnology and online)
### Economic probabilities: Las Cruces

#### Table 3. Percentage chance of positive returns at different crop selling prices and in various high tunnel scenarios, Las Cruces, NM.

<table>
<thead>
<tr>
<th>Scenario (tunnel design, crop, planting mo.)</th>
<th>Chance of positive returns (%)</th>
<th>Sale price ($/lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SL, L, October</td>
<td></td>
<td></td>
</tr>
<tr>
<td>54</td>
<td>79</td>
<td>88</td>
</tr>
<tr>
<td>SL, L, November</td>
<td></td>
<td></td>
</tr>
<tr>
<td>36</td>
<td>60</td>
<td>72</td>
</tr>
<tr>
<td>SL, S, October</td>
<td></td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>89</td>
<td>97</td>
</tr>
<tr>
<td>SL, S, November</td>
<td></td>
<td></td>
</tr>
<tr>
<td>54</td>
<td>85</td>
<td>93</td>
</tr>
<tr>
<td>DL, L, October</td>
<td></td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>83</td>
<td>93</td>
</tr>
<tr>
<td>DL, L, November</td>
<td></td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>83</td>
<td>93</td>
</tr>
<tr>
<td>DL, S, October</td>
<td></td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>84</td>
<td>96</td>
</tr>
<tr>
<td>DL, S, November</td>
<td></td>
<td></td>
</tr>
<tr>
<td>42</td>
<td>71</td>
<td>81</td>
</tr>
<tr>
<td>DL+B, L, October</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>56</td>
<td>69</td>
</tr>
<tr>
<td>DL+B, L, November</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>9</td>
<td>19</td>
</tr>
<tr>
<td>DL+B, S, October</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>40</td>
<td>63</td>
</tr>
<tr>
<td>DL+B, S, November</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>55</td>
<td>73</td>
</tr>
</tbody>
</table>

- Probabilities are not year specific, rather they are relevant for all the harvests associated with a particular crop, planting date, and high tunnel design. The probability distributions were fit based on all the harvests from each scenario.
- SL = single layer of plastic, DL = double layer, DL+B = double layer plus barrels, L = lettuce, S = spinach.
- $1.00/lb = $2.2046/kg.

From: Hecher et al., 2014 (HortTechnology and online)
Economic probabilities: Alcalde

<table>
<thead>
<tr>
<th>Scenario (tunnel design, crop, planting mo.)</th>
<th>Chance of positive returns (%)</th>
<th>Sale price ($/lb)(^x)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SL, L, October</td>
<td>59</td>
<td>70</td>
</tr>
<tr>
<td>SL, L, November</td>
<td>77</td>
<td>80</td>
</tr>
<tr>
<td>SL, S, October</td>
<td>77</td>
<td>80</td>
</tr>
<tr>
<td>SL, S, November</td>
<td>60</td>
<td>69</td>
</tr>
<tr>
<td>DL, L, October</td>
<td>47</td>
<td>68</td>
</tr>
<tr>
<td>DL, L, November</td>
<td>40</td>
<td>56</td>
</tr>
<tr>
<td>DL, S, October</td>
<td>9</td>
<td>68</td>
</tr>
<tr>
<td>DL, S, November</td>
<td>23</td>
<td>37</td>
</tr>
<tr>
<td>DL+B, L, October</td>
<td>57</td>
<td>69</td>
</tr>
<tr>
<td>DL+B, L, November</td>
<td>25</td>
<td>39</td>
</tr>
<tr>
<td>DL+B, S, October</td>
<td>11</td>
<td>22</td>
</tr>
<tr>
<td>DL+B, S, November</td>
<td>11</td>
<td>22</td>
</tr>
</tbody>
</table>

\(^x\) Probabilities are not year specific, rather they are relevant for all the harvests associated with a particular crop, planting date, and high tunnel design. The probability distributions were fit based on all the harvests from each scenario across all years.

\(^y\) SL = single layer of plastic, DL = double layer, DL+B = double layer plus barrels, L = lettuce, S = spinach.

\(^x\) $1.00/lb = $2.2046/kg.

From: Hecher et al., 2014 (HortTechnology and online)
### Economics: estimated returns

#### Table 6. Sensitivity analysis and estimated returns for high tunnel lettuce production across a range of actual yields and selling prices and three high tunnel designs: single layer of plastic (SL), double layer (DL), and double layer plus barrels (DL+B).

<table>
<thead>
<tr>
<th>Yield (lb/tunnel)</th>
<th>2.00 (SL returns $/tunnel)</th>
<th>4.00</th>
<th>6.00</th>
<th>2.00 (DL returns $/tunnel)</th>
<th>4.00</th>
<th>6.00</th>
<th>2.00 (DL+B returns $/tunnel)</th>
<th>4.00</th>
<th>6.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>(34.70)</td>
<td>(24.70)</td>
<td>(14.70)</td>
<td>(50.15)</td>
<td>(40.15)</td>
<td>(30.15)</td>
<td>(61.69)</td>
<td>(51.69)</td>
<td>(41.69)</td>
</tr>
<tr>
<td>20</td>
<td>(4.70)</td>
<td>35.30</td>
<td>75.30</td>
<td>(20.15)</td>
<td>19.85</td>
<td>59.85</td>
<td>(31.69)</td>
<td>8.31</td>
<td>48.31</td>
</tr>
<tr>
<td>35</td>
<td>25.30</td>
<td>95.30</td>
<td>165.30</td>
<td>9.85</td>
<td>79.85</td>
<td>149.85</td>
<td>(1.69)</td>
<td>68.31</td>
<td>138.31</td>
</tr>
<tr>
<td>50</td>
<td>55.30</td>
<td>155.30</td>
<td>255.30</td>
<td>39.85</td>
<td>139.85</td>
<td>239.85</td>
<td>28.31</td>
<td>128.31</td>
<td>228.31</td>
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<td>65</td>
<td>85.30</td>
<td>215.30</td>
<td>345.30</td>
<td>69.85</td>
<td>199.85</td>
<td>329.85</td>
<td>58.31</td>
<td>188.31</td>
<td>318.31</td>
</tr>
<tr>
<td>80</td>
<td>115.30</td>
<td>275.30</td>
<td>435.30</td>
<td>99.85</td>
<td>259.85</td>
<td>419.85</td>
<td>88.31</td>
<td>248.31</td>
<td>408.31</td>
</tr>
<tr>
<td>95</td>
<td>145.30</td>
<td>335.30</td>
<td>525.30</td>
<td>129.85</td>
<td>319.85</td>
<td>509.85</td>
<td>118.31</td>
<td>308.31</td>
<td>498.31</td>
</tr>
</tbody>
</table>

*Estimated returns are net of materials, seed, and electricity costs (the latter for DL and DL+B only). These returns apply to both Alcalde, NM, and Las Cruces, NM, since costs particular to each site were not included, such as labor.

*S1/lb = $2.2046/kg, 1 lb/512-ft² (47.6 m²) tunnel = 85.0781 lb/acre = 95.3599 kg/ha⁻¹, $1.00/tunnel = $85.0781/acre = $210.2326/ha.

*Parentheses within the table indicate negative returns.

#### Table 7. Sensitivity analysis and estimated returns for high tunnel spinach production across a range of actual yields and selling prices, single-layer (SL) and double-layer (DL) high tunnel designs.

<table>
<thead>
<tr>
<th>Yield (lb/tunnel)</th>
<th>2.00 (SL returns $/tunnel)</th>
<th>4.00</th>
<th>6.00</th>
<th>2.00 (DL returns $/tunnel)</th>
<th>4.00</th>
<th>6.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>(40.70)</td>
<td>(36.70)</td>
<td>(32.70)</td>
<td>(56.15)</td>
<td>(52.15)</td>
<td>(48.15)</td>
</tr>
<tr>
<td>10</td>
<td>(24.70)</td>
<td>(4.70)</td>
<td>15.30</td>
<td>(40.15)</td>
<td>(20.15)</td>
<td>(0.15)</td>
</tr>
<tr>
<td>18</td>
<td>(8.70)</td>
<td>27.30</td>
<td>63.30</td>
<td>(24.15)</td>
<td>11.85</td>
<td>47.85</td>
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<td>26</td>
<td>7.30</td>
<td>59.30</td>
<td>111.30</td>
<td>(8.15)</td>
<td>43.85</td>
<td>95.85</td>
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<td>91.30</td>
<td>159.30</td>
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<td>75.85</td>
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<td>107.85</td>
<td>191.85</td>
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<tr>
<td>50</td>
<td>55.30</td>
<td>155.30</td>
<td>255.30</td>
<td>39.85</td>
<td>139.85</td>
<td>239.85</td>
</tr>
</tbody>
</table>

*Estimated returns are net of materials, seed, and electricity costs (the latter for DL only). These returns apply to both Alcalde, NM, and Las Cruces, NM, since costs particular to each site were not included, such as labor.

*S1/lb = $2.2046/kg, 1 lb/512-ft² (47.6 m²) tunnel = 85.0781 lb/acre = 95.3599 kg/ha⁻¹, $1.00/tunnel = $85.0781/acre = $210.2326/ha.

*Parentheses within the table indicate negative returns.
Conclusions

• Daily air temperature minimums were highest in the model of highest heat retaining capacity.

• Daily air temp maximums were comparable in the DL+B model and the SL model (26.7ºC and 26.1ºC, respectively in Alcalde and 31.7ºC and 30.7ºC, respectively in Las Cruces).

• Even in extreme weather events, no crop loss.

• ’Flashy Trout Back’ lettuce and ‘Long Standing Bloomsdale’ spinach responded similarly to conditions inside the hoop house.

• Economic perspective: SL and DL are sufficient for crop production and cheaper to build. Highest expected returns.
Conclusions

- Yield trends were not consistent across the 8 analyses (season, crop and location combinations) and results varied depending on harvest dates:
  - In 2 out of 8 scenarios house model main effect did have a significant impact on yield.
  - In 4 out of 8 scenarios planting date main effect had a significant impact on yield.
- Fewer harvests were possible in Alcalde (2-3) than in Las Cruces (~5) because of lower winter temperatures. Therefore, total yields were lower than Las Cruces.
- Since houses were not ventilated, the crop yield may have been affected by extreme temperature stress. Also, salinity problems in the third season in Las Cruces hindered crop growth.
- A future study might also include crops planted outside and under row cover in order to better understand the benefits of growing in hoop houses in the southwest.
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(Mostly) Free Resources

• Project Website: [http://aces.nmsu.edu/academics/aeab/hoop-house-project.html](http://aces.nmsu.edu/academics/aeab/hoop-house-project.html)

• Hoop House Construction (12’ x 40’):

• Hoop House Vegetable Production:

• [www.hightunnels.org](http://www.hightunnels.org)

• Eliot Coleman (ME): Four Season Harvest and others

• Hard sided high tunnel construction: Edwards and Jimenez, 2014- Univ. of WY

• Hoop house economics (Hecher et al., 2014)- HortTechnology
Your Experiences/Questions?

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In January 2012 in Las Cruces, the daily low temperatures were as follows:

- DL+B = 36°F
- DL = 31°F
- Water in the barrel = 63.5°F (27.5°F temperature difference)
‘Iron and Clay’ cowpea in hoop house at LPSRC Summer 2011