Growing Conditions and Crop Performance in High Tunnels

High tunnels are easily to build, low cost, low tech greenhouses constructed by covering relatively lightweight aluminium framing with a single layer of polyethylene. There is no supplemental heat or power, but the sides and/or endwalls can be opened manually to provide ventilation. Previous research conducted by the Vegetable Crops Research Program at the University of Saskatchewan has demonstrated the potential production and economic benefits of growing high value, warm season vegetable crops in high tunnels. A major limitation of the 1<sup>st</sup> generation high tunnels was that their small size (14’ wide * 8’ tall * 100’ long) limited the range of crops that could be grown and the equipment that could be used in the high tunnel. The small size of these 1<sup>st</sup> generation tunnels also increased the material cost/unit production area and made it difficult to maintain suitable temperatures.

The objective of this project was to test the potential to utilize much larger 2<sup>nd</sup> and 3<sup>rd</sup> generation high tunnels in Saskatchewan. In 2010 a complex of 8 gutter-connected tunnels were constructed. Each of the 8 tunnels in the complex was 28’ wide, 18’ tall at the peak, 6’ tall at the eaves and 200’ long for a total covered production area of ca 44,000 sq ft. In 2011 and 2012 the performance of a range of high value vegetable crops was evaluated in these 2<sup>nd</sup> generation high tunnels, with earliness, yields and quality compared to crops growing in smaller 1<sup>st</sup> generation tunnels or under open field conditions. It was easier to establish and maintain the crops in the more spacious 2<sup>nd</sup> generation high tunnels. Temperatures were more moderate and light levels lower in the larger 2<sup>nd</sup> generation tunnels than in the smaller 1<sup>st</sup> generation high tunnels. Watermelon, muskmelons, peppers, tomato and lettuce were earlier, with higher yields and superior quality in the new larger tunnels than in the smaller 1<sup>st</sup> generation tunnels. No benefits were observed in the corn, squash, cucumber or strawberry crops growing in the larger high tunnels relative to producing these crops in open field conditions.

In June 2012 a wind event (96 km/h peak gusts) collapsed 4 of the 8 tunnels in the complex, with lesser damage to all of the tunnels – including those being used in this project. The degree of damage that occurred at wind speeds not uncommon in Saskatchewan led to the conclusion that this type of high tunnel system is not well suited to local use.

In 2013 we constructed two freestanding 3<sup>rd</sup> generation high tunnels. These structures are built of heavier materials and have a lower profile than the 2<sup>nd</sup> generation tunnels – so they should better withstand weather events. However, the 3<sup>rd</sup> generation structures are considerably more expensive than the 2<sup>nd</sup> generation tunnels previously tested. The Gothic type tunnel system is built with heavier materials and closer spaced arches as it is designed to remain covered over the winter months. Price per unit production area of the Gothic type tunnel ($3.52/sq ft) is more than double the lighter duty standard tunnel ($1.48/sq ft).
Tunnel Build

The build was initially scheduled for spring of 2013, but flooding delayed the start of the project until mid-summer. In the meantime, members of the crew had an opportunity to participate in another tunnel build at a local grower’s farm. This experience greatly facilitated the build at the U of S.

<table>
<thead>
<tr>
<th>Build Steps</th>
<th>Person Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Read instructions</td>
<td>2</td>
</tr>
<tr>
<td>2) Unpack and check materials</td>
<td>2</td>
</tr>
<tr>
<td>3) Staked out the perimeter of tunnels</td>
<td>0.5</td>
</tr>
<tr>
<td>4) Laid landscape cloth to prevent weeds from growing at the edges of the tunnel (see Fig. 1).</td>
<td>2</td>
</tr>
<tr>
<td>5) Installed anchors for the arches using motorized post-hole auger.</td>
<td>3</td>
</tr>
<tr>
<td>6) Assembled arches</td>
<td>2 people * 1.5 days</td>
</tr>
<tr>
<td>7) Installed arches into soil anchors</td>
<td>2</td>
</tr>
<tr>
<td>8) Drilled holes and installed anchor bolts at base of arches</td>
<td>8($)</td>
</tr>
<tr>
<td>9) Installed horizontal cross struts on arches</td>
<td>3 ($^c$)</td>
</tr>
<tr>
<td>10) Installed end bracing struts</td>
<td>1.5</td>
</tr>
<tr>
<td>11) Installed purlin along peak</td>
<td>4</td>
</tr>
<tr>
<td>12) Install V wire at ends</td>
<td>1</td>
</tr>
</tbody>
</table>

Sub-total 49 h

It took 49 hours to complete the basic construction of both tunnels – and each tunnel took about the same amount of time to build.

We opted to only install the plastic and the end doors on the Gothic in 2013

<table>
<thead>
<tr>
<th>Build Steps</th>
<th>Person Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>13) Installed plastic</td>
<td>4 ($^b$)</td>
</tr>
<tr>
<td>14) Installed and tighten ropes over the plastic</td>
<td>4</td>
</tr>
<tr>
<td>15) Built the doors .. and then built them again .. and again</td>
<td>8 ($^b$)</td>
</tr>
</tbody>
</table>
Sub-total  16
Total for Gothic (24.5+16) =  40.5 h

Fig. 1. Construction of the Gothic high tunnel at the University of Saskatchewan. Note the use of the landscape fabric to provide weed protection at the edges of the high tunnel.

Superscripts in the construction time budget provided above indicate construction components took far longer than required – in large part because we failed to fully read/understand the construction manual.

A – as wet field conditions prevented access to the construction site we opted to begin assembling the arches in a covered shed area. We did not adequately appreciate that each of the 4 arch components provided within a bundle have been predrilled to specifically match the other arch components within the bundle. If any of these components are mixed up after the bundles are opened, new holes must be drilled to allow the components to connect together. We opened all the bundles and in the process mixed some of the arch components. The process of trying to match the components with their partner or redrilling the holes when the previous step proved futile took hours.

B – we used bolts to anchor every arch to the soil anchor. Drilling the required holes through 4 layers of metal took time, even with a very powerful drill. The construction manual suggest that this step is really only necessary for the arches close to the ends of the tunnel.

C- Cross struts would have been easier to install from the ground.

D – Installing the cover - the trick to skinning the tunnel is to take advantage of the plastic pushers. Pushing the plastic over the peak with the plastic pushers and letting gravity pull it down is far easier than trying to pull the plastic over the peak. If you are having trouble getting the skin over push more plastic to the peak.

E - construction of the end doors. The construction manual does not adequately lay out how to attach the plastic above the door so as to not impede the ability of the clips to hold the door on. Also - when connecting the plastic on the end wall above the door, roll the plastic from the inside out onto the end cross strut to allow a good surface to attach the door plastic from the front.

2013 Cropping

As only the Gothic tunnel was skinned in 2013 – all cropping occurred within that tunnel. As the tunnel build was not completed until late July this limited the range of crops we could realistically expect to assess within the remaining available growing season. The crops we did opt to test were selected for their rapid development and/or tolerance of cool growing conditions.
The crops tested were: Spinach (cv Tyee),
Radish (cv Gourmet mix),
Bibb Lettuce (cv Optima, Santoro and Natalia),
Peas (cv. Green Arrow),
Summer savoury,
Beets (cv Ruby Queen and Merlin).

The tunnel was divided into 8 sub-plots using 1 m wide aisleways (see Fig. 2) and each
crop was planted into 1 or more of these sub-plots. While the aisle ways were
necessary to allow workers access to the plots – they took up over 20% of the total
production area within the Gothic tunnel.

Fig. 2. Crop production (beets, peas, salad greens) during fall of 2013 within a
new Gothic type high tunnel

As a result of foot and vehicle traffic during the build, the soil within the Gothic tunnel
was too compacted to allow planting. We therefore opted to water the soil, then rotovate
once the moisture had penetrated the soil profile. We quickly learned that the water
spray pattern from standard lawn-type sprinklers is not well suited to providing uniform
watering within a high tunnel. The spray tends to hit the roof of the tunnel and funnel
down to a few spots which become very wet. This same problem was encountered
when attempting to sprinkle irrigate the test crops. Ultimately the only way we could get
sufficiently uniform water distribution across the high tunnel was to water by hand – but
this was very labor intensive.

Problems with soil compaction and uneven irrigation resulted in production of a fairly
poor seedbed – and consequently some of the crops struggled to get established.
However, once established, all crops grew well within Gothic high tunnel.

Specific Crop Observations

Spinach – grew very well within the tunnels. No problems with bolting were
observed. Flavor was good.

Radish - grew rapidly in the tunnel. The crop was ready for harvest with 3 weeks
of planting. ** There were few indications root maggot damage to the
radish crop grown within the tunnels – whereas the crop grown in the
open field were extensively damaged by this pest. This was an unexpected finding – as in previous trials with various brassica crops the tunnels had provided no protection against root maggots. This finding warrants further investigation.

Peas – the pea crop was planted out fairly late and grew slowly in the cool, short days of fall. The plants appeared healthy – this was noteworthy as we expected problems with mildew to occur due to the warm, moist, calm conditions of the high tunnels.

Lettuce - multiple crops of lettuce were grown – either from transplants or from seed. All crops were of excellent quality.

**Temperature Management within the Gothic High Tunnels**

As all the crops tested through late summer/fall of 2013 were adapted to relatively cool conditions we opted to keep the tunnels fairly cool by raising the sides. As the temperature profile data indicates (see Fig. 3) – with the sides of the tunnels raised, temperatures inside the tunnel were only marginally higher than outside.

Fig. 3. Air temperatures in a Gothic high tunnel (inside) compared to the open field (outside) through late summer/fall of 2013. Sides of the tunnel were closed on October 5

As temperatures began to cool in the fall we lowered the sides of the tunnel – and by early October the tunnels were completely sealed. Raising/lowering the sides of the tunnels was very easy and took a trained crew member only 5 minutes. Once the sides of the tunnel were completely closed temperatures inside the tunnel were considerably higher than outside – both during the day and at night (see Fig. 3)
While the weather through the fall of 2013 was generally very favourable – by late October night temperatures were consistently well below 0°C. We monitored the temperatures and the health of the high tunnel crops through these frost events. The temperature profiles indicated that the high tunnels provided a few degrees of frost protection – but this limited amount of protection was sufficient to allow the cool season crop such as lettuce and spinach to continue to grow through until mid-November.

Soil temperatures in the high tunnel followed the same trends as the air temperatures – but with less day to day fluctuation (Fig. 4).

Fig. 4. Soil temperatures (10 cm depth) in a Gothic high tunnel (inside) compared to the open field (outside).

**Other Tunnel Management Observations**

Construction of the end doors proved to be quite challenging – and the operator’s manual provided by tunnel manufacturers is deficient in this area. The plastic sheet that forms the door repeatedly became disconnected from the support structure – even in the mildest wind. Aside from this issue – the roll up door worked very smoothly.

As noted above – getting a uniform distribution of water within the high tunnels was impossible using standard sprinkler systems. A sprinkler system mounted along the cross struts that connect the two sides of the greenhouse at the eaves (8’ above ground) should provide a more uniform water distribution.

We are monitoring snow accumulation and structural integrity of the Gothic structure over the winter of 2013/2014.

**In 2014 we will conduct a full spectrum of trials in the two new high tunnels.**

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