Growing Conditions and Crop Performance in High Tunnels

High tunnels are easy to build, low cost, low tech greenhouses constructed by covering lightweight aluminium framing with a single layer of polyethylene. There is no supplemental heat or power, but the sides and/or end walls 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 1st 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 the 1st generation tunnels also increased the material cost/unit production area and made it difficult to maintain suitable temperatures.

In 2010 we began testing much larger 2nd generation high tunnels. The complex tested consisted of 8 gutter-connected tunnels – with each tunnel being 28' wide, 18' tall at the peak, 6' tall at the eaves and 200' long. In 2011and 2012 the performance of a range of high value warm season vegetable crops was evaluated in these 2nd generation high tunnels, with earliness, yields and quality compared to crops growing in smaller 1st generation tunnels or under open field conditions. It was easier to establish and maintain the crops in the more spacious 2nd generation high tunnels. Temperatures were also more moderate in the 2nd generation tunnels – in part because they were taller with better ventilation – but also because the covering used in the 2nd generation tunnels was quite opaque. Watermelon, muskmelons, peppers, tomato and lettuce were earlier, with higher yields and superior quality in the new larger tunnels than in the smaller 1st generation tunnels. No benefits were observed in the corn, squash, cucumber or strawberry crops growing in the large 2nd generation high tunnels relative to producing these crops in open field conditions.

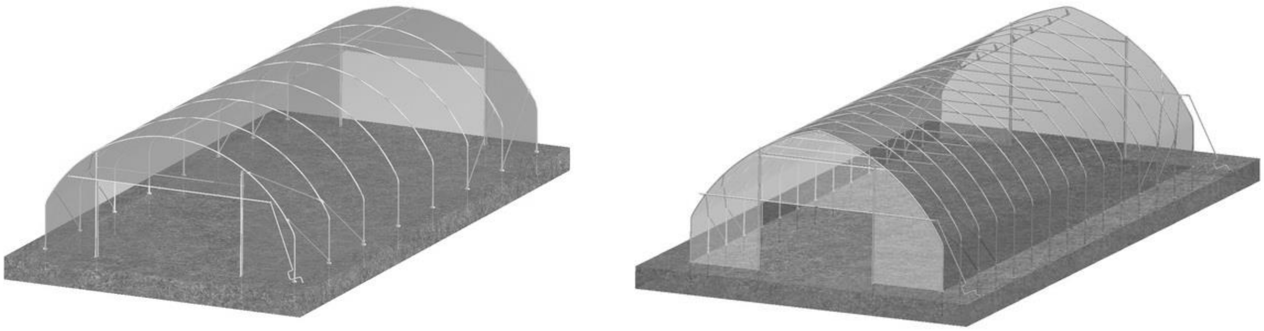
In June 2012 a wind event (96 km/h peak gusts) collapsed 4 of the 8 tunnels in the complex. In the fall of 2012 a heavy snow event caused the collapse of the remaining tunnels. **As high winds and untimely snow are common occurrences in Saskatchewan we concluded that this type of high tunnel system is not well suited to local use.**

In 2013 two freestanding 3rd generation high tunnels were constructed (Fig. 1). These structures are built of heavier materials and have a lower profile than the 2nd generation tunnels – so it was hoped that they would better withstand weather events. However, the 3rd generation structures are considerably more expensive per unit production area than the 2nd generation tunnels previously tested. The Gothic type tunnel system (Fig. 1) is designed to stay covered all winter. Its peaked roof is designed to shed snow and its stronger and more closely spaced arches are designed to withstand some snow and wind load. Price per unit production area of the Gothic type tunnel is nearly double the lighter duty standard tunnel.

It took about 40 person hours to construct each of the new tunnels and to get the plastic cover installed.

Results from the 2013 and 2014 trials have been presented elsewhere;

2013 High Tunnel Trials - http://veg.usask.ca/wp-content/uploads/High-Tunnel-2013-Website-Version.pdf
2014 High Tunnel Trials - http://veg.usask.ca/wp-content/uploads/High-Tunnel-2014-Web-Version-.pdf



Standard high tunnel (Supersolo) **Gothic-type high tunnel**

Fig. 1. Tunnel schematics courtesy of Haygrove UK

2015 Cropping Season

The cover was left on the Gothic tunnel over the winter of 2014/2015, as this would eliminate the labor cost associated with removing and then re-installing the cover (Fig. 2). Keeping the production area snow-free all winter should also accelerate drying and warming of the production area in the spring – potentially allowing an earlier start to the growing season.

Over 25cm of wet snow fell during a storm event in late April of 2015. The Gothic design very efficiently shed this snow (see Fig. 2) – and no damage occurred to the structure.

Fig. 2. Gothic tunnel following a heavy snow event in early spring of 2015.

In the first week of May the cover was re-installed on the larger Supersolo tunnel. This process went fairly smoothly and took a total of 10 person hours. Unfortunately, as the field adjacent to the tunnels was still quite wet, the cover picked up a lot of soil being moved into place prior to installation. Efforts to spray the soil off the cover met with only limited success (Fig. 3) and light levels in the tunnel were reduced by this soil.

Fig. 3. Spraying cover of a high tunnel in an effort to remove soil picked up during winter storage and subsequent installation of the cover.

The production areas inside both high tunnels were prepared by spreading N fertilizer on the soil surface and then rotovating the soil. All other nutrients were present in adequate quantities. Three 1 m wide rows of black plastic soil mulch were then laid in the tunnels. A drip irrigation line was installed beneath the mulch.

In late May, pepper (12 cultivars) and tomato (7 cultivars) crops were transplanted into the Gothic tunnel. The peppers were spaced 30 cm apart within the mulch row while the tomatoes were spaced 50 cm apart. As it was expected that the tomatoes would become the tallest crop they were located in the center row of the tunnel. Bibb and leaf lettuce (4 cultivars) were transplanted between the mulch rows in the Gothic tunnel (Fig. 4). Growing quick maturing short stature crops between the rows of the slower growing main crops or in the “waste” areas of the tunnel represents a means of making more efficient use of the valuable growing space in the high tunnel.

Fig. 4. Lettuce growing between crop rows in the high tunnel in 2015.

In late May watermelon seedlings (4 cultivars) were transplanted 50 cm apart into the mulch rows in the Supersolo.

On the 28th of May a -3C frost event damaged all warm season crops that had been planted out in the open field – but none of the crops in the high tunnels showed any cold damage. The sides of the tunnels had been lowered prior to the frost event. The tunnels also protected the newly transplanted seedlings during several damaging wind events – and by the 2nd week of June all crops in the high tunnel were more advanced than those in the open field.

Fig. 5. Bark mulch around the periphery of the high tunnel.

In the previous year, a 45 cm wide strip of plastic mulch was laid around the periphery of both high tunnels and then covered with a 15 cm thick layer of bark mulch. This combination of plastic + bark mulch continued to provide effective control of weed growth along the edges of the tunnel and also provided a high and dry walking path following rain events (Fig. 5).

In the 2nd week of June the tomatoes were large enough to be trained onto strings hung from the interior struts of the high tunnel (Fig. 6). Training the tomato plants required some additional effort but it increased space use efficiency, improved fruit quality and reduced problems with foliar diseases. The pepper plants were also supported by a network of stakes and strings – as otherwise the plants could not support the large number of fruit set.

Fig. 6. Training tomatoes onto strings in the high tunnel – 2015.

In early July, the raspberry and strawberry crops growing in the Supersolo tunnel became severely infested with spider mites. As the infestation coincided with the onset of fruit harvest in the floricane type raspberry and the June-bearing strawberry plots, it was not possible to use any pesticides – and the only control measure employed was misting the plants with water on a regular basis. Mite damage to the raspberry plants was sufficient to cause some defoliation – although the plants eventually recovered. Problems with spider mites continued until cooler temperatures and higher humidity arrived in early fall.

Many of the early fruit on the peppers were infested with the larvae of the European corn borer (Fig. 7). These pests are hard to detect and difficult to control and it is fortunate that more fruit were not damaged.

Fig. 7. European corn borer damage to pepper fruit. Entry points are circled.

The watermelons were ready for harvest by the 2nd week of August, 3 weeks ahead of the crop growing in the field. By the last week of August all crop residues from the melons were removed from the tunnel. The plot was then fertilized and rotovated and a range of cool season crops (radish, spinach, kale and lettuce) were either transplanted or direct seeded into the plot area. These crops thrived in the tunnel and were still yielding marketable produce when the cover was removed from the Supersolo tunnel in early November (Fig.8).

Fig. 8. Lettuce, spinach, kale and radish crops thriving in a high tunnel in late October 2015.

In anticipation of a frost event in mid-September, the tomato plants which were still in full production were protected by draping a field cover from the top of the plants down to ground level (Fig. 9). This protection combined with the protection provided by the high tunnels allowed the tomato plants to survive -6C frost – and fruit harvest continued through until the 3rd week of October.

Fig. 9. Field cover installed over trellised tomato plants to protect against fall frost.

In the 2nd week of Nov. the cover on the Supersolo tunnel was gathered and tied half way up the side of the tunnel (Fig. 10). The objective of this approach was to make it easier to re-deploy the cover next year. This process took 4 workers 3 hours to complete. **The cover was again left on the Gothic tunnel for the winter.** Straw mulch was applied over the strawberry plots both inside and outside the high tunnels.

Fig. 10. Supersolo tunnel with cover parked half way up the side of the tunnel in fall of 2015.

Tunnel Management in 2015

The objective of employing high tunnels is to produce a growing environment more conducive to crop development than conditions in the open field. When growing high value warm season vegetable crops within the relative short cool growing season available in Saskatchewan, the primary function of the high tunnels will be to increase air temperatures – especially during spring and fall. If the tunnels can also provide some frost protect this will extend the growing season, increasing the yield potential of the crops, while also extending the marketing season. The tunnels can also protect the crops from damaging wind, heavy rain and hail events. There is however potential for the tunnels to produce conditions not suited to optimum crop growth. Excessively high temperatures can cause the crop to fail to flower or can interfere with pollination and normal fruit development. The optimum temperature for fruit development, pollination and fruit set are 18-26^{o}C for tomatoes and 16-24^{o}C for peppers. In melons, persistent high temperatures cause the plants to produce nothing but male flowers. The female flowers that develop into the fruit will only form if the crop is exposed to cooler temperatures for several days in a row. The bees required to pollinate melon flowers also do not spend time in areas where temperatures are excessively high.

Given the crop development considerations outlined above – the overall objective for temperature management of the high tunnels in 2015 was to maintain temperatures within the optimum range for as much of each day as possible and on as many days as possible over the course of the growing season. Meeting this objective was complicated by;

a) Day to day and hourly changes in temperatures, sunlight levels and wind speeds and direction
b) Differences in temperature in different areas of a tunnel
c) Different optimum temperatures for the various crops grown within a single tunnel
d) Weekends – at which time there were no staff available to manage the tunnels

When attempting to optimize temperatures within a high tunnel, the major management tool available to the growers is the ability to raise and lower the side walls and to open/close the end doors. Raising the sides of the tunnel involved repositioning the plastic cover between ropes that hold the cover in place and then holding the raised sides in place by cinching the tensioning ropes tighter with clips supplied with the tunnels. The process of raising the sides of the tunnel took one person about 10-15 minutes. Lowering the sides took slightly less time. The end doors of the tunnels were on a crank mechanism and could be raised within a few seconds. The degree to which the side walls were raised and the doors opened was also influenced by the prevailing wind speed and direction.

Each day during the work week the tunnels were visited on at least three occasions over the course of the workday (9 am, 1 pm and 4:30 pm) at which time the position of the side walls and doors was managed in an effort to optimize the temperatures. Thermometers positioned in the crop canopy and the weather forecast were consulted before deciding what changes, if any, to make in the position of the sidewalls and end-doors.

As spring and early summer of 2015 were unusually warm, the tunnels were kept partially or fully open on most days from the start of the growing season in early May through until early fall. With the onset of cooler weather in September the tunnels were kept partially or fully closed and they stayed fully closed through October and into November. If the sidewalls and doors were only partially open during the day, they were usually closed at night but if they were fully open in the day, they were kept at least partially open at night.

Temperature management on the weekends was problematic as no staff were available to conduct any changes. Instead, late on Friday afternoon the forecast for the coming weekend was reviewed and then the sidewalls and doors were placed into a position thought least likely to result in temperature conditions damaging to the crops. This compromise undoubtedly led to the crops experiencing less than ideal conditions at some time over the course of every weekend.

Daily high temperatures in the Gothic and Supersolo tunnels as well as the open field over the course of the 2015 growing season are presented in Fig. 11. In the spring and especially in the fall, daily high temperatures in the high tunnels were well above ambient – as the sides of the tunnels were kept either fully or partially down in an effort to enhance crop growth. In mid-summer, when the tunnels were kept wide open, temperatures in the tunnels were generally comparable to the outside.

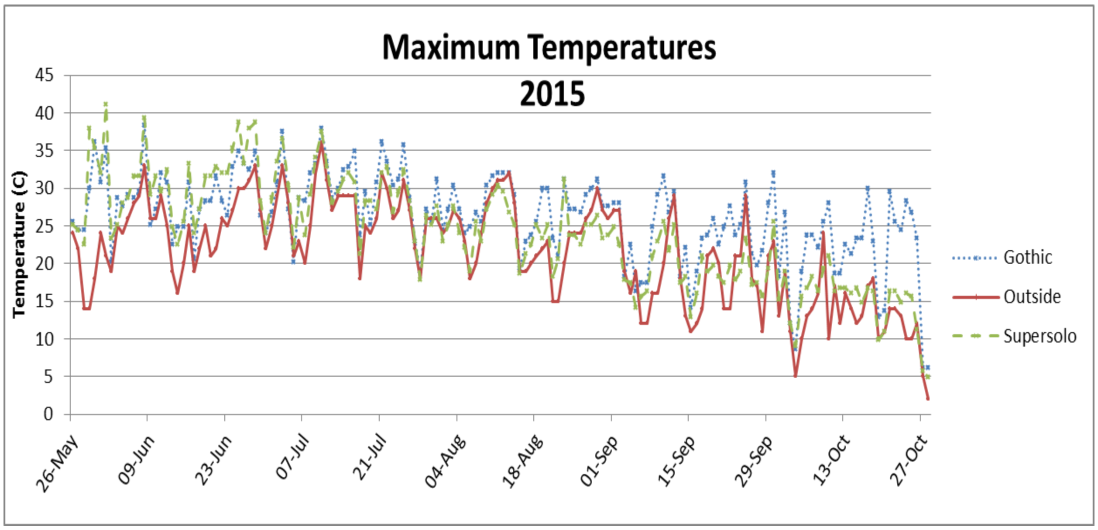


Fig. 11. Daily high temperatures in the Gothic and Supersolo high tunnels and the open field over the course of the 2015 growing season.

Daily maximum temperatures in the high tunnels in 2015 were less extreme than in previous years. This reflects better temperature management and a more thorough appreciation of the negative impact of extreme temperatures on crop development. Nonetheless, temperatures exceeding the optimum for fruit set of the test crops occurred frequently in both high tunnels over the full duration of the 2015 growing season. However, unlike previous years, in the 2015 trial we did not note any heat stress related problems such as delayed fruit set or distorted fruit development. We could not identify any particular cause for this difference – other than we have consistently been selecting cultivars which perform well under high tunnel conditions.

As has been observed in previous trials, the relative humidity inside the tunnels exceeded the dew point on many nights (Fig. 12). This resulted in very heavy dew on the plants and condensation on the cover which subsequently rained down onto the crop. While high humidity levels can contribute to disease problems – no disease issues were observed in the high tunnels in 2015.

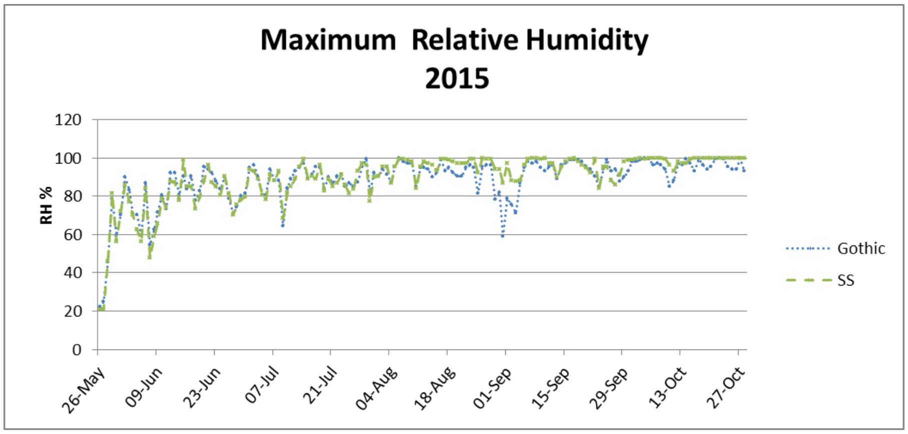


Fig. 12. Maximum relative humidity values for Gothic and SuperSolo (SS) high tunnels in 2015.

Crop Performance in 2015

Tomatoes – two grape type (Mantian 207 and 209), three cocktail type (Mantian 2015, 2019 and Tianxi) and two standard type (Arbason and Frederick) cultivars of tomato were tested in the Gothic tunnel in 2015. The cultivars were selected based on their demonstrated ability to perform well under the high temperature conditions characteristic of high tunnels. The 2015 tomato crop showed excellent vegetative growth, flowering and fruit set. Fruit yields were good and the appearance of the clusters and the individual fruit was excellent. However fruit flavour was only fair and the sugar content (^{o} Brix) was quite low compared to the same cultivars grown under open field conditions (Table 1). The best quality fruit came from harvests taken in mid-summer, and by late fall fruit quality was quite poor. Poor fruit quality could be attributed to the combination of rapid growth driven by the high temperatures in the tunnel, but reduced photosynthesis caused by the short fall days and the reduction in light caused by the relatively opaque plastic used to cover the tunnels. While the standard type tomato cultivars tested in 2015 looked great, yielded well, and were clearly well suited to high tunnel production, their fruit quality was inferior.

Table 1. Soluble solid content of six cultivars of tomato grown in a Gothic high tunnel versus the open field in 2015.

	Field Trial			High Tunnel Trial			
Cultivar	**Avg Fruit Wt (g)**	**Brix**	**Flavor (0-5)**	**Avg Fruit Wt (g)**	**Brix (Summer/Fall)**	**Flavor (0-5)**	
Mantian 207	10	8.4	4.5	17	6.2/6.1	4.0	
Mantian 209	8	9.2	4.2	15	8.2/5.8	4.5	
Mantian 2015	30	5.0	4.0	28	5.2/-	4.0	
Mantian 2019	31	3.5	3.7	32	3.0/-	3.0	
Tianxi	16	7.8	3.0	28	7.0/5.4	4.0	
Arbason				1460	3.5/-	1.0	
Frederick				1800	4.0/-	1.0	

Peppers - a total of 12 cultivars, representing different pepper types (bell, Hungarian, jalapeno, and serrano) were tested in the Gothic tunnel in 2015. The cultivars were selected based on either previous performance or information suggesting that they would perform well under high tunnel conditions.

The 2015 pepper crop in the tunnel was exceptionally good. The seedlings established quickly after being transplanted into the tunnel and the plants showed none of the problems with heat stress and poor fruit set seen in previous years of testing in the tunnels. The first full sized, fully colored peppers were ready for harvest by the 1st week of August. By late fall virtually all of the fruit had reached marketable size and degree of maturity (Table 2). This indicates that all of the pepper cultivars selected for testing in 2015 had set fruit over a limited time period. While this was desirable under the high tunnel conditions experienced in 2015, it raises questions about the potential of these cultivars to perform under a longer growing season. On average, yields of marketable fruit from the 2015 trial were more than double those obtained in the 2014 high tunnel trial.

Table 2. Productivity of various types of pepper grown in a Gothic high tunnel in 2015.

High Tunnel Peppers 2015

Cultivar	Source	Marketable Yield						% Imma-ture	Total Marketable Yield		Overall Rating	Comments
		Colored			Mature Green							
		#/m	kg/m	Avg wt (g)	#/m	kg/m	Avg wt (g)		#/m	kg/m		
Early Thickset Improved**	PK	27	6.4	235	9	1.5	175	4	36	7.9	4.4	Large blocky red fruit
King Arthur***	J	13	5.2	399	8	1.8	234	2	21	6.9	3.8	Early maturing red fruit
Super Hot Hungarian ***	ST	46	6.0	130	20	1.3	66	2	66	7.3	4.1	Early maturing. Ripens green, yellow, orange then red
Hot Portugal***	ST	98	3.4	28	14	0.2	18	5	112	3.7	2.2	Long, skinny red fruit are small with curled tips
Crimson Hot***	ST	69	5.4	78	8	0.3	32	2	77	5.6	3.4	Long flat fruit with nice red color
BOS640037***	OR	36	6.4	179	5	2.3	117	5	41	8.7	4.7	Excellent yields of small triangular red fruit. Good flavor
Vivaldi***	VIL	15	5.0	341	9	2.4	262	4	24	7.5	3.9	Large, thick walled red fruit
Excursion II***	ST	13	4.7	357	11	2.8	253	6	24	7.5	3.8	Large blocky red fruit
Mantian 4036	MA	7	2.4	374	9	2.2	259	9	15	4.6	2.2	Early fruit set but produced only a few very heavy red fruit
Mantian 4008	MA	16	4.4	281	10	1.9	202	6	25	6.4	3.4	Blocky red fruit
Golden Fairy***	EV	22	6.9	313	9	1.2	128	4	31	8.1	4.6	Early maturing with high yields of blocky yellow fruit
Ancho	J	15	2.2	149	37	3.0	81	6	52	5.2	2.3	Fruit have thin walls + tough skin. Some bacterial spot
Average		31	4.9	100	12	1.7	81	7	44	6.6	3.6	

Bold recommended in 2015 | Date seeded: April 10 | Date of first harvest: Aug 26 | Spacing in row: 0.33 m | Rating: 5 - excellent
Previously recommended *** | Date transplanted: May 26 | Date of final harvest: Sept 26 | Spacing between rows: 2 m | 1 - Poor

Overall rating calculated based on the following weighting matrix; Based on 40% on colored yield, 40% for marketable yield, 20% for % colored

Lettuce – Bibb and leaf type lettuce again proved to be an excellent crop to fill in spaces between rows in the high tunnel. Four crops of high quality lettuce were produced over the 2015 growing season. Each crop took about 4 weeks from transplanting until the plants were harvest- ready (Table 3). A 5th crop transplanted into the tunnel on September 24th failed to mature prior to a killing frost in early November. Despite the high temperatures encountered in the high tunnels throughout the growing season, none of the lettuce crops showed any symptoms of heat stress (ie; bolting, yellowing or excessive bitterness). There were also no problems with either disease or insects on any of the lettuce crops – despite the fact that each crop was replanted into exactly the same spot the previous crop had been grown in. The four lettuce cultivars tested in the high tunnel in 2015 all performed well.

Table 3. Sequential planting of bibb or leaf-type lettuce in a high tunnel in 2015.

High Tunnel Lettuce - 2015

Cultivar	Source	Planting #1		Planting #2		Planting #3		Planting #4		Average		Comments
		No./m	Weight (kg/m)	No./m	Weight (kg/m)	No./m	Weight (kg/m)	No./m	Weight (kg/m)	No./m	Weight (kg/m)	
Adriana	J	6.3	1.4	6.3	1.4	4.6	0.6	6.0	0.5	5.8	1.0	Green bibb-type lettuce. Looks good. Slightly bitter
Optima	J	6.3	1.5	5.0	1.2	4.8	0.6	6.4	0.7	5.6	1.0	Green bibb-type lettuce. Nice texture and flavour
Prize Head	EFG	6.3	1.0	6.0	1.1	5.0	0.9	6.0	0.4	5.8	0.8	Red tip leaf lettuce. Crunchy. Slightly bitter
Simpson's Elite	VE	6.3	1.2	6.0	0.9	4.0	0.8	6.3	0.7	5.6	0.9	Light green leaf lettuce. Juicy. Slightly bitter
Average		**6.3**	**1.3**	**5.8**	**1.2**	**4.6**	**0.7**	**6.2**	**0.6**	**5.7**	**0.9**	
		Planting #1:		**Planting #2:**		**Planting #3:**		**Planting #4:**				
		Seeded: April 23		Seeded: May 26		Seeded: June 22		Seeded: July 28				
		Transplanted: May 25		Transplanted: June 23		Transplanted: July 29		Transplanted: Aug 27				
		Harvested: June 23		Harvested: July 21		Harvested: Aug 26		Harvested: Oct 2				
		Total : 61 days		**Total : 56 days**		**Total : 65 days**		**Total : 66 days**				

Watermelons - the four cultivars of watermelon tested in the high tunnels in 2015 had all performed well in previous tunnel trials. The melons got off to a very quick start in the tunnels in 2015 and had achieved full ground coverage within a month of transplanting. The first watermelons were ready for harvest by mid-August and all of the fruit were harvest-ready within the next 10 days. By comparison, the first watermelons produced in the open field in 2015 were not ready for harvest until early September. In the 2014 trial, watermelons in the high tunnel had not been ready for harvest until mid-September. Overall yields in 2015 were nearly double those obtained in 2014 (Table 4) – reflecting better growing conditions and management practices. The heavy and very concentrated fruit set seen in the 2015 trial took a toll on the health of the plants – all of the plants were dead or dying within a week of the onset of fruit harvest. Cultivars with a longer production period may be able to make better use of the extended growing season provided by the high tunnels. While yields and appearance of the high tunnel watermelons were excellent, the flavour and sugar content of the fruit harvested in 2105 were rated as only fair. As noted in the tomato trial, this may be related to the combination of high temperatures and reduced low light levels encountered in the high tunnels.

Table 4. Productivity of watermelon cultivars in a Supersolo high tunnel in 2015.

High Tunnel Watermelon - 2015

Cultivar	kg/m of row	No./m of row	Avg Fruit Wt. (kg)
Crimson Sweet	10.5	2.0	5.3
New Yellow Baby	14.0	5.3	2.7
Orange Krush	14.9	2.6	5.8
Sugar Baby	8.5	2.6	3.3
Average	**12.0**	**3.1**	**4.3**

Strawberry - the performance of the day-neutral strawberry cultivar Seascape and the June-bearing cultivar Kent grown in the Supersolo type high tunnel was compared against the same cultivars grown in the open field. The strawberry cultivars tested are representative of the cultivars preferred by growers across Canada.

The Kent strawberries had been planted in the open field and in the high tunnels in spring of 2014. By the end of the 2014 growing season, the Kent plants in the high tunnels had runnered out to the point where they formed a solid, 1 m wide mat. By contrast, the June-bearing strawberries planted in the open field were much slower to runner and they struggled to out-compete the weeds. The June bearing strawberry plants were covered with straw in late fall of 2015 and uncovered in late April of 2015. Overwinter survival was excellent under both sets of conditions. Kent plants in the high tunnel began flowering about 5 days ahead of those in the open field – and the first fruit in the high tunnel were ready for harvest about a week ahead of the open field. Fruit numbers, fruit size and fruit quality were all better for the Kent plants growing in the high tunnel than in the open field. However, whether these differences were sufficient to offset the much higher cost of growing the June-bearing strawberries in the high tunnel is questionable.

In early May of 2015, plants of the day-neutral type strawberry cultivar Seascape obtained from a commercial nursery stock supplier were planted out into rows of black plastic mulch in both the open field and high tunnel. As problems with slow plant establishment had been observed in the 2014 trial with day-neutral strawberries, we tried adding peat moss to the root zone in the high tunnel as a means to enhance aeration and moisture holding capacity while reducing soil bulk density – all of these factors should have enhanced rooting. However this approach provided no obvious benefit and once again the day-neutral plants struggled to get established in both the high tunnel and the open field. Infestation by spider mites further slowed growth in the high tunnels – but the mites were less of a problem in the open field. The first fruit from the day-neutral crop were ready for harvest in the tunnels by mid-August, while outside the tunnel the fruit took another week to reach maturity. Fruit production in the high tunnels stayed relatively steady through September and well into October. By contrast, repeated light frost events caused sufficient damage that harvest in the open field day-neutral crop ceased in mid-September.

While it is clear that production within high tunnels has the potential to increase productivity of day-neutral type strawberries, until some means is found to address problems with crop establishment and spider mites, the economic viability of this practice remains questionable.

Raspberry - two cultivars of primocane type raspberry (Autumn Britten and Polka) and two cultivars of floricane type raspberry (Boyne, Mammoth, Killarney and Nova) had been established in the Supersolo tunnel in 2014. All cultivars overwintered well and rapidly produced a thick stand of healthy canes. From a development perspective, plants in the high tunnel were consistently 2 weeks ahead of the plants in the open field. Canes produced in the high tunnel were also considerably taller than those produced in the open field. Once fruit started to develop, these tall canes tended to fall over unless supported by a trellis system. The canes produced in the open field did not require supplemental support. As previously noted, problems with spider mites were much more severe in the high tunnels than in the open field. The hot, dry conditions in the high tunnel are near-ideal for the development of spider mites and growers interested in producing raspberries in high tunnels will need to have a mite management strategy in place. Installing an overhead misting system to automatically spray the foliage at regular intervals would likely represent the most ecologically effective approach to managing this problem.

Yields of the floricane raspberry cultivars were adversely affected by the mite problem –in large part because the peak of the mite infestation coincided with the period when the fruit were developing on the floricanes. As the mites had damaged the leaves to the point where many dropped off, the floricanes were unable to support much fruit. While the foliage of the primocane plants was also damaged by the mites, the plants had almost fully recovered by late August when their fruit started to develop. As growing conditions stayed favourable throughout the fall of 2015, fruit yields and fruit quality from the primocane cultivars were exceptionally good (Fig. 13). Substantial quantities of excellent quality fruit were still being harvested from the primocanes when the cover was removed from the tunnel in early November.

Fig 13. Heavy fruit production in mid-October by Autumn Britten, a primocane type raspberry growing in a high tunnel.

Recommendations to Further Enhance Crop Performance in High Tunnels

Overall, the 2015 cropping season in the high tunnels was much more successful than in previous years. This success could be attributed to a combination of more favourable production conditions (no flooding or herbicide drift) and increasing grower experience with managing crops in the tunnels. There is still room for improvement in tunnel management and production practices – any or all of which should result in greater yields, better quality and improved production economics.

a) Trellising worked very well in the 2015 high tunnel tomato crop. While training and pruning the plants was labor intensive, it allowed more effective use of the limited, high value growing space in the tunnels. Higher plant populations should be tested as a means to further increase the productivity of a trellised tomato crop in the high tunnel. Some form of trellis will also be required to assist peppers plants to support the heavy fruit loads obtained under high tunnel conditions.
b) Overheating in the high tunnels still represents a major management concern. Overheating occurred even if the sides of the tunnel were rolled all the way up and the doors were wide open. Part of the problem may stem from the fact that the tunnels were situated at a location completely surrounded by a shelterbelt. When it comes time to replace the covers, purchasing a more opaque plastic might be considered – although this will tend to further reduce light levels. Problems with fruit quality experienced in the high tunnel crops in 2015 could be attributed to the combination of high temperatures and low light levels already encountered in the tunnels.
c) Insect and disease issues – the hot, crowded conditions within the tunnel were ideal for the development and spread of insects like spider mites. Populations of corn borers seem to be on the increase in Saskatchewan. As these insects seem to preferentially target pepper fruit set early in the season, crops growing in high tunnels run an increased risk of damage. Growers will need to scout their tunnel crops regularly and have appropriate control measures on hand.
d) Identification of crops and cultivars better suited to high tunnel growing conditions and production practices will continue to represent an efficient means of increasing productivity and profitability of high tunnel production.

This project was supported by the Agriculture Development Fund of Saskatchewan Agriculture and Food.