# TUNNEL MATERIALS FOR WARM SEASON VEGETABLE CROPS

Previous trials have demonstrated the benefit of using row covers to enhance early growth of warm season crops like melons and peppers. There are many types of covers available and it is important to select the type of covering material that best suits the needs of the crop. This trial examined the performance of several warm season vegetable crops (peppers, melons and tomato) grown with different types of row cover.

The trial was conducted at the University of Saskatchewan Horticulture field Research Station in 2008, 2009 and 2010. This site features a Sutherland Series heavy clay soil which is slow to warm in the spring. The site was prepared by rotovating one week prior to transplanting the test crops. Three days before transplanting a biodegradable wavelength selective plastic mulch was applied to the test plots. Drip irrigation lines were located beneath the mulch. Three week old cantaloupe (cv. 'Strike' in 2008, 'Athena' in 2009 and 2010), 6 week old pepper (cv. 'Red Start') and 6 week old tomato transplants (cv. 'Celebrity') were planted out into the mulched rows once the risk of frost had passed in early June. The melon and pepper plants were spaced 30 cm apart within each row, while the tomatoes were spaced 0.5 m apart. Each test plot was 3 m long and the rows were 2m apart. Immediately after transplanting, row covers were installed on all plots except for a non-covered control. The cover materials tested were;

a) perforated clear polyethylene – transmits about 85% of the light in the visible spectrum. Clear perforated polyethylene creates a very warm environment.
b) non-perforated clear polyethylene – would be expected to create an environment even warmer than the equivalent perforated clear poly.
c) perforated green polyethylene - filters out about 41 % of incoming light within the visible spectrum, resulting in cooler temperatures. Filtering certain wavelengths out of the incoming light may also alter the growth pattern of the covered crops.
d) perforated white polyethylene - filters out about 26 % of the incoming visible light.
e) Novagryl woven polyester - filters out about 20 % of the incoming visible light and is also highly perforated.

The covers were supported by metal hoops (45 cm tall at peak) installed over each row to create a low tunnel. Each treatment was replicated 3 times in a randomized complete block design. Temperatures and crop condition were monitored inside the tunnels. The tunnels were kept in place until the crops started to flower - except for the non-perforated treatments where the tunnels had to be removed earlier due to problems with overheating and crop stress. No problems with insect pests or diseases were observed in 2008 trial and no pest management measures were required. In the 2009 trial some of the pepper plants were lost at mid-season to root rot. Problems with this disease were uniform across the tunnel treatments. In 2010 repeated rain events kept the soil saturated for extended periods which impaired crop vigor throughout the growing season.

The peppers were taken in a once-over harvest in mid-September. The fruit were graded into red ripe, mature green and immature categories. The melons were harvested weekly, with the fruit picked at half slip maturity. Any melons remaining after the first killing frost were taken in a once-over final harvest (Sept 22 in 2008, Oct 5 in 2009 and Sept 15 in 2010). Tomatoes reaching the breaker stage of maturity were harvested weekly. Any fruit remaining on the plants were harvested just after a killing frost.

**Results**

**2008 growing season –** temperatures in May and June were cooler than normal but there were no frosts after the trial was established. Temperatures in July and August were close to normal, while September was abnormally warm. The frost free season in 2008 (May 26 to Sept 26) was about 4 days longer than the 30 year average.

**2009 growing season** – May and June of 2009 were exceptionally cool. Frost was recorded on four occasions after the trial was established (June 1, 4, 6 and 9). Some frost damage was observed on the plants covered with clear polyethylene as well as the non-covered plants. This frost damage coupled with wind damage resulted in the loss of about 10% of the plants in the treatments that were not protected by a row cover. Temperatures in 2009 remained slightly below normal through July and August, but September was exceptionally warm, with the first frost delayed by two weeks relative to the longterm norm. The near-perfect fall conditions allowed the otherwise delayed crops to mature. The total length of the frost free season in 2009 was about 10 days shorter than normal.

**2010 growing season** – was characterized by below normal temperatures, limited sun and record rainfall. The timing of the first fall frost (Sept. 17) was near normal.

**Temperature profiles -** Temperature profiles under the various tunnel materials for the four week period when the tunnels were in place in 2008 (June 5-July 2) are presented in Fig. 1, the temperature profiles for 2009 (June 3-July 3) are presented in Fig. 2 and the temperatures for 2010 (June 15 to July 13) are presented in Fig. 3. Temperature monitors in the Novagryl treatment failed in 2009 and no data were collected. On sunny days, all of the covering materials increased air temperatures inside the tunnels relative to having no cover. The tunnels had little impact on temperatures at night or on cloudy days. Temperatures under the opaque materials (white, green and Novagryl) were comparable, running about 5C warmer than air temperatures in 2008, with slightly less temperature enhancement seen during the cooler conditions encountered in spring of 2009 and 2010. Temperatures inside tunnels constructed of clear poly were far higher than for the other materials tested. The perforated clear poly tunnels produced daytime temperatures that were a few degrees cooler than the non-perforated covering.

During the frost events that occurred in the spring of 2009, none of the tunnel treatments provided any significant degree of frost protection and in many cases temperatures under the tunnels were marginally lower than when no cover was used.

The clear poly coverings were clearly beneficial to growth of the crops early in spring when conditions were cool. However, as the season progressed temperatures inside the non-perforated clear poly tunnels became excessively high, especially for the peppers which are prone to heat stress. In the 3$^{rd}$ week of June of 2008, outdoor temperatures reached the mid-20$^{o}$C range and none of the peppers and few of the melons in the non-perforated clear poly tunnel survived, as temperatures in the tunnels exceeded 65$^{o}$C for several days in a row. Some heat stress damage was also observed on peppers in the perforated clear poly tunnels where peak temperatures reached 60$^{o}$C. The spring of 2009 was cooler than normal and there were fewer indications of heat stress in the clear poly tunnels. In 2010 few of the pepper or tomato transplants survived the first week under the clear non-perforated tunnels. Peak temperatures in the non-perforated tunnels exceeded 50$^{o}$C on many occasions within the first two weeks of transplanting in 2010. There were no obvious differences in transplant survival or early season crop growth under the various opaque coverings. At the time of tunnels removal in 2008 and 2009, all covered crops appeared to be larger than when the crops were grown without a covering but it did not appear that flowering was advanced or enhanced by the tunnels. In 2010 the crop covers appeared to enhance early growth of the melons, but were not obviously beneficial to the peppers or tomatoes.

**Fig 1. Average daily air temperatures under various opaque (a) or clear (b) tunnels in 2008.**

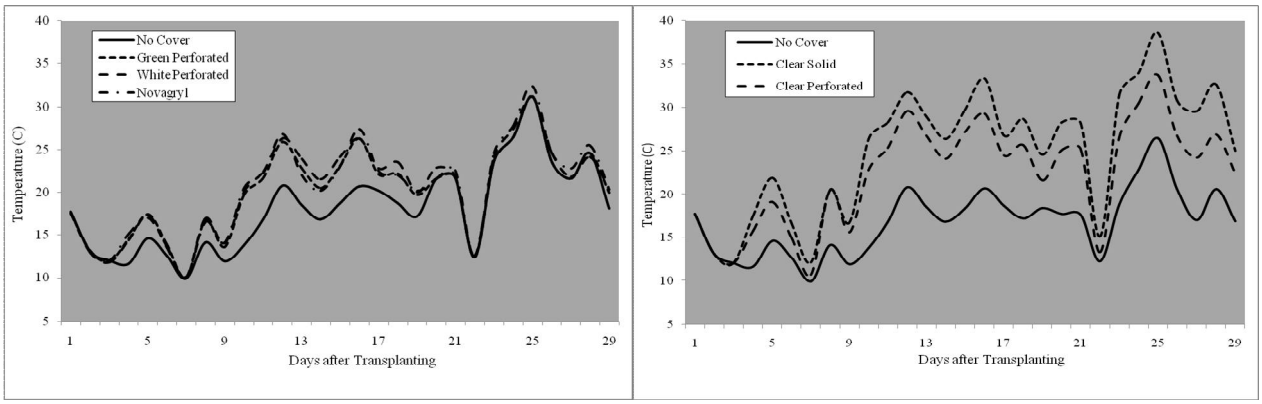



**Fig 2. Average daily air temperatures under various opaque (a) or clear (b) tunnels in 2009.**

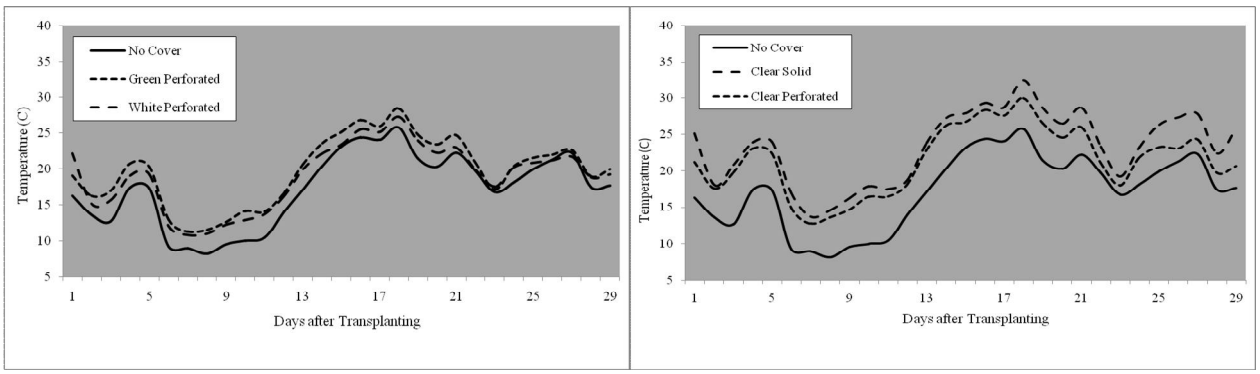
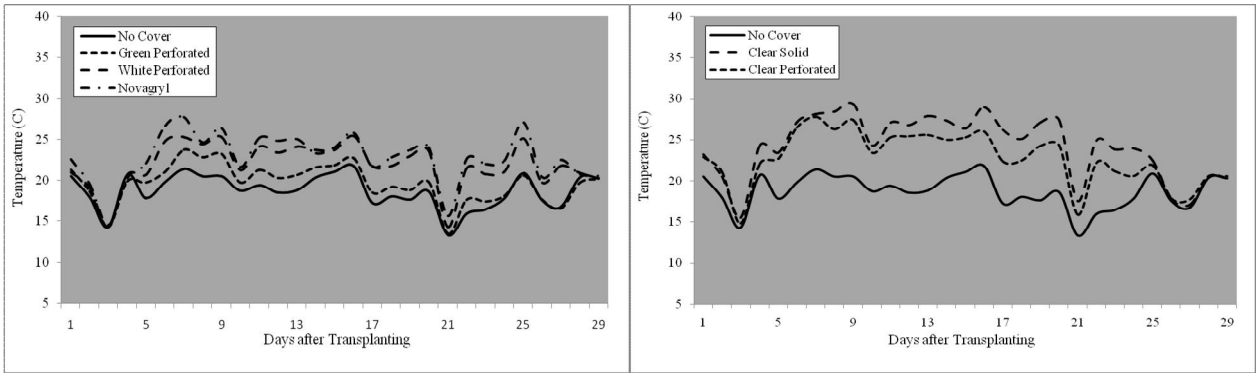



**Fig 3. Average daily air temperatures under various opaque (a) or clear (b) tunnels in 2010.**




**Peppers**

In previous trials we had found peppers to be sensitive to heat stress under any form of tunnel. As a consequence we have not recommended the use of any type of clear poly cover and have instead advocated the use of woven cover materials like Novagryl that provide a moderate degree of increase in temperatures. However, as these woven materials are relatively expensive, in this project we looked at two poly type materials that also might be expected to provide only a moderate degree of crop warming - white or green plastic. Results of using different cover types in peppers varied significantly over the 3 years of testing

(Table 1). While using the tunnels appeared to accelerate early growth in 2008, this had relatively little impact on total fruit yields. The treatments that accelerated early growth in 2008 without causing excessive heat stress (white and green poly and Novagryl) had a greater proportion of fruit that reached full maturity and turned red prior to the first killing frost. As prices for red peppers are much greater than for mature green or immature fruit, this difference would have substantially enhanced the value of the crop. All of the tunnel treatments enhanced total yields relative to the control in 2009 – this likely reflects the loss of stand that occurred due to frost and wind damage in the unprotected treatments. Only the green tunnel treatments enhanced yields of mature red fruit relative to the controls in 2009. In 2010 the green and clear perforated tunnel treatments enhanced overall yields relative to the non-covered controls, but none of the tunnels treatments enhanced yields of red fruit.

**Table 1. Influence of various types of tunnel covering on fruit yields of peppers in 2008, 2009 and 2010.**

| Covering Material | Red (kg/m) | Mature green (kg/m) | Total (kg/m) | Red % | Avg. fruit wt (g) |
|---|---|---|---|---|---|
| | **2008** | | | | |
| **Clear (non-perforated)** | - | - | - | - | - |
| **Clear (perforated)** | 0.1 b[1)] | 3.0 a | 3.4 a | 2 c | 89 b |
| **White** | 0.9 a | 3.0 a | 4.0 a | 23 a | 114 a |
| **Green** | 0.5 ab | 3.3 a | 4.0 a | 13 abc | 116 a |
| **Novagryl** | 0.7 a | 3.0 a | 3.8 a | 16 ab | 112 a |
| **No Cover** | 0.1 b | 3.2 a | 3.5 a | 4 bc | 125 a |
| | **2009** | | | | |
| **Clear (non-perforated)** | 0.2 c | 1.9 c | 3.4 b | 7 b | 85 d |
| **Clear (perforated)** | 0.4 bc | 2.6 b | 3.5 b | 13 a | 107 ab |
| **White** | 0.6 ab | 3.0 a | 3.4 b | 14 a | 104 ab |
| **Green** | 0.8 a | 3.0 a | 4.5 a | 17 a | 112 a |
| **Novagryl** | 0.5 abc | 3.0 a | 4.4 a | 12 a | 95 c |
| **No Cover** | 0.4 bc | 1.8 c | 2.8 c | 16 a | 99 bc |
| | **2010** | | | | |
| **Clear (non-perforated)** | 0 c | 0.5 d | 0.8 d | 2 b | 54 b |
| **Clear (perforated)** | 0.2 c | 3.4 a | 4.3 a | 6 b | 82 a |
| **White** | 0.5 b | 1.9 c | 2.9 c | 29 a | 82 a |
| **Green** | 1.1 a | 3.0 ab | 4.4 a | 29 a | 90 a |
| **Novagryl** | 0.7 b | 2.4 bc | 3.6 b | 27 a | 90 a |
| **No Cover** | 1.1 a | 2.2 c | 3.6 b | 34 a | 96 a |

[1)] *Values within columns followed by the same letter are not statistically different (P=0.05)(n=3)*

**Melons**

In previous trials melons had responded favorably to tunnel materials that created a relatively warm environment, with perforated clear polyethylene representing the standard recommended tunnel treatment. In all three years of testing the melons appeared to thrive for a period in the extremely warm conditions provided by the clear non-perforated polyethylene tunnels - but in 2008 the crop was killed when temperatures in these tunnels spiked above 65$^{o}$C. Less extreme high temperatures were observed after transplanting in 2009 and 2010 and at the time of tunnel removal the melon crops under the non-perforated clear poly tunnel appeared to be the most advanced.

In 2008 the clear perforated polyethylene treatment produced the highest early melon yields (by mid-Sept), in 2009 the Novagryl tunnels produced the greatest early yields, while in 2010 Novagryl and the white tunnels produced the highest early yields (Table 2). The no tunnel treatment consistently had the lowest early yields. When yields of mature fruit were calculated over all harvests in 2008, all tunnel treatments produced statistically equivalent yields, with the lowest yields occurring when no tunnels were used. By contrast in 2009, the Novagryl and white tunnels produced superior total yields while the other tunnel treatments were no better than the control. In 2010 only the Novagryl treatment enhanced total yields of mature melon fruit relative to the controls. In 2008 the yield advantage provided by the tunnel treatments was strictly due to the tunnels accelerating fruit maturity, as total fruit yields, including immature fruit were not affected by the tunnels. In 2009 the control treatment produced the fewest fruit in total but clearly set these fruit relatively early, resulting in a high proportion of the fruit maturing by the final harvest. In 2010 the beneficial effect of the Novagryl treatment reflected an increase in the total amount of fruit set rather than any acceleration of fruit maturity. Fruit harvested from the non-covered control treatments were substantially larger than in the tunnel treatments in 2008 but no corresponding treatment effects on fruit size were observed in 2009 or 2010.

**Tomato**

In the 2009 tomato trial the white poly tunnel treatment produced the greatest early season (prior to mid-Sept) yields of mature red fruit. By contrast, in 2010 all of the tunnel treatments reduced early yields of mature red fruit relative to the non-covered controls. The white tunnel treatments in 2009 produced greater total yields of mature fruit and a higher proportion of fruit that ripened prior to frost relative to the non-covered controls. The no tunnel treatment produced the greatest combined yield of red and immature green fruit in 2009. In 2010 none of the tunnel treatments enhanced any of the total yield parameters relative to the non-covered controls. In both years use of the non-perforated clear tunnel had a very negative effect on the tomato crop, with many plants dying due to heat stress and the development of the surviving plants was delayed to the point that few fruit matured prior to the first killing frost.

**Table 2. Influence of various types of tunnel covering on yields of melons in 2008, 2009 and 2010.**

| Covering Material | Early [1)] (kg/m row) | Mature (kg/m row) | Total (kg/m row) | Mature % | Avg. fruit wt (kg) |
|---|---|---|---|---|---|
| | **2008** | | | | |
| **Clear (non-perforated)** | - | - | - | - | - |
| **Clear (perforated)** | 2.6 a[2)] | 8.8 a | 14.2 a | 61 a | 1.25 b |
| **White** | 1.4 b | 7.4 ab | 12.9 a | 56 a | 1.21 b |
| **Green** | 1.1 bc | 5.8 ab | 12.9 a | 45 ab | 1.29 b |
| **Novagryl** | 2.0 ab | 9.0 a | 14.8 a | 61 a | 1.24 b |
| **No Cover** | 0.3 d | 4.0 b | 11.7 a | 33 b | 1.63 a |
| | **2009** | | | | |
| **Clear (non-perforated)** | 1.0 d | 4.4 b | 18.9 ab | 21 c | 1.12 b |
| **Clear (perforated)** | 2.6 b | 4.6 b | 17.2 b | 25 bc | 1.19 b |
| **White** | 2.0 c | 8.0 a | 15.4 bc | 50 a | 1.31 a |
| **Green** | 2.5 b | 5.0 b | 16.7 b | 28 bc | 1.16 b |
| **Novagryl** | 3.8 a | 8.1 a | 20.8 a | 36 b | 1.33 a |
| **No Cover** | 0.4 d | 5.2 b | 13.4 c | 35 b | 1.37 a |
| | **2010** | | | | |
| **Clear (non-perforated)** | 1.9 b | 6.5 b | 12.3 b | 56 | 1.14 |
| **Clear (perforated)** | 1.8 b | 6.9 b | 13.0 ab | 52 | 1.4 |
| **White** | 3.4 a | 7.2 b | 11.0 b | 64 | 1.41 |
| **Green** | 2.1 b | 7.7 b | 12.2 b | 56 | 1.35 |
| **Novagryl** | 3.6 a | 9.7 a | 14.8 a | 66 | 1.51 |
| **No Cover** | 1.6 b | 7.0 b | 11.1 b | 64 | 1.26 |

[1)] *Early harvests = yields by mid-Sept.*

[2)] *Values within columns followed by the same letter are not statistically different (P=0.05)(n=3)*

**Conclusion -** this project demonstrated the value of low tunnels in the production of warm season crops within the relatively short and cool growing season available in Saskatchewan. The results also showed the importance of selecting covering materials that match the requirements of the crop, while illustrating the impact of the growing season on the relative suitability of each covering for a given crop. In general the cover materials that provided only a moderate level of enhancement of air temperatures (Novagryl and white) appeared to provide the most consistent benefits. These results may also suggest that the wind and frost protection provided by the tunnels may be more important than the degree to which they enhance temperatures. While clear pole tunnels produced the warmest overall environment it appears that temperatures in these tunnels were occasionally excessive which offset the benefits of a warmer overall environment. Clear poly tunnels can only be recommended for use early in the season on heat tolerant crops like melons. Special care must be taken when covering tomatoes with any type of material otherwise fruit set may be delayed – leading to a corresponding delay in maturity and reduced crop value.

**Table 3. Influence of various types of tunnel covering on yields of tomato in 2009 and 2010.**

| Covering Material | Early [1] (kg/m row) | Mature (kg/m row) | Total (kg/m row) | Mature % | Avg. Fruit Wt (g) |
|---|---|---|---|---|---|
| | **2009** | | | | |
| **Clear (non-perforated)** | 0 c[2] | 0.9 d | 16.4 c | 5 c | 39 b |
| **Clear (perforated)** | 1.2 b | 5.0 bc | 21.7 b | 23 b | 72 a |
| **White** | 3.9 a | 7.0 a | 23.7 ab | 30 a | 74 a |
| **Green** | 0.8 b | 3.9 c | 22.4 ab | 17 b | 69 a |
| **Novagryl** | 1.5 b | 6.1 ab | 20.8 b | 29 a | 76 a |
| **No Cover** | 1.3 b | 5.0 bc | 26.3 a | 19 b | 78 a |
| | **2010** | | | | |
| **Clear (non-perforated)** | 0 c | 1.4 c | 3.0 c | 1 b | 101 d |
| **Clear (perforated)** | 0.2 c | 5.5 b | 8.5 b | 10 b | 124 c |
| **White** | 1.4 b | 10.3 a | 12.2 a | 27 a | 145 b |
| **Green** | 2.0 b | 10.1 a | 13.0 a | 26 a | 150 b |
| **Novagryl** | 1.9 b | 10.8 a | 12.8 a | 25 a | 172 a |
| **No Cover** | 3.2 a | 10.9 a | 13.6 a | 31 a | 173 a |

[1] *Early harvests = yields by mid-Sept.*

[2] *Values within columns followed by the same letter are not statistically different (P=0.05)(n=3)*