CLIMATE CHANGE ADAPTATION PROGRAM

Using Plastic Films in Low Tunnels for Modification of Microclimate and Enhancing Plant Growth

Funding for this project has been provided by the Governments of Canada and British Columbia through Growing Forward 2, a federal-provincial-territorial initiative. The program is delivered by the Investment Agriculture Foundation of BC.

DELIVERED BY

Investment Agriculture Foundation

FUNDING PROVIDED BY

Growing Forward 2

British Columbia

Canada

Climate Action Initiative
BC AGRICULTURE & FOOD

Using plastic films in low tunnels for modification of microclimate and enhancing plant growth Research Factsheet

Farm Adaptation Innovator Program

Hughie Jones[1], Andy Black[2], Paul Jassal[3]

Geographic Applicability This study was conducted in Vancouver, Delta and the Cariboo. The findings may be applicable to other regions in BC.

Commodity relevance This research was conducted on Padrón peppers, zucchinis and broccoli. While the relative effects on microclimate and crop yield will apply to other heat-loving vegetable crops, the magnitude of effects will differ for different soils and climatic conditions.

Timeline June 2016 – November 2017

[1] Graduate student
[2] Professor
[3] Research Associate
*Biometeorology and Soil Physics Lab, Faculty of Land and Food Systems, University of British Columbia, Vancouver, BC

Background

Enclosures (e.g., low tunnels) covered with plastic films with medium to high sunlight transparency (i.e., high transmissivity) can significantly alter air temperature (T_a) and have potential to increase crop yield. Low tunnels are not only effective during early and late in the growing season, but are also effective during peak growing season to cool crops (cover whitening), which would otherwise experience excess heat stress. Much like transparent polyethylene mulches placed on the soil surface during the daytime, low tunnels trap heat in the air that they enclose, which increases T_a. During nighttime, the effect of low tunnels on T_a is reduced due to the absence of sunlight. However, specialty plastics, such as Thermax, have the ability to prevent longwave or thermal radiation loss, much like glass, and the associated heat keeps T_a higher than for conventional polyethylene.

Objectives

- To quantify the effect of low tunnels covered with high (polyethylene) and low (Thermax) longwave transmissivity plastic films on daytime and nighttime air temperature.
- To quantify the effects of low tunnels on vegetable crop yield.

Methods

Vegetation-free low tunnels

Net radiation (R_n) is defined as the sum of net (inputs - outputs) shortwave (S) (i.e., sunlight) and longwave (L) radiation (i.e., thermal radiation) available at the Earth's surface to heat soil, air and plants or evaporate water. In this study we measured R_n inside and outside three vegetation-free low tunnels (12 m long x 1 m wide) covered with three high shortwave transmissivity plastic films, POLY, $POLY_{perf}$ and TMX (Table 1 and Figs 1 and 2).

Table 1. Plastic films, and their abbreviations, used in this study

Plastic polyethylene cover	Cover abbreviation
Polyethylene, w/BE2	POLY
Perforated polyethylene, w/BE2	$POLY_{perf}$
Thermax, w/BE2	TMX
No low tunnel, w/BE2	NLT

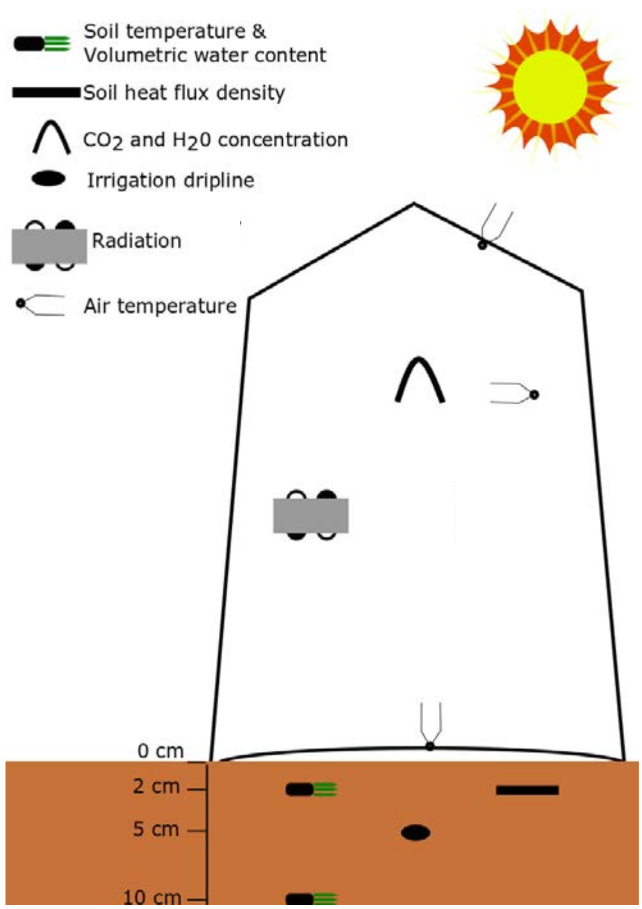

Figure 1. Cross-section of low tunnel instrumentation setup

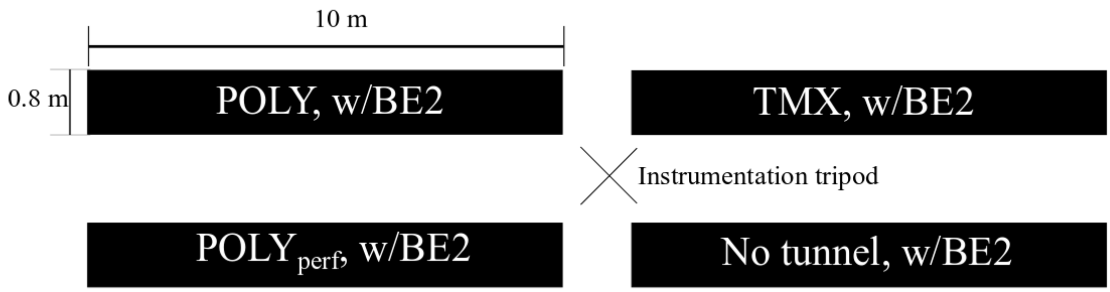

Figure 2. Overhead view of the experimental layout for comparing vegetation-free low tunnels

Results

Radiation: The R_n, S and L balances of POLY and TMX covered low tunnels, on two separate days, are shown in Fig 3. The daily sum of incoming shortwave radiation (S_d) at the top of the tunnel was 18 and 19 MJ (megajoules) m^{-2} , of which approximately 90%, i.e., 16 and 17 MJ m^{-2} for TMX and POLY, respectively, penetrates the low tunnel cover, is absorbed by the black plastic mulch floor (BE2) and is available for heating (Fig 3a). Therefore, in terms of the shortwave radiation balance, both plastics are very similar. On the other hand, due to TMX's low longwave transmissivity (i.e., glass-like property) the net loss of longwave energy over a day is only 8 MJ m^{-2} for TMX compared to 11 MJ m^{-2} for POLY (Fig 3b). The net result is that the total energy (R_n) taken up by the TMX and POLY low tunnels is 8 and 6 MJ m^{-2} day^{-1}, respectively, i.e., ~33% higher for TMX (Fig 3c).

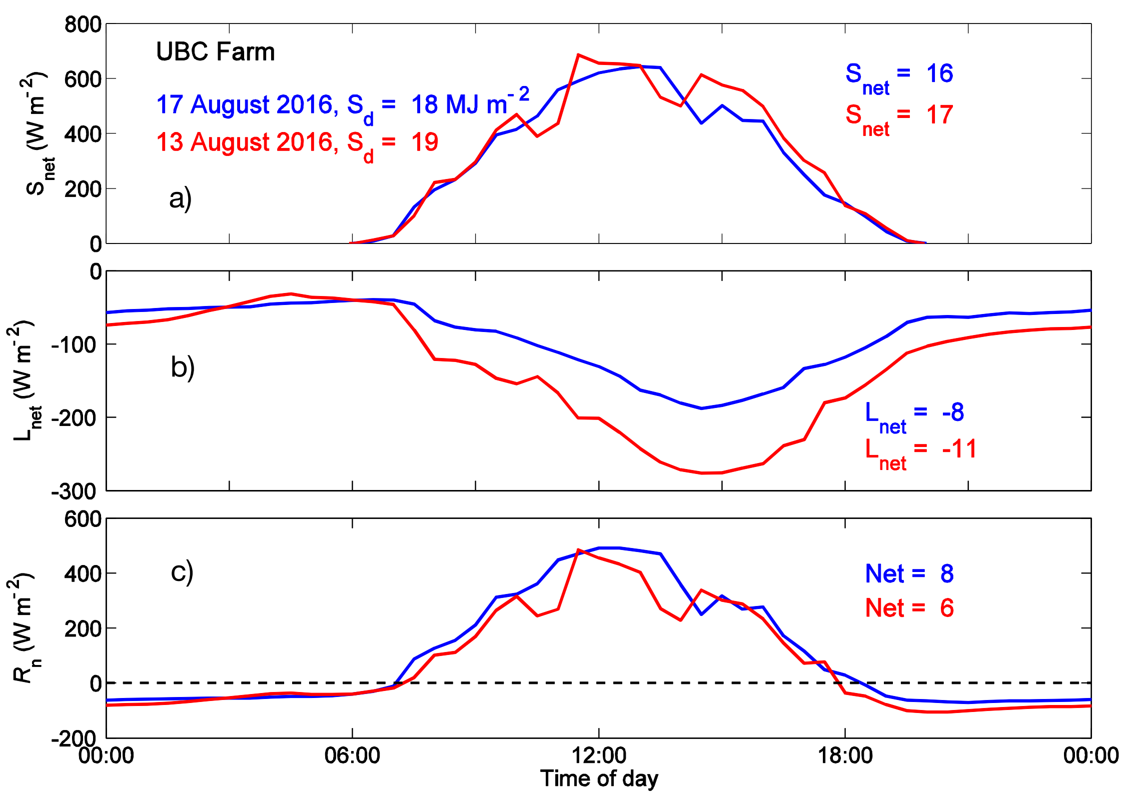

Figure 3. Net shortwave (S_n), longwave (L_n) and net radiation (R_n) for TMX (blue) and POLY (red) covered low tunnels on two sunny days

Results (con't)

Temperature: The midday temperature of the plastic mulch floor (T_m) is only slightly higher for the tunnel treatments compared to the control (i.e., NLT) (Table 1 and Fig 4a). On the other hand, at night T_m is 3 and 5 °C higher inside POLY and TMX covered tunnels, respectively, than in the NLT treatment. For T_a, the NLT treatment exhibits daytime and nighttime behavior typical of Vancouver, with the highest T_a near 4 pm PST. Interestingly, all treatments covered with low tunnels exhibit daytime behavior very different than NLT, instead behaving similar to S_d (Fig 3a). At 2 pm, T_a inside the $POLY_{perf}$ and POLY tunnels is ~10 and 12 °C, respectively, higher than NLT. TMX results in additional heating with T_a rising to 16 °C higher than NLT (Fig 4b).

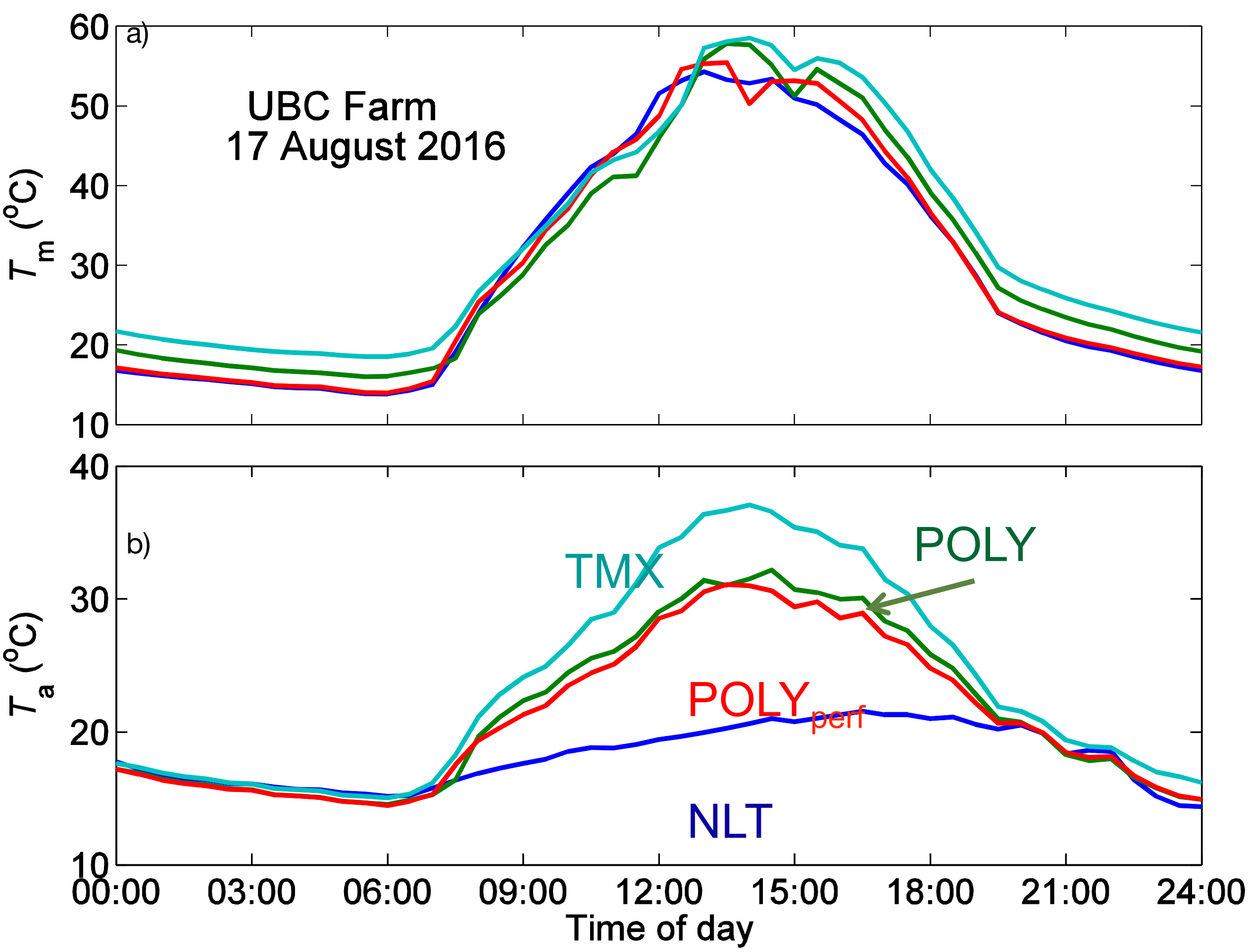

Figure 4. Mulch surface temperature (T_m) and air temperature (T_a) inside low tunnels under POLY (green), $POLY_{perf}$ (red) and TMX (cyan) films in comparison with a BE2 mulch control (NLT) (blue)

UBC Farm: low tunnels with Padrón peppers

240 greenhouse grown Padrón pepper starts were transplanted into soil covered with BE2 plastic mulch (drip irrigation at the 5-cm depth) at UBC Farm in early June 2017. The 240 peppers were split into three treatment areas (80 plants/treatment), one left uncovered (NLT_{pp}), one covered with a POLY low tunnel ($POLY_{pp}$) and one covered with a TMX low tunnel (TMX_{pp}). In early July 2017, harvesting began and ended in late October. In early August 2017, it was clear that the low tunnel grown peppers produced more peppers per harvest period, but by mid to late August, the harvest rate declined for the low tunnel grown peppers, which was attributed to a depletion of CO_2 during the daytime (Figs 5 and 6), when the plants occupied a large proportion of the low tunnel volume and were growing vigorously. These results draw attention to the potential benefits (i.e., increased heating) and drawbacks (i.e., low CO_2 concentration, high humidity) associated with using low tunnels, and suggest the need to examine the value of periodic tunnel ventilation.

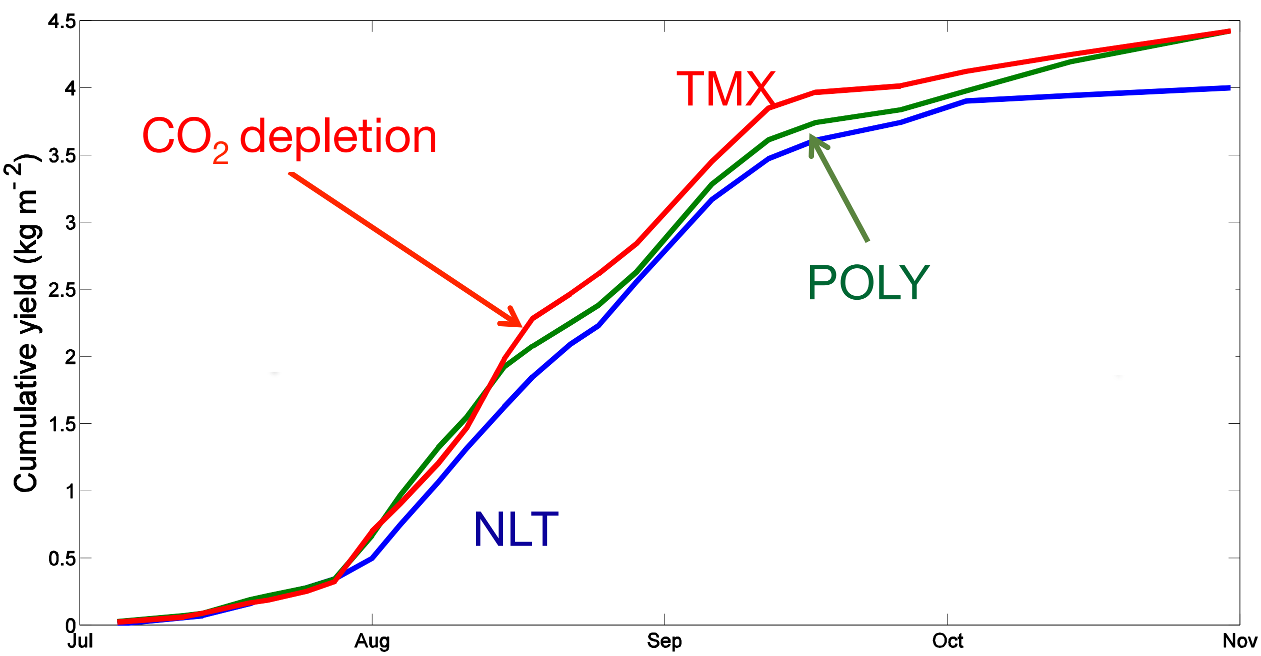

Figure 5. Cumulative Padrón pepper yield for peppers grown without a low tunnel (NLT) (blue), and in POLY (green) and TMX (red) low tunnels

Cropthorne Farm: low tunnels with zucchinis

At Cropthorne Farm, Westham Island, BC we assessed how low tunnels would affect zucchini yield. On May 10 2016, a single row of zucchini starts (36 plants, 18” spacing) were transplanted into BE2 covered soil. Half the row (18 plants) was then covered on May 12 2016 with $POLY_{perf}$ and the other half was left uncovered until June 8 2016 when harvest began. Zucchinis were harvested biweekly until July 20 2016 and fruit mass (wet) was determined. The zucchini plants that were covered with $POLY_{perf}$ from May 12 to June 8 2016 produced a 20% higher zucchini yield.

Mackin Creek Farm: low tunnels with broccoli

At Mackin Creek Farm, near Soda Creek BC we assessed how low tunnels would affect broccoli yield. Broccoli yield for plants grown outside and inside low tunnels was measured during 2016 and 2017, respectively. Broccoli harvest began June 2nd in 2016 and June 17th in 2017. 2016 was a particularly warm spring but in 2017 frost persisted (40 cm depth) until mid April 2017. Despite being the colder year, broccoli yield was 200% higher in 2017 compared to 2016. This difference in yield was attributed to increased heat and protection of the soil surface from windy conditions and subsequent soil surface drying. In this way the low tunnels helped conserve soil moisture for use by the broccoli crop later in the growing season.

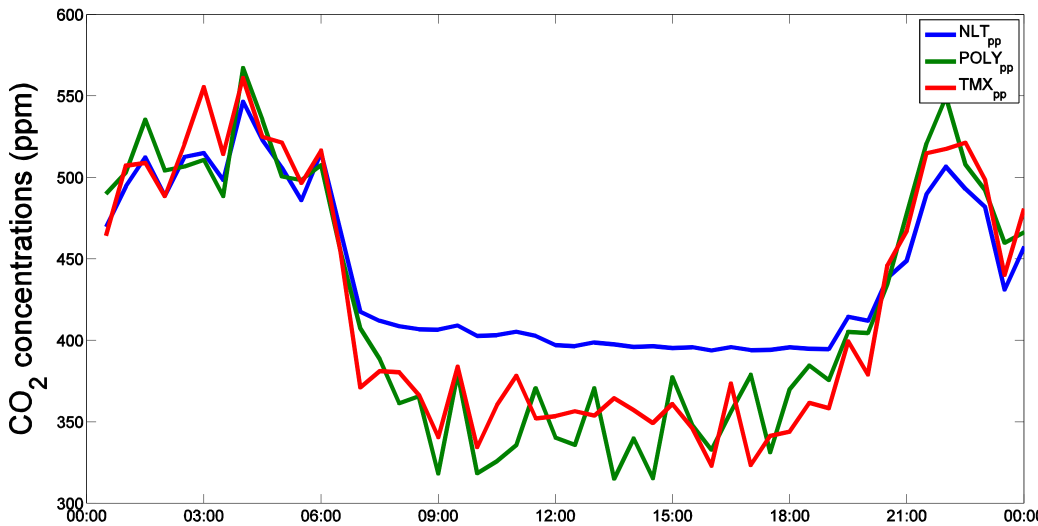

Figure 6. Daytime and nighttime CO_2 concentration near the top of the Padrón pepper plant canopies grown without a low tunnel (NLT) (blue), and in POLY (green) and TMX (red) low tunnels

To summarize, $POLY_{pp}$ and TMX_{pp} yielded ~12% more peppers than NLT_{pp} during the harvest period at UBC Farm. At Cropthorne Farm and Mackin Creek Farm, low tunnels increased zucchini and broccoli yield 20% and 200%, respectively. Future studies should focus on water and carbon balances in low tunnel grown crops to better understand how and when irrigation and CO_2 fertilization should be applied.

For more information:

For more details on the results of this project visit the Climate Action Initiative website:
https://www.bcagclimateaction.ca/faip-project/fi07/

For Soil Physics and Biometeorology Lab website:
http://lfs-biomet.sites.olt.ubc.ca/

Conclusions

- Vegetation-free low tunnels covered with polyethylene and glass-like plastic films (e.g., TMX) have the potential to increase T_a by 12°C and 16 °C, respectively.
- Low tunnels can increase crop yields but there are drawbacks (e.g., CO_2 depletion) which need to be overcome to take full advantage of low tunnels.

Funding and support for this project was provided in part by: