Plastic film mulches and low tunnels to help BC farmers adapt to climate change

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Farm Adaptation and Innovator Program

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Outline of talk

- Background – global use of plastic films in agriculture
- Objectives and experiments in our FAIP research project
- Principles of thermal effects of mulches and low tunnels
- Mulch experiments; film radiative properties
- Low tunnel experiments; microclimate alteration
- Future plans; experiments and modelling
Use of plastic films in agriculture

- Polyethylene became available in the early 1950s.
- Emery Emmert, considered by many as the father of plasticulture, pioneered the construction of plastic-covered greenhouses.
- First plastic greenhouse constructed at the Kentucky Agricultural Experimental Station in 1953.

**Uses**
- Soil mulches
- Low tunnels
- Greenhouses and walk-in high tunnels
- Floating row covers
- Wind breaks and pest barriers
Use of plastic films in agriculture

Annual consumption/production (Mt yr\(^{-1}\))

<table>
<thead>
<tr>
<th>Region</th>
<th>Consumption/production (Mt yr(^{-1}))</th>
<th>Area (Mha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global</td>
<td>6.5</td>
<td></td>
</tr>
<tr>
<td>China</td>
<td>1.25</td>
<td>(20 Mha to 50 Mha)</td>
</tr>
<tr>
<td>Europe</td>
<td>0.7</td>
<td>(0.75 Mha)</td>
</tr>
<tr>
<td>N. America</td>
<td>0.2</td>
<td>(0.22 Mha)</td>
</tr>
</tbody>
</table>

Other major users are: Japan, Korea, Spain

Liu et al. (2014)
Li et al. (2013)
Scarisca-Mugnozza (2011)
Espi et al. (2006)
Soil mulches

Espi et al. (2006)

Now as much as 50 Mha (Li 2013)

10 Mha

Covered surface (ha)

China
Asia Pacific
Europe
Middle East
S & C America
North America
Africa

Low tunnels

0.7 Mha

Espi et al. (2006)
Types of plastic films

**Standard**
- Black
- White
- Clear

**Designer**
- Colored (brown, red, green and blue)
- Hybrid (between clear and black; absorb or reflect PAR)
- UV-blocking
- Fluorescent films
- NIR-blocking
- Thermic & ultrathermic films (blocks transmission of far IR)
- Anti-dripping (or noncondensing) and anti-fog (hydrophilic)
- Biodegradable/photodegradable
- Slitted and perforated
Benefits of plastic films in agriculture

“Development and use of plastic polymers has revolutionized the production of horticultural crops worldwide…” Lamont (2005)

- Extending growing season by modifying air \( (T_a) \) and soil \( (T_s) \) temperature
- Soil water conservation and efficient water use
- Control of insects and soil-borne disease pathogens
- Reduced soil erosion
- Decreased nutrient leaching and increased fertilizer use efficiency
- Increased quality, quantity and cleanliness of produce
Commercial use of mulching in BC

Plastic mulches Klipper’s Organic Farm, Cawston, BC
Project objectives

i. To characterize different plastic films for their radiative properties and their capacity to manipulate $T_s$, $T_a$ and light.

ii. To determine efficacy of soil water conservation.

iii. To model surface energy balance and soil thermal regime from knowledge of film and soil characteristics.

iv. To provide farmers with tools enabling them to adapt to predicted climate change by using plastic films with different characteristics under different climate conditions.
Plastic films used in this study

<table>
<thead>
<tr>
<th>Soil Mulch</th>
<th>Abbreviation</th>
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</thead>
<tbody>
<tr>
<td>Black embossed # 2</td>
<td>BE2</td>
</tr>
<tr>
<td>Black embossed PABPNARB</td>
<td>BEP</td>
</tr>
<tr>
<td>Black on white</td>
<td>BonW</td>
</tr>
<tr>
<td>Infrared transmitting</td>
<td>IRT100</td>
</tr>
<tr>
<td>Infrared transmitting Green</td>
<td>Green</td>
</tr>
<tr>
<td>Infrared transmitting Red</td>
<td>Red</td>
</tr>
<tr>
<td>Dura-film thermax</td>
<td>Thermax</td>
</tr>
<tr>
<td>Dura-film super 4</td>
<td>Super4</td>
</tr>
<tr>
<td>White on black</td>
<td>WonB</td>
</tr>
</tbody>
</table>

| Low tunnels                                     |              |
| Dura-film thermax                              | Thermax      |
| Dura-film super 4                              | Super4       |
| Transparent polyethylene                       | Clear        |
Experiments conducted at three organic farms

- Mulch experiments at
  - UBC Farm (Vancouver)

- Low-tunnel experiments at
  - UBC Farm (Vancouver)
  - Cropthorne Farm (Ladner) - Lydia Ryall
  - Mackin Creek Farm (Soda Creek) – Robert Borsato and Catherine Allen

Map showing locations of UBC Farm, Cropthorne Farm, Mackin Creek Farm, and Soda Creek (near Williams Lake).
Preparing for field experiments in Spring 2015

In the Biomet Lab, Thea Rodgers wiring up a data logger

Hughie and Thea testing data logger and sensors
Installing data logging equipment

Paul Jassal with Summer Research Assistant, Ernest Wu, at UBC Farm
The effects of mulch types on soil microclimate

Experiment laid out at UBC Farm with 10 treatments (9 plastic films and a control) in 3 blocks.
Three radiation bands can be manipulated using plastic films:

- Shortwave (Solar)
- Longwave (Far IR)
- PAR/visible
- Near infrared (IR)

We can determine the film radiative characteristics:

- Reflectivity
- Transmissivity
- Absorptivity
Radiation balance

Shortwave radiation \( \rightarrow R_S \downarrow \quad R_L \downarrow \quad \rightarrow \) Longwave radiation

\[ \text{Albedo} = \frac{R_S \uparrow}{R_S \downarrow} \]

\[ R_n = R_S \downarrow - R_S \uparrow + R_L \downarrow - R_L \uparrow \]

\( R_n \) is net radiation
WonB has the highest albedo while BE2 (black) had the lowest albedo. Measurements made near mid-day in August and September at UBC Farm
Radiative characteristics of plastic-film mulches

Using an ASD Inc Field Spec 4 spectroradiometer to measure reflectivity and transmissivity spectra over the solar (shortwave) spectrum.
Spectral properties of plastic films

Green
Spectral properties of plastic films

Super4

- Reflectivity
- Transmissivity
- Absorptivity

Wavelength (nm)

0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1

350 550 750 950 1150 1350 1550 1750 1950 2150 2350
Using plastic-film mulches to modify soil temperature and moisture regimes

Installing temperature and moisture sensors (Decagon 5TM) at 2-cm and 5-cm depths at UBC Farm.
Measurement of soil heat flux

Heat flux plates were installed at the 3-cm depth to measure flow of heat beneath mulches
Effects of black and clear plastic mulches on the soil energy balance

Bare moist soil

- $R_n$
- Latent heat (evaporation)
- Sensible heat ($H$)
- Soil heat ($G$)
- Heat loss due to evaporation & sensible heat flow.

Black mulch

- Low albedo of black film increases soil heat flow as long as there is good film-soil contact (thin still air layer).

Clear mulch

- Still air layer decreases sensible heat loss & increases soil heat flow.
Effects of low tunnels on the energy balance

Wind

Low tunnel

Black mulch

$R_n$

$H$

$G$
Installing data logger and microclimate sensors at Cropthorne Farm in Delta, BC
Plastic-film low tunnels - soil and aerial microclimate

Instrumented low tunnels on melons on Cropthorne Farm
Air temperature in low tunnels

- Ambient
- Clear
- Thermax
- Super4
Plastic-film low tunnels in northern interior BC to extend growing season

Mackin Creek Farm near Williams Lake, BC.

A 6-acre organic vegetable farm in north interior BC. Plan to use low tunnels to advance the growing season to increase vegetable production in early spring. Plots instrumented and planted with spinach and lettuce. Modem connection to UBC.

Soil temperature and moisture sensors, and photosynthetically active radiation sensors.
Future research plans

• Complete measurements of radiative characteristics of plastic films.

• Conduct mulch experiments focusing on film-soil contact resistance and its effect of soil heating.

• Conduct experiments to quantify the exchange of sensible heat between film and the atmosphere for mulches and low tunnels.

• Experiments to explore use of low tunnels in starting vegetable crops much earlier in the year.

• Develop algorithms for calculating thermal effects of mulches and low tunnels, enabling quick determination of the effects on soil and air temperature.

• Support concept of a research network: researchers, farmers, etc.
Thank you

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Samantha Charlton, Climate Action Initiative
Emily MacNair, Climate Action Initiative
Questions
Spectral properties of plastic films

Red

[Graph showing spectral properties with lines for Reflectivity, Transmissivity, and Absorbptivity across different wavelengths (nm).]
Greenhouses and walk-in high tunnels

1.2 Mha

Espi et al. (2006)