Light penetration into the soybean canopy and its influence on soybean rust infection

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Andy Schuerger (UF/NASA), Dario Narváez (Monsanto)
<table>
<thead>
<tr>
<th>Early Epidemic</th>
<th>Mid Epidemic</th>
<th>Late Epidemic</th>
</tr>
</thead>
</table>

SBR progress up canopy
As you go from left to right there is decreasing energy, decreasing frequency, and increasing wavelength.
Visible light?

As frequency gets higher, energy gets higher
# Ultra Violet Radiation

<table>
<thead>
<tr>
<th>Name</th>
<th>Abbreviation</th>
<th>Wavelength Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultraviolet A</td>
<td>UVA</td>
<td>400 nm–320 nm</td>
</tr>
<tr>
<td>Ultraviolet B</td>
<td>UVB</td>
<td>320 nm–280 nm</td>
</tr>
<tr>
<td>Ultraviolet C</td>
<td>UVC</td>
<td>280 nm–100 nm</td>
</tr>
<tr>
<td>Vacuum UV</td>
<td>VUV</td>
<td>100 nm–10 nm</td>
</tr>
</tbody>
</table>
Sun Energy 8% UV, 39% visible, 53% infrared

Solar Radiation Spectrum

- 260 nm is most damaging to DNA
- Radiation at Sea Level
- 5250°C Blackbody Spectrum
- Sunlight at Top of the Atmosphere

http://upload.wikimedia.org/wikipedia/commons/4/4c/Solar_Spectrum.png
UV Index November 23, 2009
Photosynthetic Active Radiation

PAR absorption affects the quality of light the lower canopy spores are exposed to.

Impact of light on disease

- PAR necessary for plant health
- Solar radiation can directly reduce spore survival (especially UVB)
- Solar radiation increases canopy temperature and reduces humidity
- Solar radiation is reduced by canopy shading, thus older leaves are usually more shaded
- Spore release often involves some form of desiccation
Two experiments were conducted to manipulate the canopy microclimate –

The first involved manipulating the row width (18, 38, and 76 cm) while using the same seeding rate of 470,000 plants per hectare

The second involved manipulating canopy microclimate by applying shade cloth at 0, 30, 40, and 60% to soybeans in the field
Row spacing study

(18, 38, 78 cm between rows)
Row Spacing Study

Objective
Evaluate the effect of row spacing (18, 38, and 76 cm) on disease increase
20 X 20 m plot
Disease assessed weekly at every 3 m grid point at low, mid, and upper canopy
Mean severity, Time = 59 DAI, RS = 18 cm
Mean severity, Time = 59 DAI, RS = 38 cm
Conclusion

By 59 DAI, it appears that ASR spread the furthest in the 76 cm row spacing. This was likely due to the increase in air movement, and thus spore movement, down the wider rows. These data are being further analyzed.
Shade Plot Study

Objective

Evaluate the effect of solar radiation on disease increase, canopy microclimate and cuticular wax thickness

(plant leaves often produce more cuticular wax under higher light conditions, which may serve as a barrier to the direct penetration of pathogens)
• 3 X 3 m shade structures (4 sided, open on north side)
  – 30%, 40%, 60%, control
• Constructed over soybeans at growth stage V3-V4, subsequent leaves marked
• Recorded temperature, relative humidity, disease severity
• Leaves were collected at R1 for susceptibility assays & cuticle analysis
• Conducted over 2 years, with 2 plantings each year
Evaluations were done weekly, starting 10–14 days after inoculation (0.5 L of 70,000 spores/ml) or at R1 if naturally infected. Sampled 10 times at lower, middle, and upper canopy levels for each evaluation.
Disease development

<table>
<thead>
<tr>
<th>CONTROL</th>
<th>60% SHADE</th>
</tr>
</thead>
</table>

[Images of two fields: one with CONTROL and another with 60% SHADE]
2008 2 PD Upper Canopy Results

% Severity

- Control (0)
- 30% Shade
- 40% Shade
- 60% Shade

<table>
<thead>
<tr>
<th>Date</th>
<th>2-Oct</th>
<th>10-Oct</th>
<th>17-Oct</th>
<th>23-Oct</th>
</tr>
</thead>
<tbody>
<tr>
<td>R3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R4-R5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Leaves collected at R1 were placed on agar after being inoculated with ~21,000 spores/mL, ~3ml/leaf, and evaluated 10 to 14 days after inoculation.
Disease development from leaves at mid canopy level
Cuticular Wax Thickness

Cuticle wax (mg) per cm² leaf area

Canopy Level

Lower | Middle | Upper

- Control (0)
- 30% Shade
- 40% Shade
- 60% Shade

0.35
0.3
0.25
0.2
0.15
0.1
0.05
0

Effect of Shade on Temperature

Temperature (°C)

Time of Day

0 % SHADE
30 % SHADE
40 % SHADE
60 % SHADE

Graph showing the effect of different shades on temperature throughout the day.
Effect of Shade on Relative Humidity

- 0% SHADE
- 30% SHADE
- 40% SHADE
- 60% SHADE

Time of Day

% Relative Humidity

0 1 2 4 5 6 8 9 10 12 13 14 16 17 18 20 21 22
Conclusions

• Greater disease severity in 40% & 60% shaded plots

• Similarly, in leaf assays in the middle and upper canopy 40% & 60% shaded leaves have increased severity

• Trend of higher amount of cuticular wax in control across canopy levels

• Temperature and RH affected by shade cloth, regardless of thickness
In another related study

Trans-Oceanic Dust Plumes: Long Distance Dispersal of Microorganisms

(during south Florida summer up to 80% of suspended dust originates in Africa)
Effect of solar radiation on spore survival

**Objectives**

Quantify the solar radiation in the soybean canopy
Evaluate the effect of solar radiation on spore germination under field and laboratory conditions
Optronic OL754
## Energy values (W/m²)

<table>
<thead>
<tr>
<th>Canopy location</th>
<th>UVB</th>
<th>UVA</th>
<th>PAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper</td>
<td>3.00</td>
<td>43.8</td>
<td>328.3</td>
</tr>
<tr>
<td>Middle</td>
<td>1.19</td>
<td>10.5</td>
<td>78.7</td>
</tr>
<tr>
<td>Lower</td>
<td>0.34</td>
<td>3.26</td>
<td>14.9</td>
</tr>
</tbody>
</table>

As percentage of upper canopy

<table>
<thead>
<tr>
<th>Canopy location</th>
<th>UVB</th>
<th>UVA</th>
<th>PAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper</td>
<td>100%</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Middle</td>
<td>40</td>
<td>23</td>
<td>23</td>
</tr>
<tr>
<td>Lower</td>
<td>11</td>
<td>7</td>
<td>4</td>
</tr>
</tbody>
</table>
Full Solar Spectrum vs 30, 40, and 60% Shade Cloth

Irradiance (W/m²)

Wavelength (nm)
### Energy values (W/m²)

<table>
<thead>
<tr>
<th>Shade Treatment</th>
<th>UVB</th>
<th>UVA</th>
<th>PAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full sun (no shade)</td>
<td>3.37</td>
<td>47.53</td>
<td>349.2</td>
</tr>
<tr>
<td>30% shade</td>
<td>2.32</td>
<td>31.57</td>
<td>226.0</td>
</tr>
<tr>
<td>40% shade</td>
<td>1.84</td>
<td>24.66</td>
<td>173.7</td>
</tr>
<tr>
<td>60% shade</td>
<td>1.23</td>
<td>16.22</td>
<td>111.9</td>
</tr>
<tr>
<td>Full sun (no shade)</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>30% shade</td>
<td>36</td>
<td>34</td>
<td>32</td>
</tr>
<tr>
<td>40% shade</td>
<td>54</td>
<td>52</td>
<td>50</td>
</tr>
<tr>
<td>60% shade</td>
<td>69</td>
<td>66</td>
<td>65</td>
</tr>
</tbody>
</table>
Xenon lamp to simulate natural sunlight
UV-VIS-NIR Spectrum of the Xenon 6269 Lamp

- Full UV-VIS-NIR Spectrum (0 screens)
- 50% Flux (3 screens)
- 10% Flux (7 screens)

Irradiance (W/m²)

Wavelength (nm)
Effect of Simulated Solar Radiation on Spore Survival

Percent Germination (Normalized)

Hours of Exposure

- 100%
- 50%
- 10%
Effect of Simulated Solar Radiation on Spore Survival

\[ y = -0.0704x + 0.9065 \]

\[ R^2 = 0.6932 \]
Relationship between total solar irradiance and the normalized germination proportions of exposed *Phakopsora pachyrhizi* urediniospores.

Soybean rust incidence at different daily solar radiation intensities resulting from various shading effects. Incidence values were standardized to the highest values observed in each trial.

In A. Dias Dissertation “Epidemiological studies of shading effects on Asian soybean rust” Iowa State University, 2008
A.P.S. Dias, X. Li, P.F. Harmon, C.L. Harmon, and X.B. Yang  Effects of shade intensity and duration on Asian soybean rust caused by *Phakopsora pachyrhizi* Submitted to Plant Disease.
Conclusions

• Penetration of UVB higher compared to PAR and UVA, with PAR being captured by the leaves for photosynthesis
• As little as 1 hour of 100% sunlight begins to reduce spore survival, but even after 8 hours 20% or more can still germinate
• The reduced light in the lower canopy is more conducive to spore survival
Overall Conclusions

- Lower canopy disease is increased in part due to lower light conditions
- Urediniospores in the lower canopy are exposed to less light and their survival is significantly longer
- Decrease in light due to canopy density can result in reduced temperatures, increased RH and reduced cuticular wax, confounding the direct impact of light

Other factors include more dew in lower canopy, rain washing spores from upper canopy, some older leaves are more susceptible to SBR
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