Precision Viticulture: Unlocking Unseen Mysteries of the Vineyard

Ralph Brown
School of Engineering
University of Guelph
Communicate with your vines....

- Visual assessment of vines (scouting) is important - disease, nutrition, water stress, etc.
- Other information may be there but we are limited to the visible spectrum
- Instrumental spectroscopy of leaves and fruit in ultraviolet (UV), visible, near-infrared (NIR) can be useful...
1. Leaf spectral reflectance and vine health...

- Good fruit quality starts with a healthy, well-balanced vine
- Plant stress shows up in the foliage – photosynthesis apparatus and other plant pigments affected
- These absorb and reflect in different parts of the spectrum, cause changes in leaf reflectance
Spectral absorption of some plant pigments

- Chlorophyll a, b – absorb blue and red, reflect green
- Xanthophyll – absorb blue, reflect green to red
- Carotenoids – absorb blue, reflect green to red
- Anthocyanins – absorb green, reflect blue and red

<ultraviolet | visible | infrared
350 450 550 650 700 NIR
Leaf responses to physiological stress

- Environmental stress (e.g., ozone, powdery mildew) increased reflectance in 535-640 nm range, 670 nm unresponsive (Gregory Carter, 1993)
- Phylloxera-infested vines in California showed increased green reflectance (~550 nm) in remote sensing images (Lee Johnson, 1999)
- Anthocyanin biosynthesis in leaves from drought, extreme temperatures and light caused reduced green reflectance (Steele et al., 2009)
- NIR reflectance is relatively constant except under extreme water stress
Vegetation Reflectance Indices

- **Normalized Difference Vegetation Index (NDVI)** used in remote sensing is related to photosynthetically active biomass:
  \[
  \text{NDVI} = \frac{\rho_{\text{NIR}} - \rho_{\text{RED}}}{\rho_{\text{NIR}} + \rho_{\text{RED}}}
  \]

- **Normalized Green-Red Reflectance (NGRR)** uses *difference* between green (550 nm) and red (670 nm) for detecting plant stress:
  \[
  \text{NGRR} = \rho_{\text{NIR}} - \frac{(\rho_{\text{GREEN}} - \rho_{\text{RED}})}{\rho_{\text{NIR}} + (\rho_{\text{GREEN}} - \rho_{\text{RED}})}
  \]
Phylloxera study in Victoria, Australia

- Cabernet Sauvignon and Cabernet Franc vineyards where phylloxera is suspected
- 50 fully-expanded intact leaves selected at random from each of 4 blocks
- Leaves taken from clean and phylloxera-infested blocks (verified by digging up vines)
- Measured leaf reflectance with ASD FieldSpec Pro™ (350-2400nm)
- Compared leaf reflectance characteristic (NGRR) for infested and clean blocks
Light reflectance characteristic of grape leaves

(means of 50 leaves)

Wavelength, nm

Reflectance, decimal

Healthy vines
Phylloxera infested

visible
near infrared
Change in green-red reflectance indicates phylloxera infestation

Phylloxera in Cabernet Franc vineyard

- Red Reflectance
- Normalized Green-Red Reflectance

Vine Number

- Block 1 - healthy
- Block 1 - infested
- Block 2 - healthy
- Block 2 - infested
Can we use leaf reflectance to monitor vine status?

- 30-Bench Winemakers Riesling vineyard (Precision Viticulture project)
- Investigate single-leaf reflectance *in situ* and monitor vine and fruit performance
- Measure reflectance of fully-expanded leaves (5 per vine) monthly for ~ 500 sentinel vines
- Also determine soil moisture, vine water stress, harvest yield and quality
Taking leaf reflectance measurements at 30-Bench Winemakers vineyard
Normalized Green-Red Reflectance (NGRR) with Soil Moisture at 30-Bench Vineyard

NGRR July 26, 2007

NGRR August 24, 2007

Mean soil moisture
NGRR and °Brix at harvest - 2007
Leaf reflectance and fruit quality

- There is some relationship between plant stress (moisture), leaf reflectance (NGRR) and subsequent fruit quality.
- Relationship is complex, correlations are not reliable enough for easy prediction.
- Other factors (crop load, weather, pruning) have large effects.
- Leaf reflectance may have potential to map precision viticulture management zones.
Automated sensor for canopy reflectance

Greenseeker™

Images courtesy Ntech Industries, Inc.
Automated Sensors used for NDVI Mapping

GreenSeeker® NDVI Sensor on a quad bike

NDVI map from GreenSeeker® sensor

Images courtesy Ntech Industries, Inc.
Map of canopy reflectance (NDVI) used to make harvest decisions...

Courtesy Caine Thompson, Spatial Solutions NZ
Is there potential for using vineyard canopy reflectance in Precision Viticulture?

- Greenseeker® and CropCircle® systems are commercially available
- Evidence that NDVI variation (biomass) is related to harvest quantity and quality
- May be more convenient than remote sensing to define management and harvest zones
- Need more research on linkages between vine balance, health and fruit quality
2. Free-air VIS/NIR Reflectance of Grapes

• Absorbance and reflectance of light depends upon chemical composition of material
• Reflectance pattern reveals aspects of chemical composition
• Estimate fruit quality, e.g., total solids (°Brix), titratable acidity, pH, phenolics, anthocyanins from spectral reflectance characteristic
The Brimrose “le Vigneron” NIR System

• Portable handheld instrument scans one grape berry at a time in NIR spectrum
• Requires contact with berry, many berries must be sampled for representative values
• Can be used in vineyard, or with fruit samples
• Expensive, time consuming but has shown good performance
• Season-to-season prediction has not been robust, needs re-calibration
Brimrose Luminar 5030 NIR – “le Vigneron”
Free-air VIS/NIR Spectrometry

• Collaborator J-L Groux, Stratus Vineyard – Cab Sauvignon, Cab Franc, Syrah 2008 & 2009
• Use inexpensive USB spectrometer for visible and NIR reflectance characteristics
• Sample fruit according to normal pre-harvest procedure (200-berry composite sample)
• Scan entire composite sample (rapid, portable, more representative)
Free-air VIS/NIR setup used in 2008

Laptop and USB fiber-optic spectrometer with halogen lamps used for composite sample reflectance
Setup for 2009 reflectance measurements

- Enclosure modified to exclude ambient light effects
- Non-reflective container allowed re-orientation of berries between measurements
- Repeat measurements after gentle shaking
Partial least-squares regression for Brix using VIS/NIR
2009 PLS Predictions – Brix and pH

LOO BRIX prediction by 14 Component PLSR

LOO pH prediction by 7 Component PLSR
## Predictions from Spectral Reflectance

<table>
<thead>
<tr>
<th></th>
<th>2008 Brimrose</th>
<th>2008 PLS</th>
<th>2008 PLS/GA</th>
<th>2009 PLS/GA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sugar</strong></td>
<td>R²</td>
<td>0.702</td>
<td>0.785</td>
<td>0.868</td>
</tr>
<tr>
<td>(° Brix)</td>
<td>RMSEP</td>
<td>0.97</td>
<td>0.98</td>
<td>0.66</td>
</tr>
<tr>
<td><strong>pH</strong></td>
<td>R²</td>
<td>0.595</td>
<td>0.855</td>
<td>0.842</td>
</tr>
<tr>
<td></td>
<td>RMSEP</td>
<td>0.06</td>
<td>0.06</td>
<td>0.05</td>
</tr>
<tr>
<td><strong>TA</strong></td>
<td>R²</td>
<td>0.595</td>
<td>0.696</td>
<td>0.848</td>
</tr>
<tr>
<td>(g/L) Tartaric acid</td>
<td>RMSEP</td>
<td>0.73</td>
<td>0.64</td>
<td>0.84</td>
</tr>
<tr>
<td><strong>Phenolics</strong></td>
<td>R²</td>
<td>0.434</td>
<td>0.484</td>
<td>0.488</td>
</tr>
<tr>
<td>(mg/L) Gallic acid</td>
<td>RMSEP</td>
<td>35.15</td>
<td>34.88</td>
<td>34.74</td>
</tr>
</tbody>
</table>
Some recent developments in fruit reflectance applications....

1. New Pellenc Spectron™ portable handheld spectrometer
   - Based on research with “le tromblon” at Montpellier, France
2. Integration of VIS/NIR spectrometer with harvest yield monitor
   - U of Guelph and Lakeview Vineyard Equipment

Integrate VIS/NIR instrument with yield monitor

OCE – Etech /U of Guelph project with Lakeview Vineyard Equipment Inc.
Future of spectral methods for rapid fruit quality

• Currently *good results* for Brix, pH, TA
• Potential for rapid estimation of phenolics and anthocyanins
• Drawbacks to commercial equipment – expensive, need to calibrate, time consuming
• New technology for spectral sensing and information processing promises less expensive, more useful instruments soon...
Precision Viticulture: Unlocking Unseen Mysteries of the Vineyard

Thank you!

Thank you!