Straw Management and Crop Rotation
Alternatives to Stubble Burning:
Assessing Economic and Environmental Trade-offs

DOE Presentation – Feb 7, 2012
by Gerard Birkhauser

Co-Principle Investigators
Dave Huggins, Soil Scientist
Tim Paulitz, Plant Pathologist
Kate Painter, Ag. Economist
Project Objectives

Continue the 2009-2010 study, documenting:

(1) wheat stubble burning impacts (SOM; C, N, P losses);

(2) crop rotations and sequences that benefit from retaining winter wheat residues in DS systems;

(3) effects of wheat straw management and rotation alternatives on root pathogens.

(4) enterprise budget for economic analyses
DOE-1 Field Study (12 x 12 ft plots)
- 15 sites with 6 treatments (Fall ‘11 Burn, Spg. ‘12 Burn, Control, Fertilized/Nonfert.)
- Collect residue after each harvest.

DOE-2 Field Study (12 x 12 ft plots)
- Rotations after Fall Burn: (1) ww-sb-sw; (2) ww-cp-sw; (3) ww-ww-sw.

DOE-3 Field Study (10 x 50 ft plots)
- 2 rotations (ww and ww-l) and 3 tillage
Location of Field Studies based on the 3 Objectives

Cook Agronomy Farm
Direct Seed and Precision Farming Systems

2009-2010 DOE 1 & 2 Field A

2009-2010 DOE 3 Field

2011-2012 DOE 1 & 2 Field B
Fall 2009 & Spring 2010

Control

Fall 2009 Burn

Spring 2010 Burn
USDA Palouse Conservation Field Station

2011-2012
DOE 3 Field D2
### DOE 3 Field Study Parameters

- **10 x 50 ft test plots**
- **2 different rotations:**
  - continuous ww
  - ww-legume
- **3 types of tillage:**
  - conventional
  - cross slot
  - Horsh
- **4 replicates taken**

<table>
<thead>
<tr>
<th>Rotation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>W-1 CT</td>
<td>Conventional Tillage</td>
</tr>
<tr>
<td>W-2 FBCS</td>
<td>Fall Burn, Cross Slot</td>
</tr>
<tr>
<td>W-3 NBCS</td>
<td>No Burn, Cross Slot</td>
</tr>
<tr>
<td>W-4 NBH</td>
<td>No Burn, Horsh</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Rotation</th>
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<tbody>
<tr>
<td>W-L-1 CT</td>
<td>Conventional Tillage</td>
</tr>
<tr>
<td>W-L-2 FBCS</td>
<td>Fall Burn, Cross Slot</td>
</tr>
<tr>
<td>W-L-3 SBCS</td>
<td>Spring Burn, Cross Slot</td>
</tr>
<tr>
<td>W-L-4 NBCS</td>
<td>No Burn, Cross Slot</td>
</tr>
<tr>
<td>W-L-5 NBH</td>
<td>No Burn, Horsh</td>
</tr>
</tbody>
</table>
Repeated Methodology Used to Accomplish the Objectives

• Measure soil chemical and physical characteristics (soil pH, POM, bulk density, water content, nutrient contents).

• Assess the residue loads (biomass, yields, C and N contents, net collected weights).

• Compute C, N, and P losses (mass balance on soil, plants, and residue).

• Evaluate micronutrient fluxes (PRS probes).
Soil sampling done for each of the test plots.
Soil, Residue, & Plant Chemical and Physical Characteristics

Results were presented at June 14th meeting:

- **Soil** (pH, bulk density, POM, nutrient content)
- **Residue** (C & N, loads) for both spg./wtr. wheat
- **Plant** (N, biomass, staging data, yield, protein)

Report findings from residue P, K, and S content (separation process protocol improvement).

The residue load data for August 2011 was analyzed and compared to previous data (residue C & N content will soon be determined).
Residue Loads Studies

Fall 2011 Burn & Nutrient Analyses
Residue Loss from Fall 2011 Burn

• Residue mass lost to burning ranged 54 – 91%.
• Average residue lost to burning for 15 sites was 78% (compared to 64% for fall 2009 and 56% for spring 2010).
• In plotting the residue consumed from burning, the slope and linear correlation were much lower than previous burn data.
Residue Loads for Fall 2009, Spring 2010, and Fall 2011 Burns

Residue Remaining after Burning

PostBurn Residue (lb/ac)

PreBurn Residue (lb/ac)

Slope = 0.56
R² = 0.68

Slope = 0.63
R² = 0.67

Slope = 0.27
R² = 0.25

Fall 2009

Fall 2010

Spring 2010

Fall 2011
Residue Loss from Prior Burns

Percentage Residue Loss to Burning

Residue Loss

Test Plot Number

Spring 2010
Fall 2009
Refinement of residue collection and processing.
Fertilizer replacement cost for nutrient loss during burning of winter wheat:

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Fall Burn ($/ac)</th>
<th>Spring Burn ($/ac)</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>5.27</td>
<td>4.95</td>
</tr>
<tr>
<td>K₂O</td>
<td>20.40</td>
<td>2.83</td>
</tr>
<tr>
<td>P₂O₅</td>
<td>1.72</td>
<td>1.20</td>
</tr>
<tr>
<td>S</td>
<td>1.23</td>
<td>0.66</td>
</tr>
</tbody>
</table>

Total Nutrient Replacement Cost: $29/ac (fall burn) $10/ac (spring burn)
Residue Nutrient Content Values

Analyses of S, Ca, Mg, P, K
- nitric digestion method (ICP analysis)
- for Fall 2009, Spring 2010, and Control
- combined the low and high residue weights

Amount of Nutrient Loss from Burning:

<table>
<thead>
<tr>
<th>Burn Treatment</th>
<th>Nutrient Loss (lb/ac)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Calcium</td>
</tr>
<tr>
<td>Fall 2009</td>
<td>-30</td>
</tr>
<tr>
<td>Spring 2010</td>
<td>-10</td>
</tr>
</tbody>
</table>
Items to Complete (next 6 mon.)

• Analyze residue C & N contents for Fall 2011 Burn (30 samples).
• Conduct soil sampling in spring for testing.
• Plan for possible PRS probe deployment.
• Analysis of previous data (nutrient loss relationships for burn vs. non-burn sites).
• Soil erosion and condition index estimates.
• Biofuels economic assessment of lost residue.
Soil sampling to assess impact of burn treatment.
Fertilizing half of each treatment effect (split-plot).
Deployment of PRS probes to monitor nutrient flux.
Presentation Back-up Information
DOE 3 Plot Map SY2011-HY2012, PCFS Field

<table>
<thead>
<tr>
<th>Rep 1</th>
<th>Rep 2</th>
<th>Rep 3</th>
<th>Rep 4</th>
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<tbody>
<tr>
<td>W-L-3 SBCS</td>
<td>W-1 CT</td>
<td>W-3 NBCS</td>
<td>W-L-1 CT</td>
</tr>
<tr>
<td>W-L-4 NBCS</td>
<td>W-2 FBCS</td>
<td>W-4 NBH</td>
<td>W-L-3 SBCS</td>
</tr>
<tr>
<td>W-L-2 FBCS</td>
<td>W-3 NBCS</td>
<td>W-1 CT</td>
<td>W-L-5 NBCH</td>
</tr>
<tr>
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<td>W-4 NBH</td>
<td>W-L-3 SBCS</td>
<td>W-2 FBCS</td>
</tr>
<tr>
<td>W-L-5 NBH</td>
<td>W-L-4 NBCS</td>
<td>W-L-4 NBCS</td>
<td>W-1 CT</td>
</tr>
<tr>
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<td>W-L-2 FBCS</td>
<td>W-L-5 NBCH</td>
<td>W-3 NBCS</td>
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</tbody>
</table>

**Rotation**  
W - continuous winter wheat  
W-L - winter wheat-legume

- **W-1 CT**  
  - Conventional Tillage
  - Fall Burn, Cross Slot
  - No Burn, Cross Slot
  - No Burn, Horsh

- **W-L-1 CT**  
  - Conventional Tillage
  - Fall Burn, Cross Slot
  - Spring Burn, Cross Slot
  - No Burn, Cross Slot
  - No Burn, Horsh
## Winter Wheat Residue Load Impacts from Burn Treatments

<table>
<thead>
<tr>
<th>Winter Wheat Residue</th>
<th>Fall 2009 Burn</th>
<th>Spring 2010 Burn</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Pre-burn</td>
<td>Post-burn</td>
</tr>
<tr>
<td>Residue Load (lbs/ac)</td>
<td>8093a</td>
<td>3059c</td>
</tr>
<tr>
<td>Residue N (%)</td>
<td>0.44d</td>
<td>0.78a</td>
</tr>
<tr>
<td>Residue C (%)</td>
<td>39.9b</td>
<td>39.9b</td>
</tr>
<tr>
<td>Residue C/N</td>
<td>92.0a</td>
<td>54.5b</td>
</tr>
<tr>
<td>Residue N (lbs/ac)</td>
<td>35.9a</td>
<td>24.2c</td>
</tr>
<tr>
<td>Residue C (lbs/ac)</td>
<td>3228a</td>
<td>1218c</td>
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</table>
## Soil Characteristics from Burn Treatments

<table>
<thead>
<tr>
<th>Soil Property</th>
<th>Control</th>
<th>Fall Burn</th>
<th>Spring Burn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil N (%)</td>
<td>0.15a</td>
<td>0.16a</td>
<td>0.16a</td>
</tr>
<tr>
<td>Soil C (%)</td>
<td>1.84a</td>
<td>1.88a</td>
<td>1.80a</td>
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<tr>
<td>Soil C/N Ratio</td>
<td>11.84a</td>
<td>11.92a</td>
<td>11.48a</td>
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<tr>
<td>Bulk Density (g/cm³)</td>
<td>1.33a</td>
<td>1.34a</td>
<td>1.34a</td>
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<tr>
<td>Soil pH</td>
<td>6.04a</td>
<td>6.18a</td>
<td>6.03a</td>
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<tr>
<td>PON (%)</td>
<td>2.27b</td>
<td>2.58a</td>
<td>2.27b</td>
</tr>
<tr>
<td>POC (%)</td>
<td>32.2b</td>
<td>36.9a</td>
<td>32.0b</td>
</tr>
<tr>
<td>POM C/N Ratio</td>
<td>14.3a</td>
<td>14.3a</td>
<td>14.2a</td>
</tr>
</tbody>
</table>
## Grain and Residue Properties for 6 Treatments

<table>
<thead>
<tr>
<th>Spring Wheat</th>
<th>Control</th>
<th>Fall Burn</th>
<th>Spring Burn</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N Applied</td>
<td>No N Applied</td>
<td>N Applied</td>
</tr>
<tr>
<td>Grain Yield (bu/ac)</td>
<td>59a</td>
<td>47b</td>
<td>57a</td>
</tr>
<tr>
<td>Grain Protein (%)</td>
<td>11.0a</td>
<td>9.1b</td>
<td>11.4a</td>
</tr>
<tr>
<td>Crop Residue N (lbs/ac)</td>
<td>22.9a</td>
<td>8.3b</td>
<td>25.3a</td>
</tr>
<tr>
<td>Crop Residue C (%)</td>
<td>44.6a</td>
<td>44.5a</td>
<td>44.5a</td>
</tr>
<tr>
<td>Crop Residue C (lbs/ac)</td>
<td>2282a</td>
<td>1240c</td>
<td>2246a</td>
</tr>
<tr>
<td>Spring Wheat and Soil Properties</td>
<td>Control</td>
<td>Fall Burn</td>
<td></td>
</tr>
<tr>
<td>----------------------------------------------------------</td>
<td>----------</td>
<td>-----------</td>
<td></td>
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<tr>
<td>Main Stem Leaves (number)</td>
<td>3.94b</td>
<td>4.53a</td>
<td></td>
</tr>
<tr>
<td>Tillers (number)</td>
<td>1.26a</td>
<td>1.61a</td>
<td></td>
</tr>
<tr>
<td>Plant N (%)</td>
<td>3.3b</td>
<td>3.9a</td>
<td></td>
</tr>
<tr>
<td>Plant Dry Weight (lbs/ac)</td>
<td>96b</td>
<td>176a</td>
<td></td>
</tr>
<tr>
<td>Plant N (lbs/ac)</td>
<td>3.3a</td>
<td>7.0b</td>
<td></td>
</tr>
<tr>
<td>Extracted Soil NO$_3$-N, Day 1, (ppm)</td>
<td>21.5a</td>
<td>24.1a</td>
<td></td>
</tr>
<tr>
<td>PRS probe Nitrate-N, Day 1, Field, ($\mu$g 10 cm$^{-2}$ 24hr$^{-1}$)</td>
<td>10.7a</td>
<td>21.8a</td>
<td></td>
</tr>
<tr>
<td>PRS probe Nitrate-N, 7 Days, Field, ($\mu$g 10 cm$^{-2}$ 7days$^{-1}$)</td>
<td>62.5b</td>
<td>87.8a</td>
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</tr>
<tr>
<td>PRS Probe P, Day 1, Field, ($\mu$g 10 cm$^{-2}$ 24hr$^{-1}$)</td>
<td>0.80a</td>
<td>0.56a</td>
<td></td>
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<tr>
<td>PRS Probe S, Day 1, Field, ($\mu$g 10 cm$^{-2}$ 24hr$^{-1}$)</td>
<td>19.6a</td>
<td>19.6a</td>
<td></td>
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## Crop Yield Impacts from Burning

<table>
<thead>
<tr>
<th>Crop</th>
<th>Control</th>
<th>Fall Burn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter Wheat Yield following Winter Wheat, (bu/ac)</td>
<td>82a</td>
<td>82a</td>
</tr>
<tr>
<td>Garbanzo Bean Yield following Winter Wheat, (lbs/ac)</td>
<td>1624a</td>
<td>1634a</td>
</tr>
<tr>
<td>Spring Barley Yield following Winter Wheat, (lbs/ac)</td>
<td>4733b</td>
<td>5234a</td>
</tr>
</tbody>
</table>
June 2011 Reported Findings

- Fall burning impact:
  - 62% reduction in winter wheat residue mass
  - 2,010 lbs C/ac & 12 lbs N/ac

- Spring burning impact:
  - reduced residue mass by 55%
  - 1,271 lbs C/ac & 11 lbs N/ac

- Residue burning had little impact on soil properties (N%, C%, bulk density, pH, POM).
• N losses from burning were lower (40% for spring and 33% for fall) than the previously reported laboratory studies of nearly 100%.
• Fall burning of ww residue increased early season soil N availability, spring wheat growth and development and spring wheat N uptake.
• Field deployed PRS probes had 40% more µg N 10 cm\(^{-2}\) 7 days\(^{-1}\) in fall burned as compared to control plots.
In spring wheat, less Fusarium Crown Rot occurred in treatments with burning, and higher disease occurred with N fertilizer.