Northwest Columbia Plateau PM\textsubscript{10} Project

Objective 5: Wind Erosion and PM\textsubscript{10} Emission Control Methods

Title: Dryland Cropping Systems Research to Control Blowing Dust

Personnel: Principal Investigator: William Schillinger, WSU research agronomist; Co-Investigators: Tim Smith, WSU agricultural research technician; Doug Young, WSU agricultural economist; Ann Kennedy, USDA-ARS soil microbiologist; Tim Paulitz, USDA-ARS plant pathologist; Stewart Wuest, USDA-ARS soil scientist; Steve Schofstoll, WSU technical assistant; Bruce Sauer, WSU farm manager; and Cindy Warriner, WSU technical assistant.

Project 1: Long-Term Dryland Cropping Systems Research at the Ron Jirava Farm

A long-term alternative cropping systems project using direct seed and conservation tillage practices was initiated in 1997 on the Ron Jirava farm near Ritzville, Washington. The soil at the experiment site is a Ritzville silt loam. The soil is more than 6 feet deep with no rocks or restrictive layers and slope is less than 1%. Thirty-year average annual precipitation for the site is 11.5 inches. The field where the experiment is conducted was in an intensive tillage-based WW-SF rotation for more than 100 years before the onset of the experiment.

In Phase I (1997-2000) of the experiment, cropping systems treatments were: (i) a 4-year safflower (SAF)-yellow mustard (YM)-soft white spring wheat (SW)-SW crop rotation, (ii) a 2-year SW-spring barley (SB) rotation and, (iii) continuous annual SW. Experimental design was a randomized complete block with four replications. Each crop in all rotations occurred each year in 60- by 500-ft plots, making a total of 28 plots. The 4-year rotation was designed primarily to test the effects of back-to-back broadleaf crops on the epidemiology of soil fungal diseases that plague monoculture wheat.

In Phase II (2001-2004) of the experiment, existing plots were split along the long axis (i.e., from 60-by 500-ft to 30-by 500-ft for a total of 56 plots) to introduce the following cropping systems: (i) a 4-year WW-WW-SW-SW rotation, (ii) a 4-year WW-SB-YM-SW rotation, (iii) a 2-year SW-SB rotation (retained from Phase I), (iv) a 2-year hard white spring wheat (HW)-SB rotation, (v) continuous annual SW (retained from Phase I) and, (vi) continuous annual HW.

For Phase III (2005-2009), treatments were: (i) a 4-year WW-SB-SW-chemical fallow (CF) rotation, (ii) a 4-year WW-SB-SW-tilled summer fallow (undercutter method) rotation, (iii) the 2-year SW-SB rotation, (iv) the 2-year SW-SB rotation, (v) continuous annual SW, and (vi) continuous annual HW. Grain yields from all rotations during Phase III are shown in Table 1.

An advisory group meeting was held on October 15, 2009 to determine crop rotations for the next six years of the study (i.e., Phase IV, 2010-2015). The Phase IV crop rotations are (i) a 3-year CF-triticale-SW rotation, (ii) a TF-WW-SAF rotation, (iii) a 3-year TF-WW-SW rotation,
(iv) a 2-year WW-TF rotation, (v) a 2-year SW-SB rotation, and (vi) continuous SW. Note that the continuous annual SW and the 2-year SW-SB rotations have been in place since 1997. In addition to the above, a small-scale 3-year TF-winter pea-SW rotation study will be initiated in 2010 on land adjacent to the long-term study. Note that all four phases of the experiment were designed in consultation with an advisory group of regional dryland wheat farmers.

Table 1. Grain yields from various crop rotations and crop-year precipitation during Phase III (2005-2009) of the long-term cropping systems trial at the Ron Jirava farm near Ritzville, WA.

<table>
<thead>
<tr>
<th>Rotation</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>Avg.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Four-year rotation I</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Winter wheat (after tilled SF)</td>
<td>54</td>
<td>60</td>
<td>40</td>
<td>29</td>
<td>46</td>
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<tr>
<td>Spring barley</td>
<td>850</td>
<td>1614</td>
<td>733</td>
<td>646</td>
<td>1209</td>
<td>1050</td>
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<tr>
<td>Spring wheat</td>
<td>16</td>
<td>36</td>
<td>20</td>
<td>9</td>
<td>34</td>
<td>25</td>
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<tr>
<td>Four-year rotation II</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Winter wheat (after chem. SF)</td>
<td>45</td>
<td>35</td>
<td>17</td>
<td>19</td>
<td>29</td>
<td></td>
</tr>
<tr>
<td>Spring barley</td>
<td>770</td>
<td>2167</td>
<td>1126</td>
<td>403</td>
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<td>1163</td>
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<tr>
<td>Spring wheat</td>
<td>15</td>
<td>37</td>
<td>25</td>
<td>8</td>
<td>33</td>
<td>25</td>
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<tr>
<td>Two-year rotation I</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hard white spring wheat</td>
<td>16</td>
<td>36</td>
<td>16</td>
<td>8</td>
<td>25</td>
<td>21</td>
</tr>
<tr>
<td>Spring barley</td>
<td>985</td>
<td>2433</td>
<td>1202</td>
<td>426</td>
<td>1396</td>
<td>1364</td>
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<tr>
<td>Two-year rotation II</td>
<td></td>
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<tr>
<td>Soft white spring wheat</td>
<td>17</td>
<td>41</td>
<td>23</td>
<td>10</td>
<td>29</td>
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<tr>
<td>Spring barley</td>
<td>985</td>
<td>2330</td>
<td>1205</td>
<td>435</td>
<td>1407</td>
<td>1344</td>
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<td>Continuous cropping</td>
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<td></td>
<td></td>
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<tr>
<td>Soft white spring wheat</td>
<td>16</td>
<td>40</td>
<td>20</td>
<td>9</td>
<td>26</td>
<td>24</td>
</tr>
<tr>
<td>Hard white spring wheat</td>
<td>7</td>
<td>33</td>
<td>16</td>
<td>5</td>
<td>22</td>
<td>19</td>
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<tr>
<td>LSD (0.05) lbs/a</td>
<td>282</td>
<td>424</td>
<td>393</td>
<td>375</td>
<td>679</td>
<td>215</td>
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<tr>
<td>LSD (0.05) bu/a</td>
<td>4.7</td>
<td>7.1</td>
<td>6.6</td>
<td>6.3</td>
<td>11.3</td>
<td>3.6</td>
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Crop-year precipitation (in.)

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<thead>
<tr>
<th></th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>Avg.</th>
</tr>
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<tbody>
<tr>
<td>7.98</td>
<td></td>
<td></td>
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<td>13.78</td>
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<td>9.70</td>
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<tr>
<td>8.00</td>
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<td></td>
</tr>
<tr>
<td>9.51</td>
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</table>

The 20-acre Jirava site has been carefully managed through the years to maintain the integrity of the experiment. We know the exact history of each of the 56 plots. While one of the treatments in Phase III contained tilled (undercutter method) summer fallow, the other treatments have been direct seeded since 1996. Many farmers in the intermediate and high precipitation zones of the inland PNW have adopted direct seeding and more intensive cropping. These practices have not been as well accepted in <12-inch precipitation zone where tillage-based WW-SF is still, by far, the dominant system. We feel that, with current technology, the Jirava site perhaps represents the lower precipitation boundary where intensive cropping using direct seeding may be an economically viable alternative to WW-SF.
The Jirava long-term cropping systems study has become a unique laboratory for the study of Rhizoctonia bare patch, not duplicated anywhere in the world. The long-term nature of this site enables us to study the disease dynamics over time, much as the growers would encounter in the transition from a tillage-based to a direct-seeding system. This site allows us to perform experiments that have a direct benefit to growers. We are testing cultural management measures in a field with a high level of disease. These include conservation tillage using the undercutter method, chemical summer fallow, seed opener disturbance with the Cross slot versus Kile drills, and crop rotation. We can also test Rhizoctonia-tolerant germplasm under high disease pressure, the only good way of seeing how they will perform in the field. We are studying the epidemiology of patches, how they grow and disappear over time. We are especially interested in natural disease suppression, which may be due to antagonistic bacteria in the roots.

Tim Paulitz has identified a unique group of phenazine producing bacteria, not found anywhere else in the world. We can also use this site to examine microbial communities, and contrast the communities within the patches to those outside of the patches, or in different rotations. We are using a new method of DNA sequencing, 454 or pyrosequencing that can generate thousands of sequences from a single soil sample. These sequences can then be used to identify the taxa of bacteria and fungi in the soil, without culturing. This is especially useful, since most bacteria or fungi from soil have not been cultured or identified. Finally, we can study the population biology and the diversity of all the different types of Rhizoctonia. In summary, this location will continue generate invaluable information on the pathology and management of this important cereal disease.

**Major Findings and Impact:** This project is now in its 14th year. Some of the major research findings from this project are:

- Rhizoctonia bare patch caused by Rhizoctonia solani AG-8 infected all crops in all rotations beginning in year 3 and continued through year 13. The area with bare patches averaged over all crops was as high as 11.7 percent of total plot area.
- We provided the first documentation in the world literature that Rhizoctonia bare patch in wheat is suppressed when spring barley is included in the crop rotation.
- The oilseed crops safflower and yellow mustard used more soil water by harvest compared to cereals, resulting in significantly less available soil water for crops that followed in the rotation.
- Russian thistle was the only plant that flourished within Rhizoctonia bare patch areas.
- Some seeds of the winter annual grass weed downy brome remained dormant and viable for 11 years to heavily infest winter wheat. This is first conclusive documentation of downy brome seeds remaining viable under field conditions for such a long time period.
- There was a gradual increase in soil organic matter over time in the experiment in the surface 0-2 inches that approached that of native undisturbed soil by year eight. Soil organic matter levels in the no-till plots have remained statistically equal to native soil from year 8 until year 13 (Fig. 1).
- Continuous spring cereals were economically equivalent to the WW-SF system when there was at least five inches of available soil water in late March (i.e., at time of planting) and May and June precipitation was equal to the long-term average or higher.
Annual crop rotations that included yellow mustard and safflower were always the poorest economic performers.

Grain yield of winter wheat from late planting (i.e., mid October or later) on chemical summer fallow was reduced by 37% compared to early planting (i.e., late August – early September) on tilled summer fallow during Phase III (Table 1).

A decision tool was developed for growers to choose between spring wheat or fallow based on measured plant-available soil moisture in mid-to-late March and historic (or expected) probabilities of growing season (April, May, June) rainfall. Relationships between spring available soil moisture + growing-season precipitation and spring wheat grain yield are based on 13 years of field data collected from the Jirava and other experiments. We feel that the spring wheat versus summer fallow decision tool accurately represents “real world” moisture and production conditions and is of substantial value to producers in the low-precipitation zone. A scientific paper on this method was published in Field Crops Research in 2008. We feel confident that our methods are valid and that the Jirava data “subset” from the model will grow stronger with each passing year of the experiment.

Project 2: Optimum Rodweeding Frequency to Maintain Seed-zone Moisture

We are now in the final year of a 4-year field study at the WSU Dryland Research Station to evaluate the frequency of rodweeding operations on seed-zone moisture retention and several
other agronomic and environmental factors. In mid April, primary spring tillage is conducted to a depth of 5 inches with a Haybuster undercutter sweep. Aqua nitrogen fertilizer is injected into the soil with the undercutter implement during the one-pass primary tillage. Subsequent rodweeding operations are conducted at the 4-inch depth with a Calkins center-drive rodweeder. Treatments are:

1. No rodweeding (i.e., check). Weeds are controlled with a glyphosate herbicide with a sprayer as needed to maintain weed-free plots.
2. Rodweed only when required to control weeds (this will range from 1 to 3 rodweedings, depending on the year, but only one rodweeding was required in 2006, 2007, 2008, and 2009).
3. Rodweed immediately after primary spring tillage, but thereafter only as required to control weeds (as per treatment no. 2, above).
4. Rodweed immediately after primary spring tillage and then at three-week intervals until late July-early August. This was a total of five rodweedings.

Results for 2006 through September 2009 show that primary spring tillage alone (in this case mid April with a Haybuster undercutter sweep) was all that was required to retain seed-zone moisture. Rodweeding was not required to “set the moisture line” (Fig. 2). Surface clod mass (Fig. 3) was greatest in the undercut only (i.e., control) and the 1x rodweeding treatment. Subsurface clod mass in the 5-inch-deep soil mulch was greatest in the control, followed by the 1x, 2x, and 5x rodweeding treatments, respectively (Fig. 4). These data show that seed-zone moisture was not reduced by having a moderate quantity of soil clods on the surface and within the soil mulch.

![Fig. 2. Seed-zone moisture content to a depth of 10 inches in four rodweeding frequency treatments in late August of 2006, 2007, 2008, and 2009.](image-url)
An average of slightly more than 30% residue cover was retained on the surface after planting winter wheat with deep-furrow drills in the control and 1x treatments (Fig. 5). This 30% residue cover after seeding has extremely important implications for farmers who participate in the EQIP program because it is a requirement to retain this amount of residue cover or more to receive government payment.
Winter wheat plant stand establishment was enhanced with increased rodweeding frequency in 2008 (most likely due to fewer clods within the soil mulch), but there were no stand establishment differences among treatments in any other year or when averaged over the four years (Fig. 6). We still need to obtain grain yield in 2010, but the 3-year grain yield average shows no differences among treatments (Fig. 7).
Project 3: Rotational Benefits of Winter Canola on the Subsequent Wheat Crop

Multiple-year experiments are being conducted in the low (Lind and Ritzville) and intermediate (Davenport) precipitation regions of eastern Washington to document the rotation benefits of winter canola (WC) in wheat-based cropping systems. Some growers have reported that wheat following winter canola has less disease and weed pressure and produces considerably higher grain yield compared to monoculture cereals in either a two-year winter wheat-summer fallow (WW-SF) rotation or three-year WW-spring wheat (SW)-SF rotation. Additionally, it has been observed that water runoff from frozen agricultural soils does not occur from winter canola stubble in some circumstances compared to wheat stubble; presumably because the deep tap root provides open channels for water to penetrate through the frozen surface soil layer. Neither the boost in winter wheat grain yield or the soil physical, biological, or pathological factors, that may account for better water infiltration and increased wheat yield as affected by having winter canola in the crop rotation, have been documented.

Objectives:

- To determine the benefits of winter canola grown in (i) a 4-year WC-SF-WW-SF rotation compared to the traditional 2-year WW-SF rotation in the low-precipitation zone and, (ii) a 3-year WC-SW-SF rotation compared to a WW-SW-SF rotation in the intermediate precipitation zone on:
  1. Grain yield of the subsequent winter wheat (low zone) or spring wheat (intermediate zone) crop.
  2. Soil microbial changes after winter canola versus after winter wheat.
  3. Plant diseases of the subsequent winter wheat (low zone) or spring wheat (intermediate zone) crop.
  4. Soil water infiltration and frozen soil runoff after winter canola versus after winter wheat.

Results to Date: Crop rotation experiments require several years of field data to “tell the story” on the benefits of WC as a rotation crop. Winter canola is difficult to establish in tilled summer fallow because emerging seedlings are killed by the hot surface soil when air temperatures are
85°F or greater. Thus, it is necessary to time the planting of WC with the expected air temperature 6-8 days after planting. We have had no problem establishing WC in the intermediate precipitation zone in chemical summer fallow where planting depth is shallow and soil water plentiful; however, our first planting of WC at Davenport in 2007 was completely destroyed by grasshoppers.

To date, our data show that winter canola generally uses about 1.5 inches more soil water in the lower (i.e., 3 to 6 feet) profile than winter wheat does (data not shown). There was a big grain yield reduction of WW at Ritzville in 2008 that was correlated with the high water use by WC grown in 2006 (Fig. 8a). We found a similar reduction in spring wheat grain yield (56 bu./a versus 43 bu./a) at Davenport in 2009 where the previous crop was WW versus WC, respectively (Fig. 8b). In addition, so far in this study WC grain yields have not been economically competitive with WW at Lind, Ritzville, and Davenport (Fig. 8a and 8b).

Fig. 8. Winter wheat (WW) and winter canola (WC) grain yield at Ritzville, Lind, and Davenport and the rotation effects of WW and WC on grain yield of the following wheat crop.
Water infiltration rates were measured in WC and WW stubble at the Ritzville site in Feb. 2009 using the ponded water method (Fig. 9).

The PI has personally witnessed major runoff on frozen soil with WW stubble where no runoff occurred on a neighboring field of WC stubble. We feel this may be due to the deep taproot of WC and we would like to document such improved infiltration. The 2008-2009 winter was very dry. On the day the ponded water infiltration measurements were taken (Feb. 2, 2009), there was three inches of thawed soil overlying six inches of frozen soil. We conducted a 2-hour infiltration run on each plot. Water infiltration in WW stubble occurred at three times the rate as in WC stubble (Fig. 10). We feel the results may well have been the other way around if the soil had been wet and frozen solid, therefore we plan to conduct the infiltration assessment again this winter.

![Fig. 9. Overview of ponded-water infiltration measurements conducted at Ritzville on February 2, 2009 to determine infiltration into frozen soil on winter wheat stubble and winter canola stubble.](image)

**Fig. 9.** Overview of ponded-water infiltration measurements conducted at Ritzville on February 2, 2009 to determine infiltration into frozen soil on winter wheat stubble and winter canola stubble.

![Fig. 10. Cumulative water infiltration during two hours of ponded infiltration at Ritzville on winter wheat stubble and winter canola stubble on February 2, 2009.](image)

**Fig. 10.** Cumulative water infiltration during two hours of ponded infiltration at Ritzville on winter wheat stubble and winter canola stubble on February 2, 2009.
Publications and Presentations

Books

Book Chapters

Refereed Journal Articles

Extension Bulletins

Conference Proceedings Papers

Published Abstracts
Schillinger, W.F., R.I. Papendick, A.C. Kennedy, and A.M. McGuire. 2009. Adoption of erosion control practices for dryland and irrigated agriculture in the Inland Pacific


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Wheat Life Articles