Title: Dryland and Irrigated Cropping Systems Research with Winter Canola, Camelina, and Safflower

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Collaborating scientists: Timothy Paulitz, USDA-ARS; Brenton Sharratt, USDA-ARS; Ann Kennedy, USDA-ARS; William Pan, WSU; Stewart Wuest, USDA-ARS.

Funding term and duration: This progress report covers research and extension activities conducted in 2014.

Graduate students: Jeremy Hansen is a Ph.D soil science student conducting research on soil microbial changes that occur when oilseed crops are introduced into cereal-based cropping systems. Schillinger is his major professor. Megan Reese (funded and advised by Dr. Pan) is conducting her MS research project on soil water use and growth of winter canola planted into no-till fallow on several planting dates near Ritzville.

Cooperating farmers: Ron Jirava, Ritzville; Jeff Schibel, Odessa; Bruce Sauer, Lind; Hal Johnson, Davenport.

Technical support: John Jacobsen, WSU agricultural research technician III; Steve Schofstoll, WSU technical assistant III; Samantha Crow, WSU office assistant III.

Background: This progress report covers the 2014 results of seven oilseed-related research and extension projects conducted in eastern Washington. These projects are three long-term dryland cropping systems studies (Lind, Ritzville, and Davenport), a dryland winter canola planting date experiment, a new dryland winter canola cropping systems study that was initiated near Ritzville in 2014, and a residue management study for irrigated canola production near Odessa. The oilseed crops are camelina (low precipitation zone) winter canola (both low and intermediate precipitation zone as well as irrigated) and safflower (low precipitation zone).

Acronyms used: C, camelina; NTF, no-till summer fallow; SAF, safflower; SC, spring canola; SW, spring wheat; TSF, tilled summer fallow; WC, winter canola; WP, winter pea: WT, winter triticale; WW, winter wheat.

OBJECTIVES:
Winter Canola (Four studies)
Study 1. Determine the benefits of WC grown in a 3-year dryland WC-spring wheat (SW)-no-till fallow (NTF) rotation compared to the traditional winter wheat (WW)-SW-NTF rotation in the intermediate precipitation zone on soil water dynamics, foliar and root diseases, grain yield of the subsequent SW crop, and soil microbial changes.
Study 2. For irrigated winter canola production, conduct field and laboratory research to (i) better understand the physiological mechanism(s) governing winter canola health when planted soon after the harvest of winter wheat, and (ii) to learn how to effectively and profitably produce WC without burning or excessive tillage of wheat stubble. Our hypothesis is that fresh wheat stubble is not phytotoxic to WC and that WC can be successfully produced in a direct-seed system after wheat harvest as a viable alternative to field burning plus heavy tillage.

Study 3. Determine the optimum planting date to achieve the best plant stands of winter canola (WC) sown into no-till summer fallow in the low-precipitation zone and measure the effects of planting date on soil water dynamics, overwinter survival, and seed yield.

Study 4. Conductor long-term (initiated in 2014) cropping systems study to test a 4-year rotation of WC-NTF-winter triticale (WT)-NTF and a 4-year rotation of winter pea (WP)-NTF-WT-NTF at Ritzville. The 2-year WW-TSF treatment is included as a check treatment.

Camelina

Study 5. Determine the long-term suitability of camelina in the typical winter wheat-summer fallow cropping zone of eastern Washington. This would allow farmers to plant crops in two out of three years (i.e., increase cropping intensity) instead of only once every other year as currently practiced.

Safflower (two studies)

Study 6. Evaluate safflower production potential when grown in a 3-year WW-safflower (SAF)-tilled summer fallow (TF) rotation compared to a 3-year spring wheat WW-spring wheat (SW)-TF rotation and a 2-year WW-TF rotation.

Study 7. Evaluate the performance of the 12 best-performing safflower varieties from the North Dakota State University safflower variety testing program at Lind.

METHODS

Study 1: This study was initiated in August 2007 on deep, productive soils at the Hal Johnson farm east of Davenport, WA. Annual precipitation at the site averages 18 inches. We are comparing a WC-SW-NFT rotation with the more traditional WW-SW-NTF system. All crops are direct seeded with a hoe-opener drill. The experimental design is a randomized complete block with six replications. Individual plot size is 16 ft x 100 ft. Fertilizer application rate is based on soil test results. In addition to WC, WW, and SW grain yield (determined using a plot combine), we are measuring soil water content in all plots (i) just after harvest in August, (ii) in early April, and (iii) in NTF in August. Ponded water infiltration is measured using 2-ft-diameter infiltration rings in standing WC and WW stubble from the previous harvest during some winters when soils are partially frozen. Plant diseases and microbial attributes are assessed by Tim Paulitz and Ann Kennedy, respectively. Doctoral student Jeremy Hansen (he is also Ann Kennedy’s research technician) has collected soil samples for microbial analysis twice per year since 2008.

Study 2: This experiment was initiated in 2012. In the first year, four winter wheat stubble management treatments were established in August and September at the Jeff Schibel farm SW of Odessa, WA. The experiment was embedded in a circle of irrigated winter canola belonging to Mr. Schibel. Irrigated WW stubble in the plot area was burned in treatments I and III (below) on August 20 and irrigation water immediately applied to promote germination of volunteer wheat. Glyphosate was
applied to the entire plot at a rate of 24 oz/acre on September 4. Land was prepared as required by protocols for each treatment (i.e., straw chopping, diskng, moldboard plowing; see list of treatments below) on September 4-6. Winter canola was planted and fertilized in one pass on September 7 using a Kile no-till hoe drill. Assure II herbicide for grass weed control was applied on October 6.

For the second year of the experiment, an additional (i.e., fifth) treatment was added. This additional treatment consists of broadcasting WC seed into standing WW before wheat harvest. After wheat harvest, the WC germinates after the irrigation water is applied. Volunteer WW is controlled with Assure II grass-weed herbicide in October. All field operations, as well as the timing, were essentially identical to those outlined above for year one. In year three (the current 2015 crop year), field operations and timing were essentially identical as those practiced in the two preceding years.

All field equipment used in establishment of the experiment was transported to the site from the WSU Dryland Research Station. Treatments are: (i) stubble burned + disked, (ii) stubble chopped + moldboard plowed, (iii) stubble burned, then direct seeded, (iv) direct seeding into standing and undisturbed stubble, and (v) WC broadcast directly standing WW before wheat harvest. Experimental design is a randomized complete block with four replications of each treatment for a total of 20 plots. Individual treatment plot widths range from 8-to 10-ft depending on the tillage implement (if any) used. All plots are 100 ft long. Application of irrigation water, which totals about 15 inches for the crop year, is managed by Mr. Schibel. Fertilizer (N, P, K) is applied in the fall and again in the spring at rates recommended by Mr. Schibel. A fungicide is applied with irrigation water by Mr. Schibel in the spring. Winter canola is harvested with a plot combine.

Study 3: Winter canola (cv. Roundup Ready WinField 115) was planted into no-till summer fallow on June 20, July 3, and July 24, 2014 at the Ron Jirava farm near Ritzville, WA. The experimental design is a randomized complete block with four replications of each planting date. Canola was seeded at a rate of 5 lbs/acre with a Cross-slot no-till drill. Individual plots were 8 ft x 100 ft in dimension. Acceptable emergence occurred after all three planting dates, but all the WC plants died within one week of emergence. A check of the collaborating farmer’s records showed that he applied some Ally herbicide (a sulfonated urea) in his burn-down herbicide mix prior to our first planting. Ally has a long soil residual and WC does not tolerate sulfonated urea herbicide. The cooperating farmer was extremely apologetic for this error. Schillinger has worked closely with Mr. Jirava for more than 20 years and this was the first time anything of this nature has occurred. Due to the Ally herbicide application, this experiment was discontinued for the 2015 crop year. Plans have been made to establish the experiment in 2015 (i.e., 2016 crop year) on land on Mr. Jirava’s farm that has no soil-residual herbicide history for at least 10 years.

Study 4: A new WC cropping systems study was initiated at the Ron Jirava farm near Ritzville in 2014. This study will test a 4-year WC-NTF-winter triticale (WT)-NTF rotation. The timing of the WC planting will likely be after July 20. The ongoing WC planting date experiment at this site (i.e., Study 3) will help to further define the optimum planting date. Winter triticale will be included in the rotation because research by Schillinger et al. (2012) has shown that late planted (mid-October or later) WT produces equivalent grain biomass as early planted (early September) WW. This is of crucial importance because with NTF there is rarely adequate seed-zone moisture for early establishment of WW. If farmers have to wait until the onset of fall rains, which typically begin no earlier than mid-October or later, their WW grain yields will be reduced by an average of 36% compared to early-planted WW. The grain yield difference between early versus late planted WT is much less than for WW. Thus, with the use of NTF,
the 4-year rotation of WC-NTF-ST-NTF represents a promising possibility for a stable, sustainable, profitable, and ecologically-friendly crop rotation for the low precipitation zone.

This new project also includes another four year rotation of winter pea (WP)-NTF-WT. Winter pea yield has shown potential for high yield (Schilling has averaged 2300 lbs/acre WP yield planted on summer fallow in several years of testing at the Jirava site). The 2-year WW-TSF rotation is included as the check treatment. All segments of all rotations appear each year and the experiment is replicated four times for a total of 40 plots. Each plot is 24 x 100 feet in dimension at the experiment covers 2.2 acres.

Study 5. We are currently in year 7 of a 9-year-long cropping systems experiment to evaluate camelina (C) produced in a 3-year WW-C-TSF rotation compared to the 2-year WW-TSF rotation practiced throughout the low-precipitation zone. The experiment is located at the WSU Dryland Research Station near Lind. Experimental design is a randomized complete block with four replicates. There are 20 plots, each 250 ft x 30 ft. Camelina is direct drilled + fertilized into standing WW stubble during late February or early March. Winter wheat is planted into TSF in late August. Soil water content to a depth of six feet is measured in all 20 plots after C and WW harvest in July and again in March, and from the eight TSF plots in late August just before planting WW. Weed species in C and WW are identified, counted, and collected just before grain harvest within a 6 ft x 6 ft sample frame randomly placed in each plot. Above ground dry biomass of each weed species is determined after placing samples in a low-humidity greenhouse for 30 days. Surface residue remaining after planting WW into TF is measured in both rotations using the line-point method.

Study 6: Since 2010, the production potential for safflower (SAF) is being determined at the long-term dryland cropping systems experiment on the Ron Jirava farm located west of Ritzville, WA. Safflower is grown in a 3-year WW-SAF-TSF rotation and is compared to WW-SW-TSF and WW-TSF rotations. Each phase of all rotations is present each year and there are four replicates. Individual plots are 30 x 500 feet. Soil water is measured in all plots after grain harvest in August and again in early April, and from TSF in early September. Treflan, a soil-residual herbicide, is applied in March or April to be rain incorporated into plots that will be sown to SAF. Safflower is direct sown at a rate of 40 lbs/acre + fertilized into standing and undisturbed WW stubble in late April or early May. Grain yield is determined with a commercial-sized combine and a weigh wagon.

Study 7: Beginning in 2014, twelve varieties from the North Dakota State University safflower variety testing program were grown at Lind. The plot area was injected with 50 lbs N and 10 lbs S fertilizer per acre prior to planting. The study was planted with a 5-ft-wide double-disc opener small-plot drill equipped with a cone feeder on April 21. Seeding rate was 40 lbs/acre. Experimental design was a randomized complete block with four replications. Individual plot size was 20 x 5 feet. Russian thistle was hand weeded from the experiment during late spring and summer. The trial was harvested on September 8 using a plot combine.

RESULTS, DISCUSSION, AND IMPACT
Winter Canola
Study 1: Winter canola rotation benefit. Excellent plant stands of both WW and WC were achieved for the 2014 crop year, but WC was killed by cold winter temperatures. Spring wheat yields in 2014 were 29 bushel/acre following WW versus 18 bushels/acre following WC (Table 1). Spring wheat plants after WW had more rapid phenological development compared to SW after WC. For example, on June 24,
SW after WW was mostly headed out whereas SW after WC was still in the boot stage. This was visibly apparent in all six replicates. Visual differences among treatments were also obvious at time of SW grain harvest on August 25 (Photo 1).

Table 1. Grain yield of winter wheat (WW) and winter canola (WC) and the subsequent grain yield of spring wheat (SW) following either WW or WC.

<table>
<thead>
<tr>
<th>Year</th>
<th>WW (bu/A)</th>
<th>WC (lb/A)</th>
<th>SW after WW (bu/A)</th>
<th>SW after WC (bu/A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year 1</td>
<td>2008</td>
<td>68</td>
<td>602</td>
<td>2009 57 a</td>
</tr>
<tr>
<td>Year 2</td>
<td>2009</td>
<td>83</td>
<td>644</td>
<td>2010 65</td>
</tr>
<tr>
<td>Year 4 °</td>
<td>2011</td>
<td>110</td>
<td>2888</td>
<td>2012 57 a</td>
</tr>
<tr>
<td>Year 5</td>
<td>2012</td>
<td>108</td>
<td>3800</td>
<td>2013 84</td>
</tr>
<tr>
<td>Year 6</td>
<td>2013</td>
<td>105</td>
<td>3687</td>
<td>2014 29 a</td>
</tr>
<tr>
<td>Avg.</td>
<td>95 §</td>
<td>2324</td>
<td></td>
<td>58 a</td>
</tr>
</tbody>
</table>

† Within-year spring wheat grain yield means followed by a different letter are significantly different at p<0.05.
‡ Winter canola was killed by cold during the 2010 crop year; therefore, no WW or WC harvest in 2010 nor subsequent SW crop in 2011.
§ Analysis of variance was not conducted for grain yield differences between WW and WC.

Photo 1. Spring wheat near Davenport at time of harvest in 2014 where the preceding crop was either winter wheat (left) or winter canola (right).
With five years of SW yield data (WC was killed by cold in 2010, thus no SW yield data for 2011), SW wheat yield was significantly greater after WW in most years (Table 1). The 5-year average yield for SW is 58 bushels/acre after WW and 49 bushels/acre after WW; these differences being statistically significant at P<0.001.

We are as yet uncertain of the reason for these SW grain yield differences among treatments. We have achieved truly outstanding yields for WW and WC in many years (note yields in 2011, 2012, and 2013 in Table 1). Detailed soil water measurements have been obtained every year after WW and WC harvest, in late April in WW and WC stubble just before planting SW, and again after SW harvest. There was some year-to-year differences in water use by WW compared WC, but no trend. Averaged over six years, WW used 0.3 inches more soil water than WC, but this difference was not statistically different (Table 2). Overwinter soil water storage between treatments also varied somewhat from year to year but, on average, soil water content in late April was essentially equal (there was an average of 0.1 inch more water in WC stubble, Table 2). We are encouraged that, despite the fact that WW stubble has much more residue biomass than that of WC, overwinter water storage between the two treatments was equal. Does the taproot of WC allow better water infiltration compared to the fibrous roots of wheat? To test this theory, we conducted comprehensive ponded water measurements on partially frozen soils in standing WW and WC stubble in February (Photo 2). These measurements did not show greater ponded water infiltration with WC.

Table 2. Soil water content in six feet of soil: (i) after harvest of winter wheat (WW) and winter canola (WC) in August and (ii) in WW and WC stubble at the end of April. The last two columns show net overwinter soil water gain in WW and WC stubble.

<table>
<thead>
<tr>
<th>Crop year</th>
<th>Soil water (inches)</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline</td>
<td>Late April</td>
<td>+ΔH₂O</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WW stubble</td>
<td>WC stubble</td>
<td>WW stubble</td>
<td>WC stubble</td>
<td>WW stubble</td>
<td>WC stubble</td>
</tr>
<tr>
<td>2009</td>
<td>10.2 a †</td>
<td>9.0 b</td>
<td>20.3 a</td>
<td>19.8 b</td>
<td>10.1</td>
</tr>
<tr>
<td>2010</td>
<td>13.9</td>
<td>14.0</td>
<td>18.2</td>
<td>17.6</td>
<td>4.3</td>
</tr>
<tr>
<td>2011</td>
<td>10.8</td>
<td>10.7</td>
<td>21.6 a</td>
<td>20.5 b</td>
<td>10.8 a</td>
</tr>
<tr>
<td>2012</td>
<td>9.3 b</td>
<td>11.7 a</td>
<td>16.0</td>
<td>17.4</td>
<td>6.7</td>
</tr>
<tr>
<td>2013</td>
<td>10.2 b</td>
<td>11.5 a</td>
<td>19.9</td>
<td>20.5</td>
<td>9.7</td>
</tr>
<tr>
<td>2014</td>
<td>11.5</td>
<td>10.7</td>
<td>16.0</td>
<td>16.9</td>
<td>4.5</td>
</tr>
<tr>
<td>6-yr avg.</td>
<td>11.0</td>
<td>11.3</td>
<td>18.7</td>
<td>18.8</td>
<td>7.7</td>
</tr>
</tbody>
</table>

† Within-row soil water values for both sampling dates as well as net water gain values followed by a different letter are significantly different at P < 0.05.
Dr. Tim Paulitz has observed and taken plant tissue and soil samples from the WW and WC portion of the rotation every year. He never saw any foliar disease on plant tissue or soil-borne pathogens in the soil. There were essentially no weeds (including downy brome) in any crop in any year except some volunteer WC in SW in 2012 and 2013. Could the volunteer WC have used enough water to depress SW yield in 2012 and 2013? Possibly, but this still does not explain the same yield decline trend that occurred in SW in 2014 when there was no WC volunteer (the WC volunteer was killed by cold winter temperatures).

Could the yield decline in SW be caused by WC extracting more nutrients from the soil than WW, therefore leaving SW after WC inadequately fertilized? The cooperating farmer took care of all fertilizing, planting, and weed control for the SW portion of the experiment. Although we have not yet received the field soil fertility test results or the fertilizer rates used for SW, the cooperating farmer has this information in his records and has promised to share with us. Our cooperator, Hal Johnson, is known to be an excellent farmer who always applies ample fertilizer. He (as well as two very knowledgeable farm staff) is highly doubtful that soil nutrient deficiency could be an issue. Still, until we obtain the aforementioned records, this cannot yet be ruled out.

Another possible reason for the difference in SW grain yield between the two treatments is root lesion nematodes. Canola (as well as numerous other crops) is known to be a host of root lesion nematodes. According to data from Dr. Richard Smiley, OSU plant pathologist, the WC variety ‘Amanda’ used in our experiment is the most susceptible to root lesion nematodes of the WC varieties he has tested. Therefore, in early April 2015 we will obtain composite soil samples in 6-inch intervals to a depth of 18

Photo 2. Water infiltration measurements in partially frozen soil in February near Davenport in winter canola stubble and winter wheat stubble.
inches from the 2014 SW plots (2 treatments x 6 replicates x 3 depth increments = 36 samples) and have them analyzed for root lesion nematodes.

Study 2: Irrigated winter canola. Adequate stands of WC were achieved in all five treatments in all replicates in September 2013 (i.e., the 2014 crop year). We used a 5 lbs/acre seeding rate for all treatments. The broadcast seed into standing wheat stubble before wheat harvest treatment had extremely thick plant stands. The thick, 120 bushel/acre yielding WW cut at 12-inch stubble height along with completion with other WC plants in the broadcast treatment resulted in an average above ground hypocotyl length of four inches. The hypocotyl is the stem area from the seed to the lowest branches.

During the winter of 2013-2014, all plants in the broadcast as well as the direct seeding into standing stubble were killed by cold temperatures. The other treatments were heavily damaged, but survived. Of the three surviving treatments, the stubble chop + moldboard plow was most heavily damaged and stands much diminished.

A twilight field tour organized by Karen Sowers, WSU oilseeds extension specialist, was held at the experiment site on May 29. Approximately 50 farmers and agricultural industry personnel attended (Photo 3). Collaborating farmer Jeff Schibel, Schillinger, and others presented.

Photo 3. Twilight tour on May 29, 2014 of the irrigated winter canola experiment at the Jeff Schibel farm near Odessa. Photo courtesy of Darrell Kilgore, WSU CAHNRS Communications.

Winter canola seed yields in 2014 for the three surviving treatments ranged from 1830 to 2832 lbs/acre (Table 3). The chop + moldboard plow treatment had the lowest seed yield due to fewer number of plants that survived the cold winter temperatures; i.e., there were still bare areas in this treatment at time of harvest even though surviving WC plants exhibited extensive branching and number of pods per plant.
Table 3: Irrigated winter canola seed yields during the first two years of wheat stubble management experiment conducted near Odessa, Washington.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>2013</th>
<th>2014</th>
<th>2-yr avg.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stubble burned + disked</td>
<td>3092</td>
<td>2832</td>
<td>2962</td>
</tr>
<tr>
<td>Stubble burned + direct-seeded</td>
<td>3020</td>
<td>2678</td>
<td>2849</td>
</tr>
<tr>
<td>Stubble chopped + moldboard plowed</td>
<td>3246</td>
<td>1830</td>
<td>2538</td>
</tr>
<tr>
<td>Direct seeded into undisturbed stubble</td>
<td>2988</td>
<td>**</td>
<td></td>
</tr>
<tr>
<td>Broadcast into standing wheat</td>
<td>*</td>
<td>**</td>
<td></td>
</tr>
</tbody>
</table>

Statistical significance: ns (p = 0.40) ns (p = 0.06) ns (p = 0.11)

* The broadcast into standing wheat before harvest treatment was not present in 2013.
** Canola killed by cold temperatures in 2014.
ns = No significant statistical differences at p<0.05.

For the 2015 crop year, WC was planted in all five treatments according to the protocols outlined in the “Methods” section above. Excellent stands were achieved in all treatments in all four replicates. For the broadcast WC seed into standing wheat before wheat harvest treatment, we reduced the seeding rate to 3 lbs/acre (we used 5 lbs/acre in the 2013 crop year). Lowering the seeding rate for the broadcast treatment lowered the WC plants per unit area compared to the previous year. By October, the above-ground portion of the hypocotyl of WC plants average 1.5 inches (versus 4 inches in the previous year) and the hypocotyls were generally prostrate (Photo 4) compared to completely upright in the previous year. There was essentially no portion of the hypocotyl extending about the ground in the chop + moldboard plow, burn + direct seed, and the burned + disc treatments (Photo 5).

Photo 4. Aboveground (1.5-inch long) portion of the hypocotyl of the broadcast treatment in the irrigated winter canola experiment near Odessa in October 2014.

Photo 5. Winter canola in the burn + disk treatment in the Odessa experiment where there is essentially no aboveground extension of the hypocotyl.
There were no foliar diseases present in the WC in any treatment when assessed in late October, 2014. In addition, soils collected from all treatments and all replicates in October had no detectable soil-borne pathogens (See report by Dr. Tim Paulitz). Thus, we were highly optimistic about the seed yield potential in this experiment.

One day in early December 2014, a warm daytime temperature of 60 degrees F was followed that evening by a low temperature of 4 degrees F. Winter canola plants were not hardened to withstand this sudden, dramatic temperature change and essentially all WC plants in all treatments of the experiment were killed. The WC in Jeff Schibel’s circle (in which the experiment was embedded) was also killed.

Although we lost this experiment for the 2015 crop year (which was supposed to be the final year), farmer collaborator Schibel and Schillinger have decided to continue this study.

**Study 3:** The winter canola planting date study in 2014 was conducted in following the protocols outlined in the “Methods” section above. The Roundup Ready WC variety WinField 115 was planted with a Cross-slot no-till drill on 16-inch row spacing into standing, undisturbed stubble of the previous spring wheat crop. Uniform WC seedling emergence occurred from planting dates of June 20, July 3, and July 24. However, soon after emergence, all plants died. Careful examination of the collaborating farmer’s records showed that he had a sulfonated urea soil-residual herbicide (Ally) in his spring burn-down herbicide mix. The experiment was, therefore, terminated.

We plan to establish this experiment again in 2015 on land that the collaborating farmer is absolutely sure has no sulfonated urea history for at least the last 10 years. The experiment area has already been flagged for six planting dates. We will, again, plant WC with the Cross-slot drill until and unless the soil moisture line is more than 2.5 inches below the soil surface (which may likely happen by late July), in which case we will use a deep-furrow hoe drill.

One change planned for the 2015 experiment is to mow WC from a portion of the plots planted in June and early July in mid-to-late July to determine the effects on water use, subsequent dry matter production, and seed yield. WSU graduate student Megan Reese will again take extensive measurements of WC soil water use and dry matter production as affected by the various planting dates.

**Study 4:** This new long-term cropping systems study at Ritzville has two 4-year rotations and the 2-year WW-TSF rotation as a check treatment. These rotations are:

- WC-NTF-Winter triticale (WT) – NTF
- Winter pea (WP) – NTF – WT – NFT
- WW - TSF

Both 4-year crop rotations are direct seeded (there is no tillage done in any portion of the rotation). We know from research published by Sharratt and Schillinger (*Agronomy Journal, 2014*) that even undercutter tillage during fallow after camelina, SAF, canola, and WP will not retain adequate surface cover to protect the soil from wind erosion. Farmers in the low-precipitation zone are, therefore, left with two feasible options following oilseed crops and WP: (i) plant a spring crop (i.e., no summer fallow), or; (ii) practice NTF rather than TSF.
Winter canola, WP, and WW were planted into NTF on August 28, 2014 with a deep-furrow drill. Winter wheat was planted into TSF on September 2. Soil moisture adequate for germination and emergence was located three inches below the soil surface. We achieved excellent stands of WP, WT, and WW. The emerging WC seedlings, however, failed to emerge through the relatively warm soil surface (maximum air temperature was 88 degrees F seven days after planting). The WP, WT, and WW made it through the 2014-2015 winter in good shape. Spring canola (SC) will be planted in lieu of WC in this experiment for the 2015 crop year.

**Camelina**

**Study 5:** Excellent stands of ‘Calena’ camelina were achieved from a March 12, 2014 planting (Photo 6). Spring rainfall was much less than average. Total crop year (Sept. 1 – Aug. 31) precipitation at Lind in 2014 was only 7.69 inches compared to the long-term average of 9.42 inches. As a result, camelina yields were only 305 lbs/acre in 2014 compared to the 5-year average of 405 lbs/acre from this experiment (Table 4). Winter wheat grain yield in 2014 for the 3-year WW-C-TSF rotation was 27.3 bushels/acre versus 25.9 bushels/acre in the 2-year WW-TSF rotation (Table 4).

Photo 6. WSU agricultural research technician John Jacobsen in a camelina plot in the long-term cropping systems experiment at Lind in early June.
Average winter wheat grain yields in the 3-year WW-C-TSF rotation versus those in the 2-year WW-TSF rotation are 37.1 and 39.5 (a 2.4 bushel/acre or 6% difference, Table 4). This slight WW yield decline in the 3-year rotation has occurred every year, although there have never been any statistically significant differences in WW yield between the two rotations.

Table 4: Camelina (C) seed yield and subsequent grain yield of winter wheat (WW) when grown in a 3-year winter wheat-camelina-fallow rotation or a 2-year winter wheat fallow rotation at Lind, WA. Camelina yields are in pounds per acre and winter wheat in bushels per acre.

<table>
<thead>
<tr>
<th>Rotation</th>
<th>Cycle 1</th>
<th>Cycle 2</th>
<th>Cycle 3</th>
<th>Cycle 4</th>
<th>Cycle 5</th>
<th>Cycle 6</th>
<th>5-yr avg.</th>
</tr>
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<tbody>
<tr>
<td>FW–TSF</td>
<td>70†</td>
<td>47.0</td>
<td>440</td>
<td>32.8</td>
<td>325</td>
<td>38.0</td>
<td>635</td>
</tr>
<tr>
<td>TF–WW</td>
<td>51.3</td>
<td>34.9</td>
<td>41.7</td>
<td>42.4</td>
<td>27.3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

†Previous camelina yield in rotation (lbs/acre).
‡Camelina planted twice and failed twice in 2013, thus these plots left in fallow.
§The 5-yr avg. does not include 2013. The 2014 camelina yield was 305 lbs/acre.

As mentioned in previous oral and written reports on this project, the slight decline in WW grain yield in the 3-year rotation is likely due to difference in water loss in the two rotations that occur during fallow from mid-March to late-August. Although primary spring tillage with the undercutter V-sweep and any subsequent rodweedings during late spring and summer take place at the same time and at the same depth, an average of 0.5 inch of additional soil water is consistently lost in TSF after camelina compared to TSF after WW (Table 5). The 2014 fallow year was somewhat unusual in that we failed to achieve a stand of camelina in 2013, thus these plots were “double summer fallowed” (plots remained bare throughout the 2013 and 2014 crop years). The top portion of Table 5 shows the additional water that was stored in these double-summer fallowed plots compared to the WW-TSF rotation. The double-summer fallowed plots, of course, had more water throughout the 2014 fallow cycle and, by August, had stored and additional 2.3 inches compared to the 2-year rotation. However, since the 2014 fallow cycle was so dry, the fallow in the 3-year rotation actually had 10% more water in the soil profile in August 2013 (after a 12-month fallow) than it did in August 2014 (after a 24-month fallow) (Table 5). These values are reflected in the precipitation storage efficiency (PSE) data in the last column of Table 5.
In 2015, we plan extensive field and laboratory testing of the surface soil mulch characteristics in the 2-year and 3-year rotations to determine the cause of the consistently higher soil water losses from mid-March to late-August in the 3-year rotation. We expect the main reason may be surface residue cover, but it also could possibly be soil clod size distribution within the soil mulch. This new work effort will be of interest to both farmers and the scientific community.

**Safflower**

**Study 6:** We completed our fifth year of a long-term safflower (SAF) cropping systems experiment on the Ron Jirava farm near Ritzville in 2014. Safflower is grown in a 3-year WW-SAF-TSF rotation. We planted SAF on April 28 in 2014; more than a month later than other spring planted crops at this site. Due to the drought (8.14 inches of precipitation during the 2014 crop year), SAF only produced a seed yield of 125 lbs/acre in 2014 (Photo 7). The 5-year average seed yield for SAF is 534 lbs/acre.

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**Table 5.** Soil water content at the beginning (after harvest), early spring, and the end of fallow (just before planting of winter wheat) and associated gain or loss of water and precipitation storage efficiency (PSE = gain in soil water/precipitation that occurred during the fallow period) in the 6-foot soil profile in summer fallow in a 2-year winter wheat-fallow rotation versus a 3-year winter wheat-camelina-fallow rotation. The top portion of the table shows water content during the 2013-2014 fallow cycle and the bottom portion shows fallow water content for the 6-year average. ns = no significant differences.

<table>
<thead>
<tr>
<th>Fallow treatment</th>
<th>Timing in fallow period</th>
<th>Soil water content (inches)</th>
<th>Mar. to Aug. water</th>
<th>PSE† (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Beginning (late Aug.)</td>
<td>Spring (mid Mar.)</td>
<td>Over-winter gain</td>
<td>End (late Aug.)</td>
</tr>
<tr>
<td>A. 2013-2014</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>After winter wheat</td>
<td>6.0</td>
<td>9.0</td>
<td>3.0</td>
<td>7.0</td>
</tr>
<tr>
<td>(2-yr rotation)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>After camelina (3-yr rotation)</td>
<td>10.1</td>
<td>11.6</td>
<td>1.5</td>
<td>9.3</td>
</tr>
<tr>
<td>p-value</td>
<td>0.003</td>
<td>0.01</td>
<td>0.01</td>
<td>0.002</td>
</tr>
<tr>
<td>B. 6-year average</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>After winter wheat</td>
<td>6.2</td>
<td>9.7</td>
<td>3.5</td>
<td>8.9</td>
</tr>
<tr>
<td>(2-yr rotation)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>After camelina (3-yr rotation)</td>
<td>6.7</td>
<td>10.1</td>
<td>3.3</td>
<td>8.8</td>
</tr>
<tr>
<td>p-value</td>
<td>0.04</td>
<td>0.01</td>
<td>ns</td>
<td>ns</td>
</tr>
</tbody>
</table>

†2014 crop-year precipitation = 7.69"; average crop-year precipitation for five fallow years from 2009-2014 = 9.42".
Due to safflower’s relatively high soil water use (data not shown), crops grown after SAF sometimes produce lower grain yield than those following wheat. The water shortfall carries through a year of fallow after SAF harvest compared to a year of fallow after SW or WW (data not shown). Table 6 shows WW grain yield at the Ritzville site in three rotations for three cycles. The highest average WW grain yield of 72 bushels/acre is in the WW-SW-TSF rotation. The next highest average WW grain yield is 64 bushels/acre in the WW-TSF rotation. The lowest average WW grain yield of 59 bushels/acre occurred in the WW-SAF-TSF rotation.

Photo 7. Safflower in the long-term cropping systems study near Ritzville in mid-July, 2014. Safflower is usually in full flower in mid-July, but the 2014 crop was already water stressed at this time. Note the green borders where safflower is using available water from neighboring fallow (left) and spring wheat (right). This crop produced a seed yield of only 125 pounds per acre. The 2014 crop-year (Sept. 1 – Aug. 31) precipitation at the site was 8.14 inches.
Table 6. Winter wheat grains yields in three crop rotations during three complete cycles in the Jirava cropping systems study near Ritzville, WA. Crop rotations are safflower-tilled fallow (TSF)-winter wheat (WW), spring wheat (SW)-TSF-WW, and WW-TSF.

<table>
<thead>
<tr>
<th>Rotation</th>
<th>Cycle 1</th>
<th>Cycle 2</th>
<th>Cycle 3</th>
<th>Cycle 4</th>
<th>3-cycle avg.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safflower–TSF–WW</td>
<td>125†</td>
<td>62 b‡</td>
<td>1091</td>
<td>64 b</td>
<td>774</td>
</tr>
<tr>
<td>SW–TSF–WW</td>
<td>39§</td>
<td>79 a</td>
<td>43</td>
<td>81 a</td>
<td>28</td>
</tr>
<tr>
<td>TSF–WW</td>
<td>75 a</td>
<td>63 b</td>
<td>55</td>
<td>64 b</td>
<td></td>
</tr>
</tbody>
</table>

† Previous safflower yield in rotation (lbs/acre).
‡ Within-column means followed by a different letter are significantly different at P<0.05.
§ Previous spring wheat yield in rotation (bu/acre). Crop-year (Sept. 1 – Aug. 31) precipitation at the site was 8.14 inches.

Although the 3-cycle average WW grain yield is lowest in the WW-SAF-TSF rotation, the only significantly different within-year WW yield differences between the WW-SAF-TSF and WW-TSF rotations occurred in 2012. Winter wheat yield in these two rotations were essentially identical in 2013 and 2104 (Table 6). This indicates that SAF may be providing a rotation benefit to the subsequent crop that offsets its well-documented high soil water use.

Some readers may be confused as to why we only have three “cycles” of data despite having grown and harvested SAF for five years. The reason for this is there is a year of fallow in all three rotations before WW is planted. Thus, there is a two-year time period from SAF, SW, and WW harvest until the next WW harvest. The message here is that cropping systems research takes time.

Study 7: Twelve entries of the North Dakota State University safflower variety testing program were planted in a replicated study at Lind on April 21, 2014. The experiment was harvested using a plot combine on September 8. Seed yields of the twelve entries ranged from 133 to 267 lbs/acre. There were statistically significant differences among the entries with the variety ‘Gila’ producing the highest yield. As previously mentioned, only 7.69 inches of 2014 crop-year precipitation occurred at Lind.

Affiliated Projects and Funding: Schillinger and Paulitz are Co-PIs on a 3-year grant from the Washington Department of Ecology for a project titled “Management of fresh wheat residue for irrigated winter canola production”. Schillinger received $10,000 from the REACCH Project in 2014 for partial support of the large-scale (i.e., 20 acre) Jirava cropping systems experiment near Ritzville that is now in its 19th year.

Oilseed-related publications in 2014

Referred Journal Articles
**Extension Bulletins**

**Abstracts from Professional Meetings**

**Washington State University Field Day Abstracts**

**Field Tours**
A twilight tour of the irrigated winter canola residue management experiment at the Jeff Schibel farm near Odessa (50 people attended) was held on May 29, 2014.
The long-term camelina cropping systems study at Lind was presented, and winter canola studies discussed, at the 98th annual Lind Field Day (250 people in attended) on June 12, 2014.