Title: Camelina, Winter Canola, and Safflower as Biofuel Crops for the Low and Intermediate Precipitation Zones

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Background: Agronomic and cropping systems research is needed to advance production of oilseed crops in the Inland Pacific Northwest. This research project focuses on camelina (low precipitation zone) and winter canola (both low and intermediate precipitation zones). Research on winter canola under irrigated conditions will begin in 2010. Safflower will be included in Phase IV of a long-term cropping systems experiment in the low precipitation zone beginning in 2010.

OBJECTIVES

1. Camelina Agronomy
   To evaluate camelina at the WSU Dryland Research Station at Lind (9.5” annual precipitation) in four separate experiments. These experiments are:
   1. Planting date and planting method trial.
   2. Camelina cultivar evaluation from both fall and spring planting dates.
   3. Optimum fertilizer rate for camelina production.
   4. Camelina in dryland cropping systems.

2. Winter Canola
   Specific objectives are to determine the benefits of winter canola (WC) grown in (i) a 4-year WC-summer fallow (SF)-winter wheat (WW)-SF rotation compared to the traditional 2-year WW-SF rotation in the low-precipitation zone and, (ii) a 3-year WC-spring wheat (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. Plant diseases of the subsequent winter wheat (low zone) or spring wheat (intermediate zone) crop.
   3. Soil microbial changes after winter canola versus after winter wheat.
   4. Soil water infiltration and frozen soil runoff after winter canola versus after winter wheat.

3. Safflower
   Evaluate safflower in long-term cropping systems trials on the Ron Jirava farm near Ritzville (11.0” annual precipitation).
METHODS

Camelina

We are now in our third year of the camelina agronomy trials. For experiment #1, we planted camelina on several dates from October 15 through March 15. Two planting methods are used, either direct seed with a no-till drill or broadcast and lightly incorporate into the soil with a 5-bar tine harrow. Fertilizer rate is 25 lbs/acre applied in early February in Solution 32 formulation with a sprayer. Grain yield is determined using a plot combine. We replicate each treatment four times in a randomized complete block design. Each plot is 8 ft x 100 ft. Camelina is sown into standing winter wheat stubble.

For the 2009 crop year, 18 camelina varieties and numbered lines were planted in the fall and 25 varieties and numbered lines were planted in the spring. We built a small-plot drill (using John Deere 450 double-disc openers on 6-inch spacing) for this purpose. The experiment is direct-seeded into standing winter wheat stubble and fertilized with 25 lbs/acre of nitrogen.

The camelina fertility trial has eight treatments with various rates of nitrogen and sulfur using Solution 32 as the carrier. The experiment is direct seeded into standing winter wheat stubble on March 1. Each plot is 8 ft x 100 ft.

The camelina cropping systems trial, established in the 2008 crop year is a 6-year experiment to evaluate the traditional 2-year winter wheat-summer fallow rotation with a 3-year winter wheat-camelina-summer fallow rotation. Each phase of both rotations appears each year in 30 ft x 250 ft plots (total = 20 plots).

Winter Canola

A 6-year experiment was initiated in 2005 at the Ron Jirava farm near Ritzville, WA. Average annual precipitation at the site is 11 inches. Seed-zone water at Ritzville is adequate in most years for establishment of winter wheat and winter canola into summer fallow. The experiment compares the 2-year WW-SF rotation to a 4-year WC-SF-WW-SF rotation. In late August, winter wheat and winter canola are planted into summer fallow in 16 ft x 200 ft plots with a John Deere HZ deep-furrow drill. Seeding rate for winter canola is 3 lbs/acre and for winter wheat 45 lbs/acre. Experimental design is a randomized complete block with 6 replications (total area per site is 0.9 acres). After grain harvest, the entire experiment area is left in summer fallow for the next 13 months, then planted to winter wheat. Nitrogen and sulfur (the same rate for WC and WW), based on soil test, is applied during primary tillage in mid April of the summer fallow year. Grain yield of WC and WW is determined using a plot combine. The four corners of the experiment sites are mapped with a global positioning unit so that the precise location of all plots can be determined for the ensuing SF and WW cycles.

A similar experiment was initiated in late August 2007 at the Hal Johnson farm located NE of Davenport, WA. Average precipitation at this site is 17 inches. The traditional 3-year WW-SW-chemical SF rotation is compared to a 3-year WC-SW-chemical SF rotation. All crops at the Davenport site will be produced using no-till. Experimental design, plot size, and grain harvest methodology are the same as at the Ritzville site. Fertilizer rate, again based on soil test, is somewhat higher than that used at Ritzville. Winter canola and winter wheat is planted and fertilized with an 8-ft-wide no-till plot drill equipped with Kile hoe-type openers. Computerized weather stations are in place at both sites.
In addition to grain yield, soil volumetric water content is measured in all plots at time of planting in late August, in mid March, and again at grain harvest. During the winter after the harvest of WC and WW, ponded water infiltration rate is determined in plots within a 2-foot-diameter infiltrometer ring when surface soils are partially or completely frozen. Plant diseases (Paulitz) and soil microbial attributes (Kennedy) that include pH, electrical conductivity, and dehydrogenase enzyme activity are determined where the previous crop was either WC or WW.

**Safflower**
Winter safflower varieties will be evaluated at Lind. In addition, safflower will be incorporated into a long-term cropping systems experiment at the Ron Jirava farm near Ritzville beginning in 2010. A 3-year rotation of winter wheat-safflower-summer fallow will be compared with several other 3-year, 2-year, and continuous wheat rotations. The Jirava cropping systems experiment, now in its 14th year, covers 20 acres and has 56 individual plots, each 30 ft x 500 ft. Of particular interest will be safflower grain yield, safflower water use, and the rotation effect of safflower on the subsequent winter wheat yield.

**RESULTS**
Precipitation for 2009 crop year (Sept. 1 – Aug. 31) at the Lind Research Station, Ron Jirava farm, and Hal Johnson farm was 8.46, 8.00, and 14.67 inches, respectively. Long-term average precipitation at Lind, Ritzville, and Davenport is 9.50, 11.00, and 17.00 inches, respectively. Since the turn of the century, precipitation has been less than average for eight of nine years (the 2006 crop year was the exception). Accurate precipitation data at the Lind Station date back to 1921. These records attest to annual and cyclic variations in precipitation, but otherwise (until 2001) there were no clear long-term trends or predictable patterns. However, a clear pattern of drought has emerged since 2001.

**Camelina**
Camelina produced at Lind during the 2009 crop year had an average yield of about 500 lbs/acre. Yield data from the planting method and planting date trial, variety evaluation trials, and fertility trial are shown below (Fig. 1). These experiments were shown and discussed with 225 people who attended the Lind Field Day on June 18 as well as with several individuals and groups who stopped by the Lind Station during the year.
Figure 1. Grain yield of camelina (cv. Calena) at Lind, WA in 2009 as affected by two planting methods and five planting dates. There were no significant differences in planting method on any individual date, but there were some relatively minor differences in grain yield as affected by planting date. We suspect that cold temperatures may have damaged the October 17 planting in December 2008, as this was the only planting that had emerged at that time. Means followed by the same letter are not significantly different at $P < 0.05$.

Figure 2. Grain yield of camelina varieties and numbered lines at Lind, WA in 2009. (Left) 18 camelina varieties and numbered lines were direct-drilled into wheat stubble on November 17, 2008. There were no significant grain yield differences among entries. (Right) 25 camelina varieties and numbered lines were direct drilled at Lind on March 1, 2009. There were no significant grain yield differences among entries. For both the fall and spring planted trials, 25 lbs/acre of nitrogen in Solution 32 formulation was sprayed on the plot area in early February.
Figure 3. Grain yield of camelina (cv. Calena) at Lind, WA in 2009 as affected by various rates of nitrogen and sulfur fertilization. There were no significant differences in grain yield among treatments.

Figure 4. Camelina experiments were shown and discussed with 225 farmers, agricultural industry representatives, scientists, extension personnel, and other interested people at the 93rd annual Lind Field Day on June 18, 2009.
Winter Canola
1. Lind. Seeding conditions in August 2008 were very dry at Lind because only 6.77 inches of precipitation occurred during the crop-year (Sept. 1 – Aug. 31). Due to dry soil conditions, we applied three inches of irrigation water before planting both winter wheat and winter canola. Adequate stands of both crops were achieved (Fig. 6). Both the WW and WC survived bitter cold temperatures without snow cover in December 2008. In July 2009, grain yield of WW was 43 bushels per acre (2580 lbs/a) and WC was 520 lbs/acre (Fig. 7). The plots will be summer fallowed in 2009-2010 and then planted to winter wheat in August 2010 to determine the rotation benefit.

Figure 5. Camelina planting date and planting method experiment at Lind in June 2009.

Figure 6. Winter canola stands at Lind in early April 2009. These plants withstood very cold temperatures without snow cover. On the evening of December 16, 2008, air temperatures dropped to a low of −10 degree F and stayed below 0 degree F for 12 hours.
The 2009 crop year was also very dry at Lind, with just 8.46 inches of precipitation. We planted winter canola on five occasions beginning in late June but had difficulty achieving stands because of hot temperatures after planting and before emergence or birds digging out WC seedlings before they could emerge. We finally applied some irrigation water, planted WC yet again and have a partial stand (birds consumed the remainder).

Figure 7. Grain yield of winter wheat and winter canola at Ritzville in 2006 and 2008 (A) and at Davenport in 2008 and 2009 and Lind in 2009 (B). Winter wheat grain yield following winter canola was reduced by 20% compared to after winter wheat (A, center) at Ritzville. Similarly, spring wheat grain yield at Davenport following winter canola was reduced by 24% compared to after winter wheat (B, center). We believe these yield reductions are caused by greater soil water extraction by winter canola versus winter wheat.
2. Ritzville. The seed zone of summer-fallowed soils was way too dry to plant WC in August 2008 as well as August 2009, thus no trial was established at this location during these years. Please refer to Fig. 7A for details about WC rotation benefit effects at the Ritzville site.

3. Davenport. Spring wheat following WW yielded 3420 lbs/a (57 bu/a) compared to 2600 (43 bu/a) following WC (Fig. 7B). These results were very similar to what we measured at Ritzville in 2008 (Fig. 7A). The decline in WW yields following WC versus WW at Ritzville was closely correlated with soil water content (WC uses more soil water than WW). However, at Davenport, the difference in soil water at time of planting spring wheat was only 0.6 inches (Fig. 8). This, alone, cannot account for the 14-bushel yield difference in spring wheat following WW versus WC. Clearly, this research needs to be carried out for several more years to get the complete picture on rotation benefits with WC.

![Figure 8. Soil water in the 6-foot soil profile at time of winter wheat and winter canola harvest at Davenport (left) and at Lind (right) in August 2008. These data show that winter canola used about 1.3 inches more soil water than does winter wheat. However, at time of planting spring wheat at Davenport on May 1, 2009, the difference in soil water under winter canola versus winter wheat stubble was only 0.6 inches (center).](image)

Winter canola was planted on August 5, 2009 and stands are excellent (Fig. 9 and Fig. 10). Winter wheat was planted in mid-September 2009 and it, also, has excellent stands. Seed zone water has always been excellent in chemical fallow at Davenport and achieving stands of WC at this site is not a problem.
Figure 9. Excellent stands of winter canola and winter wheat were achieved at the Davenport experiment site in 2009. Winter canola was planted on August 5 and winter wheat on September 15.

Figure 10. Vigorous late-summer and early-fall growth of winter canola planted into no-till fallow at Davenport in 2009. Photos were taken on September 10 (left) and on October 6.
Figure 11. Ponded water infiltration measurements were obtained on winter wheat stubble and winter canola stubble at the Ritzville site on February 2, 2009. The top four inches of the soil was thawed, but had six inches of frozen soil beneath. (A) Overview of equipment used. (B) Ponded water in canola stubble. (C) Ponded water in winter wheat stubble.
Figure 12. Cumulative infiltration over a 2-hour time period in winter wheat stubble versus winter canola stubble at Ritzville on February 2, 2009. The infiltration rate was three times greater for winter wheat stubble than for winter canola stubble. Although the soils were frozen, they were relatively dry. We believe that water infiltration on winter canola stubble may be excellent during certain frozen soil conditions as observed (but not yet measured) on previous occasions.

Publications (2009 only)
PROPOSED NEW RESEARCH

Planting Winter Canola after Wheat Without Stubble Burning

A new 3-year study is proposed to determine the best method to plant irrigated winter canola following irrigated winter wheat without tilling or burning the wheat stubble. The study will be conducted at the WSU Dryland Research Station at Lind on 3 acres of land. Irrigated winter wheat was planted in September 2009 and the new study will begin in August 2010. The experimental design is a randomized complete block with four replicates. Treatments will be established on 100+ bushel/acre irrigated winter wheat stubble. Winter canola will be planted after the following residue management practices:

1. Burn + disk (this is the traditional practice)
2. Mechanical straw removal + 2 diskings
3. Chop stubble + direct seed
4. Burn + direct seed
5. Direct seed with row cleaners

The following equipment is already available at Lind to conduct this study:

1. Stubble chopper, 10 ft wide
2. Swather, 12 ft wide
3. Baler
4. Double disk, 10 ft wide
5. Moldboard plow, 4 ft wide
6. Direct-seed drill, Kile hoe openers with row cleaners, 8 ft wide
7. Plot combine
8. Solid set irrigation

Measurements to be obtained in winter canola:

1. Soil water dynamics and water use efficiency
2. Plant stand establishment
3. Rhizoctonia levels in the soil
4. Rhizoctonia AG-8 and AG 2-1 on roots
5. Weed pressure
6. Grain yield
7. Oil content