STEEP PROGRESS REPORT

RESEARCH PROJECT TITLE: Rotation Effects of Alternative Crops on Spring and Winter Wheat in Direct-Seed Cropping Systems.

INVESTIGATORS: R. James Cook, Rich Alldredge, Bruce Frazier, Rob Gallagher, Dave Huggins, Tim Paulitz, Doug Young

PROJECT OBJECTIVES:

1. Evaluate the agronomic performance (grain yield, quality, water- and N-use efficiency) of diverse continuous direct-seed rotations, including spatial variability of performance across typical Palouse landscapes;

2. Assess the effects of major biotic and abiotic factors that contribute to differences in agronomic performance of direct-seeded crops and crop rotations across typical Palouse landscapes, including (a) water and nitrogen availability and subsequent use by the following crop. (b) wild oats, and (c) root diseases; and

3. Determine the economic feasibility of alternative direct-seeded crop rotations under different market conditions, government policies, and site-specific practices.

KEY WORDS: Direct-Seed, Cropping Systems, Crop Rotations, Wild Oats, Root Diseases, Water-use efficiency, Nitrogen-use Efficiency

STATEMENT OF PROBLEM:
The risks of direct-seeding are well known and include more or different weed pressures, more root diseases, and the difficulty, for annual cropping systems, of planting through the residue left in the field by the previous crop. These risks are best managed by crop rotations, but currently available alternative crops are either not adapted to direct-seed systems, or their returns are not competitive with either spring or winter wheat. On the other hand, farmers that have successfully converted to direct-seed systems are spread out across the dryland Pacific Northwest from west to east and north to south, showing that this method of farming can work in virtually all agronomic zones of the region. This project is designed to test the agronomic and economic feasibility of six alternative crops for use as the third crop in a 3-year rotation where the other two crops are back-to-back spring and winter wheat, both hard red varieties intended to make protein.

ZONE OF INTEREST: (High precipitation Palouse region of ID and WA.)

ABSTRACT OF RESEARCH FINDINGS:
The 90-acre experiment on the Cunningham Agronomy Farm includes three roughly 30- to 35-acre fields, one planted in 2002 to DNS (variety Hank), one was planted to HRWW (variety Falcon) and one further divided into six strips of approximately 4-6 acres each.
(depending on topography) and planted, respectively, to winter and spring barley, winter and spring canola, and winter and spring peas. The 2001/2002 crop year represented the first chance to assess the effects of these six rotations, following the 2 years for their phase-in. The DNS (across all six strips planted to alternative crops in 2001) averaged 66 bu/A, had a test weight of only 57.6 lbs/bu and made 13.7% protein. Drought stress and Fusarium foot rot were especially apparent as this crop matured. The HRWW averaged 80 bu/A, had a test weight of 61.2 lbs/bu, and made 11.1% protein. Our goal is that the combined yields of the wheat crops be at least 150 bu/A, representing 2 year’s of production. The gross dollar returns in 2002 were $336 and $318/A, for the DNS and HRWW, respectively. The winter and spring barley (Strider and Barnonesse) averaged 1.8 and 2.0 tons/A, with gross returns of $150 and $180/A, respectively. The spring canola (Round-up Ready) averaged 1,366 lbs/A and grossed $128/A. The winter peas (Nutrigreen) produced just over 2000 lbs/A for a gross return of $220/A. The winter canola and spring peas did poorly, due largely to the dry fall when the winter canola was planted and cold wet spring when the peas were planted, each into standing stubble of winter wheat. These problems were anticipated for both of these crops direct seeded into heavy cereal stubble. Since this project is only at the beginning of its first year, the development of maps for yield and grain protein and the analysis of 2002 data on weeds (wild oats), soilborne pathogens *Rhizoctonia solani* AG8, *Rhizoctonia oryzae*, *Gaeumannomyces graminis* var. *triticci*, *Fusarium culmorum*, and *Fusarium pseudograminearum*), nitrogen and water-use efficiency, including for corresponding studies on the Palouse Conservation Field Station, are still in progress at the time of this report.

RESULTS AND INTERPRETATION: The main focus of this project is the six direct-seed crop rotations on the Cunningham Agronomy Farm and corresponding replicated rotations on the Palouse Conservation Field Station. The data received thus far from fields on the Palouse Conservation Field Station are still too preliminary to report and therefore this report is focused on early results from the study on the Cunningham Agronomy Farm. This includes six rotations, each with an alternative crop followed by spring wheat and then winter wheat (Alt. crop/SpW/WW). The six alternative crops are winter and spring barley, winter and spring canola, and winter and spring peas. The entire experiment occupies about 90 acres, divided into three 30- to 35-acre fields (approximately), where one field is planted to spring wheat, one field is planted to winter wheat, and one field is further divided into six strips of approximately 4-6 acres each (depending on topography) for the six alternative crops. Unlike most 3-year crop rotations, this study places the spring wheat after the rotation crops, followed by winter wheat seeded directly into the spring wheat stubble. The alternative crops are seeded directly into the winter wheat stubble. The rotations were first initiated in the fall of 2000, but since 2 years were required to establish them, the 2001/2002 crop year represents the first year that spring wheat was planted after the six alternative crops, the first year that winter wheat followed spring wheat, and the first year that the six alternative crops were planted into the winter wheat stubble.
Figure 1. Aerial map of the WSU Cunningham Agronomy Farm showing the three fields within the lower 90 acres of this 140-acre farm. From left to right, starting at the county road, DNS, HRWW, and the six strips planted to the six alternative crops in 2002. Continuing from left to right, the first four strips are winter canola, winter peas, spring barley, and winter barley. Spring canola was planted in both the 5th and 8th strips, and spring peas was planted in both the 6th and 7th strips. The extra area used to grow the spring peas and spring canola was necessary to more nearly equal the amount of land and topography of the land used for the other four crops.

Yields, prices, and gross returns.—The bulk fields of spring wheat (DNS, variety Hank) and winter wheat (HRWW, variety Falcon) averaged 66 and 80 bu/A, respectively (Table 1). Our goal with these consecutive crops of wheat is that the combined yields be at least 150 bu/A, representing 2 year’s of production. The 2002 combined yields (146 bu/A) fell short, largely because of the shortage of water following a cold wet spring. The role of drought stress as the crop matured was especially apparent with the DNS, which had a test weight of only 57.6 lbs/bu and made 13.7% protein. The low test weight for the DNS might also reflect the high incidence of fusarium foot rot in this crop in 2002 (see results on disease, below). The HRWW had a test weight of 61.2 lbs/bu and made 11.0% protein. Both crops were sold within a week of the time of harvest, providing a net payment of $5.30 and $4.15 per bushel and a gross payment of $336 and $318/A, for the DNS and HRWW, respectively (Table 1).

The winter and spring barley (Strider and Barnonesse) averaged 1.8 and 2.0 tons/A and, with net payments of $86.50 and 89.50/ton, returned a gross of $150 and $180/A, respectively (Table 1). The spring canola (Round-up Ready) averaged 1,366 lbs/A and, at $0.095/lb,
returned a gross of $128/A (Table 1). The winter peas (Nutrigreen) did exceptionally well, producing just over 2000 lbs/A and bringing $0.11/lb, for a gross return of $220/A (Table 1). The winter canola (Athena) emerged late due to the late fall rains, suffered some winter kill, but mostly the small plants that survived the winter never filled in, possible due to cold wet spring. This forced the decision to swathe the crop early, mainly for weed control. The planting date for the spring peas (Cruiser) was delayed so as to allow the soil covered with winter wheat stubble to dry and warm, but this left the crop vulnerable to a late spring freeze followed by heat stress during bloom, and essentially it produced no yield.

Table 1. Number of acres yield, grain quality, price received, and gross dollar return per acre for the eight crops grown in the 2001/2002 crop year as part of the direct-seed cropping systems study on the WSU Cunningham Farm near Pullman.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Variety</th>
<th>Acres</th>
<th>Yield/A</th>
<th>TW/% prot</th>
<th>Paid</th>
<th>$/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>HRWW</td>
<td>Falcon</td>
<td>27</td>
<td>80.3</td>
<td>61.5/11.0</td>
<td>$4.15</td>
<td>$318</td>
</tr>
<tr>
<td>DNS</td>
<td>Hank</td>
<td>35</td>
<td>66.3</td>
<td>57.6/13.7</td>
<td>$5.30</td>
<td>$336</td>
</tr>
<tr>
<td>W Barley</td>
<td>Stider</td>
<td>3.8</td>
<td>3,811 lbs</td>
<td>51</td>
<td>$86.50</td>
<td>$165</td>
</tr>
<tr>
<td>S Barley</td>
<td>Baronesse</td>
<td>3.5</td>
<td>4,061 lbs</td>
<td>50.5</td>
<td>$89.50</td>
<td>$182</td>
</tr>
<tr>
<td>W Canola</td>
<td>Athena</td>
<td>4.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S Canola</td>
<td>Hyola (RR)</td>
<td>5.7</td>
<td>1,366 lbs</td>
<td></td>
<td>$0.095</td>
<td>$128</td>
</tr>
<tr>
<td>W Peas</td>
<td>Nutrigreen</td>
<td>4.3</td>
<td>2,009 lbs</td>
<td></td>
<td>$0.11</td>
<td>$221</td>
</tr>
<tr>
<td>S Peas</td>
<td>Cruiser</td>
<td>5.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 Due to combination of late emergence, some winter kill, and failure of the crop to fill in, possibly because of the cold wet spring, the winter canola was swathed before fully ripe (to control weeds) and then combined so as to spread the plant residue but without determining the yield, which was less then 1000 lbs from the entire strip.

2 Essentially no yield due to a combination of frost damage followed by heat stress.

Based on extensive studies in the past using soil fumigation, we estimate a yield penalty of at least 10 bu/A for winter wheat after spring wheat than if it followed one of the alternative crops for this region and the 2002 precipitation represented by the Cunningham Agronomy Farm. At least part of this yield penalty will be offset by a higher yield (theoretically) for the spring wheat planted after the alternative crops. The higher premium for DNS compared to HRWW also helps justify the use of this crop to capture any rotational benefits of the alternative crops.

The soil was too dry for early stand establishment of winter canola direct seeded into winter wheat stubble in the fall and too cold and wet for early stand establishment of spring peas in this same stubble in the spring. These challenges are well-known or anticipated for these crops. A fall-harrow treatment may improve the prospects for direct seeding spring peas into the typically heavy stubble of winter wheat. For canola, without an early fall rain, it may be necessary to wait and plant spring canola. The dry fall of 2002 presented an even greater challenge for early establishment of winter canola than encountered in either the fall of 2000
or 2001. We currently are planning to reseed the 2002/2003 winter canola site by broadcasting seed of spring canola (Round-up Ready) on top of whatever winter canola plants are present in the spring of 2003, and use Round-up for weed control.

The fall of 2002 represents the second year since phase-in of the six rotations. As for the 2001/2002 crop year, Falcon HRWW followed the 2002 crop of DNS and winter barley, winter canola, and winter peas have been planted into stubble of the 2002 Falcon HRWW. Because of the fields for these rotations use all of the 90 acres available for this study, successive years of the study on this farm serve as replications. As outlined in the original proposal, a complete economic study that accounts for the costs of all inputs (seed, fertilizer, herbicides, fuel, time, equipment depreciation) as well as the gross returns must await completion of at least three years for each crop in each rotation (2004). We will continue to use hard red varieties of both spring and winter wheat for the three years of this study.

Development of yield, biomass, and grain-protein maps.—As done in previous years, a 4-meter-square area was harvested by hand at each of 369 GPS-referenced sites for the 90-acre experimental area. This includes roughly 120 sites within each of the spring and winter wheat fields and 20 sites within each of the six strips of alternative crops.

Figure 2 shows the yield map for the Falcon HRWW for 2002. While the yield for the field as a whole averaged 80 bu/A, yields at specific sites within the field ranged from below 60 to well above 100 bu/A. This is similar to the variability documented for wheat and barley in this and adjacent fields in 2000 and 2001.

Figure 3 shows the yield map for the Hank DNS for 2002. Again, while the yield for the field as a whole averaged 66 bu/A, yields at specific sites within the field ranged from below 40 to nearly 90 bu/A. This and the variability in yields of the HRWW relate to differences in soil depth and available water within the field. However, the alternative crop that preceded the 2002 DNS crop might also have contributed to the variable yields. Figure 4 shows yield maps for Hank DNS separated out by previous crop. While further analyses are needed, the maps indicate that yields of DNS were generally lower after winter barley and winter canola compared to the other four alternative crops. Biomass and grain protein maps must still be developed for each of the two wheat crops, and for the DNS following the respective six alternative crops. This and other analytical approaches will be used to document any rotational effects of the alternative crops on yields of spring wheat. In addition, yield, biomass, and grain protein maps must still be developed for each of the six alternative crops harvested in 2002. Biomass data only will be used to map production of the 2002 winter canola and spring peas.
Figure 2. Grain yield map for Falcon HRWW in 2002 on the Cunningham Agronomy Farm. This map was developed from geostatistical analyses with interpolations of 4-m-square areas harvested by hand at each of 120 GPS-referenced sites representing approximately 30 acres.
Figure 3. Grain yield map for Hank DNS in 2002 on the Cunningham Agronomy Farm. This map was developed from geostatistical analyses with interpolations of 4-m-square areas harvested by hand at each of 120 GPS-referenced sites representing approximately 30 acres.
Figure 4. Grain yield maps for Hank DNS in 2002 as shown in Figure 3, but separated by previous alternative crop. These maps were developed from geostatistical analyses with interpolations of 4-m-square areas harvested by hand at each of 20 GPS-referenced sites representing about 5 acres each.

Rotation and landscape effects on soilborne pathogens.—Soil samples were taken in May, 2002, from each of the 120 GPS-referenced sites representing the 2002 field of HRWW, and also the 120-GPS-reference sites representing the 2002 field of DNS and sent to Adelaide, Australia for analysis of soilborne pathogen make-up and populations based on DNA tests. The test, proprietary with the South Australian Research and Department Institute, provides a measure of the amount of DNA per gram of soil for each of *Rhizoctonia solani* AG8, *Gaeumannomyces graminis* var. tritici, *Fusarium culmorum*, and *Fusarium pseudograminearum*. The results confirm previous indications based on direct isolations from roots that *Rhizoctonia solani* AG8 is absent or present in low populations in the soils on this farm. In contrast, *Rhizoctonia solani* AG8 is common farther west in the drier parts of eastern Washington and adjacent Oregon, and is the main cause of the bare patch manifestation of Rhizoctonia root rot. Thus far, the *Rhizoctonia oryzae* appears to be the dominant *Rhizoctonia* species on this farm. Figure 5 shows a map of the distribution of this species prior to phase-in of the six rotations in the lower 90 acres now devoted to the long-term direct-seed rotations with alternative crops. Unfortunately, a DNA test for this species must still be developed, and therefore documentation of its distribution is still based on the labor intensive examination and laboratory culturing of roots.
Figure 5. Map of the distribution of *Rhizoctonia oryzae* (top) based on laboratory culture, and Rhizoctonia root rot based on inspection of the roots (bottom) on Barnonesse spring barley on the Cunningham Agronomy Farm in 2000, just prior to initiation of the phase-in of the six crop rotation.
*Gaeumannomyces graminis* var. *tritici*, cause of take-all, was found in less than half of the soil samples and then at low levels of infestation. Examination of both the spring and winter wheat plants confirmed that take-all was not a factor in the performance of either crop in 2002.

In contrast, the DNA tests revealed moderate to high infestations of *Fusarium culmorum*, *Fusarium pseudograminearum*, or both pathogens in nearly three-fourths of the soil samples. Examination of plants confirmed that fusarium foot rot was, indeed, the dominant disease in 2002, especially in the DNS. Since this disease causes whiteheads or heads with shriveled grain, and it is favored by plant water stress, it may well account, in part, for the low test weight of the 2002 DNS crop. Plant samples were collected from multiple GPS-referenced sites in the DNS field in each of the strips planted in 2001 to the three spring crops, namely spring canola, spring peas, and spring barley. These will be scored over winter for the severity of fusionary root rot to determine whether the disease is less in spring wheat following either of the two broadleaf crops compared with spring wheat following spring barley, another excellent host of the fusarium foot rot fungus.

**Effects of landscape position on the dynamics of wild oat emergence.**—In the spring of 2002, emergence of the native wild oat population was monitored across a range of landscape positions in the field of HRWW on the Cunningham Agronomy farm. Although these data must still be analyzed, clear differences were apparent in the amount of wild oat that emerged from any one position, with more emergence occurring in the toe and the foot positions compared to the shoulder and peak positions. The data are being evaluated to see if the timing of emergence was affected by landscape position. In 2003, monitoring of the emergence of the native wild oat population will continue, again in the field planted to winter wheat. In addition, control seed banks will be established using seed from two distinct wild-oat populations. These seed will be sown at various depths and be subjected to artificial aging regimes to simulate different seed bank age structures. In addition, seed will be sown under high and low residue conditions. These data will help us factor in landscape position, seed burial depth, seed age, and crop residue cover into wild oat emergence models.

**Effects of spring-versus split- (fall/spring) applications of nitrogen on DNS yields, grain protein, and fusarium foot rot.**—A study was conducted in the DNS field in 2002 to compare yields and grain protein in response to applying all nitrogen at the time of planting in the spring versus applying half the nitrogen in the fall and the remainder at the time of planting in the spring. A similar but more limited study in 2001 indicated that while yields were similar, grain protein was higher by roughly 1% in response to split applications versus applying all nitrogen in the spring. Replicated plots of these two treatments and a no-nitrogen control were imposed within each of the three strips planted, respectively, to the three spring crops in 2001. In addition to yield, grain protein, and biomass measurements from 4-m-square plots hand harvested within each of these plots, random plants were also dug just prior to harvest for assessment of fusarium foot rot. Previous work with winter wheat has indicated that high nitrogen and especially high nitrogen applied to increase grain protein content favors this disease. This study will provide the first information on any such relationship for DNS.
INTERACTION (COOPERATION) WITH OTHER SCIENTISTS CONDUCTING RELATED ACTIVITY:

The results from this study over the next three years will be compared with results of corresponding studies in the low-precipitation zones of eastern Washington, namely the STEEP-funded study of Bill Schillinger et al., *Long-term alternative crop rotations for the low rainfall dryland using no-till: Years 4 through 6*, and the STEEP-funded study of Frank Young et al. *New technologies and strategies for managing weeds in conservation cropping systems for dryland wheat*. These results will also be compared with those of The Wilke and Northwest Crops projects, underway in the intermediate precipitation and not funded by STEEP, are testing the agronomic and economic potential of 4-year crop rotations based on the Beck system developed in South Dakota. The long-term goal of these studies, collectively, is to identify common and underlying principles with broad application to direct seed cropping systems, either within specific agronomic zones or across all agronomic zones.