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Introduction

The renewed interest in direct seeding that occurred across the Pacific Northwest after the 1996 Freedom to Farm Bill spawned several research projects in eastern Washington. These included three on-farm testing projects to research and demonstrate the transition to direct seeding; the Wilke Project in Lincoln County, the Spokane County Direct Seeding Project, and the Northwest Crops Project in Whitman and Garfield Counties. This paper refers primarily to the latter two projects, but I will also mention the Wilke Project in the context of the statistical design.

The Northwest Crops Project compared a 3-year crop rotation with a 4-year rotation, all under direct seeding without irrigation or field burning, for six years (1998 to 2003). The 4-year rotation was spring wheat - winter wheat - warm season grass (corn) - broadleaf crop (cooperator’s choice). The 3-year rotation was winter wheat - spring barley - chemical fallow or broadleaf crop (cooperators’ choice). The second rotation followed closely a conventional rotation for the area, substituting chemical fallow for tillage fallow. The cooperators also selected the crop varieties that best suited their farm.

There were seven cooperating farms that each had one replication of each rotation (one site had two replications) for a total of 8 replications of both rotations. Each crop in the rotation was grown every year, so that each site had 7 plots (four for the 4-yr and three for the 3-yr rotation). At each site, the plots were randomized, but every plot followed in its designated rotation throughout the project. The plots were 500 to 700 feet long, and 30 to 60 feet wide, to accommodate the growers’ existing farm equipment for spraying, seeding and harvesting. All the experimental sites were in the intermediate rainfall area (14 to 18 inches annual precipitation) and were on Athena silt loam soil.

In the Spokane County Direct Seeding Project, the cooperating farmers decided to identify specific questions they wanted answered in their transition to direct seeding, and they designed their own trials to solve them. Many of the questions related to residue management as most of these growers farmed in the annual cropping region (18 to 22 inches precipitation) where residue management is a hindrance to successfully adopting direct seeding. Seeding through heavy residue can be tough in the fall, and especially in the spring when thick winter wheat residue tends to keep the soil cold and wet. Each of the six trials was laid out in replicated on-farm testing strips and was repeated for three years (2001 to 2003). The farmers used all their own equipment for managing the plots.

The Wilke Project compared a 3-year and a 4-year crop rotation, similar to the Northwest Crops Project. There were 3 replications of each rotation (in 10-acre strips) on the Wilke Farm at Davenport from 1998 to 2003. Five area farmers repeated one or other of these rotations on their farms in large (10 to 25 acre plots) or as whole fields.

The philosophy and statistical issues of on-farm testing

On-farm testing appeals to farmers because the large plots enable them to see the test treatments applied across the variable landscape of local farms, and they can use farm-sized equipment for all management
operations. The integral involvement of farmers in all aspects of this project helped us win the USDA-SARE grant funds. However, the management of on-farm tests and the amount of land needed for adequate replication of treatments may compromise the results.

Replication of treatments in the field and across years is essential for statistical analysis, which that is used to draw conclusions about the repeatability of a set of results or the stability of a treatment across different environments. If the number of replications is inadequate, or if replications are lost during the course of the experiments, the power of the statistical tests is reduced and it is difficult to detect differences among treatments.

In these on-farm projects, we lost replications for a variety of reasons, including planting and harvesting errors, crop loss to frost and wildlife, and herbicide damage. Where farmers planted crop rotations in strips or relatively small fields (10 to 25 acres), the crop management was not always optimal as the farmer’s large fields were his first management priority. Conversely, when the farmer did not want to divide fields into strips but included whole fields in the test crop rotation, he sometimes had to make a management choice between growing a crop that worked for his farming operation that year and what was set out in the research protocol. In these situations the research goals usually became a lower priority than the farming operation, and this had repercussions on the validity of the research data. Farmers tend to be flexible in their decision-making and often make last-minute planting decisions based on the weather and crop prices. Conversely, a project that is simple to analyze statistically and which provides clear results is usually fairly rigid in design.

Thus is often appears that farmers and statisticians are from different planets. The challenge for the researcher is to persuade the farmers of the importance of adhering to the experimental design, and then to reconcile these different ways of thinking and make a practical interpretation of research results.

The Northwest Crops Project and the Wilke Project both compared different crop rotations. In a whole systems project, many factors (seeding rate, temperature at seeding, growing conditions, residue management, weeds, diseases, harvest efficiency, etc.) affect the overall yield and viability of a rotation and crops within a rotation. Within the scope of this project we were not able to analyze the components of yield, which limited our ability to detect differences between the rotations. Conversely, in the Spokane Direct Seeding Project we looked at single factors in the transition to direct seeding. Consequently the Spokane County data showed clearer differences between treatments, but these trials did not provide a complete picture of the pros and cons of direct seeding.

The Project Results

The Northwest Crops Project

The variables we considered were crop yield and net economic return (gross revenue minus the sum of fixed and variable costs, from data the growers provided). Although we started out with seven sites (replications) we ended up with three.

Comparing the two rotations, a 3-year rotation, and a 4-year rotation, over three-year periods would mean the 4-yr rotation would be incomplete. Obviously, comparing the rotations over 12 years would reduce these concerns, but was not a practical solution. What we decided to do was make “rolling 4-yr comparisons” of the 4-yr versus the 3-yr rotations. For example, the 4-yr rotation data from 1999 to 2002 were compared first with the 3-yr rotation data from 1999 to 2001, then from 2000 to 2002.
Overall, we did not see consistently better performance by either rotation. This has some positive connotations, i.e. that choosing a rotation due to current commodity price, climatic conditions, and situations on one’s own farm is probably adequate. Although in many of the comparisons we made we could not detect consistent/statistical differences between rotations, it does not mean that those differences do not exist and that the 3-yr and 4-yr rotations will perform identically on any one farm. Although the sites chosen had similar soil types and annual precipitation, there were actually considerable differences among these locations, such as elevation and temperature, which also masked differences between the rotations.

Although our primary intent was to evaluate whole crop rotations, we also wanted to determine the specific benefits of individual crops in rotation. Thus we compared yield and net return of winter and spring wheat following different crops (Table 1). We also compared the yield and net return of corn and barley (Table 1) as the cooperators hoped that corn would occupy a similar rotational slot as barley and possibly confer some agronomic benefits to the rotation.

Planting winter wheat after spring peas or after any broadleaf (peas, mustard, or canola) provided yield and economic advantages over seeding it after spring wheat. It would appear that spring peas conferred most of the advantage (note - peas use 1 to 3 inches less moisture than does spring wheat), as there was no significant advantage to planting winter wheat after spring canola or mustard alone. However, having small data sets compromised the analyses involving spring canola or mustard alone.

Winter wheat yields and net return following chemical fallow were significantly better than following spring wheat. However, the broadleaves; peas, canola, and mustard tended to improve (but not significantly) the yield and net return of subsequent winter wheat crops more than did chemical fallow. So, in years with adequate moisture it might be better to grow a broadleaf crop rather than spring wheat, instead of having chemical fallow. In this project we did not have a rotation with winter wheat following spring barley.

Although not significant, the trends indicated that it was preferable to plant spring wheat after a spring broadleaf than after winter or spring wheat. An important aspect of all these analyses was that the sequences occurred in several crop years and on different farms, so the differences in yield and net return might well be due to variations in location and season rather than a rotation effect.

When comparing corn from the 4-yr rotation with barley from the 3-yr rotation, the yields and net returns of the two crops were not significantly different though corn tended to yield less and to cost more to produce than did barley.

The Spokane County Direct Seeding Project

- Larry Tee (Latah) compared different stubble heights for direct seeding into heavy residue. He was working on the theory that one should not have seeding problems if the height of the standing stubble was less than the distance between the rows (determined by one’s drill). Over the three years there was a consistent trend of the short stubble treatment providing a lower adjusted return ($183.93/A) than did the tall stubble treatment ($197.91/A). From this it was evident that the extra cost of mowing ($10.78/A) was not warranted. If there were stand differences due to seeding conditions, the crop consistently compensated in yield.

- David Ostheller (Fairfield) tested three residue management treatments on winter wheat stubble in preparation for seeding with a Great Plains direct seed drill the following spring: 1) mowing, 2) fall chisel rip plus spring harrowing, and 3) standing stubble. From the data obtained we were unable to draw broad conclusions about the success of different residue management treatments. Across the
three years of the project, direct seeding equaled or exceeded the tillage treatment in two years. Also, in two of the three years it tended toward or demonstrated being the treatment with the best economic return, assuming that all other management practices were the same among treatments (i.e. herbicide costs were assumed to be the same for all treatments we considered). The disk ripping treatment had very similar trends, so it seemed that neither treatment was consistently better or worse than the other. Fall mowing was either the lowest, or tended to be the lowest scoring treatment for both yield and adjusted return.

- Randy and Jeff Emtman (Rockford) had been successful at taking out bluegrass stands by direct seeding oats into them after applying Roundup™. However, they weren’t always able to achieve an acceptable test weight on the oats, so they tested a fall fertilizer regime intended to achieve adequate oat test weight while allowing them the flexibility to keep the grass stand in if it looked good in the spring. Although the oat test weight results were inconclusive, the combined data showed that the adjusted economic return for the oats decreased significantly with each increase in fertilizer rate. From this it was evident that the growers’ original decision-making process of applying 150 lb/A nitrogen in the fall was costing them a lot of money, was not increasing yield, and was possibly negatively impacting the oat test weight and marketability. This cost becomes more marked as fertilizer costs increase. In addition the growers have to pay interest on their operating loan for those inputs for an extra six months. Consequently, they are revising their decision-making process around taking out bluegrass fields and they try to make that decision in the fall.

- Glenn and Bryan Dobbins (Four Lakes) tested a commercial residue digester called Biocat™, made by Bioburst ‘n Grow. The product was not a microbial solution, but a nutrient mix that stimulates the growth of microbes found naturally in the soil. They applied Biocat to residue following harvest, and studied its effect on stand establishment and yield of direct seeded fall and spring cereal crops. Overall, the years of the study were dry and not ideal for testing Biocat. However, the economics of a product needs to benefit the farmer, and the trials clearly did not demonstrate economic benefit from using Biocat and its companion products, though they did increase crop yield in 2003 only.

- The Hutterian Brethren (Deep Creek) tested a late fall rotary subsoil treatment for its potential to improve water infiltration into the soil and boost winter wheat yield under direct seeding. Unfortunately, in none of the three seasons that we conducted this trial was there a “rain on frozen ground” event. So we were unable to realize the full potential of the rotary subsoiler. However, under the conditions that we experienced, the rotary subsoiling was not an economic practice. The cooperator will probably continue to use it on irrigated ground in order to increase water infiltration into the soil.

**Project Sponsors and Cooperators**

WSU Extension, USDA-SARE (Sustainable Agriculture Research and Education), NRCS, USDA-ARS. The Spokane County Conservation District, and the Palouse, Palouse-Rock Lake, Pine Creek, and Whitman Conservation Districts in Whitman County. The Northwest Crop Project grower cooperators were John and Cory Aeschliman (Colfax), Lee Druffel (Colton), Tracy and Kye Eriksen (St. John), Ron Kile (Pine City), Steve and Dan Moore (Lacrosse), Randy and Aaron Repp (Dusty), David and Paul Ruark (Pomeroy), and Steve and Ann Swannack (Lamont). The Spokane County Direct Seeding Project farmer cooperators were Glenn and Bryan Dobbins (Four Lakes), Randy and Jeff Emtman (Valleyford), Paul Gross and Steve Benning (Deep Creek), David Ostheller (Fairfield), and Larry Tee (Latah).
**Table 1.** Yield (lb/A) and net return ($/A) of crop sequences and crop comparisons made independent of the crop rotation.

<table>
<thead>
<tr>
<th>Sites included in the analysis</th>
<th>Comparisons made</th>
<th>Average yield of crops compared in column two (lb/A)</th>
<th>Net return of crops compared in column two ($/A)</th>
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<tbody>
<tr>
<td>Colfax, Dusty, Lamont, St John, Pomeroy, Colton</td>
<td>WW* after SP vs. WW after SW</td>
<td>3794** 2785</td>
<td>65.48 ** 11.75</td>
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<td>Dusty, Lamont</td>
<td>WW after SM or SCN vs. WW after SW</td>
<td>3088 NS 2906</td>
<td>25.05 NS 17.55</td>
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<td>Colfax, Dusty, Lamont, St John, Pomeroy, Colton</td>
<td>WW after SBL vs. WW after SW</td>
<td>3757** 2785</td>
<td>63.71 ** 11.75</td>
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<td>WW after SP vs. WW after SM or SCN</td>
<td>3520 NS 3088</td>
<td>42.92 NS 25.05</td>
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<td>Colfax, Dusty, Lamont, St John, Pomeroy, Lacrosse</td>
<td>WW after CF vs. WW after SW</td>
<td>3750** 2882</td>
<td>53.33 ** 17.11</td>
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<td>Colfax, Dusty, Lamont, St John, Pomeroy</td>
<td>WW after CF vs. WW after SP</td>
<td>3436 NS 3879</td>
<td>48.90 NS 65.48</td>
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<td>24.96 NS 25.05</td>
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<td>-1.79 NS 9.55</td>
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<td>-15.28 NS -12.52</td>
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<tr>
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<td>-2.95 NS 4.18</td>
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<tr>
<td>Colfax, Dusty, Lamont</td>
<td>Corn vs. Barley</td>
<td>2150 NS 2346</td>
<td>-46.72 NS -35.75</td>
</tr>
</tbody>
</table>

*WW = winter wheat, SP = spring peas, SW = spring wheat, CF = chemical fallow, SBL = spring broad-leaf (including peas, canola, mustard), SM = spring mustard, SCN = spring canola

** Indicates compared means within a cell were different at 5% level of probability, NS = not a significant difference statistically