Long-Term Continuous Annual Cropping in the Pacific Northwest (PNW):
Tillage and Fertilizer Effects on Grain Yield and Profitability of Winter Wheat, Spring Wheat, and Spring Barley
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Introduction
Much of eastern Oregon receives <17 inches of annual precipitation (90% occurs during winter months) and winter wheat (Triticum aestivum L.) tillage-based summer fallow is the predominant cropping pattern. Tillage fallow is practiced to control weeds, accumulate nutrients, and slow the evaporative loss of soil moisture. Soil tillage aerates the soil and accelerates biological oxidation and loss of soil organic matter. Loss of SOM can be reduced by conservation tillage and annual cropping. With the introduction of no-tillage (NT) practices, there is a renewed interest in annual cropping of winter wheat. In NT systems residues remain on the surface and protect soil from erosion at all times. The soil macropores that remain intact in NT facilitate rapid water infiltration. Surface residues form mulch that aids water infiltration and reduces evaporation. Increased water infiltration and reduced evaporation increase the potential water storage of the soil and may increase crop productivity under dryland conditions.

Information on crop productivity and profitability of continuous winter wheat (WW), spring wheat (SW), and spring barley (SB) using CT and NT cropping systems in the PNW is limited. The objective of our experiment was to determine the effects of annual mono-cropping of WW, SW, SB on grain yield and profitability under CT and NT cropping systems.

Materials and Methods
The experiment was conducted at the Columbia Basin Agricultural Research Center (CBARC), Oregon State University (OSU), near Pendleton, Oregon. The soil is a coarse, silty, mixed, mesic Typic Haplustoll (Walla Walla silt loam) to caliche and about 8 ft to bed-rock. Annual average precipitation is about 400 mm. The WW, SW, and SB were planted and harvested in 1997 and 1998, respectively. Since then plots have gone through several changes. In 1993, all crops were planted at a bed spacing of 2 ft. In 1994 and 1995, plots were planted at 13 and 25 seeds/ft, respectively. NT plots were planted at 25 seeds/ft in 1993, 22 seeds/ft in 1994, and 25 seeds/ft in 1995, respectively. NT CW plots were fertilized annually, while NT WW, SW, and SB were fertilized in 1993 and 1994, respectively. Between 1993 and 1995, plots received 90, 80, and 80 lb N/acre, respectively. All fertilized plots received 9 lb P/acre and 14 lb S/acre annually. Target seeding rates for CT and NT plots were 22 and 25 seeds/ft, respectively.

Applying N, P, and S increased grain yield of all crops under both CT and NT cropping systems. When fertilized, there were no significant differences in grain yields between CT WW and NT WW. Although there were significantly more heads/ft in NT WW than in CT WW, the reduction in kernel weight and HI under NT probably led to comparable grain yields between CT WW and NT WW. In unfertilized plots, fertilization did not equalize the grain yield between CT and NT systems. High grain yields in CT plots were attributed to significantly more heads/ft in fertilized plots of both SW and SB than in NT plots.

Overall, SB produced the highest grain yields under unfertilized CT and NT conditions. WW and WW produced the highest grain yields under unfertilized NT systems. In fertilized plots, SB produced the highest grain yields under both CT and NT conditions followed by WW and then SW. SB produced high grain yields through more heads/ft and earliness to maturity. SW grew more rapidly than WW and matured at about the same time as WW. In contrast, SW matured last and its grain filling period coincided with drought and high temperature stress.

Table 1. Tillage and fertilizer effects on grain yield and yield components of continuous annual winter wheat, spring wheat, and spring barley at CBARC, Pendleton, OR (1998-2003)

Results and Discussion: Agronomy
Precipitation
The 73 year average crop year precipitation is about 16 inches. Crop-year precipitation was greater than the 73 year average in 1999 and 2000 but was less in the last 4 years of the study. Grain yields decreased with the decreasing precipitation in the last four years of the study.

Grain Yield
The six year average grain yields of all crops are shown in Figure 1. Yield components are shown in Table 1. In unfertilized plots, grain yields of all the crops using CT were higher than grain yields of crops using NT. The difference was greater in spring crops in WW with the greatest difference in SB yields. Higher grain yields in unfertilized CTWW were due to higher HI and heavier kernels in CTWW than in NTWW. In unfertilized SW plots, higher grain yield under CT was probably attributed to higher kernel weights in CTWW than NTWW. Untilled CTWS produced higher grain yields than NTWS through high numbers of heads/ft. Reduced NT grain yields in unfertilized plots indicate that there were substantial problems associated with NT cropping systems. Low yields using NT could be attributed to N deficiency, N immobilization, slow growth due to cold wet soils, increased disease and weed pressure, and residue toxicity.

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Results and Discussion – Economic Analysis
The average cost of the residue management in NT plots was $32.93 ha−1 compared to average tillage costs for the CT plots of 70.06 ha−1. Fertilization costs were similar for each system. Planting costs, including the seed and seeding, were about $12 ha−1 greater for the NT than the CT plots because the seeding rate was increased and the cost of seeding with a no-till drill was greater than with a conventional drill. Herbicide costs tended to increase each year, regardless of tillage. Herbicide costs were the single largest input for both CT and NT plots; costs varied from $53.87 to $167.15 ha−1 for the CT plots and from $129.13 to $191.45 ha−1 for the NT plots. Total average annual variable input costs were $339.62 ha−1 and 376.55 ha−1 for the CT and NT, respectively.

Crop yields, crop values, variable input costs, and partial net returns are shown in Table 2. Crop values varied in response to changes in the crop yields and crop prices; the mean crop value for the CT and NT crops were essentially equal. The variable input costs were greater for the NT than the CT plots, primarily due to the greater herbicide expense in the NT plots. The partial net returns were extremely variable, due to the interacting effects of crop yields, crop prices, and variable input costs. The partial net returns from the CT plots ranged from $337.18 to $533.10 ha−1, while the mean partial net return of $108.41 ha−1. The partial net returns from the NT plots ranged from $154.47 ha−1 to $26.13 ha−1; the average annual partial net return was $74.60 ha−1.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Yield (lbs/a)</th>
<th>Value ($/a)</th>
<th>Variable Cost ($/a)</th>
<th>Partial Net Return ($/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>WW</td>
<td>22</td>
<td>34</td>
<td>25</td>
<td>5</td>
</tr>
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<td>SW</td>
<td>23</td>
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<td>SB</td>
<td>24</td>
<td>37</td>
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Summary and Conclusions
-Untillled CT winter wheat performed better than unfertilized NT winter wheat, indicating problems in NT systems.

Winter wheat produced similar yields using both can be grown CT and NT cropping systems when fertilized. Fertilized spring croops consistently produced lower yields under NT, indicating problems in NT cropping systems. Breeding and agronomic work is required to bring out the full potential of continuous NT wheat and barley. Continuous CT crops had lower variable costs of production, especially herbicides, and greater economic returns than NT crops.